

Justification of the Invariant IQI Core Quality Indicators

IQI JUSTIFICATION IJQ1

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Why each invariant Indicator is needed under its derived Quality Factor

INFRASTRUCTURE QUALITY INITIATIVE

Foreword

Every infrastructure system is intended to do something: carry people or goods, provide homes, deliver water or energy, or support digital services. A quality examination asks whether the infrastructure can realize its intended functions and what should be examined to judge that capability.

This paper asks why the invariant IQI Indicators are needed. Each Indicator identifies a distinct point of examination within a Quality Factor. One question guides the analysis: What would be lost if a proposed Indicator were omitted?

The same Indicators are intended to apply across infrastructure types and life-cycle stages. Technical details and required outcomes vary by context. The Indicators identify what is examined; applicable requirements state the outcomes expected in that context.

The companion Factors Justification (FJQ1) explains why the fourteen Quality Factors are needed. This paper justifies the Indicators within those Factors, including the single retained Indicator 14.1, Capability of Infrastructure to Accommodate Required Changes, under Factor 14 — Infrastructure Adaptability.

The broader methodology is set out in WQI foundational documents identified by document number in the sections where their concepts are applied. This paper focuses on why each Indicator is needed and how it differs from the others.

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1. Purpose, Scope, and Status of the Research

1.1 Purpose and central research question

FJQ1 derives and justifies the major Quality Factors needed to examine infrastructure Quality. IJQ1 continues that work by justifying the invariant Indicators assigned under those Factors. Its central question is whether each proposed Indicator identifies a necessary point of examination under its Factor, and whether that point is distinct from the points identified by neighboring Indicators.

An Indicator is not justified solely because its subject is important. Indicators may concern related subjects or use some of the same Evidence while examining different points. Their titles alone do not show whether they are distinct or redundant.

For each Indicator, the analysis asks what would be lost if that point of examination were omitted. It considers how the point relates to the Infrastructure Quality Object's Intended Functions and Intended Results, their Function Realization, the life cycle, and the conditions examined under the Factor. The Intended Functions belong to the defined Infrastructure Quality Object; the Indicator identifies what is examined.

For each Indicator, the analysis traces why its point of examination is relevant to its parent Factor and to determining the declared object's Intended Functions and Intended Results. This includes considering Function Realization, relevant Failure Modes, and the determination need represented by the Factor.

The analysis considers each Indicator on its merits. Its presence in the current set is not, by itself, evidence that it is necessary.

The article asks two related questions: is each Indicator necessary, and does the set include every point needed for the intended determinations? Showing that the existing Indicators are necessary does not prove that the set is complete. Possible gaps remain open for testing across different infrastructure contexts.

1.2 Relationship to IQI_FJQ1 — Justification of the Fourteen Derived Quality Factors

FJQ1 and IJQ1 form two consecutive parts of the justification. FJQ1 explains why the fourteen Quality Factors are necessary and distinct. IJQ1 explains why the Indicators under those Factors are needed and why each represents a distinct point of examination. A Factor's justification does not, by itself, establish the necessity of every Indicator assigned under it.

1.3 Derived Quality Factors and Indicators under study

The present IJQ1 research record examines eighty-three proposed invariant Indicators under fourteen derived Quality Factors. Factor 14 is Infrastructure Adaptability. Its retained Indicator is 14.1 — Capability of Infrastructure to Accommodate Required Changes. The earlier analysis of seven proposed Adaptability Indicators remains part of the research history; the current finding retains one Indicator.

The counts and assignments are to be verified against the accumulated FJQ1 and IJQ1 research before publication. The justification evaluates the derived Factors and their proposed Indicators on the evidence and reasoning developed in the two justification articles.

1.4 Relationship to the Factor justification

FJQ1 justifies the derived Quality Factors. IJQ1 takes those Factors as its starting point and examines whether each Indicator assigned under them is necessary and distinct. The two articles answer different

questions and should be read together. A possible gap among the Indicators does not, by itself, show that its parent Factor is unnecessary.

1.5 Scope and limits of the Indicator justification

This research applies to infrastructure generally, including energy infrastructure, data centers, residential apartment buildings, bridges, water systems, and other infrastructure. It tests whether an Indicator remains a necessary point of examination across materially different contexts while allowing the applicable requirements, evidence, and detail to differ.

IJQ1 explains why each Indicator is needed. Context-specific Quality Outcome Criteria (QOCs) are established separately in applicable requirements documents. This article does not establish those QOCs.

IJQ1 uses the applicable WQI and IQI vocabularies and methods. It keeps Quality State, Quality Determination, Quality Claim, and Evidence Quality distinct.

2. Identification of the Life-Cycle Infrastructure Quality Object

Before determining Infrastructure Quality, the object being examined must be clear. That object is not always just the physical asset. It may include, or be connected through defined Interfaces to, activities and distinct Results needed to establish, realize, preserve, restore, modify, and eventually close the infrastructure's Intended Functions and Intended Results. The relevant object and its evidence change over time.

2.1 Intended Functions, Intended Results, and the declared Quality Object

The Infrastructure Quality Object is identified by asking what the object is required or intended to do, what results are intended to arise from realization of those Intended Functions, and which activities and distinct Results are essential to that realization. The scope should be stated clearly enough that readers can tell what is being examined, what is outside the examination, and how important connections are handled.

This functional test guides the scope decision. Ownership, organization charts, contracts, geography, and the visible perimeter of an asset may provide useful information, but none of them alone determines the Quality Object boundary. The declaration must explain the functional basis for including or excluding relevant activities and distinct Results.

2.2 Virtual, physical, and residual documentary manifestations

The Quality Object changes its form through its life cycle. At first, it may be a conceptual or virtual object represented by studies, requirements, models, and design documents. It may then become a constructed and operating physical system. After decommissioning, removal, and recultivation, the physical system may no longer exist, while records and other residual Results continue to matter.

A main natural-gas pipeline illustrates this change. It begins as a proposed route and design, becomes an installed and operating pipeline, may be modified or reconstructed, and may ultimately be removed. The relevant Quality Object at each stage is not identical in physical form, but the stages may belong to the same life-cycle examination when they contribute to the pipeline's Intended Functions and Intended Results.

The evidence available also changes. A design-stage determination relies on different records and observations than an operating-stage determination. Later, decommissioning and recultivation records may be central even though the infrastructure itself is gone. The method must therefore identify the object as it exists at the stage under examination and keep the relevant life-cycle links visible.

2.3 Essential activities and Results across the life cycle

Depending on the infrastructure, essential activities and distinct Results may include conceptual development, feasibility studies, field investigations, establishment of Functional and Technical Requirements, design, construction, installation, inspection, testing, Conformity Assessment, commissioning, authorization, operation, monitoring, maintenance, repair, modification, reconstruction, decommissioning, removal, recultivation, and residual documentation.

This list is not a claim that every project has the same stages or that every activity belongs inside one Quality Object. It is a prompt to identify which activities and Results are essential in the case being examined. A stage or contribution should not disappear from consideration merely because it occurred earlier, will occur later, or was performed by another organization.

For example, an outsourced pipeline redesign may provide essential requirements, design activity, design documents, and review needed for reconstruction. Those contributions remain relevant even though the engineering company is organizationally separate from the pipeline operator. Likewise, an inspection by an external contractor may contribute to continued Function Realization in the same way as an inspection performed by the operator.

2.4 Functional boundaries, constituents, and Interfaces

The declared boundary should follow the function of the object being examined. It should identify relevant constituents and the points at which the object interacts with other systems, organizations, people, information, energy, materials, authority, responsibility, Risk, or consequences. These connections are Interfaces.

A condition may appear acceptable when only one component or organization is examined. Its meaning may change when a connected system or an Interface is considered. Quality determination should therefore ask whether the parts and their interactions support the Intended Functions and Intended Results of the declared object.

A boundary does not have to match an ownership line, contract boundary, organizational affiliation, geographic perimeter, or physical fence. Those lines may be relevant, but they are not substitutes for a functional explanation of what is included and how external contributions are handled.

2.5 Internal, outsourced, external, and governmental contributions

Contributions may come from the infrastructure owner or operator, an internal unit, an engineering firm, a construction contractor, an inspector, a supplier, a public authority, or another external participant. They may include activities, distinct Results, or both. The performer’s identity does not by itself decide whether the contribution is relevant to the infrastructure Quality determination.

The key question is whether an activity or Result is essential to establishing, preserving, restoring, modifying, or examining the realization of the infrastructure’s Intended Functions and Intended Results. If it

is essential, it must be accounted for in the declared scope or through an identified Interface. Outsourcing alone is not a reason to exclude it.

At the same time, including an essential contribution does not make the entire external organization part of the infrastructure Quality Object. A contract alone does not establish functional inclusion. The scope should identify the relevant activities and Results and their connection to the infrastructure, while leaving unrelated organizational activities outside the boundary.

A governmental examination or an authorization may also be essential to a life-cycle pathway. The authorization is a Result of that examination; it does not by itself demonstrate satisfactory Infrastructure Quality across all Factors. The governmental assessment activity and its Result may also be examined as a separate Quality Object.

2.6 Independently identifiable contributing Quality Objects

A constituent or contributing Quality activity may itself be separately identified as a Quality Object for its own Quality Determination. Examples include design, inspection, governmental Conformity Assessment, and other activities that contribute to infrastructure Function Realization. For that determination, identify the activity, its Intended Functions and Intended Results, its relevant Results, boundaries, Interfaces, applicable Factors and Indicators, and context-specific QOCs. A separately identified Quality activity need not be a service.

This is a fractal application of Quality determination: the same invariant IQI architecture can be applied to a whole infrastructure object and, where relevant, to a contributing object at an appropriate scale and methodological resolution. The application may require different detail, but a change in scale, resolution, life-cycle stage, or performer does not by itself create a new Factor or Indicator.

Satisfactory Quality of a contributing object does not automatically establish satisfactory Quality of the whole infrastructure. The reverse is also true: a satisfactory infrastructure condition does not automatically establish the Quality of every separately examined design, inspection, or assessment activity that contributed to it. Each determination needs its own defined object and applicable basis.

2.7 Scope declaration, essentiality, and justified exclusions

A sound scope declaration identifies the object, its Intended Functions and Intended Results, the relevant life-cycle stage or stages, the essential activities and relevant Results, the boundaries and Interfaces, and any separate contributing Quality Objects. It also explains exclusions that could otherwise affect the determination.

The declaration should not attempt to include every remote support activity or the whole organization of every contributor. It should include what is functionally essential and explain how other relevant contributions are addressed. Where an activity remains outside the declared object but affects it, the Interface should make that relationship visible.

These scope principles apply across all Factors and Indicators, not only Factor 3 — Conformity Assessment. They help test whether an Indicator remains necessary when the full object and its connections are considered. They do not, by themselves, establish that the proposed Indicator set is complete. A possible gap should first be tested against the proposed Indicators before any additional Indicator is justified.

Context Guides should establish applicable Quality Outcome Criteria (QOCs) for relevant requirements under the invariant Indicators. A QOC may specify what is required in a particular context; it does not redefine the invariant Factor and Indicator architecture. The general method for identifying boundaries, Interfaces, and fractal Quality Objects remains a research question for the wider WQI methodology.

3. Factors, Indicators, and Contextual Application

3.1 Relationship between the derived Factors and their Indicators

A Quality Factor represents a major quality-relevant dimension necessary for Infrastructure Quality determination. An Indicator identifies an invariant point of examination under a Factor. The Factor names the dimension; the Indicator identifies the point examined. Neither states the context-specific required outcome.

The declared Infrastructure Quality Object is the object whose Intended Functions and Intended Results provide the reference for the Quality determination. Indicators do not create additional Intended Functions or Intended Results for that object.

The fourteen Factors are different views for determining the Quality of the same declared Infrastructure Quality Object. They do not describe fourteen separate objects.

3.2 Indicators as invariant points of examination

An Indicator keeps the same meaning across relevant IQI contexts. A Context Guide may explain how that point of examination applies to a defined infrastructure type and connect it to relevant requirements, Evidence, Failure Modes, and Critical Conditions. Context-specific detail may change; the meaning of the Indicator does not.

The Indicator justification therefore tests whether each point of examination is needed across the intended range of infrastructure, rather than requiring identical technical criteria or identical Evidence in every context.

3.3 QOCs are stated in applicable requirements documents

Applicable requirements documents establish or identify the QOCs used for a particular application. IJQ1 justifies why an Indicator is needed; it does not set the context-specific QOC.

3.4 Methodological sources applied by IJQ1

The meanings of Quality State, Quality Determination, Quality Claim, and Evidence Quality are established in the applicable WQI and IQI vocabularies and methods, including WQI_EQC1 and WQI_QCC1. IJQ1 uses these distinctions without restating their general theory.

3.5 Scale and methodological resolution

Scale identifies the Quality Object or constituent being examined. Methodological Resolution identifies the depth and detail needed for the Determination. The Indicator architecture remains the same across relevant Scales and Resolutions; the required detail depends on the object and the Determination being made. Each Indicator is tested at an appropriate Resolution, consistent with WQI FTA11.

3.6 Application across life-cycle stages and constituent Quality activities

Indicators are tested across the life cycle described in Section 2. A constituent or contributing Quality activity may also be separately defined for its own Quality Determination. The applicable Factors and Indicators can then be applied at a suitable Scale and Resolution. This fractal application is considered across all Factors and Indicators, not only Factor 3.

3.7 Separate determination of constituent and whole objects

A satisfactory finding about one constituent Quality Object does not establish satisfactory Quality of the whole infrastructure, and a satisfactory infrastructure finding does not establish the Quality of every separately examined constituent activity. Each Determination has a defined object and its own applicable basis and Evidence.

WQI FTA14's Dual-Nature Postulate applies to every Factor and Indicator. Each has an independent Quality nature and a latent Harm-related nature. A Quality deficiency alone does not establish Harm; a Harm-related consequence requires a demonstrable pathway in context.

4. Method for Justifying an Invariant IQI Indicator

This section sets out a common method for examining every proposed Indicator under its Factor. The tests ask whether the Indicator preserves a needed point of examination, whether that point is distinct, and whether it remains meaningful across the relevant life cycle and infrastructure contexts. The tests guide reasoned judgment; they are not a mechanical score.

The method also checks the declared Quality Object and its boundaries. Essential activities and Results may be performed by different organizations or examined as separate Quality Objects. These facts can change the scope and evidence for a determination, but do not by themselves change the meaning of an Indicator.

Each Indicator is examined at a suitable methodological resolution under WQI FTA11 and in light of the Dual-Nature Postulate in WQI FTA14. These are explicit tests for every Indicator, not matters reserved for selected Factors.

4.1 Indicator necessity test

Begin by identifying the major Quality-relevant dimension represented by the parent Factor. Then state, in plain terms, the point of examination represented by the Indicator. Ask why that point must remain visible when determining the Factor.

A subject can be important without requiring a separate Indicator. The justification must show that the Indicator preserves a necessary point of examination under its Factor and that the point contributes to a responsible determination of the declared Infrastructure Quality Object.

The analysis connects the point to the object's Intended Functions and Intended Results, Function Realization, and relevant conditions that may support or impair that realization. It also asks whether the point is needed to determine the object's Quality, rather than merely describing a technical topic or preferred method.

Context-specific requirements, a particular Failure Mode, an acceptance value, an inspection method, or an Evidence source may be essential in one application. That alone does not show that a new invariant Indicator is needed. The invariant question is whether a distinct point of examination remains necessary as the infrastructure type, life-cycle stage, or technical means changes.

For each Indicator, record: the Factor it serves; the point it identifies; why that point matters; its connection to Intended Functions, Intended Results, and Function Realization; and whether another Indicator already covers it adequately.

The parent Factor and its Indicator answer questions at different levels. The Factor identifies a major Quality-relevant dimension. The Indicator identifies a particular point that must be examined within that dimension. The method should make both levels visible rather than infer necessity from the Indicator's title.

A simple test is to identify what the Factor must determine and what point the Indicator examines. Then ask whether the Factor could still be determined responsibly if that point were omitted. If the answer depends on a technical requirement or method unique to one Context, that material may belong in the Context's requirements or QOC. If the point remains necessary across Contexts even when the method changes, that supports treating it as invariant.

The test also asks what could happen if the point were not examined. The concern may be a condition that directly affects Function Realization, a weakness in the ability to determine whether the condition is acceptable, or another gap that leaves the Factor inadequately determined. State the connection; do not rely on a general claim that the subject is important.

4.2 Removal test

Ask what would be lost if the Indicator were removed. Would another Indicator still make the same necessary point visible and determinable? Or would a relevant condition become harder to identify, examine, or connect to the parent Factor?

A meaningful loss supports retaining the Indicator. The loss may concern visibility of a condition, the ability to make a supported finding, or the ability to relate evidence to the question represented by the Factor. Similar wording in another Indicator does not prove that the point is preserved.

Conversely, if removing an Indicator causes no meaningful loss because another Indicator already preserves the same point, the separate status of the two Indicators requires closer examination. That finding does not itself settle the issue; distinguishability and overlap must also be tested.

The removal test separates loss of context-specific detail from loss of an invariant point of examination. A specific method, threshold, evidence source, or technical example may be supplied by applicable requirements and QOCs. Its removal does not establish an Indicator gap if the underlying point remains represented.

Apply the test across the intended range of infrastructure where evidence permits. A point may be simple or less prominent in one context and essential in another. The question is whether removing it would create a meaningful gap across the range, not whether it has identical importance in every case.

Consider the Indicators that remain after the proposed removal. Identify the specific point that would be lost, and check whether it is still clearly represented through another Indicator, an applicable QOC, or

context-specific interpretation. A detail can move to a context-specific requirement while the invariant point remains intact. But a QOC cannot cure the disappearance of a necessary invariant point from the architecture.

The test is not a vote based on how many other Indicators appear related. It asks whether the same determination can still be made with adequate visibility and support. An Indicator may be necessary even where its evidence is used elsewhere, because a reader may need a separate finding to understand the parent Factor.

An unclear removal result is a reason to compare the Indicators and test them in application, not a reason to remove one automatically. The final account should explain the practical loss or absence of loss and note where the available research does not settle the question.

4.3 Distinguishability test

Compare an Indicator with neighboring Indicators under the same Factor. State the point of examination for each, then ask whether one can be determined while the other remains unresolved. If so, that supports a meaningful distinction.

Indicators can address related conditions, share evidence, or be affected by the same event while preserving different points of examination. Complete separation is not required. The question is whether each Indicator adds a needed view that cannot safely be assumed from the other.

Titles and subject labels are not enough. Two differently named Indicators may ask substantially the same question. Two Indicators with related names may ask different questions. Compare what must actually be examined and what a finding under each would establish.

Combining Indicators is not justified merely because a shorter list appears simpler. Separation is useful when it preserves a necessary distinction. It is unnecessary when it repeats the same point without adding meaningful visibility or determination.

For a close pair, write a short question that each Indicator asks. Then test whether a satisfactory determination of one necessarily answers the other. If one can be adequately determined while the other remains unresolved, they preserve different points. The same Evidence may contribute to both findings, but it must be interpreted against the point represented by each Indicator.

The test protects against two opposite mistakes. It prevents duplicate Indicators that add no separate finding, and it prevents an overly broad Indicator from hiding differences that matter to the determination. The goal is not to maximize or minimize the number of Indicators. It is to keep the points that are needed and meaningfully distinct.

A real condition may affect several points at once. For example, one event may affect a technical condition, operational reliability, monitoring information, and traceability. That interaction does not erase the distinct questions. The analysis should show the relationship among the findings without treating one as a substitute for all the others.

4.4 Nonredundancy and overlap test

Quality conditions are connected, so overlap is expected. One condition, event, record, test, or analysis may be relevant to several Indicators. Overlap is not redundancy by itself.

For Indicators that appear to overlap, compare their points of examination, the findings each permits, and the consequence of removing either one. Shared subject matter or shared evidence can be acceptable when the Indicators support different necessary findings.

Overlap becomes a concern when the same point is represented more than once and keeping both Indicators separate adds no meaningful determination value. The analysis should also guard against the opposite error: combining distinct points so broadly that a needed finding becomes difficult to see.

This comparison applies within a Factor and across Factors. A condition may affect several dimensions of the same object. That does not mean the Factors or Indicators are interchangeable. State what each one examines and how its finding contributes to the overall determination.

Where the distinction remains uncertain, test the Indicators in different infrastructure contexts and against actual examples. Ask whether separate findings reveal different conditions, support different decisions, or expose different Failure Modes. Record the result and any remaining uncertainty.

Shared Evidence is common. An inspection record, test result, operating log, calculation, analysis, observation, or report may inform more than one Indicator. The record is not itself proof that the Indicators are redundant. Ask what each Indicator requires the Evidence to establish and whether an acceptable finding under one could coexist with an unresolved or unacceptable finding under another.

Overlap may also occur across Factors because the Factors are different views of the Quality of one declared object. A condition can therefore have implications under more than one Factor. That does not make the Factors or Indicators interchangeable. For each, state the point being examined and why that dimension is needed.

If two Indicators remain difficult to distinguish, examine whether combining them would make one necessary point less visible. If separation is retained, explain the added value. If combination is considered, explain why no needed distinction is lost. A shorter list is not, on its own, evidence of a better architecture.

4.5 Function Realization, Failure Modes, and life-cycle coverage

For every Indicator, explain its relationship to the declared object's Intended Functions and Intended Results. The relationship may be direct, or it may concern a condition needed to establish, support, preserve, restore, modify, or examine Function Realization.

Failure Modes help test this relationship. Ask how Function Realization could fail, degrade, be interrupted, or become uncertain, and whether the point of examination helps identify or assess relevant conditions. A new technical mechanism does not automatically require a new Indicator. A recurring necessary point that the existing Indicators cannot adequately represent may warrant further research.

Do not limit this test to the operating asset. The Quality Object may be virtual or documentary during early development, physical during construction and operation, and residual or documentary after removal and recultivation. Determine which life-cycle stages and Results are relevant to the point being examined.

As applicable, test the Indicator against conceptual development, feasibility studies, field investigations, requirements, design, construction, installation, inspection, testing, Conformity Assessment, commissioning, authorization, operation, monitoring, maintenance, repair, modification, reconstruction, decommissioning, removal, recultivation, and continuing documentation. The stages will differ by object; this list is a prompt for coverage, not a claim that every stage applies in every case.

The examination should follow the object as it changes. Evidence and relevant conditions at design stage may differ from those during operation or after decommissioning. A change in manifestation or stage does not by itself create a new Factor or Indicator.

The relationship to Function Realization is not limited to conditions that directly make an asset operate. A point may concern the requirements, information, competence, or examination needed to establish whether the object can perform its Intended Functions and produce its Intended Results. These indirect relationships should be stated rather than treated as self-evident.

Use Failure Modes to challenge the proposed point. Ask how the object could fail, fall short of its required performance, be interrupted, or become difficult to assess. Causes may be physical, operational, environmental, human, informational, or related to the Quality of activities that establish or examine the object. Examples include inadequate requirements, unreliable conformity determination, loss of monitoring capability, insufficient competence, failure to meet applicable requirements, and loss of traceability. Any of these may affect Function Realization or its determination.

Do not create an Indicator for every Failure Mode. Different technologies may have different mechanisms, and those differences may be handled through requirements and QOCs under existing Indicators. A new mechanism supports a new Indicator only when it reveals a recurring, necessary point of examination that the established set cannot adequately represent.

Use removal as a further challenge: if this Indicator disappeared, would an important way of identifying a threat to Function Realization, or a limitation in determining that realization, become materially less visible? If so, that strengthens the case for retaining it.

Lifecycle relevance also concerns continuity. A design decision can shape construction and operation; a construction condition can persist in operation; operating experience can lead to maintenance or modification; and a modification can change earlier assumptions, requirements, boundaries, or Interfaces. Decommissioning and transition can introduce conditions that did not arise during normal operation. Check the transitions as well as the separate stages.

The Indicator need not be equally important or supported by the same Evidence at every stage. The test is whether it preserves a needed point at one or more stages where that point can materially affect Function Realization or responsible Quality Determination. A stage-specific method or test does not automatically require a stage-specific Indicator.

Context Guides can test this in practice. If repeated application shows that a lifecycle stage or transition raises a necessary point not adequately represented by the existing Indicators, preserve the finding for comparison across different objects. One context-specific example is a prompt for research, not by itself proof of an invariant gap.

4.6 Boundary, Interface, and fractal-application tests

Test each Indicator against the declared Quality Object boundary and its relevant Interfaces. Ownership, contract, organizational affiliation, geography, and physical perimeter may inform the analysis, but none alone determines the functional boundary.

Ask whether activities and Results essential to Function Realization or to its examination are included in the declared scope or accounted for through identified Interfaces. Outsourcing does not by itself make an

essential contribution irrelevant. Including a contribution does not make the contributor's entire organization part of the Quality Object.

A contributing activity or Result may also be examined as a separate Quality Object, with its own Intended Functions, Intended Results, boundaries, Interfaces, applicable Factors and Indicators, and context-specific QOCs. The same IQI architecture can apply at a suitable scale and methodological resolution. A separate contributing determination does not replace the determination of the whole infrastructure object.

Fractal Quality determination applies across all Factors and Indicators, not only to Conformity Assessment. Satisfactory Quality of a contributing object does not automatically establish satisfactory Quality of the whole infrastructure. Nor does a satisfactory finding for the whole establish the Quality of each separately examined contribution.

Before treating an apparent gap as an Indicator gap, check whether the declared boundary, an omitted Interface, or an unexamined contributing Quality Object explains it. Apply the same check to every Factor and Indicator.

A Quality determination needs a defined object. Ask whether the point remains necessary when the object is examined across its functional boundary and at the Interfaces where it interacts with other systems, organizations, people, information, energy, materials, authority, responsibility, Risk, or consequences. A condition inside one component may appear acceptable until its interaction with the wider object is considered.

The same physical or functional condition can have different meaning depending on the declared object and its boundary. The Indicator must therefore be tested against the object actually under determination, not applied as an isolated technical topic. Ask whether an apparent gap is caused by an incomplete object definition or a missing Interface.

Necessary contributions can be internal, outsourced, external, or governmental. Operator inspection and contractor inspection may each support continued pipeline Function Realization. An outsourced redesign may supply requirements, design activity, documents, and review needed for reconstruction. A governmental examination or authorization may be part of a life-cycle pathway. The performer's organizational status alone does not settle whether these activities or Results are relevant.

Functional contribution and inclusion inside the declared Quality Object are related but not identical decisions. The scope should explain whether a contribution is included in the object or remains a separate contributing Quality Object linked through Interfaces. Neither a contract nor a supplier relationship makes every activity of the external organization part of the infrastructure object.

A governmental authorization is a Result of an examination. It does not by itself establish satisfactory Quality across all Factors. The governmental examination activity and its Result may also be assessed as a separate Quality Object. The infrastructure and the assessment each have their own declared scope and determination.

The boundary and Interface test applies under every Factor and Indicator. Functional Requirements, Technical Requirements, Harm, Risk and Safety, design, construction, inspection, monitoring, and other activities may involve external contributors. Before proposing a new Indicator, ask whether the point is already covered when the full realization pathway, declared boundary, and Interfaces are considered.

Quality-object determination is fractal: an activity or Result that contributes to infrastructure may itself be examined as a Quality Object with its own Intended Functions, Intended Results, Evidence, applicable Factors and Indicators, and QOCs. The same architecture can be used at a suitable scale and methodological resolution. The finding about the constituent does not automatically establish the finding about the whole, or vice versa.

Boundary and Interface differences among pipelines, production zones, storage facilities, LNG facilities, distribution networks, data centers, residential buildings, bridges, and water systems may change the details. The research question is whether a necessary point of examination remains represented across those differences. If a condition appears not to fit, first test it against existing Indicators; preserve a recurring unmet point for horizontal comparison.

4.7 Evidence, determinability, and context-invariance tests

An Indicator identifies what is examined. Evidence supports a finding about that point in relation to the applicable requirements and QOC. The existence of data, records, completed activities, or an absence of observed failure does not by itself establish a supported finding. Evidence Quality is addressed through WQI_EQC1.

For every Indicator, ask what must be known, what evidence could support the finding, and whether that evidence can be connected to the declared Quality Object and applicable QOC. Identify what remains uncertain if evidence is missing, unreliable, incomplete, or cannot be traced to the object. Do not turn an evidence source into an Indicator unless it represents a distinct necessary point of examination.

Keep the object's actual Quality State distinct from the determination of that state and from a Quality Claim about it. An indeterminate result describes the status of a determination; it is not a third actual Quality State. WQI_EQC1 governs Evidence Quality, and WQI_QCC1 governs Quality Claims. IJQ1 uses these distinctions without restating their general theory.

Then test context invariance. Compare materially different infrastructure objects, technologies, operating conditions, life-cycle stages, boundaries, Interfaces, Failure Modes, requirements, QOCs, and evidence. The details may differ while the underlying point of examination remains necessary.

An Indicator need not be equally important or applied in an identical way in every context. The question is whether its basic point remains meaningful across the intended range and whether context-specific requirements and QOCs can address differences without changing the Indicator's meaning. A concern confined to one context may remain context-specific. A recurring unmet point across different contexts may warrant further comparison.

The Evidence test distinguishes the condition being determined from the information used to support a finding. Actual condition is not necessarily known condition; available data are not necessarily sufficient Evidence; and a reported condition is not necessarily a demonstrated condition. Evidence must be relevant to the point, linked to the declared object, and considered against the applicable QOC.

Ask what must be known for each Indicator, what kinds of Evidence could support a finding, and what uncertainty remains if Evidence is incomplete, unreliable, unavailable, or not traceable. A measurement, inspection, test, record, calculation, observation, analysis, or testimony may provide Evidence. A source becomes relevant through its connection to the point of examination; it does not become an Indicator merely because it is important.

Some Indicators primarily concern the infrastructure condition. Others may bear more directly on whether that condition can be determined reliably. Monitoring, records, traceability, or information limitations may therefore expose a need to examine determinability. Test this possibility against existing Indicators before treating it as a gap.

Do not confuse a lack of Evidence with an unacceptable Quality State, or a large volume of information with an adequate determination. Where Evidence does not support a conclusion, state the determination status as indeterminate and identify what is missing. Indeterminate is not a third actual Quality State.

For context-invariance, compare the underlying point across different objects, technologies, physical and operating conditions, life-cycle stages, boundaries, Interfaces, Failure Modes, requirements, QOCs, and Evidence. Context Guides can provide this comparison across production, transportation, distribution, storage, LNG, and other infrastructure.

The point need not be equally important in every application, use the same technical means, or require the same amount of Evidence. Ask whether it remains meaningful across the intended range and whether context-specific requirements and QOCs can address differences without changing its meaning. If it has no meaningful role beyond one narrow context and can be handled under another Indicator, its invariant status deserves further review.

The comparison can also reveal gaps. A single context-specific issue may belong in that context's requirements. A repeated necessary point across materially different objects is stronger evidence for a horizontal research question. In either case, first test whether existing Indicators already represent the point.

4.8 Methodological-resolution test for every Indicator

Apply WQI FTA11 explicitly to each Indicator. First identify the scale: the whole Infrastructure Quality Object or a defined constituent being examined. Then identify the methodological resolution: the depth and detail needed for the intended Quality Determination. Scale and resolution are related but distinct.

At a larger scale, a determination may use summary evidence and broad examination. At a smaller scale or for a more detailed determination, it may require closer examination of components, activities, or Results. The same Indicator can apply at both resolutions while the evidence, detail, and QOCs differ.

Ask whether the Indicator remains meaningful at the selected resolution and whether that resolution is sufficient for the determination at hand. A change in scale or examination detail does not by itself justify changing the Factor or Indicator architecture. If an apparent gap arises, first test whether it results from insufficient resolution or an incorrectly defined object.

The resolution test does not change the scale. It specifies how deeply the declared object or constituent must be examined to make the intended determination. A whole-object review may be adequate for one question; a closer examination of subsystems, activities, or Results may be needed for another. State both the object examined and the depth of examination so a broad conclusion is not mistaken for a detailed one.

A change in resolution may change the amount and type of Evidence, the detail of the interpretation, and the applicable QOCs. It does not by itself change the Indicator. If a point appears absent at one resolution, test whether the intended determination requires greater detail before proposing a new Indicator or finding the current architecture incomplete.

4.9 Dual-Nature Postulate test for every Indicator

Apply WQI FTA14 to each Factor and each Indicator. Each has an independent Quality nature and a latent Harm-related nature. The independent Quality nature concerns the point's contribution to determining Quality. Its Harm-related nature concerns possible consequences if a deficiency exists.

A Quality deficiency does not, by itself, establish Harm. The analysis must identify a demonstrable pathway from the condition to a possible Harm-related consequence and examine that pathway in context, including relevant relationships among Quality, Harm, Risk, and Safety. Avoid assuming either that every deficiency causes Harm or that a matter without an immediate Harm consequence lacks Quality significance.

This test applies throughout the Indicator analysis. It is not confined to Factor 5. Where a Harm-related pathway is absent, uncertain, or not established, record that separately from the Quality finding.

Apply the two natures separately. First explain why the point matters to Quality even if no Harm has occurred or can be shown. Then consider whether a deficiency could lead to Harm through a demonstrable pathway. That pathway may depend on context, exposure, severity, likelihood, or other relationships addressed by the relevant methods.

Record uncertainty about a Harm pathway without erasing the Quality question. Also avoid treating a Quality finding as proof of Harm. This distinction applies to every Factor and Indicator, including points whose consequences are indirect or become visible only over time.

4.10 Standard analytical record applied to each Indicator

Use the same short record for every Indicator so readers can compare the reasoning. The record should state:

- Factor and Indicator identity;
- the invariant point of examination, in plain language;
- why the point is needed under the Factor and what its removal would lose;
- how it differs from neighboring Indicators and any overlap that remains;
- its connection to Intended Functions, Intended Results, Function Realization, Failure Modes, and relevant life-cycle stages;
- the Quality Object scale and methodological resolution used, applying WQI FTA11;
- relevant boundaries, Interfaces, contributing activities or Results, and any separate Quality Objects;
- the kinds of evidence and applicable QOCs needed for the context, without treating either as the Indicator itself;
- the result of the context-invariance test and any limits in the available research; and
- the independent Quality nature and any demonstrable Harm-related pathway, applying WQI FTA14.

This record supports consistent analysis; it does not assign a numerical score or replace the reasoned explanation. An indeterminate conclusion should identify what information or analysis is missing.

4.11 Conditions for provisional retention and future research

An Indicator has a sound basis for provisional retention when the analysis shows that it preserves a necessary point under its Factor; removal would cause a meaningful loss; it is sufficiently distinguishable from other Indicators; and its overlap does not amount to unnecessary repetition.

The analysis should also show a meaningful connection to Function Realization, relevant life-cycle stages, boundaries and Interfaces, evidence-supported determinability, and application across materially different infrastructure contexts. It must state the scale and methodological resolution tested under WQI FTA11 and apply the Dual-Nature Postulate under WQI FTA14.

No single test decides the result. A weak result on one test calls for closer analysis; it does not automatically require removal. Apparent overlap may disappear when the points are stated clearly. A difficulty with evidence may reflect an unclear object boundary, insufficient resolution, or context-specific interpretation.

Use the same discipline when a possible additional point is identified. Importance alone is not enough. First ask whether the point is already represented by an existing Indicator, whether it is context-specific, and whether a distinct necessary point recurs across different contexts. Preserve unresolved findings for later horizontal review.

The method therefore supports reasoned retention and careful consideration of possible gaps while keeping each Factor and Indicator distinct. Section 6 applies these tests to the Indicators under each of the fourteen derived Quality Factors.

The review record should make clear whether each condition is supported, partly supported, or unresolved. A failure to establish one condition does not mechanically decide removal. It identifies where more comparison, Evidence, or contextual interpretation is needed.

The case for retaining an Indicator should show that it preserves a necessary point under its Factor and that removing it would cause a meaningful loss. It should show that the point is distinct from those covered by other Indicators and relates to Function Realization or its determination. The analysis should establish where in the life cycle the point matters, how it fits the declared object, boundaries, and Interfaces, and how Evidence and context-specific QOCs can support its determination. It should also show that the point matters across relevant infrastructure Contexts.

For a possible additional point, use the same criteria. It must be distinct from existing points, necessary for responsible determination, and not adequately addressed as context-specific detail. Repeated findings from materially different contexts strengthen the case. Preserve supporting examples, counterexamples, and limits so later review can test the conclusion rather than inherit it as settled.

5. Cross-Cutting Classification of Indicator Points of Examination — Provisional Framework

Sections 1–4 explain how each Indicator is examined under its Factor. This section adds a horizontal view: it compares what different points of examination contribute to determining Quality, even when they belong to different Factors and concern different subjects.

The subject of an Indicator and its role in a determination are not the same thing. An Indicator may concern integrity, safety, competence, monitoring, documentation, reliability, or another subject. Its title helps identify the subject. A separate analysis asks what the point contributes to a Quality Determination.

This section provisionally uses three role labels: Quality-State, Quality-State Determination, and Quality-State Influence. They are research classifications for comparing points of examination. They do not add a

Factor or Indicator, and they do not create another required layer. The labels also do not describe the Intended Functions of the infrastructure object.

5.1 Points bearing on Quality State

A point bearing on Quality State concerns the actual quality-relevant condition of the declared Infrastructure Quality Object, or of a condition that affects it. Its central question is: What is the condition?

The condition may relate to physical integrity, functional performance, operational reliability, interaction with the environment or people, compliance, or another dimension represented by its Factor. The Indicator directs attention to the condition itself. Evidence supports a finding about that condition; one Indicator does not by itself determine the complete Quality State of the infrastructure.

Current operation is not the same as an acceptable Quality State. Infrastructure may continue to operate while an important condition has degraded or is not adequately known. An absence of observed failure does not demonstrate an acceptable condition, and a reported condition is not necessarily the actual condition.

This point can be examined at different stages. During construction it may concern the condition being realized; during operation it may concern present integrity, performance, or reliability; during maintenance or modification it may concern the condition before, during, or after the activity. The technical meaning depends on the Indicator and context.

The Quality-State role is not exclusive. A point that provides information about an actual condition may also help determine whether that condition is reliably known. It may also relate to a capability to preserve or change the condition. The classification asks which role is primary for the analysis; it does not force an Indicator into one permanent category.

The role label is about the finding's subject: the condition itself. It does not mean that the Indicator reports only a momentary operating status. It asks about a quality-relevant condition tied to Function Realization, whether or not a visible failure has occurred.

This distinction guards against treating continued service as proof that every relevant condition is acceptable. It also guards against treating the absence of a detected problem as proof of good condition when the examination has not been sufficient. The applicable Factor, requirements, QOC, and Evidence determine what condition is examined in a particular context.

5.2 Points bearing on Quality-State Determination

A point bearing on Quality-State Determination concerns whether a quality-relevant condition can be determined reliably. Its central question is: Can the actual condition be known and supported with enough confidence for the determination being made?

The actual condition and the ability to determine it are different matters. An object has a condition whether or not that condition is accurately known. A condition may be acceptable while the available Evidence is insufficient to demonstrate it. A condition may also be unacceptable while weak monitoring, inspection, testing, information, traceability, or evaluation prevents the problem from becoming visible.

The determination path runs from the actual condition through observation, measurement, inspection, testing, records, analysis, or other information; then through Evidence and a supported finding; and finally to the Quality Determination. A weakness at any point may reduce confidence in the result.

Information does not become adequate Evidence simply because it exists. It must be relevant, credible, traceable, and connected to the declared Quality Object, the Indicator, and the applicable QOC. Evidence Quality is governed by WQI_EQC1. The Indicator identifies the point to be determined; it is not the evidence source itself.

Conditions that may affect this role include the adequacy of monitoring, reliability of measurement or inspection, ability to evaluate performance, availability and traceability of information, and competence needed to make or interpret a determination. These are examples for testing the role, not proposals for additional Indicators.

Monitoring and Documentation and Traceability clearly contribute to the ability to determine Quality State. Similar contributions may be made by points under Conformity Assessment, Competence of Personnel, or other Factors. The horizontal review should establish where the role occurs rather than assume it from an Indicator's title.

Some points may both describe the condition and test whether the means of determining it are adequate. The roles can overlap. The research asks whether the Indicators collectively provide enough visibility to determine actual conditions responsibly, and whether a recurring determination need remains insufficiently represented.

The question is about the reliability of the path from actual condition to finding, not simply whether a test, record, or monitoring system exists. Information must be evaluated and connected to the correct object and point of examination before it supports a finding. Weaknesses in traceability, analysis, or interpretation can matter even where many records are available.

This distinction also works in both directions. An acceptable condition may not be demonstrated because the evidence path is weak. An unacceptable condition may remain hidden because monitoring or evaluation is inadequate. Neither situation should be collapsed into a claim about the actual condition without stating the limits of the determination.

The relevant capability may be spread across different Factors. For example, monitoring can generate information, documentation and traceability can preserve its connection to the object, and competent personnel may be needed to interpret it. The horizontal analysis asks how these contributions fit together while preserving the distinct point under each Factor.

5.3 Points bearing on Quality-State Influence

A point bearing on Quality-State Influence concerns the capability to preserve, control, restore, or change a quality-relevant condition when action is needed. Its central question is: Can the condition be influenced enough to support or restore the object's Function Realization?

This question differs from asking what the condition is or whether it can be determined. A condition may be known and unacceptable, while the responsible people, organization, system, or decision point lack the capability or authority to address it effectively. The influence role concerns whether that capability can be examined. It does not mean that the Indicator itself performs the action.

A simple illustration is: What is the condition? Can it be reliably determined? Can it be preserved, controlled, restored, or changed when necessary? The three questions may lead from recognition of a condition to action and then to a new determination, but this is not always a one-way sequence.

Action may depend on resources, technical capability, authority, responsibility, and coordination across organizational or system boundaries. Context Guides can test whether those conditions are adequately represented by existing points, especially where responsibility is divided across Interfaces. A context-specific action requirement does not by itself establish a new invariant Indicator.

For each proposed influence role, ask whether the capability is necessary to preserve or restore acceptable Function Realization, whether the point is already represented under another Indicator, and whether the need recurs across different infrastructure contexts. The role should be recorded only where the evidence supports it.

The influence question can arise before or after a condition changes. It may concern preventing deterioration, maintaining an acceptable condition, restoring a condition after a problem, or changing the infrastructure when continued Function Realization requires it. The relevant action and capability depend on the object, the life-cycle stage, and the context.

The relationship can be followed as a practical sequence: a condition exists; it is determined; a need for action is recognized; someone or something has the capability and authority to act; the condition is preserved, restored, or changed; and a further determination checks the result. Not every case follows each step in this order, but the sequence helps identify where an influence point may matter.

A person's or organization's ability to act may depend on an Interface or divided responsibility. The analysis should identify those relationships without assuming that every participant is inside the infrastructure Quality Object. It should ask whether the relevant capability is included in scope or addressed through the declared Interfaces.

5.4 Points relevant to more than one aspect and legitimate overlap

The three roles are not isolated categories. One point may primarily concern an actual condition and also contribute to determining whether that condition is known reliably. Another may concern determination and also support action to influence the condition. The analysis should identify the primary role and record meaningful secondary roles where they help explain the point.

Different Indicators may perform similar roles while examining different necessary conditions. Two Indicators can both bear on Quality-State Determination, for example, without being redundant if each supports a distinct finding under its own Factor. Conversely, Indicators with different subjects may prove redundant if they preserve substantially the same point and neither adds meaningful determination value.

The relationship may be continuing: a condition changes, the change is determined, an action is taken, and the condition is examined again. Monitoring may identify change; intervention may alter the condition; further monitoring may show whether the intervention worked. This cycle can recur across the life cycle.

A horizontal comparison may reveal an uneven pattern—for example, many points about actual conditions but little visibility into whether those conditions can be determined, or strong determination capability but limited visibility into whether an unacceptable condition can be influenced. Such a pattern is a question for analysis, not proof that an Indicator is missing. Existing points elsewhere may already provide the needed role, or the need may be context-specific.

The purpose is not to produce equal numbers of Quality-State, Quality-State Determination, and Quality-State Influence points. No such balance is assumed. The question is whether the roles needed for

responsible determination remain visible across the set, without losing the distinct points established by the Factors.

When a point appears to bear on more than one role, ask which role is primary, which roles support it, and whether the answer changes with context or life-cycle stage. A point about monitoring, for example, may provide information about an actual condition and also bear on whether that condition can be determined reliably. The classification should describe this relationship instead of forcing one label.

The roles can interact repeatedly over time. Monitoring may show a change; a decision may lead to intervention; intervention may alter the condition; and later monitoring may show whether it was effective. The Quality-State, Determination, and Influence perspectives may therefore be interdependent rather than a single straight line.

Use the distinction between subject and role when assessing overlap. The same subject with different roles may support complementary points. Different subjects with substantially the same role may still be necessary if they concern different conditions. Redundancy requires a comparison of what each Indicator establishes and what would be lost if one were removed.

5.5 Limits of this provisional classification

The three role labels are provisional. The research has not established that every Indicator can be meaningfully described through one or more of them, that the boundaries between them are always clear, or that the three roles cover every recurring contribution to Quality Determination.

Some Indicators may combine roles. Some may not fit the proposed labels well. Horizontal analysis or Context Guide application may reveal another recurring role. Record those cases rather than forcing them into one of the three labels. The classification itself is being tested alongside the Indicators.

The classification does not replace the derived Factors or the points assigned under them. It does not reorganize them, determine context-specific QOCs, or settle whether the set is complete. A useful research pattern is not, by itself, a reason to add a normative category or an Indicator.

Retain the classification only to the extent that it clarifies the contributions made by different Indicators and supports comparison across materially different infrastructure contexts. If it creates unclear distinctions, unnecessary duplication, or leaves recurring needs unexplained, revise or set it aside.

The classification is not assumed to be complete or exhaustive. It may not describe every Indicator clearly. Its boundaries may blur where a point both concerns a condition and supports knowledge of that condition, or where a determination point also supports action. Those cases are findings about the limits of the classification, not errors to be hidden.

Nor is there an assumed need for a balanced distribution among the three roles. A count of Indicators in each role would not, by itself, show whether the set is adequate. What matters is whether the different contributions needed for responsible Quality Determination are visible, while the distinct Factor-level points remain intact.

5.6 Status of the classification in this research

This article uses the three roles as an analytical aid. The Factor-by-Factor analysis asks why each point is necessary under its parent Factor. The horizontal analysis asks what that point contributes to determining,

knowing, preserving, controlling, restoring, or changing a quality-relevant condition. These are related but different questions.

Apply the classification after identifying the point of examination and testing its necessity, removal, distinguishability, overlap, relationship to Function Realization and Failure Modes, life-cycle relevance, boundaries and Interfaces, Evidence, context invariance, methodological resolution, and Dual-Nature Postulate. The classification adds a perspective; it does not replace those tests.

First examine each Indicator vertically within its Factor. Then compare Indicators across Factors. Two points may have different subjects but similar roles; several may perform similar roles while remaining necessary because they examine different conditions. Preserve both findings.

If repeated analysis suggests that a necessary role is not adequately represented, first test whether another Indicator already covers the point, whether the issue is specific to one context, and whether applicable QOCs and Evidence can address it. A recurring unresolved point across materially different contexts may be preserved for later horizontal review; the classification alone does not justify adding an Indicator.

The analysis also tests whether the three roles are useful and repeatable. If an Indicator cannot be examined meaningfully through them, or another recurring role emerges, record that result. The classification is a working research tool, not a settled part of the Factor and Indicator structure.

The classification is tested in two directions. It helps examine the Indicators, and the Indicators test whether the classification is useful. If it repeatedly clarifies what different points contribute across Factors and contexts, that supports its continued use as a research tool. If it obscures distinctions or fails to describe recurring roles, revise or set it aside.

The vertical analysis first asks why a point is necessary under its Factor. The horizontal analysis then compares that point with those under other Factors. For example, a technical point and a personnel point may concern different subjects but both contribute to knowing whether a condition is acceptable. That similarity of role does not make their subject-specific points interchangeable.

If a recurring role seems insufficiently represented, the analyst must still test the possible gap against the full set of Indicators. Ask whether another point already supports the needed determination, whether the need belongs to one context, and whether context-specific QOCs or evidence provisions can address it. Only a repeated, unresolved need across materially different contexts should be carried forward for further review.

The classification therefore contributes to the research without predetermining its result. It is not a new set of requirements, and assigning a role to an Indicator does not establish that the Indicator is necessary or that another one should be added. Those conclusions remain subject to the tests in Section 4 and the Factor-by-Factor reasoning in Section 6.

6. Factor-by-Factor Justification of the Indicators under the Fourteen Derived Quality Factors

This section examines the proposed Indicators under each derived Quality Factor. For every Indicator, the analysis identifies the point to be examined, explains why it is needed, tests whether it is distinct from neighboring Indicators, and considers its application across relevant infrastructure and life-cycle contexts.

Each Factor and each Indicator is also examined at an appropriate methodological resolution under WQI FTA11 and under both aspects of the Dual-Nature Postulate in WQI FTA14.

6.1 Factor 1 — Functional Requirements

Factor 1 establishes the functional basis for the declared Infrastructure Quality Object.

Its purpose is to ensure that the Infrastructure Intended Functions and Infrastructure Intended Results are explicitly defined, complete, coherent, and traceable across the Lifecycle.

This functional basis must exist before technical realization can be responsibly examined.

Factor 1 therefore asks a broad question:

Is what the Infrastructure Quality Object is required to do sufficiently defined to provide a valid basis for its realization and Quality State determination?

This research examines the Factor through six proposed Indicators:

Indicator 1.1 — Completeness of Functional Requirements

Indicator 1.2 — Clarity and Unambiguity of Functional Intent

Indicator 1.3 — Explicit Treatment of Functional Boundaries and Interfaces

Indicator 1.4 — Identification and Documentation of Functional Assumptions and Uncertainties

Indicator 1.5 — Traceability of Functional Requirements Across the Lifecycle

Indicator 1.6 — Functional Changes.

The six Indicators address related parts of the same functional basis.

The question is whether each Indicator identifies a necessary point that is distinct from the points covered by the others.

Cross-context applicability test. The six invariant Indicators concern the definition and continuity of Intended Functions and Intended Results, irrespective of infrastructure technology. Their application is illustrated below using physical data-center infrastructure, residential apartment buildings, bridges, and water-supply systems. The examples identify Context-specific subjects for examination; they do not prescribe universal Quality Outcome Criteria or constitute completed conformity assessments.

Methodological resolution under WQI FTA11. The scale here is the declared Infrastructure Quality Object. The depth of examination depends on its size, life-cycle stage, boundaries, and the determination being made. A broad review may examine the functional basis as a whole; a closer review may trace functions and requirements through defined constituents and Interfaces. The Indicator meanings remain the same as the scale or detail changes.

Dual-Nature Postulate under WQI FTA14. Factor 1 has an independent Quality nature and a latent Harm-related nature. Its Quality question concerns whether the functional basis is adequate. A Harm-related conclusion requires a demonstrable pathway from a deficiency in that basis to a possible consequence in context; a deficiency alone does not establish Harm.

Indicator 1.1 — Completeness of Functional Requirements

Indicator 1.1 asks whether the Infrastructure Intended Functions and Infrastructure Intended Results have been completely defined for the applicable Lifecycle conditions within the declared Boundary.

Its determination question is:

Have all necessary functions and intended results been identified?

This question is necessary.

A functional specification may be clear, traceable, and well documented while still being incomplete.

A missing primary, supporting, protective, or Lifecycle function can leave the Infrastructure Quality Object without a defined requirement for something it must actually do.

The removal test therefore produces a direct loss:

Remove Indicator 1.1
→ completeness of the required functional basis is no longer explicitly determined.

None of the other Factor 1 Indicators necessarily preserves this question.

Clarity does not establish completeness.

Boundary definition does not establish completeness.

Documentation of assumptions does not establish completeness.

Traceability does not establish completeness.

Control of functional change does not establish completeness.

Indicator 1.1 therefore preserves a necessary and distinguishable determination function.

Its provisional functional classification is primarily Quality-State Determination.

The Indicator concerns whether the required functional basis has been sufficiently established so that later realization can be judged against it.

It also has a relationship to Quality-State Influence because an incomplete functional basis can affect later design and operating decisions.

That secondary relationship does not change its primary determination role.

No Indicator gap is identified from this test.

Cross-context examples: a data center requires a defined functional scope for computing-support infrastructure and service continuity; an apartment building requires defined habitation and supporting building functions; a bridge requires defined transportation and load-carrying functions; and a water-supply system requires defined supply, delivery, and relevant water-quality functions. Indicator 1.1 asks whether the functions required for the declared object are all represented, not whether their Context-specific QOCs have already been achieved.

Methodological resolution under WQI FTA11. At the whole-object scale, this Indicator asks whether all required functions and Intended Results are represented across applicable life-cycle conditions. At finer resolution, it may be necessary to examine the functional basis of a defined constituent. The required detail can change without changing the Indicator.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the required functions and Intended Results are complete. Consider Harm only where an omission has a demonstrable pathway to a possible consequence in context; incompleteness alone does not establish Harm.

Indicator 1.2 — Clarity and Unambiguity of Functional Intent

Indicator 1.2 asks whether functional requirements are stated clearly enough to avoid materially different interpretations.

Its determination question is:

Can the required functions and results be understood without material ambiguity, implicit assumptions, or dependence on unstated expert knowledge?

This question is different from completeness.

A complete set of functional requirements may still be ambiguous.

Different designers, operators, maintainers, regulators, or other parties may interpret the same requirement differently.

The removal test is therefore:

Remove Indicator 1.2
→ all required functions may remain listed, but their meaning may not be sufficiently determinable.

Indicator 1.1 cannot replace this function.

Completeness asks whether the necessary requirements exist.

Indicator 1.2 asks whether their meaning is sufficiently clear.

The two Indicators are therefore complementary rather than redundant.

Indicator 1.2 primarily performs a Quality-State Determination function.

It protects the reliability of the functional reference basis from ambiguity and inconsistent interpretation.

No separate Indicator gap is identified at this stage.

Cross-context examples: data-center availability and capacity terms, building habitability and access functions, bridge service and traffic functions, and water-supply delivery and quality functions must each have a sufficiently clear meaning within their applicable Context. Indicator 1.2 preserves the distinct question of unambiguous functional intent.

Methodological resolution under WQI FTA11. At the selected scale, examine whether the requirements for the declared object or constituent can be understood without materially different interpretations. A closer review may test particular requirements or Interfaces. The depth changes with the determination; the point remains clarity of functional intent.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether functional intent is clear enough to guide realization and determination. Any Harm-related pathway from ambiguity must be demonstrated in context; ambiguity alone does not establish Harm.

Indicator 1.3 — Explicit Treatment of Functional Boundaries and Interfaces

Indicator 1.3 asks whether the functional extent of the declared Infrastructure Quality Object and its relevant Boundaries and Interfaces are explicitly defined.

Its determination question is:

Where does the functional responsibility of the declared Infrastructure Quality Object begin and end, and through which Interfaces must its functions interact with other parts of the wider system?

This question is necessary because a function cannot always be determined adequately without knowing which object, subsystem, party, or Interface is responsible for its realization.

A functional requirement may be complete and clear while responsibility at a Boundary or Interface remains uncertain.

The removal test is:

Remove Indicator 1.3
→ functions may be defined, but their functional extent and important interactions may remain ambiguous.

This determination function is not adequately replaced by Indicator 1.1 or Indicator 1.2.

Completeness does not necessarily define functional extent.

Clarity of an individual requirement does not necessarily establish how functions are divided or transferred across Boundaries and Interfaces.

Indicator 1.3 is therefore necessary and distinguishable.

Its provisional function is primarily Quality-State Determination.

It establishes whether the functional basis is sufficiently connected to the actual bounded Infrastructure Quality Object and its relevant Interfaces.

It may also support Quality-State Influence where responsibility or authority across an Interface affects the ability to act.

That possibility should be tested later across other Factors and Context Guides rather than treated here as a new Indicator.

Cross-context examples: a data center interfaces with utility power, communications, and cooling systems; an apartment building interfaces with utilities, access arrangements, and emergency services; a bridge interfaces with approaches and transport networks; and a water-supply system interfaces with sources, treatment, distribution, and users. Indicator 1.3 concerns the functional extent and interactions of the declared object, without prescribing identical Interface requirements.

Methodological resolution under WQI FTA11. At the selected scale, identify the functional boundary of the declared object and the Interfaces that matter to its functions. A closer examination may trace responsibility or interactions at a particular Interface. The scale and detail may change; the Indicator continues to concern functional extent and interaction.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether boundaries and Interfaces are sufficiently explicit for the functional basis. A Harm-related consequence of an unclear boundary or Interface must be traced through a demonstrable pathway in context.

Indicator 1.4 — Identification and Documentation of Functional Assumptions and Uncertainties

Indicator 1.4 asks whether assumptions and fundamental uncertainties affecting functional requirements have been made explicit.

Its determination question is:

What assumptions and uncertainties affect the functional basis, and are they sufficiently visible for responsible interpretation?

This question is necessary because a functional requirement can appear precise while depending on conditions that are uncertain.

Environmental conditions may change.

Demand may differ from assumptions.

Subsurface conditions may remain uncertain.

Operating conditions may develop differently from those originally expected.

If these uncertainties remain hidden, the functional basis may appear more certain than the available Evidence supports.

The removal test is:

Remove Indicator 1.4
→ the functional requirements may remain complete and clear on paper while important assumptions or uncertainties underlying them become invisible.

The other Factor 1 Indicators do not necessarily preserve this question.

Indicator 1.4 therefore performs a distinguishable function.

Its provisional classification is strongly Quality-State Determination.

It concerns the reliability and limits of the basis used to understand what the Infrastructure Quality Object is required to do.

It may also identify conditions that later require Quality-State Influence through mitigation, adaptation, or other action.

Those responses are principally examined under other Factors; Indicator 1.4 itself does not establish a mitigation requirement.

Cross-context examples: projected computing loads and cooling demands, building occupancy and use, bridge traffic and loading assumptions, and water demand and source conditions may each involve assumptions or uncertainty. Indicator 1.4 preserves visibility of these assumptions as part of the functional basis; the applicable QOCs and Evidence remain Context-specific.

Methodological resolution under WQI FTA11. At the selected scale, identify assumptions and uncertainties that affect the functional basis. A closer examination may address a particular life-cycle condition, constituent, or Interface. The amount of detail depends on the determination, while the Indicator remains focused on visibility of assumptions and uncertainty.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether assumptions and uncertainties that affect functional requirements are visible. Any Harm-related implication must be supported by a demonstrable pathway; uncertainty by itself does not establish Harm.

Indicator 1.5 — Traceability of Functional Requirements Across the Lifecycle

Indicator 1.5 asks whether the functional requirements remain traceable as the Infrastructure Quality Object moves through its Lifecycle.

Its determination question is:

Can the original and current functional requirements be reliably followed through Design, Construction, Commissioning, Operation, Repair/Modification, and Decommissioning/Transition?

This question is necessary because functional intent can be lost even when it was originally complete and clear.

The Infrastructure Quality Object changes over time.

Specifications develop.

Construction realizes a physical configuration.

Operating conditions develop.

Repairs and modifications occur.

The functional basis must remain connected to these changes.

The removal test is:

Remove Indicator 1.5
→ the original functional basis may exist, but the ability to determine its continuity through the Lifecycle becomes weaker.

Indicator 1.5 is related to Factor 13 — Documentation and Traceability.

But the determination questions are not identical.

Factor 13 addresses wider continuity, identity, history, documentation, and traceability of the Infrastructure Quality Object and its Evidence.

Indicator 1.5 addresses specifically the continuity of functional requirements within Factor 1.

This apparent cross-Factor overlap should therefore be preserved for horizontal analysis rather than treated as redundancy at this stage.

Indicator 1.5 primarily performs a Quality-State Determination function.

It helps determine whether the functional reference basis being used at a particular Lifecycle Stage remains connected to the required functions established for the Infrastructure Quality Object.

Cross-context examples: data-center expansion and replacement, apartment-building renovation, bridge rehabilitation, and water-network renewal all require continuity between original, modified, and current functional requirements. Indicator 1.5 concerns that continuity, distinct from the wider documentation and traceability functions of Factor 13.

Methodological resolution under WQI FTA11. At the whole-object scale, examine whether functional requirements remain traceable through the relevant life cycle. At finer resolution, follow the requirements through a defined constituent or change where needed. The evidence and detail may vary by stage, but the Indicator retains its focus on continuity of functional requirements.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the functional basis can be followed over time. If loss of traceability could lead to Harm, identify the pathway and examine it in context; a traceability deficiency alone does not establish Harm.

Indicator 1.6 — Functional Changes

Indicator 1.6 asks whether changes to Intended Functions, Intended Results, or governing functional conditions are explicitly identified, evaluated, documented, and authorized before implementation.

Its determination question is:

When the required function changes, is that change recognized and controlled rather than occurring implicitly?

This question is different from traceability.

Traceability allows the functional basis and its changes to be followed through time.

Indicator 1.6 asks whether the change itself is deliberately identified and evaluated before it becomes part of the realized Infrastructure Quality Object.

The removal test is:

Remove Indicator 1.6
→ functional requirements may remain traceable, but an important change may occur without sufficient recognition, evaluation, or authorization.

Indicator 1.6 therefore preserves a necessary and distinguishable determination function.

It also provides an important example for the provisional three-function analysis.

The Indicator has a Quality-State Determination function because the functional change must first be recognized and understood.

It also has a strong Quality-State Influence function because the requirement concerns whether change is evaluated and controlled before implementation.

This dual function should be preserved for the horizontal analysis.

Cross-context examples: a change in data-center capacity or redundancy, building occupancy or use, bridge permitted loads, or water-supply service requirements may alter Intended Functions or Intended Results. Indicator 1.6 asks whether such functional changes are recognized and controlled; it does not itself define the Context-specific acceptance criteria.

Methodological resolution under WQI FTA11. At the selected scale, examine how changes to functions, results, or governing conditions are recognized and evaluated before implementation. A closer review may follow one change through affected constituents and Interfaces. The resolution may vary, while the Indicator remains focused on controlled functional change.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether functional change is recognized and controlled. A Harm-related conclusion requires a demonstrable pathway from an uncontrolled change to a possible consequence in context; a change-control deficiency alone does not establish Harm.

Relationship Among the Six Indicators

The six Indicators form a connected sequence.

They ask:

Are the necessary functions defined?

→ Indicator 1.1.

Are they sufficiently clear?

→ Indicator 1.2.

Are their Boundaries and Interfaces explicit?

→ Indicator 1.3.

Are important assumptions and uncertainties visible?

→ Indicator 1.4.

Can the functional requirements be followed through the Lifecycle?

→ Indicator 1.5.

Are changes to those functions explicitly recognized and controlled?

→ Indicator 1.6.

The Indicators therefore overlap in subject matter because all concern the functional basis.

But the present analysis does not identify unnecessary duplication.

A functional specification can be:

complete but ambiguous;

clear but incomplete;

complete and clear but uncertain at an Interface;

well defined but dependent on hidden assumptions;

correctly established but later lose traceability;

or

fully traceable while an inadequately controlled functional change is introduced.

These possibilities demonstrate that Evidence supporting achievement of the QOCs associated with one Indicator does not automatically establish achievement of the QOCs associated with the other Indicators.

Interim Finding for Factor 1

The analysis supports retaining all six proposed Indicators under Factor 1.

Each preserves a necessary determination question.

Removal of any one would reduce visibility of a different part of the functional basis required for later technical realization and Infrastructure Quality State Determination.

The provisional functional analysis also produces an early finding.

Factor 1 is strongly weighted toward Quality-State Determination functions.

This is reasonable.

The Factor establishes the functional reference basis against which later realization is examined.

Indicator 1.6 also provides a clear Influence function through controlled functional change.

Indicator 1.3 may have an Influence aspect where Boundary or Interface responsibility affects the ability to act, but the current research does not justify treating this as a separate invariant Indicator.

No additional Factor 1 Indicator is justified at this stage.

This conclusion is limited.

It establishes the necessity of the six present Indicators.

It does not establish that the Factor 1 Indicator set is permanently sufficient.

Possible additional findings should remain open to repeated Evidence from Context Guide application and later horizontal comparison across the fourteen Factors.

Broader-infrastructure finding. The six proposed Factor 1 Indicators remain necessary and distinguishable across the four additional infrastructure contexts examined here. Their distinct points of examination are retained without proposing infrastructure-type-specific Indicators. The examples provide a reasoned applicability test, not empirical proof of universal sufficiency; possible gaps remain subject to subsequent Context Guide application and horizontal comparison.

6.2 Factor 2 — Technical Requirements

Factor 2 examines whether the Functional Requirements established under Factor 1 have been correctly translated into Technical Requirements that can be realized and examined.

Its purpose is to ensure that Technical Specifications are correct, complete, coherent, and valid across the Lifecycle of the declared Infrastructure Quality Object.

Factor 2 therefore asks a broad question:

Has the required function been translated into an adequate technical basis for realization and Lifecycle use?

This research examines Factor 2 through seven proposed Indicators:

Indicator 2.1 — Completeness of Technical Specifications

Indicator 2.2 — Correctness and Unambiguity of Translation from Functional to Technical Requirements

Indicator 2.3 — Internal Consistency and Coherence of Technical Specifications

Indicator 2.4 — Explicit Treatment of Technical Assumptions and Uncertainties

Indicator 2.5 — Alignment of Technical Specifications with Lifecycle Conditions

Indicator 2.6 — Traceability of Technical Specifications to Functional Requirements

Indicator 2.7 — Technical Specification Changes.

The seven Indicators examine different conditions needed for an adequate technical basis.

Cross-context applicability test. The seven invariant Indicators concern the adequacy of the technical basis for Function Realization, irrespective of infrastructure type. The following comparisons use physical data centers, residential apartment buildings, bridges, and water-supply systems. They illustrate distinct determination questions, not universal technical requirements or evidence of completed conformity assessment.

Methodological resolution under WQI FTA11. The scale is the declared Infrastructure Quality Object. The depth of review depends on the object and the determination being made. A broad review may examine whether the technical basis supports the object as a whole; a closer review may trace requirements through defined systems, components, and Interfaces. These changes in detail do not change the meaning of the Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 2 has an independent Quality nature and a latent Harm-related nature. Its Quality question concerns whether the technical basis is adequate for Function Realization and later determination. A Harm-related conclusion requires a demonstrable pathway from a deficiency in that basis to a possible consequence in context; a deficiency alone does not establish Harm.

Indicator 2.1 — Completeness of Technical Specifications

Indicator 2.1 asks whether all Technical Requirements necessary to realize the defined Functional Requirements have been established.

Its determination question is:

Have the Functional Requirements been completely translated into the Technical Requirements needed to realize them?

This question is necessary.

A Functional Requirement may be correctly defined under Factor 1 but still lack one or more Technical Requirements needed for its realization.

The gap may then be filled implicitly during Design, Construction, or Operation.

The removal test is:

Remove Indicator 2.1
→ the Functional Requirements may remain defined, but completeness of their technical translation is no longer explicitly determined.

None of the other Factor 2 Indicators necessarily preserves this question.

Correct translation does not establish that all necessary requirements have been translated.

Internal consistency does not establish completeness.

Traceability does not establish completeness.

Indicator 2.1 is therefore necessary and distinguishable.

Its provisional function is primarily Quality-State Determination.

It determines whether a sufficient technical reference basis exists against which later realization can be examined.

Cross-context examination — Indicator 2.1. A data center may require technical provisions for power, cooling, connectivity, and redundancy; an apartment building for structure, utilities, access, and habitability; a bridge for loads, foundations, deck, and connections; and a water-supply system for sources, treatment, pumping, storage, and distribution. The Indicator asks whether the technical specification covers the functions of the declared object. Applicable technical values and Quality Outcome Criteria (QOCs) remain Context-specific.

Methodological resolution under WQI FTA11. At the whole-object scale, ask whether the technical requirements cover the functions of the declared infrastructure across applicable conditions. At finer resolution, examine requirements for defined systems or constituents where needed. The detail may change; the Indicator remains about completeness.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the technical basis includes all requirements needed for the defined functions. Consider Harm only where a missing technical requirement has a demonstrable pathway to a possible consequence in context; a gap alone does not establish Harm.

Indicator 2.2 — Correctness and Unambiguity of Translation from Functional to Technical Requirements

Indicator 2.2 asks whether the meaning of the Functional Requirements has been correctly preserved when translated into Technical Requirements.

Its determination question is:

Do the Technical Requirements correctly and clearly represent the Functional Requirements they are intended to realize?

This question differs from completeness.

A complete set of Technical Requirements may still incorrectly translate the Functional Intent.

The technical requirements may unintentionally alter the required performance, protection, operating conditions, or other functional meaning.

The removal test is:

Remove Indicator 2.2
→ all Functional Requirements may appear to have corresponding Technical Requirements, but correctness of the translation is no longer explicitly determined.

Indicator 2.6, traceability, cannot replace this function.

A technical requirement may be traceable to a functional requirement while interpreting that requirement incorrectly.

The research distinguishes these questions.

Indicator 2.2 is therefore necessary and distinguishable.

Its provisional function is primarily Quality-State Determination.

It tests the reliability of the connection between the functional basis and the technical basis.

Cross-context examination — Indicator 2.2. Translation may concern a data center's continuity requirements becoming electrical and cooling design requirements; a building's occupancy and accessibility functions becoming design provisions; a bridge's carrying function becoming load and structural criteria; or a water system's supply functions becoming flow, pressure, and treatment requirements. The separate question is whether the translation correctly preserves the functional meaning.

Methodological resolution under WQI FTA11. At the selected scale, compare the functional meaning with its technical translation. A closer review may trace a particular function into its technical requirements and Interfaces. The resolution may vary; the Indicator remains about correctness and clarity of that translation.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether technical requirements preserve the intended functional meaning. A Harm-related consequence of a mistaken or ambiguous translation must be demonstrated through a pathway in context.

Indicator 2.3 — Internal Consistency and Coherence of Technical Specifications

Indicator 2.3 asks whether the Technical Specifications work together without contradiction, incompatible assumptions, or unresolved dependencies.

Its determination question is:

Are the Technical Requirements mutually consistent and coherent as one technical basis?

This question is necessary because individual Technical Requirements may each appear reasonable while conflicting when considered together.

Such conflicts may occur across disciplines, documents, Lifecycle conditions, or interfacing systems.

The removal test is:

Remove Indicator 2.3
→ completeness and correctness of individual translations may remain examined, but contradictions among Technical Requirements may remain insufficiently visible.

Indicator 2.3 therefore preserves a separate determination function.

Its provisional function is primarily Quality-State Determination.

It determines whether the technical basis can be relied upon as a coherent whole rather than only as a collection of individual requirements.

Cross-context examination — Indicator 2.3. Incompatibilities can arise between data-center power and cooling assumptions, building architectural and fire-protection systems, bridge structural components and approaches, or water-system pumping, treatment, and distribution specifications. The Indicator retains the question of coherence of the technical basis across disciplines and interfaces.

Methodological resolution under WQI FTA11. At the whole-object scale, examine whether the technical requirements work together as one basis. At finer resolution, test interactions among defined disciplines, systems, components, or Interfaces. The amount of detail varies; the Indicator remains about coherence.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the technical basis is internally consistent. Any Harm-related conclusion requires a demonstrable pathway from a contradiction or unresolved dependency to a possible consequence; inconsistency alone does not establish Harm.

Indicator 2.4 — Explicit Treatment of Technical Assumptions and Uncertainties

Indicator 2.4 asks whether assumptions and uncertainties underlying the Technical Specifications are explicitly identified and retained.

Its determination question is:

What assumptions and uncertainties affect the Technical Requirements, and are their effects sufficiently visible?

Technical requirements may depend on uncertain loads, capacities, environmental conditions, degradation behavior, demand profiles, models, or other information.

If those uncertainties are hidden, a Technical Requirement may appear more certain than its basis supports.

The removal test is:

Remove Indicator 2.4
→ the Technical Specifications may remain complete, clear, and internally consistent while important uncertainty in their basis becomes insufficiently visible.

Indicator 2.4 therefore performs a necessary and distinguishable function.

Its provisional classification is strongly Quality-State Determination.

It helps determine the reliability and limits of the technical basis used for later realization and examination.

The Indicator does not itself prescribe how the uncertainty must be mitigated.

That distinction is important.

Monitoring, mitigation, design margin, or other responses may be examined through other applicable Factors and Indicators or through Context-specific requirements.

Cross-context examination — Indicator 2.4. Relevant assumptions may concern future data-center loads, building occupancy, bridge traffic and environmental exposure, or water demand and source variability. The Indicator asks whether such assumptions and uncertainties are explicit; the required treatment and evidence are determined through the applicable Context and Reference Layer.

Methodological resolution under WQI FTA11. At the selected scale, identify assumptions and uncertainties that affect technical requirements. A closer review may examine a particular model, load, constituent, environmental condition, or life-cycle stage. Detail may vary while the Indicator remains focused on making the basis visible.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether relevant technical assumptions and uncertainties are visible. Consider Harm only where an assumption or uncertainty has a demonstrable pathway to a possible consequence in context; uncertainty alone does not establish Harm.

Indicator 2.5 — Alignment of Technical Specifications with Lifecycle Conditions

Indicator 2.5 asks whether the Technical Specifications address the conditions under which the Infrastructure Quality Object must realize its functions across relevant Lifecycle Stages.

Its determination question is:

Are the Technical Requirements adequate for the relevant Lifecycle conditions, rather than only for one selected condition such as normal Operation?

This question is necessary.

A technical specification may be adequate for normal Operation but inadequate for Construction, Commissioning, abnormal operation, Maintenance, Repair/Modification, or Decommissioning/Transition.

The removal test is:

Remove Indicator 2.5
→ a technically complete and internally consistent specification may still fail to address conditions that arise during other relevant Lifecycle Stages.

This function is not adequately replaced by Indicator 2.1.

Completeness of the Technical Specifications must be judged against the Functional Requirements.

Indicator 2.5 separately preserves the question of whether the technical basis remains adequate across the relevant Lifecycle conditions.

The two Indicators therefore interact but are not redundant.

Indicator 2.5 primarily performs a Quality-State Determination function.

It determines whether the technical basis remains valid for the conditions in which Function Realization is required.

Cross-context examination — Indicator 2.5. Data-center maintenance and expansion, building renovation and continued occupancy, bridge inspection and rehabilitation, and water-system repair or transition illustrate differing Lifecycle conditions. The Indicator examines whether the technical basis remains aligned with relevant stages and conditions without imposing identical Lifecycle criteria.

Methodological resolution under WQI FTA11. The scale remains the declared object or a defined constituent; the resolution includes the relevant life-cycle conditions for that object. A broad review may cover the life-cycle basis, while a closer review may examine specific stages or transitions. The Indicator remains about adequacy across relevant conditions.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the technical basis addresses the life-cycle conditions in which functions must be realized. A Harm-related pathway associated with an omitted condition must be demonstrated in context; an omission alone does not establish Harm.

Indicator 2.6 — Traceability of Technical Specifications to Functional Requirements

Indicator 2.6 asks whether Technical Requirements can be traced to the Functional Requirements they are intended to realize.

Its determination question is:

Can each Technical Requirement be connected to its functional basis, and can each Functional Requirement be followed into the Technical Requirements intended to realize it?

This bidirectional relationship is necessary.

Without it, a Technical Requirement may exist without a clear functional justification.

A Functional Requirement may also remain without a demonstrable technical realization path.

The removal test is:

Remove Indicator 2.6
→ the technical basis may appear complete and correct, but the connection between individual Functional Requirements and Technical Requirements becomes less demonstrable.

Indicator 2.2 cannot replace this function.

Correctness asks whether the translation preserves the functional meaning.

Traceability asks whether the connection itself can be followed and demonstrated.

A translation may be traceable but incorrect.

It may also appear technically correct while lacking sufficient traceability to demonstrate its basis.

Indicator 2.6 is therefore necessary and distinguishable.

Its provisional function is primarily Quality-State Determination.

It preserves the demonstrable connection between what the Infrastructure Quality Object is required to do and the Technical Requirements intended to make that function realizable.

Cross-context examination — Indicator 2.6. The traceable relationship may connect data-center continuity functions to redundancy provisions, building habitability to ventilation and utilities, bridge transport functions to structural design provisions, or water-delivery functions to hydraulic and treatment specifications. This relationship is distinct from the correctness of the translation examined by Indicator 2.2.

Methodological resolution under WQI FTA11. At the whole-object scale, examine whether the technical basis can be followed back to the functional basis. At finer resolution, trace particular requirements and their links through defined systems or Interfaces. Detail may change; the Indicator remains about demonstrable connection.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether technical requirements can be connected to the functions they are intended to realize. If a loss of traceability could contribute to Harm, establish and examine that pathway in context; traceability weakness alone does not establish Harm.

Indicator 2.7 — Technical Specification Changes

Indicator 2.7 asks whether changes to Technical Specifications are explicitly identified, evaluated, documented, and authorized before implementation.

Its determination question is:

When the technical basis changes, is that change recognized and controlled before it affects the realized Infrastructure Quality Object?

This question is necessary because a previously adequate technical basis does not remain adequate automatically when conditions, knowledge, regulations, operating experience, or the Infrastructure Quality Object itself change.

The removal test is:

Remove Indicator 2.7
→ the Technical Specifications may remain documented and traceable, but changes may occur without sufficient evaluation of their effects on Function Realization, assumptions, safety margins, Interfaces, or other Technical Requirements.

Indicator 2.7 is therefore distinguishable from Indicator 2.6.

Traceability allows the relationship between functional and technical requirements to be followed.

Indicator 2.7 asks whether alteration of the technical basis is deliberately evaluated and controlled.

Its provisional classification includes both Quality-State Determination and Quality-State Influence functions.

The change must first be identified and its effects determined.

The change must then be controlled before implementation.

Cross-context examination — Indicator 2.7. Changes in computing load or cooling design, building use or systems, bridge permitted loads or structural repairs, and water treatment or network configuration may change the technical basis. The Indicator concerns identification, evaluation, authorization, and control of technical-specification changes; it does not itself set the acceptance criteria for those changes.

Methodological resolution under WQI FTA11. At the selected scale, examine how a technical change is identified and assessed before implementation. A closer review may trace effects through affected requirements, components, and Interfaces; a broader review may consider effects on the whole object. The resolution changes, but the Indicator remains about controlled technical change.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether changes to the technical basis are recognized and controlled. A Harm-related conclusion requires a demonstrable pathway from an inadequately controlled change to a possible consequence in context; a change-control deficiency alone does not establish Harm.

Relationship Among the Seven Indicators

The seven Indicators form a connected set of questions:

Have all necessary Technical Requirements been established?

→ Indicator 2.1.

Do they correctly and clearly translate the Functional Requirements?

→ Indicator 2.2.

Are the Technical Requirements mutually consistent and coherent?

→ Indicator 2.3.

Are important assumptions and uncertainties visible?

→ Indicator 2.4.

Do the Technical Specifications remain adequate for relevant Lifecycle conditions?

→ Indicator 2.5.

Can the Technical Requirements be traced to their Functional Requirements and back?

→ Indicator 2.6.

Are changes to the technical basis explicitly recognized and controlled?

→ Indicator 2.7.

The Indicators overlap because all concern the same technical basis.

The present analysis does not identify unnecessary duplication.

A Technical Specification can be:

complete but incorrectly translated;

correctly translated but incomplete;

complete and correctly translated but internally contradictory;

coherent but dependent on hidden assumptions;

adequate for normal Operation but inadequate for another Lifecycle condition;

technically reasonable but insufficiently traceable to Functional Requirements;

or

originally adequate but later changed without sufficient evaluation and control.

These possibilities show that satisfactory determination under one Indicator does not necessarily establish satisfactory determination under the others.

Relationship Between Factor 1 and Factor 2

The analysis also reveals an important parallel between Factors 1 and 2.

Factor 1 establishes the functional basis.

Factor 2 establishes the technical basis needed to realize it.

Several determination questions therefore appear similar across the two Factors.

Both examine completeness.

Both examine clarity or correctness.

Both examine assumptions and uncertainties.

Both examine traceability.

Both examine change.

This similarity does not establish redundancy.

The objects of determination are different.

Factor 1 asks whether what the Infrastructure Quality Object must do has been adequately defined.

Factor 2 asks whether that functional requirement has been adequately translated into technical conditions capable of realization and examination.

The distinction can be expressed simply as:

Factor 1
→ What must the Infrastructure Quality Object do?

Factor 2
→ What Technical Requirements must be satisfied so that it can do it?

The repeated determination questions across these two Factors are an important finding for later horizontal analysis.

They may show that similar questions recur across different quality-relevant dimensions while remaining necessary within each.

Interim Finding for Factor 2

The analysis supports retaining all seven proposed Indicators under Factor 2.

Each preserves a necessary determination question within Technical Requirements.

Removal of any one would leave a different part of the technical basis materially less visible or less determinable.

The provisional functional analysis shows that Factor 2, like Factor 1, is strongly weighted toward Quality-State Determination functions.

This is consistent with its role in establishing the technical reference basis against which the realized Infrastructure Quality Object can later be examined.

Indicator 2.7 also contains a clear Quality-State Influence function through controlled technical change.

No additional Factor 2 Indicator is justified by this analysis at this stage.

This conclusion does not establish permanent sufficiency.

Across the four additional infrastructure Contexts, all seven established Factor 2 Indicators remain necessary and distinct. The evidence examined does not support changing an Indicator title. Factor 2 remains separate from Factor 1: Functional Requirements define the Intended Functions and Intended Results; Technical Requirements establish the technical basis for realizing them. Whether the requirements are achieved is assessed against applicable context-specific QOCs, not by changing the Indicators. This is a methodological test across Contexts, not empirical proof of permanent sufficiency.

Context Guide application should continue to test whether repeated technical determination needs arise that cannot be adequately represented through these seven Indicators.

6.3 Factor 3 — Conformity Assessment

Reviews, inspections, tests, verification, and other conformity-assessment activities produce Work and Results with Quality characteristics of their own.

When they contribute to Infrastructure Function Realization, examine their Work and Results using applicable requirements, Factors, Indicators, and QOCs for that Context. These activities may also be identified as Quality Objects in their own right. Keep three questions distinct: What requirements apply? Does the declared Infrastructure Quality Object conform to them? Do the conformity-assessment Work and Results have adequate Quality?

Factor 3 examines whether the condition of the declared Infrastructure Quality Object and its alignment with Functional Intent and Technical Requirements are sufficiently examined and supported by Evidence.

Its purpose is to ensure that Conformity Findings and Conformity Statements are based on an identified assessment basis rather than on assumption or unsupported assertion.

Factor 3 therefore asks a broad question:

Can conformity of the Infrastructure Quality Object to the applicable requirements be responsibly demonstrated?

This research examines Factor 3 through seven proposed Indicators:

Indicator 3.1 — Defined Basis for Conformity Assessment

Indicator 3.2 — Assessment of Conformity to Technical Specifications

Indicator 3.3 — Assessment of Continued Consistency Between Technical and Functional Specifications

Indicator 3.4 — Risk-Proportionate Depth of Conformity Assessment

Indicator 3.5 — Independence and Objectivity of Conformity Assessment

Indicator 3.6 — Treatment of Non-Conformity and Unresolved Conditions

Indicator 3.7 — Traceability of Conformity Statements.

The seven Indicators do not establish one universal assessment method.

Inspection methods, testing methods, validation, verification, sampling, assurance levels, certification methods, and other assessment means remain dependent on the applicable Context and Reference Layer.

The seven Indicators preserve the questions that must remain visible regardless of which assessment methods are used.

The seven Factor 3 Indicators are examined against physical data centers, residential apartment buildings, bridges, and water-supply systems, alongside existing energy-infrastructure applications. These examples support methodological testing; they are not completed Conformity Assessments. Factor 3 examines the declared Infrastructure Quality Object against its Applicable Basis. Work-integrated checking or verification, and assessment of a provider organization’s quality-management system, may provide relevant information. Neither is automatically equivalent to object-level Conformity Assessment.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object fixes the scale of examination. The resolution depends on the determination being made: a review may examine whether conformity has been demonstrated for the whole object, or trace assessment results through a system, component, life-cycle stage, or Interface. The needed depth may vary without changing the questions represented by Factor 3 and its Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 3 has an independent Quality nature: whether conformity has been adequately examined and supported. It also has a latent Harm-related nature. A weakness in assessment does not by itself establish Harm; a Harm-related conclusion requires a demonstrable pathway from that weakness to a possible consequence in context.

Indicator 3.1 — Defined Basis for Conformity Assessment

Indicator 3.1 asks whether the basis for the conformity assessment is explicitly defined.

Its determination question is:

What is being assessed, against which requirements, under which Lifecycle conditions, and within what scope?

This question is necessary.

A statement that infrastructure “conforms” has limited meaning if the object, requirements, scope, or Lifecycle Stage are not clear.

Conformity cannot be interpreted responsibly without knowing what the statement actually covers.

The removal test is:

Remove Indicator 3.1
→ an assessment may be performed, but the basis against which conformity is claimed may remain ambiguous.

None of the other Factor 3 Indicators necessarily preserves this question.

Assessment depth does not define the assessment basis.

Independence does not define it.

Traceability of the final statement does not by itself establish that the original basis was adequately defined.

Indicator 3.1 is therefore necessary and distinguishable.

Cross-context application: the assessment basis may identify power, cooling, and facility requirements for a physical data center; building-code, occupancy, and life-safety requirements for an apartment building; design-load and inspection requirements for a bridge; or treatment, delivery, and water-quality requirements for a water-supply system. Indicator 3.1 preserves the need to declare which requirements, boundaries, lifecycle stage, and criteria are actually assessed.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how closely the Applicable Basis, assessment scope, included Results, and Interfaces are examined. A whole-object assessment may require more detailed examination of selected constituents. These differences in depth do not change the Indicator’s question about whether the basis and scope are defined.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the basis and scope of assessment are clear and appropriate. Consider Harm only where an inadequately defined basis has a demonstrable pathway to a possible consequence in context; a scope gap alone does not establish Harm.

Its provisional function is strongly Quality-State Determination.

It establishes the reference basis needed to interpret what a conformity finding actually means.

Indicator 3.2 — Assessment of Conformity to Technical Specifications

Indicator 3.2 asks whether the realized Infrastructure Quality Object or relevant design result has actually been examined against the applicable Technical Specifications.

Its determination question is:

Has conformity to the Technical Requirements been demonstrated rather than assumed?

This question is central to Factor 3.

Factors 1 and 2 establish functional and technical requirements.

They do not demonstrate that the realized Infrastructure Quality Object satisfies those requirements.

The removal test is therefore direct:

Remove Indicator 3.2
→ Technical Requirements may exist, but demonstrated correspondence between those requirements and the realized object becomes insufficiently represented.

Indicator 3.2 cannot be replaced by Factor 2.

Factor 2 determines the quality of the Technical Specifications themselves.

Indicator 3.2 determines whether design results and realized infrastructure conform to those Technical Specifications.

The distinction is:

Adequate Technical Requirement
≠ demonstrated conformity to that requirement.

Indicator 3.2 is therefore necessary and clearly distinguishable.

Cross-context application: the realized data-center physical plant, residential building systems, bridge structure, or water-supply assets must be assessed against their own applicable technical specifications. The necessary inspections, tests, calculations, and Evidence differ by Context; the invariant determination question does not.

Methodological resolution under WQI FTA11. The scale may be the whole declared object or a constituent; resolution determines the detail used to compare the examined condition or Result against applicable Technical Requirements. A broad determination may be supported by closer checks of selected systems or components. The Indicator remains about conformity to those requirements.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the examined object conforms to applicable Technical Requirements. A Harm-related conclusion requires a demonstrable pathway from a nonconformity or assessment deficiency to a possible consequence; a nonconformity alone does not establish Harm.

Its provisional function includes both Quality-State and Quality-State Determination.

It contributes information about the actual realized condition of the Infrastructure Quality Object.

At the same time, its primary role within Factor 3 is to determine whether that condition has been adequately demonstrated against the applicable Technical Requirements.

Indicator 3.3 — Assessment of Continued Consistency Between Technical and Functional Specifications

Indicator 3.3 asks whether Technical Specifications continue to reflect the approved Functional Specifications as conditions change through the Lifecycle.

Its determination question is:

Do the Technical Requirements still represent the Functional Intent on which they were based?

This question is necessary because initial conformity between functional and technical requirements does not remain valid automatically.

Operating experience may develop.

Knowledge may improve.

Conditions may change.

The Infrastructure Quality Object may be modified or repurposed.

A Technical Specification may continue to be followed exactly while no longer adequately representing the required function.

The removal test is:

Remove Indicator 3.3
→ technically compliant infrastructure may still be treated as acceptable even when the Technical Requirements no longer adequately reflect the Functional Intent.

This Indicator is related to Factor 2, especially Indicators 2.2, 2.6, and 2.7.

But the determination functions differ.

Factor 2 examines whether the technical basis is correctly established, traceable, and controlled when changed.

Indicator 3.3 asks whether continued consistency between the technical and functional bases has actually been reassessed at appropriate Lifecycle points.

The distinction can be expressed as:

Factor 2
→ Is the technical basis adequately established and maintained?

Indicator 3.3
→ Has its continued consistency with Functional Intent been demonstrated?

Indicator 3.3 is therefore necessary and distinguishable.

Cross-context application: increased computing loads, changed building use or occupancy, revised bridge traffic or load assumptions, and altered water-demand or water-quality functions may require renewed assessment of whether the technical basis remains aligned with the approved functional basis. Indicator 3.3 remains distinct from both the original specification and its initial conformity assessment.

Methodological resolution under WQI FTA11. At the declared-object scale, examine continued alignment between Technical and Functional Requirements across relevant life-cycle conditions. At finer resolution, trace selected changes, assumptions, or Interfaces. The needed depth may change; the Indicator remains about continued consistency.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the technical basis continues to reflect the Functional Requirements. Any Harm-related conclusion requires a demonstrable pathway from lost alignment to a possible consequence in context; misalignment alone does not establish Harm.

Its provisional function is primarily Quality-State Determination.

It tests whether an earlier conclusion remains valid under changed conditions.

Indicator 3.4 — Risk-Proportionate Depth of Conformity Assessment

Indicator 3.4 asks whether the depth of conformity assessment is sufficient for the importance and possible consequences of the condition being assessed.

Its determination question is:

Is the level of confidence in conformity adequate for the criticality of the function, consequence of failure, and Lifecycle Stage?

This question is necessary because conformity assessment can be performed at very different levels of depth.

A superficial review may be sufficient for a low-consequence condition but inadequate for a condition where failure could produce severe consequences.

The simple existence of an assessment therefore does not establish that the assessment was sufficient.

The removal test is:

Remove Indicator 3.4
→ conformity may be declared on the basis of an assessment whose depth is not adequate for the consequence, criticality, uncertainty, or Lifecycle maturity involved.

Indicator 3.2 cannot replace this function.

Indicator 3.2 asks whether conformity has been assessed.

Indicator 3.4 asks whether the depth of that assessment is sufficient for the determination being made.

The distinction is:

Assessment performed
≠ assessment depth sufficient.

Indicator 3.4 is therefore necessary and distinguishable.

Cross-context application: assessment depth may depend on consequences associated with data-center electrical and cooling failures, building fire and egress conditions, bridge structural performance, or water contamination and loss of supply. Indicator 3.4 preserves the question of justified assessment depth without prescribing one universal test or certification scheme.

Methodological resolution under WQI FTA11. The declared object or constituent sets the scale, while resolution determines the depth needed for the particular determination. More detailed examination may be justified by function, possible consequence, uncertainty, or life-cycle stage. The Indicator remains about whether the depth is sufficient.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether assessment depth is adequate for the determination. A Harm-related conclusion requires a demonstrable pathway from inadequate depth to a possible consequence in context; insufficient depth alone does not establish Harm.

Its provisional function is strongly Quality-State Determination.

It concerns the reliability of the determination rather than the underlying physical condition itself.

Indicator 3.5 — Independence and Objectivity of Conformity Assessment

Indicator 3.5 asks whether the assessment judgment is sufficiently protected from relevant bias.

Its determination question is:

Can the conformity assessment be relied upon as sufficiently objective for the decision being made?

This question is necessary because the technical adequacy of an assessment method does not eliminate the possibility of biased interpretation.

Self-confirmation, normalization of deviation, institutional pressure, or other forms of bias can affect what is recognized, accepted, or reported.

The removal test is:

Remove Indicator 3.5
→ an assessment may have a defined basis, adequate technical depth, and substantial Evidence while the resulting judgment remains vulnerable to material bias.

The Indicator does not require third-party certification.

It does not prescribe a particular organizational structure.

Its determination question is narrower.

It preserves the need to determine whether independence and objectivity are sufficient for the assessment Context.

Indicator 3.5 is therefore distinguishable from competence, which is addressed principally under Factor 9.

A person may be highly competent but not sufficiently independent.

A person may also be independent but not competent.

The two conditions are not interchangeable.

Indicator 3.5 primarily performs a Quality-State Determination function.

It concerns the reliability of the path from Evidence to assessment judgment.

This Indicator is particularly important to the horizontal research developed in Section 5.

It provides a clear example where the quality of the determination process itself can affect whether the reported state corresponds sufficiently to the actual condition.

Cross-context application: the potential for bias or conflicts of interest must be examined where conformity judgments concern data-center commissioning, building inspections, bridge evaluations, or water-system testing. The required form and degree of independence depend on the Applicable Basis and the assessment scheme; the invariant need for objective judgment remains.

Methodological resolution under WQI FTA11. The scale is the declared object or constituent; resolution determines where independence and objectivity need examination, including relevant organizational relationships and Interfaces. Examination may focus on particular judgments without changing the Indicator's meaning.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether assessment judgment is sufficiently independent and objective. A Harm-related conclusion requires a demonstrable pathway from compromised judgment to a possible consequence; a potential conflict alone does not establish Harm.

Indicator 3.6 — Treatment of Non-Conformity and Unresolved Conditions

Indicator 3.6 asks whether identified non-conformities, assessment limitations, Evidence gaps, and other Unresolved Conditions remain explicitly visible.

Its determination question is:

When conformity cannot be demonstrated, or when a limitation remains unresolved, is that condition preserved rather than hidden inside a broader positive statement?

This question is necessary.

A conformity assessment does not produce only positive findings.

It may identify deviations.

It may reveal incomplete Evidence.

It may identify conditions that cannot yet be resolved.

If those findings are omitted, minimized, or absorbed into a general Conformity Statement, the final picture of the Infrastructure Quality Object may become misleading.

The removal test is:

Remove Indicator 3.6
→ known limitations or non-conformities may disappear from the visible assessment basis even though other parts of the object have satisfactory findings.

Indicator 3.6 therefore has a strong relationship to non-compensability and uncertainty.

A satisfactory finding elsewhere does not eliminate an unresolved condition.

The Indicator does not prescribe corrective action procedures.

Its function is to preserve the condition and its implications for determination.

Its provisional classification includes Quality-State and Quality-State Determination functions.

A non-conformity may describe an actual condition of the Infrastructure Quality Object.

An unresolved condition may describe a limitation in the ability to determine that condition.

The Indicator therefore provides an important example of one invariant Indicator serving more than one provisional horizontal function.

Cross-context application: incomplete testing, an unresolved building inspection finding, an uncertain bridge condition, or missing water-quality Evidence must remain visible in the assessment conclusion. Non-achievement of an applicable QOC and insufficient Evidence to determine achievement are different findings; neither constitutes a deficiency of the invariant Indicator itself.

Methodological resolution under WQI FTA11. The scale may be the whole object or a constituent. Resolution determines the detail needed to identify non-conformities, limitations, Evidence gaps, and unresolved conditions and to follow them across relevant Interfaces. The Indicator remains about keeping these conditions visible.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether non-conformities and unresolved conditions remain visible. A Harm-related conclusion requires a demonstrable pathway from concealment or mishandling to a possible consequence; an unresolved condition alone does not establish Harm.

Indicator 3.7 — Traceability of Conformity Statements

Indicator 3.7 asks whether a Conformity Statement can be traced back to the assessments performed, the requirements assessed, and the Lifecycle Stage to which the statement applies.

Its determination question is:

Can the meaning and basis of the Conformity Statement be reconstructed and verified?

This question is necessary because a conformity statement can become misleading when separated from its scope and supporting assessment.

A statement such as “conforming” may later be repeated without identifying:

what was assessed;

against which requirements;

at what Lifecycle Stage;

under what conditions;

and on the basis of which Evidence.

The removal test is:

Remove Indicator 3.7
→ conformity findings may exist, but later users may be unable to determine reliably what the statement actually demonstrates.

Indicator 3.7 is related to Factor 13 — Documentation and Traceability.

But the determination functions are not identical.

Factor 13 addresses wider lifecycle identity, documentation, Evidence continuity, and traceability.

Indicator 3.7 addresses specifically the traceability of Conformity Statements to their assessment basis.

This apparent cross-Factor overlap should therefore be preserved for later horizontal analysis rather than treated as redundancy.

Indicator 3.7 primarily performs a Quality-State Determination function.

It protects the reliability and limits of the communicated conformity finding.

Cross-context application: a conformity statement for a data-center subsystem, apartment building, bridge, or water-supply facility must be traceable to the specific declared object, assessed requirements, Evidence, assessment conditions, and relevant Lifecycle Stage. Such traceability does not imply that a limited constituent finding establishes conformity of the whole Infrastructure Quality Object.

Methodological resolution under WQI FTA11. The declared object sets the scale of the statement; resolution determines how far its traceability must extend into the assessment basis, scope, findings, and relevant life-cycle stage. A closer review may trace a statement to constituent-level evidence. The Indicator remains about traceability.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether conformity statements can be traced to their basis and supporting assessment. A Harm-related conclusion requires a demonstrable pathway from deficient traceability to a possible consequence; a traceability gap alone does not establish Harm.

Relationship Among the Seven Indicators

The seven Indicators form a connected sequence of conformity determination questions.

They ask:

Is the assessment basis defined?

→ Indicator 3.1.

Has conformity to the Technical Specifications actually been demonstrated?

→ Indicator 3.2.

Does the technical basis still remain consistent with Functional Intent?

→ Indicator 3.3.

Is the assessment sufficiently deep for the Risk, criticality, and Lifecycle condition?

→ Indicator 3.4.

Is the assessment judgment sufficiently independent and objective?

→ Indicator 3.5.

Are non-conformities and unresolved conditions kept visible?

→ Indicator 3.6.

Can the resulting Conformity Statement be traced to what was actually assessed?

→ Indicator 3.7.

The Indicators therefore address different possible weaknesses in conformity determination.

An assessment may have:

a poorly defined basis;

a clear basis but insufficient Evidence of actual conformity;

demonstrated technical conformity but loss of alignment with Functional Intent;

adequate technical assessment but insufficient depth for the consequence of failure;

adequate depth but biased judgment;

sound assessment but hidden unresolved conditions;

or a valid finding that later becomes misleading because its scope and basis are no longer traceable.

These possibilities demonstrate that Evidence supporting achievement of the QOCs associated with one Indicator does not automatically establish achievement of the QOCs associated with the others.

Boundary and Fractal Application Test for Indicators 3.1–3.7

The boundary of the declared Infrastructure Quality Object and the scope of a particular Conformity Assessment are related but distinct. Routine pipeline inspection performed by the operator and the same inspection procured from an external provider can both contribute to the pipeline Infrastructure Realization Pathway. Organizational outsourcing alone does not decide whether the assessment Work and Results fall within the declared Quality Object boundary or contribute through a defined Interface.

Indicator 3.1 requires the assessment basis and scope to identify the infrastructure, included Work and Results, and relevant Interfaces. For outsourced pipeline redesign, the design activity and its Results may themselves be examined as a contributing Quality Object, even when those Results contribute to the pipeline reconstruction. A contract alone neither establishes conformity nor settles the object boundary.

Indicators 3.2 and 3.3 concern the substantive determination of conformity and continued alignment between Technical Requirements and Functional Requirements; they cannot be satisfied merely by showing that an operator or contractor performed an inspection or design review. Indicator 3.4 addresses the justified depth of examination in light of Risk, consequence, and Lifecycle conditions, whether assessment Work is internal or external.

Indicator 3.5 examines independence and objectivity of assessment judgment, not the simple presence of an external contractor. Outsourcing may change possible conflicts of interest but does not automatically demonstrate objectivity. Indicator 3.6 requires non-conformities and unresolved conditions to remain visible across organizational Interfaces. Indicator 3.7 requires Conformity Statements to remain traceable to the applicable basis, examined object, assessment scope, findings, and relevant contributing Work and Results.

Fractal distinction: the Quality of the Conformity Assessment Work and its Results can itself be examined under the applicable Quality architecture and context-specific QOCs. That examination is distinct from determining the pipeline Quality State and from determining the Quality of the assessment provider’s organizational management system. The Quality of one contributing activity neither establishes nor negates, by itself, the Quality of the larger infrastructure object.

Interim methodological finding. The internal-versus-outsourced test does not currently justify removal, renaming, or addition of any of the seven established Factor 3 Indicators. It does expose boundary declarations and Interfaces as conditions requiring explicit treatment when establishing context-specific QOCs and assessment scopes. This remains a provisional research finding, not a completed proof of sufficiency across infrastructure Contexts.

Relationship of Factor 3 to Factors 1 and 2

Factors 1, 2, and 3 form a particularly important sequence.

Factor 1 establishes what the Infrastructure Quality Object is required to do.

Factor 2 establishes the Technical Requirements through which that function is to be realized.

Factor 3 asks whether alignment between requirements and the realized Infrastructure Quality Object has been sufficiently demonstrated.

The relationship can be expressed as:

Factor 1
→ What must the Infrastructure Quality Object do?

Factor 2
→ What Technical Requirements are needed to realize it?

Factor 3
→ Has conformity of the realized object to those requirements been sufficiently demonstrated?

This sequence explains why Factor 3 should not be reduced to a simple compliance check.

Its function is demonstrability.

A requirement may exist.

The infrastructure may actually conform.

But unless the conformity can be supported by sufficient Evidence within a defined assessment basis, the determination remains incomplete.

Interim Finding for Factor 3

The analysis supports retaining all seven proposed Indicators under Factor 3.

Each preserves a necessary determination question.

Removal of any one would weaken a different part of the conformity determination.

The provisional functional analysis also produces a strong horizontal finding.

Factor 3 is heavily concentrated in Quality-State Determination functions.

This is consistent with its role as the bridge that demonstrates the relationship between requirements and Evidence-Supported Findings.

Indicator 3.2 also contains a clear Quality-State function because conformity assessment produces Evidence about the realized condition itself.

Indicator 3.6 can serve both State and Determination functions because it may describe either an actual non-conforming condition or an unresolved limitation in the ability to determine conformity.

No clear Quality-State Influence Indicator is established within Factor 3.

This appears consistent with the Factor's defined scope.

Factor 3 determines and preserves conformity findings.

It does not prescribe corrective action systems or redesign decisions.

This absence should therefore not presently be interpreted as an Indicator gap.

The capability to influence an unacceptable condition is addressed through other Factors and Context-specific requirements.

No additional Factor 3 Indicator is justified at this stage.

Broader-infrastructure finding. The seven Factor 3 Indicators remain necessary and distinguishable across the four additional contexts examined. Factor 3 retains its independent place among the fourteen proposed Factors and its applicability at relevant constituent and whole-object levels. Context-specific conformity assessment methods, schemes, depth, and Evidence are determined through the Applicable Basis and QOCs; these variations do not by themselves require additional invariant Indicators.

This conclusion remains open to continued Context Guide testing, particularly where repeated experience may reveal limitations in the reliability, independence, timing, or communication of conformity determinations that are not adequately represented by the existing seven Indicators.

6.4 Factor 4 — Structural and Functional Integrity

Factor 4 examines whether the declared Infrastructure Quality Object preserves the structural and functional condition required to realize its Intended Functions and Intended Results over time.

Its scope includes Degradation and Aging, damage, Interfaces, foreseeable abnormal conditions, transient conditions, degraded conditions, and changes across the Lifecycle.

Factor 4 therefore asks a broad question:

Does the assembled Infrastructure Quality Object preserve the integrity needed to realize its Intended Functions under the conditions in which it is expected to exist and operate?

This research examines Factor 4 through seven proposed Indicators:

Broader-infrastructure applicability test. The seven invariant Indicators are examined for physical data-center infrastructure, residential apartment buildings, bridges, and water-supply systems, alongside the established energy-infrastructure examples. The examination tests the necessity and distinguishability of each determination function; it does not establish universal technical QOCs or claim completed empirical validation. The declared Infrastructure Quality Object remains one whole, including relevant constituent systems, components, and interfaces.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object sets the scale of examination. The resolution depends on what must be determined: a broad review may consider the integrity of the whole object, while a closer review may examine a load path, system, constituent, change, or life-cycle condition. The required depth may vary without changing what Factor 4 and its Indicators ask.

Dual-Nature Postulate under WQI FTA14. Factor 4 has an independent Quality nature: whether structural and functional integrity are adequately established and preserved. It also has a latent Harm-related nature. A deficiency in integrity does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway from the deficiency to a possible consequence in context.

Indicator 4.1 — Definition of Integrity-Critical Functions and Failure Modes

Indicator 4.2 — Integrity of the Declared Infrastructure Quality Object

Indicator 4.3 — Consideration of Degradation, Damage, and Aging Mechanisms

Indicator 4.4 — Integrity Under Foreseeable Abnormal and Transient Conditions

Indicator 4.5 — Preservation of Integrity Through Change and Modification

Indicator 4.6 — Integrity Margin and Tolerance to Uncertainty

Indicator 4.7 — Integrity-Relevant Information Retention.

These Indicators examine integrity from several different directions.

Some concern the actual condition of the Infrastructure Quality Object.

Others concern the ability to determine whether integrity has been preserved.

Others concern preservation of integrity under change.

Indicator 4.1 — Definition of Integrity-Critical Functions and Failure Modes

Indicator 4.1 asks whether the functions whose loss or degradation could compromise Infrastructure Safety, Operational Reliability, Intended Results, or another Critical Infrastructure Condition have been explicitly identified together with relevant Failure Modes.

Its determination question is:

Which functions are critical to integrity, and how can their loss or degradation occur?

This question is necessary because integrity examination cannot be based only on a general review of components.

The analysis must identify which functions and Failure Modes matter to the Infrastructure Quality Object as a whole.

Without this step, significant attention may be given to individual components while an infrastructure-level failure path remains insufficiently visible.

The removal test is:

Remove Indicator 4.1
→ integrity may still be examined, but the connection between critical functions, Failure Modes, and infrastructure-level consequences becomes less explicit and less systematic.

Indicator 4.2 cannot replace this function.

Indicator 4.2 asks whether the assembled Infrastructure Quality Object preserves integrity.

Indicator 4.1 first identifies which functions and failure paths require particular integrity attention.

The two Indicators therefore perform different roles.

Indicator 4.1 primarily performs a Quality-State Determination function.

It establishes the basis for determining which integrity conditions and Failure Modes must be examined.

It may also support Quality-State Influence because identification of critical functions and Failure Modes can guide protection or intervention.

But the Indicator itself does not prescribe those actions.

Cross-context examination: integrity-critical functions and Failure Modes may concern data-center electrical supply and cooling continuity; building load-bearing, enclosure, and life-supporting systems; bridge load paths and structural connections; and water-system conveyance, containment, and treatment functions. Indicator 4.1 preserves identification of the functions and Failure Modes requiring examination; applicable QOCs remain Context-specific.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how closely integrity-critical functions and Failure Modes must be identified across its systems, constituents, and Interfaces. The examination may focus on particular functions without changing the Indicator's question.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether integrity-critical functions and Failure Modes are identified. A Harm-related conclusion requires a demonstrable pathway from an omitted function or failure mode to a possible consequence; an omission alone does not establish Harm.

Indicator 4.2 — Integrity of the Declared Infrastructure Quality Object

Indicator 4.2 asks whether Structural Integrity and Functional Integrity are determined for the declared Infrastructure Quality Object as assembled and configured within its Boundary.

Its determination question is:

Does the Infrastructure Quality Object as a whole preserve the structural and functional condition required for Function Realization?

This question is central to Factor 4.

Component adequacy does not automatically establish integrity of the assembled object.

Interactions, dependencies, load sharing, combined degradation mechanisms, and configuration can produce system-level behavior that is not visible when parts are examined separately.

The removal test is:

Remove Indicator 4.2
→ integrity findings may remain available for individual components or subsystems while integrity of the declared Infrastructure Quality Object itself becomes insufficiently represented.

None of the other Factor 4 Indicators fully replaces this question.

They examine important contributors to integrity.

Indicator 4.2 preserves the integrated condition itself.

Its provisional function is strongly Quality-State.

It directly concerns the actual structural and functional condition of the declared Infrastructure Quality Object.

It also depends on Quality-State Determination functions because that integrated condition must be supported by Evidence.

But its principal focus is the state of the object.

Cross-context examination: the integrity of a data-center facility depends on interactions among its physical support systems; a residential building on the assembled structure and supporting systems; a bridge on its complete structural load path and interfaces; and a water-supply system on interconnected treatment, storage, and distribution assets. Findings for individual components cannot alone establish the integrity of the declared whole object.

Methodological resolution under WQI FTA11. The scale is the declared object or a constituent; resolution determines the detail needed to examine how structural and functional integrity are established in the assembled and configured object. A whole-object determination may rely on closer examination of selected components and Interfaces.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the declared object preserves structural and functional integrity. Consider Harm only where an integrity deficiency has a demonstrable pathway to a possible consequence in context; a deficiency alone does not establish Harm.

Indicator 4.3 — Consideration of Degradation, Damage, and Aging Mechanisms

Indicator 4.3 asks whether mechanisms that can reduce structural or functional integrity over time have been explicitly identified and considered.

Its determination question is:

What mechanisms can degrade or damage integrity over time, and have their effects been considered over the intended service life?

This question is necessary because integrity is not a fixed condition established once at Design or Commissioning.

Materials age.

Corrosion may develop.

Fatigue may accumulate.

Wear may occur.

Damage may arise.

Other degradation mechanisms may progressively change the condition of the Infrastructure Quality Object.

The removal test is:

Remove Indicator 4.3
→ present integrity may be examined while the mechanisms capable of changing that condition over time become insufficiently visible.

Indicator 4.2 does not fully replace this function.

Indicator 4.2 addresses integrated integrity.

Indicator 4.3 requires explicit examination of the mechanisms through which that integrity may degrade.

A satisfactory condition today does not establish that degradation has been adequately understood.

Indicator 4.3 therefore preserves a necessary and distinguishable determination function.

Its provisional classification includes Quality-State and Quality-State Determination functions.

Evidence of degradation or damage concerns actual condition.

Identification and understanding of degradation mechanisms concern the ability to determine how integrity may evolve.

No separate inspection or maintenance Indicator is created here because the proposed Indicator does not establish inspection intervals or maintenance techniques.

Cross-context examination: equipment wear and thermal cycling may affect a data center; moisture intrusion and material aging a building; fatigue, corrosion, and foundation movement a bridge; and corrosion, erosion, fouling, or deterioration a water-supply system. Indicator 4.3 preserves the examination of degradation mechanisms, without prescribing one mechanism or technical threshold for all Contexts.

Methodological resolution under WQI FTA11. At the object scale, examine relevant degradation, damage, and aging mechanisms over the life cycle. At finer resolution, examine mechanisms affecting particular materials, systems, or constituents. The depth may vary; the Indicator remains about identifying and considering these mechanisms.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether relevant mechanisms that may reduce integrity are identified and considered. Any Harm-related conclusion requires a demonstrable pathway from a mechanism or its effects to a possible consequence; the presence of a mechanism alone does not establish Harm.

Indicator 4.4 — Integrity Under Foreseeable Abnormal and Transient Conditions

Indicator 4.4 asks whether Structural and Functional Integrity remain adequately addressed outside normal steady-state operation.

Its determination question is:

Can the Infrastructure Quality Object preserve required integrity during foreseeable abnormal, transient, and degraded conditions?

This question is necessary because infrastructure may experience very different loads, configurations, temperatures, pressures, flows, stresses, or control conditions during startup, shutdown, upset, temporary overload, degraded operation, or recovery.

Integrity demonstrated only for normal operation may therefore provide incomplete assurance.

The removal test is:

Remove Indicator 4.4
→ integrity may be demonstrated under normal conditions while important integrity behavior during foreseeable non-normal conditions remains insufficiently visible.

Indicator 4.3 cannot replace this function.

Degradation and aging concern changes that develop over time.

Indicator 4.4 concerns integrity under particular operating conditions that may occur even without long-term degradation.

Indicator 4.6 also cannot replace it.

Tolerance to uncertainty concerns variability and uncertainty in the basis of the integrity determination.

Indicator 4.4 concerns identifiable abnormal and transient operating states.

Indicator 4.4 is therefore necessary and distinguishable.

Its provisional function is primarily Quality-State.

It asks about the actual ability of the Infrastructure Quality Object to preserve integrity under these conditions.

It also has a Quality-State Determination aspect because the behavior must be examined and evidenced.

Cross-context examination: data-center power interruptions or cooling transients, building emergency loads or fire conditions, bridge exceptional loading or thermal movement, and water-system pressure surges or supply interruptions may require distinct integrity determinations. Indicator 4.4 addresses foreseeable abnormal or transient conditions rather than long-term degradation alone.

Methodological resolution under WQI FTA11. The scale remains the declared object or a constituent; resolution depends on which foreseeable abnormal or transient conditions must be examined and how they may affect integrity. A closer review may consider a particular operating state, load, or transition.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether integrity is addressed under foreseeable abnormal and transient conditions. A Harm-related conclusion requires a demonstrable pathway from inadequate integrity under those conditions to a possible consequence; the condition alone does not establish Harm.

Indicator 4.5 — Preservation of Integrity Through Change and Modification

Indicator 4.5 asks whether changes and modifications have been evaluated for their effects on structural and functional integrity.

Its determination question is:

When the Infrastructure Quality Object changes, is preservation of integrity explicitly determined?

This question is necessary because a change that appears acceptable locally can affect the wider Infrastructure Quality Object through changed loads, Interfaces, configuration, operating envelope, assumptions, or interaction effects.

The removal test is:

Remove Indicator 4.5
→ the original integrity basis may remain valid for the earlier configuration while effects of later modification on the assembled object become insufficiently determined.

This Indicator is related to Indicators 1.6 and 2.7.

But the questions are different.

Indicator 1.6
→ Was a Functional Change identified and controlled?

Indicator 2.7
→ Was a Technical Specification change identified and controlled?

Indicator 4.5
→ Does the changed or modified Infrastructure Quality Object preserve structural and functional integrity?

The same change may therefore require examination under all three Indicators without creating redundancy.

Indicator 4.5 has a strong Quality-State Influence function.

It concerns whether integrity is preserved when the Infrastructure Quality Object is intentionally changed.

It also has Quality-State and Quality-State Determination functions because the resulting integrity condition and the implications of the modification must be determined.

Cross-context examination: data-center equipment replacement or capacity expansion, building renovation or change of use, bridge strengthening or alteration, and water-system network modification can change integrity-relevant configurations. Indicator 4.5 preserves examination of the changed object, beyond merely recording a functional or technical specification change.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how deeply a proposed change or modification must be traced through affected requirements, systems, constituents, and Interfaces. The Indicator remains about whether integrity is preserved through change.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether changes and modifications are evaluated for their effects on integrity. A Harm-related conclusion requires a demonstrable pathway from an inadequately evaluated change to a possible consequence; a change alone does not establish Harm.

Indicator 4.6 — Integrity Margin and Tolerance to Uncertainty

Indicator 4.6 asks whether integrity remains sufficiently robust when identified uncertainty and variability are considered.

Its determination question is:

Is the integrity condition dependent on overly optimistic assumptions, or is there sufficient tolerance to relevant uncertainty and variability?

This question is necessary because loads, material properties, environmental conditions, degradation rates, and operational behavior may not be known with complete precision.

An Infrastructure Quality Object may appear acceptable under one assumed value while becoming unacceptable within a realistic range of conditions.

The removal test is:

Remove Indicator 4.6
→ integrity may be demonstrated against nominal assumptions while sensitivity to uncertainty and variability becomes insufficiently visible.

Indicator 4.3 does not replace this function.

Indicator 4.3 asks what degradation and aging mechanisms exist.

Indicator 4.6 asks whether the resulting integrity determination remains robust when uncertainty and variability in relevant conditions are considered.

Indicator 4.4 also does not replace it.

Abnormal and transient conditions are identifiable operating conditions.

Uncertainty concerns limits in knowledge and variability within or around those conditions.

Indicator 4.6 is therefore necessary and distinguishable.

Its provisional function combines Quality-State and Quality-State Determination.

Integrity margin concerns the condition and capability of the object.

Tolerance to uncertainty also concerns confidence in the determination of that condition.

Cross-context examination: uncertainty in electrical and cooling demand, building loading or ground conditions, bridge traffic and material properties, or water pressure and demand can affect integrity margins. Indicator 4.6 preserves a distinct examination of robustness and uncertainty; the relevant margins and acceptance criteria arise from the Applicable Basis and Context-specific QOCs.

Methodological resolution under WQI FTA11. The scale is the object or constituent for which integrity is determined; resolution depends on the uncertainty and variability relevant to that determination. A closer review may examine margins under selected conditions, assumptions, or scenarios without changing the Indicator’s question.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether integrity remains sufficiently robust when relevant uncertainty and variability are considered. A Harm-related conclusion requires a demonstrable pathway from an inadequate margin to a possible consequence; uncertainty alone does not establish Harm.

Indicator 4.7 — Integrity-Relevant Information Retention

Indicator 4.7 asks whether information needed to understand and evaluate structural and functional integrity remains available over time.

Its determination question is:

Can the integrity basis, known vulnerabilities, assumptions, limitations, and earlier assessments still be understood later in the Lifecycle?

This question is necessary because integrity determination depends partly on information accumulated over many years.

Personnel may change.

Organizations may change.

Assets may be modified.

Earlier assumptions or vulnerabilities may otherwise be forgotten.

Loss of this information can produce unsafe later decisions even where the physical Infrastructure Quality Object has not changed immediately.

The removal test is:

Remove Indicator 4.7
→ the Infrastructure Quality Object may retain physical integrity, but the ability to understand and evaluate that integrity through time may weaken as important information is lost.

This Indicator is closely related to Factor 13 — Documentation and Traceability.

The overlap should be examined carefully.

Factor 13 addresses wider documentation, identity, history, and Evidence continuity across the Infrastructure Quality Object.

Indicator 4.7 addresses the narrower question of retaining information specifically necessary to understand structural and functional integrity.

The present analysis therefore does not identify redundancy.

Instead, it records a recurring horizontal pattern:

Some Factors contain their own subject-specific information-retention or traceability Indicators while Factor 13 preserves the wider lifecycle traceability function.

This pattern should be examined later across all proposed Factors and Indicators.

Indicator 4.7 primarily performs a Quality-State Determination function.

It preserves the information basis needed to understand and evaluate integrity over time.

Cross-context examination: configuration and maintenance records for data-center systems, building structural and renovation records, bridge inspection and repair histories, and water-network material and condition records may be necessary for integrity determination. Indicator 4.7 retains this integrity-specific information function while Factor 13 addresses documentation and traceability more broadly.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines what integrity-relevant information must remain available for the object and its constituents across relevant life-cycle stages. A closer review may trace selected records through changes or Interfaces.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether information needed to understand and evaluate integrity remains available over time. A Harm-related conclusion requires a demonstrable pathway from missing or unusable information to a possible consequence; a record gap alone does not establish Harm.

Relationship Among the Seven Indicators

The seven Indicators form a connected integrity determination.

They ask:

Which functions and Failure Modes are integrity-critical?

→ Indicator 4.1.

Does the assembled Infrastructure Quality Object preserve Structural and Functional Integrity?

→ Indicator 4.2.

How can degradation, damage, and aging change that integrity over time?

→ Indicator 4.3.

Is integrity preserved during foreseeable abnormal, transient, and degraded conditions?

→ Indicator 4.4.

Is integrity preserved when the Infrastructure Quality Object is changed or modified?

→ Indicator 4.5.

Is integrity sufficiently robust to uncertainty and variability?

→ Indicator 4.6.

Is the information needed to understand integrity retained through the Lifecycle?

→ Indicator 4.7.

The Indicators overlap because they all concern integrity.

But they preserve different questions.

An Infrastructure Quality Object can:

have acceptable present integrity while an important Failure Mode has not been identified;

have satisfactory individual components while the assembled object has an unacceptable interaction;

be acceptable today while degradation threatens later integrity;

be adequate in normal operation but not under foreseeable transient conditions;

have an acceptable original design but lose integrity after modification;

appear acceptable only under optimistic assumptions;

or

remain physically unchanged while loss of integrity information makes its condition difficult to determine responsibly.

These possibilities demonstrate that the seven Indicators are not simply alternative ways of asking the same question.

Relationship to the Provisional State / Determination / Influence Functions

Factor 4 provides the first strong example of all three provisional horizontal categories.

Quality-State functions are especially visible in Indicators 4.2 and 4.4 because they directly address the structural and functional condition of the Infrastructure Quality Object.

Quality-State Determination functions appear strongly in Indicators 4.1 and 4.7 and also contribute to Indicators 4.3 and 4.6.

Quality-State Influence is especially visible in Indicator 4.5 because it addresses preservation of integrity through intentional change and modification.

Indicator 4.3 may also contribute indirectly to Influence because understanding degradation can support action to preserve integrity.

The analysis does not make inspection, maintenance, or mitigation methods part of Indicator 4.3.

Those actions should therefore not be added to the meaning of this Indicator in this analysis.

Interim Finding for Factor 4

The analysis supports retaining all seven proposed Indicators under Factor 4.

Each preserves a necessary determination question related to Structural and Functional Integrity.

Removal of any one would leave a different integrity condition, failure path, Lifecycle condition, change condition, uncertainty, or information need materially less visible or less determinable.

The present analysis also reveals two findings for later horizontal comparison.

First, Factor 4 demonstrates clearly that State, Determination, and Influence functions can coexist within one Factor.

Second, Indicator 4.7 reinforces the recurring relationship between Factor-specific information needs and the wider Documentation and Traceability function under Factor 13.

No additional Factor 4 Indicator is justified from this analysis at this stage.

This conclusion should remain open to Context Guide testing.

Different infrastructure Contexts may reveal recurring integrity determination needs that are not adequately represented by the present seven Indicators.

Such findings should be preserved and compared across Contexts before any additional invariant Indicator is considered.

Broader-infrastructure finding. All seven Factor 4 Indicators remain necessary and distinguishable in the additional infrastructure Contexts examined. Each Indicator may manifest at applicable constituent and whole-object levels, with different technical QOCs and Evidence. The present cross-context illustrations do not establish permanent sufficiency of the Indicator set; possible gaps remain subject to Context Guide application and horizontal comparison.

6.5 Factor 5 — Harm, Risk, and Safety

Factor 5 examines whether relevant internal and external hazards, threats, and infrastructure vulnerabilities, credible scenarios, associated Risk, and necessary controls are sufficiently identified and addressed for the declared Infrastructure Quality Object.

The broader Factor title, Harm, Risk, and Safety, does not restrict examination to industrial processes. Its existing Indicators are to be tested for their ability to address context-relevant hazards and consequences, including building occupancy and egress, bridge loading and use, water-service continuity and contamination, and data-center power, cooling, and fire conditions. The invariant Indicator questions remain distinct from the context-specific QOCs and supporting Evidence.

Its purpose is to support determination of Safety and the prevention, control, or limitation of context-relevant Harm and unacceptable consequences.

Factor 5 does not establish universal acceptable-Risk levels.

Applicable Risk thresholds and tolerability criteria remain Context-specific Quality Outcome Criteria.

Factor 5 therefore asks a broad question:

Are context-relevant internal and external hazards, threats, and vulnerabilities sufficiently understood, and are the necessary capabilities present to prevent, control, or limit unacceptable consequences?

This research examines Factor 5 through seven proposed Indicators:

Indicator 5.1 — Identification of Hazards, Threats, and Infrastructure Vulnerabilities

Indicator 5.2 — Identification of High-Consequence and Loss-of-Control Scenarios

Indicator 5.3 — Definition of Risk Control Objectives

Indicator 5.4 — Effectiveness of Risk Controls Across Operating Modes

Indicator 5.5 — Systemic and Cumulative Risk Consideration

Indicator 5.6 — Preservation of Risk Mitigation Alignment Under Change

Indicator 5.7 — Risk Information Retention and Transparency.

The seven Indicators form a sequence from identification of hazards, threats, and vulnerabilities to preservation of Risk knowledge and control capability through changing conditions.

Broader-infrastructure applicability test. The seven established Indicators are examined for physical data-center infrastructure, residential apartment buildings, bridges, and water-supply systems, in addition to the existing energy-infrastructure applications. These illustrations test whether each invariant examination question remains meaningful; they are not completed assessments, and the applicable QOCs, Risk tolerability criteria, and Evidence are determined for the declared object and Context.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object sets the scale. Resolution depends on the determination being made: a broad review may consider the object’s overall exposure to Harm and the adequacy of its risk controls, while a closer review may examine selected hazards, scenarios, systems, or Interfaces. The necessary depth may vary without changing the questions represented by Factor 5 and its Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 5 has an independent Quality nature: whether hazards, scenarios, Risk Controls, and Safety-related conditions are adequately identified and examined. It also has a latent Harm-related nature. A Quality deficiency or identified Risk does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

Indicator 5.1 — Identification of Hazards, Threats, and Infrastructure Vulnerabilities

Indicator 5.1 asks whether hazards, threats, and vulnerabilities capable of producing Harm or compromising infrastructure Function Realization have been explicitly identified, including those originating within infrastructure, at its interfaces, and externally.

Its determination question is:

What internal or external hazards and threats are relevant to the declared Infrastructure Quality Object, and where is the infrastructure vulnerable to their effects?

This question is necessary.

Risk cannot be responsibly examined if relevant hazards, threats, exposure conditions, and infrastructure susceptibilities have not first been recognized.

Normal operation or satisfactory historical performance does not demonstrate that all important external threats or vulnerabilities have been identified.

The removal test is:

Remove Indicator 5.1
→ Risk analysis may proceed while a relevant internal hazard, external threat, or infrastructure vulnerability remains outside the determination.

Indicator 5.2 cannot replace this function.

Indicator 5.1 identifies hazards, threats, and infrastructure vulnerabilities that can lead to Harm or compromise Function Realization.

Indicator 5.2 identifies important scenarios through which loss of control, escalation, or Cascading Failure may occur.

The two questions are connected but different.

Indicator 5.1 primarily performs a Quality-State Determination function.

It establishes whether relevant hazardous conditions, external threats, and vulnerabilities are sufficiently known.

Hazardous energies, materials, and process conditions remain within this Indicator; so do external events, dependencies, and infrastructure susceptibility. Identification of exposure or vulnerability does not by itself determine Risk, Harm, or conformity with an applicable QOC.

Cross-context application: data-center electrical energy, cooling systems, and fire loads; apartment-building electrical, fire, structural, and occupancy-related hazards; bridge loads, deterioration, and interaction with traffic; and water-system pressure, treatment chemicals, contamination pathways, and supply interruption demonstrate why the sources of potential Harm cannot be limited to industrial processes. Indicator 5.1 remains an invariant identification question, not a fixed hazard list.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how closely hazards, threats, and vulnerabilities are identified across the object, its constituents, and relevant Interfaces. The examination may focus on a system or life-cycle stage without changing the Indicator’s question.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether relevant hazards, threats, and vulnerabilities are identified. Their presence does not by itself establish Harm; examine any Harm-related conclusion through a demonstrable pathway to a possible consequence in context.

Examples include a data center exposed to external power interruption, flooding, or extreme heat; an apartment building exposed to floodwater, wind, or utility loss; a bridge exposed to scour, seismic loading, or impact; and a water-supply system exposed to drought, source contamination, or failure of an external dependency. Factor 6 identifies the environmental exposure pathway where applicable. Factor 5 examines susceptibility and potential for Harm or functional loss. Identifying vulnerability does not establish the probability or consequence of a Risk scenario; Indicator 5.2 addresses that distinct question.

Indicator 5.2 — Identification of High-Consequence and Loss-of-Control Scenarios

Indicator 5.2 asks whether credible scenarios involving loss of control, escalation, or Cascading Failure with high consequences have been explicitly identified and considered.

Its determination question is:

How can identified hazards develop into loss-of-control or high-consequence conditions?

This question is necessary because identification of a hazard does not establish understanding of how that hazard can develop into a serious event.

A hazardous material may be known.

A hazardous energy source may be known.

But the pathways through which control can be lost, failures can propagate, or consequences can escalate may remain insufficiently understood.

The removal test is:

Remove Indicator 5.2
→ hazards may be listed while important high-consequence sequences and escalation paths remain insufficiently visible.

The Indicator is especially important because frequency alone cannot determine importance.

Rare scenarios may have consequences severe enough to require explicit consideration.

Indicator 5.2 therefore preserves a necessary and distinguishable determination function.

Its provisional function is primarily Quality-State Determination.

It makes possible failure and escalation paths visible so that the Risk they create can be responsibly interpreted.

Cross-context application: a data-center cooling or power failure may cascade across dependent systems; an apartment-building fire or loss of egress can escalate; a bridge failure can disrupt transportation and endanger users; and a water-supply failure can affect large populations. Indicator 5.2 concerns identification of credible high-consequence sequences, while scenario selection and supporting Evidence remain Context-specific.

Methodological resolution under WQI FTA11. The scale may be the whole object or a constituent; resolution determines the detail needed to identify credible loss-of-control, escalation, or Cascading Failure scenarios and their interactions. The Indicator remains about identifying high-consequence scenarios.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether credible high-consequence and loss-of-control scenarios are identified and considered. A scenario is not itself Harm; a Harm-related conclusion requires a demonstrable pathway from the scenario to a possible consequence.

Indicator 5.3 — Definition of Risk Control Objectives

Indicator 5.3 asks whether the required purpose of Risk Controls has been explicitly defined in relation to identified hazards and scenarios.

Its determination question is:

What must Risk Controls accomplish to prevent, detect, mitigate, or limit unacceptable consequences?

This question is necessary because the existence of a safeguard or control does not establish why it is needed or what result it must achieve.

A control can exist symbolically while lacking a clearly defined relationship to an identified Risk.

The removal test is:

Remove Indicator 5.3
→ hazards and scenarios may be understood, and controls may exist, but the required result of those controls may remain insufficiently defined.

Indicator 5.4 cannot replace this function.

Indicator 5.3 defines what the control must achieve.

Indicator 5.4 asks whether the control remains effective across relevant operating conditions.

The distinction is:

Required control result
≠ demonstrated control effectiveness.

Indicator 5.3 has a strong Quality-State Influence function.

Its subject is the capability required to prevent, detect, mitigate, or limit an identified adverse condition.

It also performs a Quality-State Determination function because the required control result must first be explicitly established before effectiveness can be judged.

Cross-context application: required outcomes of data-center fire protection and power resilience, building egress and life-safety provisions, bridge load restrictions and protective measures, and water-treatment barriers and emergency supply measures differ. Indicator 5.3 asks whether the objectives of the relevant Risk Controls are defined, without imposing a universal control objective or Risk threshold.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how specifically Risk Control Objectives must be stated for relevant hazards, scenarios, and interfaces. A broad objective may require closer examination of selected controls.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the required purpose of Risk Controls is defined. An inadequate objective does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway from the deficiency to a possible consequence.

Indicator 5.4 — Effectiveness of Risk Controls Across Operating Modes

Indicator 5.4 asks whether Risk Controls remain effective under the operating conditions in which they may be required.

Its determination question is:

Do the Risk Controls actually remain capable of achieving their objectives during normal, abnormal, degraded, and transitional operating conditions?

This question is necessary.

A control that works under normal steady-state operation may fail during startup, shutdown, upset, maintenance, degraded operation, or another condition in which it is especially important.

The removal test is:

Remove Indicator 5.4
→ Risk Controls may be present and their objectives may be defined, but their ability to perform when needed may remain insufficiently determined.

Indicator 5.4 is therefore distinguishable from both Indicators 5.3 and 4.4.

Indicator 5.3 defines Risk Control Objectives.

Indicator 5.4 examines control effectiveness.

Factor 4 Indicator 4.4 examines Structural and Functional Integrity under abnormal and transient conditions.

Indicator 5.4 examines the effectiveness of Risk Controls under those conditions.

The subjects are related, but the determination questions are different.

Indicator 5.4 strongly combines Quality-State and Quality-State Influence functions.

The actual effectiveness of the control is a quality-relevant condition.

The purpose of the control is to influence the Risk by prevention, detection, mitigation, or consequence limitation.

The Indicator also contains a Determination function because that effectiveness must be supported by Evidence.

Cross-context application: controls must be examined in data-center maintenance or power-transfer conditions, building evacuation and emergency conditions, bridge restrictions or rehabilitation, and water-system abnormal operation or treatment interruptions. Indicator 5.4 is distinct from the mere existence of a control; assessment of effectiveness depends on the applicable QOCs and Evidence.

Methodological resolution under WQI FTA11. The scale may be the whole object or a constituent; resolution depends on the operating modes and conditions in which a control may be needed. A closer

examination may test selected modes or transitions. The Indicator remains about effectiveness across relevant conditions.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether Risk Controls remain effective in relevant operating modes. A control weakness does not by itself establish Harm; demonstrate a pathway to a possible consequence in context.

Indicator 5.5 — Systemic and Cumulative Risk Consideration

Indicator 5.5 asks whether Risks created or increased through interactions, degradation, organizational factors, repeated deviations, or other combined conditions are explicitly considered.

Its determination question is:

Can individually limited conditions combine or accumulate into a significant infrastructure-level Risk?

This question is necessary because Risk may develop gradually or through relationships among conditions that appear acceptable when examined separately.

Repeated deviations may become normalized.

Several small vulnerabilities may interact.

A change in one subsystem may affect another.

Degradation may combine with organizational or operational conditions.

The removal test is:

Remove Indicator 5.5
→ individual hazards and scenarios may be examined while accumulation, interaction, and long-term Risk development remain insufficiently visible.

Indicator 5.2 does not fully replace this function.

Indicator 5.2 examines high-consequence and loss-of-control scenarios.

Indicator 5.5 specifically preserves the possibility that Risk develops through cumulative, distributed, interacting, or slowly evolving conditions.

Indicator 5.5 therefore preserves a necessary and distinguishable determination function.

Its provisional function is primarily Quality-State Determination.

It helps reveal Risk that may not be visible through isolated examination.

Where cumulative degradation or vulnerability already exists, it may also contribute to the Quality-State function.

Cross-context application: interacting data-center electrical and cooling vulnerabilities, building aging and deferred maintenance, bridge deterioration combined with traffic and environmental exposure, and water-network leakage combined with pressure or contamination conditions illustrate cumulative or interacting Risk. Indicator 5.5 preserves the whole-object and interface perspective without treating satisfactory constituent findings as sufficient.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how deeply to examine interactions, cumulative effects, degradation, repeated deviations, and organizational or life-cycle conditions. The Indicator remains about systemic and cumulative Risk.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether Risk arising from combined or accumulating conditions is considered. A combination of conditions does not by itself establish Harm; examine the pathway from those conditions to a possible consequence.

Indicator 5.6 — Preservation of Risk Mitigation Alignment Under Change

Indicator 5.6 asks whether Risk mitigation remains aligned with changing infrastructure and operating conditions.

Its determination question is:

When the Infrastructure Quality Object or its Context changes, do the existing Risk Controls remain appropriate for the changed Risk?

This question is necessary because Risk Controls are developed against assumptions about configuration, throughput, materials, operating envelopes, Interfaces, environment, and use.

Those assumptions may later change.

A control may continue to exist while no longer addressing the actual Risk.

The removal test is:

Remove Indicator 5.6
→ Risk Controls may remain in place while changes in infrastructure or operating Context make them insufficient, misaligned, or misleading.

This Indicator is related to Indicators 4.5 and 2.7.

But the determination questions differ.

Indicator 2.7
→ Are Technical Specification changes identified and controlled?

Indicator 4.5
→ Is Structural and Functional Integrity preserved through change?

Indicator 5.6
→ Does Risk mitigation remain aligned with the changed Risk?

The overlap therefore reflects different consequences of the same change rather than duplication.

Indicator 5.6 strongly combines Quality-State Determination and Quality-State Influence.

The changed Risk must be determined.

The mitigation capability must then remain aligned with that Risk.

Cross-context application: changes in data-center computing density, apartment-building occupancy, bridge loading or use, and water demand or source conditions may alter Risk and the suitability of established controls. Indicator 5.6 concerns continuing alignment with the changed Context, while the required changes to controls and applicable QOCs remain object-specific.

Methodological resolution under WQI FTA11. The scale remains the changed or modified object; resolution determines how changes in infrastructure, operation, and context affect hazards, Risk, and mitigation alignment. A closer review may trace effects through selected controls or Interfaces.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether mitigation remains aligned as conditions change. Misalignment alone does not establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

Indicator 5.7 — Risk Information Retention and Transparency

Indicator 5.7 asks whether information necessary to understand hazards, scenarios, Risk Control Objectives, limitations, and residual Risk remains available over time.

Its determination question is:

Can the basis and limitations of the Risk and Safety determination still be understood later in the Lifecycle?

This question is necessary.

Risk knowledge can be lost through personnel turnover, organizational change, incomplete records, modification, or separation of decisions from the assumptions on which they were based.

A control may remain physically present while the reason for the control or its limitations are forgotten.

The removal test is:

Remove Indicator 5.7
→ Risk Controls and earlier analyses may remain, but the ability to understand their basis, assumptions, limitations, and residual Risk may weaken over time.

Indicator 5.7 is related to Factor 13 — Documentation and Traceability and to Factor 4 Indicator 4.7.

The present analysis does not identify redundancy.

Indicator 4.7 preserves integrity-relevant information.

Indicator 5.7 preserves Risk- and Safety-relevant information.

Factor 13 addresses the wider documentation and traceability function across the Infrastructure Quality Object.

This recurring pattern should be examined horizontally later in this paper.

Indicator 5.7 primarily performs a Quality-State Determination function.

It preserves the information needed to understand and reassess Risk and the basis of Risk mitigation.

Cross-context application: the documented basis for data-center emergency controls, building fire and evacuation provisions, bridge inspection or load restrictions, and water-system treatment or emergency procedures must remain intelligible to relevant decision-makers. Indicator 5.7 preserves Risk-specific knowledge; Factor 13 addresses documentation and traceability across the wider Infrastructure Quality Object.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines what Risk- and Safety-related information must remain available across its life cycle and relevant Interfaces. A closer review may trace selected information through a change or event.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether information needed to understand Risk, control objectives, limitations, and residual Risk remains available. A gap in information alone does not establish Harm; demonstrate a pathway to a possible consequence in context.

Relationship Among the Seven Indicators

The seven Indicators form a connected sequence.

They ask:

What hazardous energies, materials, and processes exist?

→ Indicator 5.1.

How can they develop into loss-of-control or high-consequence scenarios?

→ Indicator 5.2.

What must Risk Controls accomplish?

→ Indicator 5.3.

Do those controls remain effective across relevant operating modes?

→ Indicator 5.4.

Can Risk accumulate or develop through interactions and repeated conditions?

→ Indicator 5.5.

Do Risk Controls remain aligned when infrastructure or operating conditions change?

→ Indicator 5.6.

Is the information needed to understand Risk and its controls retained?

→ Indicator 5.7.

The Indicators therefore preserve different parts of the Risk determination and control chain.

An Infrastructure Quality Object can:

contain an unidentified hazard;

have identified hazards but an unrecognized high-consequence scenario;

have a known scenario but no clearly defined control objective;

have a defined control objective but an ineffective control;

have individually addressed hazards while cumulative Risk remains hidden;

have initially adequate Risk Controls that become misaligned after change;

or

retain physical controls while losing the information needed to understand their purpose and limitations.

These possibilities demonstrate that the seven Indicators are not redundant.

Relationship to the Provisional State / Determination / Influence Functions

Factor 5 provides particularly strong support for treating Quality-State Influence as a separate provisional horizontal category.

Indicators 5.3, 5.4, and 5.6 directly concern the capability to prevent, detect, mitigate, limit, or remain aligned with identified Risk.

Their role is not limited to describing the existing state.

They examine whether the Infrastructure Quality Object has sufficient capability to influence conditions that could otherwise lead to unacceptable Infrastructure Results or Infrastructure Outcomes.

At the same time, Quality-State Determination remains essential.

Indicators 5.1, 5.2, 5.5, and 5.7 are strongly concerned with identifying and understanding hazards, scenarios, cumulative Risk, and retained Risk information.

Indicator 5.4 also contains a clear Quality-State component because actual Risk Control effectiveness is itself a condition of the Infrastructure Quality Object.

Factor 5 therefore provides stronger evidence than the preceding Factors that the Influence function may represent a useful horizontal distinction.

This remains a provisional finding.

It does not justify an additional invariant Indicator at this stage.

Interim Finding for Factor 5

The analysis supports retaining all seven proposed Indicators under Factor 5.

Each preserves a necessary determination question.

Removal of any one would weaken a different part of the Harm, Risk, and Safety determination and control basis.

The analysis also identifies Factor 5 as an important test case for the provisional Quality-State Influence concept.

The Factor contains a clear progression from identifying hazardous conditions, to understanding possible loss-of-control scenarios, to defining and maintaining the capability to influence Risk.

No additional Factor 5 Indicator is justified from this analysis at this stage.

However, Factor 5 should remain important in later horizontal and Context Guide analysis.

Repeated Context Guide Evidence may show whether the ability to intervene in a developing Critical Infrastructure Condition, including the timing and authority of such intervention, is adequately represented by the existing Indicators or reveals a recurring determination need that requires further research.

That question should presently be preserved as a provisional research finding rather than answered in advance.

Across the four additional infrastructure Contexts, the seven proposed Factor 5 Indicators remain necessary and distinct. Examples first developed for energy infrastructure remain useful, but they do not limit the Factor to energy. These examples alone do not justify another invariant Indicator.

Context-specific hazards, protective arrangements, Risk limits, and Evidence must be assessed against applicable QOCs. Failure to achieve a QOC does not automatically establish Harm, Risk, or a Safety condition; that relationship requires separate support.

6.6 Factor 6 — Infrastructure and Environment

Factor 6 examines the bidirectional relationship between the declared Infrastructure Quality Object and its natural, physical, and ecological environment as an integral dimension of Infrastructure Quality. Environment here means relevant environmental surroundings and conditions, including human-created changes to those surroundings and effects on people; it does not mean everything external to the declared object.

The Factor requires examination in both directions: how environmental conditions affect the infrastructure's Intended Functions and Intended Results, and how the infrastructure affects its environment. Connected infrastructure, utility supplies, and other external contributions are addressed as functional dependencies through the relevant Boundaries and Interfaces, not classified as environmental conditions merely because they are external. Their environmental interactions remain relevant where applicable.

Its scope includes environmental conditions and exposures affecting infrastructure and infrastructure effects on its environment: Environmental Interactions, Exposure Pathways, emissions, discharges, Unintended Releases, Environmental Harm, and cumulative or long-term effects across the Lifecycle. Factor 6 identifies environmental interactions; other Factors examine their specific functional, technical, integrity, safety, and reliability consequences.

Factor 6 does not establish universal environmental limits.

Applicable environmental conditions, exposure assumptions, emission and discharge limits, permit conditions, receptor classifications, remediation criteria, and acceptance thresholds remain Context-specific.

Factor 6 therefore asks a broad question:

Are the interactions between the declared infrastructure and its natural, physical, and ecological environment sufficiently identified and addressed in both directions, without confusing environmental conditions with external functional supplies?

Broader-infrastructure determination. Data centers, residential apartment buildings, bridges, and water-supply systems encounter environmental conditions affecting Function Realization and can also affect environmental receptors. Electricity supplied by an external network, for example, is a functional contribution through an Interface; ambient heat, flooding, and environmental effects of installations are examined under Factor 6 where relevant.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object sets the scale. Resolution depends on the environmental determination being made: a broad review may consider relevant effects and exposures for the whole object, while closer examination may trace selected pathways, systems, emissions, or Interfaces. The required detail may vary without changing Factor 6 or its Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 6 has an independent Quality nature: whether relevant environmental interactions and protection needs are identified and addressed. It also has a latent Harm-

related nature. An environmental effect or deficiency does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

This research examines Factor 6 through seven proposed Indicators:

Indicator 6.1 — Identification of Bidirectional Environmental Interactions and Exposure Pathways

Indicator 6.2 — Prevention and Limitation of Unintended Releases and Environmental Harm

Indicator 6.3 — Environmental Interactions Under Abnormal and Degraded Conditions

Indicator 6.4 — Consideration of Cumulative and Long-Term Environmental Effects

Indicator 6.5 — Environmental Protection Alignment Under Change

Indicator 6.6 — Understanding and Limitation of Emissions and Discharges

Indicator 6.7 — Environmental Information Retention and Transparency.

The seven Indicators examine distinct aspects of the infrastructure–environment relationship. Indicator 6.1 identifies interactions in both directions; Indicators 6.3 and 6.5 explicitly address environmental conditions affecting the infrastructure as well as environmental protection; the other Indicators retain their distinct functions.

Indicator 6.1 — Identification of Bidirectional Environmental Interactions and Exposure Pathways

Indicator 6.1 asks whether relevant interactions and exposure pathways between the declared Infrastructure Quality Object and its natural, physical, and ecological environment have been identified in both directions.

Its determination question is:

What environmental conditions and exposure pathways affect the Infrastructure Quality Object, and how does the object affect air, water, soil, ecosystems, surrounding areas, and other relevant environmental receptors?

This question is necessary.

Determination of the infrastructure–environment relationship cannot be responsibly based only on a list of regulatory obligations or only on the infrastructure’s emissions and releases.

Both the pathways by which infrastructure affects environmental receptors and the pathways by which environmental conditions affect infrastructure must be identified. External functional supplies and connected systems are considered through Boundaries and Interfaces; they are not environmental conditions solely because they are external. Factor 1 addresses resulting Functional Requirements, Factor 5 examines Harm and Risk, and Factor 6 identifies environmental interactions.

The removal test is:

Remove Indicator 6.1
→ relevant environmental requirements or protection provisions may remain known while an important interaction or Exposure Pathway in either direction remains insufficiently visible.

Indicator 6.6 cannot replace this function.

Indicator 6.6 specifically concerns emissions and discharges.

Indicator 6.1 is broader.

It includes releases, seepage, migration, noise, thermal effects, land or habitat interaction, weather, ambient temperature, groundwater, flooding, corrosion exposure, and other relevant environmental relationships, as applicable to the declared object.

Indicator 6.1 preserves a necessary and distinguishable bidirectional examination function without replacing the detailed requirements for Functional Requirements, Integrity, Risk, or Operational Reliability under other Factors.

Indicator 6.1 applies to environmental interactions in different infrastructure types. A data center exchanges heat with its surroundings and depends on ambient conditions. A residential building is exposed to weather and groundwater. A bridge interacts with river flow, temperature, wind, and corrosion. A water-supply system interacts with source water and catchment conditions. These examples fit the broad wording of Indicator 6.1, although its current determination question focuses mainly on environmental receptors. Context Guides still need to test whether incoming influences are adequately covered.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how closely relevant interactions and exposure pathways are examined in both directions. A whole-object review may require closer examination of selected systems, environmental conditions, or Interfaces. The Indicator remains about identifying both directions.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether relevant environmental interactions and exposure pathways are identified. Their existence alone does not establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence.

Incoming conditions include ambient heat affecting data-center cooling, floodwater or extreme cold affecting building habitability, river flow and scour affecting a bridge, and drought or source-water changes affecting a water-supply system. Outgoing effects include waste heat, stormwater runoff, discharges, noise, and impacts on land or water. Indicator 6.1 identifies both directions of interaction. It does not determine whether a particular vulnerability is tolerable or whether the applicable functional QOCs have been achieved.

Its provisional function is primarily Quality-State Determination.

It establishes whether the environmental relationships needed for later determination have been sufficiently identified.

Where an interaction already exists, it may also contribute information about the actual Quality State.

Indicator 6.2 — Prevention and Limitation of Unintended Releases and Environmental Harm

Indicator 6.2 asks whether provisions exist to prevent or limit unintended releases and Environmental Harm and whether those provisions are aligned with the identified environmental interactions and Exposure Pathways.

Its determination question is:

Is there sufficient capability to prevent or limit Environmental Harm through the identified pathways?

This question is necessary.

Identification of an environmental interaction does not establish that the interaction is adequately controlled.

A release mechanism may be understood while no adequate prevention, containment, isolation, or limitation provision exists.

The removal test is:

Remove Indicator 6.2
→ environmental interactions and risks may be known while the capability to prevent or limit resulting harm becomes insufficiently represented.

Indicator 6.2 therefore preserves a strong Quality-State Influence function.

It concerns the capability to influence the environmental result before or while harm occurs.

Indicator 6.2 cross-context test. Cooling-fluid releases or runoff from data centers, building wastewater or fuel releases, bridge maintenance discharges, and treatment-chemical releases from water systems illustrate distinct unintended-release pathways. The established prevention-and-limitation function remains necessary; exposure of the infrastructure to external conditions should not be conflated with its potential to cause environmental harm.

Methodological resolution under WQI FTA11. The scale may be the whole object or a constituent; resolution determines the detail needed to examine provisions for preventing or limiting unintended releases and their alignment with identified pathways. A closer review may follow a specific release route or protection measure.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether provisions to prevent or limit unintended releases and environmental Harm are defined and aligned. A deficiency alone does not prove Harm; establish any Harm-related conclusion through a demonstrable pathway in context.

It also contains a Quality-State Determination function because the adequacy and alignment of the protection provisions must be determined.

The Indicator does not prescribe a particular technology.

The technical means remain Context-specific.

Indicator 6.3 — Environmental Interactions Under Abnormal and Degraded Conditions

Indicator 6.3 asks whether the infrastructure adequately addresses relevant abnormal and degraded environmental conditions affecting its Intended Functions and Intended Results, and whether provisions preventing or limiting adverse environmental effects remain effective under those conditions.

Its determination question is:

Are relevant abnormal and degraded environmental conditions affecting the infrastructure addressed, and do environmental protection provisions remain effective under those conditions?

This question is necessary because abnormal environmental conditions such as flooding, extreme heat, storms, or changed groundwater conditions may affect the infrastructure, while startup, shutdown, upset, maintenance, or recovery conditions may also impair provisions that protect its environment.

A provision that is adequate during normal operation may be ineffective when it is most needed.

The removal test is:

Remove Indicator 6.3 → environmental interactions may be identified and normal-condition provisions may appear adequate, while the handling of abnormal or degraded environmental conditions and associated environmental protection effectiveness remain insufficiently examined.

Indicator 6.2 cannot replace this function.

Indicator 6.2 asks whether prevention and limitation provisions are defined and aligned with identified interactions.

Indicator 6.3 examines the distinct environmental-interaction question under abnormal and degraded conditions, including environmental exposure affecting the object and protection against adverse effects arising from the object.

The distinction is:

Environmental interactions identified for normal conditions ≠ environmental interactions adequately addressed under abnormal or degraded conditions.

Indicator 6.3 strongly combines Quality-State and Quality-State Influence functions.

Actual protection effectiveness is a quality-relevant condition.

Indicator 6.3 cross-context test. Heatwaves and flooding can affect data centers and buildings; storms and scour can affect bridges; drought or source-water changes can affect water systems. Environmental protection provisions may also be impaired by these conditions. Context-specific Quality Outcome Criteria determine required environmental outcomes. Detailed integrity, safety, and reliability consequences are examined under the corresponding other Factors.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines the detail required to examine abnormal or degraded environmental conditions, exposure pathways, and relevant protection provisions. Closer examination may address selected conditions, constituents, or Interfaces without changing the Indicator's question.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether environmental interactions are adequately addressed under abnormal and degraded conditions. A deficiency alone does not establish Harm; a Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

Its purpose includes addressing environmental conditions affecting the object and preserving the ability to prevent or limit adverse environmental consequences.

It also contains a Determination function because that effectiveness must be demonstrated.

Indicator 6.4 — Consideration of Cumulative and Long-Term Environmental Effects

Indicator 6.4 asks whether environmental effects that accumulate, interact, persist, or develop over extended periods have been explicitly considered.

Its determination question is:

Can repeated, distributed, interacting, or persistent environmental effects create a significant condition that is not visible from examination of individual events?

This question is necessary.

Environmental Harm may develop gradually.

Individual emissions or disturbances may appear limited.

Their combined effect over time or space may be materially different.

The removal test is:

Remove Indicator 6.4
→ individual environmental interactions may be examined while cumulative or long-term consequences remain insufficiently visible.

Indicator 6.1 cannot replace this function.

Indicator 6.1 identifies interactions and pathways.

Indicator 6.4 examines what may result when those interactions accumulate or persist.

Indicator 6.6 also cannot replace it.

Understanding individual emissions and discharges does not necessarily establish understanding of their cumulative or long-term effects.

Indicator 6.4 is therefore necessary and distinguishable.

Its provisional function includes Quality-State and Quality-State Determination.

Indicator 6.4 cross-context test. Repeated thermal discharge, cumulative urban runoff, long-term bridge deicing impacts, and water-source or watershed effects illustrate environmental consequences across different infrastructure types. These examples support the established cumulative-effects function without resolving the separate question of long-term environmental exposure affecting infrastructure performance.

Methodological resolution under WQI FTA11. The scale is the declared object or relevant constituent; resolution determines how deeply cumulative, interacting, persistent, or long-term effects must be examined. A closer review may consider a particular pathway, receptor, or life-cycle period.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether cumulative and long-term environmental effects are considered. The presence of an effect does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence.

Cumulative or long-term effects may represent actual environmental conditions.

Their recognition also depends on the ability to determine effects that may not be immediately observable.

Indicator 6.5 — Environmental Protection Alignment Under Change

Indicator 6.5 asks whether relevant environmental interactions, exposure pathways, and protection provisions remain aligned when the declared object or its environmental conditions change, in either direction of interaction.

Its determination question is:

When the Infrastructure Quality Object or its environmental conditions change, are the effects on both directions of environmental interaction identified and are relevant environmental protection provisions still aligned with the applicable requirements and Quality Outcome Criteria?

This question is necessary.

Throughput may change.

Materials may change.

Operating envelopes may change.

Infrastructure may be modified or repurposed.

Climate or surrounding land use may change.

A protection provision that was adequate under earlier conditions may become insufficient.

The removal test is:

Remove Indicator 6.5 → changes in environmental conditions affecting the infrastructure, or changes in the infrastructure affecting its surroundings, may remain unexamined or leave environmental protection provisions misaligned.

This Indicator is related to Indicators 4.5 and 5.6.

But the determination questions are different.

Indicator 4.5
→ Is Structural and Functional Integrity preserved through change?

Indicator 5.6
→ Does Risk mitigation remain aligned with changed Risk?

Indicator 6.5 → Are environmental interactions and relevant protection provisions kept aligned when the object or its environmental conditions change?

The overlap therefore reflects different quality-relevant consequences of change.

Indicator 6.5 strongly combines Quality-State Determination and Quality-State Influence.

Changed environmental conditions must be recognized.

Indicator 6.5 cross-context test. Changes in data-center cooling, building use, bridge drainage, or water-treatment operations may alter environmental effects. Changes in climate, flooding, or site conditions may alter environmental exposure affecting infrastructure. The Indicator examines both directions of environmental change; it does not substitute for detailed structural, safety, or reliability requirements.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how changes in configuration, operation, environmental conditions, or context affect interactions and protection. A closer review may trace a specific change through the affected systems and Interfaces.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether environmental interactions and relevant protection provisions remain aligned under change. Misalignment alone does not establish Harm; demonstrate a pathway to a possible consequence in context.

Protection provisions must then remain capable of influencing the resulting environmental state.

Indicator 6.6 — Understanding and Limitation of Emissions and Discharges

Indicator 6.6 asks whether emissions and discharges are understood and limited in relation to their environmental effects.

Its determination question is:

What emissions and discharges arise from infrastructure behavior, what environmental effects can they produce, and are they sufficiently limited?

This question is necessary.

Numerical compliance alone does not necessarily provide a complete understanding of environmental consequence.

An emission or discharge must also be understood in relation to its source, pathway, receiving environment, and environmental effect.

The removal test is:

Remove Indicator 6.6
→ environmental interactions may remain broadly identified while routine and non-routine emissions and discharges receive insufficient direct determination in relation to their effects.

Indicator 6.6 overlaps with Indicator 6.1 but is not redundant.

Indicator 6.1 establishes the wider set of Environmental Interactions and Exposure Pathways.

Indicator 6.6 focuses specifically on emissions and discharges and their limitation.

It also overlaps with Indicator 6.2.

But Indicator 6.2 concerns prevention and limitation of unintended releases and harm.

Indicator 6.6 includes routine and non-routine emissions and discharges, including those that may be intended parts of infrastructure operation.

The distinction is therefore meaningful.

Indicator 6.6 combines all three provisional functions.

Understanding the emission or discharge contributes to Quality-State Determination.

Indicator 6.6 cross-context test. Data-center heat rejection and generator emissions, building combustion exhaust and wastewater, bridge runoff, and water-system treatment discharges illustrate the specificity of this Indicator. Its focus on emissions and discharges remains distinguishable from the general identification of interactions in Indicator 6.1.

Methodological resolution under WQI FTA11. The scale may be the whole object or a constituent; resolution determines the detail needed to understand and limit relevant emissions and discharges and their effects. A closer review may examine specific sources, pathways, operating modes, or environmental conditions.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether emissions and discharges are understood and limited in relation to environmental effects. Their presence alone does not establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence.

The actual emission or discharge is part of the Quality-State question.

Limitation of its environmental impact provides a Quality-State Influence function.

Indicator 6.7 — Environmental Information Retention and Transparency

Indicator 6.7 asks whether information necessary to understand environmental risks, protection provisions, limitations, and residual impacts remains documented and available.

Its determination question is:

Can the environmental basis, known vulnerabilities, protection limitations, and residual impacts still be understood through the Lifecycle?

This question is necessary.

Environmental knowledge can be lost through personnel change, organizational change, modification, incomplete records, or separation of current decisions from earlier assumptions.

The physical Infrastructure Quality Object may remain unchanged while the ability to understand its environmental interactions becomes weaker.

The removal test is:

Remove Indicator 6.7
→ environmental analyses and protection provisions may exist while their assumptions, limitations, or residual impacts become insufficiently visible over time.

Indicator 6.7 is related to Factor 13 — Documentation and Traceability and to the information-retention Indicators already identified under Factors 4 and 5.

The present analysis does not establish redundancy.

Indicator 4.7 preserves integrity-relevant information.

Indicator 5.7 preserves Risk information.

Indicator 6.7 preserves environmental information.

Factor 13 addresses the wider documentation and traceability function.

The repeated appearance of Factor-specific information-retention Indicators is becoming a clear horizontal pattern.

That pattern should be tested later rather than resolved within Factor 6.

Indicator 6.7 primarily performs a Quality-State Determination function.

It preserves the information needed to understand and reassess environmental conditions and protection capability over time.

Indicator 6.7 cross-context test. Environmental exposure records, discharge data, changing site conditions, and assumptions relevant to data centers, buildings, bridges, and water systems may all require retention.

The environmental subject matter remains distinct from the general documentation architecture of Factor 13.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines which environmental information must remain available over the relevant life cycle and across relevant Interfaces. A closer review may trace records for particular pathways, conditions, or changes.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether environmental information needed to understand risks, provisions, limitations, and residual impacts remains available. A record gap alone does not establish Harm; demonstrate a pathway to a possible consequence in context.

Relationship Among the Seven Indicators

The seven Indicators form a connected sequence.

They ask:

How does the Infrastructure Quality Object interact with the environment?

→ Indicator 6.1.

Are provisions present to prevent or limit unintended releases and Environmental Harm?

→ Indicator 6.2.

Are environmental interactions adequately addressed under abnormal and degraded conditions, including protection of the environment?

→ Indicator 6.3.

Are cumulative and long-term effects understood?

→ Indicator 6.4.

Are environmental interactions and relevant protection provisions aligned when the object or environmental conditions change?

→ Indicator 6.5.

Are emissions and discharges understood and limited in relation to their environmental effects?

→ Indicator 6.6.

Is the information needed to understand environmental conditions, limitations, and residual impacts retained?

→ Indicator 6.7.

The Indicators therefore preserve different determination questions.

An Infrastructure Quality Object can:

have an unidentified Environmental Interaction or Exposure Pathway;

have a known pathway but insufficient prevention or limitation capability;

have identified environmental interactions but fail to address abnormal or degraded environmental conditions adequately;

have individually limited environmental effects that become significant cumulatively;

have environmental interactions or protection provisions that become misaligned after change;

meet individual emission requirements while the environmental consequence remains insufficiently understood;

or

retain protection provisions while losing the information needed to understand their basis and limitations.

These possibilities support the separate necessity of the seven Indicators.

Relationship to the Provisional State / Determination / Influence Functions

Factor 6 provides another strong example of all three provisional horizontal categories.

Quality-State Determination is especially visible in Indicators 6.1 and 6.7.

Quality-State functions appear clearly in Indicators 6.3, 6.4, and 6.6 because they concern environmental conditions, effects, emissions, discharges, and protection performance.

Quality-State Influence is represented in Indicators 6.2, 6.3, 6.5, and 6.6 because they concern prevention, limitation, handling of environmental conditions, and continued alignment under change.

This pattern resembles Factor 5.

Both Factors move from understanding potentially adverse conditions toward the capability to prevent or limit unacceptable consequences.

The subjects differ.

Factor 5 concerns Harm, Risk, and Safety, including internal and external threats and infrastructure vulnerability.

Factor 6 concerns bidirectional interactions with the natural, physical, and ecological environment. It does not subsume external functional supplies, Interfaces, or the distinct technical, integrity, safety, and reliability consequences examined under other Factors.

The repeated functional pattern may therefore be significant for the later horizontal analysis.

Interim Finding for Factor 6

The analysis supports retaining all seven Indicators under Factor 6. Indicator 6.1 expressly identifies both directions of environmental interaction; Indicator 6.3 now addresses environmental interactions under abnormal and degraded conditions; and Indicator 6.5 examines alignment of interactions and protection provisions under change.

Each preserves a necessary determination question.

Removing any one would leave a distinct environmental interaction or exposure pathway, prevention capability, abnormal-condition response, cumulative effect, change condition, emission/discharge issue, or information need materially less visible or determinable.

No eighth Factor 6 Indicator is justified by this clarification. The revised scope and requirements for Indicators 6.1, 6.3, and 6.5 should be tested across infrastructure contexts and against the distinct functions of Factors 1, 2, 4, 5, and 7.

Broader-infrastructure qualification. Factor 6 concerns relevant environmental surroundings and conditions, including those altered by human activity. A connected electrical network or utility supply is not itself an environmental condition merely because it lies outside the declared object; its environmental interactions remain in scope where applicable. Context Guides and horizontal analysis will test practical completeness.

Methodological boundary. Factor 1 establishes Functional Requirements; Factor 2 establishes Technical Requirements; Factor 6 identifies and addresses environmental interactions in both directions. Factor 4 examines Structural and Functional Integrity, Factor 5 examines Harm, Risk, and Safety, and Factor 7 examines Operational Reliability. These distinct questions may share evidence without becoming interchangeable.

The analysis does, however, strengthen two provisional horizontal findings.

First, the Quality-State Influence function appears repeatedly where Indicators address the capability to prevent or limit unacceptable consequences.

Second, Factor-specific information retention now appears under Factors 4, 5, and 6 while a wider Documentation and Traceability Factor also exists.

Whether this represents necessary subject-specific visibility or unnecessary overlap among Indicators should be tested later across all fourteen Factors and through Context Guide application.

The present analysis does not assume the answer.

6.7 Factor 7 — Operational Reliability

Factor 7 examines whether the declared Infrastructure Quality Object realizes its Intended Functions and Intended Results consistently, stably, and recoverably under relevant operating conditions.

Its scope includes Operational Variability, Operational Disturbance, Disruption, Degradation and Aging, and change across the Lifecycle.

Factor 7 therefore asks a broad question:

Can the Infrastructure Quality Object continue to realize its required functions reliably under the operating conditions it is expected to face?

Broader-infrastructure applicability test. The seven existing Indicators are examined for physical data centers, residential apartment buildings, bridges, and water-supply systems. Reliability concerns the declared functions and results of each Quality Object, including those determined by applicable environmental conditions under Factor 1. These examples test transferability of the determination questions; they do not impose common Context-specific Quality Outcome Criteria.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object sets the scale. Resolution depends on the determination being made: a broad review may examine whether the required functions remain reliable across the object, while a closer review may examine selected systems, functions,

operating conditions, disturbances, or Interfaces. The depth may vary without changing Factor 7 or its Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 7 has an independent Quality nature: whether required functions can be realized consistently and recover after disruption. It also has a latent Harm-related nature. A reliability deficiency does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

This research examines Factor 7 through seven proposed Indicators:

Indicator 7.1 — Identification of Reliability-Critical Functions

Indicator 7.2 — Consistency of Functional Performance Under Expected Operating Conditions

Indicator 7.3 — Tolerance to Operational Variability and Disturbance

Indicator 7.4 — Recovery Capability Following Disruption

Indicator 7.5 — Reliability Implications of Degradation and Aging

Indicator 7.6 — Reliability Under Change and Modification

Indicator 7.7 — Reliability-Relevant Information Retention.

The seven Indicators examine different parts of continuing Function Realization.

Indicator 7.1 — Identification of Reliability-Critical Functions

Indicator 7.1 asks whether the Intended Functions whose loss, degradation, or interruption would materially affect Intended Results have been explicitly identified.

Its determination question is:

Which functions must remain reliable because their interruption or degradation materially affects the required Infrastructure Results or Outcomes?

This question is necessary.

Operational Reliability cannot be determined responsibly by examining all equipment or functions as if they had equal importance.

The analysis must identify which functions are critical to continuity, controllability, recoverability, safety, environmental protection, or other important Intended Results.

The removal test is:

Remove Indicator 7.1
→ reliability may be examined at equipment or component level while the functions most important to infrastructure-level performance remain insufficiently visible.

Indicator 7.2 cannot replace this function.

Indicator 7.1 identifies which functions are reliability-critical.

Indicator 7.2 asks whether those required functions actually perform consistently under expected operating conditions.

The two questions are different.

Indicator 7.1 primarily performs a Quality-State Determination function.

It establishes what must be examined when Operational Reliability is determined.

Cross-context application: critical functions may include electrical supply and thermal control for physical data centers; habitability-related building services and safe access for apartment buildings; load-carrying and traffic service for bridges; and delivery, pressure, and water-quality functions for water-supply systems. The criticality judgment depends on the declared object and Applicable Basis, not an assumed uniform priority.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how closely reliability-critical functions are identified across systems, constituents, and Interfaces. A closer review may focus on functions whose loss would affect Intended Results. The Indicator remains about identifying critical functions.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether functions critical to reliable realization are identified. Their criticality or possible failure alone does not establish Harm; demonstrate a pathway to a possible consequence in context.

Indicator 7.2 — Consistency of Functional Performance Under Expected Operating Conditions

Indicator 7.2 asks whether required functions are performed consistently under expected operating conditions.

Its determination question is:

Does the Infrastructure Quality Object actually provide the required functional performance consistently during expected operation?

This question is central to Factor 7.

A system may be structurally intact and technically conforming but still perform unreliably.

It may require exceptional operator effort.

It may perform only under especially favorable conditions.

It may show repeated instability or interruption.

The removal test is:

Remove Indicator 7.2
→ Operational Reliability may be discussed through variability, recovery, aging, or change while actual consistency of normal functional performance is no longer directly determined.

Indicator 7.2 therefore preserves a necessary and distinguishable determination function.

Its provisional function is strongly Quality-State.

It directly concerns the actual operational performance of the Infrastructure Quality Object.

The Indicator also requires a Determination function because performance must be demonstrated through operating experience or other Evidence.

Cross-context application: consistency may concern data-center power and cooling performance, residential heating and water services, bridge availability for declared use, and continuous water delivery

within applicable conditions. Operational records and other Evidence must address the declared functions and relevant QOCs.

Methodological resolution under WQI FTA11. The scale may be the whole object or a constituent; resolution determines the detail needed to examine performance consistency under expected operating conditions. Closer review may consider selected functions, time periods, or operating conditions.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether required functions perform consistently under expected conditions. Variability alone does not establish Harm; a Harm-related conclusion requires a demonstrable pathway to a possible consequence.

Indicator 7.3 — Tolerance to Operational Variability and Disturbance

Indicator 7.3 asks whether the Infrastructure Quality Object can tolerate foreseeable variability and disturbance without losing required function.

Its determination question is:

Does required Function Realization remain sufficiently stable when operating conditions vary or the system is disturbed?

This question is necessary because reliable infrastructure cannot depend on one narrow or ideal operating condition.

Demand changes.

Inputs vary.

Environmental conditions vary.

Human interaction changes.

Routine disturbances occur.

The removal test is:

Remove Indicator 7.3
→ consistent performance may be demonstrated under typical conditions while the ability to tolerate foreseeable variation or disturbance remains insufficiently visible.

Indicator 7.2 does not replace this function.

Indicator 7.2 asks whether expected performance is consistent.

Indicator 7.3 asks how robust that performance is when expected variability or disturbance challenges it.

The distinction is:

Consistent performance
≠ tolerance to disturbance.

Indicator 7.3 primarily performs a Quality-State function.

Tolerance to disturbance is a capability of the Infrastructure Quality Object.

It also contains a Quality-State Determination function because that capability must be supported by Evidence.

Cross-context application: computing loads and outdoor temperature may vary at a data center; occupancy and weather conditions at an apartment building; traffic, wind, and temperature at a bridge; and demand or source-water conditions in a water-supply system. Environmental interactions identified under Factor 6 and hazards or vulnerabilities examined under Factor 5 may inform this reliability determination, without replacing it.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines which foreseeable variability and disturbances must be examined and how much tolerance is needed. A closer review may test selected functions, systems, or conditions without changing the Indicator's question.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the object can tolerate foreseeable variability and disturbance without losing required function. A disturbance or limited tolerance alone does not establish Harm; show a pathway to a possible consequence in context.

Indicator 7.4 — Recovery Capability Following Disruption

Indicator 7.4 asks whether required Function Realization can be restored after foreseeable disruption.

Its determination question is:

If required function is interrupted or materially degraded, can the Infrastructure Quality Object recover within conditions consistent with Intended Function and safety?

This question is necessary.

An infrastructure system may be unable to prevent every disturbance or interruption.

Operational Reliability therefore includes not only continuity but also recoverability.

The removal test is:

Remove Indicator 7.4
→ the Infrastructure Quality Object may be examined for steady performance and disturbance tolerance while its ability to restore required function after disruption remains insufficiently determined.

Indicator 7.3 cannot replace this function.

Tolerance asks whether function can be maintained through disturbance.

Recovery asks what happens after function has been lost or materially degraded.

The distinction is:

Tolerance
→ avoid loss of required function.

Recovery
→ restore required function after loss or degradation.

Indicator 7.4 strongly performs a Quality-State Influence function.

Recovery is the capability to move the Infrastructure Quality Object from a disrupted or degraded state toward restored Function Realization.

It also performs a Quality-State function because recovery capability is itself a condition of the object.

Cross-context application: restoration after an electrical or cooling interruption at a data center, failure of essential building services, temporary bridge closure, or water-supply disruption must be examined against the relevant recovery functions and conditions. The existence of backup equipment or a recovery plan alone does not establish achievement of applicable QOCs.

Methodological resolution under WQI FTA11. The scale is the declared object or affected constituent; resolution determines how closely restoration of required Function Realization must be examined after foreseeable disruption. The review may trace recovery through relevant systems and Interfaces.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether required functions can be restored after foreseeable disruption. Delayed or incomplete recovery alone does not establish Harm; a Harm-related conclusion requires a demonstrable pathway to a possible consequence.

Indicator 7.5 — Reliability Implications of Degradation and Aging

Indicator 7.5 asks whether the effects of degradation, aging, wear, and obsolescence on Operational Reliability are explicitly considered.

Its determination question is:

How does the changing condition of the Infrastructure Quality Object affect its ability to continue performing required functions reliably?

This question is necessary because reliability can deteriorate gradually.

A system may continue to operate while interruptions become more frequent, margins decrease, or performance becomes increasingly dependent on favorable conditions.

The removal test is:

Remove Indicator 7.5
→ present operational performance may appear acceptable while gradual erosion of reliability through aging, wear, degradation, or obsolescence becomes insufficiently visible.

This Indicator is related to Factor 4 Indicator 4.3.

But the determination questions are different.

Indicator 4.3 asks how Degradation and Aging affect Structural and Functional Integrity.

Indicator 7.5 asks how they affect continuity and reliability of operational performance.

The same degradation mechanism may therefore be relevant to both Factors without making the Indicators redundant.

Indicator 7.5 combines Quality-State and Quality-State Determination functions.

It concerns the changing operational condition itself and the ability to understand how that condition affects continuing reliability.

Cross-context application: aging electrical and cooling equipment, building mechanical systems, bridge structural components, and water-distribution assets may each change service continuity. Factor 4 addresses integrity implications; Indicator 7.5 independently addresses consequences for reliable Function Realization.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how closely degradation, aging, wear, and obsolescence are examined for their effects on Operational Reliability. A closer review may focus on vulnerable constituents or life-cycle stages.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the effects of degradation and aging on reliability are considered. Degradation alone does not establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

Indicator 7.6 — Reliability Under Change and Modification

Indicator 7.6 asks whether changes in configuration, operation, or Context have been evaluated for their effects on Operational Reliability.

Its determination question is:

When the Infrastructure Quality Object changes, does it continue to provide reliable Function Realization?

This question is necessary.

A change intended to increase capacity, efficiency, flexibility, or another benefit may unintentionally reduce continuity, stability, or recoverability.

The removal test is:

Remove Indicator 7.6
→ changes may be technically acceptable and preserve integrity while their effects on Operational Reliability remain insufficiently determined.

This Indicator is related to the change Indicators already examined under Factors 1, 2, 4, 5, and 6.

But the determination question remains distinct.

Indicator 4.5
→ Is integrity preserved through change?

Indicator 5.6
→ Does Risk mitigation remain aligned through change?

Indicator 6.5
→ Does Environmental Protection remain aligned through change?

Indicator 7.6
→ Is Operational Reliability preserved through change?

The repeated appearance of change-related Indicators across Factors is therefore becoming another important horizontal pattern.

Indicator 7.6 combines Quality-State Determination and Quality-State Influence functions.

The reliability effect of the change must be determined.

Where needed, the configuration or operating approach must preserve or restore acceptable reliability.

Cross-context application: data-center capacity upgrades, building-use changes, bridge rehabilitation, and water-system network modifications may alter reliability even when other requirements are met. Environmental conditions and their foreseeable changes may also alter the reliability Context.

Methodological resolution under WQI FTA11. The scale is the changed or modified object; resolution determines how deeply changes in configuration, operation, or context must be traced for their effects on reliability, including relevant systems and Interfaces.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether changes are evaluated for their effects on Operational Reliability. Change alone does not establish Harm; demonstrate any claimed pathway from an inadequately assessed change to a possible consequence.

Indicator 7.7 — Reliability-Relevant Information Retention

Indicator 7.7 asks whether information necessary to understand and evaluate Operational Reliability remains available over time.

Its determination question is:

Can reliability assumptions, performance patterns, vulnerabilities, and limitations still be understood later in the Lifecycle?

This question is necessary.

Operational knowledge can be lost.

Repeated disruptions may be treated as isolated events.

Performance trends may no longer be recognized.

Earlier assumptions may remain in use after their basis has changed.

The removal test is:

Remove Indicator 7.7
→ operating records may exist in fragments while the knowledge needed to understand reliability patterns and limitations becomes weaker over time.

Indicator 7.7 is related to Factor 13 and to the information-retention Indicators already identified under Factors 4, 5, and 6.

Again, the present analysis does not establish redundancy.

Factor 7 requires retention of information specifically needed to determine Operational Reliability.

Factor 13 addresses the wider continuity and traceability of information and Evidence across the Infrastructure Quality Object.

This recurring pattern should be tested horizontally.

Indicator 7.7 primarily performs a Quality-State Determination function.

Cross-context application: service interruption histories, maintenance and inspection findings, observed disturbance responses, recovery outcomes, and changing operating assumptions can provide reliability-relevant knowledge for each infrastructure type. Factor 13 remains responsible for broader documentation and traceability.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines which reliability-relevant information must remain available over the life cycle and across relevant

Interfaces. A closer review may trace interruption histories, disturbances, recoveries, or changing assumptions.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether information needed to understand and evaluate Operational Reliability remains available over time. Missing information alone does not establish Harm; a Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

Relationship Among the Seven Indicators

The seven Indicators form a connected reliability determination.

They ask:

Which functions are reliability-critical?

→ Indicator 7.1.

Are those required functions performed consistently under expected conditions?

→ Indicator 7.2.

Can that performance tolerate expected variability and disturbance?

→ Indicator 7.3.

Can required Function Realization be restored after disruption?

→ Indicator 7.4.

How do degradation and aging affect continuing reliability?

→ Indicator 7.5.

Is reliability preserved when infrastructure or operating conditions change?

→ Indicator 7.6.

Is the information needed to understand reliability retained over time?

→ Indicator 7.7.

The Indicators preserve different questions.

An Infrastructure Quality Object can:

fail to identify which functions are critical to service continuity;

perform consistently under normal conditions but be highly sensitive to routine variability;

tolerate small disturbances but be unable to recover after disruption;

operate acceptably today while reliability is degrading through aging or wear;

preserve structural integrity after modification while operational reliability decreases;

or

continue operating while loss of operational knowledge prevents repeated reliability problems from being understood.

These possibilities support separate retention of the seven Indicators.

Relationship Between Factor 4 and Factor 7

Factor 4 and Factor 7 are closely related but preserve different major questions.

Factor 4 asks:

Does the Infrastructure Quality Object preserve the Structural and Functional Integrity required for Function Realization?

Factor 7 asks:

Does the Infrastructure Quality Object actually realize its required functions consistently, stably, and recoverably in operation?

The distinction is important.

An Infrastructure Quality Object can preserve structural integrity while failing to provide reliable service.

Conversely, it can continue providing service for some time while integrity is degrading.

Therefore:

Integrity
≠ Operational Reliability.

The overlap between the Factors reflects their connection in the real Infrastructure Quality Object.

It does not establish redundancy.

Relationship to the Provisional State / Determination / Influence Functions

Factor 7 contains a strong Quality-State component.

Indicators 7.2 and 7.3 directly examine actual functional performance and tolerance to disturbance.

Indicator 7.5 also concerns the changing operational state as degradation affects performance.

Quality-State Determination is visible in Indicators 7.1 and 7.7 and contributes to the other Indicators.

Quality-State Influence is especially clear in Indicator 7.4 because recovery capability concerns restoration of required Function Realization after disruption.

Indicator 7.6 also contains an Influence aspect because reliability must be preserved as the Infrastructure Quality Object changes.

Factor 7 therefore provides another useful example where the three provisional functions interact within one Factor.

Interim Finding for Factor 7

The analysis supports retaining all seven proposed Indicators under Factor 7.

Each preserves a necessary determination question concerning continuity, stability, disturbance tolerance, recovery, aging, change, or reliability knowledge.

Removal of any one would leave a different part of Operational Reliability materially less visible or less determinable.

The analysis also strengthens two horizontal findings.

First, recovery capability provides a particularly clear example of a Quality-State Influence function.

Second, both change-related Indicators and Factor-specific information-retention Indicators now recur across several Factors.

These patterns should be tested across all fourteen Factors to determine whether they reflect necessary repeated applications of common points of examination or unnecessary overlap.

No additional Factor 7 Indicator is justified at this stage.

The present seven-Indicator set should remain open to continued testing through Context Guides, especially where different infrastructure systems reveal recurring reliability needs involving continuity, disturbance tolerance, recovery, or changing operational dependencies.

Across the additional Contexts examined, the seven established Indicators retain distinct determination functions. Factor 7 covers continuity, stability, tolerance of disturbance, recovery, aging, change, and reliability knowledge at whole-object and constituent levels, as applicable. External conditions may affect Functional Requirements (Factor 1), environmental exposure (Factor 6), and hazard and vulnerability (Factor 5). Indicator 7.3 examines tolerance; Indicator 7.4 examines recovery. These examples do not justify another invariant Indicator by themselves. Further Context Guide testing is needed to assess sufficiency.

6.8 Factor 8 — Human and Infrastructure Interaction

Factor 8 examines how interaction between people and the Infrastructure Quality Object affects Infrastructure Safety and Function Realization.

Human and Infrastructure Interaction extends beyond workplace personnel to relevant users, occupants, visitors, operators, maintainers, and emergency responders. The existing workplace-oriented Indicator wording should therefore be examined for invariance across infrastructure Contexts rather than presumed sufficient for every Context.

Broader-infrastructure scope. Human interaction includes residents, occupants, users, visitors, operations and maintenance personnel, inspectors, and emergency responders, as applicable to the declared Infrastructure Quality Object. Workplace activities remain important applications, but are not the sole basis for invariant Indicators.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object sets the scale. Resolution depends on which interactions must be understood: a broad review may consider the people expected to interact with the object, while closer examination may focus on access, operation, control points, or particular conditions. The necessary detail may vary without changing Factor 8 or its Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 8 has an independent Quality nature: whether the infrastructure supports appropriate and understandable human interaction. It also has a latent Harm-related nature. A poor interaction condition does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

Its scope includes infrastructure configuration, interfaces, foreseeable human capabilities and limitations, interaction safety, clarity for users, and human interaction under normal and non-normal conditions.

Physical, spatial, and operational conditions of interaction are examined through the applicable Functional and Technical Requirements and the remaining Factor 8 Indicators.

Factor 8 therefore asks a broad question:

Does the Infrastructure Quality Object support safe and reliable human interaction across relevant infrastructure use, occupancy, operation, maintenance, and emergency response?

This research examines Factor 8 through five proposed Indicators:

Indicator 8.1 — Identification of Human–Infrastructure Interactions

Indicator 8.2 — Suitability of Infrastructure for Human Interaction

Indicator 8.3 — Prevention of Unsafe Human–Infrastructure Interaction

Indicator 8.4 — Safety of Human Interaction Under Abnormal Conditions

Indicator 8.5 — Clarity of Infrastructure for Its Users

Indicator 8.2 uses “suitability” for relevant human capabilities and limitations; it does not prescribe a specific user group.

Indicator 8.3 concerns infrastructure features that encourage unsafe actions. This is distinct from Factor 5’s general Harm and Risk determinations.

Indicator 8.5 uses “clarity” for whether relevant users and operators can understand infrastructure use, controls, warnings, and responses. This narrower question remains distinct from overall suitability under Indicator 8.2.

Former proposed Indicators 8.6 and 8.7 concerned contextual influences on interaction and interaction-related knowledge beyond safety incidents.

The five Indicators examine distinguishable ways in which infrastructure supports appropriate, clear, and safe human interaction. Relevant conditions of interaction are addressed through Indicators 8.1, 8.2, and 8.4 and the applicable Context-specific QOCs; they do not require a separate invariant Indicator.

Cross-context examination. For physical data centers, relevant interactions include facility operation, maintenance access, alarms, and emergency response; for residential apartment buildings, resident use, accessibility, egress, and maintenance; for bridges, drivers, pedestrians, inspectors, and responders; and for water-supply systems, operators, maintenance personnel, service users, and emergency responders. These examples test the determination questions; they do not establish universal Context-specific QOCs.

Indicator 8.1 — Identification of Human–Infrastructure Interactions

Indicator 8.1 asks whether relevant interactions between people and the declared Infrastructure Quality Object have been identified, including use, occupancy, access, operation, maintenance, and emergency response as applicable.

Its determination question is:

Where can human–infrastructure interaction affect safety or infrastructure behavior?

This question is necessary.

Human factors cannot be examined responsibly only as a general property of personnel.

The actual interaction points must be visible.

These may involve operation, monitoring, inspection, maintenance, testing, modification, or commissioning.

The removal test is:

Remove Indicator 8.1
→ human–infrastructure interaction safety may be discussed generally while important points of human–infrastructure interaction remain unidentified.

Indicator 8.2 cannot replace this function.

Indicator 8.1 identifies the relevant interactions and circumstances in which they occur.

Indicator 8.2 asks whether the Infrastructure Quality Object is suitable for the people expected to interact with it, considering their foreseeable capabilities, limitations, and variability.

The two questions are connected but different.

Indicator 8.1 primarily performs a Quality-State Determination function.

It establishes the human–infrastructure interaction locations and conditions that must be examined.

Applicability finding for 8.1. Interaction points must be identified for the persons who can interact with the declared object, not only personnel working at it. Examples include resident access and evacuation routes, bridge pedestrian and driver interfaces, and water-system public access points where relevant.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how closely interactions are identified across users, occupants, operators, maintainers, visitors, and responders and across relevant life-cycle conditions. A closer review may trace particular access points or Interfaces.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether relevant human–infrastructure interactions and their circumstances are identified. An unidentified interaction does not by itself establish Harm; demonstrate a pathway to a possible consequence in context.

Indicator 8.2 — Suitability of Infrastructure for Human Interaction

Indicator 8.2 asks whether infrastructure design and configuration are suitable for relevant human interaction, considering foreseeable human capabilities, limitations, and variability.

Context-specific physical, spatial, and operational conditions—including entrances, hallways, stairs, elevators, lighting, access, circulation, and foreseeable occupancy—are part of the assessment of suitability. Their consideration is not a separate invariant Indicator.

Its determination question is:

Does safe Function Realization depend on unrealistic assumptions about human performance?

This question is necessary.

Infrastructure should not require idealized perception, strength, memory, vigilance, reaction, workload tolerance, or error-free execution as a condition of safe operation.

The removal test is:

Remove Indicator 8.2
→ interaction points may be known, but the Infrastructure Quality Object may still depend on capabilities that cannot reasonably be assumed in the actual conditions of use, occupancy, operation, maintenance, or emergency response.

Indicator 8.2 is distinguishable from Factor 9 — Competence of Personnel.

Factor 9 examines whether personnel possess the necessary competence.

Indicator 8.2 asks whether infrastructure itself is suitable for its relevant users and other interacting persons, without presuming capabilities or specialized training that cannot reasonably be expected.

The distinction can be expressed as:

Factor 8
→ Can the infrastructure be interacted with safely by people with foreseeable human capabilities and limitations?

Factor 9
→ Do the people performing the relevant work have the required competence?

A competent worker can still be placed in a poorly designed human–infrastructure interaction.

Indicator 8.2 therefore preserves a necessary and separate determination function.

Its provisional function includes Quality-State and Quality-State Influence.

The compatibility of infrastructure with foreseeable human capability is part of the actual state of the object.

Design and configuration also influence the probability of safe human action.

Applicability finding for 8.2. Foreseeable human capabilities and limitations include those of occupants, users, and visitors as well as trained personnel; Context-specific accessibility, comprehension, perception, and physical-access QOCs remain determined by the Applicable Basis.

Methodological resolution under WQI FTA11. The scale is the declared object or a constituent; resolution determines how closely suitability is examined for relevant capabilities, limitations, and variability. A closer review may focus on specific users, access routes, controls, or operating conditions.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether infrastructure is suitable for the people expected to interact with it. Unsuitability alone does not establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence.

Indicator 8.3 — Prevention of Unsafe Human–Infrastructure Interaction

Indicator 8.3 asks whether infrastructure characteristics that could encourage unsafe human action are identified and appropriately addressed in the applicable Context.

Its determination question is:

Does the Infrastructure Quality Object create conditions that make error, delay, misinterpretation, or unsafe action more likely?

This question is necessary.

A worker may be competent.

The interaction point may be known.

But poor visibility, misleading feedback, difficult access, confusing layout, interface complexity, or problematic task sequencing may still increase the likelihood of error.

The removal test is:

Remove Indicator 8.3
→ human–infrastructure interaction may be examined while infrastructure-created conditions that increase the likelihood of error remain insufficiently visible.

Indicator 8.2 cannot fully replace this function.

Human capabilities and limitations concern characteristics and variability of people.

Indicator 8.3 concerns infrastructure-created conditions that can encourage unsafe action; it is not a general assessment of all Harm, Risk, and Safety under Factor 5.

The distinction is:

Human limitation
≠ A condition created by the infrastructure that encourages unsafe action.

Indicator 8.3 strongly combines Quality-State Determination and Quality-State Influence.

The error-provoking condition must first be identified.

The infrastructure configuration can then influence the likelihood of safe or unsafe action.

Applicability finding for 8.3. Error-provoking conditions may arise in everyday occupancy and public use, including misleading building controls, confusing bridge wayfinding, or unclear access to water-system interfaces, not solely at industrial workplaces.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how closely infrastructure characteristics and interaction conditions that may encourage unsafe action are examined. A closer review may examine a particular control, layout, feedback, task sequence, or Interface.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether infrastructure-created conditions that could encourage unsafe action are identified and addressed. A condition that could increase error likelihood does not itself establish Harm; show a pathway to a possible consequence.

Indicator 8.4 — Safety of Human Interaction Under Abnormal Conditions

Indicator 8.4 asks whether human interaction remains sufficiently safe when the Infrastructure Quality Object is in foreseeable abnormal, degraded, or transitional conditions.

Crowding, restricted routes, impaired visibility, time pressure, and other foreseeable conditions must be considered where they affect safe interaction under abnormal, degraded, or transitional circumstances.

Its determination question is:

Can people continue to understand and interact safely with the Infrastructure Quality Object when it behaves differently from normal operation?

This question is necessary.

Startup, shutdown, upset, temporary configurations, degraded states, and recovery situations may change what people see, what actions are required, and how much time is available.

The conditions may also become more error-sensitive.

The removal test is:

Remove Indicator 8.4
→ human–infrastructure interaction may appear safe under normal conditions while interaction during foreseeable abnormal, degraded, or transitional conditions remains insufficiently examined.

This Indicator is related to Factor 4 Indicator 4.4, Factor 5 Indicator 5.4, and Factor 6 Indicator 6.3.

But the questions differ.

Factor 4 asks whether integrity is preserved under abnormal and transient conditions.

Factor 5 asks whether Risk Controls remain effective.

Factor 6 asks whether environmental interactions are adequately addressed.

Indicator 8.4 asks whether human interaction remains safe under abnormal, degraded, or transitional infrastructure conditions.

The same operating condition may therefore require examination across several Factors without creating redundancy.

Indicator 8.4 combines Quality-State and Quality-State Determination functions.

It concerns the safety of relevant human–infrastructure interactions under these conditions and whether assumptions about human action remain valid.

Applicability finding for 8.4. Abnormal and degraded conditions include loss of lighting or access in apartment buildings, traffic disruptions at bridges, and utility or control failures at data centers and water systems. The question concerns safety of relevant human interaction, without replacing Factors 4, 5, or 7.

Methodological resolution under WQI FTA11. The scale may be the whole object or a constituent; resolution depends on the abnormal, degraded, or transitional conditions and interactions that require examination. A closer review may follow what users see and do during particular operating changes.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether human interaction remains sufficiently safe under foreseeable non-normal conditions. A deficiency alone does not establish Harm; demonstrate a pathway to a possible consequence in context.

Indicator 8.5 — Clarity of Infrastructure for Its Users

Indicator 8.5 asks whether relevant users and operators can clearly understand infrastructure use, controls, signs, warnings, feedback, and responses to the extent necessary for appropriate interaction.

Information needed to evaluate clarity may include interaction-related experience, incidents, observed limitations, and lessons learned. The preservation and traceability of this information are addressed through Factor 13 rather than a separate Factor 8 Indicator.

Its determination question is:

Does the Infrastructure Quality Object make its relevant condition and behavior sufficiently understandable to support safe human action?

This question is necessary.

A worker may have the necessary competence and physical capability but still receive misleading, incomplete, ambiguous, or poorly structured information from the Infrastructure Quality Object.

The removal test is:

Remove Indicator 8.5
→ people may be capable and competent while infrastructure design still obscures state, provides poor feedback, or encourages incorrect action.

Indicator 8.5 is related to Indicator 8.3 but remains distinguishable.

Indicator 8.3 asks whether infrastructure creates conditions that increase the likelihood of error.

Indicator 8.5 asks more specifically whether infrastructure information, controls, and responses are clear to its relevant users and operators.

An interaction can lack obvious error-provoking conditions while still provide insufficient feedback about actual system state.

Indicator 8.5 is particularly important to the provisional Quality-State Determination concept.

Human understanding may be part of the pathway through which infrastructure state is recognized and acted upon.

If the Infrastructure Quality Object provides misleading or inadequate information, the actual condition may exist while the person at the observation or control point cannot determine it reliably.

Indicator 8.5 therefore performs a strong Quality-State Determination function.

It also has a Quality-State Influence function because better alignment between design and human understanding can support safer and more effective action.

Applicability finding for 8.5. Correct understanding includes meaningful warnings, signs, controls, feedback, and information for the relevant interacting persons. A resident or bridge user need not possess the specialized competence expected of a facility operator.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines what users and operators need to understand about its condition, controls, warnings, feedback, and responses. A closer review may examine particular interaction points without changing the Indicator's question.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether infrastructure communicates clearly enough to support appropriate interaction. Unclear information alone does not establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence.

Relationship Among the Five Indicators

The five Indicators form a connected human–infrastructure interaction determination.

They ask:

Where do people interact with the Infrastructure Quality Object in ways that can affect safety or behavior?

→ Indicator 8.1.

Does the infrastructure account for foreseeable human capabilities and limitations?

→ Indicator 8.2.

Do infrastructure characteristics encourage unsafe human actions?

→ Indicator 8.3.

Does human–infrastructure interaction remain safe under abnormal, degraded, and transitional conditions?

→ Indicator 8.4.

Does infrastructure design support correct human understanding and action?

→ Indicator 8.5.

The five Indicators preserve distinct determination questions.

A human–infrastructure interaction can:

remain unidentified;

be identified but depend on unrealistic human performance;

be compatible with human capabilities but contain error-provoking conditions;

be adequate during normal operation but unsafe during degraded conditions;

avoid obvious error-provoking conditions while still providing misleading feedback;

Relevant physical, spatial, and operational conditions—including circulation, access, lighting, crowding, and time pressure—remain subject to the applicable Functional and Technical Requirements and to Indicators 8.1, 8.2, and 8.4; their consideration does not establish a sixth invariant determination function.

Interaction-related information, incidents, limitations, and lessons learned remain subject to Factor 13 — Documentation and Traceability and its applicable Context-specific QOCs; their retention does not establish a separate Factor 8 Indicator.

The removal test supports retaining five Indicators. Deleting the former 8.6 and 8.7 does not eliminate necessary examinations: interaction conditions remain covered by the retained Indicators and applicable requirements, while information retention and traceability remain covered by Factor 13.

Relationship Between Factor 8 and Factor 9

Factor 8 and Factor 9 are closely connected but should not be combined.

Factor 8 examines the human–infrastructure interaction.

Factor 9 examines the competence of the personnel performing relevant functions.

The distinction can be expressed simply as:

Factor 8
→ Does the Infrastructure Quality Object support safe human interaction?

Factor 9

→ Are the personnel capable of performing their required functions competently?

A competent person can make an error when the Infrastructure Quality Object provides poor feedback, confusing controls, difficult access, or severe time pressure.

Likewise, a well-designed human–infrastructure Interface cannot compensate for a person who lacks required competence.

The two Factors therefore preserve different determination questions.

Relationship to the Provisional State / Determination / Influence Functions

Factor 8 provides an important development of the provisional three-function analysis.

Quality-State functions appear in infrastructure characteristics relevant to interaction, especially under Indicators 8.2, 8.3, and 8.4.

Quality-State Determination is especially strong in Indicators 8.1 and 8.5.

Indicator 8.5 is particularly significant because it concerns whether infrastructure use, controls, warnings, and responses are clear to its relevant users and operators.

This creates a direct connection between human–infrastructure interaction and the reliability of Quality-State determination.

Quality-State Influence also appears.

Infrastructure design, feedback, access, configuration, and operating conditions can materially influence whether people are able to take safe and effective action.

Indicators 8.2, 8.3, and 8.5 therefore contain possible Influence functions.

However, the present Factor does not directly establish authority to intervene, escalation rights, or decision authority at the point where an unsafe condition is observed.

That subject should not be added to the existing Indicator meanings without Evidence.

It should remain available for later horizontal and Context Guide analysis.

Interim Finding for Factor 8

The analysis supports retaining five proposed Indicators under Factor 8, following the removal and nonredundancy tests for former proposals 8.6 and 8.7.

Each of the five retained Indicators preserves a distinct determination question concerning human–infrastructure interaction.

The former 8.6 concerned conditions already required to be identified and evaluated through Functional Requirements, Technical Requirements, and the retained interaction Indicators. The former 8.7 concerned knowledge retention already addressed by Factor 13 — Documentation and Traceability. Neither establishes a sufficiently independent invariant determination function.

Factor 8 also strengthens the provisional Quality-State Determination and Quality-State Influence research.

It shows that the ability of people to perceive and correctly understand infrastructure condition can be part of the determination path.

It also shows that infrastructure design and operating conditions can influence whether safe action is realistically possible.

No additional Factor 8 Indicator is justified by this review.

Broader-infrastructure conclusion. Five proposed Factor 8 Indicators remain necessary and distinguishable across the additional infrastructure contexts. The two removed Indicator justifications have been reconciled with the retained Indicators and Factor 13, rather than treated as dispensable Quality concerns. Existing workplace examples remain valid Context-specific applications. Achievement or non-achievement concerns applicable Context-specific QOCs, not the invariant Indicators.

However, later horizontal analysis should test whether repeated Context Guide Evidence identifies another necessary human–infrastructure determination function concerning timely intervention, authority, escalation, or the ability to act when an unacceptable condition is recognized.

That possibility should remain provisional rather than being built into the conclusion before the wider analysis is completed.

6.9 Factor 9 — Competence of Personnel

Factor 9 examines whether personnel whose decisions, actions, omissions, judgment, or authority can materially affect the Infrastructure Quality Object possess and maintain Role-Appropriate Competence.

Its scope is limited to competence where Function Realization, Infrastructure Results, Infrastructure Outcomes, Evidence, Quality Claims, or Critical Infrastructure Conditions materially depend on that competence.

Factor 9 does not prescribe personnel-management systems, training systems, credentials, or qualification frameworks.

Factor 9 therefore asks a broad question:

Do the people performing Infrastructure-Critical Roles have the competence needed to act and decide responsibly under the actual conditions of those roles?

Broader-infrastructure scope. Infrastructure-critical roles may be performed by designers, constructors, inspectors, operators, maintainers, and emergency responders, as applicable to the declared object. A residential building also involves specialized roles in inspection, building systems, maintenance, and emergency preparedness; its residents are not thereby classified as infrastructure personnel. Factor 9 concerns competence necessary to carry out infrastructure-critical work and judgments, rather than general human capabilities of users examined under Factor 8.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object sets the scale. Resolution depends on which roles, decisions, Lifecycle Stages, and conditions must be understood. A broad review may identify infrastructure-critical roles across the object; closer examination may trace a particular task, competence requirement, handoff, or Interface. The necessary detail may vary without changing Factor 9 or its Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 9 has an independent Quality nature: whether personnel performing infrastructure-critical roles have the competence needed for those roles. It also has a latent Harm-related nature. A competence gap does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

This research examines Factor 9 through six proposed Indicators:

Indicator 9.1 — Identification of Infrastructure-Critical Roles

Indicator 9.2 — Role-Appropriate Technical and Contextual Competence

Indicator 9.3 — Competence for Abnormal, Degraded, and Non-Routine Conditions

Indicator 9.4 — Recognition of Limits of Authority and Expertise

Indicator 9.5 — Evolution of Competence with Lifecycle and Context

Indicator 9.6 — Competence-Related Risk Awareness

The six Indicators examine different competence-dependent conditions that can affect infrastructure behavior and its determination.

Indicator 9.1 — Identification of Infrastructure-Critical Roles

Indicator 9.1 asks whether roles capable of materially affecting Infrastructure Safety, Structural or Functional Integrity, Operational Reliability, Environmental Protection, Evidence, or Quality Claims have been explicitly identified.

Its determination question is:

Which roles can materially affect Function Realization, important Infrastructure Results or Outcomes, Critical Infrastructure Conditions, Evidence, or Quality Claims?

This question is necessary.

Competence cannot be examined effectively if it is applied generically to all personnel without identifying the roles that can materially affect the Infrastructure Quality Object.

Job title alone is not sufficient.

Organizational position alone is not sufficient.

The relevant question is what the role can actually affect.

The removal test is:

Remove Indicator 9.1
→ competence requirements may exist, but the roles where competence is materially important to Infrastructure Quality may remain insufficiently identified.

Indicator 9.2 cannot replace this function.

Indicator 9.1 identifies the roles for which competence is critical.

Indicator 9.2 asks whether personnel performing those roles possess the required competence.

The distinction is:

Which roles are critical?

≠

Are the people performing those roles competent?

Indicator 9.1 is therefore necessary and distinguishable.

Cross-context test of 9.1. Roles that can materially affect a data center's electrical and cooling continuity, an apartment building's structural and life-safety systems, a bridge's inspection and load management, or a water-supply system's treatment and distribution must be identified according to the declared Quality Object and Applicable Basis. The indicator does not prescribe a uniform list of roles.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how thoroughly roles that may affect Function Realization, Quality determination, or relevant Results are identified. Closer review may trace specific tasks, handoffs, or Interfaces.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether infrastructure-critical roles have been identified. An omitted role does not by itself establish Harm; any conclusion requires a demonstrable pathway to a possible consequence.

Its provisional function is primarily Quality-State Determination.

It identifies where competence must be examined as part of determining the Infrastructure Quality State.

Indicator 9.2 — Role-Appropriate Technical and Contextual Competence

Indicator 9.2 asks whether personnel performing Infrastructure-Critical Roles possess competence appropriate to the actual technical, operational, and contextual demands of those roles.

Its determination question is:

Does the person performing the Infrastructure-Critical Role possess the knowledge, skill, judgment, experience, and contextual understanding needed for that role?

This question is central to Factor 9.

Formal qualification alone does not demonstrate Role-Appropriate Competence.

Technical knowledge alone may also be insufficient.

A person may understand a technical subject but lack sufficient understanding of the actual Infrastructure Quality Object, its configuration, operating conditions, Interfaces, responsibilities, or local Context.

The removal test is:

Remove Indicator 9.2
→ Infrastructure-Critical Roles may be identified while actual competence of the people performing those roles is no longer directly determined.

None of the other Factor 9 Indicators replaces this basic question.

Indicator 9.2 is therefore necessary.

Its provisional function includes Quality-State and Quality-State Determination.

The competence available at an Infrastructure-Critical Role is a real condition affecting Function Realization.

Evidence of that competence is also necessary to determine whether the condition is adequate.

Cross-context test of 9.2. Required competence differs for data-center electrical maintenance, residential building fire-system inspection, bridge structural assessment, and water-treatment operation. The invariant determination concerns adequacy for the assigned critical role; qualifications and Evidence are Context-specific.

Methodological resolution under WQI FTA11. The scale may be the whole object or a constituent; resolution determines how closely the competence required by each role is compared with actual capability and context.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether people performing critical roles have suitable competence. A gap does not by itself establish Harm; a contextual pathway to a possible consequence must be shown.

Indicator 9.3 — Competence for Abnormal, Degraded, and Non-Routine Conditions

Indicator 9.3 asks whether competence extends beyond routine and normal conditions.

Its determination question is:

Can personnel recognize, interpret, and respond appropriately when the Infrastructure Quality Object enters an abnormal, degraded, or non-routine condition?

This question is necessary.

A person may perform routine work competently while lacking the judgment needed when expected conditions change.

This distinction becomes especially important when information is incomplete, signals conflict, infrastructure behaves unexpectedly, or normal procedures no longer fit the actual condition.

The removal test is:

Remove Indicator 9.3
→ competence may be demonstrated for normal work while the ability to act responsibly under the conditions where Risk may be highest remains insufficiently determined.

Indicator 9.2 cannot fully replace this function.

Indicator 9.2 establishes Role-Appropriate Competence generally.

Indicator 9.3 deliberately tests that competence under conditions requiring additional recognition, interpretation, and judgment.

Indicator 9.3 is therefore necessary and distinguishable.

Its provisional function combines Quality-State Determination and Quality-State Influence.

Personnel must first recognize and interpret the non-routine condition.

They must then be capable of responding appropriately.

This creates a direct sequence:

condition exists
→ condition is recognized
→ condition is correctly interpreted
→ appropriate action becomes possible.

Indicator 9.3 therefore provides an important connection between determination of the Quality State and the capability to influence it.

Cross-context test of 9.3. Relevant non-routine competence may include response to data-center power loss, apartment-building smoke-control or evacuation-system failures, bridge damage after severe weather, or water-system contamination events. The need to respond competently does not replace separate assessments of infrastructure safety or reliability.

Methodological resolution under WQI FTA11. Resolution depends on the non-routine conditions relevant to the declared object, including abnormal, degraded, and transitional conditions. Closer review may examine a specific task or response.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether competence covers relevant non-routine conditions. A deficiency alone does not establish Harm; demonstrate a pathway to a possible consequence in context.

Indicator 9.4 — Recognition of Limits of Authority and Expertise

Indicator 9.4 asks whether infrastructure-related decisions reflect recognition of the limits of authority, knowledge, and expertise.

Its determination question is:

Does the person know when the matter exceeds the limits within which that person can responsibly act or conclude?

This question is necessary.

Competence does not mean unlimited competence.

Expertise does not mean unlimited Authority.

A person may be highly competent within one field while lacking sufficient knowledge, Context, or Authority for another decision.

Failure to recognize such limits can produce overconfidence, normalization of deviation, or unsupported conclusions.

The removal test is:

Remove Indicator 9.4
→ personnel may be competent within their normal roles while decisions beyond their actual knowledge, expertise, or Authority remain insufficiently controlled.

Indicator 9.2 cannot replace this function.

Knowing something well is different from knowing the boundary of what one knows.

Likewise, possessing expertise is different from possessing Authority to make a particular decision.

Indicator 9.4 therefore preserves a necessary and distinguishable function.

Its provisional function strongly combines Quality-State Determination and Quality-State Influence.

Recognition of a competence or Authority limit affects whether a person can responsibly interpret the condition.

Recognition of that limit can also lead to consultation, reassessment, or escalation.

This Indicator does not prescribe reporting lines or escalation procedures.

That Boundary should be preserved.

However, the Indicator clearly establishes recognition of when escalation, consultation, or reassessment is required.

Cross-context test of 9.4. Critical personnel must recognize when an issue exceeds their competence or decision authority, whether in commissioning a data center, evaluating a residential building, assessing bridge damage, or investigating a water-quality anomaly. This determination remains distinct from merely possessing routine technical skills.

Methodological resolution under WQI FTA11. Resolution determines how closely decisions, handoffs, and escalation needs are examined in relation to the declared object and the authority and expertise available.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether personnel recognize limits of authority and expertise. Failure to recognize a limit does not itself establish Harm; any Harm-related conclusion needs a demonstrable pathway.

Indicator 9.5 — Evolution of Competence with Lifecycle and Context

Indicator 9.5 asks whether competence remains adequate as Lifecycle Stages and operating Contexts change.

Its determination question is:

When the Infrastructure Quality Object, its operating condition, or the role changes, does the competence required for responsible Function Realization change with it?

This question is necessary.

Competence is not permanently adequate merely because it was adequate at an earlier Lifecycle Stage.

Commissioning may require different judgment from routine Operation.

Aging infrastructure may require different knowledge from new infrastructure.

New Operating Modes, repurposing, modification, or external Context changes may alter what personnel must understand.

The removal test is:

Remove Indicator 9.5
→ personnel may retain earlier qualifications and experience while the actual competence demands of the Infrastructure Quality Object change around them.

Indicator 9.5 is therefore distinguishable from Indicator 9.2.

Indicator 9.2 asks whether competence is appropriate to the role.

Indicator 9.5 asks whether that relationship remains valid as the role, Lifecycle, or Context changes.

Indicator 9.5 primarily performs Quality-State Determination.

It determines whether the competence basis remains aligned with the changing Infrastructure Quality Object.

It also has an Influence aspect because continued adequate competence supports responsible action as conditions change.

Cross-context test of 9.5. Changing equipment, occupancy, loads, technologies, operating conditions, or Applicable Bases can alter the competence required for critical roles. This applies to all four additional infrastructure contexts and is not limited to industrial facilities.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how competence is reviewed as roles, Lifecycle Stages, technologies, and operating Contexts change.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether competence remains suitable as relevant conditions change. A competence mismatch does not by itself establish Harm; demonstrate a pathway to a possible consequence.

Indicator 9.6 — Competence-Related Risk Awareness

Indicator 9.6 asks whether Risks arising from gaps, degradation, or misalignment of Personnel Competence are explicitly recognized where they can affect the Infrastructure Quality Object.

Its determination question is:

Can a competence gap, loss, or mismatch itself create or increase infrastructure Risk?

This question is necessary.

Competence should not be treated as a constant simply because a role is filled.

Experience may be lost.

Role complexity may increase.

Operating conditions may become atypical.

Knowledge may no longer match the actual Infrastructure Configuration.

The removal test is:

Remove Indicator 9.6
→ competence may be examined person by person while infrastructure Risk created by competence gaps or misalignment remains insufficiently visible.

Indicator 9.2 does not replace this function.

Indicator 9.2 asks whether personnel possess Role-Appropriate Competence.

Indicator 9.6 asks whether limitations or changes in competence create a material Risk to Function Realization, Evidence, Critical Infrastructure Conditions, or other relevant results.

Indicator 9.6 is therefore necessary and distinguishable.

Its provisional function is primarily Quality-State Determination.

It makes competence-related vulnerability visible as part of the Infrastructure Quality State Determination.

Where such Risk is recognized before an adverse result occurs, it can also support Quality-State Influence.

The Indicator itself, however, does not prescribe personnel-management or corrective-action systems.

Cross-context test of 9.6. Competence-related Risk may arise when a critical judgment is made without adequate expertise, when specialist coverage is unavailable, or when an assignment changes without reassessing competence. The relevant consequences and controls depend on the infrastructure Context and do not imply a deficiency of the invariant Indicator.

Methodological resolution under WQI FTA11. Resolution determines which competence gaps, changes, and dependencies could materially affect the declared object, its Results, or Quality determination.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question concerns recognition of competence-related Risk. Identifying a Risk is distinct from establishing Harm; any Harm conclusion requires evidence of a demonstrable pathway to a possible consequence.

Relationship Among the Six Indicators

The six Indicators form a connected competence determination.

They ask:

Which roles can materially affect the Infrastructure Quality Object?

→ Indicator 9.1.

Do the people performing those roles possess appropriate technical and contextual competence?

→ Indicator 9.2.

Does that competence remain sufficient under abnormal, degraded, and non-routine conditions?

→ Indicator 9.3.

Do personnel recognize the limits of their Authority and expertise?

→ Indicator 9.4.

Does competence remain aligned as Lifecycle and Context change?

→ Indicator 9.5.

Are Risks created by competence gaps, degradation, or misalignment recognized?

→ Indicator 9.6.

The Indicators therefore preserve six distinct competence-determination questions.

An Infrastructure Quality Object can:

depend on an Infrastructure-Critical Role that has not been recognized as critical;

have the role identified but filled by a person lacking sufficient contextual competence;

have competent personnel for routine conditions but insufficient competence for degraded conditions;

have technically competent personnel who fail to recognize the limits of their expertise or Authority;

have competence that was adequate earlier but becomes misaligned after Lifecycle or Context change;

contain competence-related vulnerabilities that are not recognized as infrastructure Risk;

or

depend on critical knowledge that disappears when experienced personnel leave.

These possibilities support separate retention of the six Indicators. The critical-knowledge example remains covered through the competence-Risk question in Indicator 9.6 and information continuity under Indicator 13.6.

Relationship Between Factor 8 and Factor 9

The analysis confirms the distinction identified under Factor 8.

Factor 8 examines whether the Infrastructure Quality Object supports safe human interaction.

Factor 9 examines whether the people whose actions and decisions matter possess the competence needed to perform their roles.

Therefore:

good infrastructure design
≠ competent personnel;

and

competent personnel
≠ good human–infrastructure interaction.

Both are necessary where Function Realization depends on human action.

Relationship to the Provisional State / Determination / Influence Functions

Factor 9 strongly supports the provisional Quality-State Determination concept.

Infrastructure Quality State Determination itself may depend on competent human observation, interpretation, judgment, assessment, and decision-making.

This is especially visible where personnel affect Evidence or Quality Claims, not only physical operation. The Factor 9 analysis expressly includes these roles. [0]

Indicators 9.3 and 9.4 are particularly important.

Indicator 9.3 concerns the capability to recognize, interpret, and respond to abnormal, degraded, and non-routine conditions.

Indicator 9.4 concerns recognition of the limits of knowledge, expertise, and Authority, including when consultation, reassessment, or escalation is required. [1] [2]

These Indicators show that competence can affect both:

determination of the condition;

and

the ability to act upon that determination.

Factor 9 therefore also contains Quality-State Influence functions.

However, an important distinction remains.

Competence to recognize a condition and competence to know that escalation is required do not necessarily establish that the person has Authority to intervene directly.

The terminology used in this research distinguishes Expertise from Authority and defines a Competence Limit partly through Authority. [3]

This may become important in the later horizontal analysis.

The present Indicator set addresses recognition of Authority limits.

It does not appear to establish a general requirement that Authority to preserve or restore the Quality State must exist at a particular observation or interaction point.

That should remain a provisional research question.

It should not be added to Factor 9 without repeated Context Guide Evidence.

Interim Finding for Factor 9

An earlier proposal for a seventh Factor 9 Indicator concerned the loss of critical knowledge when experienced personnel leave. The current Factor 9 set comprises Indicators 9.1–9.6. The knowledge-retention concern remains relevant, but it does not establish a separate invariant Indicator: Indicator 9.6 examines competence-related Risk, and Indicator 13.6 examines accessibility and continuity of Quality-critical information. Context-specific requirements and QOCs determine what information and competence evidence are needed.

Each preserves a necessary competence-related determination question.

Removal of any one of the six Indicators would leave a distinct critical-role, competence, non-routine-condition, Authority-limit, Lifecycle-change, or competence-Risk issue materially less visible or less determinable.

Factor 9 also strengthens the provisional distinction between Quality-State Determination and Quality-State Influence.

A person may be competent to determine that a condition is unacceptable but lack Authority to influence that condition directly.

A person may also possess Authority while lacking sufficient competence to determine the condition responsibly.

Competence and Authority therefore should not be treated as interchangeable.

No additional Factor 9 Indicator is justified beyond Indicators 9.1–9.6 on the evidence examined. The earlier 9.7 proposal is not part of the current 83-Indicator architecture; its relevant concerns remain examined through Indicators 9.6 and 13.6.

Broader-infrastructure interim finding. Indicators 9.1–9.6 retain six distinct, necessary competence-determination functions across physical data centers, residential apartment buildings, bridges, and water-

supply systems. The earlier knowledge-retention proposal is not retained as a separate Factor 9 Indicator. Indicator 9.6 examines competence-related Risk, while Indicator 13.6 addresses accessibility and continuity of Quality-critical information. Context-specific requirements and QOCs determine what information and competence evidence are needed. No additional invariant Indicator is proposed.

However, the relationship among competence, observation, determination, Authority, escalation, and timely intervention should be preserved as a provisional finding for the horizontal analysis and later Context Guide testing.

6.10 Factor 10 — Regulatory and Standards Compliance

Factor 10 examines whether Applicable Requirements from the Reference Layer are correctly identified, interpreted, integrated into infrastructure decisions, and supported by Evidence of Compliance.

Its purpose is also to preserve an important limit:

Compliance is necessary where applicable, but Compliance alone does not establish Infrastructure Quality.

Factor 10 therefore asks a broad question:

Does the declared Infrastructure Quality Object satisfy the Applicable Requirements that govern it, and are the limits of that compliance correctly understood?

This research examines Factor 10 through six proposed Indicators:

For a physical data center, the Applicable Basis may include building, electrical, fire, environmental, and other requirements. For an apartment building, it may include building, accessibility, fire, occupancy, and housing requirements. For a bridge, it may include structural, transportation, inspection, and public-safety requirements. For a water-supply system, it may include water-quality, treatment, distribution, environmental, and public-health requirements. For each declared Infrastructure Quality Object, determine which requirements apply, their legal force and edition, the jurisdiction, and the relevant Lifecycle Stage. A voluntary standard does not become a binding legal obligation merely because it is referenced.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object sets the scale. Resolution depends on which requirements, jurisdictions, Lifecycle Stages, and decisions must be examined. A broad review may identify the applicable requirements for the whole object; closer examination may trace a particular permit, technical obligation, interface, or change. The necessary detail may vary without changing Factor 10 or its Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 10 has an independent Quality nature: whether applicable regulatory and standards requirements are identified, reflected in decisions, and met to the extent required. It also has a latent Harm-related nature. Noncompliance does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

Indicator 10.1 — Identification of Applicable Regulatory and Standards Obligations

Indicator 10.2 — Integration of Regulatory and Standards Requirements into Infrastructure Decisions

Indicator 10.3 — Demonstration of Conformity with Applicable Requirements

Indicator 10.4 — Treatment of Conflicting or Overlapping Requirements

Indicator 10.5 — Continued Validity of Compliance Under Change

Indicator 10.6 — Recognition of Compliance Limitations

The six Indicators examine different parts of the relationship between the Infrastructure Quality Object and its governing Reference Layer.

Indicator 10.1 — Identification of Applicable Regulatory and Standards Obligations

Indicator 10.1 asks whether the laws, regulations, permits, and recognized standards that actually apply to the Infrastructure Quality Object have been explicitly identified.

Its determination question is:

Which regulatory and standards requirements apply to this Infrastructure Quality Object, Boundary, Lifecycle Stage, jurisdiction, and purpose?

This question is necessary.

Compliance cannot be determined before applicability is established.

A requirement may exist but not apply to the declared object or condition.

Another requirement may apply but remain unidentified.

The removal test is:

Remove Indicator 10.1
→ compliance activity may occur without sufficient confidence that the complete and correct set of Applicable Requirements has been identified.

None of the other Factor 10 Indicators replaces this question.

Indicator 10.3 cannot demonstrate conformity to a requirement that has not first been recognized as applicable.

Indicator 10.1 therefore preserves a necessary and distinguishable determination function.

Its provisional function is strongly Quality-State Determination.

It establishes the Reference Layer basis against which Compliance can later be examined.

Cross-context test of 10.1. The applicability determination must distinguish binding law and permit conditions from standards incorporated by reference, contractual requirements, and voluntary guidance. Jurisdiction, infrastructure type, use, and Lifecycle Stage may change the applicable set.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how thoroughly requirements are identified across relevant authorities, jurisdictions, Lifecycle Stages, and parts of the object.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether applicable obligations have been identified. An omission does not by itself establish Harm; a demonstrable pathway to a possible consequence is needed for a Harm-related conclusion.

Indicator 10.2 — Integration of Regulatory and Standards Requirements into Infrastructure Decisions

Indicator 10.2 asks whether Applicable Requirements are actually reflected in infrastructure decisions.

Its determination question is:

Are the identified regulatory and standards obligations incorporated into the functional, technical, realization, operational, and Lifecycle decisions that they govern?

This question is necessary.

Identification of an obligation does not establish that the Infrastructure Quality Object has actually been developed or operated in accordance with it.

Requirements can exist in a separate compliance list while infrastructure decisions proceed without sufficiently incorporating them.

The removal test is:

Remove Indicator 10.2
→ Applicable Requirements may be correctly identified but remain disconnected from the decisions that determine actual infrastructure behavior.

Indicator 10.1 therefore cannot replace Indicator 10.2.

The distinction is:

Requirement identified
≠ requirement integrated into infrastructure decisions.

Indicator 10.2 has both Quality-State Determination and Quality-State Influence functions.

The applicable requirement must be understood.

It must then influence the decisions through which the Infrastructure Quality Object is defined, realized, operated, or changed.

Cross-context test of 10.2. Applicable requirements must inform design, construction, commissioning, operation, maintenance, modification, and other relevant decisions for the declared object. Merely listing requirements does not demonstrate their effective integration.

Methodological resolution under WQI FTA11. Resolution determines how closely applicable requirements are traced into relevant design, construction, commissioning, operation, maintenance, and change decisions. The scale may be the whole object or a constituent.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether applicable requirements influence infrastructure decisions. Failure to integrate a requirement does not itself establish Harm; demonstrate a pathway to a possible consequence in context.

Indicator 10.3 — Demonstration of Conformity with Applicable Requirements

Indicator 10.3 asks whether actual conformity with Applicable Requirements can be demonstrated.

Its determination question is:

Can conformity of the Infrastructure Quality Object to the applicable regulatory and standards requirements be supported by Evidence?

This question is necessary.

A requirement can be identified.

It can also be incorporated into specifications or decisions.

Neither establishes that the realized Infrastructure Quality Object actually conforms.

The removal test is:

Remove Indicator 10.3
→ requirements may be identified and integrated while actual conformity remains assumed rather than demonstrated.

Indicator 10.3 therefore preserves a central Factor 10 function.

Its provisional classification includes Quality-State and Quality-State Determination.

The actual conformity condition concerns the state of the Infrastructure Quality Object relative to the Reference Layer.

The demonstration of that condition depends on Evidence.

Indicator 10.3 is closely related to Factor 3 — Conformity Assessment.

The overlap is real but not necessarily redundant.

Factor 3 establishes the broader basis for demonstrating conformity to specified requirements or criteria.

Indicator 10.3 applies that demonstrability specifically to Applicable Requirements from the regulatory and standards Reference Layer.

The distinction can be expressed as:

Factor 3
→ Can conformity to identified requirements or criteria be responsibly demonstrated?

Factor 10, Indicator 10.3
→ Can conformity specifically to Applicable Regulatory and Standards Requirements be demonstrated?

This relationship should remain visible in later horizontal analysis.

Cross-context test of 10.3. Demonstration of conformity is assessed against the specifically applicable regulatory and standards requirements. Factor 3 addresses object-level Conformity Assessment against the full Applicable Basis; Factor 10 independently determines the applicable regulatory and standards obligations and their satisfaction. The two Factors are connected, not interchangeable.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines the evidence and examination detail needed to demonstrate conformity with the applicable requirements at the relevant Lifecycle Stage.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether conformity with applicable requirements can be demonstrated. Lack of demonstration is distinct from Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence.

Indicator 10.4 — Treatment of Conflicting or Overlapping Requirements

Indicator 10.4 asks whether conflicts, overlap, or ambiguity among Applicable Requirements have been explicitly identified and addressed.

Its determination question is:

When multiple requirements apply, are conflicts, overlaps, or ambiguities sufficiently understood so that compliance is not based on silent or selective interpretation?

This question is necessary.

Infrastructure may be governed by several jurisdictions, standards, permit conditions, contracts, or Lifecycle requirements.

These requirements may overlap.

They may use different language.

In some cases, they may appear inconsistent.

The removal test is:

Remove Indicator 10.4
→ all applicable requirements may be identified individually while their combined application remains unclear or contradictory.

Indicator 10.1 cannot replace this function.

Identification asks what applies.

Indicator 10.4 asks how simultaneously applicable requirements relate to one another.

Indicator 10.4 therefore preserves a necessary and distinguishable determination function.

Its provisional function is primarily Quality-State Determination.

It protects the reliability of the compliance basis where several Reference Layer sources interact.

Cross-context test of 10.4. A building, bridge, data center, or water-supply facility may be subject to requirements from multiple authorities, codes, permits, and incorporated standards. The question is whether overlap, conflicts, precedence, and unresolved interpretation are recognized and handled under the applicable authority, not whether one universal rule resolves every case.

Methodological resolution under WQI FTA11. Resolution depends on the requirements and authorities involved; a closer review may examine particular conflicts, overlap, precedence, and unresolved interpretation for a constituent or decision.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether conflicts and overlaps among requirements are recognized and addressed. An unresolved conflict does not by itself establish Harm; a contextual pathway to a possible consequence must be shown.

Indicator 10.5 — Continued Validity of Compliance Under Change

Indicator 10.5 asks whether an earlier compliance conclusion remains valid when the Infrastructure Quality Object, operating conditions, Context, or governing requirements change.

Its determination question is:

Does the existing compliance basis remain applicable after relevant change?

This question is necessary.

Compliance is not permanent merely because it was demonstrated once.

Infrastructure may be modified.

Throughput may change.

Use may change.

Location or jurisdiction may change.

The governing requirements themselves may change.

The removal test is:

Remove Indicator 10.5
→ an earlier Compliance Statement may continue to be relied upon even when the conditions on which it was based no longer apply.

Indicator 10.3 cannot replace this function.

Indicator 10.3 asks whether conformity can be demonstrated at the relevant time and Lifecycle Stage.

Indicator 10.5 specifically preserves the need to reassess continued applicability after change.

Indicator 10.5 is also part of the recurring cross-Factor change pattern already identified.

Its provisional function combines Quality-State Determination and Quality-State Influence.

Changed conditions must be recognized.

Infrastructure decisions may then need to remain aligned with the changed Reference Layer requirements.

Cross-context test of 10.5. Alterations to occupancy, data-center capacity, bridge loading or use, water-treatment processes, jurisdictional rules, or adopted standards may change applicability or invalidate an earlier compliance conclusion. Reassessment is required when the Applicable Basis or assessed conditions change.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how closely changes in infrastructure, operation, context, jurisdiction, or requirements are traced to prior compliance conclusions.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether earlier compliance conclusions remain valid after relevant change. A stale conclusion alone does not establish Harm; any conclusion about Harm requires a demonstrable pathway.

Indicator 10.6 — Recognition of Compliance Limitations

Indicator 10.6 asks whether the limits of regulatory and standards compliance as evidence of Infrastructure Quality are explicitly recognized.

Its determination question is:

What does Compliance demonstrate, and what does it not demonstrate about the broader Infrastructure Quality State?

This question is necessary.

Compliance may be complete with respect to the Applicable Requirements and still not address every infrastructure-specific Risk, uncertainty, interaction, or system-level condition relevant to Quality.

The removal test is:

Remove Indicator 10.6
→ a valid Compliance Statement may be incorrectly interpreted as proof of overall Infrastructure Safety, integrity, acceptable Results or Outcomes, or a positive Infrastructure Quality State.

This Indicator is unusual because it does not primarily ask whether a requirement has been met.

It asks whether the meaning and limits of the resulting compliance finding are correctly understood.

Indicator 10.6 therefore strongly performs a Quality-State Determination function.

It protects the wider Quality State determination from over-reliance on one type of Evidence.

This Indicator also supports the fundamental IQI proposition:

Compliance
≠ Infrastructure Quality.

Its separate visibility is therefore important.

Cross-context test of 10.6. Compliance with a building code, electrical standard, bridge specification, or drinking-water regulation is evidence about specified obligations, but is not automatically proof of all applicable Functional Requirements, Structural and Functional Integrity, Operational Reliability, or overall Infrastructure Quality.

Methodological resolution under WQI FTA11. Resolution determines which aspects of overall Infrastructure Quality are and are not established by evidence of compliance with specific requirements.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the limits of compliance evidence are recognized. Overreliance on compliance evidence does not itself establish Harm; demonstrate a pathway to a possible consequence in context.

Nonredundancy determination — former Indicator 10.7. Traceability of Compliance Statements remains necessary, including identification of applicable requirements, assessment scope, supporting Evidence, and Lifecycle applicability. Nevertheless, this is not a distinct invariant Factor 10 determination: Indicator 3.7 addresses Conformity Statement traceability and Factor 13 addresses Quality-critical documentation and traceability. The removal test therefore supports deleting former Indicator 10.7 while retaining its essential subject matter through these existing determinations.

Relationship Among the Six Indicators

The six Indicators form a connected compliance determination.

They ask:

What regulatory and standards obligations apply?

→ Indicator 10.1.

Are those obligations reflected in infrastructure decisions?

→ Indicator 10.2.

Can actual conformity to them be demonstrated?

→ Indicator 10.3.

Are conflicts or overlaps among requirements explicitly addressed?

→ Indicator 10.4.

Does the compliance conclusion remain valid after change?

→ Indicator 10.5.

Are the limits of Compliance as Evidence of Infrastructure Quality recognized?

→ Indicator 10.6.

The six Indicators therefore preserve different determination questions.

An Infrastructure Quality Object can:

fail to identify an applicable requirement;

identify a requirement but fail to integrate it into infrastructure decisions;

integrate a requirement but fail to demonstrate actual conformity;

satisfy individual requirements while unresolved conflicts exist among them;

have valid earlier Compliance that becomes outdated after change;

be fully compliant while still having quality-relevant conditions outside the scope of the applicable requirements;

These possibilities support separate retention of Indicators 10.1–10.6. Traceability of compliance statements remains necessary but is addressed by Indicators 3.7 and 13.4 and the wider Factor 13 requirements.

Relationship Between Factor 3 and Factor 10

Factor 3 and Factor 10 have an important connection.

Factor 3 concerns demonstrated conformity.

Factor 10 concerns a specific source of requirements: the applicable regulatory and standards Reference Layer.

The relationship can be expressed as:

Factor 3
→ Is conformity to the defined basis demonstrable?

Factor 10
→ What external regulatory and standards requirements apply, and is alignment with them demonstrated and correctly interpreted?

Factor 10 therefore should not be absorbed into Factor 3.

Conformity can be assessed against many requirements.

Factor 10 separately preserves the requirement to identify and interpret the authoritative Reference Layer obligations that govern the Infrastructure Quality Object.

Relationship to the Provisional State / Determination / Influence Functions

Factor 10 is strongly weighted toward Quality-State Determination functions.

Indicators 10.1, 10.4, and 10.6 primarily concern whether the compliance basis and the meaning of compliance can be determined reliably.

Indicator 10.3 also contains a Quality-State function because actual conformity is a condition of the Infrastructure Quality Object relative to the Reference Layer.

Indicator 10.2 provides a clear Influence function because Applicable Requirements must influence infrastructure decisions rather than remain external statements.

Indicator 10.5 also contains an Influence function because changed requirements or changed infrastructure conditions may require changed decisions to preserve Compliance.

The provisional analysis therefore again shows that one Factor can contain all three functions without requiring a new normative classification.

Interim Finding for Factor 10

The analysis supports retention of six invariant Factor 10 Indicators, 10.1–10.6. Former proposed Indicator 10.7 was removed after the nonredundancy and removal tests established that its traceability function is addressed by Factors 3 and 13.

Each preserves a necessary determination question.

Removal of any of Indicators 10.1–10.6 would leave a distinct applicability, integration, conformity, conflict, change, or compliance-limitation determination less visible. Removal of former 10.7 does not remove the obligation to preserve the basis, scope, Evidence, and Lifecycle relevance of Compliance Statements.

The analysis also strengthens two horizontal findings.

First, Factor-specific traceability functions must be tested against the wider documentation and traceability provisions of Factor 13 to avoid unnecessary duplication.

Second, change-related Indicators continue to recur across several Factors.

These repeated patterns should be tested later to determine whether they represent necessary application of common determination functions to different quality dimensions or unnecessary duplication.

No additional Factor 10 Indicator is justified by this review. The traceability function of former Indicator 10.7 is retained through Factors 3 and 13 as described above.

The present analysis also supports retaining Indicator 10.6 separately.

Its function is not simply regulatory compliance.

It protects the IQI Quality State determination from the false conclusion that demonstrated Compliance alone establishes Infrastructure Quality.

Broader-infrastructure finding. Indicators 10.1–10.6 remain necessary and distinguishable across physical data centers, residential apartment buildings, bridges, and water-supply systems. The removal of former

Indicator 10.7 does not eliminate traceability of Compliance Statements: the relevant obligations are covered by Indicator 3.7 where conformity statements are concerned and by Factor 13 for the broader preservation of Quality-critical information and Evidence. No additional Factor 10 Indicator is proposed.

6.11 Factor 11 — Infrastructure and Stakeholders

Agreed revision: former proposed Indicator 11.7 — Retention of Stakeholder and Community Impact Knowledge — is removed as an independent Indicator. Its necessary information-retention content is addressed through Factor 13 — Documentation and Traceability. Factor 11 comprises Indicators 11.1–11.6.

Factor 11 examines whether Infrastructure Quality interpretation accounts for the effects of the Infrastructure Quality Object on affected Stakeholders and Communities.

The affected Stakeholders of a declared Infrastructure Quality Object may include occupants, residents, users, customers, operators, owners, neighboring Communities, and other affected parties, as applicable. Examples differ by Context. For a data center, they may include facility impacts on users, workers, and neighbors. For an apartment building, they may include habitability and access for residents. For a bridge, they may include mobility and accessibility for road users and nearby Communities. For a water-supply system, they may include service, water quality, and other effects on customers and affected Communities. Factor 11 does not assume these groups have identical interests or that stakeholder opinion replaces evidence-based Quality determination.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object sets the scale. Resolution depends on which affected Stakeholders, Communities, effects, and Lifecycle Stages must be understood. A broad review may consider groups affected by the whole object; a closer review may trace a specific location, service, exposure, or concern. The needed detail may vary without changing Factor 11 or its Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 11 has an independent Quality nature: whether relevant effects of the infrastructure and their relation to affected Stakeholders and Communities are understood and addressed in the Quality determination. It also has a latent Harm-related nature. An impact, concern, or deficiency does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

Infrastructure and Stakeholders extends beyond community satisfaction to the quality-relevant relationship between the declared object and its affected or dependent stakeholders, including occupants, users, neighboring communities, infrastructure operators, and service recipients, as applicable.

Its scope includes Infrastructure Safety, Environmental Protection, accessibility, Operational Reliability, Declared Commitments, Relevant Stakeholder Expectations, Infrastructure Impacts, and trust across the Lifecycle.

Factor 11 does not reduce satisfaction to opinion polling, popularity, or absence of complaint.

It examines whether Infrastructure Results and Infrastructure Outcomes affecting Stakeholders and Communities align with Declared Commitments, Relevant Stakeholder Expectations, applicable obligations, and actual observed effects.

Factor 11 therefore asks a broad question:

Do the Infrastructure Results and Infrastructure Outcomes affecting Stakeholders and Communities remain consistent with the commitments, expectations, and quality-relevant effects applicable to the declared Infrastructure Quality Object?

This research examines Factor 11 through six proposed Indicators:

Indicator 11.1 — Identification of Affected Stakeholders and Communities

Indicator 11.2 — Identification of Infrastructure Impacts Relevant to Stakeholders and Communities

Indicator 11.3 — Alignment with Declared Commitments and Expectations

Indicator 11.4 — Consideration of Cumulative and Long-Term Community Effects

Indicator 11.5 — Responsiveness to Infrastructure-Related Community Concerns

Indicator 11.6 — Transparency of Infrastructure Impacts and Limitations

The six Indicators examine different parts of the relationship between infrastructure behavior and its effects on people and Communities.

Indicator 11.1 — Identification of Affected Stakeholders and Communities

Indicator 11.1 asks whether the people, groups, and Communities affected by infrastructure behavior have been explicitly identified.

Its determination question is:

Who is affected by, or credibly exposed to, the Infrastructure Impacts of the declared Infrastructure Quality Object?

This question is necessary.

Infrastructure effects cannot be responsibly interpreted if the affected people or Communities remain outside the determination.

A technically defined Boundary does not by itself establish who experiences the resulting safety, environmental, accessibility, service, nuisance, or other impacts.

The removal test is:

Remove Indicator 11.1
→ Infrastructure Impacts may be examined while some affected Stakeholders or Communities remain unidentified and therefore outside the determination.

Indicator 11.2 cannot replace this function.

Indicator 11.1 asks who is affected.

Indicator 11.2 asks what Infrastructure Impacts affect them.

The two questions are connected but different.

Indicator 11.1 therefore preserves a necessary and distinguishable determination function.

Cross-context test for 11.1. Identify the actual affected Stakeholders and Communities, including direct users, occupants, and recipients of infrastructure functions, not only neighboring communities.

Methodological resolution under WQI FTA11. Resolution determines how closely affected people and groups are identified in relation to the declared object, its Interfaces, services, locations, and Lifecycle Stages.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether affected Stakeholders and Communities are identified. An omitted group does not itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence.

Its provisional function is primarily Quality-State Determination.

It establishes the affected persons and Communities whose experience and exposure must be considered.

Indicator 11.2 — Identification of Infrastructure Impacts Relevant to Stakeholders and Communities

Indicator 11.2 asks whether the actual infrastructure effects relevant to stakeholder and Community experience have been explicitly identified.

Its determination question is:

What effects of infrastructure behavior materially affect the identified Stakeholders and Communities?

This question is necessary.

Identification of an affected Community does not establish what infrastructure behavior or result is affecting it.

The effects may involve safety.

They may involve environmental conditions.

They may involve accessibility, service continuity, nuisance, disruption, or cumulative effects.

The removal test is:

Remove Indicator 11.2
→ affected Stakeholders and Communities may be known while the actual infrastructure effects relevant to their experience remain insufficiently determined.

Indicator 11.2 therefore preserves a separate function from Indicator 11.1.

It also prevents Factor 11 from becoming an opinion-based assessment.

The Indicator requires the relationship to be grounded in infrastructure behavior and Infrastructure Impacts.

Its provisional classification includes Quality-State and Quality-State Determination functions.

The Infrastructure Impact is part of the actual condition and result of the Infrastructure Quality Object.

Its relationship to affected Stakeholders and Communities must also be determined.

Cross-context test for 11.2. Distinguish identifying affected persons from identifying the relevant Infrastructure Impacts experienced by those persons; the latter can include service accessibility, continuity, nuisance, and other context-dependent effects.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how fully relevant effects are identified across affected groups, locations, and stages.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether relevant infrastructure effects on Stakeholders and Communities are understood. An unrecognized effect does not itself establish Harm; demonstrate a pathway to a possible consequence in context.

Indicator 11.3 — Alignment with Declared Commitments and Expectations

Indicator 11.3 asks whether Infrastructure Results and Infrastructure Outcomes affecting Stakeholders and Communities align with Declared Commitments, applicable obligations, Relevant Stakeholder Expectations, and associated Quality Outcome Criteria.

Its determination question is:

Do the effects actually experienced by Stakeholders and Communities correspond to the commitments and relevant expectations used to justify the infrastructure?

This question is necessary.

An infrastructure owner or operator may make a commitment concerning service, access, environmental impact, safety, disruption, or another result.

The actual Infrastructure Outcome may differ.

The removal test is:

Remove Indicator 11.3
→ Stakeholders and Infrastructure Impacts may be identified, but the relationship between promised or expected results and actual results is no longer explicitly determined.

Indicator 11.3 is central to how this research examines Infrastructure and Stakeholders under Factor 11.

Satisfaction is not simply whether people approve of the infrastructure.

It concerns realization of applicable commitments and Relevant Stakeholder Expectations in relation to actual Infrastructure Impacts.

Its provisional function is primarily Quality-State.

It compares actual Infrastructure Results and Outcomes with the expected or committed condition.

It also performs a Quality-State Determination function because the comparison must be supported by Evidence.

Cross-context test for 11.3. Applicable commitments and expectations must be established for the declared object and affected Stakeholders; expectations do not automatically become binding obligations merely because they are expressed.

Methodological resolution under WQI FTA11. Resolution determines how closely results and outcomes are compared with applicable commitments, obligations, and relevant expectations for the declared object and affected groups.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether actual results and outcomes align with relevant commitments and expectations. A mismatch alone does not establish Harm; a demonstrable pathway to a possible consequence is required.

Indicator 11.4 — Consideration of Cumulative and Long-Term Community Effects

Indicator 11.4 asks whether repeated, distributed, persistent, or delayed Infrastructure Impacts on Stakeholders and Communities are explicitly considered.

Its determination question is:

Can individually limited Infrastructure Impacts combine over time or space into a significant Community effect?

This question is necessary.

A single disruption may appear minor.

Repeated disruption may become important.

A temporary nuisance may appear acceptable.

Persistent nuisance may produce a materially different result.

Several limited Infrastructure Impacts may interact with existing Community burdens.

The removal test is:

Remove Indicator 11.4
→ individual Infrastructure Impacts may be examined while their cumulative or long-term Community effect remains insufficiently visible.

Indicator 11.2 cannot replace this function.

Indicator 11.2 identifies relevant Infrastructure Impacts.

Indicator 11.4 examines how those impacts may accumulate, interact, persist, or develop over time.

This distinction parallels the cumulative-effect Indicators already examined under Factors 5 and 6.

The subject differs.

Factor 5 concerns cumulative Risk.

Factor 6 concerns cumulative environmental effects.

Indicator 11.4 concerns cumulative and long-term effects on Stakeholders and Communities.

This recurring pattern should be preserved for horizontal analysis.

Indicator 11.4 combines Quality-State and Quality-State Determination functions.

Cumulative Community effect can be an actual Infrastructure Outcome.

Its recognition may require longitudinal or combined interpretation rather than observation of isolated events.

Cross-context test for 11.4. Cumulative effects may arise from recurring building-service disruptions, sustained data-center neighborhood impacts, repeated bridge access restrictions, or persistent water-service effects. Their determination remains distinct from identifying an individual impact.

Methodological resolution under WQI FTA11. Resolution depends on the duration, recurrence, distribution, and interaction of effects relevant to the declared object and affected Communities.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether cumulative and long-term effects are considered. Their existence does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway in context.

Indicator 11.5 — Responsiveness to Infrastructure-Related Community Concerns

Indicator 11.5 asks whether infrastructure-related concerns raised by Stakeholders or Communities are recognized and addressed where they may indicate a quality issue.

Its determination question is:

When Stakeholder or Community input may indicate an infrastructure quality problem, is that signal considered rather than dismissed?

This question is necessary.

Stakeholder and Community observations may reveal conditions that are not sufficiently visible through existing technical monitoring or internal Evidence.

A recurring report of service disruption, environmental effect, accessibility problem, safety issue, or another impact may provide information relevant to the Infrastructure Quality Object.

The removal test is:

Remove Indicator 11.5
→ Infrastructure Impacts may be assessed only through internally selected Evidence while potentially important external observations remain insufficiently considered.

The Indicator does not require agreement with every concern.

For this research, responsiveness means evidenced consideration and appropriate treatment of a concern, not automatic acceptance.

Indicator 11.5 should also not be reduced to a complaint-handling requirement.

This Indicator does not prescribe complaint-handling processes or engagement mechanisms.

Its determination question is whether a Community Concern that may indicate an infrastructure quality issue is recognized as relevant to the determination.

Indicator 11.5 is therefore strongly connected to Quality-State Determination.

Stakeholder or Community input can provide a possible observation path to the actual condition or effect of the Infrastructure Quality Object.

It may also contain a Quality-State Influence function where recognition of a valid concern leads to changes that preserve or restore an acceptable condition.

The present Indicator, however, does not prescribe those actions.

Cross-context test for 11.5. Concerns raised by residents, users, customers, and other affected Stakeholders can reveal quality-relevant conditions even where they do not originate from a geographic Community. Their credibility and relation to the declared object require Evidence; concern alone does not establish non-achievement of a QOC.

Methodological resolution under WQI FTA11. The needed detail depends on which concerns may reveal effects or conditions relevant to the declared object, including patterns across locations and time.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether relevant concerns are recognized and considered. A concern is not proof of Harm; a demonstrable pathway to a possible consequence must be established.

Indicator 11.6 — Transparency of Infrastructure Impacts and Limitations

Indicator 11.6 asks whether known effects, residual impacts, and limitations are made sufficiently transparent.

Its determination question is:

Are Stakeholders and Communities given a representation of Infrastructure Impacts that does not conceal known limitations or residual effects?

This question is necessary.

An Infrastructure Quality Object may have unavoidable residual Risk, nuisance, or another effect.

The existence of such a condition does not necessarily establish unacceptable Quality.

But failure to acknowledge it may produce a misleading representation of the Infrastructure Results or Outcomes.

The removal test is:

Remove Indicator 11.6
→ Infrastructure Impacts may be internally understood while external representation of those effects remains incomplete or misleading.

Indicator 11.6 is distinguishable from Indicator 11.3.

Indicator 11.3 asks whether actual results align with commitments and expectations.

Indicator 11.6 asks whether known limitations and residual impacts are sufficiently visible.

A commitment may be satisfied while a residual effect still requires transparent acknowledgement.

Indicator 11.6 primarily performs a Quality-State Determination function.

It supports a more accurate understanding of the actual Infrastructure Impacts and the limits of any claim concerning them.

It also supports trust, but trust alone is not the determination function.

The determination question remains whether the actual effect and its limitation are represented transparently.

Cross-context test for 11.6. Known impacts, limits, and residual conditions should be represented clearly to relevant Stakeholders in a manner determined by the Applicable Basis; this does not replace the general documentation and traceability functions of Factor 13.

Methodological resolution under WQI FTA11. Resolution determines which known effects, limits, and residual conditions must be visible to which affected groups, and at what Lifecycle Stage.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether known effects and limitations are represented transparently. Lack of transparency alone does not establish Harm; demonstrate a pathway to a possible consequence in context.

Relationship Among the Six Indicators

The six Indicators form a connected determination.

They ask:

Who is affected?

→ Indicator 11.1.

What Infrastructure Impacts affect them?

→ Indicator 11.2.

Do actual Infrastructure Results and Outcomes align with applicable commitments and Relevant Stakeholder Expectations?

→ Indicator 11.3.

Do repeated or persistent impacts produce cumulative or long-term Community effects?

→ Indicator 11.4.

Are Community Concerns that may indicate an infrastructure quality issue recognized and considered?

→ Indicator 11.5.

Are known impacts, residual effects, and limitations sufficiently transparent?

→ Indicator 11.6.

The remaining Indicators preserve distinct determination questions.

An Infrastructure Quality Object can:

affect a Community that has not been identified;

have identified Stakeholders while the relevant Infrastructure Impacts remain poorly understood;

have known impacts that do not align with Declared Commitments;

have limited individual impacts that accumulate into a significant long-term effect;

produce a quality issue first visible through Community Concern;

have known residual impacts that are not made transparent;

or

Relationship to Other Quality Factors

Factor 11 should not substitute for the Factors that directly examine Safety, Environmental Protection, Operational Reliability, or another technical or operational condition.

For example:

A Community Concern about repeated service interruption does not replace Factor 7.

It may provide Evidence that a reliability condition requires examination.

A Community Concern about environmental effects does not replace Factor 6.

It may provide Evidence of an Environmental Interaction or effect not adequately visible elsewhere.

Factor 11 therefore adds a different determination direction.

The other Factors often examine:

Infrastructure Quality Object
→ condition or behavior
→ resulting finding.

Factor 11 also examines:

Infrastructure Quality Object
→ Infrastructure Impact
→ affected Stakeholder or Community
→ observed Infrastructure Result or Infrastructure Outcome.

This direction is necessary because some effects of infrastructure behavior become fully visible only at the receiving side of the interaction.

Relationship to the Provisional State / Determination / Influence Functions

Factor 11 contains strong Quality-State and Quality-State Determination functions.

Indicators 11.2, 11.3, and 11.4 concern actual Infrastructure Impacts, Results, and Outcomes experienced by Stakeholders and Communities.

Indicators 11.1, 11.5, and 11.6 support the ability to determine and interpret those effects. The retention function formerly proposed as Indicator 11.7 is addressed through Factor 13.

Indicator 11.5 is particularly important to the horizontal research.

It shows that Stakeholders and Communities can sometimes act as an information path through which a quality-relevant condition becomes observable.

The concern itself is not proof.

But it may be Evidence or lead to Evidence when its relevance and credibility are established.

This provides another example of Quality-State Determination occurring through information paths that extend beyond the immediate physical infrastructure workplace.

Quality-State Influence is less direct in Factor 11.

Responsiveness may lead to action.

Declared Commitments may influence infrastructure decisions.

This research does not prescribe stakeholder-management or engagement mechanisms.

The present analysis should therefore avoid turning Factor 11 into a general management-system requirement.

Interim Finding for Factor 11

Each preserves a necessary determination question concerning affected Stakeholders, Infrastructure Impacts, commitments and expectations, cumulative effects, Community Concerns, transparency, or retained impact knowledge.

Removal of any one would leave a different part of the Stakeholder and Community dimension materially less visible or less determinable.

Factor 11 also strengthens two horizontal findings.

First, Quality-State determination may depend on information originating outside the immediate Infrastructure Quality Object, including observations from affected Stakeholders and Communities.

Second, cumulative-effect and information-retention functions continue to recur across different Factors.

No additional Factor 11 Indicator is justified by this analysis at this stage.

Repeated Context Guide Evidence should continue to test whether important Stakeholder or Community determination functions remain outside the present six Indicators, particularly where external observations provide early or independent visibility of infrastructure conditions not sufficiently visible through internal information paths.

Broader-infrastructure interim finding. Indicators 11.1–11.6 preserve distinguishable determination questions when applied to data centers, residential apartment buildings, bridges, and water-supply systems. Indicator 11.5 should cover relevant concerns raised by affected Stakeholders, not only geographic Communities. Former proposed Indicator 11.7 has been removed as a separate Indicator because its information-retention function is addressed through Factor 13. No additional Indicator is presently justified by this cross-context examination.

Broader-infrastructure scope. Monitoring concerns observable infrastructure behavior and the adequacy of its interpretation in relation to the declared Infrastructure Quality Object. It applies to physical data centers, residential apartment buildings, bridges, water-supply systems, and energy infrastructure. Monitoring methods, frequencies, and Evidence are Context-specific; no particular instrument or monitoring platform is universally prescribed.

Agreed Factor 11 revision: former Indicator 11.7 is removed because retention of stakeholder-related Quality-critical information is a general documentation and traceability function of Factor 13. Its useful historical examples remain relevant as Context-specific Evidence, not as a separate Factor 11 determination.

6.12 Factor 12 — Infrastructure Monitoring

Factor 12 examines whether the behavior, Infrastructure Results, and Infrastructure Outcomes of the declared Infrastructure Quality Object remain sufficiently observable and interpretable.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object sets the scale. Resolution depends on which behaviors, conditions, interactions, and Lifecycle Stages must be observed and interpreted. A broad review may consider the monitoring capability for the whole object; closer examination may trace a particular process, Interface, signal, or condition. The needed detail may vary without changing Factor 12 or its Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 12 has an independent Quality nature: whether infrastructure behavior can be observed and interpreted well enough to support a reliable Quality determination. It also has a latent Harm-related nature. A monitoring gap or adverse observation does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

Infrastructure Monitoring includes context-relevant observation and interpretation of infrastructure condition, performance, and change; the applicable monitoring methods and acceptance criteria are established at the Context and Reference Layer levels.

Its purpose is to support timely detection of Degradation and Aging, deviation, Uncertainty, Emerging Risk, and loss of Function Realization.

Factor 12 does not prescribe monitoring systems, sensors, data platforms, dashboards, reporting structures, or performance-management processes.

It examines whether the information needed to understand actual infrastructure behavior can be obtained and correctly interpreted.

Factor 12 therefore asks a broad question:

Can relevant infrastructure behavior and change be observed and technically interpreted sufficiently to support timely recognition of degradation, deviation, and emerging warning patterns?

This research examines Factor 12 through five proposed Indicators:

Indicator 12.1 — Identification of Monitoring-Relevant Infrastructure Behaviors

Indicator 12.2 — Adequacy of Monitoring to Detect Degradation and Deviation

Indicator 12.3 — Interpretation of Monitoring Information in Context

Indicator 12.4 — Detection of Emerging and Systemic Risk

Indicator 12.5 — Monitoring Relevance Under Change

The five Indicators examine different parts of the ability to observe and understand infrastructure behavior.

Indicator 12.1 — Identification of Monitoring-Relevant Infrastructure Behaviors

Indicator 12.1 asks whether the behaviors, conditions, changes, and interactions that can reveal infrastructure quality have been explicitly identified.

Its determination question is:

What must be observed to reveal degradation, deviation, loss of function, abnormal interaction, or Emerging Risk?

This question is necessary.

Monitoring cannot be justified merely because particular data are easy to obtain or have traditionally been collected.

Available data are not necessarily the data needed to determine the Quality State.

The removal test is:

Remove Indicator 12.1
→ monitoring may continue while important infrastructure behaviors that reveal degradation, deviation, or loss of function remain outside observation.

Indicator 12.2 cannot replace this function.

Indicator 12.1 identifies what behavior must be observable.

Indicator 12.2 asks whether the monitoring is sufficient to detect relevant changes in that behavior.

The distinction is:

What must be observed?

≠

Can it be observed adequately?

Indicator 12.1 therefore preserves a necessary and distinguishable determination function.

Its provisional function is strongly Quality-State Determination.

It establishes what observable behavior is relevant to determining the Infrastructure Quality State.

Cross-context test of 12.1. Relevant behavior may include electrical and cooling conditions in data centers, building system performance and envelope conditions in apartments, structural response and deterioration in bridges, and pressure, flow, and treatment conditions in water-supply systems. The invariant question is whether the behavior that matters has been identified.

Methodological resolution under WQI FTA11. Resolution determines which behaviors, conditions, changes, and interactions must be observed for the declared object and relevant Lifecycle Stages.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether monitoring-relevant behavior has been identified. An omission does not by itself establish Harm; a demonstrable pathway to a possible consequence is required.

Indicator 12.2 — Adequacy of Monitoring to Detect Degradation and Deviation

Indicator 12.2 asks whether monitoring has sufficient scope, sensitivity, coverage, timeliness, continuity, and interpretability to detect important degradation, deviation, or loss of function.

Its determination question is:

Can relevant deterioration or deviation be detected early enough to prevent or limit unacceptable consequences?

This question is necessary.

Monitoring can exist without being adequate.

A sensor can collect data but lack sufficient sensitivity.

Monitoring can cover one part of the Infrastructure Quality Object while an important condition develops elsewhere.

Information can also arrive only after failure has occurred.

The removal test is:

Remove Indicator 12.2
→ Monitoring-Relevant Infrastructure Behaviors may be identified while the ability to detect important changes in those behaviors remains insufficiently determined.

This Indicator is particularly important to the provisional Quality-State Determination function.

A physical condition may exist.

But if the available monitoring cannot detect it with sufficient coverage, sensitivity, continuity, or timeliness, the actual Quality State may remain unknown.

Therefore:

existence of a condition
≠ ability to determine that condition.

Indicator 12.2 is primarily a Quality-State Determination Indicator.

It may also support Quality-State Influence because sufficiently timely detection can make intervention possible before unacceptable consequences occur.

The Indicator itself, however, does not prescribe intervention or real-time control.

Cross-context test of 12.2. Monitoring adequacy may depend on the detectability of cooling failure, building-system deterioration, bridge damage, or water-quality deviation. The Indicator asks whether meaningful changes can be detected, not whether a particular technology has been installed.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines whether monitoring has adequate scope, sensitivity, coverage, timeliness, continuity, and interpretability for the changes that matter.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether monitoring can detect relevant degradation or deviation. A detection gap alone does not establish Harm; any Harm-related conclusion requires a demonstrable pathway in context.

Indicator 12.3 — Interpretation of Monitoring Information in Context

Indicator 12.3 asks whether monitoring information is interpreted in relation to the conditions under which it was obtained.

Its determination question is:

Does the observed information correctly represent the infrastructure condition when operating Context, trends, interactions, and known Uncertainty are considered?

This question is necessary.

Data do not interpret themselves.

A value that appears normal in isolation may be abnormal when viewed as part of a trend.

A deviation may appear insignificant without understanding the operating condition.

Several individually limited signals may become important when considered together.

The removal test is:

Remove Indicator 12.3
→ monitoring information may be available while its meaning is incorrectly interpreted, normalized, or separated from the Context needed to understand it.

Indicator 12.2 cannot replace this function.

Adequate detection does not guarantee correct interpretation.

The distinction is:

Condition detected
≠ condition correctly understood.

Indicator 12.3 therefore preserves a necessary and distinguishable determination function.

Its provisional function is strongly Quality-State Determination.

It addresses the reliability of the step between observation and understanding.

Cross-context test of 12.3. A temperature, vibration, pressure, or quality measurement can have different meanings depending on operating state, location, weather, loading, and measurement limitations. Interpretation must account for that Context.

Methodological resolution under WQI FTA11. Resolution determines what contextual information is needed to interpret observations, including operating conditions, uncertainty, instruments, methods, and relevant changes.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether monitoring information is interpreted in the context in which it was obtained. Misinterpretation does not itself establish Harm; demonstrate a pathway to a possible consequence.

Indicator 12.4 — Detection of Emerging and Systemic Risk

Indicator 12.4 asks whether patterns of observed infrastructure behavior can reveal Emerging or Systemic Risk.

Its determination question is:

Can weak, distributed, interacting, or developing signals be recognized before they become a major failure or unacceptable Infrastructure Outcome?

This question is necessary.

Not all important Risks appear as one clear alarm or one large deviation.

Risk may develop through small changes.

Several signals may interact.

A pattern may become significant only over time.

The removal test is:

Remove Indicator 12.4
→ individual monitored conditions may be evaluated while developing or Systemic Risk remains invisible because no single observation appears decisive.

Indicator 12.4 is related to Factor 5 Indicator 5.5 — Systemic and Cumulative Risk Consideration.

The relationship is close but the questions are different.

Indicator 5.5 asks whether systemic and cumulative Risk is considered.

Indicator 12.4 asks whether such developing Risk can actually become identifiable through observed patterns of infrastructure behavior.

The distinction can be expressed as:

Factor 5
→ Is systemic or cumulative Risk part of the Risk determination?

Factor 12
→ Can infrastructure behavior provide sufficient signals to reveal that Risk as it develops?

Indicator 12.4 therefore preserves a distinct Quality-State Determination function.

It may also support Quality-State Influence because earlier recognition increases the possibility of timely intervention.

Cross-context test of 12.4. Trends across multiple data-center subsystems, building components, bridge elements, or water-network locations may reveal developing Risk not evident from isolated measurements. This remains distinct from Factor 5, which determines hazards, vulnerabilities, Risk, and Safety.

Methodological resolution under WQI FTA11. The needed detail depends on the time span, frequency, and pattern needed to recognize emerging or systemic behavior relevant to the declared object.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether emerging and systemic patterns can be recognized. A warning pattern does not itself establish Harm; the pathway to a possible consequence must be demonstrated.

Indicator 12.5 — Monitoring Relevance Under Change

Indicator 12.5 asks whether monitoring remains relevant when infrastructure configuration, operating conditions, Interfaces, environment, throughput, or use changes.

Its determination question is:

Does the existing monitoring still observe the behaviors that matter after the Infrastructure Quality Object or its Context changes?

This question is necessary.

Monitoring that was adequate for one configuration may become inadequate after modification.

A measurement location may remain unchanged while the behavior that matters has moved elsewhere.

Earlier assumptions about operating ranges or failure mechanisms may no longer apply.

The removal test is:

Remove Indicator 12.5
→ monitoring may continue unchanged even though it no longer reflects the actual infrastructure behavior or Risk profile.

Indicator 12.5 is part of the recurring change-related pattern across the Factors.

Its purpose, however, is specific.

It asks whether the ability to observe and understand infrastructure behavior remains valid under changed conditions.

Indicator 12.5 primarily performs a Quality-State Determination function.

It protects the continued validity of the observation path.

Cross-context test of 12.5. Changed computing loads, building occupancy, bridge traffic, or water-demand patterns can make formerly adequate monitoring less relevant. This Indicator examines whether monitoring remains fit for the changed Infrastructure Quality Object and Applicable Basis.

Methodological resolution under WQI FTA11. Resolution determines how closely changed configurations, operating conditions, Interfaces, environment, throughput, and use are checked for effects on monitoring relevance.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether monitoring remains relevant under change. A stale monitoring approach does not by itself establish Harm; any such conclusion requires a demonstrable pathway in context.

Relationship Among the Five Indicators

Removal test for former proposed Indicator 12.7. Historical monitoring data, assumptions, blind spots, and interpretive knowledge remain relevant Quality-critical information. However, their retention and traceability are addressed through Factor 13 — Documentation and Traceability. A monitoring-specific subject does not alone establish a separate invariant determination function. The agreed revision removes former proposed Indicator 12.7 while preserving relevant monitoring considerations through Factors 12 and 13.

The five Indicators form a connected monitoring determination path.

They ask:

What infrastructure behavior must be observed?

→ Indicator 12.1.

Can relevant degradation or deviation be detected adequately and in time?

→ Indicator 12.2.

Can the observed information be correctly interpreted in Context?

→ Indicator 12.3.

Can developing and Systemic Risk be recognized from patterns over time?

→ Indicator 12.4.

Does the monitoring remain relevant when conditions change?

→ Indicator 12.5.

The five Indicators preserve distinct monitoring determination questions.

An Infrastructure Quality Object can:

monitor the wrong behavior;

monitor the right behavior with insufficient sensitivity or coverage;

detect a condition but interpret it incorrectly;

correctly interpret individual signals while missing an emerging pattern;

retain an earlier monitoring approach after the Infrastructure Quality Object has changed;

Relationship to the Provisional State / Determination / Influence Functions

Factor 12 provides the strongest evidence so far for the provisional Quality-State Determination function.

The Factor directly examines whether the actual condition and behavior of the Infrastructure Quality Object can be observed and correctly understood.

A useful distinction emerges:

Quality State
→ the actual condition of the Infrastructure Quality Object.

Quality-State Determination
→ the capability to observe, detect, interpret, and support a justified conclusion about that condition.

Factor 12 shows why these cannot be assumed to be the same.

An unacceptable condition may physically exist while remaining undetected.

A condition may be detected but misunderstood.

Monitoring may be technically functional but directed at the wrong behavior.

Data may be accurate while their interpretation is wrong.

A monitoring system may also have worked correctly in the past but become irrelevant after change.

Factor 12 therefore demonstrates that the quality of the determination path can materially affect the reliability of the Infrastructure Quality State conclusion.

Quality-State Influence is also present, but less directly.

Indicators 12.2 and 12.4 require detection sufficiently early to support prevention or limitation of unacceptable consequences.

However:

timely detection
≠ timely intervention.

The present Factor establishes observability and interpretability.

It does not establish who has Authority to act, whether the information reaches that person in time, or whether intervention capability exists.

Those questions should remain separate.

They may become important in the later horizontal analysis.

Relationship to Other Quality Factors

The Factor 12 review removed former proposed Indicator 12.6 because Indicator 12.3 covers technical interpretation of monitoring information. Assessment of whether Intended Functions and Intended Results are achieved belongs to the applicable object-level determination, including Factor 3. The review also removed former proposed Indicator 12.7 because Factor 13 covers continuity, retention, and traceability of monitoring information. Indicator 12.4 remains focused on recognizing emerging patterns and warning signals from observations; Factor 5 determines the resulting Risk. Indicator 12.2 remains focused on the capability and adequacy of monitoring to detect relevant degradation or deviation. These are distinct functions, much like obtaining diagnostic images, interpreting them, and making a later professional determination.

Factor 12 has strong relationships with many other Factors because monitoring can provide Evidence used to determine them.

For example:

Factor 4 may depend on monitoring to reveal degradation affecting Structural and Functional Integrity.

Factor 5 may depend on monitoring to reveal developing Risk.

Factor 6 may depend on monitoring to reveal Environmental Interactions or effects.

Factor 7 may depend on monitoring to reveal changing Operational Reliability.

Factor 11 may provide external observations that supplement internally monitored behavior.

But Factor 12 is not simply an Evidence provider for the other Factors.

It asks a separate question:

Is the observation and interpretation capability itself sufficient to support reliable determination of infrastructure behavior?

This is why Factor 12 remains necessary as an invariant Factor.

Broader-infrastructure interim finding. Indicators 12.1–12.5 remain distinguishable across the additional infrastructure types examined. Former proposed Indicators 12.6 and 12.7 have been removed: interpretation is addressed by Indicator 12.3, assessment of Intended Functions and Results belongs to the applicable object-level determination, and monitoring-information retention is addressed through Factor 13. No additional Indicator is proposed by this cross-context examination.

Interim Finding for Factor 12

The five retained Indicators preserve distinct determination questions: what behavior must be observed, whether relevant change can be detected, whether monitoring information is interpreted in context, whether emerging patterns can be recognized, and whether monitoring remains relevant after change.

Removal of any one would weaken a different part of the Quality-State determination path.

No additional Factor 12 Indicator is justified by this analysis at this stage.

However, Factor 12 produces an important provisional finding for the later horizontal analysis.

The present Indicators establish:

observation;

detection;

interpretation;

recognition of developing patterns;

continued relevance under change;

The connection to Intended Functions and Results is addressed through the applicable object-level determination; retention and traceability of monitoring knowledge are addressed through Factor 13.

They do not by themselves establish the complete path from detection of a Critical Infrastructure Condition to effective intervention.

Repeated Context Guide Evidence should therefore test the relationships among:

observation;

determination;

communication of the determined condition;

decision time;

Authority to act;

and

actual capability to preserve, restore, or move the Infrastructure Quality Object toward an acceptable Quality State.

This should remain a provisional research question.

It should not be converted into an additional Indicator unless repeated cross-Context Evidence demonstrates that an invariant determination question is missing.

6.13 Factor 13 — Documentation and Traceability

Factor 13 examines whether quality-relevant knowledge and Evidence remain available, connected, traceable, and usable across the Infrastructure Lifecycle.

Its scope includes decisions, Assumptions, requirements, findings, determinations, claims, changes, Infrastructure Configuration, Decision Rationale, Evidence, Uncertainty, and the basis of the current Infrastructure Quality State.

Factor 13 does not prescribe document-control systems, record-management systems, data platforms, or administrative documentation practices.

It also preserves an important limit:

Documentation
≠ Evidence of actual Infrastructure Quality.

Factor 13 therefore asks a broad question:

Can the basis of the current Infrastructure Quality State be understood and traced through the Lifecycle, including the decisions, Assumptions, Evidence, changes, and limitations that shaped it?

Broader-infrastructure application. For physical data centers, relevant information includes facility configuration, electrical and cooling dependencies, commissioning, modifications, and operating assumptions. For residential apartment buildings, it includes design and occupancy bases, life-safety arrangements, renovations, and inspection findings. For bridges, it includes design loads, inspections, repairs, and changes in use. For water-supply systems, it includes source and treatment assumptions, system configuration, testing, and changes. These examples do not prescribe one document-management system or establish universal Context-specific Quality Outcome Criteria.

Methodological resolution under WQI FTA11. The declared Infrastructure Quality Object sets the scale. Resolution depends on what information, relationships, or Lifecycle Stages must be examined. A broad review may consider information supporting the whole object; closer examination may trace a decision, requirement, assessment, change, or record. The needed detail may vary without changing Factor 13 or its Indicators.

Dual-Nature Postulate under WQI FTA14. Factor 13 has an independent Quality nature: whether quality-relevant information and Evidence remain available, traceable, and usable for Quality determination. It also has a latent Harm-related nature. Missing or unusable information does not by itself establish Harm; any Harm-related conclusion requires a demonstrable pathway to a possible consequence in context.

This research examines Factor 13 through the six retained Indicators:

Indicator 13.1 — Documentation of Infrastructure-Relevant Decisions and Assumptions

Indicator 13.2 — Traceability Between Functional Intent, Technical Requirements, and Realized Infrastructure

Indicator 13.3 — Documentation of Uncertainty, Limitations, and Known Vulnerabilities

Indicator 13.4 — Traceability of Assessments, Evaluations, and Conformity Statements

Indicator 13.5 — Documentation of Changes and Their Rationale

Indicator 13.6 — Accessibility and Continuity of Quality-Critical Information

Former proposed Indicator 13.7 was removed by agreement. Its methodological principle remains: Documentation does not by itself demonstrate Infrastructure Quality. This is addressed through the Evidence Quality and Conformity Assessment methodology.

The six Indicators examine different parts of information continuity and traceability.

Indicator 13.1 — Documentation of Infrastructure-Relevant Decisions and Assumptions

Indicator 13.1 asks whether the reasoning and Assumptions behind quality-relevant infrastructure decisions remain available.

Its determination question is:

Can later users understand why an important infrastructure decision was made and which Assumptions supported it?

This question is necessary.

A decision may remain visible while its reasoning is lost.

A Design choice may remain in the realized infrastructure while the Assumptions that justified it are no longer known.

This can become especially important during Repair/Modification, repurposing, or life extension.

The removal test is:

Remove Indicator 13.1
→ the result of an earlier decision may remain visible while its rationale, Assumptions, limitations, and original intent become difficult or impossible to reconstruct.

The other Factor 13 Indicators do not fully replace this function.

Traceability between requirements and realized infrastructure does not necessarily preserve Decision Rationale.

Documentation of changes does not necessarily preserve the original reasoning behind earlier decisions.

Indicator 13.1 is therefore necessary and distinguishable.

Its provisional function is strongly Quality-State Determination.

It preserves part of the information basis needed to understand why the Infrastructure Quality Object has its present condition and configuration.

Cross-context finding for 13.1. Decisions concerning data-center redundancy, building occupancy and egress, bridge load assumptions, or water-treatment configuration may remain visible while their original reasoning is lost. The determination concerns preservation of decision rationale, not whether the decision itself was correct.

Methodological resolution under WQI FTA11. Resolution determines which decisions and Assumptions materially affect the declared object, its intended use, and the information needed to understand them.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether important decisions and their Assumptions remain available. A missing rationale does not itself establish Harm; a demonstrable pathway to a possible consequence is required.

Indicator 13.2 — Traceability Between Functional Intent, Technical Requirements, and Realized Infrastructure

Indicator 13.2 asks whether the relationship among Functional Intent, Technical Requirements, and the realized Infrastructure Quality Object can be followed through the Lifecycle.

Its determination question is:

Can the realized Infrastructure Quality Object be traced back to what it was intended to do and to the Technical Requirements through which that intent was to be realized?

This question is necessary.

An Infrastructure Quality Object can physically exist and operate while its relationship to the original or current Functional Intent becomes unclear.

The removal test is:

Remove Indicator 13.2
→ Functional Specifications, Technical Specifications, and realized infrastructure may each exist, but their supported relationship may become difficult to follow.

Indicator 13.2 is related to Indicators 1.5 and 2.6.

The overlap is important but not automatically redundant.

Indicator 1.5 concerns traceability of Functional Requirements across the Lifecycle.

Indicator 2.6 concerns traceability between Technical Specifications and Functional Requirements.

Indicator 13.2 preserves the wider continuity linking Functional Intent, Technical Requirements, and the realized Infrastructure Quality Object.

This appears to be a broader traceability function.

The later horizontal analysis should therefore test whether the narrower Factor-specific traceability Indicators remain necessary in addition to this wider Factor 13 Indicator.

At this stage, the present analysis does not assume redundancy.

Indicator 13.2 primarily performs a Quality-State Determination function.

It supports understanding of whether the realized object still corresponds to the intended and technically defined object.

Cross-context finding for 13.2. Traceability must connect the declared functional basis and technical requirements with the realized data-center facility, apartment building, bridge, or water-supply system. This whole-object continuity differs from narrower requirements traceability within Factors 1 and 2.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines how closely Functional Intent, Technical Requirements, and realized infrastructure are linked and traced through relevant Lifecycle Stages.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether the relationship among intent, requirements, and the realized object can be followed. A traceability gap alone does not establish Harm; demonstrate a pathway to a possible consequence in context.

Indicator 13.3 — Documentation of Uncertainty, Limitations, and Known Vulnerabilities

Indicator 13.3 asks whether known limits in understanding or capability remain explicitly visible.

Its determination question is:

What important Uncertainty, limitation, or known vulnerability affects the current understanding of Infrastructure Quality, and is that information retained?

This question is necessary.

An Infrastructure Quality State can appear more certain than the Evidence supports if known limitations are lost or omitted.

A condition may be technically acceptable only under particular Assumptions.

A vulnerability may remain unresolved.

The removal test is:

Remove Indicator 13.3
→ the retained documentation may present a complete-looking picture while important limitations, vulnerabilities, or Uncertainty become invisible.

Indicator 13.1 cannot replace this function.

A decision and its rationale may be documented while later uncertainty or known vulnerability remains inadequately recorded.

Indicator 13.3 therefore preserves a necessary and distinguishable determination function.

Its provisional function is strongly Quality-State Determination.

It protects the determination from false certainty.

Cross-context finding for 13.3. Known limitations such as incomplete bridge inspection coverage, unverified building conditions, data-center cooling assumptions, or uncertain water-source conditions must remain visible to later users of the Evidence. This records the limits of what can be determined; it does not itself determine associated Risk.

Methodological resolution under WQI FTA11. Resolution determines which uncertainties, limitations, and known vulnerabilities could affect the declared object or a Quality determination, and how specifically they must be recorded.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether known limitations and vulnerabilities remain visible. Missing information does not by itself establish Harm; any such conclusion requires a demonstrable pathway.

Indicator 13.4 — Traceability of Assessments, Evaluations, and Conformity Statements

Indicator 13.4 asks whether assessments, evaluations, and Conformity Statements remain traceable to their scope, basis, Assumptions, and Lifecycle Stage.

Its determination question is:

Can a later user determine what an earlier assessment or statement actually demonstrated and within what limits?

This question is necessary.

An assessment result can become misleading when separated from its original scope or assumptions.

The removal test is:

Remove Indicator 13.4
→ an earlier assessment or Conformity Statement may continue to be cited even though its basis, limits, or Lifecycle applicability can no longer be reconstructed.

Indicator 13.4 is related to Indicator 3.7; former Indicator 10.7 was deleted because its separate traceability determination was redundant with Factors 3 and 13.

The scopes of the retained Indicators must nevertheless remain explicit.

Indicator 3.7 concerns traceability of Conformity Statements within Factor 3.

Traceability of Compliance Statements is addressed by the relevant Factor 3 and Factor 13 determinations, without a separate Factor 10 Indicator.

Indicator 13.4 preserves broader traceability of assessments, evaluations, and Conformity Statements across the infrastructure quality determination.

This strengthens the horizontal question already identified:

Factor-specific traceability is retained only where its distinct necessity is demonstrated; otherwise the broader Factor 13 traceability function is sufficient.

The removal of former Indicator 10.7 provides a concrete application of this nonredundancy test.

Indicator 13.4 primarily performs a Quality-State Determination function.

Cross-context finding for 13.4. A previous building inspection, bridge evaluation, data-center commissioning assessment, or water-system compliance statement must remain connected to its original basis, scope, Evidence, and Lifecycle Stage. This supports but does not replace object-level Conformity Assessment under Factor 3.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines what scope, basis, assumptions, findings, and Lifecycle Stage must be traceable for relevant assessments and Conformity Statements.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether assessments and statements can be traced to their basis and scope. A traceability deficiency alone does not establish Harm; demonstrate a pathway to a possible consequence.

Indicator 13.5 — Documentation of Changes and Their Rationale

Indicator 13.5 asks whether changes affecting Infrastructure Quality remain understandable through their description, rationale, and implications.

Its determination question is:

Can the evolution of the Infrastructure Quality Object be reconstructed sufficiently to understand what changed, why it changed, and what quality-relevant conditions were affected?

This question is necessary.

Infrastructure changes accumulate.

A small change may interact with earlier changes.

An original Assumption may no longer remain valid.

Without retained rationale, later users may understand the final configuration but not how or why it developed.

The removal test is:

Remove Indicator 13.5
→ current configuration may be visible while the sequence and rationale of changes affecting Infrastructure Quality become unclear.

Indicator 13.5 is related to many change-specific Indicators under earlier Factors.

Again, the relationship appears to be one of broader and narrower functions.

Earlier Factors ask whether change preserves:

Functional Intent;

Technical adequacy;

Integrity;

Risk mitigation;

Environmental Protection;

Operational Reliability;

Compliance;

and other Factor-specific conditions.

Indicator 13.5 asks whether the change itself and its rationale remain documented and traceable.

The Indicator does not establish that the change was acceptable.

It preserves the information needed to understand and evaluate it.

Its provisional function is primarily Quality-State Determination.

Cross-context finding for 13.5. Changes in building use, bridge repair or loading, data-center expansion, or water-treatment processes require a reconstructable record of what changed and why. The adequacy of the change remains determined under the applicable substantive Factors.

Methodological resolution under WQI FTA11. Resolution determines which changes and rationales materially affect the declared object, its requirements, configuration, or conclusions across the Lifecycle.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether changes and their reasons can be understood and traced. An incomplete change record does not itself establish Harm; any conclusion requires a demonstrable pathway in context.

Indicator 13.6 — Accessibility and Continuity of Quality-Critical Information

Indicator 13.6 asks whether Quality-Critical Information remains accessible and usable when needed.

Its determination question is:

Can the relevant person retrieve and understand the information needed for an infrastructure decision or Quality State determination at the time it is required?

This question is necessary.

Information can exist but still be unavailable.

It can be retained but difficult to retrieve.

It can be retrievable but no longer understandable because Context or attribution has been lost.

The removal test is:

Remove Indicator 13.6
→ quality-relevant information may formally exist while being functionally unavailable or unusable when an important decision must be made.

This Indicator therefore differs from simple information retention.

The distinction is:

Information exists
≠ information is accessible.

Information is accessible
≠ information is understandable and usable.

Indicator 13.6 is strongly a Quality-State Determination Indicator.

It concerns whether the information path required for responsible determination remains usable.

It may also have a Quality-State Influence function.

If required information cannot reach the relevant decision point when needed, the ability to act on the actual condition may also be weakened.

Cross-context finding for 13.6. Records must remain accessible and understandable after personnel changes, ownership changes, contractor turnover, or system replacement. This includes relevant interaction, competence, stakeholder, and monitoring knowledge whose separate retention Indicators were deleted from earlier Factors.

Methodological resolution under WQI FTA11. The declared object sets the scale; resolution determines which information must remain accessible, understandable, and usable by relevant people at the necessary time.

Dual-Nature Postulate under WQI FTA14. Its independent Quality question is whether Quality-Critical Information remains accessible and usable when needed. An access gap alone does not establish Harm; demonstrate a pathway to a possible consequence in context.

Removal analysis of former proposed Indicator 13.7 — Prevention of Documentation Substitution for Quality

The accumulated review examined a separate Indicator intended to prevent complete Documentation from being mistaken for proof of actual Infrastructure Quality. That proposal was removed by agreement and is not part of the six retained Indicators. The analysis below is preserved because it explains the concern and why its methodological safeguard remains important.

Former proposed Indicator 13.7 — Prevention of Documentation Substitution for Quality

The former proposal asked whether Documentation is being incorrectly treated as proof of actual infrastructure behavior or performance.

Its determination question is:

Is the existence or completeness of Documentation being mistaken for Evidence that the Infrastructure Quality Object is actually in an acceptable Quality State?

This question is necessary.

A fully documented system can still perform poorly.

A complete record can describe an unacceptable condition.

A procedure can exist without being effective.

A conformity record can be outdated.

The removal concern tested was:

Remove the proposed Indicator 13.7 → the Documentation and Traceability Factor itself can create a false positive if documentary completeness is interpreted as proof of Infrastructure Quality.

The proposal was unusual but addressed an important concern.

It was intended to limit the meaning of the Factor in which it appeared.

The distinction is:

Documentation → supports understanding and traceability.

Evidence → supports a finding.

Infrastructure Quality State → requires interpretation of Evidence-Supported Findings across the applicable Factors.

Documentation alone cannot perform all three functions.

The proposal was considered to perform a Quality-State Determination function.

Its purpose was to protect the validity of the overall determination from a category error.

Methodological finding and agreed disposition. The distinction between Documentation, Evidence, and demonstrated Infrastructure Quality is essential. Preventing documentary completeness from being mistaken for demonstrated Quality is a cross-cutting methodological safeguard, rather than a separate invariant Indicator. Former proposed Indicator 13.7 was removed by agreement. The safeguard remains explicit in this Factor and is addressed through WQI_EQC1 and the applicable Conformity Assessment methodology.

Relationship Among the six Indicators

The six Indicators form a connected information-continuity determination.

They ask:

Can important decisions and Assumptions be understood?

→ Indicator 13.1.

Can Functional Intent, Technical Requirements, and realized infrastructure be traced to one another?

→ Indicator 13.2.

Are Uncertainty, limitations, and known vulnerabilities retained and visible?

→ Indicator 13.3.

Can assessments, evaluations, and Conformity Statements be traced to their actual basis and scope?

→ Indicator 13.4.

Can infrastructure changes and their rationale be reconstructed?

→ Indicator 13.5.

Is Quality-Critical Information accessible and usable when needed?

→ Indicator 13.6.

Is Documentation being kept in its proper role rather than treated as proof of Infrastructure Quality?

The Indicators therefore preserve different questions.

An Infrastructure Quality Object can:

retain a decision but lose its rationale;

retain requirements but lose traceability to the realized object;

retain technical records while known Uncertainty disappears from view;

retain an assessment result while losing its original scope;

retain a final configuration while losing the history of how it changed;

retain information that cannot be found or understood when needed;

or

possess complete Documentation that is incorrectly interpreted as proof of acceptable Quality.

These possibilities support separate retention of the six Indicators.

Relationship Between Factor 13 and the Factor-Specific Information-Retention Indicators

Factor 13 creates one of the most important horizontal questions identified so far.

Factors 4 through 12 contain several Indicators requiring retention of information specific to their subject matter.

Factor 13 then establishes a broad, cross-Lifecycle Documentation and Traceability function.

There are at least two possible interpretations.

The first is necessary layered visibility:

Factor-specific Indicators
→ preserve information necessary to determine a particular Quality Factor.

Factor 13
→ preserves the wider continuity, accessibility, traceability, and usability of quality-relevant information across the complete Infrastructure Quality Object.

The second possibility is unnecessary duplication:

some Factor-specific information-retention Indicators may substantially repeat a function already adequately represented by Factor 13.

The present Factor-by-Factor analysis is not sufficient to decide between these possibilities.

This question should therefore be carried into Section 7 for horizontal comparison.

The removal test should later be applied across Factors:

If the Factor-specific retention Indicator were removed, would Factor 13 necessarily preserve the same determination question with sufficient visibility?

If yes, possible redundancy exists.

If no, the narrower Indicator may remain necessary.

Relationship to the Provisional State / Determination / Influence Functions

Factor 13 is overwhelmingly a Quality-State Determination Factor.

It does not primarily determine the physical or operational state of the Infrastructure Quality Object.

It determines whether the knowledge and Evidence needed to understand that state remain available, connected, traceable, interpretable, and usable.

This supports the provisional Quality-State Determination classification strongly.

Factor 13 also reveals an important distinction:

Information retention
≠ information accessibility.

Information accessibility
≠ information usability.

Information usability
≠ Evidence Sufficiency.

Evidence Sufficiency
≠ positive Infrastructure Quality State.

These distinctions are essential to the reliability of Quality-State determination.

A limited Quality-State Influence function may also exist through Indicator 13.6.

Information that reaches the right decision point in usable form can support timely action.

But Factor 13 does not itself establish intervention capability or decision Authority.

Interim Finding for Factor 13

The analysis supports retaining the six listed Factor 13 Indicators at this stage.

Each preserves a necessary determination question concerning decisions and Assumptions, traceability to realized infrastructure, Uncertainty and limitations, assessment traceability, change history, information accessibility, or correct interpretation of Documentation.

Removal of any one would weaken a different part of the information basis supporting Infrastructure Quality State Determination.

However, Factor 13 also creates the strongest non-redundancy question identified in Section 6 so far.

Several earlier Factors contain subject-specific retention or traceability Indicators that appear closely related to Factor 13.

The present analysis should not assume that all such repetition is permanently necessary.

Section 7 should compare these Indicators horizontally and apply the removal and distinguishability tests across Factor boundaries.

No additional Factor 13 Indicator is justified by this analysis at this stage.

The six retained Indicators provide broad coverage of information continuity, traceability, accessibility, and limits of Documentation.

Whether repeated Context Guide Evidence reveals another invariant information function remains an open question.

6.14 Factor 14 — Infrastructure Adaptability

Factor 14 concerns the capability of an Infrastructure Quality Object to accommodate changes required for continued realization of its Intended Functions and Intended Results. Such changes may arise as demand, operating conditions, technology, surrounding conditions, or applicable requirements change during the object's life cycle.

Adaptability does not mean change for its own sake. It does not require continuous redesign, adoption of every new technology, or maximum flexibility. Unnecessary change may introduce new Failure Modes, Interfaces, configuration uncertainty, disruption, training needs, or other unwanted effects.

Factor 14 asks whether the Infrastructure Quality Object has the capability to accommodate a change when that change is required for continued realization of its Intended Functions and Intended Results. Whether a particular change is required, and what outcome is acceptable, depends on the applicable Context and Quality Outcome Criteria.

This Factor concerns the Infrastructure Quality Object and its Function Realization. It is not a general measure of the capability of an owner, operator, designer, or other organization. Work and Results supplied by those parties are considered where they contribute to the declared object's required capability, within its determined boundaries and interfaces.

A change may be needed because demand has increased, a component has become obsolete, environmental or surrounding conditions have changed, an interface has changed, or new evidence shows that an earlier assumption is no longer adequate. The need and its consequences may become visible at different life-cycle stages.

The Quality Object may change form during its life cycle. The capability may first be considered in a concept or design, then in a constructed and operating system, and later during modification, reconstruction, decommissioning, or recultivation. The relevant Work and Results remain part of the determination when they are essential to realizing the Intended Functions and Intended Results.

Factor 14 does not prescribe how a change must be designed, approved, assessed, or implemented. It asks whether the required capability exists and can be established from suitable information and Evidence. Context-specific requirements and QOCs supply the detail for a particular Infrastructure Quality Object.

Factor 14 therefore asks a broad question:

Can the Infrastructure Quality Object accommodate changes required for continued realization of its Intended Functions and Intended Results?

Why Factor 14 remains distinct

Factors 1–13 determine important quality-related dimensions, such as Functional Requirements, Technical Requirements, Integrity, Harm, Risk and Safety, Environmental Protection, Reliability, Compliance, Monitoring, and Documentation and Traceability. Factor 14 asks whether the Infrastructure Quality Object can accommodate changes required to continue realizing its Intended Functions and Intended Results as relevant conditions change.

An indicator under another Factor may determine whether a particular quality condition is preserved when change occurs. Factor 14 asks whether the Infrastructure Quality Object has the capability to accommodate a required change. These questions are related, but their meanings differ.

For example, a bridge may meet its current load requirements while lacking a feasible way to accommodate a required increase in load. A data center may currently provide its required computing capacity while lacking the capability to accommodate a required increase in demand. A residential building may meet its present occupancy requirements while lacking the capability to accommodate a required change in accessibility or building services. A water system may meet current demand while lacking the capability to accommodate a required change in source, treatment, or distribution.

The removal test is:

Remove Factor 14

→ the ability to accommodate a required change may not remain visible as a distinct question, even where the existing condition is acceptable but the Infrastructure Quality Object cannot continue to realize its Intended Functions and Intended Results under changed conditions.

This is a Factor-level question. It does not imply that every change requires an additional Indicator under each of Factors 1–13. Each Factor remains responsible for its own quality-related determination.

Indicator 14.1 — Capability of Infrastructure to Accommodate Required Changes

Indicator 14.1 asks whether the Infrastructure Quality Object has the capability to accommodate changes required for continued realization of its Intended Functions and Intended Results.

Its determination question is:

Can this Infrastructure Quality Object accommodate the changes required to continue realizing its Intended Functions and Intended Results under the applicable Context?

This question is necessary because a change in demand, conditions, technology, Interfaces, or applicable requirements can make an earlier capability insufficient. The existing object may remain physically intact and may continue to function for a time, while lacking the capability needed to maintain required Function Realization as conditions change.

The Indicator does not require the object to accommodate every possible change. It concerns changes shown to be required in the applicable Context, at the methodological resolution needed for the intended Quality determination.

Nor does it require an object to adopt every new technology or organizational practice. Newness alone does not establish better Quality. A change is considered when required or justified by the applicable requirements, conditions, and QOCs.

The removal test is:

Remove Indicator 14.1

→ an Infrastructure Quality determination may establish current conditions but leave unresolved whether the object can accommodate a change required for continued realization of its Intended Functions and Intended Results.

No other Indicator under Factor 14 is retained. The earlier proposed functions concerning preservation of safety and integrity, functional compatibility, innovation uncertainty, reversibility or recovery, learning from outcomes, and retention of adaptation knowledge were reviewed as possible separate Indicators. Their underlying concerns remain important where applicable, but they do not establish additional invariant Indicators under Factor 14.

The earlier seven-proposal analysis

The accumulated research explored seven functions proposed for separate Indicators. That analysis is retained here as part of the justification record. The current result is one Indicator. The proposal analysis shows why the remaining concerns do not require separate invariant Indicators within Factor 14.

Earlier proposed function — identification of adaptability constraints and opportunities

The earlier analysis asked whether physical, technical, operational, interface, capacity, or dependency conditions that enable or constrain adaptation were identified. It noted that physical configuration may prevent modification, an Interface may limit compatibility, spare capacity may be insufficient, or a dependency may cause a seemingly local change to affect a wider system.

Those examples remain relevant to determining whether the Infrastructure Quality Object can accommodate a required change. They are considered within Indicator 14.1 when they affect that capability. The earlier proposal described a necessary part of the determination, but did not establish a need for an additional Indicator separate from the capability question.

The context examples remain useful: capacity and cooling limits in data centers; structural and occupancy constraints in housing; load and geometry constraints for bridges; and treatment or network constraints in water systems. Their detail depends on the declared Quality Object, its boundaries and interfaces, the life-cycle stage, and the applicable QOCs.

Earlier proposed function — preservation of safety and integrity during change

The earlier analysis observed that a change may improve one aspect of performance while weakening another. Innovation may improve efficiency while reducing a safety margin, and a local modification may create an integrity or environmental problem elsewhere. It asked whether adaptation preserves critical safety and integrity conditions.

These concerns remain necessary to assess when relevant. The independent determinations of Integrity, Harm, Risk and Safety, Environmental Protection, and other applicable Factors continue to address their respective conditions. The applicable QOCs determine what must be preserved in a particular Context.

This function does not establish a second Factor 14 Indicator. Indicator 14.1 asks whether required change can be accommodated. The other applicable Factors determine whether the resulting conditions meet their requirements. A change may be feasible but unacceptable under an applicable Factor; conversely, acceptable current safety and integrity do not by themselves show that the required change can be accommodated.

The earlier cross-context examples remain relevant: changes can introduce new Interfaces, loading, fire or electrical conditions, or exposure pathways. The object must be assessed at a resolution sufficient to identify those effects, while preserving the distinct determination under each applicable Factor.

Earlier proposed function — compatibility with functional intent, boundaries, and interfaces

The earlier analysis asked whether an adaptation remained consistent with Functional Intent and the declared Boundaries and Interfaces. It recognized that a modification may technically work while changing the meaning, extent, or relationships of the declared Infrastructure Quality Object.

The Functional Requirements and object-boundary methodology address the intended function and the relationships needed to realize it. In the Factor 14 determination, those requirements provide the basis for identifying which changes are required to continue Function Realization. Applicable QOCs establish the context-specific acceptance criteria.

This concern therefore remains part of the determination of required capability and the relevant Functional Requirements. It does not need a separate invariant Indicator under Factor 14. Safety may remain acceptable while functional alignment is lost, and functional alignment may remain while a safety condition is unacceptable; the applicable Factors retain these separate determinations.

Examples include a building conversion, a data-center capacity upgrade, bridge rehabilitation, or a water-treatment change. Each must be assessed against the declared Intended Functions, Boundaries, and Interfaces, without treating a change in one part as proof of the quality of the whole object.

Earlier proposed function — treatment of uncertainty introduced by innovation

The earlier analysis observed that new technologies, materials, configurations, operating modes, or Interfaces may have uncertain behavior, interactions, degradation, Failure Modes, or performance. A promising solution may have limits that remain poorly understood.

Uncertainty remains relevant to the Quality determination. Evidence Quality is governed by WQI_EQC1, and applicable Factors and QOCs establish what must be known and assessed in the Context. A novel cooling system, building material, bridge-strengthening method, or water-treatment technology may need closer examination because its behavior is not yet well established.

This does not establish a separate invariant Indicator under Factor 14. Uncertainty is considered within the relevant Quality determination and through Evidence Quality. Indicator 14.1 remains focused on the capability to accommodate changes that are required; it does not itself certify an innovation as suitable or establish that uncertainty has been resolved.

Earlier proposed function — reversibility and recoverability

The earlier analysis asked whether an adaptation could be reversed, or whether acceptable Function Realization could be recovered if unintended consequences occurred. It recognized that not every effect of

innovation can be predicted in advance and that permanent structural work may not be physically reversible.

Where reversal or recovery is required or practicable, the applicable requirements and QOCs determine what capability is expected. Relevant integrity, reliability, safety, and other Factor determinations remain in force. Recovery may depend on contingency arrangements, staged commissioning, or alternate operating configurations.

The earlier proposal also recognized an important limit: not every infrastructure change can be physically reversed. The relevant requirement may concern recovery rather than exact reversal. This is a Context-specific consideration, not a universal standalone Indicator. It may inform whether the required change can be accommodated, but does not create an additional invariant Indicator.

Earlier proposed function — learning from actual results and outcomes

The earlier analysis asked whether actual results and outcomes after adaptation or innovation are evaluated and used to inform later decisions. It observed that actual behavior may confirm, weaken, or contradict assumptions made before implementation.

Observed conditions and results are addressed through applicable monitoring, Evidence, Conformity Assessment, and other Factor determinations. Infrastructure Monitoring addresses observation and interpretation of relevant behavior. Evidence Quality governs the support for findings. Learning from actual results may be important in a Context, but it is not a separate invariant Indicator under Factor 14.

A data-center retrofit, building renovation, bridge strengthening, or water-system modification may produce effects that were not anticipated in design. Those observations can inform later decisions. They do not by themselves establish that all infrastructure contexts require a separate adaptation-learning Indicator.

Earlier proposed function — retention of adaptation knowledge

The earlier analysis asked whether information about adaptation decisions, assumptions, results, outcomes, uncertainty, and limitations remains available to later users. It noted that a successful local trial might be repeated in another Context without its original limitations, or an unsuccessful approach might be repeated because its Evidence was lost.

These are valid information-continuity concerns. Factor 13, Documentation and Traceability, determines the availability, continuity, and traceability of quality-relevant information. Evidence Quality and applicable Factor determinations govern the interpretation and use of retained information.

The earlier proposal therefore does not establish a separate Factor 14 Indicator. Adaptation-specific information remains subject to the broader Documentation and Traceability determination. The fact that information concerns adaptation does not make its retention a distinct invariant function.

Cross-context application of the single Indicator

The same Indicator applies across relevant infrastructure types, although its application and evidence differ by Context.

For a data center, the required change may concern computing capacity, cooling, electrical supply, or an Interface with supporting systems. For a residential apartment building, it may concern occupancy, accessibility, building services, or a required modernization. For a bridge, it may concern load, traffic,

rehabilitation, or a changed surrounding environment. For a water system, it may concern source conditions, treatment, demand, or distribution.

These examples do not prescribe changes or acceptance criteria. They test whether the same invariant question—capability to accommodate required change—remains meaningful across contexts. Applicable requirements and QOCs establish what change is required and what constitutes an adequate capability.

The Quality Object may be examined at different scales. A constituent system or activity may itself be a separately declared Quality Object. Satisfactory Quality of a constituent does not automatically establish satisfactory Quality of the whole infrastructure object. This fractal application applies across Factors and Indicators.

Work by an external designer, contractor, inspector, or authority may contribute to the capability or the determination. Its contribution is considered within the declared object's scope or through identified Interfaces. The outside organization does not thereby become part of the Infrastructure Quality Object.

Methodological resolution under WQI FTA11

At Factor level, scale identifies the Infrastructure Quality Object or constituent being examined. Methodological resolution determines the depth of the determination: which required changes, assumptions, interfaces, conditions, and evidence must be considered to decide whether the object can accommodate those changes.

At Indicator level, the same distinction applies. The declared object sets the scale. Resolution determines which change and capability need enough detail to support a reliable finding. It may be sufficient to assess a broad system capability at one stage; a closer assessment may be needed where a specific component, requirement, or Interface controls the result.

A change in scale may change the object being examined. A change in resolution changes how deeply the same object is examined. Neither alone creates a new Factor or Indicator. Different infrastructure contexts may require different evidence and detail while the invariant meaning of Indicator 14.1 remains the same.

Dual-Nature Postulate under WQI FTA14

Factor 14 has an independent Quality nature: whether the Infrastructure Quality Object can accommodate changes required for continued realization of its Intended Functions and Intended Results. It also has a latent Harm-related nature. A lack of capability may contribute to service loss, unsafe operation, environmental effects, or other consequences in a particular Context, but a Quality deficiency alone does not establish Harm.

At Indicator level, the independent Quality question is whether the required change can be accommodated. Any Harm-related conclusion requires a demonstrable pathway from a specific deficiency to a possible consequence, considered with relevant exposure, conditions, and relationships among Quality, Harm, Risk, and Safety.

The same dual-nature analysis applies at any relevant methodological resolution. A more detailed determination may identify additional pathways or evidence, but it does not convert a deficiency into Harm without contextual support.

Relationship to the provisional horizontal functions

Indicator 14.1 primarily supports Quality-State Determination because the capability to accommodate required change must be established from relevant requirements and Evidence. It may also support Quality-State Influence where an identified capability is used to preserve, restore, or change Function Realization.

These provisional horizontal labels describe research classifications. They are not additional normative layers, and they do not change the meaning of the Factor or Indicator.

Interim finding for Factor 14

The accumulated research supports retaining Factor 14 — Infrastructure Adaptability as a distinct Quality Factor.

It supports one invariant Indicator: Indicator 14.1 — Capability of Infrastructure to Accommodate Required Changes.

The earlier seven functions proposed for separate Indicators have been reviewed for necessity, distinguishability, removal consequences, and nonredundancy. The constraints-and-opportunities analysis is included in the single capability determination. The other concerns remain addressed through applicable Factors, Evidence Quality, Documentation and Traceability, and context-specific QOCs where applicable.

No additional Factor 14 Indicator is supported by the current research. Future cross-context findings may reopen this question if repeated evidence demonstrates a distinct invariant determination need that is not represented by Indicator 14.1 or another applicable Factor.

This finding is consistent with the Factor's broader purpose: to keep visible whether the Infrastructure Quality Object can accommodate changes required for continued Function Realization, without requiring change for its own sake or substituting adaptability for the other quality dimensions.

Indicator-level finding

Indicator 14.1 preserves a distinct question within Factor 14: whether the Infrastructure Quality Object can accommodate changes required to continue realizing its Intended Functions and Intended Results.

Its necessity is not established merely because adaptation is important. It is established because, without this question, an object's current condition may be assessed while its capability to accommodate a required change remains undetermined.

The Indicator remains invariant across infrastructure types. Context-specific requirements, Evidence, scale, methodological resolution, lifecycle stage, boundaries, and Interfaces determine how it is applied and what findings mean.

The Indicator's Quality nature is independent. A possible Harm-related consequence must be demonstrated through a contextual pathway; it must not be inferred from a capability deficiency alone.

7. Horizontal Analysis Across the Fourteen Quality Factors

This analysis uses the current assignments established in Section 6: six Indicators under Factor 13 and one Indicator under Factor 14. Earlier proposals for Indicator 13.7 and separate Factor 14 functions are treated as research history, not as current Indicator assignments.

7.1 Recurring Determination Questions Across Different Factors

Section 6 examined each Indicator within its parent Factor.

The analysis began with each Quality Factor and asked whether each established Indicator preserves a necessary and distinguishable determination question within that Factor.

The present Section changes the direction of analysis.

Instead of asking:

What does each Indicator contribute to its parent Quality Factor?

the horizontal analysis asks:

Do Indicators located under different Quality Factors perform recurring functions in determining, understanding, or influencing the Infrastructure Quality State?

Two Indicators may address different subjects but perform a similar function.

For example:

one Indicator may address change in Functional Specifications;

another may address change in Technical Specifications;

another may address Integrity during change;

another may address Monitoring relevance after change.

Their subjects differ.

But each contains a recurring function:

determining whether an earlier quality basis remains valid after a relevant change.

The same pattern appears with information retention.

Different Factors require retention of different information.

The subjects differ.

But the recurring function is preservation of information needed for later Quality State determination.

The horizontal analysis therefore does not begin by assuming either duplication or independence.

Similarity of function does not establish redundancy.

Different Quality Factors may require the same general determination function to be applied to different quality-relevant conditions.

At the same time, repeated use of substantially the same function across Factors creates a legitimate non-redundancy question.

The purpose of this Section is to identify these recurring functions and test their meaning.

Recurring Function 1 — Identification of What Must Be Determined

Several Indicators first establish what must be made visible before a Quality conclusion can be reached.

Examples include identification of:

Applicable Requirements;

Critical Infrastructure Conditions;

Environmental Interactions;

Infrastructure-Critical Roles;

affected Stakeholders and Communities;

Monitoring-Relevant Infrastructure Behaviors;

Adaptability-Relevant Constraints and Opportunities.

The subject matter differs.

The recurring function is:

identify the quality-relevant condition, relationship, role, effect, or behavior that must enter the determination.

This is a basic Quality-State Determination function.

If the relevant subject is not identified, later Evidence may be complete only with respect to an incomplete determination basis.

The recurring pattern can be expressed as:

relevant condition exists
→ condition is not identified
→ condition is excluded from determination
→ resulting Quality State conclusion may be incomplete.

This function appears necessary across several Factors because the object of determination differs in each case.

The present analysis does not indicate that these Indicators can simply be combined.

Recurring Function 2 — Alignment with Intended Function or Intended Result

Another recurring function concerns continued alignment with what the Infrastructure Quality Object is intended to do.

This appears directly in Factors 1 and 2 and reappears in later Factors.

Examples include:

alignment of Technical Requirements with Functional Requirements;

interpretation of infrastructure behavior in relation to Intended Functions and Intended Results;

compatibility of Adaptation with Functional Intent;

and preservation of Function Realization through Lifecycle change.

The recurring function is:

determine whether the condition being examined remains connected to the Infrastructure Intended Function and Intended Result.

This function is important because a technically successful local condition does not necessarily demonstrate successful Function Realization.

The horizontal pattern can be expressed as:

local condition acceptable
≠ Intended Function necessarily realized.

The recurrence therefore appears to reflect the central role of Intended Function throughout IQI rather than simple duplication.

Recurring Function 3 — Treatment of Change

Change is one of the strongest recurring functions identified in Section 6.

Change-related Indicators appear under multiple Factors.

They examine whether an established quality basis remains valid when:

requirements change;

configuration changes;

operating conditions change;

Interfaces change;

Lifecycle Stage changes;

Context changes;

regulatory or standards requirements change;

Monitoring needs change;

or

Adaptation and Innovation are introduced.

The recurring determination question is:

Does the earlier quality conclusion remain valid after relevant change?

This is not a minor supporting issue.

Infrastructure Quality is determined across a Lifecycle.

A condition demonstrated at one point does not automatically remain demonstrated after the object or its Context changes.

The recurring function can therefore be expressed as:

previously acceptable condition
+ relevant change
≠ automatically acceptable current condition.

The horizontal analysis must later test whether the Factor-specific change Indicators remain necessary because each protects a different Quality Factor, or whether some substantially repeat a function already sufficiently represented elsewhere.

Factor 14 is particularly relevant because it asks whether the Infrastructure Quality Object can accommodate changes required for continued realization of its Intended Functions and Intended Results.

Recurring Function 4 — Treatment of Abnormal, Degraded, and Non-Routine Conditions

Several Factors separately examine conditions outside normal operation.

These include questions concerning:

Structural and Functional Integrity;

Harm, Risk, and Safety;

Environmental Protection;

Operational Reliability;

Human and Infrastructure Interaction;

and

Personnel Competence.

The recurring function is:

determine whether a quality-relevant capability remains valid when normal assumptions no longer fully apply.

This recurrence appears methodologically important.

Normal operation can conceal weaknesses that become visible only under abnormal, degraded, transient, or non-routine conditions.

The horizontal pattern is:

adequate under normal conditions
≠ necessarily adequate under abnormal conditions.

The subject examined under each Factor remains different.

Integrity under an abnormal condition is not the same question as Personnel Competence under that condition.

Therefore, recurrence alone does not support combining these Indicators.

Recurring Function 5 — Treatment of Uncertainty and Limitations

Uncertainty and limitations recur across several Factors.

They appear in relation to:

requirements;

Evidence;

Risk;

Monitoring;

Documentation;

Innovation;

and

Quality Claims.

The recurring function is:

make visible what is not sufficiently known, demonstrated, resolved, or bounded.

This function is strongly related to Quality-State Determination.

A determination may become misleading not because the available Evidence is false, but because its limitations are not visible.

The recurring pattern is:

Evidence exists
+ important limitation is hidden
→ confidence in the Quality State may exceed what the Evidence supports.

Factor 13 makes this particularly explicit through documentation of Uncertainty, limitations, and known vulnerabilities.

Uncertainty introduced by innovation remains relevant where it affects the determination of required change. It is considered through Evidence Quality and the applicable Factors and QOCs, not through a separate Factor 14 Indicator.

The subject differs, but the determination function recurs.

Recurring Function 6 — Detection and Interpretation

Several Indicators concern the path from an actual infrastructure condition to a justified understanding of that condition.

This is most explicit in Factor 12.

However, similar functions appear elsewhere through:

Conformity Assessment;

recognition of Risk;

human understanding of infrastructure behavior;

Personnel Competence;

Community observations;

and

interpretation of Evidence.

The recurring function is:

make a quality-relevant condition observable and correctly interpretable.

This horizontal finding is especially important to the provisional Quality-State Determination concept.

The analysis repeatedly shows that:

condition exists
≠ condition is detected;

condition detected
≠ condition is correctly interpreted;

condition interpreted
≠ conclusion is sufficiently supported.

This recurring sequence suggests that the reliability of Quality-State determination is itself an important cross-Factor subject.

Recurring Function 7 — Cumulative, Systemic, and Developing Effects

Several Factors require interpretation beyond isolated events or observations.

This appears in:

Systemic and Cumulative Risk;

cumulative Environmental Effects;

cumulative and long-term Community effects;

and

detection of Emerging and Systemic Risk through Monitoring.

The recurring function is:

determine whether individually limited conditions combine, persist, interact, or develop into a materially different quality-relevant condition.

The horizontal pattern is:

individual observation appears acceptable
≠ combined or developing condition necessarily acceptable.

This function is particularly important where no single event, measurement, or deviation is sufficient to reveal the wider condition.

The subject again differs by Factor.

Therefore, the present analysis does not treat the recurring cumulative function as evidence of redundancy.

Recurring Function 8 — Traceability

Traceability appears in Indicators under several Factors.

It includes relationships among:

Functional Requirements;

Technical Requirements;

realized infrastructure;

Conformity Statements;

Compliance Statements;

assessments;

Evidence;

changes;

and

Decision Rationale.

The recurring function is:

preserve the ability to reconstruct the basis, scope, relationship, and limits of a quality-relevant conclusion or infrastructure condition.

Factor 13 provides the broadest traceability function.

This creates an important horizontal test.

The analysis must determine whether Factor-specific traceability Indicators preserve necessary visibility within their parent Factors or whether some are substantially covered by Factor 13.

This question cannot be answered merely because the word "traceability" appears in several places.

The removal test remains necessary.

The correct question is:

If the Factor-specific Indicator were removed, would the same determination function remain sufficiently explicit and usable through Factor 13?

If not, the Indicator remains necessary.

Recurring Function 9 — Retention of Quality-Relevant Knowledge

Information-retention Indicators recur especially strongly in the later Factors.

They concern retention of knowledge relating to:

Integrity;

Risk;

Environmental Protection;

Operational Reliability;

Workplace Human Interaction;

Personnel Competence;

Stakeholder and Community impacts;

Monitoring;

and

Adaptation and Innovation.

The recurring function is:

prevent loss of knowledge required for later Infrastructure Quality State Determination.

Factor 13 again provides the wider information-continuity function.

This creates one of the strongest horizontal non-redundancy questions in the current Indicator set.

However, a distinction may exist between:

retaining quality-relevant information generally;

and

explicitly preserving the Factor-specific knowledge without which that Factor can no longer be responsibly determined.

This distinction should be tested rather than assumed. A stronger cross-Factor non-redundancy test is therefore required: if the subject-specific Indicator is removed, does the broader Indicator in another Factor necessarily preserve both the subject and the determination consequence at the same required resolution? If not, the subject-specific Indicator retains a separate function even where the horizontal function is shared.

Recurring Function 10 — Recognition of the Limits of a Positive Finding

Several Indicators perform another important function.

They prevent a valid but limited finding from being interpreted too broadly.

Examples include the propositions that:

Conformity does not by itself establish overall Infrastructure Quality;

Compliance does not by itself establish overall Infrastructure Quality;

Documentation does not by itself establish actual Infrastructure Quality;

technology or Innovation does not substitute for Infrastructure Quality State Determination or Evidence Sufficiency.

The recurring function is:

preserve the Boundary of what a finding or information source actually demonstrates.

This is a Quality-State Determination function.

A technically correct finding can still produce an incorrect overall conclusion if its meaning is extended beyond its supported scope.

The horizontal pattern is:

valid limited finding
+ unjustified extension
→ potentially invalid wider Quality State conclusion.

This recurring function is therefore not merely cautionary language.

It protects the logic of the determination.

Recurring Function 11 — Preservation or Restoration of an Acceptable Condition

A further recurring function begins to appear across several Factors.

Some Indicators do more than describe or determine a condition.

They concern capability to prevent deterioration, preserve required conditions, respond to developing problems, or recover after an unacceptable change.

Examples include:

Risk mitigation;

preservation of safety and integrity during Adaptation;

which applicable Factor determinations and context-specific QOCs apply to the consequences of change;

responsiveness to quality-relevant Community Concerns;

and

timely detection where intervention remains possible.

These Indicators provide preliminary support for the provisional Quality-State Influence function.

However, the horizontal analysis also reveals a possible unresolved determination question that may recur across Indicators.

The Factors and Indicators frequently address:

whether the condition can be recognized;

whether the condition can be interpreted;

whether safeguards or recovery capability exist;

and

whether limits of Authority or expertise are recognized.

It does not yet follow that the complete path from recognition to effective intervention is always explicitly represented.

That path may include:

recognition
→ communication
→ decision
→ Authority
→ action
→ resulting change in Quality State.

The present paper should not assume that this sequence requires another invariant Indicator.

It should be tested through the remaining horizontal analysis and through repeated Context Guide Evidence.

Interim Horizontal Finding

The Factor-by-Factor analysis reveals substantial recurrence of similar determination questions across the fourteen Quality Factors.

The strongest recurring functions identified so far include:

identification of what must be determined;

alignment with Intended Function and Intended Result;

treatment of change;

treatment of abnormal and degraded conditions;

treatment of Uncertainty and limitations;

detection and interpretation;

recognition of cumulative, Systemic, and developing effects;

traceability;

retention of quality-relevant knowledge;

recognition of the limits of positive findings;

and

preservation or restoration of acceptable conditions.

These recurring functions do not establish that the current Indicator set contains unnecessary duplication.

Nor do they establish that the present Indicator set is complete.

They provide the basis for the next stage of horizontal analysis.

The next three Sections examine the provisional functional classification more directly:

Quality-State Indicators;

Quality-State Determination Indicators;

and

Quality-State Influence Indicators.

The purpose is not to add another layer to this Indicator justification.

The purpose is to test whether this functional view helps explain why the established Indicators are necessary, where apparently similar Indicators remain distinguishable, and where repeated Context Guide Evidence may eventually reveal a missing invariant determination function.

7.2 Quality-State Indicators Across the Factors

The provisional Quality-State category asks:

What is the actual quality-relevant condition of the Infrastructure Quality Object?

This function differs from the ability to determine that condition.

It also differs from the ability to preserve, restore, or change that condition.

The Factor-by-Factor analysis shows that Quality-State functions appear across many of the fourteen derived Quality Factors.

However, they do not appear with the same strength in every Factor.

Some Factors primarily establish a basis for determination.

Others directly examine the actual condition, behavior, capability, effect, or result of the Infrastructure Quality Object.

The purpose of this Section is not to permanently classify every Indicator.

It is to identify where the Quality-State function is clearly present and what that horizontal pattern means.

Quality-State Functions in the Functional and Technical Basis

Factors 1 and 2 are not dominated by direct Quality-State Indicators.

Factor 1 establishes the Functional Specification basis.

Factor 2 establishes the Technical Specification basis.

Their Indicators primarily ask whether the conditions needed to define and judge the Infrastructure Quality Object have been adequately established.

These are mainly Quality-State Determination functions.

However, this does not mean that Factors 1 and 2 are separated from the actual Quality State.

If the Functional or Technical basis is incomplete, incorrect, contradictory, or no longer valid, that condition affects the Quality State determination.

The principal function nevertheless remains establishment of the determination basis rather than direct observation of realized infrastructure condition.

Quality-State Functions in Conformity Assessment

Factor 3 contains a clearer State function.

Indicator 3.2 asks whether conformity to Technical Specifications has actually been demonstrated.

Indicator 3.6 may identify an actual non-conforming condition.

These findings concern the realized Infrastructure Quality Object.

At the same time, Factor 3 remains strongly a Determination Factor because the central issue is whether the condition has been adequately demonstrated.

This illustrates an important horizontal point:

One Indicator can concern the actual state while also serving the ability to determine that state.

Quality-State Functions in Structural and Functional Integrity

Factor 4 contains some of the clearest Quality-State Indicators across the Factors.

Indicator 4.2 directly concerns the Structural and Functional Integrity of the declared Infrastructure Quality Object.

Indicator 4.4 concerns integrity under foreseeable abnormal and transient conditions.

Indicator 4.3 concerns degradation, damage, and aging affecting that condition.

Indicator 4.6 concerns integrity margin and tolerance to uncertainty.

These Indicators ask directly about the condition and capability of the Infrastructure Quality Object.

The Quality-State function is therefore strong.

The horizontal pattern is:

actual integrity condition
→ direct evidence about the Quality State.

Quality-State Functions in Harm, Risk, and Safety

Factor 5 contains both State and Influence functions.

Actual Risk Control effectiveness under Indicator 5.4 is itself a quality-relevant condition.

Actual hazardous conditions, vulnerabilities, or cumulative Risk may also contribute to the State function.

However, several Factor 5 Indicators primarily concern recognition and control of Risk rather than description of present infrastructure condition alone.

This shows that the Quality-State function can coexist with Determination and Influence within the same Factor.

Quality-State Functions in Environmental Protection

Factor 6 also contains clear State functions.

Actual emissions and discharges are infrastructure conditions and results.

Environmental Protection effectiveness under abnormal or degraded conditions is also part of the actual state.

Cumulative and long-term environmental effects may represent Infrastructure Outcomes that exist independently of whether they were recognized early.

The State function is therefore visible through:

actual Environmental Interactions;

actual emissions or discharges;

actual protection performance;

and

actual environmental effects.

Factor 6 also demonstrates that Quality State is not limited to the physical condition inside the Infrastructure Boundary.

Infrastructure Results and Outcomes at relevant external Interfaces may also be part of the bounded Quality State determination.

Quality-State Functions in Operational Reliability

Factor 7 contains a strong State function.

Operational Reliability concerns the actual capability of the Infrastructure Quality Object to realize its required functions consistently, stably, and recoverably.

Indicators 7.2 and 7.3 directly examine functional performance and disturbance tolerance.

Indicator 7.5 concerns the changing operational state as degradation and aging affect reliability.

Indicator 7.4 concerns Recovery Capability.

These are not merely questions about available information.

They concern actual infrastructure capability.

The relationship is:

required Function Realization
→ actual operational performance
→ Quality-State finding.

Factor 7 therefore confirms that the Quality-State function includes functional capability as well as physical condition.

Quality-State Functions in Human and Infrastructure Interaction

Factor 8 extends the State function to workplace human–infrastructure interaction.

The actual condition of an Interface can make safe interaction easier or more difficult.

Human capability assumptions can be compatible or incompatible with infrastructure design.

Error-Provoking Workplace Conditions may physically or functionally exist.

Workplace interaction may be safe under normal conditions but unsafe under degraded conditions.

These are actual conditions of the declared Infrastructure Quality Object and its relevant workplace Interfaces.

The State function therefore includes:

physical configuration;

information presentation;

access;

feedback;

interaction conditions;

and

workplace pressures arising from infrastructure behavior.

This supports the IQI treatment of humans as interacting parts of the infrastructure system rather than as external administrative subjects.

Quality-State Functions in Personnel Competence

Factor 9 contains a more qualified State function.

Personnel Competence is not a physical infrastructure property.

However, where Function Realization materially depends on an Infrastructure-Critical Role, the available Role-Appropriate Competence is a real condition affecting the Infrastructure Quality Object.

Indicator 9.2 therefore has a State function.

Competence for abnormal and degraded conditions may also represent an actual capability of the human part of the infrastructure system.

The Factor nevertheless retains a strong Determination component because competence must be demonstrated rather than assumed.

Quality-State Functions in Regulatory and Standards Compliance

Factor 10 contains a limited but clear State function.

Actual conformity to Applicable Requirements is a condition of the Infrastructure Quality Object in relation to its Reference Layer.

Indicator 10.3 therefore has a Quality-State component.

However:

Compliance State
≠ complete Infrastructure Quality State.

This limit is fundamental.

Factor 10 provides Evidence about one dimension of Quality.

It does not replace the remaining Factors.

Quality-State Functions in Infrastructure and Stakeholders

Factor 11 extends the State function to Infrastructure Impacts, Infrastructure Results, and Infrastructure Outcomes experienced by affected Stakeholders and Communities.

Actual service disruption is a result.

Actual environmental exposure is a result.

Actual accessibility limitation is a result.

Actual cumulative Community effect is an outcome.

These conditions may therefore form part of the Quality State determination within the declared Boundary and claim scope.

Factor 11 shows that Quality-State Indicators need not be limited to conditions observed inside the physical infrastructure.

A quality-relevant result can become visible at the receiving side of an Interface.

The State function therefore includes:

what the Infrastructure Quality Object does;

and

what results from what it does.

Quality-State Functions in Infrastructure Monitoring

Factor 12 is dominated by Quality-State Determination.

Interpreted monitoring observations can supply Evidence relevant to Intended Functions and Intended Results; determining achievement of their applicable QOCs belongs to the relevant object-level examination, including Factor 3 where applicable.

The behavior itself is part of the actual state.

Monitoring does not create that state.

It makes the state observable.

This distinction is important:

Infrastructure behavior
→ Quality-State condition.

Monitoring and interpretation
→ means of determining that condition.

Factor 12 therefore helps preserve the boundary between State and Determination.

Quality-State Functions in Documentation and Traceability

Factor 13 is predominantly a Quality-State Determination Factor.

Documentation, traceability, accessibility, and information continuity support understanding of the Infrastructure Quality Object.

They are not the Quality State itself.

This is why the earlier proposal to distinguish Documentation from Quality was useful. The safeguard remains part of the methodology, but it does not require a separate Indicator.

Complete Documentation does not demonstrate acceptable infrastructure condition or performance.

The horizontal distinction is therefore particularly clear:

documented state
≠ actual state.

Factor 13 supports knowledge of the Quality State.

It does not substitute for the State.

Quality-State Functions in Infrastructure Adaptability

Factor 14 has one Indicator concerning the actual capability to accommodate required changes. This capability is a quality-relevant condition; its adequacy must be determined in context.

An Infrastructure Quality Object may or may not possess the actual capability to adapt responsibly.

The effect of change on safety and integrity remains important where applicable and is determined under the relevant Factors and QOCs.

Functional Requirements, Boundaries, and Interfaces inform whether a required change can be accommodated.

Reversibility or recovery may be required in a particular Context, but is not a separate invariant Indicator.

Actual Results and Outcomes remain relevant Evidence for the applicable determinations.

Factor 14 asks whether required changes can be accommodated; other Factors determine the resulting safety, integrity, reliability, and other conditions.

Horizontal Pattern

Across the Factors, the Quality-State function appears in several forms.

It may concern:

physical condition;

Structural or Functional Integrity;

functional performance;

Operational Reliability;

Risk Control effectiveness;

environmental condition or effect;

workplace human–infrastructure interaction;

available Personnel Competence;

conformity to Applicable Requirements;

Infrastructure Impacts and Outcomes affecting Stakeholders and Communities;

observed Infrastructure Behavior;

or

Adaptation and Recovery Capability.

These subjects differ.

Their common function is that they provide information about what condition, capability, behavior, effect, or result actually exists.

The horizontal relationship can be expressed as:

Infrastructure Quality Object
→ actual condition, capability, behavior, interaction, result, or outcome
→ Quality-State category.

This finding supports the provisional Quality-State classification.

It also shows why the term should not be interpreted too narrowly.

Quality State is not limited to the physical condition of equipment.

For an infrastructure Quality Object, the actual state may include functional, operational, environmental, human-interaction, competence-dependent, compliance-related, stakeholder-impact, and adaptation-related conditions where those conditions materially affect Function Realization or Infrastructure Results and Outcomes.

At the same time, the analysis also shows an important limit.

Not every invariant Indicator that contributes to Quality State determination is itself primarily a Quality-State Indicator.

Several Indicators determine:

what must be examined;

whether the state can be observed;

whether Evidence is sufficient;

whether information is correctly interpreted;

whether knowledge is retained;

or

whether the limits of a finding are understood.

These are better described provisionally as Quality-State Determination functions.

Interim Finding

The horizontal analysis confirms that Quality-State functions recur across multiple derived Quality Factors.

They are especially strong where the Factors and Indicators directly address:

Integrity;

Risk Control effectiveness;

Environmental Protection;

Operational Reliability;

workplace interaction;

Personnel Competence where infrastructure behavior materially depends on it;

actual conformity;

Stakeholder and Community impacts;

Infrastructure Behavior;

and

Adaptation results or capabilities.

The function is therefore sufficiently recurring to remain useful as a provisional horizontal classification.

However, the analysis does not support creating a separate class of Quality-State Indicators at this stage.

Many established Indicators perform more than one function.

Some primarily describe actual condition.

Others combine State with Determination or Influence.

The classification is therefore better used as an analytical tool.

The next Section examines the second horizontal function:

Quality-State Determination Indicators.

7.3 Quality-State Determination Indicators Across the Factors

The provisional Quality-State Determination category asks:

Can the actual Quality State of the Infrastructure Quality Object be determined with sufficient reliability?

This question differs from:

What is the actual Quality State?

It also differs from:

Can the Quality State be preserved, restored, or intentionally changed?

The distinction became increasingly visible during the Factor-by-Factor analysis.

A condition may physically exist without being detected.

It may be detected without being correctly interpreted.

It may be correctly interpreted but supported by insufficient Evidence.

Evidence may exist but be unavailable to the person making the determination.

A technically correct finding may also be interpreted beyond what it actually demonstrates.

The Quality-State Determination function therefore concerns the reliability of the path from the actual condition to a justified Quality State conclusion.

The basic relationship can be expressed as:

actual condition
→ observation or Evidence
→ interpretation
→ Evidence-Supported Finding
→ Quality State determination.

Weakness at any important point in this path can weaken the resulting determination.

Quality-State Determination in Factors 1 and 2

Factors 1 and 2 contain strong Determination functions.

Factor 1 establishes what the Infrastructure Quality Object is intended to do.

Factor 2 establishes the Technical Requirements through which that Functional Intent is to be realized.

These Factors therefore provide part of the basis against which actual infrastructure condition and performance can later be interpreted.

Without a sufficiently defined Functional Specification, it may be unclear what successful Function Realization means.

Without a sufficiently defined Technical Specification, it may be unclear what technical conditions are necessary to support that Function Realization.

The recurring Determination function is:

define the basis against which the actual state can be judged.

This is different from directly observing the state.

Quality-State Determination in Factor 3

Factor 3 provides another strong Determination function.

Conformity must be demonstrated rather than assumed.

The Factor therefore requires a supported relationship among:

specified requirement;

Evidence;

finding;

and

Conformity Statement.

This relationship is important to Quality-State Determination because a conclusion is only as reliable as the Evidence and reasoning supporting it.

Factor 3 also demonstrates that:

requirement exists
≠ conformity demonstrated.

Likewise:

Evidence exists
≠ Evidence necessarily sufficient.

The Determination function therefore includes the reliability of the evidential basis.

Quality-State Determination in Factor 4

Factor 4 concerns actual Structural and Functional Integrity, but several of its Indicators also perform Determination functions.

Degradation and Aging must be recognized.

Integrity under abnormal and transient conditions must be understood.

Integrity Margin and Uncertainty must be interpreted.

Integrity-relevant information must remain available.

The actual physical condition therefore cannot be separated from the means used to determine that condition.

A structure may be degraded without the degradation being known.

An integrity margin may be smaller than assumed.

A condition may also be incorrectly interpreted because earlier Assumptions or information have been lost.

Factor 4 therefore combines State and Determination strongly.

Quality-State Determination in Factor 5

Factor 5 requires identification of hazardous energies, materials, processes, and high-consequence or Loss-of-Control Scenarios.

It also requires consideration of Systemic and Cumulative Risk and retention of Risk information.

These are primarily Determination functions.

The Risk may exist before it is recognized.

The scenario may be physically possible before it has been identified.

Several limited vulnerabilities may already interact before their combined significance is understood.

The recurring relationship is:

Risk exists
≠ Risk is necessarily known.

A Risk determination can fail through incomplete recognition even when the underlying infrastructure condition is unchanged.

Quality-State Determination in Factor 6

Factor 6 contains a similar pattern.

Environmental Interactions and Exposure Pathways must be identified.

Cumulative and long-term effects must be understood.

Emissions and discharges must be interpreted in relation to environmental effects.

Environmental knowledge must remain available.

An Environmental Interaction can exist without being recognized.

A release can occur without its complete Exposure Pathway being understood.

A cumulative effect can develop without any individual observation appearing decisive.

Factor 6 therefore demonstrates that Quality-State Determination may require interpretation of relationships extending beyond the immediate physical Boundary of the infrastructure equipment.

Quality-State Determination in Factor 7

Factor 7 requires determination of reliability-critical functions, changing reliability under degradation and aging, and retention of reliability-relevant knowledge.

Actual Operational Reliability is a State function.

But determining that reliability requires more than observing whether the Infrastructure Quality Object is currently operating.

Continued operation does not necessarily demonstrate adequate reliability.

Performance trends, disturbance tolerance, recovery capability, degradation, and changing conditions may also need to be understood.

Therefore:

Infrastructure Quality Object is operating
≠ Operational Reliability necessarily demonstrated.

Factor 7 again shows the difference between visible activity and justified Quality-State determination.

Quality-State Determination in Factor 8

Factor 8 introduces an important human dimension to the determination path.

The Infrastructure Quality Object may communicate its condition through:

displays;

controls;

alarms;

physical signs;

instrumentation;

access conditions;

equipment behavior;

or other human–infrastructure Interfaces.

The relevant person must be able to perceive and correctly understand that information.

Indicator 8.5 is particularly important.

Alignment between infrastructure design and human understanding affects whether the actual infrastructure condition can be correctly recognized.

The horizontal relationship becomes:

actual infrastructure condition
→ information presented through an Interface
→ human perception and interpretation
→ possible determination.

A failure in the Interface can therefore weaken Quality-State Determination even where the underlying technical information exists.

Quality-State Determination in Factor 9

Factor 9 extends this issue from the Interface to the competence of the person interpreting or acting upon the information.

Personnel in Infrastructure-Critical Roles may affect:

observation;

interpretation;

judgment;

Evidence;

Quality Claims;

and

decisions concerning Critical Infrastructure Conditions.

Role-Appropriate Competence therefore affects the reliability of the determination path.

Indicator 9.3 is especially important under abnormal, degraded, and non-routine conditions.

Indicator 9.4 adds recognition of the limits of expertise and Authority.

The horizontal relationship can be expressed as:

information available
≠ information correctly understood;

information correctly understood
≠ person necessarily competent to make the required conclusion;

competent person
≠ unlimited expertise or Authority.

Factor 9 therefore strongly supports treating Quality-State Determination as a distinct horizontal function.

Quality-State Determination in Factor 10

Factor 10 shows that determination also depends on correct interpretation of the Reference Layer.

Applicable Requirements must be identified.

Conflicting or overlapping requirements must be addressed.

Actual conformity must be demonstrated.

The limits of Compliance must be recognized.

Compliance Statements must remain traceable.

A Compliance finding can therefore be technically correct while being incorrectly used as a wider Quality State conclusion.

The recurring problem is:

valid finding
≠ unlimited meaning.

Indicator 10.6 is particularly important because it protects the determination from treating Compliance as proof of overall Infrastructure Quality.

Quality-State Determination in Factor 11

Factor 11 introduces another possible information path.

Stakeholders and Communities may observe Infrastructure Impacts that are not sufficiently visible through internal monitoring.

Their observations do not automatically establish a finding.

However, a credible Community Concern may identify a condition requiring examination.

The possible determination path becomes:

Infrastructure Quality Object
→ Infrastructure Impact
→ affected Stakeholder or Community
→ observation or concern
→ examination and Evidence
→ Quality-State finding.

This is important because it shows that information relevant to Quality-State Determination may originate outside the immediate workplace or operating organization.

The source of information does not determine its validity.

The Evidence supporting the resulting finding remains necessary.

Quality-State Determination in Factor 12

Factor 12 provides the clearest direct expression of the Determination function.

It asks:

What must be observed?

Can it be detected adequately?

Can the information be interpreted correctly?

Can developing or Systemic Risk be recognized?

Does Monitoring remain relevant after change?

What does observed behavior mean for Intended Function Realization?

Is the knowledge needed to interpret Monitoring retained?

Factor 12 therefore makes explicit several separate stages of Quality-State Determination.

The sequence can be expressed as:

relevant condition
→ observable behavior
→ detection
→ interpretation in Context
→ relationship to Intended Result
→ supported Quality-State finding.

This sequence shows why Monitoring cannot be treated as equivalent to determination.

Monitoring Data are inputs.

They must still be interpreted.

The information must also be sufficiently relevant, sensitive, timely, and complete for the determination being made.

Quality-State Determination in Factor 13

Factor 13 protects continuity of the determination basis over time.

Important decisions and Assumptions must remain understandable.

Functional Intent, Technical Requirements, and realized infrastructure must remain traceable.

Uncertainty and known vulnerabilities must remain visible.

Assessments and statements must remain connected to their actual basis.

Changes and their rationale must remain reconstructable.

Quality-Critical Information must remain accessible.

Factor 13 therefore addresses a fundamental problem:

Evidence or knowledge may once have existed but later become unavailable, disconnected, or misunderstood.

The determination path is not reliable if the information needed to support it cannot be reconstructed when required.

The earlier proposal for Indicator 13.7 highlighted another important limit, which remains without a separate Indicator:

Documentation
≠ Quality State.

The existence of information does not establish that the information demonstrates an acceptable condition.

Quality-State Determination in Factor 14

Indicator 14.1 requires determination of:

whether required changes have been identified;

whether the Infrastructure Quality Object can accommodate those changes;

which conditions, capacities, Boundaries, and Interfaces affect that capability;

what Evidence supports the capability determination;

which applicable Factor determinations and context-specific QOCs apply to the consequences of change;

Actual Results and Outcomes after a change may provide Evidence for the relevant determinations.

They are considered as Evidence, not as a separate Factor 14 Indicator.

This Factor demonstrates that the determination basis itself may need to change when the Infrastructure Quality Object changes.

Earlier Evidence may no longer be sufficient.

Earlier Assumptions may no longer apply.

Earlier monitoring may no longer observe the most relevant behavior.

The recurring relationship is:

changed Infrastructure Quality Object
→ earlier determination basis may no longer be sufficient.

Factor 14 therefore reinforces the importance of reassessing the determination path after significant change.

Horizontal Determination Path

Across the fourteen Factors, a broader pattern becomes visible.

Quality-State Determination may depend on several distinct functions:

identifying what must be determined;

defining the basis against which it will be judged;

making the relevant condition observable;

obtaining appropriate Evidence;

detecting relevant change;

interpreting information in Context;

recognizing Uncertainty and limitations;

applying competent judgment;

recognizing limits of expertise and Authority;

relating observed behavior to Intended Function and Intended Result;

preserving traceability;

retaining Quality-Critical Information;

and

keeping the meaning of findings within the limits supported by Evidence.

These functions do not necessarily occur in one fixed sequence in every Context.

But together they demonstrate that Quality-State Determination is more than measurement.

A useful general representation is:

Quality State exists

→ relevant aspects of that state must become observable

→ Evidence must be obtained

→ Evidence must be interpreted in Context

→ limitations and Uncertainty must remain visible

→ the finding must be related to the applicable Quality Factor and Quality Outcome Criterion

→ the resulting conclusion must remain within the scope supported by the Evidence.

This horizontal pattern is sufficiently strong to support continued use of Quality-State Determination as a provisional analytical classification.

Independent and Parallel Determination Paths

The analysis also raises a further research question.

If determination depends entirely on one observation path, one information source, one person, or one interpretation path, failure or distortion within that path may affect the resulting Quality State conclusion.

Several Factors already provide parts of this problem.

Factor 8 concerns human understanding at the Infrastructure Interface.

Factor 9 concerns Personnel Competence and limits of expertise and Authority.

Factor 11 shows that relevant observations may arise from Stakeholders and Communities.

Factor 12 concerns Monitoring and interpretation.

Factor 13 concerns information accessibility, continuity, and traceability.

Together they suggest a possible horizontal question:

When the consequence of an incorrect Quality-State determination is high, is one determination path sufficient?

The present Indicator set does not appear to establish a general requirement for independent or parallel Quality-State information paths across all infrastructure Contexts.

This paper should therefore not introduce such a requirement.

However, repeated Context Guide Evidence may show that independence, diversity, or parallelism of information paths is necessary in particular Critical Infrastructure Conditions.

This should be preserved as a provisional research finding.

Time as Part of Quality-State Determination

The Factor-by-Factor analysis also suggests that time may affect the adequacy of determination.

Indicator 12.2 expressly concerns sufficiently timely detection.

Factor 8 examines interaction under conditions where available response time may change.

Factor 9 examines competence under abnormal and non-routine conditions.

Factor 5 examines Loss-of-Control and high-consequence scenarios.

A determination that arrives after the available intervention time may be technically correct but operationally insufficient for preventing an unacceptable Infrastructure Outcome.

This suggests another horizontal relationship:

correct determination
+ excessive delay
→ possibly insufficient determination for the infrastructure condition being managed.

The present Indicator set already contains parts of this issue.

The analysis does not yet demonstrate that a separate invariant Indicator is required.

The question should remain open for Context Guide testing.

Interim Finding

The horizontal analysis provides strong support for Quality-State Determination as a recurring category across the derived Factors and Indicators.

This function is not limited to Monitoring.

It appears in:

definition of Functional and Technical bases;

Conformity Assessment;

recognition of degradation and Risk;

environmental interpretation;

reliability evaluation;

human understanding;

Personnel Competence;

Reference Layer interpretation;

Stakeholder and Community observations;

Monitoring;

Documentation and Traceability;

and

Adaptation.

The central finding is simple:

actual Quality State
≠ automatically known Quality State.

The reliability of the determination depends on the path through which the actual condition becomes observable, evidenced, interpreted, and supported as a finding.

The analysis also identifies two provisional questions for continued research:

whether Critical Infrastructure Conditions sometimes require independent or parallel determination paths;

and

whether timeliness of determination should be treated more explicitly where the Quality State can change faster than the existing determination and decision process can respond.

Neither finding presently justifies addition of a new invariant Indicator.

They should remain provisional until tested through horizontal comparison and repeated Context Guide Evidence.

The next Section examines the third provisional function:

Quality-State Influence Indicators.

7.4 Quality-State Influence Indicators Across the Factors

The provisional Quality-State Influence category asks:

Does the Infrastructure Quality Object possess the capability to preserve, restore, or intentionally move a quality-relevant condition toward an acceptable state?

This function differs from Quality-State and Quality-State Determination.

Quality-State asks:

What condition actually exists?

Quality-State Determination asks:

Can that condition be reliably determined?

Quality-State Influence asks:

Can something be done, through the capabilities represented within the Infrastructure Quality Object, to preserve an acceptable condition or influence an unacceptable or developing condition?

The Factor-by-Factor analysis shows that this function already appears in several parts of the derived Factor and Indicator set.

However, it is not equally visible across all fourteen Factors.

Some Indicators primarily describe or determine conditions.

Others clearly concern prevention, control, recovery, adaptation, or another capability capable of affecting the resulting Quality State.

The purpose of this Section is to examine that recurring function.

It does not establish Quality-State Influence as a new additional layer in this Indicator analysis.

Quality-State Influence in Factors 1 and 2

Factors 1 and 2 primarily establish the Functional and Technical basis of the Infrastructure Quality Object.

Their dominant function is Quality-State Determination.

However, Functional and Technical Specifications also influence the realized Infrastructure Quality Object.

A requirement can shape Design, Construction, Operation, Repair/Modification, or another Lifecycle decision.

This creates an indirect Influence function.

The distinction is important.

A Functional or Technical requirement does not itself physically preserve or restore the Quality State.

It establishes conditions that infrastructure decisions are intended to realize.

The Influence function in Factors 1 and 2 is therefore less direct than in later Factors concerned with Risk Controls, recovery, or Adaptation.

Quality-State Influence in Factor 3

Factor 3 primarily concerns demonstrated conformity.

Its dominant function is Determination.

However, identification of Nonconformity can lead to decisions affecting the Infrastructure Quality Object.

The invariant Indicator set does not make corrective action itself the primary subject of Factor 3.

Therefore, the Influence function should not be overstated.

Factor 3 shows an important distinction:

determination that a condition is unacceptable
≠ capability to correct that condition.

This distinction becomes important later in the horizontal analysis.

Quality-State Influence in Factor 4

Factor 4 contains Influence functions where Structural and Functional Integrity must be preserved through operating conditions, degradation, and change.

The relevant capability may involve maintaining sufficient Integrity Margin or preventing a change from weakening the conditions required for Function Realization.

However, Factor 4 remains strongly concerned with the actual integrity state and its determination.

The Influence function is present where the Infrastructure Quality Object possesses capability to preserve that state.

Quality-State Influence in Factor 5

Factor 5 provides one of the clearest examples of Quality-State Influence.

Risk Controls exist specifically to affect the development or consequence of hazardous conditions.

They may:

prevent a Loss-of-Control Scenario;

detect a developing condition;

limit escalation;

mitigate consequences;

or

reduce the likelihood that a hazardous condition produces an unacceptable Infrastructure Outcome.

Indicators 5.3 and 5.4 are particularly important.

Indicator 5.3 establishes what the Risk Controls must accomplish.

Indicator 5.4 asks whether those controls remain effective across relevant operating modes.

Indicator 5.6 asks whether Risk mitigation remains aligned when conditions change.

The horizontal relationship can be expressed as:

hazardous condition or scenario
→ Risk Control
→ prevention, detection, mitigation, or consequence limitation
→ influenced Infrastructure Result or Outcome.

Factor 5 therefore strongly supports Quality-State Influence as a recurring horizontal category.

Quality-State Influence in Factor 6

Factor 6 contains a similar pattern.

Environmental Protection provisions exist to prevent or limit Environmental Harm.

Indicator 6.2 directly examines prevention and limitation capability.

Indicator 6.3 asks whether that protection remains effective under abnormal and degraded conditions.

Indicator 6.5 asks whether Environmental Protection remains aligned under change.

Indicator 6.6 includes limitation of emissions and discharges.

The Influence function is therefore clear.

The relevant capability affects the pathway between infrastructure behavior and Environmental Harm.

The general relationship is:

Environmental Interaction
→ protection or limitation capability
→ changed environmental consequence.

Again, Influence does not mean that every environmental effect can be eliminated.

It means that the Infrastructure Quality Object contains or depends on capability intended to preserve or move the relevant condition toward an acceptable result.

Quality-State Influence in Factor 7

Factor 7 provides another strong example.

Indicator 7.4 concerns Recovery Capability following Disruption.

Recovery is different from simply determining that Operational Reliability has been lost.

It concerns the capability to restore required Function Realization.

The relationship is:

required function lost or degraded
→ recovery capability
→ required Function Realization restored.

This is a direct Quality-State Influence function.

Indicator 7.3 may also contain an Influence aspect where infrastructure capability allows required function to be preserved through Operational Variability or Disturbance.

Indicator 7.6 concerns preservation of reliability through change.

Factor 7 therefore shows two forms of Influence:

preservation of acceptable Function Realization;

and

restoration after its loss or degradation.

Quality-State Influence in Factor 8

Factor 8 shows that infrastructure design and configuration can influence human action.

Controls, displays, access, layout, feedback, and workplace conditions can make correct action easier or more difficult.

Error-Provoking Workplace Conditions can increase the likelihood of Human Error.

Alignment between infrastructure design and human understanding can improve the likelihood of correct interpretation and action.

The Influence function therefore operates partly through the human–infrastructure Interface.

The relationship can be expressed as:

infrastructure condition or information
→ human–infrastructure Interface
→ human understanding and action
→ effect on Infrastructure Quality State.

This does not mean that infrastructure design determines human behavior completely.

It means that the Infrastructure Quality Object can materially influence the conditions under which human action occurs.

Factor 8 therefore broadens the provisional Influence concept beyond automatic or technical controls.

Quality-State Influence in Factor 9

Factor 9 also contains Influence functions.

Personnel Competence can affect whether appropriate action is taken after a condition is recognized.

Indicator 9.3 concerns competence to recognize, interpret, and respond under abnormal, degraded, and non-routine conditions.

Indicator 9.4 concerns recognition of the limits of expertise and Authority.

This creates an important distinction.

A person may:

recognize a condition;

correctly determine its significance;

and

recognize that action is required;

while still lacking Authority to perform that action.

Therefore:

competence to determine
≠ Authority to influence.

Likewise:

Authority to act
≠ competence to determine what action is appropriate.

This distinction is one of the most important provisional findings produced by the horizontal analysis.

Factor 9 contains parts of the Influence path.

It does not establish that every person capable of determining a Critical Infrastructure Condition must possess direct Authority to change it.

Quality-State Influence in Factor 10

Factor 10 contains a less direct Influence function.

Applicable Requirements influence infrastructure decisions through Indicator 10.2.

Changed requirements may also require changed infrastructure decisions under Indicator 10.5.

The relationship is:

Applicable Requirement
→ infrastructure decision
→ effect on realized or operated Infrastructure Quality Object.

The requirement itself does not physically influence the state.

Its influence occurs through decisions and actions.

Factor 10 therefore provides another example of indirect Quality-State Influence.

Quality-State Influence in Factor 11

Factor 11 contains a limited but important Influence function.

Indicator 11.5 requires responsiveness where Community Concerns may indicate an infrastructure quality issue.

A concern can therefore contribute to a sequence such as:

Infrastructure Impact
→ external observation
→ concern
→ examination
→ supported finding
→ possible action.

However, Factor 11 does not prescribe Community engagement or corrective-action processes.

The Influence function should therefore remain limited to what the Indicator actually supports.

Community input may initiate or inform a determination.

Whether that determination leads to effective intervention depends on other capabilities.

Quality-State Influence in Factor 12

Factor 12 creates one of the most important boundaries between Determination and Influence.

Monitoring can detect a developing condition.

Interpretation can establish its significance.

Emerging Risk may be recognized.

But:

detection
≠ intervention.

Indicator 12.2 requires detection sufficiently early to prevent or limit unacceptable consequences.

This makes time relevant.

However, early detection alone does not establish that effective action will occur.

The sequence may be:

condition develops
→ condition becomes observable
→ condition is detected
→ condition is interpreted
→ significance is determined.

The Influence function begins when the resulting information can affect what happens next.

That may require:

communication;

decision;

Authority;

available response capability;

and

sufficient remaining time.

Factor 12 therefore provides a strong connection between Determination and Influence while preserving the distinction between them.

Quality-State Influence in Factor 13

Factor 13 primarily supports Quality-State Determination.

However, Indicator 13.6 shows how information availability may affect Influence.

Quality-Critical Information may exist but fail to reach the relevant decision point when needed.

Therefore:

information retained
≠ information available when action is required.

Accessible and usable information can support action.

But Factor 13 does not itself establish decision Authority or intervention capability.

Its Influence function is therefore supporting rather than direct.

Quality-State Influence in Factor 14

Factor 14 may support Quality-State Influence when the ability to accommodate required change helps preserve or restore Function Realization. Its single Indicator primarily supports Quality-State Determination.

Adaptation involves change, but Factor 14 does not require change for its own sake.

Effects on safety and integrity are determined under the applicable Factors and QOCs.

Functional Requirements, Boundaries, and Interfaces inform whether a required change can be accommodated.

Reversibility and recovery may be context-specific considerations.

Actual Results and Outcomes provide Evidence for the relevant determinations.

The earlier proposal to treat reversibility and recovery as separate Factor 14 Indicators was not retained.

Where recovery is required, the applicable Factors and QOCs determine what capability is needed.

The relationship is directly:

changed state
→ unacceptable result identified
→ reversal or recovery capability
→ movement toward acceptable Function Realization.

This contribution to Quality-State Influence is conditional; the Indicator does not itself establish intervention authority or require a particular change.

Preservation, Prevention, Mitigation, Recovery, and Adaptation

The horizontal analysis reveals that Quality-State Influence does not appear in only one form.

At least five forms can presently be distinguished.

Preservation:

maintain an acceptable condition despite disturbance, degradation, or change.

Prevention:

prevent an unacceptable condition or Loss-of-Control Scenario from developing.

Mitigation:

limit the consequence of a condition that cannot be fully prevented.

Recovery:

restore required Function Realization after disruption or degradation.

Adaptation:

intentionally change the Infrastructure Quality Object while preserving the necessary quality basis.

These forms are different.

But they share a common function:

they concern capability to affect the direction or result of a quality-relevant condition.

The horizontal relationship can therefore be expressed as:

existing or developing Quality State
→ available influence capability
→ preserved, limited, restored, or intentionally changed Quality State.

The Gap Between Determination and Influence

The analysis also identifies a potentially important gap between knowing and acting.

The invariant Indicator set contains strong provisions concerning:

hazard recognition;

Monitoring;

interpretation;

Personnel Competence;

recognition of Authority limits;

information retention;

Risk Controls;

recovery;

and

Adaptation.

However, these provisions do not necessarily establish one continuous path from determination of an unacceptable condition to effective intervention.

A simplified path is:

actual condition

→ observation

→ detection

→ interpretation

→ Quality-State determination

→ communication

→ decision

→ Authority

→ action

→ resulting Quality-State change.

Several existing Indicators address different parts of this sequence.

But the existence of the parts does not automatically establish the reliability of the complete path.

This question becomes especially important where the Infrastructure Quality State can deteriorate rapidly.

If the available time between recognition and unacceptable consequence is short, an otherwise valid escalation or decision process may be too slow.

The horizontal problem can be expressed as:

correct determination
+ available intervention capability
+ insufficient connection or excessive delay
→ unsuccessful Quality-State Influence.

This is a significant provisional research finding.

However, it does not yet demonstrate that the derived Factor and Indicator set lacks an invariant Indicator.

The issue may already be sufficiently represented through combinations of existing Indicators when interpreted in Context.

Alternatively, repeated Context Guide Evidence may show that a distinct invariant determination function is missing.

That question must remain open.

Authority at the Point of Observation

The relationship between Factor 8, Factor 9, Factor 12, and the Influence-oriented Indicators also raises a more specific question.

Where a person directly observes a rapidly developing Critical Infrastructure Condition:

must that person possess Authority to intervene?

must that person possess Authority to place the relevant activity into a safe or HOLD condition?

or

is reliable and sufficiently rapid escalation to another decision point adequate?

The derived Factor and Indicator set, as presently analyzed, does not support one universal answer.

Different infrastructure Contexts may require different arrangements.

In some Contexts, direct intervention may itself create unacceptable Risk.

In others, delay caused by escalation may make intervention ineffective.

Therefore, the invariant issue may not be:

every observer must have direct Authority.

The deeper possible invariant function may instead concern:

whether the complete determination-to-intervention path is capable of acting within the time available for the relevant Critical Infrastructure Condition.

This formulation should remain provisional.

It requires Context Guide testing.

Influence and the Quality Outcome Criterion

Quality-State Influence must also remain connected to the Quality Outcome Criterion.

Influence does not mean change for its own sake.

The relevant question is whether the capability can preserve, restore, or move the Quality State toward the expected or acceptable condition established for the applicable Context.

Therefore:

action occurred
≠ successful Quality-State Influence.

The action must be interpreted through its Result or Outcome.

A control may activate and still fail.

A recovery action may occur but restore only partial function.

An Adaptation may solve one problem while creating another.

The Influence function therefore requires connection back to the actual Quality State.

This creates a feedback relationship:

Quality-State determination
→ Influence
→ changed condition
→ renewed Quality-State determination.

This relationship may repeat throughout the Infrastructure Lifecycle.

Interim Finding

The horizontal analysis provides substantial support for Quality-State Influence as a recurring category across the derived Factors and Indicators.

The function appears most clearly in:

Risk prevention and mitigation;

Environmental Protection;

disturbance tolerance;

Recovery Capability;

human–infrastructure interaction;

competent response;

integration of Applicable Requirements into decisions;

responsiveness to quality-relevant external observations;

timely Monitoring;

availability of Quality-Critical Information;

and

Adaptation, Reversibility, and Recoverability.

The analysis also identifies an important distinction:

ability to determine the Quality State
≠ ability to influence the Quality State.

A further distinction is equally important:

ability to influence
≠ demonstrated successful influence.

The resulting condition must still be determined.

The provisional Influence classification therefore adds useful explanatory power to the horizontal analysis.

It helps reveal why some Indicators concern actual condition, others concern reliable knowledge of that condition, and others concern capability to preserve, restore, or change it.

At the same time, the analysis identifies a provisional question concerning the complete path from Quality-State determination to timely intervention.

The present evidence does not justify creating an additional invariant Indicator.

The question should be carried forward into the analysis of overlap among the three functions, apparent gaps, and later Context Guide testing.

7.5 Indicators Serving More Than One Determination Function

The preceding Sections examined three provisional horizontal categories:

Quality-State Indicators;

Quality-State Determination Indicators;

and

Quality-State Influence Indicators.

The horizontal analysis shows that these functions are distinguishable.

However, it also shows that they are not necessarily separate categories of Indicators.

A single invariant Indicator may perform more than one function.

This is an important finding.

The provisional classification should therefore not be interpreted as a requirement to place every Indicator into only one group.

The relevant question is:

What function or functions does the Indicator perform in relation to the Infrastructure Quality State?

State and Determination in the Same Indicator

The most common overlap is between Quality-State and Quality-State Determination.

An Indicator may examine an actual condition while also examining whether that condition can be reliably determined.

Structural and Functional Integrity provides a clear example.

The actual integrity condition is part of the Quality State.

But the integrity condition must also be supported by Evidence and interpreted with appropriate consideration of degradation, operating conditions, and Uncertainty.

The same relationship appears in Operational Reliability.

Actual functional performance is a State condition.

But reliability must be determined through Evidence concerning performance, disturbance tolerance, degradation, Recovery Capability, and other relevant conditions.

Environmental Protection provides another example.

An actual emission, discharge, or Environmental Effect is part of the Quality State.

But its significance may depend on identification of an Exposure Pathway, interpretation of cumulative effects, and other determination functions.

The general relationship is:

actual condition
→ Quality-State function;

ability to observe and interpret that condition
→ Quality-State Determination function.

The same Indicator may contribute to both.

Determination and Influence in the Same Indicator

A second recurring overlap occurs between Quality-State Determination and Quality-State Influence.

Risk Control provides a clear example.

The relevant hazardous condition must first be recognized.

The Risk Control must then be capable of preventing, detecting, mitigating, or limiting the consequence of that condition.

The Indicator therefore contains both:

understanding of the condition;

and

capability to affect what happens.

Monitoring provides another example.

Timely detection is primarily a Determination function.

But the reason timeliness matters is often that intervention must remain possible before an unacceptable consequence occurs.

The Indicator therefore approaches the boundary between Determination and Influence.

Personnel Competence provides another example.

A person may need competence to:

recognize a condition;

interpret its significance;

and

respond appropriately.

Recognition and interpretation concern Determination.

Response concerns Influence.

The functions are different, but they may be represented within the same Indicator because the infrastructure interaction itself connects them.

State and Influence in the Same Indicator

A third overlap occurs between Quality-State and Quality-State Influence.

Recovery Capability is a clear example.

The actual capability to recover required Function Realization is itself a quality-relevant condition.

At the same time, recovery exists for the purpose of changing a degraded or disrupted state.

Therefore:

Recovery Capability as an existing capability
→ Quality-State function;

use of that capability to restore Function Realization
→ Quality-State Influence function.

The earlier proposal to treat reversibility and recoverability as a separate Factor 14 Indicator illustrates the relationship, but those matters remain context-specific and are not retained as an independent Indicator.

Where a recovery capability is required, its existence may be a quality-relevant condition.

Its use may influence the state, but Factor 14 does not establish a universal recovery requirement.

All Three Functions in One Indicator

Some Indicators may contain all three provisional functions.

Consider an Indicator concerned with Risk Control effectiveness.

It may ask:

Does an effective Risk Control actually exist?

This concerns Quality State.

Can its effectiveness be demonstrated?

This concerns Quality-State Determination.

Can it prevent, mitigate, or limit the developing hazardous condition?

This concerns Quality-State Influence.

The same pattern may occur with Recovery Capability.

Does recovery capability exist?

Can that capability be demonstrated?

Can it actually restore required Function Realization?

These are three different questions contained within one quality-relevant subject.

This overlap does not weaken the provisional classification.

It clarifies its purpose.

The classification describes functions.

It does not necessarily classify Indicators into mutually exclusive groups.

Why Overlap Does Not Automatically Mean Redundancy

The same principle applies when similar functions appear in different Indicators.

Two Indicators may both contain a Quality-State Determination function but examine different conditions.

Two Indicators may both contain an Influence function but affect different failure paths.

Therefore:

same function
≠ same Indicator purpose.

For example:

Monitoring adequacy
and
Personnel Competence

both contribute to Quality-State Determination.

But they are not interchangeable.

Monitoring may correctly detect a condition while the person interpreting it lacks the necessary competence.

A competent person may also be unable to determine the condition because the Monitoring does not reveal it.

Likewise:

Risk mitigation
and
Recovery Capability

both contain Quality-State Influence functions.

But prevention or mitigation of a hazardous scenario is not the same as restoration of required function after disruption.

The distinguishability test therefore remains necessary.

Functional overlap alone is not sufficient evidence for combining Indicators.

Why Multiple Functions Do Not Automatically Justify Splitting an Indicator

The opposite problem must also be avoided.

If one Indicator performs State, Determination, and Influence functions, this does not automatically mean that it should be divided into three separate Indicators.

The invariant Indicator should remain connected to a necessary quality-relevant determination question.

If the functions operate together around one coherent subject, splitting them may create artificial complexity without improving Quality State determination.

For example:

Risk Control effectiveness

can legitimately involve the existence, demonstrability, and actual influence of the control.

Creating separate invariant Indicators merely because three analytical functions can be identified would not necessarily improve the Factor and Indicator set.

The proper question remains:

Would separating the functions reveal a necessary determination question that is otherwise materially obscured?

If not, separation is not justified.

The Three Functions as a Relationship

The horizontal analysis suggests that State, Determination, and Influence are better understood as related functions than as three independent groups.

A simplified relationship is:

Quality State
→ what condition exists.

Quality-State Determination
→ how that condition becomes sufficiently observable and supportable as a finding.

Quality-State Influence
→ how the condition may be preserved, restored, limited, or intentionally changed.

The relationship can continue:

Quality State

→ Determination

→ Influence

→ changed or preserved Quality State

→ renewed Determination.

This creates a recurring loop rather than a one-direction sequence.

For example:

a condition is detected;

its significance is determined;

a Risk Control or recovery capability acts;

the resulting condition changes;

the changed condition must then be determined again.

The three functions therefore interact throughout the Infrastructure Lifecycle.

A Break in the Relationship

The overlap analysis also helps identify where the relationship can fail.

The actual Quality State may be unacceptable but not determinable.

The Quality State may be correctly determined but no adequate Influence capability may exist.

An Influence capability may exist but not be activated.

It may be activated too late.

It may act but fail to produce the required Result.

The resulting state may change but not be re-determined.

The general sequence can therefore fail at several points:

actual condition

→ observation

→ determination

→ communication

→ decision

→ Authority

→ action

→ resulting condition

→ renewed determination.

Not every part of this sequence must necessarily be represented by a separate invariant Indicator.

However, the complete sequence is useful for testing whether the current Indicator set leaves a recurring determination function insufficiently visible.

Importance of the Infrastructure Boundary

The overlap among the three functions also reinforces the importance of correctly declaring the Infrastructure Boundary and Interfaces.

The relevant observation point may be physically remote from the equipment whose condition is being observed.

A person affecting the Infrastructure Quality State may work from a remote location.

Monitoring information may pass through communication systems before reaching the person who interprets it.

A decision may be made at another location.

An action may then be transmitted back through another Interface.

Therefore, the Quality-State determination and Influence path may extend beyond one physical site.

For the purposes of IQI analysis, the important question is not simply physical proximity.

The question is whether the person, workplace, communication path, Interface, or capability materially participates in:

determining;

communicating;

deciding upon;

or

influencing

the Quality State of the declared Infrastructure Quality Object.

This observation does not change the methodological definition of a Boundary.

It shows why Boundary and Interface declaration can become important when State, Determination, and Influence functions are analyzed together.

Provisional Functional Mapping

The analysis so far suggests a broad pattern.

Some Indicators are predominantly State-oriented.

Some are predominantly Determination-oriented.

Some are predominantly Influence-oriented.

Many are mixed.

A provisional functional mapping could therefore use:

S — Quality-State function;

D — Quality-State Determination function;

I — Quality-State Influence function;

or combinations such as:

S/D;

D/I;

S/I;

S/D/I.

This notation could be useful during research.

It could help compare Indicators horizontally across Context Guides without changing the current Factor and Indicator assignments.

However, such coding should remain provisional.

Its usefulness should be demonstrated before it is incorporated into any formal IQI document structure.

The purpose is analytical clarity, not creation of another classification system.

Interim Finding

The horizontal analysis shows that Quality-State, Quality-State Determination, and Quality-State Influence are distinguishable but frequently overlapping functions.

They should therefore not presently be treated as mutually exclusive Indicator categories.

An established invariant Indicator may legitimately perform:

one function;

two functions;

or

all three functions.

This does not by itself justify combining or splitting Indicators.

The controlling tests remain:

necessity;

removal;

distinguishability;

non-redundancy;

and

Context invariance.

The provisional three-function classification is useful because it reveals what each Indicator contributes to the relationship between:

the actual Infrastructure Quality State;

the ability to determine that state;

and

the capability to preserve, restore, or influence that state.

It also provides a useful basis for the next question.

If these functions are compared horizontally across all fourteen Factors, do any important determination functions appear insufficiently represented?

That question is examined in Section 7.6.

7.6 Apparent Gaps Revealed by Horizontal Comparison

The horizontal analysis does not only test the established invariant Indicators for overlap.

It also provides a way to look for possible gaps.

A gap would exist if a quality-relevant determination function repeatedly appears necessary across different infrastructure Contexts but is not sufficiently represented by the established invariant Indicators.

This is a demanding test.

An apparent gap is not automatically a missing invariant Indicator.

The first question must always be:

Is the function already represented by one or more existing Indicators?

Only if the answer is insufficient should an additional Indicator be considered.

The analysis in Sections 6 and 7.1–7.5 identifies several areas that deserve further testing.

At this stage, they are provisional findings only.

Apparent Gap 1 — Continuity from Quality-State Determination to Quality-State Influence

The strongest apparent gap concerns the connection between determining a quality-relevant condition and acting upon that determination.

The current Indicator set contains Indicators addressing many parts of this path.

These include:

hazard recognition;

Risk Controls;

Monitoring;

interpretation;

Workplace Human Interaction;

Personnel Competence;

recognition of limits of expertise and Authority;

Quality-Critical Information;

Recovery Capability;

and

Adaptation.

However, horizontal comparison raises a question:

Is the complete path from determination of a Critical Infrastructure Condition to effective intervention sufficiently represented?

A simplified path is:

actual condition

→ observation

→ detection

→ interpretation

→ Quality-State determination

→ communication

→ decision

→ Authority

→ action

→ resulting Quality State.

The existing Indicators address several individual parts of this sequence.

But reliable individual parts do not automatically establish a reliable complete path.

For example:

a condition may be correctly detected;

the person observing it may correctly understand its significance;

the information may be technically accurate;

and

an appropriate response capability may exist.

Yet the response may still fail if the information does not reach the required decision point in time.

Similarly, the person who recognizes the condition may lack Authority to act.

The person with Authority may be remote.

Communication may introduce delay.

The required action may therefore occur after the available intervention time has passed.

The horizontal issue can be expressed as:

correct determination
+ available response capability
≠ necessarily effective Quality-State Influence.

The missing element, if one exists, may concern the functional connection between determination and intervention.

The present analysis does not yet establish that a new invariant Indicator is required.

Several existing Indicators may collectively provide sufficient coverage when properly interpreted in Context.

This must be tested through Context Guides.

Apparent Gap 2 — Time Available for Determination and Intervention

The preceding issue reveals a related question concerning time.

Several established Indicators already contain time-related elements.

Monitoring must detect relevant conditions sufficiently early.

Risk Controls must operate effectively.

Operational Reliability includes Recovery Capability.

Personnel Competence must remain adequate under abnormal and degraded conditions.

However, horizontal comparison raises a broader question:

Is the time available between the development of a Critical Infrastructure Condition and an unacceptable Infrastructure Outcome adequately represented?

The problem can be expressed as:

time required to detect
+
time required to interpret
+
time required to communicate
+
time required to decide
+
time required to act

compared with

time available before unacceptable consequence.

If:

required response time
>
available intervention time,

the determination and Influence path may be inadequate even if every individual step eventually works correctly.

This is different from simple Monitoring timeliness.

Monitoring may detect a condition early enough in technical terms but still not leave enough time for the complete decision and intervention path.

This apparent gap is therefore important.

However, the Factor and Indicator set already addresses Risk, Monitoring, human interaction, Personnel Competence, and recovery.

The issue may be adequately represented through their combined application.

A separate invariant Indicator should not be introduced unless repeated Context Guide Evidence shows that this time relationship remains materially underrepresented.

Apparent Gap 3 — Authority to Act on a Critical Infrastructure Condition

Factor 9 explicitly recognizes limits of expertise and Authority.

This establishes that Authority is relevant to Infrastructure-Critical Roles.

Horizontal analysis raises the next question:

When a Critical Infrastructure Condition is identified, is the available Authority structure compatible with the time and action required?

This does not mean that every person observing infrastructure behavior should have unrestricted Authority.

Such a rule would not be Context-invariant and could itself create Risk.

The question is narrower:

Does someone capable of recognizing a Critical Infrastructure Condition have a sufficiently reliable path to an authorized action within the time available?

In some infrastructure Contexts, escalation may be fully adequate.

In others, escalation may be too slow.

In some cases, predetermined HOLD or safe-state criteria may allow immediate action without requiring a new discretionary decision.

The possible invariant function may therefore concern:

adequacy of Authority and decision paths for time-critical Quality-State Influence.

This remains a provisional research proposition.

The present Indicator set may already represent it through the interaction of Factors 5, 8, 9, 12, and 14.

Context Guide evidence is needed before addition of an invariant Indicator can be justified.

Apparent Gap 4 — Integrity of the Quality-State Information Path

Quality-State Determination depends on information.

Factor 12 examines Monitoring and interpretation.

Factor 13 examines Documentation, Traceability, accessibility, and continuity.

Factor 8 examines human interaction with infrastructure information.

Factor 9 examines Personnel Competence.

Factor 11 recognizes that relevant observations may also originate from affected Stakeholders and Communities.

Together these Factors raise a wider question:

Can quality-relevant information change, weaken, disappear, or become distorted between the original observation and the final decision point?

The possible path may be:

condition

→ observation

→ recorded information

→ communication

→ interpretation

→ reporting

→ decision.

At each step, the information may remain accurate.

But the horizontal analysis must also consider the possibility that it does not.

Information may be:

incomplete;

delayed;

summarized incorrectly;

separated from its Context;

interpreted beyond the Evidence;

or

not transmitted at all.

Some of these problems are already addressed by Factors 12 and 13.

The apparent gap is therefore not simply "information quality."

The more specific provisional question is:

Does the Factor and Indicator set sufficiently determine whether Quality-State information remains materially faithful to the observed condition throughout the path by which it reaches the relevant decision point?

This may be described provisionally as Quality-State Information Integrity.

The term should remain a research term at this stage.

It should not yet be introduced as a new Factor or Indicator at this stage.

Apparent Gap 5 — Independent or Parallel Quality-State Information Paths

The preceding issue creates another possible question.

Where a Quality-State determination depends entirely on one information path, failure of that path may prevent the condition from becoming visible.

A single path may include:

one sensor;

one communication channel;

one person;

one organizational reporting route;

or

one interpretation source.

The invariant Indicator set already contains requirements relevant to Monitoring adequacy, Evidence, Personnel Competence, Interfaces, and information continuity.

But it does not necessarily follow that one path is always sufficient.

The horizontal question is:

For Critical Infrastructure Conditions, when is independence or parallelism of Quality-State information paths necessary to support reliable determination?

This should not be converted into a universal requirement.

Many infrastructure conditions do not require independent or parallel paths.

In some Contexts, one sufficiently reliable path may be adequate.

In other Contexts, consequence severity, uncertainty, response time, or vulnerability to common failure may justify independent or diverse paths.

Therefore, the possible invariant issue is not:

multiple information paths are always required.

The research question is:

Under what conditions does dependence on a single Quality-State information path create an unacceptable weakness in determination?

Repeated Context Guide evidence is required.

Apparent Gap 6 — Human and Organizational Distortion of Quality-State Information

Factor 8 examines workplace conditions affecting human interaction.

Factor 9 examines Personnel Competence and limits of expertise and Authority.

Factor 13 examines information continuity and traceability.

These Factors provide parts of another possible problem.

Quality-State information may be technically available and correctly understood at the observation point but later be minimized, delayed, reclassified, or otherwise changed before reaching a decision point.

This possibility is different from lack of competence.

A person may understand the condition correctly.

The problem may arise because the surrounding decision or reporting environment affects whether unfavorable information is transmitted with its original meaning.

The horizontal research question is:

Are there recurring infrastructure Contexts in which pressure within the human or organizational information path materially weakens the reliability of Quality-State determination?

If repeated evidence supports this pattern, it may require more explicit treatment.

At present, however, this paper should not introduce a separate invariant Indicator for organizational behavior.

The derived Factor and Indicator set concerns the Infrastructure Quality Object.

Any proposed addition would first have to demonstrate that the condition materially participates in determination or Influence of the Infrastructure Quality State within the declared Boundary and Interfaces.

This remains a provisional research question.

Apparent Gap 7 — Re-Determination After Quality-State Influence

Section 7.5 identified a recurring loop:

Quality State

→ Determination

→ Influence

→ changed Quality State

→ renewed Determination.

The current Indicator set strongly addresses Monitoring, Risk Controls, recovery, Adaptation, and evaluation of Results and Outcomes.

However, horizontal comparison raises a useful question:

After an intervention, how is it established that the intended acceptable state was actually achieved?

Action alone does not demonstrate success.

For example:

a Risk Control may activate but fail to control the condition;

a recovery action may restore only part of the required function;

an environmental mitigation action may reduce but not sufficiently limit an effect;

an Adaptation may correct one problem while creating another.

Therefore:

action completed
≠ acceptable Quality State demonstrated.

This issue may already be represented through existing Indicators concerning control effectiveness, Monitoring, Intended Results, and Adaptation Results and Outcomes.

The present analysis does not establish a missing Indicator.

But the requirement for renewed determination after Influence should be tested explicitly in Context Guides.

Relationship Among the Apparent Gaps

The apparent gaps are not independent.

Several form one possible chain:

Quality-State condition

→ observation

→ reliable information

→ determination

→ communication

→ decision

→ Authority

→ timely action

→ changed condition

→ renewed determination.

The horizontal analysis therefore reveals a broader research subject:

the integrity of the complete Quality-State determination-and-influence path.

This does not mean that a separate Indicator should be assigned to every step.

Doing so could create unnecessary detail and duplicate functions already represented under existing Factors.

The purpose of identifying the chain is different.

It gives the Context Guide research a structure for testing whether the current Indicator set leaves any recurring function materially uncovered.

Why an Apparent Gap Does Not Yet Show a Missing Indicator

The distinction between an apparent gap and a demonstrated gap in the invariant Indicator set is essential.

An apparent gap may disappear when:

existing Indicators are applied together;

the declared Boundary and Interfaces are correctly defined;

context-specific interpretation makes the existing Indicator sufficiently precise;

or

the issue proves to be specific to one infrastructure Context rather than invariant.

A demonstrated gap in the invariant Indicator set requires stronger Evidence.

The candidate function should:

be necessary to reliable Infrastructure Quality State Determination;

not already be sufficiently represented by existing Indicators;

remain distinguishable from existing Indicators;

apply across multiple infrastructure Contexts;

and

materially weaken Quality State determination if omitted.

Until these conditions are supported, the finding should remain provisional.

Interim Finding

Horizontal comparison has identified several areas requiring continued research.

The strongest concern the relationships among:

Quality-State determination and intervention;

available response time;

Authority;

Quality-State Information Integrity;

independent or parallel information paths;

possible human or organizational distortion of quality-relevant information;

and

re-determination after intervention.

These findings do not demonstrate that the current invariant Indicator set is insufficient.

They demonstrate why permanent sufficiency should not be claimed.

The existing Indicator set can remain stable while repeated Context Guide evidence is accumulated.

Where a possible gap is found, the first response should not be immediate addition or change to the invariant Indicator set.

The first response should be:

record the finding;

test it against existing Indicators;

test it in additional infrastructure Contexts;

compare it horizontally across Factors;

and

determine whether it represents a Context-Specific need or a missing invariant function.

The next Section applies this distinction directly:

7.7 Distinguishing a Missing Invariant Indicator from a Context-Specific Need

The identification of an apparent Indicator gap does not establish that an invariant Indicator is missing.

This distinction is essential.

Infrastructure Contexts differ.

A natural gas main pipeline, local gas distribution network, electric grid, data center, offshore production facility, processing plant, or other Infrastructure Quality Object may require detailed determination questions that are important in that Context but are not invariant across infrastructure generally.

The derived Factor and Indicator set must therefore remain stable enough to provide a common quality basis while allowing Context Guides to provide the detail required for particular Infrastructure Quality Objects.

The central question is:

Does the identified need reveal a missing invariant determination function, or does it require only context-specific interpretation of an existing invariant Indicator?

Context-Specific Need

A finding should normally remain Context-specific when an existing invariant Indicator already represents the necessary determination function.

The Context Guide may then identify:

the specific condition to be examined;

the relevant infrastructure component or system;

the applicable Boundary or Interface;

the required Evidence;

the applicable Lifecycle Stage;

and

the Quality Outcome Criterion.

For example, one infrastructure Context may require a particular method of detecting degradation.

Another may require a different method.

The methods may differ substantially.

But if both serve the established invariant function of determining degradation affecting Structural and Functional Integrity, the difference does not justify another invariant Indicator.

The same principle applies to:

specific hazards;

specific Environmental Interactions;

specific Monitoring methods;

specific competence requirements;

specific regulatory obligations;

specific Stakeholder impacts;

or

specific recovery arrangements.

The Context may change the content of the determination.

It does not necessarily change the invariant determination function.

The basic relationship is:

existing invariant Indicator
→ context-specific interpretation
→ Context-Specific Evidence
→ Context-Specific Quality Outcome Criterion.

In such a case, no gap in the invariant Indicator set exists.

Greater Detail Does Not Establish a Missing Indicator

Context Guides normally operate at a smaller resolution than the Factor and Indicator set.

They examine the Infrastructure Quality Object in greater detail.

Greater detail will naturally reveal conditions that do not appear explicitly in the invariant Indicator wording.

This is expected.

It does not mean that every newly visible condition requires another invariant Indicator.

For example, a Context Guide may identify several different physical degradation mechanisms.

The invariant Indicator set does not need a separate invariant Indicator for each mechanism if they are already sufficiently represented by the established degradation-related Indicator.

Likewise, a Context Guide may identify several different communication paths, operating modes, human Interfaces, or Risk Controls.

The existence of those detailed elements does not itself demonstrate missing invariant functions.

The test concerns function, not level of detail.

The question is:

Does the existing Indicator still ask the necessary quality-relevant question when applied at the more detailed Context level?

If yes, context-specific interpretation is sufficient.

A Possible Missing invariant Indicator

A stronger finding occurs when repeated Context Guide analysis reveals a necessary determination question that cannot be adequately represented through the established Indicators.

A possible missing invariant Indicator should therefore satisfy several conditions.

First, the function must be quality-relevant.

Its presence or absence must materially affect the ability to determine, preserve, restore, or understand the Infrastructure Quality State.

Second, the function must be necessary.

If the function is removed from the determination, an important part of Infrastructure Quality must become materially less visible or less determinable.

Third, the function must be distinguishable.

It must ask a question not already sufficiently represented by another invariant Indicator.

Fourth, the function must not merely represent a preferred method.

The derived Factor and Indicator set should identify what must be determined.

It should not normally prescribe one technical or organizational means of doing so.

Fifth, the function must show evidence of Context invariance.

A need appearing in only one specialized infrastructure Context may be important without being suitable for the invariant Indicator set.

Repeated appearance across substantially different Infrastructure Quality Objects provides stronger evidence that the function may be invariant.

Sixth, the function must remain meaningful at selected methodological resolution.

If it can only be stated through highly Context-specific technical detail, it is more likely to belong in a Context Guide.

The tests can therefore be summarized as:

quality relevance;

necessity;

distinguishability;

non-redundancy;

method independence;

Context invariance;

and

suitability for selected methodological resolution.

Testing a Proposed Indicator Against the Current Indicator Set

Before a new invariant Indicator is proposed, the candidate function should be tested against the complete current Indicator set.

This is important because a function first discovered under one Quality Factor may already be represented elsewhere.

The test should therefore not ask only:

Is this function explicitly present under the Factor where it was discovered?

It should ask:

Is this function already sufficiently represented anywhere in the fourteen Factors and current Indicator set?

This horizontal test is particularly important for the apparent gaps identified in Section 7.6.

For example, a Context Guide may reveal a problem involving delayed intervention after a Critical Infrastructure Condition is detected.

The first conclusion should not be:

a new time-critical intervention Indicator is required.

The finding should first be tested against existing Indicators concerning:

Risk Controls;

Workplace Human Interaction;

Personnel Competence;

Authority limitations;

Monitoring timeliness;

Quality-Critical Information;

Operational Recovery;

and

Adaptation or Recoverability.

If these Indicators, applied together, adequately represent the determination question, the finding does not justify another invariant Indicator.

If they do not, the finding becomes a stronger candidate for continued research.

Testing the Same Finding in Different Contexts

Repeated occurrence is important.

However, simple repetition is not enough.

The same technical problem may occur in several Context Guides belonging to closely related infrastructure systems.

That may still represent one sector-specific issue.

Stronger evidence of invariance exists when the same underlying determination function appears in materially different infrastructure Contexts.

For example, the physical mechanisms may differ while the underlying question remains the same.

One Context may involve rapid pressure change.

Another may involve electrical instability.

Another may involve loss of cooling.

Another may involve a process upset.

If each case reveals the same underlying problem concerning the time between Quality-State determination and effective intervention, the evidence for an invariant function becomes stronger.

The invariant candidate is then not the physical mechanism.

It is the recurring determination function revealed by those different mechanisms.

The Indicator set should capture the common function.

The Context Guide should capture the specific realization.

Testing Boundary and Interface Effects

An apparent gap may also result from an incorrectly declared Infrastructure Boundary.

This is particularly important for the provisional findings concerning Quality-State Determination and Quality-State Influence.

A Monitoring device may be inside one physical site.

The person interpreting its information may be remote.

The person with decision Authority may be located elsewhere.

Communication may pass through several physical and digital Interfaces.

An external operator, control center, specialist, or other Infrastructure-Critical Role may materially participate in determining or influencing the Infrastructure Quality State.

If these elements are excluded merely because they are geographically remote, the resulting Context analysis may falsely appear to reveal a missing Indicator.

The first question should therefore be:

Has the Infrastructure Quality Object and its relevant Boundaries and Interfaces been declared broadly enough to include the elements that materially participate in Function Realization, Quality-State determination, or Quality-State Influence?

Only after this question is resolved should an apparent Indicator gap be evaluated.

Testing Whether the Finding Is Evidence Rather Than an Indicator

Another possible source of false gaps is confusion between an Indicator and the Evidence used to evaluate it.

A Context Guide may identify a new measurement, record, test, observation, alarm, inspection result, or information source.

This does not automatically establish a new Indicator.

The new item may simply provide Evidence for an existing Indicator.

The distinction is:

Indicator
→ what quality-relevant condition or determination function is examined.

Evidence
→ what supports the finding concerning that Indicator.

Therefore:

new Evidence source
≠ new invariant Indicator.

This distinction is especially important as Context Guides become more detailed.

Testing Whether the Finding Is a Quality Outcome Criterion Rather Than an Indicator

A similar distinction applies to Quality Outcome Criteria.

A Context Guide may determine that a specific condition must remain within a defined range, limit, response time, performance level, or other acceptable state.

This does not necessarily establish a new Indicator.

The existing Indicator may already identify what must be examined.

The newly identified condition may define what result is expected or acceptable.

Therefore:

new Context-Specific acceptance condition
≠ new invariant Indicator.

The correct relationship remains:

Indicator
→ identifies what is examined.

Evidence
→ supports the finding.

Quality Outcome Criterion
→ defines the expected or acceptable condition.

The horizontal research must preserve these distinctions.

Testing Whether the Finding Is a Method

A further false gap may occur when one Context requires a particular technical or organizational method.

For example, a Context may require:

a particular Monitoring arrangement;

a specific independent verification method;

a particular safe-state mechanism;

a defined communication route;

or

a particular redundancy arrangement.

Such a method may be necessary in that Context.

But the invariant Indicator question should remain at the level of the function that makes the method necessary.

For example:

specific redundant sensors
may be a Context-Specific method.

The possible invariant function may instead concern:

sufficient reliability of Quality-State determination for the Critical Infrastructure Condition.

Similarly:

a specific emergency shutdown arrangement
may be a Context-Specific method.

The possible invariant function may concern:

effective and timely capability to prevent or limit an unacceptable Infrastructure Outcome.

The Indicator set should not be expanded merely because different Contexts use different means to realize an already established function.

Threshold for an Additional Invariant Indicator

A candidate should therefore move from a Context-Specific finding toward a possible invariant Indicator only when the evidence supports a stronger proposition:

The determination function is necessary for Infrastructure Quality State Determination or Influence;

its removal materially weakens that determination;

the function is not sufficiently represented by the current Indicator set;

it is distinguishable from existing Indicators;

it is not merely Evidence, a Quality Outcome Criterion, or a method;

and

it recurs across materially different infrastructure Contexts at a level that remains meaningful for the invariant Indicator set.

Even then, the finding should first be recorded as provisional.

an invariant Indicator should not be added automatically.

Interim Finding

The horizontal analysis supports a controlled distinction between Context-specific detail and a possible missing invariant Indicator.

Most additional detail discovered through Context Guides should be expected to remain within the Context Guide.

This includes:

specific infrastructure conditions;

specific Failure Modes;

specific Evidence;

specific technical methods;

specific limits;

specific Quality Outcome Criteria;

and

specific arrangements used to satisfy an established invariant function.

A possible gap in the invariant Indicator set exists only where repeated analysis reveals a necessary, distinguishable, non-redundant, Context-invariant determination function that the existing Indicator set does not sufficiently represent.

This distinction allows the derived Factor and Indicator set to remain stable without declaring the present Indicator set permanently sufficient.

It also provides the methodological bridge to Section 8.

The next Section explains how Context Guide applications can test whether the derived Indicator set remains adequate across different infrastructure types, while distinguishing Context-specific detail from a possible invariant determination need.

8. Testing the Indicator Architecture Through Infrastructure Context Guides

This Section treats Context Guides as applications and research cases for the derived Factors and invariant Indicators. A Factor represents a major quality-relevant dimension of Function Realization; an Indicator identifies what is examined within that Factor. The Quality Outcome Criterion states the expected or acceptable condition for the declared context. The agreed current assignments remain six Indicators under Factor 13 and one Indicator under Factor 14.

8.1 Context Guides as Applications and Research/Test Cases

Infrastructure Context Guides apply the invariant Factors and Indicators to a declared infrastructure Context.

They do not create a separate quality model for each type of infrastructure.

The fourteen Quality Factors and invariant Indicators remain the common basis.

The Context Guide makes that basis specific to the Infrastructure Quality Object being examined.

Its first role is therefore application.

However, the present study identifies a second role.

Context Guides can also serve as research and test cases for the continuing adequacy of the Indicators.

These two roles should remain distinct but connected.

Context Guide as an Application of the Indicators

As an application, a Context Guide begins with the established set of Indicators.

It does not begin by independently creating a new set of Quality Factors and Indicators.

The basic relationship is:

derived Factors and Indicators
→ declared Infrastructure Quality Object
→ context-specific interpretation
→ Evidence
→ Quality Outcome Criteria
→ Infrastructure Quality State Determination.

The invariant Indicator identifies the quality-relevant subject to be examined.

The Context Guide then determines what that Indicator means for the particular Infrastructure Quality Object.

For example, an invariant Indicator concerning degradation may require very different Evidence in:

a pipeline;

an electric grid;

a data center;

an offshore facility;

or

a processing plant.

The physical mechanisms differ.

The relevant equipment differs.

The Evidence differs.

The acceptable conditions may differ.

But the invariant determination question may remain the same.

The Context Guide therefore provides greater detail without automatically changing the set of Indicators.

Context Guide as a Test of Indicator Adequacy

Applying the Indicators also tests their adequacy.

When an invariant Indicator is applied to a real infrastructure Context, several questions become visible.

Can the Indicator be interpreted clearly?

Does it identify a necessary quality-relevant determination question?

Can appropriate Evidence be identified?

Can a meaningful Quality Outcome Criterion be established?

Does the Indicator remain distinguishable from other Indicators?

Does another Indicator already address the same question?

Does an important quality-relevant determination question appear that no existing Indicator adequately represents?

These questions cannot always be answered at the abstract invariant Indicator level alone.

The Context Guide provides a smaller resolution.

It makes the infrastructure relationships more detailed.

That detail can expose strengths, overlap, ambiguity, or possible gaps that are difficult to see at the invariant level.

This gives Context Guide development a legitimate research function.

Application can produce Evidence about the Factors and Indicators.

Testing Necessity Through Context

Section 6 applied a general removal test to the established invariant Indicators.

Context Guides allow that test to become more concrete.

For an established Indicator, the Context Guide can ask:

If this Indicator were removed from the analysis of this Infrastructure Quality Object, what quality-relevant condition would no longer be sufficiently determined?

If the answer is clear across different Contexts, evidence for the Indicator's invariant necessity becomes stronger.

For example, the technical realization of Operational Reliability may differ greatly among infrastructure systems.

But if removal of an Operational Reliability Indicator repeatedly leaves a material reliability question outside the determination, the case for its invariant necessity is strengthened.

Context Guide evidence therefore provides a practical test of the theoretical necessity argument.

Testing Distinguishability Through Context

Context Guides can also test whether apparently similar Indicators remain distinguishable in practice.

This is particularly important for recurring functions identified in Section 7.

Examples include:

change-related Indicators;

traceability Indicators;

information-retention Indicators;

cumulative-effect Indicators;

and

Indicators concerning abnormal or degraded conditions.

At selected Indicator resolution, two Indicators may appear similar.

At Context Guide resolution, their different subjects or consequences may become clearer.

The opposite can also occur.

Two Indicators that appear distinguishable in abstract wording may repeatedly require the same determination, the same Evidence, and the same interpretation in different Contexts.

That would provide a legitimate reason to examine possible overlap more closely.

The Context Guide therefore tests both:

necessary distinction;

and

possible redundancy.

Neither should be assumed from wording alone.

Testing the Three Provisional Horizontal Categories

Context Guides also provide the appropriate place to test the provisional horizontal functions identified in Section 7:

Quality-State;

Quality-State Determination;

and

Quality-State Influence.

For each established Indicator, the Context Guide can ask:

Does this Indicator primarily reveal an actual condition, capability, behavior, Result, or Outcome?

Does it primarily support the ability to determine that condition?

Does it concern capability to preserve, restore, limit, or intentionally change that condition?

Does it perform more than one of these functions?

This analysis may help explain why apparently similar Indicators remain necessary.

It may also reveal where one of the questions is repeatedly weak or absent.

The classification should remain analytical.

The Context Guide does not need to create a new normative S/D/I layer.

The purpose is to use the three functions as a research tool.

Testing the Complete Determination Path

Context Guides are especially useful for examining the apparent gaps identified in Section 7.6.

At the abstract invariant Indicator level, it is possible to identify a general path such as:

actual condition

→ observation

→ detection

→ interpretation

→ Quality-State determination

→ communication

→ decision

→ Authority

→ action

→ resulting Quality State

→ renewed determination.

A Context Guide can test how this path actually operates for a specific Infrastructure Quality Object.

It can identify:

where the condition physically develops;

how it becomes observable;

which equipment or person detects it;

which Interfaces carry the information;

who interprets it;

where the decision is made;

who possesses Authority;

what action is available;

how much time is available;

and

how the resulting condition is determined.

This does not mean that every Context Guide must contain a separate section describing this complete sequence for every Indicator.

The sequence is a research tool.

It becomes particularly useful for Critical Infrastructure Conditions where failure of the determination or Influence path may materially affect Infrastructure Results or Outcomes.

Testing Boundaries and Interfaces

Context Guide development also provides a practical test of Infrastructure Boundaries and Interfaces.

The relevant infrastructure system may not be contained within one physical site.

A quality-relevant function may involve:

field equipment;

control equipment;

communication connections;

remote workplaces;

control centers;

external technical support;

or

other physically separated elements.

A remote person may materially participate in determination or Influence of the Infrastructure Quality State.

If so, the relevant workplace and communication Interface cannot be ignored merely because it is geographically distant from the principal infrastructure facility.

The Context Guide must therefore ask:

Which physical and functional elements materially participate in Function Realization, Quality-State determination, or Quality-State Influence?

This can produce a distributed physical structure.

The infrastructure may have a central physical object with several remote connections extending to other locations.

The important issue is not geometric simplicity.

The important issue is whether the declared Boundary and Interfaces represent the actual quality-relevant system.

This Boundary test is especially important when evaluating possible Indicator gaps.

A problem should not be classified as a missing Indicator if it actually results from excluding a relevant part of the Infrastructure Quality Object from the declared Boundary or Interfaces.

Testing Evidence Sufficiency

Context Guides also test whether an invariant Indicator can be supported by adequate Evidence.

An Indicator may be conceptually necessary but difficult to determine in a particular Context.

This difficulty is itself important.

The Context Guide may reveal:

limited observability;

insufficient Monitoring;

uncertain historical information;

weak traceability;

dependence on human interpretation;

limited access to a remote condition;

or

another restriction affecting Evidence Sufficiency.

Such a finding does not automatically mean that the Indicator is defective.

It may reveal an actual limitation in the ability to determine the Infrastructure Quality State.

This distinction is important:

Indicator difficult to evaluate
≠ Indicator unnecessary.

In some cases, difficulty in obtaining sufficient Evidence may be precisely why the Indicator is necessary.

Testing Possible Additional Indicators

A Context Guide may also reveal a quality-relevant question that appears not to fit adequately under any existing Indicator.

The finding should first be recorded without changing the Indicators.

It should then be tested.

The first test is:

Can an existing Indicator reasonably represent this question?

The second is:

Is the finding actually Evidence for an existing Indicator?

The third is:

Is it a Quality Outcome Criterion?

The fourth is:

Is it only a Context-Specific method?

The fifth is:

Does the issue result from an incomplete Boundary or Interface declaration?

Only after these possibilities are excluded should the finding be treated as a candidate question not represented by the current Indicators.

Even then, one Context Guide is not normally sufficient to establish invariance.

Accumulation of Evidence Across Context Guides

The research value of Context Guides increases as the Context Guide family grows.

One Context Guide provides one test.

Several Context Guides allow comparison.

Context Guides covering materially different Infrastructure Quality Objects provide stronger evidence about invariance.

The research sequence can therefore be expressed as:

Context Guide finding

→ provisional Indicator finding

→ comparison with current Indicators

→ testing in additional Context Guides

→ horizontal comparison across different infrastructure Contexts

→ determination of whether the question is Context-specific or invariant

→ possible addition or change to the set of invariant Indicators.

This sequence prevents immediate change to the invariant Indicators after every new Context finding.

At the same time, it prevents the set of Indicators from becoming artificially closed.

Negative Evidence Is Also Useful

Context Guide testing does not need to produce new Indicators to be valuable.

Repeated failure to identify an unrepresented determination question is itself useful.

If materially different Context Guides continue to show that the established Indicators can represent the necessary quality-relevant determination questions, confidence in the adequacy of the present set of Indicators increases.

This does not prove permanent sufficiency.

A new infrastructure Context may later reveal another determination question.

But the accumulated evidence strengthens the practical basis of the set of Indicators.

Likewise, if a provisional candidate repeatedly disappears when tested against existing Indicators, that finding should be recorded.

It may demonstrate that the current set of Indicators is broader than initially apparent.

Context Guides as Applications and Research Tests

The combined application and research roles of Context Guides therefore support controlled development of the derived Factors and Indicators.

The invariant Indicators remain stable.

Context Guides become more detailed.

Findings are recorded.

Recurring functions are compared horizontally.

Possible gaps are tested rather than immediately accepted.

Only sufficiently supported invariant findings move toward addition or change to the set of invariant Indicators.

This relationship can be summarized as:

stable set of invariant Indicators

→ multiple Context-Specific applications

→ accumulated Evidence

→ horizontal research

→ provisional Indicator findings

→ controlled revision only when justified.

Interim Finding

Infrastructure Context Guides can serve two legitimate purposes at the same time.

They apply the invariant Factors and Indicators to specific Infrastructure Quality Objects.

They also provide practical research and test cases for evaluating the continuing adequacy of the invariant Indicators.

These roles are compatible.

The first preserves consistency.

The second prevents artificial closure.

The Context Guide therefore becomes the principal practical mechanism through which the necessity, distinguishability, applicability, and continuing adequacy of the invariant Indicators can be tested against increasingly detailed infrastructure conditions.

The next Section examines the Evidence already available from existing Infrastructure Context Guides:

8.2 Evidence from Existing Infrastructure Context Guides

The existing Infrastructure Context Guides already provide an initial practical basis for testing the invariant Indicators.

The present Context Guide family includes infrastructure objects with substantially different Intended Functions, technologies, physical configurations, Boundaries, Interfaces, Failure Modes, operating conditions, Reference Layer requirements, Evidence, and Quality Outcome Criteria.

These differences are important.

If the same invariant Indicators remain meaningful across materially different infrastructure Contexts, this provides practical support for their invariance.

It does not prove permanent sufficiency.

Existing Context Guides as Evidence

IQI FJQ1 examined the existing Context Guide family as part of the justification of the fourteen invariant Quality Factors.

That analysis found that the same fourteen major quality-relevant dimensions remained meaningful across the examined infrastructure Contexts even though their specific realization differed.

The same Context Guides can now be examined at the smaller Indicator resolution.

The question changes from:

Do the fourteen Quality Factors remain necessary across different infrastructure Contexts?

to:

Do the established Indicators under those Factors continue to represent necessary and distinguishable determination questions when applied to different Infrastructure Quality Objects?

This is a more detailed test.

A Factor may remain clearly necessary while its internal Indicator set still requires further examination.

Evidence of Different Infrastructure Realizations

The existing Context Guides show that one invariant Indicator can have very different physical or operational realization in different infrastructure Contexts.

For example, Structural and Functional Integrity is relevant across infrastructure types.

But the conditions through which Integrity is determined may differ substantially.

The relevant:

loads;

materials;

degradation mechanisms;

equipment;

Interfaces;

Failure Modes;

Monitoring;

inspection;

and

Evidence

may differ from one Infrastructure Quality Object to another.

The invariant Indicator therefore does not require identical physical realization.

Its invariance concerns the determination question.

The same principle applies to Operational Reliability.

Different infrastructure objects may realize their Intended Functions through completely different technical processes.

The specific disturbance, degradation mechanism, failure path, and Recovery Capability may differ.

But the determination question concerning reliable Function Realization remains meaningful.

This provides practical support for separating:

the question addressed by the invariant Indicator

from

Context-Specific realization.

Evidence from Different Boundaries and Interfaces

The existing Context Guides also show that Infrastructure Boundaries and Interfaces differ substantially by Context.

Some infrastructure objects extend over large geographic areas.

Others are concentrated within a facility.

Some depend strongly on interfaces with upstream or downstream infrastructure.

Others depend on external energy, communications, control, transport, or human interaction.

This difference is useful for Indicator testing.

An invariant Indicator should remain meaningful even when the physical arrangement through which the relevant condition occurs changes.

For example, an Interface-related condition may occur:

between physical components;

between infrastructure segments;

between infrastructure and the environment;

between infrastructure and a human workplace;

or

through a communication connection to a remote location.

The physical form changes.

The quality-relevant determination question may remain the same.

This supports the need to test Indicators against the declared Infrastructure Quality Object rather than against one assumed physical arrangement.

Evidence from Different Failure Modes

The existing Context Guides also contain different Failure Modes.

This is particularly important because the Quality Factors and Indicators are intended to remain meaningful despite these differences.

One infrastructure Context may be vulnerable to:

loss of containment;

another to loss of electrical function;

another to loss of cooling;

another to structural degradation;

another to control failure;

another to loss of required throughput or service.

The specific Failure Mode does not itself define the invariant Indicator.

Instead, the Failure Mode helps test whether the Indicator captures the quality-relevant condition associated with loss or degradation that affects realization of Intended Functions.

This provides practical evidence for the distinction:

Failure Mode
→ Context-specific manifestation of possible Function Realization failure.

invariant Indicator
→ identifies what is examined.

Evidence from Different Quality Outcome Criteria

The existing Context Guides also demonstrate why invariant Indicators should not be confused with Quality Outcome Criteria.

The same Indicator may require different acceptable conditions in different infrastructure Contexts.

For example, the required:

capacity;

reliability;

response;

integrity condition;

environmental performance;

Risk level;

or

recovery condition

may differ according to the Infrastructure Quality Object and its applicable Reference Layer.

This does not require different invariant Indicators.

The Indicator remains invariant.

The Quality Outcome Criterion defines the expected or acceptable condition for the specific Context.

Therefore:

same Indicator
+ different Infrastructure Context
→ different Quality Outcome Criterion may be appropriate.

This is expected within the IQI model.

Evidence from Different Reference Layers

The existing Context Guides also operate under different Reference Layer requirements.

Applicable laws, regulations, codes, standards, specifications, permits, and other requirements may differ by:

infrastructure type;

jurisdiction;

Lifecycle Stage;

technology;

location;

and

intended use.

This provides another practical test of invariance.

The invariant Indicator should not depend on one particular regulatory or standards system.

For example, Factor 10 requires determination of Applicable Regulatory and Standards Requirements.

The actual requirements differ by Context.

The invariant determination question does not.

This supports the separation between:

invariant Indicator
→ what must be determined;

Reference Layer
→ applicable external basis;

Quality Outcome Criterion
→ expected or acceptable Context-Specific condition.

Evidence from Different Evidence Sources

The existing Context Guides also show that Evidence supporting an Indicator may differ substantially.

Depending on the Context, Evidence may include:

Design information;

technical specifications;

inspection results;

test results;

Monitoring Data;

operational records;

maintenance information;

Conformity Statements;

regulatory records;

environmental information;

workplace observations;

or

other Context-relevant Evidence.

This variation is expected.

It reinforces the distinction:

same invariant Indicator
≠ same Evidence in every Context.

The Indicator identifies what must be examined.

The Context determines what Evidence is appropriate to support the finding.

This is particularly important when testing whether a new item identified during Context Guide development is actually a new Indicator.

A new Evidence source does not establish a new determination question.

Evidence of Indicator Necessity

The existing Context Guides can also strengthen the removal test developed in Section 4.

Where an Indicator addresses a necessary condition across materially different infrastructure Contexts, its removal would repeatedly weaken the Quality State determination.

For example, removing the ability to examine degradation would not affect only one infrastructure type.

The physical degradation mechanism may change, but the need to determine whether degradation affects Function Realization remains.

Likewise, removing consideration of abnormal or degraded conditions would create problems across infrastructure systems even though the abnormal conditions themselves differ.

The same logic applies to:

change;

Uncertainty;

Monitoring;

Personnel Competence;

traceability;

and

other recurring functions identified in Section 7.

Repeated Context application therefore provides practical support for necessity.

Evidence of Indicator Distinguishability

Context Guides can also show why apparently similar Indicators remain separate.

For example:

Monitoring relevance under change

and

Technical Specification change

both concern change.

But their practical application differs.

One asks whether the technical basis remains appropriate.

The other asks whether the observation capability remains appropriate.

Likewise:

retention of Risk knowledge

and

retention of Monitoring knowledge

both concern information retention.

But the knowledge needed to determine Risk may differ from the knowledge needed to interpret Monitoring Data.

Context application can therefore demonstrate that similar horizontal functions remain necessary within different subjects.

This is important evidence against premature consolidation.

Evidence of Possible Overlap

The opposite finding is also possible.

If two Indicators repeatedly:

ask substantially the same determination question;

require substantially the same Evidence;

produce the same interpretation;

and

cannot be meaningfully distinguished across different Context Guides,

the case for separate invariant treatment becomes weaker.

Such a finding should not immediately result in removal or combination.

It should first be recorded as a provisional finding about a possible Indicator addition or change.

The apparent overlap should then be tested in additional Contexts.

This is especially important for the repeated:

traceability;

information-retention;

and

change-related

functions identified in Section 7.

Evidence Concerning the Three Provisional Functions

The existing Context Guide family also provides an initial basis for testing the provisional:

Quality-State;

Quality-State Determination;

and

Quality-State Influence

functions.

Different infrastructure Contexts may realize these functions differently.

A Quality-State condition may be physical in one Context and operational in another.

Quality-State Determination may depend primarily on instrumentation in one Context and substantially on human observation or interpretation in another.

Quality-State Influence may occur through an automatic protective system in one Context, through an operator action in another, and through recovery or modification in another.

The physical means differ.

The underlying functions may recur.

This is precisely the type of evidence needed to determine whether the three-function classification has useful horizontal meaning.

Evidence of Possible Gaps

The existing Context Guides can also reveal where the present set of Indicators should be examined more closely.

However, the current evidence should be interpreted carefully.

A Context Guide finding may reveal:

a new technical condition;

a new Failure Mode;

a new Evidence source;

a new Quality Outcome Criterion;

a new Context-Specific method;

or

a more detailed Boundary or Interface.

None of these automatically demonstrates a missing invariant Indicator.

The stronger question is:

Does the Context Guide reveal a necessary determination question that cannot be adequately represented through the current Indicators?

If the answer is uncertain, the finding should remain provisional.

Evidence from one Context should not be used to redesign the set of Indicators prematurely.

What the Existing Context Guides Demonstrate

The existing Context Guide evidence supports several conclusions.

First, the Indicators can be applied to Infrastructure Quality Objects that differ substantially in Intended Function, technology, physical form, Boundaries, Interfaces, Failure Modes, operating conditions, Reference Layer requirements, Evidence, and Quality Outcome Criteria.

Second, the same question addressed by the Indicator can remain meaningful even when its physical realization is very different.

Third, Context-specific detail can usually be introduced through interpretation, Evidence, and Quality Outcome Criteria without changing the invariant Indicator.

Fourth, repeated application can strengthen the case for Indicator necessity and distinguishability.

Fifth, Context Guides can also reveal possible overlap or determination questions not yet represented that deserve further testing.

What the Existing Context Guides Do Not Demonstrate

The existing Context Guide family does not demonstrate that the present set of Indicators is permanently sufficient.

The number and variety of infrastructure Contexts remain limited.

New Contexts may reveal relationships or determination questions not sufficiently visible in the present applications.

The existing Context Guides also do not demonstrate that every apparent repetition among Indicators is permanently necessary.

Horizontal comparison may reveal opportunities for refinement.

The correct conclusion is therefore limited:

Existing Context Guide evidence supports the present set of Indicators as a workable invariant basis for continued application and testing.

It does not establish permanent closure of that set.

Interim Finding

The existing Infrastructure Context Guides provide practical evidence supporting the use of invariant Indicators across different infrastructure Contexts.

Their value comes partly from their differences.

Different Intended Functions, technologies, Boundaries, Interfaces, Failure Modes, operating conditions, Reference Layer requirements, Evidence, and Quality Outcome Criteria provide different tests of the same invariant Indicators.

The evidence presently supports continued use of the established Indicators.

It also supports continued testing.

No conclusion of permanent sufficiency follows.

The next Section examines how one invariant Indicator can retain its meaning while being interpreted differently across infrastructure Contexts:

8.3 Interpretation of Invariant Indicators in Different Infrastructure Contexts

An invariant Indicator must remain meaningful across different infrastructure Contexts.

This does not mean that the Indicator must look the same in every Context.

The Indicator remains invariant.

Its context-specific interpretation changes.

This distinction is central to the IQI approach.

The relationship can be expressed as:

Invariant Indicator
→ context-specific interpretation
→ Context-Specific Evidence
→ Context-Specific Quality Outcome Criterion.

The Indicator identifies what must be examined.

The Context Guide identifies what that examination means for the declared Infrastructure Quality Object.

The Meaning of context-specific interpretation

context-specific interpretation does not replace or rewrite the invariant Indicator.

It explains how the invariant Indicator applies to a particular Infrastructure Quality Object.

The interpretation may identify:

which parts of the Infrastructure Quality Object are relevant;

which Boundaries and Interfaces are involved;

which Lifecycle Stages are relevant;

which Failure Modes affect the Indicator;

which operating conditions must be considered;

which Evidence can support the finding;

and

which Context-Specific conditions must be satisfied.

The interpretation therefore moves from the general question addressed by the invariant Indicator to the smaller resolution required for actual Infrastructure Quality State Determination.

The Indicator remains the same determination subject.

Its realization becomes specific.

Different Physical Realizations of the Same Indicator

The same invariant Indicator may apply to very different physical conditions.

Consider an Indicator concerning Structural and Functional Integrity.

In one infrastructure Context, the relevant condition may concern:

pipe wall condition;

welds;

supports;

valves;

pressure-containing components;

or

ground movement.

In another Context, the relevant condition may concern:

buildings;

structural supports;

electrical equipment;

cooling equipment;

power distribution equipment;

cabling;

or

other physical elements necessary for Function Realization.

These physical elements differ.

The invariant question does not.

The Indicator still asks whether the relevant Structural and Functional Integrity condition is sufficient for the declared Infrastructure Quality Object.

The Context Guide determines what must be examined to answer that question.

Different Failure Modes

The same principle applies to Failure Modes.

An invariant Indicator may be relevant to different Failure Modes in different infrastructure Contexts.

For example, loss or degradation that prevents realization of a required Intended Function may result from:

loss of containment;

structural failure;

equipment degradation;

loss of electrical supply;

loss of cooling;

control-system failure;

communication failure;

or

another Context-Specific condition.

The Failure Modes differ.

But the invariant Indicator may continue to represent the same quality-relevant determination question.

Therefore:

different Failure Mode
≠ different invariant Indicator necessarily required.

The Context Guide must determine whether the existing Indicator adequately represents the quality-relevant question created by that Failure Mode.

Different Boundaries

context-specific interpretation is also affected by the declared Infrastructure Boundary.

Some Infrastructure Quality Objects are geographically compact.

Others extend over long distances.

Some consist of several physically separated facilities or operating locations.

Some depend on remote elements that materially participate in Function Realization or Quality-State determination.

The physical Boundary therefore cannot be assumed from the name of the infrastructure alone.

It must be declared for the Quality Object being examined.

This becomes particularly important when applying Indicators concerning:

Monitoring;

Workplace Human Interaction;

Personnel Competence;

Documentation and Traceability;

Operational Reliability;

and

Quality-State Influence.

A relevant element may be geographically remote while still participating materially in the Infrastructure Quality Object.

The invariant Indicator does not change because the physical arrangement changes.

Its context-specific interpretation must reflect the actual Boundary.

Different Interfaces

The same principle applies to Interfaces.

An Interface may connect:

one infrastructure component to another;

one infrastructure segment to another;

the infrastructure to an upstream or downstream system;

the infrastructure to an energy source;

the infrastructure to the environment;

the infrastructure to a workplace;

or

the infrastructure to a remote person or system through a communication connection.

The physical form of the Interface may differ greatly.

The quality-relevant question may remain invariant.

For example, information required for Quality-State determination may travel through a physical communication connection to a remote workplace.

The person at that workplace may observe, interpret, decide upon, or influence the Infrastructure Quality State.

In such a Context, the communication Interface becomes part of the quality-relevant analysis.

The Indicator should therefore be interpreted according to the actual functional relationship, not merely according to geographic proximity.

Different Lifecycle Realizations

The same invariant Indicator may also require different interpretation at different Lifecycle Stages.

During Design, an Indicator may be evaluated mainly through:

requirements;

Assumptions;

analyses;

Design information;

and

technical decisions.

During Construction, the same Indicator may depend on:

materials;

installation;

inspection;

testing;

Conformity Evidence;

and

realized configuration.

During Operation, it may depend on:

actual behavior;

Monitoring;

inspection;

degradation;

maintenance;

operating conditions;

and

Infrastructure Results.

During Repair/Modification, the Indicator may require determination of:

what changed;

why it changed;

whether earlier Assumptions remain valid;

whether Interfaces changed;

and

whether the earlier Quality State determination remains applicable.

The Indicator remains invariant.

The Evidence and interpretation change with the Lifecycle Stage.

Different Evidence for the Same Indicator

context-specific interpretation also determines what Evidence is appropriate.

The same invariant Indicator may be supported by different Evidence in different Contexts.

For example, Evidence may include:

physical inspection;

test results;

instrument readings;

Monitoring Data;

operating history;

Design analysis;

technical calculations;

Conformity Evidence;

human observation;

or

other Context-relevant information.

The set of invariant Indicators does not need to prescribe one universal Evidence type.

Each Indicator identifies what must be examined; the Context Guide specifies what Evidence can support a finding in that Context.

This distinction protects the set of Indicators from becoming tied to one technology or infrastructure sector.

It also protects against another error:

different Evidence
≠ different Indicator.

Different Quality Outcome Criteria

The Quality Outcome Criterion may also differ while the Indicator remains invariant.

One infrastructure Context may require one acceptable condition.

Another may require another.

The difference may arise from:

Intended Function;

operating conditions;

Risk;

Reference Layer requirements;

environmental conditions;

Interfaces;

Lifecycle Stage;

or

other Context-Specific conditions.

Therefore:

same Indicator
+ different Context
→ different Quality Outcome Criterion may be appropriate.

This does not weaken invariance.

It is the reason the invariant Indicator and Quality Outcome Criterion are separate.

The Indicator identifies what is examined.

The Context determines what condition is expected or acceptable.

Different Resolution

Context Guides also operate at a smaller resolution than the set of Indicators.

This means that one invariant Indicator may require several detailed Context-Specific questions.

For example:

one invariant Indicator
→ several Context-Specific conditions
→ several Evidence sources
→ one or more Context-Specific findings.

This is not necessarily Indicator multiplication.

The smaller resolution simply makes visible the detailed conditions needed to determine the invariant Indicator for that Infrastructure Quality Object.

This distinction is important for the continuing development of Context Guides.

As the resolution becomes smaller, more detail will appear.

The appearance of additional detail should not automatically lead to expansion of the set of Indicators.

The test remains functional:

Does the existing Indicator still represent the necessary quality-relevant determination question?

If yes, the additional detail belongs in the Context Guide.

Limits of context-specific interpretation

context-specific interpretation must also have limits.

It should not be used to hide a genuine gap among the Indicators.

If a necessary quality-relevant determination question repeatedly cannot be represented by the established set of Indicators, it should not be artificially placed under the nearest existing Indicator merely to preserve the current set of Indicators.

Doing so would create apparent stability at the cost of determination quality.

Therefore, context-specific interpretation should remain faithful to the meaning of the invariant Indicator.

It may make the Indicator more specific.

It should not make the Indicator address an unrelated question.

The test is:

Can the Context-Specific question reasonably be understood as an application of the invariant Indicator?

If yes, context-specific interpretation is appropriate.

If no, the finding should be recorded separately and tested as a possible additional Indicator role.

Interpretation and Apparent Overlap

context-specific interpretation can also help resolve apparent overlap among invariant Indicators.

At the level of the set of Indicators, two Indicators may use similar concepts.

At smaller Context resolution, they may produce clearly different questions.

For example:

one Indicator may ask whether Monitoring remains relevant after change;

another may ask whether Technical Specifications remain valid after change.

Both concern change.

But the Context Guide may show that they require different Evidence and protect different parts of the Quality State determination.

In that case, Context application supports their distinguishability.

If repeated Context Guides instead show that two Indicators consistently collapse into the same determination question, the possible overlap should be recorded for horizontal research.

Interpretation and the Three Provisional Functions

context-specific interpretation can also help test the provisional Quality-State, Quality-State Determination, and Quality-State Influence functions.

An Indicator may appear primarily Determination-oriented at selected Indicator resolution.

In a particular Context, its connection to Influence may become more visible.

For example, timely Monitoring is clearly a Determination function.

But in a rapidly developing Critical Infrastructure Condition, its Context-Specific importance may depend on whether sufficient time remains for intervention.

Likewise, Personnel Competence may support Determination in one situation and both Determination and Influence in another.

This does not mean that the invariant Indicator changes.

It shows that its functional role may become clearer when applied to a real Infrastructure Quality Object.

Interpretation Must Follow the Declared Quality Object

The context-specific interpretation must always follow the declared Infrastructure Quality Object.

It should not be limited by an assumed conventional description of the infrastructure.

If Function Realization depends on:

a building;

equipment;

utilities;

control systems;

communication connections;

remote workplaces;

human–infrastructure Interfaces;

or

other physically distributed elements,

those elements must be considered according to their actual quality-relevant role.

The same principle applies to external Interfaces.

For example, a physical connection to another infrastructure system may define an important Boundary condition even where the connected external system itself is outside the declared Quality Object.

The purpose is not to make the Infrastructure Boundary unlimited.

The purpose is to declare it correctly.

Only then can the invariant Indicators be interpreted correctly.

Interim Finding

The existing invariant Indicators can remain invariant while their practical meaning becomes specific through Context Guides.

This relationship is essential to the IQI model.

The invariant Indicator identifies the quality-relevant determination subject.

The Context Guide identifies how that subject appears in the declared Infrastructure Quality Object.

The Evidence supports the resulting finding.

The Quality Outcome Criterion establishes the expected or acceptable Context-Specific condition.

Therefore:

invariance
≠ identical physical realization.

And:

context-specific interpretation
≠ modification of the invariant Indicator.

This distinction allows the set of Indicators to remain stable across different infrastructure systems while allowing Context Guides to operate at the smaller resolution required for meaningful Infrastructure Quality State Determination.

At the same time, context-specific interpretation must not be used to conceal a determination question not represented by an invariant Indicator.

Where a necessary determination question cannot reasonably be represented by an existing Indicator, the finding should remain visible and be tested through additional Context Guides.

The next Section examines the relationship among the invariant Indicator, Context-Specific Evidence, and Quality Outcome Criterion:

8.4 Context-Specific Evidence and Quality Outcome Criteria

The invariant Indicator identifies what must be examined.

It does not by itself determine what Evidence must be used in every infrastructure Context.

It also does not establish one universal acceptable result for every Infrastructure Quality Object.

These functions belong at different levels of the IQI structure.

The relationship is:

invariant Indicator
→ identifies what must be examined;

Context-Specific Evidence
→ supports the finding concerning what is examined;

Quality Outcome Criterion
→ establishes the expected or acceptable condition against which the finding is interpreted.

This distinction becomes particularly important when Context Guides are used to test the continuing adequacy of the set of Indicators.

Different Evidence does not necessarily mean that a different Indicator is needed.

A different acceptable condition does not necessarily mean that a different Indicator is needed.

Context-Specific Evidence

Evidence must relate to the Infrastructure Quality Object, the Indicator being examined, the applicable Lifecycle Stage, and the specific condition being determined.

The Evidence needed for one Indicator may therefore differ substantially among infrastructure Contexts.

Evidence may include, as applicable:

Design information;

technical specifications;

calculations;

inspection findings;

test results;

Monitoring Data;

operating records;

maintenance records;

repair or modification records;

Conformity Evidence;

Compliance Evidence;

environmental information;

workplace observations;

Stakeholder or Community observations;

and

other information relevant to the determination.

The important question is not whether every Context uses the same Evidence.

The question is:

Does the available Evidence sufficiently support the finding required by the Indicator?

The same invariant Indicator can therefore remain applicable even where the Evidence used to evaluate it is completely different.

Evidence Must Support the Finding

The existence of Evidence does not by itself establish a Quality-State finding.

Evidence must be relevant to the condition being examined.

It must also be sufficient for the conclusion being made.

This distinction can be expressed as:

information exists
≠ relevant Evidence necessarily exists;

relevant Evidence exists
≠ Evidence is necessarily sufficient;

sufficient Evidence exists
≠ acceptable Quality State necessarily exists.

The Evidence supports the finding.

It does not predetermine the result.

This is particularly important where an Infrastructure Quality Object has extensive records, Monitoring Data, inspection information, or other documentation.

A large amount of information does not necessarily provide sufficient Evidence for the particular Indicator being examined.

Evidence and the Declared Infrastructure Quality Object

Evidence must also correspond to the declared Infrastructure Quality Object.

If the Boundary is incomplete, the Evidence may also be incomplete.

If a relevant Interface is excluded, information concerning that Interface may not enter the determination.

If a remote workplace materially participates in Quality-State determination or Influence but is excluded from the analysis, Evidence concerning that part of the determination path may also be missed.

Therefore:

correct declaration of the Infrastructure Quality Object
→ correct identification of relevant Evidence.

This relationship is especially important for distributed infrastructure systems.

The relevant Evidence may originate from physically separated locations.

Its location does not determine its relevance.

Its relationship to the declared Infrastructure Quality Object does.

Evidence and Lifecycle Stage

Evidence may also change across the Infrastructure Lifecycle.

During Design, Evidence may primarily concern:

Functional and Technical Requirements;

Design Assumptions;

analyses;

calculations;

and

planned realization.

During Construction and Commissioning, Evidence may include:

material records;

installation information;

inspection;

testing;

Conformity Assessment;

and

realized configuration.

During Operation and Maintenance, Evidence may include:

actual performance;

Monitoring;

inspection;

degradation;

failures;

maintenance;

Risk information;

and

Infrastructure Results and Outcomes.

During Repair or Modification, Evidence may need to show:

what changed;

why it changed;

whether earlier Assumptions remain valid;

whether Boundaries or Interfaces changed;

and

whether the earlier Quality State determination remains applicable.

The Indicator can remain invariant while its supporting Evidence changes across the Lifecycle.

Evidence and Uncertainty

Evidence also has limits.

Measurement uncertainty may exist.

Historical information may be incomplete.

Operating conditions may not cover every foreseeable condition.

A new technology may have limited operating history.

A human observation may require interpretation.

Monitoring may have limited sensitivity or coverage.

A Quality-State determination should therefore not hide material limitations in the Evidence on which it depends.

This is especially important where a positive finding could otherwise create confidence beyond what the available Evidence supports.

The question is not simply:

Is Evidence available?

It is also:

What does the Evidence actually support?

And:

What does it not support?

Quality Outcome Criteria

The Quality Outcome Criterion performs a different function.

It establishes the expected or acceptable condition for the Indicator in the applicable Context.

The invariant Indicator may remain invariant while the Quality Outcome Criterion changes.

For example, an Indicator may concern Operational Reliability.

Different Infrastructure Quality Objects may require different:

performance levels;

continuity conditions;

recovery conditions;

or

acceptable limits.

The invariant Indicator remains Operational Reliability-related.

The Context-Specific Quality Outcome Criterion establishes what acceptable reliability means for the particular Infrastructure Quality Object.

The same principle applies to:

Structural and Functional Integrity;

Environmental Protection;

Risk;

Monitoring;

Personnel Competence;

Compliance;

Stakeholder and Community effects;

and

Adaptability.

Different Contexts may require different acceptable conditions.

This does not require different invariant Indicators.

Sources of Quality Outcome Criteria

A Context-Specific Quality Outcome Criterion may be established from the applicable basis for the Infrastructure Quality Object.

Depending on the Context, that basis may include:

Functional Requirements;

Technical Requirements;

Applicable Regulatory Requirements;

Applicable Standards;

Design requirements;

operating requirements;

Risk-based conditions;

environmental requirements;

or

other justified Context-Specific requirements.

The relevant basis must be identifiable.

The Quality Outcome Criterion should not be an unsupported preference.

It must represent an expected or acceptable condition appropriate to the determination being made.

Indicator and Quality Outcome Criterion Must Remain Separate

The separation between Indicator and Quality Outcome Criterion protects the invariance of the set of Indicators.

If every Context-Specific acceptable value or condition were placed directly into the invariant Indicator, the Indicator could no longer remain invariant across different Infrastructure Quality Objects.

The relationship is instead:

Indicator
→ What must be examined?

Quality Outcome Criterion
→ What condition is expected or acceptable here?

Evidence
→ What supports the finding about the actual condition?

The resulting comparison is:

Evidence-Supported Finding
↔ Quality Outcome Criterion.

That comparison contributes to determination of the Infrastructure Quality State.

A New Criterion Is Not a New Indicator

Context Guide development will naturally produce new Quality Outcome Criteria.

This is expected.

A newly identified acceptable:

limit;

range;

response time;

capacity;

performance condition;

recovery condition;

safety condition;

or

other Context-Specific result

does not by itself justify another invariant Indicator.

The first question must be:

Does an existing Indicator already identify the quality-relevant subject to which this criterion applies?

If yes, the new finding belongs at the Quality Outcome Criterion level.

This prevents unnecessary expansion of the invariant Indicators.

A New Evidence Source Is Not a New Indicator

The same rule applies to Evidence.

A Context Guide may identify a new:

sensor;

test;

inspection;

record;

calculation;

observation;

data source;

or

assessment method.

This may materially improve Quality-State determination.

But it does not automatically create a new invariant Indicator.

The question remains:

What quality-relevant condition does this Evidence help determine?

If that condition is already represented by an established Indicator, the finding belongs at the Evidence level.

The distinction is:

new way of determining an established subject
≠ new invariant determination subject.

Evidence May Reveal a Possible Indicator Gap

Although new Evidence does not itself create a new Indicator, Evidence may reveal a condition that the existing Indicators do not adequately represent.

For example, repeated Context Guide Evidence may reveal a quality-relevant relationship that was not previously visible.

The correct response is not to classify the Evidence itself as an Indicator.

The underlying determination question must first be identified.

The research sequence is:

new Evidence
→ previously insufficiently visible condition
→ identification of the underlying determination question
→ test against current Indicators
→ test for necessity and distinguishability
→ comparison across additional Contexts
→ possible provisional Indicator finding.

This preserves the distinction between what reveals the problem and what the set of Indicators may eventually need to examine.

Quality Outcome Criteria May Also Reveal a Possible Gap

A similar situation can arise when Context Guide development repeatedly requires a Quality Outcome Criterion that cannot reasonably be connected to any established invariant Indicator.

This may indicate that the underlying quality-relevant subject is not sufficiently represented.

Again, the criterion itself is not the missing Indicator.

The research question becomes:

What invariant determination question makes this criterion necessary?

That determination question should then be tested against the current set of Indicators.

Only after that analysis could a possible additional invariant Indicator be considered.

Evidence, Criteria, and the Three Provisional Functions

The distinction among Indicator, Evidence, and Quality Outcome Criterion also helps clarify the provisional Quality-State, Quality-State Determination, and Quality-State Influence functions.

Evidence is especially important to Quality-State Determination.

It supports the path from actual condition to justified finding.

The Quality Outcome Criterion provides the basis against which that finding is interpreted.

Quality-State Influence may then act upon the condition where preservation, prevention, mitigation, recovery, or Adaptation is required.

The resulting condition must again be supported by Evidence and interpreted against the applicable Quality Outcome Criterion.

The relationship can therefore become:

actual Quality State

→ Evidence

→ Evidence-Supported Finding

→ comparison with Quality Outcome Criterion

→ Quality-State determination

→ where required, Quality-State Influence

→ changed or preserved Quality State

→ new Evidence

→ renewed determination.

This reinforces the conclusion reached in Section 7.

Determination and Influence form a continuing relationship rather than a one-time assessment.

Context Guides Preserve the Separation

A well-developed Context Guide should therefore preserve clear separation among:

the invariant Indicator;

its context-specific interpretation;

the Evidence used to evaluate it;

and

the applicable Quality Outcome Criterion.

This separation provides several benefits.

It allows the invariant Indicator to remain stable.

It allows Evidence to change as technology, Monitoring, knowledge, or Lifecycle conditions change.

It allows Quality Outcome Criteria to reflect the actual Infrastructure Context and applicable Reference Layer.

It also makes possible a more reliable test of whether a newly identified issue represents:

additional Evidence;

a different criterion;

a more detailed Context-Specific interpretation;

or

a genuinely missing determination question that no existing Indicator addresses.

Interim Finding

Context-Specific Evidence and Quality Outcome Criteria are essential to applying the invariant Indicators, but they perform different functions.

The invariant Indicator identifies what must be examined.

Evidence supports the finding concerning the actual condition.

The Quality Outcome Criterion establishes the expected or acceptable Context-Specific condition.

Therefore:

new Evidence
≠ new Indicator;

new Quality Outcome Criterion
≠ new Indicator;

greater Context-Specific detail
≠ new Indicator.

A possible new invariant Indicator should be considered only where the underlying necessary determination question cannot be adequately represented by the established set of Indicators.

This distinction is important for keeping the derived Factors and Indicators both stable and open to justified development.

The next Section examines how repeated Context Guide work can identify recurring Indicator gaps:

8.5 Identification of Recurring Indicator Gaps

A possible Indicator gap should not be identified from one isolated Context Guide finding.

The stronger question is whether the same underlying determination question repeatedly appears across different Infrastructure Quality Objects and remains insufficiently represented by the established invariant Indicators.

This Section therefore focuses on recurrence.

The basic research sequence is:

Context Guide finding
→ identification of the underlying determination question
→ test against the current set of Indicators
→ preservation as a provisional finding if still unresolved
→ comparison across additional Context Guides
→ determination of whether the same function recurs.

A recurring Indicator gap is therefore not simply the repetition of the same technical problem.

Different infrastructure Contexts may reveal different physical problems that point to the same underlying determination question.

For example, one Context may reveal a problem involving pressure.

Another may reveal a problem involving electrical supply.

Another may reveal a problem involving cooling.

Another may reveal a problem involving communication.

The physical mechanisms differ.

The relevant research question is:

Do these different mechanisms reveal the same missing quality-relevant determination question?

If yes, the evidence for a possible invariant gap among the Indicators becomes stronger.

Recurring Technical Detail Is Not Enough

A recurring technical feature does not automatically justify an invariant Indicator.

Several Context Guides may contain:

valves;

sensors;

alarms;

remote operators;

backup systems;

inspection methods;

or

particular communication links.

Their repeated appearance may reflect common technology rather than a quality-relevant question not represented by an invariant Indicator.

The Indicator set should therefore not be expanded merely because the same technical element appears repeatedly.

The test must remain functional.

The question is:

What necessary quality-relevant determination question does this repeated technical feature reveal?

If an existing invariant Indicator already represents that question, no gap among the Indicators exists.

Recurring Quality Outcome Criteria Are Not Enough

The same principle applies to Quality Outcome Criteria.

Several Context Guides may require similar:

response times;

performance margins;

recovery requirements;

monitoring sensitivity;

or

acceptance limits.

This may be important.

But recurrence of a criterion does not itself establish a missing Indicator.

The question remains:

What invariant subject is this criterion evaluating?

If the subject is already represented by an established Indicator, the criterion remains Context-specific.

Recurring Evidence Sources Are Not Enough

Repeated use of the same Evidence source also does not establish a gap.

Several infrastructure Contexts may rely on:

inspection;

Monitoring Data;

operator observation;

testing;

or

historical performance information.

This shows that the Evidence source is useful.

It does not necessarily identify a new determination question addressed by the Indicator.

The distinction remains:

Evidence
→ supports the finding.

Indicator
→ identifies what must be examined.

What Counts as a Recurring Gap

A stronger recurring gap appears when several conditions are present.

First, the same underlying determination question appears in more than one Context.

Second, the Contexts are materially different.

Third, the question is necessary for responsible Infrastructure Quality State Determination or Influence.

Fourth, the question cannot be adequately represented by the current set of Indicators.

Fifth, omission of the question creates a material loss of visibility or determinability.

Sixth, the question can be stated at a selected methodological resolution without depending on one technology or sector.

The relationship can be expressed as:

different infrastructure Contexts
→ different physical manifestations
→ same unresolved determination question
→ possible significance for the invariant Indicators.

Strength of Recurrence

Not all recurrence provides the same level of support.

A finding repeated across closely related Context Guides provides useful evidence.

A finding repeated across substantially different infrastructure systems provides stronger evidence.

For example:

the same issue appearing in several natural-gas pipeline Contexts
→ useful recurrence;

the same underlying question appearing in pipelines, electric-power infrastructure, data centers, offshore facilities, and other different Infrastructure Quality Objects
→ stronger evidence of invariance.

The research should therefore record not only how often the finding appears but also how different the Contexts are.

Factor Location of the Gap

A recurring finding may first appear under one Quality Factor.

That does not necessarily mean that a new Indicator belongs under that Factor.

Horizontal analysis must test the complete set of Indicators.

For example, a finding identified during Monitoring analysis may actually be adequately represented through:

Personnel Competence;

Documentation and Traceability;

Process Safety;

Operational Reliability;

or

another Factor.

The research question should therefore be:

Where, if anywhere, is this determination question already represented in the complete set of Indicators?

Only after that question is answered should a possible Factor location for a new Indicator be considered.

Recurring Gaps and the Three Provisional Functions

The provisional Quality-State, Quality-State Determination, and Quality-State Influence functions provide one way to organize recurring findings.

A recurring gap may concern:

an actual condition that is not sufficiently represented;

a capability needed to determine the Quality State reliably;

or

a capability needed to preserve, restore, or influence the Quality State.

This classification can help reveal patterns.

For example, several Context Guides may independently show adequate Quality-State Indicators but weak visibility of the determination path.

That may suggest a recurring Quality-State Determination issue.

Another set of Context Guides may show that unacceptable conditions are detected reliably but that the path to effective intervention remains uncertain.

That may suggest a recurring Quality-State Influence issue.

The classification therefore helps organize the research.

It does not determine the answer.

Possible Recurring Determination Findings

The horizontal analysis has already identified several provisional findings that should be tested for recurrence through Context Guides.

These include:

continuity from detection to intervention;

timeliness of the determination and decision path;

Authority to act on Critical Infrastructure Conditions;

Quality-State Information Integrity;

independent or parallel information paths;

possible human or organizational distortion of quality-relevant information;

and

re-determination after intervention.

These are not established gaps in the set of Indicators.

They are candidate research questions.

Context Guide work should test whether they:

appear repeatedly;

remain necessary;

remain distinguishable;

and

cannot be adequately represented by the existing Indicators.

Recording Negative Results

It is also important to record when a provisional gap does not survive testing.

For example, a Context Guide may initially suggest that a new Indicator is needed.

Further analysis may show that:

the issue is already represented by an existing Indicator;

the problem resulted from an incomplete Boundary;

the need is only a Quality Outcome Criterion;

the finding is merely a new Evidence source;

or

the issue is specific to one Context.

Such a result is useful.

It shows that the current set of Indicators is able to absorb the new Context without expansion.

Negative results should therefore not be treated as failed research.

They help test the adequacy of the present set of Indicators.

Avoiding Confirmation Bias

The research process should not begin by trying to prove that a new Indicator is needed.

It should also not begin by trying to prove that the present set of Indicators is already complete.

Both approaches would weaken the analysis.

The correct question is:

What does repeated Context Guide Evidence support?

The answer may be:

the existing Indicator is sufficient;

the Context Guide requires a more precise Quality Outcome Criterion;

the Boundary must be refined;

the Evidence basis must be improved;

the finding is Context-specific;

or

a genuinely unresolved invariant determination question remains.

The research method should permit all of these outcomes.

Threshold Before Escalation

A provisional finding should become a stronger candidate for adding or changing an Indicator only after repeated testing.

At minimum, the research should establish that:

the question recurs;

the recurrence is not merely technical similarity;

the question remains necessary;

the question remains unresolved after testing against the complete set of Indicators;

the question is distinguishable from existing Indicators;

and

the question can be expressed at invariant selected Indicator resolution.

Only then should the candidate move into the formal provisional Indicator findings discussed in Section 9.

Interim Finding

Recurring Indicator gaps should be identified through repeated functional comparison, not through isolated Context-specific detail.

The important question is not:

Does the same technical problem appear again?

It is:

Does the same necessary determination question appear again in a materially different Context and remain insufficiently represented by the current set of Indicators?

This distinction protects both sides of the IQI Indicator structure.

It protects the set of Indicators from unnecessary expansion.

It also protects the set of Indicators from artificial closure.

Repeated Context Guide evidence can therefore strengthen confidence in the present set of Indicators or identify a legitimate candidate for later controlled addition or change to the set of invariant Indicators.

The next Section addresses the threshold for that transition:

8.6 When a Context-Guide Finding May Support an Additional Invariant Indicator

A Context Guide may reveal an important quality-relevant condition that is not explicitly visible in the present set of Indicators.

That finding should not automatically result in a new invariant Indicator.

The threshold must be higher.

The Indicator set is intended to remain invariant across different infrastructure Contexts.

A new invariant Indicator should therefore represent a necessary determination question that belongs at the invariant level.

The central question is:

When does a Context-Specific finding become strong enough to support consideration of a new invariant Indicator?

The Starting Point — A Context-Guide Finding

The process begins with application of the current set of Indicators.

During development of a Context Guide, a quality-relevant question may appear that is difficult to place under an established Indicator.

The first response should be to record the finding.

The Indicator set should not immediately be changed.

The finding should first be described in simple functional terms:

What must be determined?

Why does it matter to the Infrastructure Quality State?

What would become insufficiently visible or determinable if this question were omitted?

This prevents the candidate from being defined too early by one technical solution or one infrastructure Context.

Test 1 — Is the Finding Already Covered by an Existing Indicator?

The first test is coverage.

The complete set of Indicators should be examined.

The question is:

Can an established Indicator reasonably and sufficiently represent this determination question?

The test should not be limited to the Quality Factor under which the finding first appeared.

This determination question may already be addressed by another Indicator.

If an existing Indicator adequately covers the question, a new invariant Indicator is not justified.

The Context Guide may require more detailed interpretation.

But:

need for greater detail
≠ missing invariant Indicator.

Test 2 — Is the Finding Actually context-specific interpretation?

The second test asks whether the finding simply explains how an existing Indicator applies to the particular Infrastructure Quality Object.

For example, a Context Guide may identify a specific:

Failure Mode;

degradation mechanism;

hazard;

Environmental Interaction;

human–infrastructure Interface;

Monitoring condition;

recovery arrangement;

or

Adaptation condition.

If the existing Indicator already identifies the underlying determination question, the finding belongs in context-specific interpretation.

No new invariant Indicator is required.

Test 3 — Is the Finding Evidence?

A Context Guide may identify a new way of observing or demonstrating a condition.

This may include:

a test;

measurement;

inspection;

Monitoring Data;

record;

human observation;

calculation;

or

another information source.

The finding may be very important.

But if it merely supports evaluation of an existing Indicator, it is Evidence.

Therefore:

new Evidence
≠ new Indicator.

The underlying determination question must be identified before any addition of an invariant Indicator is considered.

Test 4 — Is the Finding a Quality Outcome Criterion?

The same test applies to a newly identified expected or acceptable condition.

A Context Guide may establish a specific:

limit;

range;

response time;

capacity;

performance level;

recovery condition;

or

other acceptance condition.

If an existing Indicator already identifies what is being evaluated, the new finding is a Quality Outcome Criterion.

Therefore:

new Quality Outcome Criterion
≠ new Indicator.

The invariant Indicator should not be expanded merely because different Contexts require different acceptable conditions.

Test 5 — Is the Finding a Method?

A Context Guide may identify a particular means of satisfying an established quality function.

Examples may include:

a particular inspection method;

a particular Monitoring arrangement;

a specific communication route;

a redundant system;

an automatic protective action;

a specific escalation path;

or

another technical or organizational arrangement.

The method may be necessary in that Context.

But the Indicators should normally identify the required determination question rather than one method used to realize it.

Therefore:

necessary Context-Specific method
≠ necessarily an invariant Indicator.

The research should ask:

What underlying determination question makes this method necessary?

That question, rather than the method itself, is what a possible additional Indicator would need to address.

Test 6 — Does the Finding Result from an Incomplete Boundary or Interface?

Before identifying a gap among the Indicators, the declared Infrastructure Quality Object must also be checked.

An apparent gap may result from leaving out a quality-relevant part of the Infrastructure Quality Object.

This may occur where:

a remote workplace participates in operation;

a communication connection carries Quality-Critical Information;

an external Interface materially affects Function Realization;

a remote specialist participates in Quality-State determination;

or

a physically separated control point can influence the Infrastructure Quality State.

If such an element belongs within the declared Quality Object or must be represented as a relevant Interface, the first correction is to the Context definition.

It is not necessarily to the set of Indicators.

Test 7 — Is the Determination Question Necessary?

If the finding remains unresolved, the necessity test should be applied.

The question is:

If this determination question is omitted, is the ability to determine or influence the Infrastructure Quality State materially weakened?

If removal makes no material difference, the candidate does not justify status as an invariant Indicator.

If removal creates a meaningful blind area, the case becomes stronger.

The removal test can be expressed as:

candidate question not addressed
→ important quality-relevant condition no longer sufficiently determined
→ possible necessity established.

Necessity alone is still not sufficient.

Test 8 — Is the Determination Question Distinguishable?

The candidate must also preserve a determination question that is meaningfully different from the established Indicators.

Two proposed Indicator questions may use different words while asking substantially the same thing.

A new Indicator should not be created merely because another formulation is possible.

The test is:

Does the candidate reveal something that the existing Indicator set cannot reveal with sufficient clarity?

If not, the candidate is redundant.

If yes, the distinguishability case becomes stronger.

Test 9 — Does the Question Recur Across Different Contexts?

A finding from one Context may be necessary but still remain Context-specific.

Evidence for invariant status becomes stronger when the same underlying question appears in materially different Infrastructure Quality Objects.

The physical manifestations do not need to be identical.

In fact, different physical manifestations may provide stronger evidence.

For example:

Context A
→ one physical problem;

Context B
→ a different physical problem;

Context C
→ another physical problem;

but all three
→ reveal the same unresolved determination question.

This is stronger evidence of invariance than simple repetition of the same technical problem within one infrastructure sector.

Test 10 — Can the Question Be Stated at the Selected Methodological Resolution?

A candidate invariant Indicator must also be expressible at the same general level as the current Indicators.

If the candidate can only be defined through one technology, one equipment type, one jurisdiction, or one operating method, it is unlikely to belong in the invariant Indicators.

The Indicator wording should identify the common quality-relevant question.

The Context Guide should provide the smaller-resolution realization.

The relationship should remain:

invariant Indicator question
→ Context-Specific realization.

Test 11 — Does the Candidate Remain Valid Across the Infrastructure Lifecycle?

Lifecycle relevance should also be examined.

This does not mean that every Indicator must have identical importance at every Lifecycle Stage.

However, the candidate should be tested against the Lifecycle of the Infrastructure Quality Object.

The research should ask whether the question remains meaningful during relevant stages such as:

Design;

Construction;

Commissioning;

Operation;

Maintenance;

Repair/Modification;

and

Decommissioning/Transition.

A question that arises only because of one highly specific Lifecycle activity may be more appropriately handled through context-specific interpretation.

A question that remains important across several relevant Lifecycle Stages provides stronger support for invariant treatment.

Test 12 — Does the Candidate Support the Existing Fourteen-Factor Structure?

IQI FJQ1 justified the fourteen invariant Quality Factors.

The present paper does not reopen that Factor derivation merely because a possible additional Indicator is identified.

A candidate Indicator should therefore first be tested for placement under one of the established fourteen Factors.

The question is:

Which existing Quality Factor does this determination question make observable or determinable?

If the candidate fits within an established Factor, it may represent a possible additional Indicator under that Factor.

If it does not fit reasonably under any of the fourteen Factors, the finding is more significant.

But such a result should not immediately produce a fifteenth Factor.

It would require separate examination against the factor-derivation method established in IQI FJQ1.

This paper concerns the Indicator layer.

It should preserve that Boundary.

The Role of Repeated Context-Guide Evidence

No fixed number of Context Guides can by itself prove invariance.

The strength of the Evidence depends on the diversity and relevance of the Contexts.

Three closely related pipeline applications may provide less evidence of broad invariance than the same underlying question appearing independently in:

pipeline infrastructure;

electric-power infrastructure;

data-center infrastructure;

processing infrastructure;

and

other materially different Infrastructure Quality Objects.

The question is therefore not simply:

How many times did the finding appear?

It is:

Across what different Infrastructure Quality Objects did the same necessary determination question remain visible?

This makes Context diversity important to development of the Indicators.

The Three Provisional Functions as an Additional Test

The provisional Quality-State, Quality-State Determination, and Quality-State Influence functions may also help test a candidate.

The candidate can be examined by asking:

Does it reveal an actual Quality-State condition that is otherwise insufficiently represented?

Does it protect the reliability of Quality-State Determination?

Does it represent a necessary capability to preserve, restore, or influence the Quality State?

Does it combine more than one of these functions?

This test does not determine whether the candidate belongs in the set of Indicators.

It helps explain what the candidate contributes.

A candidate whose determination question cannot be clearly stated may not yet be developed enough to justify an invariant Indicator.

From a Context Finding to a Possible Invariant Indicator

The complete process can therefore be expressed as:

Context Guide finding

→ identify the underlying determination question

→ test against current Indicators

→ test whether it is context-specific interpretation

→ test whether it is Evidence

→ test whether it is a Quality Outcome Criterion

→ test whether it is a method

→ check Boundary and Interfaces

→ apply necessity and removal tests

→ apply distinguishability and non-redundancy tests

→ test across materially different Contexts

→ test Lifecycle relevance

→ determine whether it can be stated at selected Indicator resolution

→ identify its relationship to an existing Quality Factor

→ record as a provisional invariant Indicator candidate.

Even at this point, addition or change to the set of invariant Indicators does not automatically follow.

A Provisional Candidate Is Not an Invariant Indicator

This distinction must remain explicit.

A candidate may satisfy enough tests to deserve continued study without having sufficient support for normative inclusion as an invariant Indicator.

The appropriate status is then:

Provisional Additional Indicator Finding.

This allows the finding to remain visible.

It can be tested in later Context Guides.

Its relationship to existing Indicators can be examined further.

Its provisional State, Determination, or Influence function can be compared horizontally.

Evidence can accumulate without destabilizing the set of Indicators.

Only after sufficient support exists should controlled addition or change to the set of invariant Indicators be considered.

Interim Finding

A Context-Guide finding may support consideration of a new invariant Indicator only after a demanding sequence of tests.

The finding must represent more than:

additional detail;

new Evidence;

a new Quality Outcome Criterion;

a preferred method;

or

an incomplete Boundary or Interface description.

The determination question must be:

quality-relevant;

necessary;

distinguishable;

non-redundant;

meaningful at selected Indicator resolution;

and

supported as recurring across materially different infrastructure Contexts.

It should also fit within the established fourteen-Factor structure unless separate research demonstrates a deeper Factor-level issue.

This threshold allows the set of Indicators to develop when Evidence requires development.

At the same time, it prevents Context-specific findings from producing unnecessary additions to the set of Indicators.

Section 8 therefore establishes the practical research mechanism:

Context Guides apply the set of Indicators.

Application tests the Indicators.

Repeated findings are compared horizontally.

Unresolved recurring functions are preserved provisionally.

Only sufficiently supported invariant findings become candidates for controlled addition or change to the set of invariant Indicators.

The next Section provides the formal place for preserving those findings for continued research:

9. Provisional Additional Indicator Findings

The findings in this Section are provisional research questions. They help test whether each established Indicator already identifies what must be examined across relevant infrastructure contexts, life-cycle stages, and methodological resolutions. A provisional finding does not itself establish an additional Indicator.

9.1 Purpose of Provisional Indicator Findings

The analysis in Sections 6 through 8 does not establish that additional invariant Indicators are required.

It does, however, identify several questions that deserve continued testing.

These questions should not be lost merely because the present Evidence is insufficient for addition or change to an invariant Indicator.

At the same time, they should not be treated as established Indicators before their invariant necessity has been demonstrated.

A separate category is therefore useful:

Provisional Additional Indicator Finding.

A Provisional Additional Indicator Finding is a research finding.

It records a possible quality-relevant determination question that may not be sufficiently represented by the present Indicators.

Its purpose is to preserve the finding for continued testing.

It is not an additional invariant Indicator.

It does not modify the established Indicators.

It does not create a new requirement for Infrastructure Context Guides.

It does not establish that the present Indicator set is deficient.

The distinction can be expressed simply:

possible unresolved function
→ Provisional Additional Indicator Finding;

repeated supporting Evidence
→ stronger possible invariant Indicator;

sufficient justification
→ possible controlled addition or change to an invariant Indicator.

Why Provisional Findings Are Needed

The present paper applies two different levels of evidence.

For an established invariant Indicator, the question is:

Is this Indicator necessary, distinguishable, and non-redundant?

For a possible new Indicator, the question must be more demanding:

Is there sufficient Evidence that an additional invariant determination question is actually required?

These questions are not the same.

The analysis may identify an important issue without yet demonstrating that it belongs in the invariant Indicators.

Without a provisional category, two undesirable results are possible.

The first is premature expansion of the invariant Indicators.

Every important Context Guide finding could produce another invariant Indicator.

The invariant Indicators would gradually become a collection of Context-specific details.

The second is artificial closure.

A finding that does not immediately justify addition or change to an invariant Indicator could be discarded.

Repeated evidence supporting the same finding might then remain invisible across separate Context Guides.

Provisional findings avoid both problems.

They preserve research without changing the established Indicators.

What Should Be Recorded

A Provisional Additional Indicator Finding should identify the underlying question rather than only the event or technical condition that revealed it.

For example, a Context Guide may reveal a delayed response to a rapidly changing infrastructure condition.

The provisional finding should not simply record:

response was delayed.

It should ask:

Does the Infrastructure Quality Object have a recurring quality-relevant need to connect determination of its Quality State to effective intervention within the available time?

This wording allows the same question to be tested in other infrastructure Contexts where the physical circumstances may be completely different.

Each provisional finding should therefore record, as applicable:

the determination question being considered;

the Quality Factor or Factors to which it may relate;

the Context in which it was identified;

the condition or Failure Mode that revealed it;

the current Indicators tested against it;

why existing coverage may be insufficient;

the consequence of removing the question from the determination;

its possible Quality-State, Quality-State Determination, or Quality-State Influence question;

and

the additional Context Guide Evidence needed to test it.

The purpose is not to create a complex administrative record.

The purpose is to preserve enough information for later horizontal comparison.

A Provisional Finding Must Be Question-Based

The distinction between the determination question and the method used to answer it remains important.

For example, repeated Context Guides may show use of:

independent sensors;

automatic shutdown systems;

remote control centers;

parallel communication paths;

or

specific escalation arrangements.

These are possible means.

They should not automatically become provisional invariant Indicators.

The research should ask what common determination question makes those means necessary.

For example:

independent sensors
→ may reveal a need for sufficiently reliable or independent Quality-State determination;

automatic shutdown
→ may reveal a need for timely Quality-State Influence;

parallel communication paths
→ may reveal a need for continuity or integrity of Quality-State information;

escalation arrangements
→ may reveal a need for a reliable determination-to-decision path.

The provisional finding should be stated at the question level.

Relationship to the Existing invariant Indicators

Every provisional finding should remain linked to the current Indicators.

The research should identify which established Indicators already provide partial or possible coverage.

This is important because a provisional finding may later be resolved without adding an Indicator.

Further analysis may show that:

an existing Indicator already covers the question;

two or more existing Indicators together provide sufficient coverage;

the context-specific interpretation was initially too narrow;

the Infrastructure Boundary was incomplete;

a relevant Interface was omitted;

the issue is Evidence rather than an Indicator;

the issue is a Quality Outcome Criterion;

or

the issue is only Context-specific.

In any of these cases, the provisional finding may be closed without addition or change to an invariant Indicator.

This is a valid research result.

Provisional Findings and Indicator Necessity

A provisional finding should remain subject to the same necessity logic applied to the established Indicators.

The removal question is:

If this question is not represented, what becomes materially less determinable?

If no meaningful loss can be identified, the finding should not progress toward status as an invariant Indicator.

The practical means may still be useful in a particular Context.

But usefulness alone is not enough.

The invariant Indicators should address necessary determination questions, not every issue that may improve a particular application.

Provisional Findings and Repeated Evidence

One Context may identify a provisional finding.

Additional Contexts test it.

The finding becomes stronger when the same underlying question appears in materially different Infrastructure Quality Objects.

The research path is therefore:

first observation
→ provisional finding;

second application
→ comparison;

additional materially different Contexts
→ recurrence testing;

horizontal comparison
→ possible evidence of invariance.

The number of occurrences alone is not decisive.

The diversity of the Contexts matters.

Repeated appearance of the same technical issue within one infrastructure type may support a Context Guide requirement without supporting an invariant Indicator.

Repeated appearance of the same underlying question across very different Infrastructure Quality Objects provides stronger evidence.

Provisional Findings Can Be Rejected

The provisional category must permit rejection.

A finding should not remain permanently open merely because it was once recorded.

Later Evidence may show that it is:

redundant;

Context-specific;

method-specific;

already represented;

not materially necessary;

or

not suitable for selected methodological resolution.

The finding can then be closed.

This prevents the provisional research record from becoming an informal second invariant Indicators.

Provisional Findings Can Also Be Combined

Separate Context Guides may initially produce apparently different provisional findings.

Horizontal analysis may later show that they represent one common question.

For example:

delay in escalation;

lack of Authority at an observation point;

slow communication;

and

late protective action

may initially appear to be four separate issues.

Further analysis may show that they are different manifestations of one broader question concerning the adequacy of the complete determination-to-intervention path.

In that case, the provisional findings should be combined at the common question level.

The opposite is also possible.

One broad provisional finding may later prove to contain two distinguishable necessary determination questions.

The research structure must allow both results.

Relationship to the Three Provisional Indicator Categories

The Quality-State, Quality-State Determination, and Quality-State Influence classification provides a useful way to organize Provisional Additional Indicator Findings.

A candidate may concern:

a quality-relevant condition insufficiently represented in the Indicators;

a weakness in the ability to determine that condition;

a weakness in the capability to preserve, restore, or influence the condition;

or

a combination of these categories.

This classification may help reveal horizontal patterns.

For example, the present analysis has identified several provisional questions that appear primarily related to Quality-State Determination.

Others appear primarily related to Quality-State Influence.

The distinction may help determine whether apparently separate findings are parts of one larger question.

However, the S/D/I classification remains provisional.

A candidate should not be retained merely because it fits one of these three categories.

It must still pass the necessity, distinguishability, non-redundancy, and Context-invariance tests.

Present Status of the Research

At the present stage, the analysis does not justify adding another invariant Indicator.

The established Indicators remain the governing Indicators.

However, the horizontal analysis has identified several questions that should be preserved for continued testing.

The strongest presently concern:

Quality-State Information Integrity;

continuity between Quality-State determination and Quality-State Influence;

timeliness of determination and intervention;

Authority in relation to Critical Infrastructure Conditions;

independent or parallel Quality-State information paths;

possible distortion of quality-relevant information between observation and decision;

and

re-determination after intervention.

These findings are not equivalent in maturity.

Some may prove to be sufficiently represented by existing Indicators.

Some may remain Context-specific.

Some may be different manifestations of the same underlying question.

They should therefore not yet be formulated as proposed new invariant Indicators.

Their proper status is provisional research findings.

Research Without Premature Addition or Change to the Invariant Indicators

Provisional findings allow this research to follow Evidence rather than assumptions.

The invariant Indicators need not change whenever a new question arises.

Nor should the set of Indicators be declared permanently complete.

The relationship is:

stable invariant Indicators
+
open research
→ controlled development.

This is particularly important at the Indicator layer.

The fourteen Quality Factors provide the dimensions under which the Indicators are organized.

The Indicator layer operates at a smaller resolution.

Repeated Context Guide work may therefore reveal determination questions that were not sufficiently visible when the present set of Indicators was first established.

Keeping this possibility open is not a weakness in the Indicators.

It is a controlled way of testing the Indicators against increasing practical Evidence.

Interim Finding

Provisional Additional Indicator Findings provide a formal research space between a Context-Specific observation and an invariant addition or change to an invariant Indicator.

They allow a possible unrepresented question to be:

identified;

recorded;

tested against the current Indicators;

compared across Context Guides;

examined horizontally;

strengthened;

combined;

rejected;

or

eventually supported for controlled addition or change to an invariant Indicator.

At the present stage, no provisional finding identified in this paper should be treated as an additional IQI invariant Indicator.

The next Section sets out criteria for recording a candidate finding:

9.2 Criteria for Recording a Candidate Indicator

A Provisional Additional Indicator Finding should not be recorded merely because an issue appears important.

The threshold for recording a candidate should be lower than the threshold for changing the established Indicators, but it should still be controlled.

The purpose is to preserve a potentially important determination question for further testing without filling the research record with every Context-Specific detail.

A candidate should therefore be recorded only when there is a reasonable basis to believe that the finding may represent a necessary determination question not sufficiently visible in the present Indicators.

The first criterion is quality relevance.

The candidate must materially relate to Infrastructure Quality State Determination, Function Realization, Infrastructure Results, Infrastructure Outcomes, Critical Infrastructure Conditions, Evidence, or the capability to preserve or restore an acceptable condition.

If the issue has no material effect on these subjects, it should not be recorded as an Indicator candidate.

The second criterion is a clear determination question.

The candidate should be capable of being stated as a question such as:

What condition must be known?

What capability must be demonstrated?

What determination path must remain reliable?

What capability must exist to preserve or restore the Quality State?

If the candidate cannot yet be expressed as a clear determination question, it may still require research, but it is not yet mature enough to record as a possible Indicator.

The third criterion is possible necessity.

The removal test should produce at least a plausible material loss.

The research should ask:

If this question is omitted, what becomes insufficiently visible, insufficiently determinable, or insufficiently controllable?

If no meaningful loss can be identified, the finding should not be recorded as an Indicator candidate.

The fourth criterion is possible distinction from existing Indicators.

The candidate does not need to be proven fully non-redundant at this stage.

But there should be a reasonable basis to believe that it may preserve a determination question not already adequately represented.

If the finding is obviously and completely covered by an established Indicator, it should remain under that Indicator rather than being recorded separately.

The fifth criterion is uncertainty about present Indicators coverage.

A candidate may be worth recording precisely because its relationship to the current set of Indicators is not yet fully resolved.

For example, the question may appear partly represented across several Indicators, but no single Indicator clearly preserves it.

This is an appropriate reason to record a provisional finding.

The purpose of the record is then to test whether the existing combined coverage is sufficient.

The sixth criterion is question-based rather than method-based formulation.

The candidate should not be stated as:

a specific sensor;

a specific procedure;

a particular alarm;

a certain organizational position;

a named communication system;

a fixed technical solution;

or

another Context-Specific method.

The candidate should state the underlying question.

For example:

not

independent sensor channel;

but possibly

sufficiently independent Quality-State information path where single-path failure could materially weaken determination.

Not

automatic shutdown;

but possibly

timely capability to place the Infrastructure Quality Object into an appropriate safe condition when the available decision time is insufficient for ordinary escalation.

The examples remain provisional.

Their purpose is to illustrate the level of formulation.

The seventh criterion is separation from Evidence.

A candidate should not be recorded merely because a new Evidence source has been identified.

The research must ask:

What determination question does this Evidence support?

If that question is already represented, the finding remains Evidence.

If the Evidence reveals a previously insufficiently represented function, that question may be recorded as the candidate.

The eighth criterion is separation from a Quality Outcome Criterion.

A new threshold, response time, capacity, limit, margin, or acceptable condition should not automatically become an Indicator candidate.

The question is:

Does the criterion evaluate an established Indicator?

If yes, it remains a Quality Outcome Criterion.

Only if the criterion cannot reasonably be connected to an existing Indicator should the underlying determination question be examined as a possible candidate.

The ninth criterion is separation from Boundary or Interface correction.

An apparent Indicator gap may result from an incomplete Infrastructure Quality Object Description.

If a remote operator, communication path, external Interface, supporting facility, or other element materially participates in Function Realization, Quality-State determination, or Quality-State Influence, the first question is whether the declared Boundary or Interface is incomplete.

If correcting the Boundary resolves the problem, no candidate Indicator is needed.

The tenth criterion is possible Context recurrence.

A finding may first appear in one Context.

That is acceptable for recording a candidate.

But the candidate should be stated so that it can be tested in other materially different Infrastructure Quality Objects.

A finding that is so technically specific that it cannot reasonably be tested outside one Context is less suitable for provisional research about invariant Indicators.

The eleventh criterion is wording of the invariant Indicator.

The candidate should be capable of being expressed at a level consistent with the current Indicators.

It should identify what must be examined.

It should not prescribe how the examination must be performed.

This criterion helps prevent gradual movement of Context Guide detail into the invariant Indicators.

The twelfth criterion is possible placement within the existing fourteen-Factor structure.

The research record should identify the Factor or Factors to which the candidate may relate.

The candidate may initially have more than one possible location.

That is acceptable.

The purpose is not to force immediate placement.

It is to understand the relationship between the candidate and the established Indicators.

If the candidate cannot reasonably fit under any of the fourteen Factors, the finding should be marked as more fundamental and require separate review.

The thirteenth criterion is possible State, Determination, or Influence function.

Where useful, the candidate should be provisionally examined as:

Quality-State;

Quality-State Determination;

Quality-State Influence;

or

a combination.

This is not required for validity.

It is a research aid.

It may help compare apparently different findings across Context Guides.

The fourteenth criterion is sufficient description of the originating Context.

The research record should identify enough of the original Context to understand why the candidate arose.

This may include:

the Infrastructure Quality Object;

the relevant Lifecycle Stage;

the Boundary or Interface involved;

the Failure Mode or condition;

the Evidence available;

and

the consequence of inadequate determination.

The record should remain concise.

Its purpose is later comparison, not duplication of the Context Guide.

Minimum Candidate Record

A practical provisional record may therefore contain:

Candidate working name;

Underlying determination question;

Originating Infrastructure Context;

Related Quality Factor or Factors;

Existing Indicators tested against the finding;

Reason present coverage may be insufficient;

Possible consequence if the question is omitted;

Possible State / Determination / Influence question;

Evidence needed from additional Contexts;

and

Current status.

The current status may be recorded as, for example:

Open — initial finding;

Open — recurring finding;

Coverage likely sufficient under current Indicators;

Context-specific;

Method-specific;

Combined with another provisional finding;

Rejected as non-necessary;

or

Candidate for controlled review of possible additional Indicators.

These are research statuses.

They do not create additional categories for the established Factors and Indicators.

When Not to Record a Candidate

A candidate should normally not be recorded when the finding is clearly:

a more detailed application of an existing Indicator;

a new Evidence source;

a Quality Outcome Criterion;

a Context-Specific technical method;

a Boundary correction;

a one-time administrative issue;

or

a condition with no material effect on Infrastructure Quality State Determination.

This discipline is important.

An uncontrolled provisional list would provide little research value.

The purpose is to preserve plausible unresolved functions, not every issue encountered during Context Guide development.

Candidate Recording Should Not Bias the Result

Recording a candidate should not imply that the research team expects it to become an invariant Indicator.

The wording should remain neutral.

For example:

Possible determination-to-intervention continuity question.

is preferable to:

Needed new intervention Indicator.

The first formulation records a question.

The second assumes the conclusion.

This distinction is important because the candidate may later be:

absorbed by an existing Indicator;

combined with another candidate;

shown to be Context-specific;

or

rejected.

Interim Finding

A Provisional Additional Indicator Finding should be recorded only when there is a reasonable basis to believe that a necessary and potentially distinguishable determination question addressed by an invariant Indicator may remain insufficiently represented.

The candidate should be:

quality-relevant;

question-based;

clear enough to test;

separated from Evidence, criteria, methods, and Boundary issues;

and

capable of comparison across additional infrastructure Contexts.

The recording threshold is therefore deliberately controlled.

It is lower than the threshold for justifying an additional or changed Indicator.

But it is high enough to keep the provisional research record focused on findings that may materially affect the continuing adequacy of the invariant Indicators.

The next Section applies this approach to the first group of provisional findings identified by the present analysis:

9.3 Quality-State Influence Findings

The horizontal analysis identified several provisional findings that relate primarily to the capability to preserve, restore, or intentionally change a quality-relevant condition.

These findings do not establish new invariant Indicators.

They identify possible recurring Influence functions that should be tested through Context Guides and later horizontal comparison.

The strongest provisional Influence findings concern:

continuity from determination to intervention;

timeliness of intervention;

Authority to act;

safe-state or HOLD capability where ordinary decision paths may be too slow;

recovery after intervention;

and

confirmation that the intervention actually produced the required result.

These findings arise from the interaction of several current Indicators rather than from one isolated Factor.

They should therefore be examined horizontally.

Finding 1 — Continuity from Quality-State Determination to Intervention

The current set of Indicators contains strong provisions for:

Monitoring;

Risk recognition;

Personnel Competence;

human–infrastructure interaction;

Quality-Critical Information;

Risk Controls;

Recovery Capability;

and

Adaptation.

However, the Factor-by-Factor analysis showed that reliable parts do not automatically create a reliable complete path.

A condition may be:

observed;

detected;

correctly interpreted;

and

recognized as unacceptable,

while effective intervention still fails to occur.

The provisional determination question is:

Is the path from recognition of a quality-relevant condition to effective intervention sufficiently continuous for the condition being managed?

This possible question can be expressed as:

Quality-State determination
→ communication
→ decision
→ Authority
→ action.

The present Indicators address several of these elements separately.

The provisional question is whether their combined application is always sufficient.

This finding should therefore remain open.

Context Guides should test whether failures in the connection among these steps recur across materially different Infrastructure Quality Objects.

Finding 2 — Timeliness of Quality-State Influence

Time appears repeatedly in the horizontal analysis.

Factor 12 requires Monitoring adequate to reveal relevant degradation or deviation in time.

Factor 5 concerns Loss-of-Control and high-consequence scenarios.

Factor 7 includes Recovery Capability.

Factor 9 requires competence under abnormal and degraded conditions.

These existing Indicators provide important coverage.

However, they do not necessarily answer a broader question:

Is the complete determination-and-intervention path fast enough for the physical rate at which the Critical Infrastructure Condition develops?

The provisional relationship is:

time required for detection
+
time required for interpretation
+
time required for communication
+
time required for decision
+
time required for action

compared with

time available before unacceptable consequence.

The provisional question is therefore not simply rapid Monitoring.

It concerns whether Quality-State Influence remains possible within the available physical decision time.

This may be highly Context-dependent.

A slowly developing condition may allow normal escalation.

A rapidly changing condition may not.

The present finding should therefore not be converted into a universal time-response requirement.

Context Guides should determine whether this problem recurs at a question level across different infrastructure systems.

Finding 3 — Authority to Act on a Critical Infrastructure Condition

Factor 9 already requires recognition of the limits of Authority and expertise.

This is important.

However, horizontal analysis identified a separate possible Influence question.

A person may:

correctly recognize a Critical Infrastructure Condition;

correctly understand its significance;

and

correctly recognize that action is needed,

while lacking Authority to take the necessary action.

The provisional question is:

Is sufficient Authority available at the point in the determination path where intervention must occur?

This does not imply that every observer should possess unrestricted Authority.

The appropriate arrangement may differ substantially by Context.

Possible arrangements may include:

direct Authority;

rapid escalation;

pre-authorized action;

automatic protective action;

or

predetermined safe-state criteria.

These are possible methods.

They are not the provisional question.

The possible question is:

availability of sufficient Authority for effective Quality-State Influence within the time and conditions of the Critical Infrastructure Condition.

This finding should remain provisional until tested through multiple Context Guides.

Finding 4 — Predetermined Safe-State or HOLD Capability

A related finding concerns situations where ordinary discretionary decision-making may be too slow.

If the Infrastructure Quality State cannot be demonstrated as acceptable within the available decision time, continued operation may create an unacceptable condition.

This raises a provisional question:

Are there infrastructure Contexts in which predetermined criteria should require a HOLD, safe state, or equivalent protective condition when acceptable Quality State cannot be demonstrated in time?

This question should be treated carefully.

A universal HOLD rule is not established by the established Indicators.

Different infrastructure systems may require very different responses.

In some Contexts, immediate shutdown may increase Risk.

In others, continued operation may be the greater Risk.

The possible invariant question is therefore not:

shutdown whenever uncertainty exists.

The provisional question is narrower:

whether the Infrastructure Quality Object has an appropriate predetermined protective response when ordinary determination and decision processes cannot act within the available time.

This may ultimately prove to be Context-specific.

Repeated cross-Context Evidence is required before any stronger conclusion is justified.

Finding 5 — Recovery Capability After Unsuccessful Influence

The current Indicators already includes Recovery Capability under Operational Reliability and Reversibility and Recoverability under Infrastructure Adaptability.

These Indicators provide substantial coverage.

However, horizontal comparison raises a broader question.

An intervention intended to preserve or restore the Quality State may itself fail.

The provisional question is:

If the first Influence action does not produce the required result, does the Infrastructure Quality Object retain another capability to recover acceptable Function Realization?

The sequence may be:

unacceptable condition
→ intervention
→ insufficient result
→ secondary recovery capability
→ restored acceptable condition.

This finding may already be sufficiently represented through existing Recovery and Risk Control Indicators.

The Context Guide research should test that first.

If existing coverage remains adequate, no additional Indicator is needed.

Finding 6 — Re-Determination After Influence

Quality-State Influence cannot be evaluated only by confirming that action occurred.

The resulting state must be determined.

This relationship is already visible in several invariant Indicators.

Risk Control effectiveness must be determined.

Monitoring interprets resulting behavior.

Adaptation Results and Outcomes must be evaluated.

Recovery Capability concerns restoration of Function Realization.

Horizontal analysis nevertheless identifies a general recurring function:

After intervention, is the resulting Quality State re-determined?

The sequence is:

determined condition
→ Influence
→ changed condition
→ renewed Evidence
→ renewed Quality-State determination.

This finding is important because:

action completed
≠ acceptable result demonstrated.

A protective action may occur without fully controlling the condition.

A repair may be completed without restoring required Function Realization.

An Adaptation may solve one problem while creating another.

The present set of Indicators appears to provide substantial coverage of this question.

The provisional finding should therefore be tested primarily for adequacy of existing coverage rather than assumed to require another Indicator.

Finding 7 — Influence Through Distributed Infrastructure and Remote Workplaces

The horizontal analysis also showed that Quality-State Influence may occur through physically distributed elements.

A remote operator may issue a control action.

A remote technical specialist may affect a decision.

A communication connection may transmit an action back to field equipment.

The relevant Influence path may therefore extend across:

physical Boundaries;

communication Interfaces;

remote workplaces;

and

responsibility Interfaces.

The provisional question is:

Does the declared Infrastructure Quality Object include the physical and functional path required for effective Quality-State Influence?

This may not represent a missing Indicator at all.

In many cases, the issue may be resolved through correct Boundary and Interface declaration.

It should nevertheless be preserved as an Influence-related research finding because incomplete Boundary definition could create the false appearance that Influence capability is adequate when an essential remote element has been excluded.

Relationship Among the Influence Findings

The provisional Influence findings can be combined into one general chain:

Quality-State condition

→ determination

→ communication

→ decision

→ Authority

→ timely action

→ preservation, mitigation, recovery, or change

→ resulting Quality State

→ renewed determination.

The horizontal research question is:

Does the established Indicators sufficiently represent the necessary capabilities across this complete path?

The present analysis does not answer that question negatively.

Several existing Indicators already address substantial parts of the chain.

The purpose of preserving the finding is to test whether any recurring break in the determination path remains insufficiently visible when the Indicators are applied to different Infrastructure Quality Objects.

Possible Consolidation of the Influence Findings

The individual findings in this Section may not remain separate.

For example:

timeliness;

Authority;

communication;

and

HOLD capability

may prove to be different manifestations of one broader function:

adequacy of the determination-to-intervention path.

Alternatively, Context Guide evidence may show that some are meaningfully distinguishable.

The research should not force the answer now.

The correct process is:

record separate findings where useful;

test them through different Contexts;

compare their underlying questions;

combine them if they repeatedly represent the same determination question;

or

retain them separately if removal of one produces a distinguishable loss.

Present Status

At the present stage, none of the Quality-State Influence findings identified above justifies addition of a new invariant Indicator.

The strongest present candidate research subject is the continuity and adequacy of the complete determination-to-intervention path.

This subject includes possible questions concerning:

timeliness;

Authority;

communication;

pre-authorized protective action;

recovery;

and

renewed determination.

Existing invariant Indicators coverage must be tested before any new Indicator is proposed.

Interim Finding

The present Indicators clearly address Quality-State Influence questions.

They are especially visible in Risk mitigation, Environmental Protection, Operational Recovery, human interaction, Personnel Competence, and Adaptation and Recoverability.

The horizontal analysis nevertheless identifies a possible unresolved issue:

the existence of individual Influence-related capabilities does not necessarily demonstrate that the complete path from Quality-State determination to effective and timely intervention is reliable.

This is a legitimate provisional research finding.

It should be preserved for repeated Context Guide testing.

It should not yet be treated as a missing invariant Indicator.

The next Section examines the second group of provisional findings:

9.4 Quality-State Determination Findings

The horizontal analysis identified a second group of provisional findings concerning the reliability of Quality-State Determination.

These findings differ from the Quality-State Influence findings examined in Section 9.3.

The central question here is not:

Can the Infrastructure Quality State be preserved, restored, or changed?

It is:

Can the actual Infrastructure Quality State be determined with sufficient reliability?

The established Indicators already contains strong Determination questions.

They appear in:

Functional Specification;

Technical Specification;

Conformity Assessment;

Structural and Functional Integrity;

Risk;

Environmental Protection;

Operational Reliability;

Workplace Human Interaction;

Personnel Competence;

Applicable Regulatory and Standards Requirements;

Stakeholder and Community Effects;

Monitoring;

Documentation and Traceability;

and

Infrastructure Adaptability.

The present analysis therefore does not suggest that Quality-State Determination is absent from the Indicators.

The provisional question is narrower:

Are some recurring conditions affecting the reliability of the complete Quality-State Determination path insufficiently visible when the established Indicators are considered individually?

The strongest findings concern:

Quality-State Information Integrity;

continuity of the information path;

independent or parallel information paths;

human interpretation;

possible distortion between observation and decision;

Uncertainty;

and

the relationship between inability to determine the Quality State and the resulting Quality-State conclusion.

Finding 1 — Quality-State Information Integrity

A Quality-State determination may depend on information passing through several stages.

A simplified path is:

actual condition
→ observation
→ information
→ communication
→ interpretation
→ Evidence-Supported Finding
→ Quality-State determination.

The information may originate from:

Monitoring;

inspection;

testing;

human observation;

operating experience;

Stakeholder or Community observation;

or

another Evidence source.

The established Indicators address many parts of this path.

Factor 12 addresses Monitoring and interpretation.

Factor 13 addresses Documentation, Traceability, continuity, and accessibility.

Factor 8 addresses human interaction with infrastructure information.

Factor 9 addresses Personnel Competence.

Factor 3 addresses the relationship between Evidence and Conformity findings.

Horizontal analysis nevertheless raises a broader provisional question:

Does quality-relevant information remain sufficiently faithful to the actual observed condition as it moves through the determination path?

The possible question may be described provisionally as:

Quality-State Information Integrity.

This term should remain a research term.

It is not presently proposed as a new term used in this article.

The relevant issue is whether information supporting a Quality-State determination remains sufficiently:

complete;

accurate;

traceable to its source and Context;

available;

and

protected from material loss or change in meaning.

The present Indicators may already provide sufficient coverage through existing Indicators.

Context Guide testing is required.

Finding 2 — Continuity of the Quality-State Information Path

Information may be correct at its point of origin but fail to reach the point where it is needed for determination.

This creates a related but distinguishable provisional question:

Is the quality-relevant information path sufficiently continuous from the condition being observed to the point where the Quality-State determination is made?

The possible path may include:

physical condition;

sensor or human observation;

local display or record;

communication connection;

remote workplace;

technical interpretation;

decision point;

and

retained Evidence.

A break anywhere in this path may weaken determination.

For example:

condition observable
≠ condition necessarily detected;

condition detected
≠ information necessarily transmitted;

information transmitted
≠ information necessarily received;

information received
≠ information necessarily available to the relevant person;

information available
≠ information necessarily correctly interpreted.

Several existing Indicators already address these relationships.

The research question is whether their combined coverage is sufficient when the complete path is examined in specific infrastructure Contexts.

Finding 3 — Independent or Parallel Quality-State Information Paths

The horizontal analysis also raises a question concerning dependence on one information path.

If determination of a Critical Infrastructure Condition depends entirely on:

one sensor;

one communication connection;

one person;

one reporting route;

or

one interpretation source,

failure of that path may prevent or weaken Quality-State Determination.

The provisional question is:

When the consequence of an incorrect or unavailable Quality-State determination is significant, is one information path sufficient?

This should not be interpreted as a proposed universal requirement for redundancy.

Different infrastructure Contexts may justify different arrangements.

One sufficiently reliable path may be adequate in many cases.

In other cases, independent, diverse, or parallel paths may be necessary.

The possible invariant question is therefore not:

multiple information paths shall always exist.

The research question is:

Does dependence on a single information path create an unacceptable weakness in Quality-State Determination for the condition being examined?

This question should be tested through materially different Context Guides.

Finding 4 — Human Interpretation of Quality-State Information

Quality-State information does not always produce a finding automatically.

Human interpretation may be necessary.

Factor 8 addresses the human–infrastructure Interface.

Factor 9 addresses Personnel Competence.

Factor 12 addresses interpretation of Monitoring.

These Factors already provide substantial coverage.

Horizontal analysis nevertheless shows that the path may involve several distinct questions:

Was the relevant condition presented to the person?

Was it perceptible?

Was its meaning understandable?

Did the person possess the necessary competence?

Was the person aware of the limits of available information?

Was the resulting conclusion supported by the Evidence?

The relationship can therefore be expressed as:

information technically available
≠ information necessarily perceived;

information perceived
≠ information necessarily understood;

information understood
≠ conclusion necessarily justified.

This finding may not require any new Indicator.

Its principal research value may be in testing the interaction of existing Factors 8, 9, 12, and 13.

Finding 5 — Distortion Between Observation and Decision

A further provisional finding concerns a condition different from technical information loss or lack of competence.

Quality-relevant information may be correctly observed and correctly understood at its origin but later reach another decision point with changed meaning.

The information may be:

minimized;

incompletely communicated;

delayed;

reclassified;

separated from important Context;

or

presented with a level of certainty not supported by the original Evidence.

The provisional question is:

Can the Quality-State determination remain reliable when information passes through several human or organizational points before the final determination or decision is made?

This issue should not be reduced automatically to individual misconduct.

The research question concerns the reliability of the information path.

The relevant relationship is:

correct original observation
≠ correct final representation necessarily preserved.

The present set of Indicators contains relevant provisions concerning:

Personnel Competence;

Monitoring interpretation;

Documentation;

Traceability;

Quality-Critical Information;

and

Evidence-supported findings.

It remains uncertain whether these provisions fully represent the possible recurring function.

Context Guide testing is required.

Finding 6 — Pressure Affecting Quality-State Information

The preceding finding raises a more specific research question.

People participating in the Quality-State information path may operate under conditions that affect how unfavorable information is communicated.

Such conditions may include pressure associated with:

responsibility;

schedule;

production or service continuity;

organizational position;

or

consequences attached to reporting an unfavorable condition.

The important issue for IQI research is not the motivation of the individual.

The quality-relevant question is:

Can such pressure materially affect the reliability of the Quality-State information reaching the relevant determination or decision point?

If so, the underlying question concerns the reliability of Quality-State Determination.

This possible condition may be described provisionally as pressure affecting the Quality-State information path.

A more specific term should not be introduced into the terminology used in this article at this stage.

The present analysis does not establish that this condition requires a separate invariant Indicator.

It may already be adequately addressed through existing Indicators when the relevant human–infrastructure Interfaces, Personnel Competence, information paths, and Documentation are correctly interpreted.

The finding should remain open for Context Guide research.

Finding 7 — Uncertainty in Quality-State Determination

Uncertainty already appears in the established Indicators.

It is therefore not a newly discovered function.

However, horizontal analysis shows that Uncertainty can affect several stages of Quality-State Determination.

There may be uncertainty concerning:

the actual physical condition;

measurement;

Evidence completeness;

Failure Modes;

Risk;

environmental effects;

reliability;

human interpretation;

or

the continuing validity of earlier Assumptions.

The provisional horizontal question is:

Is material Uncertainty sufficiently visible in the final Quality-State determination?

This is important because:

Evidence-Supported Finding
≠ certainty.

A finding may be justified while still containing material Uncertainty.

The determination should therefore not communicate greater certainty than the Evidence supports.

The present set of Indicators appears to provide substantial coverage of this issue.

The research task is primarily to test whether that coverage remains sufficiently visible across Context Guides rather than to presume that another Indicator is needed.

Finding 8 — Inability to Demonstrate an Acceptable Quality State

The preceding findings lead to a particularly important question.

What does it mean when the available Evidence is insufficient to demonstrate that the relevant Quality State is acceptable?

The following conclusions are not equivalent:

acceptable Quality State demonstrated;

unacceptable Quality State demonstrated;

The available Evidence does not presently support a sufficiently confident determination of the Quality State.

The third condition should not automatically be converted into either of the first two.

The relationship is:

absence of Evidence demonstrating an unacceptable state
≠ Evidence demonstrating an acceptable state.

Likewise:

insufficient Evidence for an acceptable finding
≠ proof that the state is physically unacceptable.

The provisional Determination question is therefore:

Does the IQI assessment preserve the distinction between an acceptable or unacceptable Quality State and an indeterminate determination when available Evidence supports neither conclusion?

This question is particularly important where the consequence of an incorrect positive determination is high.

The Determination issue must also remain separate from the Influence decision.

An indeterminate finding may, in a particular Context, trigger:

additional examination;

additional Monitoring;

restricted operation;

HOLD;

safe-state action;

or

another response.

But those are Context-Specific Influence decisions.

The Determination function itself is:

do not claim an acceptable Quality State beyond what the Evidence supports.

This finding should be examined carefully against the existing Quality State model and vocabulary before any new invariant Indicators provision is considered.

Finding 9 — Timeliness of Quality-State Determination

Section 9.3 considered time primarily from the Influence perspective.

Time also affects Determination.

A Quality-State determination may be correct when finally completed but no longer describe the current condition if the Infrastructure Quality State has changed during the determination process.

The provisional question is:

Is the Quality-State determination sufficiently current for the rate at which the relevant infrastructure condition can change?

This differs from simple Monitoring frequency.

The complete determination may require:

observation;

data transmission;

analysis;

human interpretation;

additional Evidence;

and

a final finding.

If the condition changes faster than this process, the resulting determination may describe an earlier state rather than the present state.

The relationship can be expressed as:

correct determination of earlier condition
≠ necessarily correct determination of current Quality State.

The present Indicators may already address this issue through Monitoring timeliness, Risk, Operational Reliability, and change-related Indicators.

Repeated Context Guide Evidence is needed before any separate invariant question is proposed.

Relationship Among the Determination Findings

The provisional Determination findings can be viewed as parts of one broader path:

actual Quality State

→ condition becomes observable

→ Evidence is obtained

→ information remains materially faithful to the condition

→ information remains available through the necessary path

→ relevant persons correctly interpret it

→ Uncertainty and limitations remain visible

→ the finding remains within the meaning supported by the Evidence

→ the determination remains sufficiently current

→ Quality State conclusion.

This broader path may ultimately provide the most useful research formulation.

Several individual findings in this Section may prove to be different manifestations of one common question:

reliability of the complete Quality-State Determination path.

Alternatively, Context Guide evidence may demonstrate that some are distinguishable enough to require separate treatment.

The present paper should not decide this prematurely.

Interaction with Quality-State Influence

Determination and Influence must also remain distinct.

For example:

insufficient Evidence may result in an indeterminate finding about the Quality State.

That is a Determination finding.

What should then be done is an Influence question.

Similarly:

information may correctly establish a Critical Infrastructure Condition.

That is Determination.

Whether Authority and intervention capability can respond in time belongs primarily to Influence.

The relationship is:

Quality-State Determination
→ establishes what can justifiably be concluded;

Quality-State Influence
→ concerns what can be done about the determined condition.

Preserving this distinction is important for later Indicator research.

Present Status

At the present stage, none of the Quality-State Determination findings identified in this Section justifies addition of a new invariant Indicator.

The strongest provisional research subjects are:

reliability and integrity of the complete Quality-State information path;

possible need for independent or parallel determination paths in Critical Infrastructure Conditions;

preservation of the original meaning of quality-relevant information;

visibility of material Uncertainty;

appropriate treatment of an indeterminate finding;

and

timeliness of the complete determination process.

These subjects should be tested through Context Guides before any an invariant Indicator addition or change is considered.

Interim Finding

The current set of Indicators contains extensive Quality-State Determination questions.

The horizontal analysis nevertheless reveals an important general proposition:

actual Quality State
≠ automatically known Quality State;

available information
≠ necessarily reliable Quality-State determination;

and

insufficient Evidence
≠ demonstrated acceptable Quality State.

The reliability of the determination depends on the complete path through which the actual condition becomes observable, evidenced, communicated, interpreted, and supported as a conclusion.

This complete path should remain a major subject of horizontal Context Guide research.

The next Section examines provisional findings concerning the interaction among Quality-State, Quality-State Determination, and Quality-State Influence:

9.5 Cross-Function Findings

Sections 9.3 and 9.4 examined provisional findings primarily through two separate functions:

Quality-State Determination;

and

Quality-State Influence.

The horizontal analysis also reveals findings that cannot be understood adequately through either function alone.

They arise from the relationship among:

the actual Quality State;

the ability to determine that state;

and

the capability to preserve, restore, or intentionally influence that state.

These are Cross-Function Findings.

They do not establish an additional Indicator category.

Their purpose is to identify relationships among the three provisional categories that may become important when the invariant Indicators are applied together.

The basic relationship is:

Quality State
→ Quality-State Determination
→ Quality-State Influence
→ resulting Quality State
→ renewed Quality-State Determination.

This relationship may repeat throughout the Infrastructure Lifecycle.

A weakness at one point may affect the usefulness of the other functions.

Finding 1 — An Acceptable State Must Be Both Real and Demonstrable

The first Cross-Function Finding concerns the difference between the actual condition and knowledge of that condition.

An Infrastructure Quality Object may physically be in an acceptable state while available Evidence is insufficient to demonstrate that state.

Conversely, available information may appear to support an acceptable determination while the actual physical state is unacceptable because an important condition has not been observed.

Therefore:

actual acceptable Quality State
≠ acceptable Quality State necessarily demonstrated;

and

acceptable Quality-State determination
≠ actual acceptable Quality State necessarily guaranteed.

This distinction is fundamental.

The purpose of Quality-State Determination is to reduce the gap between the actual condition and the condition that can justifiably be concluded from Evidence.

It cannot eliminate all Uncertainty.

The cross-function research question is therefore:

Do the established Indicators sufficiently connect the actual Quality State with the reliability of the determination made about that state?

The present set of Indicators provides substantial coverage of this relationship.

No additional Indicator is presently justified.

Finding 2 — Determination Without Influence May Be Insufficient

A condition may be determined correctly without any adequate capability to affect it.

For example:

a hazardous condition may be recognized;

degradation may be correctly identified;

loss of required function may be detected;

or

an unacceptable Environmental Interaction may be demonstrated.

These are valid Quality-State Determination findings.

But they do not themselves preserve or restore an acceptable Quality State.

Therefore:

correct Quality-State Determination
≠ adequate Quality-State Influence.

The distinction becomes especially important where the condition is developing rapidly.

The cross-function question is:

When a quality-relevant condition is determined, does the Infrastructure Quality Object possess an appropriate capability to preserve, restore, limit, or otherwise influence the resulting state where such Influence is required?

This question is substantially represented through existing Risk Control, Environmental Protection, Operational Reliability, human interaction, Personnel Competence, and Adaptability Indicators.

Context Guide research should test whether any recurring break in the determination path remains.

Finding 3 — Influence Without Reliable Determination May Be Misapplied

The opposite relationship is equally important.

An Infrastructure Quality Object may possess strong Influence capability while lacking reliable information about when or how that capability should be used.

A protective system may exist.

An operator may possess Authority.

Recovery capability may be available.

A system may be capable of Adaptation.

But if the actual condition is not determined correctly, the available Influence capability may:

not be activated;

be activated too late;

be activated unnecessarily;

or

produce an inappropriate response.

Therefore:

Influence capability
≠ effective Quality-State Influence without adequate Determination.

The cross-function relationship becomes:

reliable Determination
+
appropriate Influence capability
→ possibility of effective Quality-State Influence.

Neither element alone is sufficient.

Finding 4 — Quality-State Influence Changes the Object Being Determined

Influence may change the Quality State.

Once the condition changes, the earlier determination may no longer describe the current Infrastructure Quality Object.

This creates a recurring relationship:

Quality-State determination at Time 1
→ intervention
→ changed Quality State at Time 2
→ earlier determination may no longer be sufficient.

This applies to:

Risk mitigation;

repair;

recovery;

operating changes;

Environmental Protection actions;

and

Adaptation.

The cross-function requirement is therefore not merely to determine and then act.

The resulting condition must become the subject of renewed determination.

This creates a loop:

determine
→ influence
→ re-determine.

The present set of Indicators appears to provide substantial coverage through Monitoring, control effectiveness, Operational Reliability, Documentation and Traceability, and Adaptation Results and Outcomes.

The finding should nevertheless remain visible during Context Guide testing.

Finding 5 — The Rate of State Change Connects Determination and Influence

Time creates a direct relationship among all three functions.

The actual Quality State may change.

Determination requires time.

Influence also requires time.

The relevant comparison is therefore not only whether each function works.

It is whether both functions operate sufficiently quickly relative to the rate at which the Quality State can change.

A simplified relationship is:

rate of Quality-State change

compared with

time required to determine the state
+
time required to influence the state.

If the Quality State changes slowly, ordinary Monitoring, interpretation, decision, and intervention paths may be adequate.

If the Quality State changes rapidly, the same paths may become inadequate.

The cross-function question is:

Are the Determination and Influence capabilities compatible with the time available before an unacceptable Infrastructure Outcome can occur?

This finding connects the provisional timeliness questions identified in Sections 9.3 and 9.4.

It may prove more useful to study them together rather than as separate candidate Indicators.

Finding 6 — Indeterminate Finding and Influence

Section 9.4 distinguished three possible determination conditions:

acceptable Quality State demonstrated;

unacceptable Quality State demonstrated;

and

The available Evidence does not presently support a sufficiently confident determination of the Quality State.

The third condition creates an important Cross-Function Finding.

An indeterminate finding is a Determination result, not a third actual Quality State.

It does not by itself prescribe an Influence response.

The appropriate response depends on Context.

For one Infrastructure Quality Object, additional Evidence may be sufficient.

For another, increased Monitoring may be appropriate.

For another, continued operation under restrictions may be justified.

For a time-critical or high-consequence condition, a HOLD or other safe-state response may be necessary.

Therefore:

indeterminate finding
≠ universally unacceptable physical state;

but also:

indeterminate finding
≠ demonstrated acceptable state.

The cross-function question is:

What Influence response, if any, is justified when an acceptable Quality State cannot be demonstrated within the time and conditions of the applicable Context?

An invariant Indicator should not prescribe one universal answer.

Context Guides provide the appropriate level for testing this relationship.

Finding 7 — Information Integrity Affects Both Determination and Influence

Quality-State Information Integrity was identified primarily as a Determination finding.

However, its consequence extends directly into Influence.

If quality-relevant information is:

lost;

delayed;

changed in meaning;

incompletely communicated;

or

interpreted beyond the Evidence,

the resulting Influence decision may also be affected.

The relationship is:

actual condition
→ information
→ determination
→ decision
→ Influence.

A material weakness in the information path may therefore affect both:

what is believed about the Quality State;

and

what is done about it.

This makes Quality-State Information Integrity a potentially important Cross-Function research subject.

The present analysis does not establish whether it requires a separate invariant Indicator.

Its relationship to Factors 3, 8, 9, 12, and 13 should first be tested through Context Guides.

Finding 8 — Authority Connects Knowledge to Action

Authority was examined primarily as an Influence finding.

However, it also forms an Interface between Determination and Influence.

A person may know that a Critical Infrastructure Condition exists.

Another person may possess Authority to act.

The quality-relevant path then depends on the connection between them.

The problem is therefore not simply:

Does Authority exist?

It is:

Is Authority located and connected in a way that allows a supported Quality-State determination to result in appropriate action within the available time?

Possible Context-Specific arrangements include:

Authority at the observation point;

rapid escalation;

pre-authorized protective action;

automatic response;

or

another justified arrangement.

The methods differ.

The cross-question issue is the effective connection between knowledge and action.

Finding 9 — Human Participation May Span All Three Functions

Human participation in the Infrastructure Quality Object should not be reduced to one question.

A person may participate in determining the Quality State by:

observing;

interpreting;

evaluating;

or

making a finding.

The same person may participate in Influence by:

controlling equipment;

authorizing action;

initiating a HOLD;

performing recovery;

or

changing an operating condition.

Human performance may also become part of the actual Quality State where Function Realization depends materially on an Infrastructure-Critical Role.

Therefore, depending on Context, human participation may contribute to:

Quality State;

Quality-State Determination;

Quality-State Influence;

or

all three.

This reinforces the importance of correctly declaring the relevant workplace, Boundary, and human–infrastructure Interfaces.

A geographically remote person may still participate materially in the Infrastructure Quality Object.

Physical distance does not by itself remove the quality-relevant function.

Finding 10 — Communication Paths May Span the Infrastructure Boundary

A similar cross-question issue arises with communication.

A physical or digital communication connection may transmit:

Monitoring information;

operator observations;

technical findings;

decisions;

commands;

or

other Quality-Critical Information.

The same connection may therefore participate first in Determination and later in Influence.

For example:

Infrastructure Quality Object
→ Monitoring information
→ communication connection
→ remote workplace
→ interpretation and decision
→ communication connection
→ control action
→ Infrastructure Quality Object.

This creates a distributed physical and functional structure.

The communication path is not merely an administrative convenience where it materially participates in the ability to determine or influence the Infrastructure Quality State.

The Context Guide must therefore examine the relevant Boundary and Interfaces accordingly.

This finding may be particularly important for infrastructure increasingly dependent on remote operation and control.

Finding 11 — Failure of One Function Can Create Failure in Another

The three questions are distinguishable but interdependent.

A Determination failure may cause an Influence failure.

An Influence failure may create a new unacceptable Quality State.

A failure to determine the resulting state may conceal an unsuccessful Influence action.

The sequence may become:

actual condition
→ incorrect determination
→ inappropriate Influence
→ worsened Quality State
→ inadequate re-determination
→ continued incorrect conclusion.

This shows why the three categories should not be analyzed only in isolation.

Horizontal Context Guide research should also examine their interactions.

Finding 12 — Successful Influence Must Be Judged by the Resulting Quality State

Quality-State Influence should not be judged solely by whether an action was performed.

A control may activate.

A repair may be completed.

An operator may intervene.

A recovery procedure may be executed.

An Adaptation may be implemented.

None of these actions alone demonstrates successful Quality-State Influence.

The relevant question is:

What Quality State resulted?

Therefore:

action performed
≠ successful Influence;

successful Influence
→ must be demonstrated through the resulting Quality State.

This connects Influence back to State and Determination.

The complete relationship is:

determined condition
→ Influence action
→ actual Result or Outcome
→ Evidence
→ renewed Quality-State determination.

This relationship should be tested consistently in Context Guides.

A Possible Common Cross-Function Subject

The findings above may initially appear to represent several separate possible Indicator gaps.

However, horizontal comparison suggests that many may be parts of one broader subject:

the integrity of the complete Quality-State determination-and-influence path.

That path can be represented as:

actual Quality State

→ observation

→ Evidence

→ information

→ interpretation

→ Quality-State determination

→ communication

→ decision

→ Authority

→ Influence

→ resulting Quality State

→ renewed Evidence and determination.

The present Indicators address many parts of this path.

The research question is not whether every step needs a separate invariant Indicator.

It is:

Does the current Indicators, when applied as a whole, sufficiently determine the reliability of this complete relationship?

This may become one of the most important questions for horizontal Context Guide research.

However, it remains provisional.

Present Status

The Cross-Function Findings do not presently justify another invariant Indicator.

They demonstrate that the three provisional categories should not be studied independently.

Quality State provides the actual condition.

Quality-State Determination provides the supported understanding of that condition.

Quality-State Influence provides capability to preserve, restore, limit, or intentionally change the condition.

Influence then creates a condition that must again be determined.

The relationship is therefore continuous:

State
→ Determination
→ Influence
→ State
→ Determination.

The strongest Cross-Function research question concerns whether the complete path remains reliable where:

the Quality State changes rapidly;

information passes through multiple Interfaces;

human interpretation is required;

decision Authority is separated from observation;

or

the resulting condition cannot immediately be demonstrated as acceptable.

Interim Finding

The three provisional Indicator roles are distinguishable but interdependent.

Their interaction reveals quality-relevant questions that may not be visible when individual Indicators are examined separately.

The most important general finding is:

reliable Infrastructure Quality State Determination requires more than knowing the condition;

effective Quality-State Influence requires more than possessing an intervention capability;

and

successful Influence must ultimately be demonstrated through the resulting Quality State.

These Cross-Function Findings should therefore be preserved as part of the continuing Context Guide research program.

The next Section explains why provisional findings do not themselves establish that another Indicator is needed:

9.6 Why Identifying a Provisional Finding Does Not Establish an Additional Indicator

Identifying a Provisional Additional Indicator Finding does not by itself establish that another Indicator is needed.

This distinction is necessary to preserve both stability and continued research.

The fourteen Quality Factors and their Indicators provide the dimensions examined in this article.

A provisional finding has a different status.

It identifies a question that deserves further testing.

It does not establish that the current Indicator set is incorrect.

It does not establish that an existing Indicator is unnecessary.

It does not establish that a new invariant Indicator is required.

The relationship is:

provisional finding
≠ demonstrated gap among the Indicators;

demonstrated gap among the Indicators
≠ automatic addition or change to an invariant Indicator;

sufficient accumulated justification
→ possible controlled addition or change to an invariant Indicator.

Why One Finding Is Not Enough

A Context Guide can reveal an important condition.

That condition may be essential for the Infrastructure Quality Object being examined.

But importance within one Context does not establish invariance.

The finding may prove to be:

Context-specific;

a particular Failure Mode;

a specific technical method;

Evidence;

a Quality Outcome Criterion;

a Boundary or Interface issue;

or

a more detailed interpretation of an established Indicator.

The first occurrence therefore establishes a research question.

It does not establish a new invariant Indicators requirement.

Existing invariant Indicators Coverage Must Be Tested First

Before considering an additional Indicator, test the finding against all existing Indicators.

This test should not be limited to the Factor where the issue was first identified.

Horizontal analysis may show that the question is already represented elsewhere.

It may also show that several existing Indicators together provide adequate coverage.

For example, the provisional determination-to-intervention question identified in this paper may involve existing Indicators concerning:

Risk Controls;

Operational Reliability;

Workplace Human Interaction;

Personnel Competence;

Monitoring;

Documentation and Traceability;

and

Adaptability and Recoverability.

The fact that no single Indicator uses the proposed research wording does not prove that the question is missing.

The correct test is functional:

Can the current Indicators sufficiently determine the condition when its relevant Indicators are applied together?

If yes, adding or changing an Indicator is not justified.

context-specific interpretation Must Be Tested

A provisional finding may also disappear when an existing Indicator is interpreted at the smaller Context Guide resolution.

The invariant Indicator is intentionally general.

The Context Guide provides the detail.

Therefore, absence of specific technical wording in the established Indicators should not be treated as evidence of a gap.

The question is:

Can the existing invariant Indicator reasonably support the necessary Context-Specific determination?

If yes, the appropriate response is Context Guide development.

It is not addition or change to an invariant Indicator.

Boundary and Interface Questions Must Be Resolved

The same caution applies to Infrastructure Boundaries and Interfaces.

An apparent Indicator gap may result from an incomplete description of the Infrastructure Quality Object.

For example, a quality-relevant path may include:

field equipment;

Monitoring equipment;

communication connections;

remote workplaces;

control centers;

Infrastructure-Critical Roles;

or

external Interfaces.

If one of these elements materially participates in Function Realization, Quality-State Determination, or Quality-State Influence, excluding it from the relevant analysis may create an artificial gap.

The first correction should therefore be to the declared Quality Object, Boundary, or Interface where appropriate.

addition or change to the Indicators should not be used to correct an incomplete Context definition.

Repeated Evidence Is Required

A stronger case begins when the same underlying determination question appears repeatedly.

Even then, repetition alone is not sufficient.

The research must determine whether the question recurs across materially different Infrastructure Quality Objects.

The physical manifestations may differ.

The underlying question should remain recognizable.

The relationship is:

different Contexts
→ different physical manifestations
→ same unresolved necessary function
→ stronger evidence of possible invariance.

This is why continued Context Guide development is important.

Each Context Guide provides another test of the present Indicators.

Diversity of Contexts Matters

Several findings within one infrastructure family may reveal an important sector need.

They do not necessarily demonstrate an invariant infrastructure need.

Evidence becomes stronger when the same function appears across substantially different infrastructure Contexts.

The relevant question is therefore not only:

How often does the finding occur?

It is also:

Across how different Infrastructure Quality Objects does it remain necessary?

This protects the invariant Indicators from becoming dominated by the needs of one infrastructure sector.

Necessity Must Be Demonstrated

A candidate should not enter the Indicators merely because it improves description.

The removal test remains necessary.

The research must ask:

If this candidate question is not represented, what material part of Infrastructure Quality State Determination is lost?

If the answer is unclear, the claim that another Indicator is needed is weak.

If repeated Context Guide analysis shows that omission consistently creates a material blind area, the case becomes stronger.

The Indicators should contain necessary invariant determination questions.

It should not become a collection of every useful question that can be asked about infrastructure.

Distinguishability Must Be Demonstrated

The candidate must also remain distinguishable from established Indicators.

A new Indicator should not be added merely because the same function can be described with different words.

The candidate must preserve a determination question that cannot be represented sufficiently through the existing Indicators.

Therefore:

different wording
≠ different function;

additional detail
≠ different function;

different method
≠ different function.

The test concerns what becomes determinable through the candidate that is not sufficiently determinable without it.

The Candidate Must Be Examined at the Selected Methodological Resolution

A provisional finding may be necessary and recurring but still belong below selected methodological resolution.

This is possible where the question depends strongly on:

one infrastructure technology;

one equipment type;

one particular operating arrangement;

one specialized Failure Mode;

or

one sector-specific method.

Such a finding may justify a recurring Context Guide provision without justifying an invariant Indicator.

The possible invariant Indicator must be capable of being stated independently of those particular realizations.

The relationship must remain:

invariant determination question
→ different Context-Specific realizations.

If that relationship cannot be established, the finding should remain below the level of an invariant Indicator.

Provisional State, Determination, and Influence Categories Do Not Establish Additional Indicators

The Quality-State, Quality-State Determination, and Quality-State Influence questions examined in this paper are research tools.

Their usefulness does not itself justify an additional Indicator.

The present Indicators may address more than one of these categories without being reorganized into three new groups.

Likewise, identifying a recurring Influence or Determination function does not automatically require a new Indicator.

The three-function analysis is useful if it helps answer questions such as:

What does the existing Indicator actually contribute?

Where do several Indicators overlap?

Where does one question appear weak?

Does a possible gap recur across Factors or Contexts?

The classification should therefore support analysis.

It should not predetermine Factor and Indicator structure.

A Provisional Finding May Strengthen the Existing Indicators Without Requiring an Addition

Continued research may show that a provisional finding is already adequately represented.

This is an important possible result.

For example, Context Guide testing may demonstrate that the apparent determination-to-intervention gap is sufficiently covered when existing Indicators concerning Monitoring, Competence, Risk Controls, Authority, Recovery, and Adaptation are applied together.

In that case, the research does not fail.

It strengthens the justification of the current Indicators.

Likewise, research into Quality-State Information Integrity may show that Factors 8, 9, 12, and 13 already provide sufficient coverage when properly interpreted.

The provisional finding can then be closed without adding an Indicator.

A Provisional Finding May Remain Open

Some findings may remain unresolved for an extended period.

That is also acceptable.

Insufficient Evidence for addition does not require rejection.

Insufficient Evidence for rejection does not require addition.

The appropriate status may remain:

Open — additional Context Guide Evidence required.

This is preferable to forcing a conclusion before the research supports one.

A Provisional Finding May Be Rejected

Continued research may also show that a candidate should not be retained.

It may prove:

unnecessary;

redundant;

Context-specific;

method-specific;

already covered;

or

outside the proper Indicator level.

The finding should then be closed.

There is no reason to preserve a candidate merely because it was once considered.

A Provisional Finding May Support an Additional Indicator

addition or change to an invariant Indicator becomes a legitimate question only after a substantially stronger case has developed.

The research should support that:

the question is quality-relevant;

the question is necessary;

removal materially weakens Quality-State determination;

current Indicators do not sufficiently represent it;

the question is distinguishable and non-redundant;

the finding is not merely Evidence, a Quality Outcome Criterion, or a method;

the issue is not resolved through correct Boundary or Interface declaration;

the question recurs across materially different infrastructure Contexts;

and

the question can be stated at invariant selected methodological resolution.

Only then does the question change from:

Should this finding continue to be researched?

to:

Should this question be considered for inclusion in the invariant Factors and Indicators?

Even this stronger finding raises the question whether an additional Indicator is justified.

It does not answer it automatically.

Why This Caution Is Necessary

The invariant Indicators serve a different purpose from a Context Guide.

The Context Guide should become detailed.

The Indicators should remain general enough to apply across infrastructure Contexts.

If every important Context finding changed the Indicators, the distinction between the Indicators and Context Guides would gradually disappear.

The opposite error must also be avoided.

If the present Indicators were treated as permanently closed, repeated evidence of a determination question not represented by an invariant Indicator could not be incorporated.

The appropriate approach is neither automatic addition nor permanent closure.

It is:

stable invariant Indicators
+
continued testing
+
preserved provisional findings
+
additional Indicators only when justified.

This approach is consistent with the central conclusion of this paper.

Necessity of the established invariant Indicators can be tested.

Permanent sufficiency of the present Indicators need not be claimed.

Interim Finding

Provisional Additional Indicator Findings provide evidence for continued research.

They do not themselves provide sufficient grounds for changing the established Indicators.

A finding should first be tested against:

current Indicators coverage;

context-specific interpretation;

Evidence and Quality Outcome Criteria;

Boundary and Interface definition;

necessity;

distinguishability;

Context recurrence;

and

invariant Indicator level applicability.

The finding may then be:

resolved through the current Indicators;

retained for additional research;

combined with another finding;

rejected;

or

eventually supported as a candidate for controlled addition or change to an invariant Indicator.

This distinction allows the Indicators to remain stable while their adequacy continues to be tested.

The next Section brings the Indicator-necessity analysis together:

10. Why the Present Indicator Set Is Necessary but Not Declared Closed

The analysis developed in this paper supports two conclusions that must be kept together.

First:

the established Indicators are necessary within their respective Quality Factors for examining Infrastructure Quality State at the present stage of development.

Second:

the set of Indicators should not be declared permanently closed.

These conclusions are not contradictory.

Necessity concerns the established Indicators individually.

Closure concerns whether any additional invariant Indicator could ever be justified.

The research supports the first conclusion without claiming the second.

Necessity of the Established Indicators

The Factor-by-Factor analysis examined the established invariant Indicators through the removal test.

The central question was:

What becomes materially less determinable if this Indicator is removed?

An Indicator is necessary where its removal creates a meaningful loss in the ability to determine the Infrastructure Quality State under its Quality Factor.

This necessity does not require every Indicator to represent a completely isolated concept.

The horizontal analysis showed that similar determination questions recur across multiple Indicators.

These include:

change;

traceability;

retention of information and knowledge;

Uncertainty;

abnormal and degraded conditions;

cumulative effects;

and

relationships among Quality State, Quality-State Determination, and Quality-State Influence.

Such recurrence does not automatically establish redundancy.

The same kind of determination question may apply to different quality-relevant subjects.

For example:

retention of Risk information
≠ retention of Monitoring knowledge;

Technical Specification change
≠ Monitoring relevance after change;

Risk under abnormal conditions
≠ Operational Reliability under abnormal conditions.

The common question does not eliminate the distinct determination question.

Necessity must therefore be judged by what is lost when the individual Indicator is removed.

Distinguishability Supports Necessity

The analysis also showed that necessity and distinguishability are closely related.

If two Indicators appear similar, the question is not simply whether they share words or concepts.

The question is:

Does each preserve a determination question that the other does not sufficiently preserve?

If yes, both may remain necessary.

This distinction is particularly important at the Indicator layer because Indicators operate at a smaller resolution than Quality Factors.

The fourteen Quality Factors establish broad invariant dimensions.

The Indicators identify what must be examined to determine the Quality State within each Factor.

Removing an Indicator may therefore weaken the resolution of a Factor even though the Factor itself remains present.

The relationship can be expressed as:

Quality Factor remains
+
necessary Indicator removed
→ part of the Factor becomes insufficiently determinable.

This provides the principal basis for the necessity conclusion.

Necessity Does Not Mean Equal Importance in Every Context

An invariant Indicator does not need to have identical practical importance in every infrastructure Context.

One Indicator may become especially significant for one Infrastructure Quality Object.

Another may become especially significant for another.

The relevant:

Evidence;

Failure Modes;

Lifecycle Stages;

Boundaries;

Interfaces;

and

Quality Outcome Criteria

may also differ.

Invariance therefore does not mean identical application.

It means that the determination question remains available and meaningful when the applicable infrastructure Context requires it.

A Context Guide provides interpretation at a more specific level of detail.

Necessity Does Not Mean Every Indicator Relates to Only One Category

The horizontal analysis also showed that one Indicator may contribute to more than one provisional category.

It may concern:

Quality State;

Quality-State Determination;

Quality-State Influence;

or

a combination.

This does not weaken its necessity.

For example, a Risk Control may be:

an actual capability of the Infrastructure Quality Object;

something whose effectiveness must be determined;

and

a means of influencing a developing condition.

The Indicator does not need to be split merely because several analytical questions can be identified.

The relevant test remains whether its removal creates a meaningful determination loss.

Why Permanent Sufficiency Cannot Be Demonstrated

The conclusion concerning the present Indicators must be more limited.

The analysis examines the established Indicators and asks whether each remains necessary.

It cannot demonstrate that no additional invariant determination question will ever be identified.

Infrastructure Contexts are numerous.

Technologies change.

Infrastructure systems become more interconnected.

Remote operation and communication may change the physical and functional structure of the Infrastructure Quality Object.

New Context Guides may reveal relationships not sufficiently visible in earlier applications.

Analysis at greater methodological detail may expose determination questions that were hidden at the selected resolution.

For these reasons, permanent sufficiency would be a stronger claim than the present Evidence supports.

The appropriate conclusion is therefore:

the established set of Indicators is supported as necessary and adequate for continued application and testing at this stage;

it is not demonstrated to be permanently exhaustive.

Present Adequacy and Permanent Closure Are Different

The distinction can be stated as:

present adequacy
≠ permanent closure.

Present adequacy means that the established Indicators provide a workable basis for current IQI application and continued Context Guide development.

Permanent closure would mean that no additional invariant Indicator could ever be justified.

This study does not make that claim.

This distinction allows the Indicators to remain stable without becoming conceptually closed.

Context Guides Provide the Continuing Test

The principal mechanism for testing continuing adequacy is the Infrastructure Context Guide family.

Each Context Guide applies the invariant set of Indicators to a more specific Infrastructure Quality Object.

This produces a repeated test.

The relationship is:

stable invariant Indicators
→ Context-Specific application
→ smaller-resolution analysis
→ Evidence
→ horizontal comparison
→ possible provisional findings.

As the Context Guide family expands, the diversity of these tests also expands.

Repeated successful application strengthens confidence in the existing Indicators.

Repeated unresolved findings may identify a possible gap among the Indicators.

Both results are useful.

Evidence for an Additional Indicator Can Accumulate

The absence of a new Indicator finding is not an absence of research results.

If materially different Context Guides continue to show that the existing Indicators adequately represent the necessary quality-relevant determination questions, the Evidence supporting the present Indicators becomes stronger.

The research sequence may therefore produce:

new Context
→ apparent issue

→ existing Indicator found sufficient
→ stronger evidence supporting current Indicators coverage.

This is an important possible outcome.

The purpose of continued testing is not to find additional Indicators.

It is to determine whether additional Indicators are actually necessary.

Evidence for an Additional Indicator Can Also Accumulate

The opposite result must remain possible.

A Context Guide may identify a determination question that appears insufficiently represented.

The finding may then recur in another Context.

Further comparison may show that:

the physical manifestations differ;

the technical methods differ;

the Evidence differs;

but

the same necessary determination question remains unresolved.

If this continues across materially different Infrastructure Quality Objects, the case for possible invariant status becomes stronger.

The research sequence then becomes:

Context-Specific finding
→ provisional finding
→ recurrence
→ horizontal comparison
→ necessity test
→ distinguishability test
→ test at the selected methodological resolution
→ possible review of additional Indicators.

This process allows any addition or change to follow Evidence rather than assumption.

Why Immediate Addition Would Be a Weakness

Immediate addition or change to an invariant Indicator after every important Context finding would create several problems.

The invariant Indicators could become increasingly:

technology-specific;

sector-specific;

method-specific;

and

difficult to apply consistently across infrastructure Contexts.

Context Guide detail would gradually move into the invariant Indicators.

The distinction between the two levels would weaken.

A stable set of invariant Indicators therefore has methodological value.

It allows the same Indicator structure to be tested repeatedly.

Without a period of stability, it becomes difficult to determine whether an apparent gap is truly invariant or merely a feature of one application.

Why Permanent Closure Would Also Be a Weakness

The opposite approach would create a different problem.

If the present Indicators were declared permanently complete, new Evidence could not meaningfully test its sufficiency.

Context Guides would then become only applications of the Indicators.

They could no longer serve as research and test cases for development of the Indicators.

A necessary determination question discovered repeatedly across different infrastructure Contexts might then be forced artificially under an existing Indicator even where the fit is poor.

This would preserve the appearance of stability while weakening the quality of the model.

The appropriate approach is therefore:

stability without closure.

The Role of Provisional Findings

Provisional Additional Indicator Findings provide the mechanism for maintaining this balance.

They allow a possible gap to remain visible without changing the established Indicators.

A finding can be:

recorded;

tested;

compared;

combined;

refined;

rejected;

or

eventually supported for controlled review of possible additional Indicators.

This creates a separation between:

research finding;

and

invariant Indicators requirement.

That separation is important for disciplined development of the Indicator layer.

The Three Provisional Horizontal Categories Support Continued Testing

The Quality-State, Quality-State Determination, and Quality-State Influence classification developed in this paper provides an additional research tool.

It does not replace or reorganize the fourteen Quality Factors and their Indicators.

It does not reorganize the invariant Indicators.

Its purpose is to make horizontal categories and relationships more visible.

It allows Context Guide research to ask:

What part of the actual Quality State does this Indicator reveal?

How does the Indicator contribute to determining that state?

How does it contribute to preserving, restoring, or influencing that state?

Do recurring determination questions remain insufficiently addressed?

This may help identify both hidden overlap and hidden gaps.

The classification itself should also remain subject to testing.

Controlled Development of the Indicator Layer

The resulting approach to Indicator development can be summarized as:

1. Maintain the established set of Indicators.

2. Apply the Indicators through Context Guides.

3. Interpret the Indicators at a more specific Context-dependent level of detail.

4. Identify appropriate Evidence and Quality Outcome Criteria.

5. Record apparent gaps without immediately changing the Indicators.

6. Test those findings against the complete existing Indicators.

7. Compare recurring findings across materially different Contexts.

8. Apply necessity, removal, distinguishability, and non-redundancy tests.

9. Determine whether the finding remains Context-specific or demonstrates a possible invariant question.

10. Consider adding or changing an invariant Indicator only when accumulated Evidence justifies it.

This approach does not assume that revision will be required.

It establishes how revision can be justified if the Evidence eventually requires it.

Central Conclusion

The present research therefore supports a deliberately limited conclusion.

Removing an established Indicator would leave a distinct determination question less adequately addressed within its Quality Factor. The analysis therefore supports the need for the established Indicators. It does not show that each Indicator has the only possible wording, structure, or placement.

Overlap among Indicators does not by itself make them redundant.

Different Indicators may address similar questions while preserving distinct subjects of determination.

At the same time, the present research does not establish that no further Indicator could ever be justified.

Such a conclusion would require knowledge of all relevant infrastructure Contexts and all determination questions that may become visible through continuing application.

That Evidence does not exist.

The defensible position is therefore:

The present analysis supports the need for the established Indicators as the current basis for determining Infrastructure Quality State.

Their continuing adequacy should be tested through Context Guide application and horizontal comparison.

Possible additional invariant questions should be preserved as provisional findings. An Indicator should be added only when its necessity, distinctness, nonredundancy, and invariance across Contexts are sufficiently supported.

In shorter form:

necessary
≠ permanently exhaustive;

stable
≠ closed;

open to evidence-supported addition or change
≠ continuously changing.

The following Subsections consolidate the results of this analysis, distinguish what the research supports from what it does not establish, and state the present status of the Indicators.

10.1 Results of the Indicator Necessity Tests

The Factor-by-Factor analysis in Section 6 applied the Indicator necessity method developed in Section 4 to the established Indicators.

The purpose was not to show that every Indicator is equally important in every infrastructure Context.

The purpose was to determine whether each established Indicator preserves a necessary quality-relevant determination question within its parent Quality Factor.

The principal test was removal.

For each Indicator, the question was:

If this Indicator is removed, does a material part of the Quality State represented by the parent Quality Factor become insufficiently observable or determinable?

The analysis supports an affirmative answer for the established Indicators.

Removal of an Indicator may leave the parent Quality Factor in place.

However, the Factor may then lose part of the resolution required for meaningful Quality State determination.

The general relationship is:

Quality Factor
→ identifies a major quality-relevant dimension;

invariant Indicators
→ make the necessary parts of that dimension observable and determinable.

Therefore:

Factor retained
+
necessary Indicator removed
→ incomplete determination of the Factor.

Results Across the Fourteen Factors

The necessity tests produced the same general result across all fourteen Quality Factors.

The established Indicators address distinguishable questions needed to determine the condition represented by their parent Factor.

Under Factor 1, the Indicators identify the Functional Requirements and related parts of the Functional basis to examine.

Under Factor 2, the Indicators identify the Technical Requirements and related matters to examine in determining whether the technical basis can realize the required functions.

Under Factor 3, the Indicators identify what must be examined to determine whether applicable requirements have been fulfilled through Conformity Assessment supported by Evidence.

Under Factor 4, the Indicators identify conditions to examine in determining whether the infrastructure can maintain required physical and functional integrity.

Under Factor 5, the Indicators identify conditions to examine in determining Harm, Risk, and Safety, including conditions that may lead to Loss-of-Control or other unacceptable consequences.

Under Factor 6, the Indicators identify conditions to examine in determining Environmental Protection, including Environmental Interaction, prevention, limitation, and resulting Environmental Effects.

Under Factor 7, the Indicators identify actual Function Realization, disturbance tolerance, degradation, Recovery Capability, and related operating conditions to examine in determining Operational Reliability.

Under Factor 8, the Indicators identify quality-relevant conditions at the human–infrastructure Interface to examine in determining Human and Infrastructure Interaction.

Under Factor 9, the Indicators identify the competence of Personnel in Infrastructure-Critical Roles to examine under normal, abnormal, degraded, and non-routine conditions.

Under Factor 10, the Indicators identify the identification, application, maintenance, and change of Applicable Requirements to examine in determining Regulatory and Standards Compliance.

Under Factor 11, the Indicators identify Infrastructure Effects, supporting observations, and resulting conditions affecting Stakeholders and Communities to examine.

Under Factor 12, the Indicators identify observation, detection, interpretation, and continuing relevance of information about infrastructure performance and condition to examine.

Under Factor 13, the Indicators identify preservation, linkage, accessibility, and continuity of Quality-Critical Information and Evidence to examine.

Under Factor 14, the Indicator identifies whether infrastructure can accommodate required changes while preserving Functional Intent and Integrity, including through Reversibility or Recoverability and the evaluation of Adaptation Results and Outcomes.

The specific necessity argument differs among Indicators.

The general result does not.

Each established Indicator preserves a determination question whose removal would reduce the ability to determine the Quality State represented by its parent Factor.

Results of the Removal Test

The removal test was especially useful because it avoided a weaker question:

Is this Indicator useful?

Many additional questions could be useful.

Usefulness alone does not justify status as an invariant Indicator.

The stronger question was:

What is lost if the Indicator is removed?

The analysis showed several types of loss.

Removal may cause loss of visibility of:

a necessary condition;

a Failure Mode or failure-related condition;

a required capability;

a change affecting the earlier determination basis;

a Boundary or Interface condition;

a source of material Uncertainty;

a condition affecting Evidence reliability;

or

a Result or Outcome needed to determine whether the Intended Function is actually being realized.

These losses differ.

But each can materially weaken Quality State determination.

Results of the Distinguishability Test

The analysis also found recurring conceptual overlap among Indicators.

This was expected.

Infrastructure quality is not composed of completely independent conditions.

For example:

change appears under several Factors;

Uncertainty appears under several Factors;

abnormal and degraded conditions appear under several Factors;

information retention and Traceability appear under several Factors;

and

Monitoring, Competence, Evidence, and interpretation interact across several Factors.

The distinguishability test showed that recurrence of a concept does not by itself establish redundancy.

The relevant question is:

What subject does the Indicator identify for examination?

For example:

change in Technical Specifications
and
change affecting Monitoring relevance

share the concept of change.

They do not determine the same condition.

Likewise:

retention of Risk knowledge
and
retention of Monitoring knowledge

share a retention function.

They preserve different quality-relevant information.

Therefore:

shared function
≠ redundant Indicator.

The necessity of an Indicator remains supported where removal eliminates a distinguishable determination question.

Results of the Non-Redundancy and Overlap Test

The analysis did not identify sufficient grounds to remove an established Indicator merely because it overlaps functionally with another Indicator.

Some overlap is necessary because the fourteen Factors describe different but interacting dimensions of one Infrastructure Quality Object.

A condition may legitimately affect more than one Factor.

The important distinction is between:

functional interaction;

and

unnecessary duplication.

Functional interaction occurs where different Indicators examine different quality-relevant subjects that affect one another.

Unnecessary duplication would occur where two Indicators repeatedly preserve substantially the same determination question without a meaningful difference in subject or result.

The present analysis supports the first interpretation for the established Indicators.

However, continued Context Guide testing remains appropriate.

If two Indicators repeatedly collapse into the same determination question across materially different infrastructure Contexts, their separation should be re-examined.

Results of the Lifecycle Relevance Test

The necessity analysis also confirmed that Indicator relevance may change across Lifecycle Stages without eliminating invariance.

An Indicator may be especially important during Design.

Another may become especially visible during Construction, Commissioning, Operation, Maintenance, Repair/Modification, or another applicable Lifecycle Stage.

This does not require every Indicator to have identical weight at every stage.

The test is whether the determination question remains necessary where the relevant quality condition exists.

Therefore:

invariant Indicator
≠ identical Lifecycle application.

Context Guides provide the smaller resolution needed to identify where and how the Indicator applies.

Results of the Boundary and Interface Test

The analysis also confirmed that Indicator necessity cannot always be tested correctly without proper declaration of the Infrastructure Quality Object, its Boundaries, and its Interfaces.

This is particularly important for Indicators involving:

Monitoring;

human interaction;

Personnel Competence;

Operational Reliability;

Documentation and Traceability;

and

Quality-State Influence.

A relevant workplace may be remote.

A communication connection may cross the principal physical site Boundary.

A person making an infrastructure-critical decision may be geographically separated from the equipment affected by that decision.

An external infrastructure connection may materially affect Function Realization while the external system itself remains outside the declared Quality Object.

Therefore, the necessity test must follow the actual quality-relevant relationships of the Infrastructure Quality Object.

It should not assume that every necessary question is physically located inside one facility.

Results of the Evidence and Determinability Test

The analysis also confirmed the importance of separating an Indicator from the Evidence used to evaluate it.

An Indicator remains necessary even where the available Evidence is presently weak.

Indeed, weak Evidence may reveal a limitation in the ability to determine the Quality State.

Therefore:

difficulty evaluating an Indicator
≠ Indicator unnecessary.

The appropriate question is:

What Evidence is required to support the determination represented by the Indicator, and what conclusion can the available Evidence actually support?

This result also reinforces the distinction between:

Indicator;

Evidence;

and

Quality Outcome Criterion.

The three perform different questions.

Results of the Context-Invariance Test

The existing Context Guide evidence supports continued treatment of the established Indicators as invariant Indicators.

Their physical realization differs across infrastructure Contexts.

Their supporting Evidence differs.

Their applicable Quality Outcome Criteria differ.

Their Failure Modes differ.

Their Boundaries and Interfaces may differ.

Yet the underlying determination questions remain meaningful.

This supports the proposition:

invariance belongs to the determination question, not to identical physical realization.

The present Context Guide evidence is not sufficient to demonstrate permanent completeness of the Indicators.

But it supports continued use of the established Indicators as the basis of the invariant Indicators.

Results of the Three-Category Horizontal Test

The provisional Quality-State, Quality-State Determination, and Quality-State Influence analysis produced an additional result.

The established Indicators do not fall into three separate and exclusive groups.

Some primarily concern the actual Quality State.

Some primarily concern the ability to determine that state.

Some primarily concern capability to preserve, restore, or influence that state.

Many perform more than one of these categories.

This overlap does not weaken the necessity finding.

Instead, it helps explain how different Indicators participate in the complete Quality State relationship:

actual Quality State

→ Quality-State Determination

→ where required, Quality-State Influence

→ resulting Quality State

→ renewed Quality-State Determination.

The three-category analysis therefore remains useful as a horizontal research tool.

The analysis does not support introducing it as a new established Indicators layer at this stage.

Results Concerning Possible Gaps

The necessity tests also produced an important secondary result.

Testing the established Indicators revealed questions that do not yet justify additional invariant Indicators but deserve continued research.

These include possible recurring functions concerning:

the integrity of the Quality-State information path;

continuity from Quality-State determination to intervention;

timeliness of determination and intervention;

Authority in relation to Critical Infrastructure Conditions;

independent or parallel information paths where needed;

possible distortion of quality-relevant information between observation and decision;

and

re-determination following Quality-State Influence.

The existence of these questions does not weaken the necessity conclusion for the established Indicators.

It addresses a different question:

whether the present necessary Indicators are also permanently sufficient.

The present research does not make that stronger claim.

Overall Result

The Indicator necessity tests support retention of the established Indicators.

The principal reason concerns what each Indicator enables us to determine.

Each Indicator preserves a quality-relevant determination question whose removal would materially reduce the ability to determine the Quality State represented by its parent Quality Factor.

The analysis did not identify sufficient grounds for removing, combining, or replacing an established Indicator at this stage.

At the same time, the analysis identified several provisional questions for continued Context Guide testing.

The resulting conclusion is therefore deliberately limited:

Each established Indicator is necessary within its Quality Factor because it preserves a distinct determination question.

The analysis does not demonstrate that no additional invariant Indicator may ever be justified.

The next Section separates these two conclusions more precisely:

10.2 What the Analysis Demonstrates

The analysis in this paper supports several conclusions concerning the established Indicators.

These conclusions should be stated carefully.

The purpose is not to claim more than the analysis demonstrates.

The principal conclusion is that each established Indicator preserves a necessary determination question within its Quality Factor.

This conclusion is supported by the Factor-by-Factor necessity analysis, the removal test, the distinguishability analysis, horizontal comparison, and the existing Context Guide evidence.

The analysis also demonstrates several broader characteristics of the Indicator layer.

1. The Indicators Are Required to Make the Quality Factors Determinable

The fourteen invariant Quality Factors identify the major dimensions relevant to Infrastructure Quality State.

However, a Quality Factor alone operates at a larger resolution.

Its invariant Indicators identify the smaller determination questions needed to make that Factor sufficiently observable and determinable.

The relationship is:

Quality Factor
→ major quality-relevant dimension;

invariant Indicators
→ necessary determination subjects within that dimension.

The analysis supports the conclusion that removal of an established Indicator can leave the parent Factor formally present while reducing the ability to determine part of the condition represented by that Factor.

Therefore, the Indicator layer is not merely descriptive detail added beneath the Factors.

It addresses a necessary determination question.

2. Indicator Necessity Can Be Tested Through Removal

The analysis supports the conclusion that the removal test provides a useful method for examining Indicator necessity.

The test asks:

What becomes materially less observable or determinable if the Indicator is removed?

This question is stronger than asking whether the Indicator is useful.

Many Context-Specific questions may be useful.

Invariant status as an invariant Indicator requires a stronger justification.

Where removal creates a material loss in Quality State determination, the necessity case is supported.

This method can also be used in continuing invariant Indicators research.

3. Similarity Does Not Automatically Mean Redundancy

The horizontal analysis demonstrates that different Indicators may contain recurring concepts without becoming redundant.

Examples include:

change;

Uncertainty;

traceability;

retention of information;

abnormal and degraded conditions;

Monitoring;

and

recovery.

The important question is not whether the same concept appears more than once.

It is:

What quality-relevant subject does the Indicator identify for examination?

The same kind of determination question may operate on different subjects.

Therefore:

shared concept
≠ same determination question;

and

shared function
≠ redundancy necessarily.

This distinction is important when evaluating whether apparently similar Indicators should remain separate.

4. Indicator Invariance Does Not Require Identical Physical Realization

The analysis supports the conclusion that an invariant Indicator may have materially different physical realization in different infrastructure Contexts.

The relevant:

equipment;

technology;

Failure Modes;

Boundaries;

Interfaces;

Lifecycle conditions;

Evidence;

and

Quality Outcome Criteria

may differ.

The invariant element is the determination question.

Therefore:

invariant Indicator
≠ identical physical condition in every Context.

This allows the same invariant Indicator to be interpreted through different Context Guides without changing the Indicator's meaning.

5. Context-Specific Interpretation Does Not Change the Indicator's Meaning

The analysis demonstrates the importance of separating:

invariant Indicator;

context-specific interpretation;

Evidence;

and

Quality Outcome Criterion.

The relationship is:

Invariant Indicator
→ context-specific interpretation
→ Evidence-Supported Finding
→ comparison with the applicable Quality Outcome Criterion.

A Context Guide may introduce substantial detail.

That detail does not automatically become part of the invariant Indicators.

This separation allows the Indicators to remain stable while the Context Guide reaches the smaller resolution needed for the particular Infrastructure Quality Object.

6. New Evidence Does Not Automatically Mean a New Indicator

The analysis supports the conclusion that new Evidence should first be connected to the determination question it supports.

A new:

sensor;

inspection;

test;

record;

calculation;

observation;

Monitoring source;

or

other Evidence source

does not itself establish a new invariant Indicator.

The relevant question is:

What quality-relevant condition does this Evidence help determine?

If an existing Indicator already represents that condition, the new item belongs at the Evidence level.

Therefore:

new Evidence
≠ new Indicator.

7. A New Quality Outcome Criterion Does Not Automatically Mean a New Indicator

The same conclusion applies to Quality Outcome Criteria.

Different infrastructure Contexts may require different:

limits;

ranges;

response times;

performance conditions;

recovery conditions;

or

other expected or acceptable results.

These differences do not necessarily require different invariant Indicators.

The Indicator identifies what must be examined.

The Quality Outcome Criterion establishes what condition is expected or acceptable in the particular Context.

Therefore:

new or different Quality Outcome Criterion
≠ new invariant Indicator.

8. Boundary and Interface Definition Affect Indicator Application

The analysis supports the conclusion that correct Indicator application depends on correct declaration of the Infrastructure Quality Object.

A relevant quality function may extend through:

physical equipment;

buildings or supporting facilities;

communication connections;

remote workplaces;

human–infrastructure Interfaces;

upstream or downstream Interfaces;

or

other physically distributed elements.

A geographically remote element may still materially participate in Function Realization, Quality-State Determination, or Quality-State Influence.

Therefore:

geographic separation
≠ quality-relevant separation necessarily.

An apparent Indicator gap should not be identified before the relevant Boundary and Interfaces have been examined.

9. Quality-State Determination Is a Path, Not Only an Observation

The horizontal analysis demonstrates that determining the Infrastructure Quality State may require more than obtaining information.

A simplified determination path is:

actual condition
→ observation
→ Evidence
→ communication
→ interpretation
→ Evidence-Supported Finding
→ Quality-State determination.

Weakness at any point may affect the reliability of the final determination.

This observation does not establish a new invariant Indicator.

It does demonstrate the importance of examining the interaction among existing Indicators concerning:

Conformity;

human interaction;

Personnel Competence;

Monitoring;

Documentation and Traceability;

Risk;

and

other relevant Factors.

10. Quality-State Influence Is Distinguishable from Quality-State Determination

The analysis supports the usefulness of distinguishing between:

determining the condition;

and

possessing capability to preserve, restore, limit, or intentionally change that condition.

A condition may be determined correctly while effective intervention remains unavailable.

Likewise, intervention capability may exist while the condition requiring intervention is not reliably determined.

Therefore:

Quality-State Determination
≠ Quality-State Influence.

The distinction is analytically useful even though individual invariant Indicators may contribute to both functions.

11. Determination and Influence Are Interdependent

Although distinguishable, the two functions are connected.

The analysis demonstrates the recurring relationship:

Quality State
→ Determination
→ Influence where required
→ resulting Quality State
→ renewed Determination.

This relationship means that successful intervention cannot be demonstrated merely by showing that an action occurred.

The resulting condition must be determined.

Therefore:

action performed
≠ acceptable Quality State demonstrated.

The actual Result or Outcome must become Evidence for renewed Quality-State determination.

12. Time Can Connect State, Determination, and Influence

The analysis supports the conclusion that time may affect the complete relationship among the three provisional categories.

The Quality State may change while:

information is being obtained;

information is being communicated;

the condition is being interpreted;

a decision is being made;

or

an intervention is being performed.

A determination that was correct for an earlier condition may no longer describe the current condition.

Likewise, an Influence capability that is technically available may not be effective if it cannot act within the available time.

This supports continued Context Guide research into the relationship between:

rate of Quality-State change;

time required for determination;

and

time required for effective intervention.

It does not establish one universal response-time requirement.

13. An Indeterminate Finding Is Distinguishable from an Acceptable or Unacceptable Quality State

The analysis demonstrates an important logical distinction.

The following conclusions are not equivalent:

acceptable Quality State demonstrated;

unacceptable Quality State demonstrated;

The available Evidence does not presently support a sufficiently confident determination of the Quality State.

Therefore:

absence of Evidence demonstrating an unacceptable state
≠ demonstration of an acceptable state.

At the same time:

insufficient Evidence demonstrating an acceptable state
≠ proof of a physically unacceptable state.

This distinction is important for preserving the meaning actually supported by Evidence.

The appropriate response to an indeterminate finding remains Context-specific.

14. Human Participation May Span Several Quality Activities

The analysis supports the conclusion that human participation cannot always be assigned to only one part of the quality model.

A person may participate in:

observing the Quality State;

interpreting information;

making a determination;

communicating Quality-Critical Information;

making a decision;

authorizing action;

performing an intervention;

or

confirming the resulting condition.

The same person or workplace may therefore participate in work relating to:

Quality State;

Quality-State Determination;

Quality-State Influence;

or

a combination.

This reinforces the importance of correctly identifying Infrastructure-Critical Roles, workplaces, communication connections, Boundaries, and Interfaces.

15. Context Guides Can Serve as Tests of the Indicators

The analysis supports two compatible roles for Context Guides.

They apply the invariant Indicators to specific Infrastructure Quality Objects.

They can also provide practical Evidence for testing the continuing adequacy of the Indicators.

The relationship is:

invariant Indicators
→ Context Guide application
→ findings at greater methodological detail
→ horizontal comparison
→ stronger evidence supporting existing coverage

or

→ provisional unresolved finding
→ additional Context testing.

This does not mean that a Context Guide can independently modify the established Indicators.

Repeated Context Guide application can provide Evidence for later research on the Indicators.

16. Provisional Findings Can Be Preserved While the Indicators Remain Stable

The analysis supports the usefulness of maintaining Provisional Additional Indicator Findings.

This allows a possible unresolved determination question to remain visible without treating it as an established requirement.

A provisional finding may later be:

resolved through an existing Indicator;

shown to be Context-specific;

identified as Evidence or a Quality Outcome Criterion;

combined with another finding;

rejected;

or

strengthened through repeated cross-Context Evidence.

This connects a stable set of Indicators with continuing research.

17. The Three Provisional Horizontal Categories Support Research

The analysis supports the conclusion that the provisional distinction among:

Quality-State;

Quality-State Determination;

and

Quality-State Influence

can help expose relationships among Indicators that are difficult to see within a purely Factor-by-Factor analysis.

These categories can help identify:

recurring determination questions;

possible overlap;

possible gaps;

connections between information and action;

and

relationships among different Factors.

The analysis does not establish that these research categories should be treated as additional normative requirements.

Their present value is analytical.

18. The Established Indicator Set Is Supported for Continued Use

Taken together, the analysis supports continued use of the established invariant Indicators.

No established Indicator has been shown to be unnecessary.

No pair of established Indicators has been shown sufficiently redundant to justify consolidation.

No provisional finding has yet been demonstrated sufficiently to justify addition of a new invariant Indicator.

The present result is therefore one of stability.

But it is stability supported by continued testing rather than by an assumption of permanent completeness.

Overall Finding

The analysis supports the conclusion that each established Indicator identifies a necessary and distinct determination question within the fourteen Quality Factors.

It also demonstrates that the Indicator layer should be understood through relationships among:

the actual Infrastructure Quality State;

the Evidence used to determine that state;

the reliability of the determination path;

and

the capability to preserve, restore, or influence the state where required.

Context Guide application provides a practical means of continuing to test these relationships.

The analysis therefore supports:

retention of the established Indicators;

continued Context Guide application;

horizontal comparison of recurring Indicator roles;

and

preservation of unresolved questions as provisional findings.

The next Subsection establishes the equally important limits of these conclusions:

10.3 What the Analysis Does Not Demonstrate

The conclusions of this paper should not extend beyond the Evidence examined and the method applied.

The analysis supports the need for the established Indicators and their continued use.

It does not demonstrate several stronger propositions.

These limitations are important because they define the boundary between what the present research supports and what remains open for continued IQI research.

1. The Analysis Does Not Demonstrate That the Indicator Set Is Permanently Complete

The analysis does not demonstrate that the present Indicator set contains every invariant Indicator that could ever be required.

Such a conclusion would require evidence that no materially different infrastructure Context could reveal another necessary and distinguishable determination question.

The present research cannot establish this.

Infrastructure Contexts are numerous.

Their:

Intended Functions;

technologies;

physical configurations;

Boundaries;

Interfaces;

Failure Modes;

Lifecycle conditions;

human interactions;

and

operating environments

can differ substantially.

Continued Context Guide development may therefore reveal determination questions that are not sufficiently visible in the present applications.

The supported conclusion is:

present Indicator necessity and adequacy for continued use;

not

permanent Indicator completeness.

2. The Analysis Does Not Demonstrate That a Fifteenth Quality Factor Is Required

The provisional findings identified in this paper do not establish another invariant Quality Factor.

The present research operates at the Indicator layer.

Possible findings concerning:

Quality-State Information Integrity;

determination-to-intervention continuity;

timeliness;

Authority;

independent or parallel information paths;

or

other horizontal functions

must first be tested against the established invariant Indicators and the fourteen-Factor structure.

A finding that appears across several Factors does not automatically become another Factor.

If repeated research were eventually to identify a necessary invariant dimension that cannot reasonably be represented within the established fourteen Factors, that would require separate Factor-level justification.

The present paper does not make such a finding.

3. The Analysis Does Not Demonstrate That an Additional Invariant Indicator Is Currently Required

Several provisional research questions have been identified.

None has yet satisfied the complete threshold established in Sections 8 and 9 for addition to the invariant Indicators.

In particular, the present analysis does not yet demonstrate that any provisional question is simultaneously:

necessary;

distinguishable;

non-redundant;

insufficiently represented by the current Indicators;

recurring across materially different infrastructure Contexts;

and

expressible at the selected methodological resolution for an invariant Indicator.

Therefore, no additional invariant Indicator is proposed by this paper.

4. The Analysis Does Not Demonstrate That Any Existing Indicator Should Be Removed

The horizontal analysis identified recurring concepts and functional relationships among Indicators.

This does not establish that an existing Indicator is unnecessary.

The removal tests instead support retention of the established Indicators.

No Indicator has been shown to be removable without a material loss of determination capability within its parent Quality Factor.

Therefore, the analysis does not support deletion of an established Indicator.

5. The Analysis Does Not Demonstrate That Similar Indicators Should Be Combined

Some Indicators contain similar horizontal functions.

For example, several Indicators concern:

change;

Uncertainty;

information retention;

abnormal or degraded conditions;

Monitoring;

or

recovery.

Similarity does not establish duplication.

The same kind of question may apply to different quality-relevant subjects.

No pair or group of established Indicators has yet been shown to preserve the same determination question so completely that consolidation is justified.

The analysis therefore does not presently support Indicator combination.

6. The Analysis Does Not Demonstrate That the Indicators Should Be Reorganized into State, Determination, and Influence Groups

The provisional distinction among:

Quality-State;

Quality-State Determination;

and

Quality-State Influence

proved useful for horizontal analysis.

However, the established Indicators do not fall into three exclusive groups.

Many contribute to more than one question.

For example, an Indicator may describe an actual infrastructure capability while also supporting determination of that capability and its effectiveness.

The three-category model should therefore remain a research tool at this stage.

The analysis does not demonstrate that the established Indicators should be reorganized around these three categories.

7. The Analysis Does Not Establish Quality-State Information Integrity as a New Indicator

Quality-State Information Integrity emerged as an important provisional research subject.

However, the present analysis does not demonstrate that it requires a separate invariant Indicator.

Its underlying questions may already be substantially represented through existing Indicators concerning:

Conformity Evidence;

Workplace Human Interaction;

Personnel Competence;

Monitoring;

Documentation and Traceability;

and

other relevant invariant Indicators provisions.

Context Guide testing is required to determine whether any material gap remains after these Indicators are applied together.

The term should therefore remain provisional in this paper.

8. The Analysis Does Not Establish a Universal Requirement for Independent or Parallel Information Paths

The possibility of independent or parallel Quality-State information paths was identified as a research question.

This does not establish that every Infrastructure Quality Object requires:

multiple sensors;

multiple communication paths;

independent observers;

parallel reporting routes;

or

other redundant arrangements.

The need depends on the applicable Context, including the consequence of information-path failure and the reliability required for Quality-State Determination.

The possible invariant question concerns adequacy of the determination path.

The present research does not establish one universal technical solution.

9. The Analysis Does Not Establish a Universal HOLD or Shutdown Rule

The analysis identified circumstances in which the available time for determination and intervention may be limited.

It also identified the important distinction between:

acceptable Quality State demonstrated;

unacceptable Quality State demonstrated;

and

Quality State not presently determinable with sufficient confidence.

These findings do not establish a universal rule requiring shutdown whenever uncertainty exists.

In some infrastructure Contexts, immediate shutdown may itself create additional Risk.

In others, continued operation may create the greater Risk.

The appropriate response must therefore depend on the applicable Context, Failure Modes, available Evidence, and Quality Outcome Criteria.

The present analysis supports examination of predetermined protective responses where appropriate.

It does not prescribe one universal response.

10. The Analysis Does Not Establish Universal Authority at the Observation Point

The analysis identified Authority as an important part of the possible determination-to-intervention path.

However, it does not establish that every person observing an abnormal condition should possess direct Authority to control or stop the Infrastructure Quality Object.

Different Contexts may appropriately use:

direct Authority;

rapid escalation;

pre-authorized actions;

automatic protective systems;

or

other arrangements.

The quality-relevant research question concerns whether sufficient Authority and action capability are available within the conditions and time required.

The organizational arrangement remains Context-specific unless further research demonstrates otherwise.

11. The Analysis Does Not Establish One Universal Time Requirement

Timeliness appeared repeatedly in both Determination and Influence analysis.

However, the present research does not establish one acceptable:

Monitoring interval;

communication time;

decision time;

intervention time;

or

recovery time.

The relevant time depends on the rate at which the particular Infrastructure Quality State can change and the consequences associated with that change.

Therefore:

time-criticality may be an invariant consideration;

specific acceptable time
→ Context-specific Quality Outcome Criterion.

The present paper does not convert the first proposition into a universal numerical requirement.

12. The Analysis Does Not Demonstrate That Every Remote Workplace Belongs Inside the Infrastructure Boundary

The analysis showed that a geographically remote workplace may materially participate in:

Quality-State Determination;

Quality-State Influence;

or

Function Realization.

This does not mean that every remote workplace associated with an infrastructure organization becomes part of the Infrastructure Quality Object.

The relevant test is functional.

A remote workplace becomes quality-relevant where its activities materially participate in the questions being examined.

Other workplaces may remain outside the declared Quality Object.

The Context Guide must determine the appropriate Boundary and Interfaces.

13. The Analysis Does Not Demonstrate That Every Communication Connection Must Be Included Within the Quality Object

Communication connections may carry:

Monitoring Data;

Quality-Critical Information;

technical findings;

decisions;

or

control actions.

Where such a connection materially participates in Function Realization, Determination, or Influence, it must be considered in the Context analysis.

However, this does not mean that every external communication network through which information passes must become part of the Infrastructure Quality Object.

The appropriate treatment may be:

inside the Boundary;

at the Boundary;

or

as an external Interface.

The correct treatment depends on the declared Quality Object and the question being examined.

14. The Analysis Does Not Demonstrate That Human or Organizational Distortion Always Occurs

The possibility that quality-relevant information may be:

delayed;

minimized;

incompletely communicated;

reclassified;

or

changed in meaning

was identified as a provisional Determination concern.

The analysis does not establish that such distortion necessarily occurs in every organization or infrastructure Context.

Nor does it assume that unfavorable information is deliberately concealed.

The relevant research question is narrower:

Can the quality-relevant information path remain sufficiently reliable where human and organizational transmission or interpretation is involved?

This question should be tested through Evidence rather than assumed.

15. The Analysis Does Not Demonstrate That Every Uncertainty Prevents an Acceptable Quality-State Finding

Uncertainty is inherent in many infrastructure determinations.

The existence of Uncertainty does not automatically mean that an acceptable Quality State cannot be demonstrated.

The relevant question is whether the remaining Uncertainty is material to the conclusion being made and whether the Evidence supports the applicable Quality Outcome Criterion.

Therefore:

Uncertainty exists
≠ acceptable determination impossible.

The analysis supports visibility and appropriate treatment of material Uncertainty.

It does not require certainty.

16. The Analysis Does Not Establish Context Guides as Independent Documents for Revising the Indicators

Context Guides provide Evidence for testing the Indicators.

They do not independently modify the established Indicators.

A Context Guide may identify a provisional finding.

That finding may recur in other Contexts.

Horizontal research may then strengthen or reject it.

Only a separate, controlled review of possible additions could determine whether the established Indicators should change.

Therefore:

Context Guide finding
≠ addition or change to an invariant Indicator.

This separation preserves the distinct roles of the Indicators and the Context Guides.

17. The Analysis Does Not Demonstrate That Adding or Changing an Indicator Is Currently Necessary

Taken together, the present findings do not provide sufficient grounds for immediate revision of the invariant Indicators.

The established Indicators remain supported for continued use.

The provisional findings provide a research agenda.

They do not show that a change to the established Indicators is currently necessary.

The appropriate present approach is therefore:

maintain the Indicators;

continue Context Guide development;

preserve provisional findings;

compare them horizontally;

and

reconsider the Indicators only when accumulated Evidence justifies reconsideration.

Overall Limitation

The present analysis is a justification and testing study.

It supports the necessity of the established invariant Indicators.

It identifies horizontal relationships among them.

It establishes a method for identifying and testing possible gaps.

It does not establish permanent completeness.

It does not establish a present need to add, remove, combine, or reorganize the invariant Indicators.

It does not convert provisional research concepts into additional Indicators.

The conclusion should therefore remain deliberately bounded:

The present Indicator set is supported for continued application.

Continued Context Guide research may strengthen that conclusion or may reveal sufficiently supported grounds for later controlled development.

The next Subsection states the resulting present status of the Indicators:

10.4 Present Status of the Indicator Set

The analysis supports retaining the established Indicators in their present form.

At this stage, the research does not provide sufficient justification to:

add a new invariant Indicator;

remove an established invariant Indicator;

combine established Indicators;

reorganize the Indicators into a different Factor and Indicator structure;

or

revise the established fourteen Quality Factors.

The appropriate present status is therefore:

Indicators retained
+
continued Context Guide testing
+
horizontal Indicator research
+
provisional findings preserved separately.

This position does not mean that the Indicator set has been demonstrated to be permanently complete.

It means that the present Evidence supports continued use of the established set while additional Evidence is developed through application.

Status of the Established Indicators

The established Indicators remain the basis for IQI application.

The necessity analysis supports their retention because each Indicator preserves a quality-relevant determination question whose removal would materially weaken determination of its parent Quality Factor.

The horizontal analysis identified relationships and recurring determination questions across Indicators.

It did not establish sufficient redundancy to justify removal or combination.

Therefore, the established Indicators should continue to be applied as presently structured.

Status of the Fourteen Quality Factors

The present Indicator analysis does not identify a need to change the fourteen invariant Quality Factors.

The provisional horizontal categories identified in this paper should not be interpreted as additional Factors.

In particular:

Quality-State;

Quality-State Determination;

and

Quality-State Influence

are used in this paper as provisional horizontal research functions.

They do not replace the fourteen Factors.

They do not create additional Indicators or reorganize the relationship between Factors and Indicators.

They do not require restructuring of the existing Factor–Indicator relationship.

The present structure remains:

Quality Factor
→ invariant Indicators
→ context-specific interpretation
→ Quality Outcome Criteria
→ Evidence.

Status of the Three Provisional Categories

The three provisional categories should be retained as research tools.

They provide a useful second view of the established Indicators.

The Factor structure asks:

What major dimension of Infrastructure Quality is being determined?

The provisional horizontal analysis asks:

What role does the Indicator have in relation to the Infrastructure Quality State?

That role may concern:

the actual Quality State;

the ability to determine that state;

the capability to influence that state;

or

a combination.

The two views therefore serve different purposes.

At the present stage, there is no need to choose between them.

The Indicators remain organized under the fourteen Quality Factors.

The three-category view remains an analytical tool for continuing research.

Status of Quality-State Information Integrity

Quality-State Information Integrity should remain a provisional research concept.

The analysis identified a potentially important question concerning whether quality-relevant information remains sufficiently faithful to the observed condition as it moves through the determination path.

However, substantial existing coverage may already exist through Indicators concerning:

Conformity Evidence;

Workplace Human Interaction;

Personnel Competence;

Monitoring;

Documentation and Traceability;

and

related quality-relevant functions.

The present Evidence does not demonstrate that Quality-State Information Integrity requires a separate invariant Indicator.

It should therefore remain a subject for Context Guide testing and horizontal comparison.

Status of Determination-to-Intervention Continuity

The possible continuity between Quality-State Determination and Quality-State Influence should also remain a provisional research subject.

The current Indicators already address relevant questions concerning:

Risk Controls;

Monitoring;

Operational Reliability;

Workplace Human Interaction;

Personnel Competence;

Recovery Capability;

Documentation and Traceability;

and

Adaptability.

The unresolved question is whether these Indicators, when applied together, sufficiently determine the complete path from recognition of a quality-relevant condition to effective intervention.

No additional Indicator is presently justified.

The function should be tested through different infrastructure Contexts.

Status of Timeliness

Timeliness should remain a horizontal research consideration rather than a new standalone invariant Indicator at this stage.

Time appears in several existing quality-relevant functions.

Its importance depends on the physical rate at which the Infrastructure Quality State can change.

The continuing research question is whether:

Quality-State Determination

and

Quality-State Influence

can occur within the time available before the relevant condition produces an unacceptable Result or Outcome.

Specific acceptable times remain Context-Specific Quality Outcome Criteria.

No universal time requirement is established by this paper.

Status of Authority

Authority should also remain a provisional cross-function research subject.

The present analysis does not establish a universal requirement concerning where Authority must be located.

The quality-relevant question is whether the Infrastructure Quality Object possesses an effective path from supported determination to appropriate action under the applicable conditions and available time.

Different Contexts may realize this through different arrangements.

No new Authority Indicator is presently justified.

Status of Independent or Parallel Information Paths

The possible need for independent or parallel Quality-State information paths remains Context-dependent.

The present paper does not establish redundancy as a universal requirement.

The relevant research question concerns the reliability of Quality-State Determination where failure or distortion of one information path could materially affect the resulting conclusion.

The appropriate arrangement may differ according to:

Risk;

Failure Mode;

consequence;

available technology;

and

other Context-Specific conditions.

This finding should therefore remain provisional.

Status of an Indeterminate Finding

The analysis identified an important distinction among:

acceptable Quality State demonstrated;

unacceptable Quality State demonstrated;

and

Quality State not presently determinable with sufficient confidence.

This distinction should be preserved in continuing research.

However, the present Indicator study should not independently establish a new normative Quality State classification without separate examination of the existing Quality State model and terminology.

For the purpose of this paper, the supported principle is narrower:

a Quality-State conclusion should not exceed what the available Evidence supports.

The appropriate response where an acceptable state cannot be demonstrated remains Context-specific.

Status of Boundary and Interface Research

The present analysis strengthens the importance of Boundary and Interface determination.

This is especially relevant where Infrastructure Quality Objects include distributed physical and human functions.

Context Guide development should continue to examine whether relevant:

buildings;

equipment;

support systems;

communication connections;

remote workplaces;

human–infrastructure Interfaces;

and

external infrastructure Interfaces

have been appropriately represented.

This work should not be treated automatically as Indicator development.

In many cases, correct Boundary and Interface determination may resolve an apparent Indicator gap.

Status of Context Guides

Context Guides should continue to serve as the principal practical test environment for the invariant Indicators.

Their primary question remains application of the Indicators to specific Infrastructure Quality Objects.

At the same time, their accumulated findings can provide Evidence for invariant Indicators research.

Each Context Guide may therefore contribute to two related activities:

application
→ determine the Quality State of the specific Infrastructure Quality Object;

research
→ test whether the Indicators remain adequate at smaller Context-specific resolution.

The second function does not give an individual Context Guide authority to modify the Indicators.

It provides Evidence for later horizontal research.

Status of Provisional Additional Indicator Findings

Provisional Additional Indicator Findings should remain outside the established Indicators.

Their purpose is to preserve unresolved questions.

A provisional finding may remain:

Open — initial finding;

Open — additional Context testing required;

Open — recurring finding;

Likely covered by current Indicators;

Context-specific;

Combined with another finding;

Rejected;

or

Candidate for controlled review of possible additional Indicators.

Only the last status would justify beginning a formal review of possible invariant Indicator change.

Even then, addition or change to an invariant Indicator would require separate justification.

Present Research Direction

The most useful next research step is therefore not immediate revision of the established Indicators.

It is continued application.

New Context Guides should apply the established Indicators without assuming either:

that a new Indicator must be found;

or

that the present Indicators must always be sufficient.

Where an apparent gap occurs, it should first be tested against:

the complete existing Indicators;

the declared Quality Object;

Boundaries and Interfaces;

context-specific interpretation;

Evidence;

Quality Outcome Criteria;

and

the provisional State, Determination, and Influence functions.

The finding should then be preserved only if a meaningful unresolved determination question remains.

Horizontal comparison can follow as the Context Guide family grows.

Present invariant Indicators Position

The present Indicators position can therefore be stated simply:

The fourteen invariant Quality Factors remain unchanged.

The established invariant Indicators remain unchanged.

No additional invariant Indicator is presently justified.

No established Indicator is presently justified for removal or combination.

The provisional Quality-State, Quality-State Determination, and Quality-State Influence categories remain research tools.

The provisional findings identified in this paper remain outside the established Indicators.

Context Guides remain the principal practical means for continued testing.

Future addition or change to the Indicators remain possible only where accumulated Evidence demonstrates a necessary, distinguishable, non-redundant, and Context-invariant question not adequately represented by the current Indicators.

Overall Finding of Section 10

Section 10 therefore reaches a deliberately balanced conclusion.

The present Indicator set is supported.

It should remain stable.

But stability should not be confused with permanent closure.

The appropriate IQI position is:

retain what has been justified;

continue testing what has been retained;

preserve unresolved findings;

and

revise only where accumulated Evidence provides sufficient justification.

This approach allows the derived Factors and Indicators to remain invariant enough for consistent application while remaining capable of controlled development when research supports it.

The next Section considers the implications of these findings for continuing derived Factors and Indicators development:

11. Research Findings and Implications for Development of the Derived Factors and Indicators

The analysis in this paper produces findings that extend beyond the necessity test of individual invariant Indicators.

The Factor-by-Factor analysis, horizontal comparison, and Context Guide research method together provide a basis for continuing development of the derived Factors and Indicators without requiring immediate revision of the established Indicators.

The principal implication is that development of the Indicators should proceed through accumulated Evidence.

The present Indicator set should remain stable while Context Guides continue to test it at greater methodological detail.

This creates a continuing relationship:

derived Factors and Indicators
→ Context Guide application
→ Context-Specific findings
→ horizontal comparison
→ stronger justification of the current Indicators

or, where appropriate,

→ provisional unresolved finding
→ additional testing
→ possible later invariant Indicators review.

11.1 Context Guides as Applications and Research Cases

Infrastructure Context Guides have a primary practical function.

They interpret the invariant Indicators for a defined Infrastructure Quality Object and its specific Context.

This includes the applicable:

Intended Function;

Boundary;

Interfaces;

Lifecycle Stages;

Failure Modes;

Reference Layer;

Evidence;

and

Quality Outcome Criteria.

This practical function should remain unchanged.

However, the present analysis shows that Context Guides can also serve a second function.

Their application can also test the continuing adequacy of the Indicators.

These two functions are compatible.

Application of the Indicators

For application purposes, the Context Guide begins with the established Indicators.

It does not begin by creating a new Indicator structure.

The relationship remains:

Quality Factor
→ invariant Indicator
→ context-specific interpretation
→ Quality Outcome Criterion
→ Evidence
→ Quality-State finding.

This provides consistency across different infrastructure Contexts.

The same determination questions remain available across Contexts, although their physical realization may differ substantially.

Testing Through Application

Every application also creates an opportunity to test the Indicators.

At the smaller Context Guide resolution, questions may become visible that were not obvious at the invariant Indicator level.

A Context Guide may reveal:

a previously insufficiently visible Failure Mode;

a Boundary or Interface relationship;

a new Evidence source;

a new Quality Outcome Criterion;

a different physical realization of an established Indicator;

an apparent overlap between Indicators;

or

a possible determination question not clearly represented by the existing Indicators.

Most such findings will not require addition or change to an invariant Indicator.

Their value is that they test whether the current Indicators can adequately represent the new Context.

Successful Application Is Evidence

Where a materially different infrastructure Context can be adequately described and evaluated through the established invariant Indicators, this provides practical support for the existing Indicators.

The research result may therefore be:

new Context
→ detailed application
→ no unresolved invariant question
→ current Indicators coverage supported.

This is important.

Context Guide research should not be designed primarily to discover missing Indicators.

A Context Guide that reveals no gap among the Indicators is still a valuable test.

Repeated successful application across increasingly different Infrastructure Quality Objects strengthens the practical basis for treating the Indicators as invariant.

Apparent Gaps Should First Be Tested Locally

When an apparent gap appears, the first response should remain within the Context Guide analysis.

The following questions should be asked:

Is the Quality Object correctly declared?

Is the Boundary complete?

Are the relevant Interfaces identified?

Is the issue already represented by an existing invariant Indicator?

Does the issue require only a more detailed context-specific interpretation?

Is it a new Evidence source?

Is it a new Quality Outcome Criterion?

Is it a Context-Specific method?

Is the apparent gap caused by insufficient resolution of the present analysis?

Only after these questions have been examined should the finding be preserved as a possible invariant Indicator research issue.

This prevents unnecessary movement from Context detail to addition or change to an invariant Indicator.

Horizontal Comparison Across Context Guides

The second research stage occurs across Context Guides.

A finding from one Context should be compared with findings from other Contexts.

The comparison should focus on the underlying question rather than identical terminology or technology.

For example, different Context Guides may identify problems involving:

pressure information;

electrical condition information;

cooling-system information;

structural-condition information;

or

remote operating information.

These are technically different.

Horizontal comparison should ask whether they reveal a common determination question.

The research movement is therefore:

vertical Context analysis
→ horizontal cross-Context comparison.

Vertical analysis provides depth.

Horizontal analysis tests invariance.

Importance of Context Diversity

The strength of horizontal Evidence depends partly on the diversity of the Context Guides being compared.

Several closely related infrastructure systems can provide useful Evidence.

However, broader support for invariance requires testing across materially different Infrastructure Quality Objects.

Differences may include:

technology;

physical scale;

geographic distribution;

operating process;

Failure Modes;

rate of Quality-State change;

human participation;

remote operation;

environmental conditions;

and

Reference Layer requirements.

If the same determination question remains necessary across such differences, the case for invariant significance becomes stronger.

Context Guides as Tests of Boundaries and Interfaces

Context Guide development is also particularly useful for testing the IQI concepts of Boundary and Interface.

At selected methodological resolution, a Quality Object may appear relatively simple.

At smaller resolution, its quality-relevant structure may be distributed.

For example, Function Realization or Quality-State Determination may depend on:

buildings;

process or operating equipment;

energy supply;

cooling or supporting systems;

Monitoring equipment;

communication connections;

local workplaces;

remote workplaces;

control centers;

and

external infrastructure Interfaces.

This does not mean that every connected system belongs inside the Infrastructure Quality Object.

It means that the Context Guide must determine which elements belong:

inside the Boundary;

at the Boundary;

or

outside the Boundary as quality-relevant Interfaces.

This work can materially affect how the invariant Indicators are interpreted.

Context Guides as Tests of Human Participation

Context Guides can also provide practical tests of human participation in Infrastructure Quality.

Different Contexts may involve humans primarily as:

operators;

inspectors;

maintainers;

technical specialists;

decision-makers;

remote controllers;

or

other Infrastructure-Critical Roles.

The human contribution may affect:

the actual Quality State;

Quality-State Determination;

Quality-State Influence;

or

more than one of these categories.

Context Guide analysis can therefore help determine whether the existing Indicators concerning Workplace Human Interaction, Personnel Competence, Monitoring, Documentation, Risk, and other relevant Factors provide sufficient combined coverage.

Context Guides as Tests of Information Paths

Another important research use concerns Quality-State information.

Modern infrastructure may depend on information passing through several physical and human Interfaces.

A Context Guide can identify the actual path:

physical condition
→ observation
→ information
→ communication
→ interpretation
→ determination.

Where remote control or intervention is involved, the path may continue:

determination
→ decision
→ communication
→ action
→ resulting physical condition.

Mapping these relationships at Context Guide resolution can test whether the current Indicators sufficiently represents:

Monitoring;

Quality-Critical Information;

Personnel Competence;

human interaction;

Documentation and Traceability;

Risk Controls;

and

Recovery.

This provides a practical basis for testing the provisional findings identified in Section 9.

Context Guides as Tests of Time-Critical Conditions

Different infrastructure systems also provide different tests of time.

Some quality-relevant conditions develop slowly.

Others may change rapidly.

A Context Guide can therefore examine the relationship among:

the rate at which the physical condition changes;

the time needed to detect the change;

the time needed to determine its significance;

the time needed to communicate and decide;

and

the time needed to influence the condition.

This does not require a universal time requirement.

It allows the same horizontal question to be tested under different physical conditions.

Such comparison may help determine whether timeliness is already adequately represented through existing Indicators or whether a recurring unresolved question remains.

Context Guides as Tests of Provisional Findings

The provisional findings identified in Section 9 should therefore be treated as research questions during Context Guide development.

They should not be inserted automatically as additional requirements.

Where relevant, Context Guide research can ask:

Does Quality-State information remain sufficiently reliable through the determination path?

Does dependence on one information path create a material weakness?

Can the condition be determined within the time available?

Can a supported determination lead to appropriate Influence within the available time?

Is sufficient Authority available through the applicable decision path?

Is the resulting Quality State re-determined after intervention?

These questions should be used to test the current Indicators first.

Only an unresolved function should be preserved for later horizontal comparison.

Preserving Provisional Findings About Possible Indicator Additions or Changes

Where a Context Guide reveals a plausible unresolved invariant question, the finding should be preserved separately from the normative Context Guide requirements.

The record should identify:

the originating Context;

the underlying determination question;

the existing Indicators tested;

why existing coverage may be insufficient;

the consequence of omission;

the possible State, Determination, or Influence function;

and

the additional Contexts needed for testing.

This creates continuity between separate Context Guide projects.

A finding discovered during one project is not lost when work moves to another.

At the same time, it does not prematurely change the Indicators.

No Immediate Addition or Change to an Indicator Is Required

The present research therefore supports continued Context Guide development before any broad revision of the IQI invariant Indicator structure.

This sequence has an important methodological advantage.

If the Indicator set remains stable while materially different Context Guides are developed, the same Indicators can be tested repeatedly.

If the Indicator set were revised after every Context Guide, it would become difficult to distinguish:

a genuinely invariant improvement

from

a response to one particular infrastructure Context.

A period of stable application provides stronger comparative Evidence.

Implication for Continuing IQI Research

The immediate research priority should therefore be:

continued development of materially different Context Guides under the present derived Factors and Indicators.

Each new Context Guide should be treated simultaneously as:

an application of the established Indicators;

and

a test of its continuing adequacy.

Provisional findings about possible Indicator additions or changes should be accumulated separately.

Horizontal comparison should follow as the Context Guide family becomes broader.

Only then should the Indicator layer be reconsidered for possible controlled revision.

Interim Finding

Context Guides provide the practical bridge between an invariant derived Factors and Indicators and the diversity of real Infrastructure Quality Objects.

Their detailed application tests whether the established Indicator set remains meaningful at a more specific methodological resolution.

Repeated successful application strengthens the practical support for the Indicators. Because Context Guides are developed through application of the established Indicators, they provide structured application and test Evidence rather than fully independent validation of the Indicators. Their strongest research value lies in showing cross-Context applicability and in revealing recurring unresolved functions or interpretation difficulties.

Repeated unresolved functions identify legitimate subjects for further research.

The resulting development method is:

apply first;

observe;

preserve unresolved findings;

compare across Contexts;

and

revise only when accumulated Evidence supports revision.

The next Subsection examines the horizontal research program that can be built across the expanding Context Guide family:

11.2 Horizontal Comparative Research Across Context Guides

The Context Guide family provides a practical basis for horizontal comparative research at the Indicator layer.

A single Context Guide examines one defined Infrastructure Quality Object in depth.

Horizontal research examines several Context Guides together.

The purpose is different.

The principal question is not:

How is this invariant Indicator realized in this particular infrastructure Context?

It is:

What recurring Indicator roles become visible when materially different infrastructure Contexts are compared?

This comparison can strengthen the justification of the current Indicators.

It can also reveal possible overlap, relationships among Indicators, and possible determination questions requiring further research.

Vertical and Horizontal Research

The two directions of research should remain distinct.

Vertical research moves from the invariant Indicators into one specific Context:

Quality Factor
→ invariant Indicator
→ context-specific interpretation
→ Quality Outcome Criterion
→ Evidence
→ Quality-State finding.

Horizontal research moves across applications:

Context Guide A
↔ Context Guide B
↔ Context Guide C
↔ additional Context Guides.

The first provides depth.

The second provides comparison.

Together they provide a stronger method for testing Indicator invariance than either approach alone.

The Unit of Horizontal Comparison

Horizontal comparison should not begin with identical technical components.

Different infrastructure systems may contain completely different:

equipment;

materials;

processes;

operating conditions;

Failure Modes;

Monitoring methods;

human roles;

and

control arrangements.

The appropriate unit of comparison is therefore the quality-relevant function.

For each Context Guide, the research should ask:

What condition is being determined?

Why is that condition necessary for determining the Infrastructure Quality State?

What Evidence makes it observable?

What happens if the determination question is removed?

How does the question relate to the applicable Quality Factor?

Does the same function appear in other Contexts through a different physical realization?

This allows technical differences to remain visible without preventing comparison.

Comparing the Same invariant Indicator Across Contexts

The first horizontal research method is to compare one established invariant Indicator across several Context Guides.

The research can examine:

how the Indicator is interpreted;

which Failure Modes make it important;

which Boundaries and Interfaces are involved;

which Evidence supports it;

which Quality Outcome Criteria are applied;

which Lifecycle Stages make it especially important;

and

what determination capability would be lost if it were omitted.

If the same Indicator remains necessary despite substantial differences among the Contexts, the practical evidence supporting its invariance becomes stronger.

The relationship is:

same invariant Indicator
+
different Context-Specific realizations
→ evidence supporting invariant question.

Comparing Determination Questions Across Different Indicators

The second horizontal method is different.

Instead of following one Indicator across Contexts, the research can identify a recurring function appearing under several Indicators.

The present analysis has already identified examples such as:

change;

Uncertainty;

traceability;

retention of information or knowledge;

abnormal and degraded conditions;

Monitoring;

recovery;

and

evaluation of Results and Outcomes.

These categories may appear under different Quality Factors because they apply to different quality-relevant subjects.

Horizontal comparison can determine whether the repetition represents:

necessary application of one question to different subjects;

unnecessary duplication;

or

a broader relationship not sufficiently visible in the present Indicators structure.

This research should not begin with an assumption that repetition is a problem.

Recurring Determination Questions Across Indicators

A particularly useful research direction is classification of recurring Indicator roles.

The present analysis suggests three provisional horizontal groups:

Quality-State Indicators;

Quality-State Determination Indicators;

and

Quality-State Influence Indicators.

The classification should remain provisional.

Its value is comparative.

Quality-State Indicators

These primarily concern the actual condition or capability of the Infrastructure Quality Object.

They help answer:

What is the quality-relevant state of the object?

Examples may concern actual:

Integrity;

Reliability;

Risk condition;

Environmental condition;

human–infrastructure condition;

or

Adaptation result.

The precise Indicator placement remains within the established fourteen-Factor invariant Indicators.

The horizontal classification simply identifies the role being performed.

Quality-State Determination Indicators

These primarily concern the capability and reliability of determining the Quality State.

They help answer:

Can the relevant condition be observed, evidenced, interpreted, and supported as a justified finding?

Possible recurring subjects include:

Monitoring;

Evidence;

Conformity;

Competence;

Traceability;

information continuity;

Uncertainty;

and

interpretation.

Again, this does not create a second Factor and Indicator structure.

It provides a way to compare determination questions that presently appear under different Factors.

Quality-State Influence Indicators

These primarily concern capability to preserve, restore, limit, or intentionally change the Quality State.

They help answer:

Can the Infrastructure Quality Object respond appropriately when preservation, mitigation, recovery, or change is required?

Possible recurring subjects include:

Risk Controls;

protective actions;

Recovery Capability;

human intervention;

Authority;

and

Adaptation.

Some established Indicators may contribute to more than one group.

This is expected.

The purpose is not exclusive classification.

The purpose is to make recurring determination questions easier to compare.

Horizontal Research Across Categories

The most important horizontal findings may occur between the three provisional categories.

The recurring relationship is:

Quality State
→ Determination
→ Influence
→ resulting Quality State
→ renewed Determination.

Horizontal research can therefore examine whether materially different Context Guides reveal similar weaknesses at the connections between these categories.

For example:

State → Determination
may reveal questions concerning observability, Evidence, information integrity, or Uncertainty.

Determination → Influence
may reveal questions concerning communication, decision, Authority, or timeliness.

Influence → State
may reveal questions concerning effectiveness, recovery, unintended effects, or actual Results.

State after Influence → renewed Determination
may reveal questions concerning re-examination, Monitoring, and confirmation of the resulting condition.

This approach may reveal relationships that are difficult to see when Indicators are studied only within their parent Factors.

Horizontal Research on Information Integrity

Quality-State Information Integrity should be one subject of continuing horizontal comparison.

The research should examine how quality-relevant information moves in different infrastructure Contexts.

A general path may be:

physical condition
→ observation
→ Evidence
→ communication
→ interpretation
→ Quality-State determination.

In another Context, the path may be much shorter.

In another, it may pass through several:

sensors;

communication systems;

workplaces;

persons;

organizations;

or

decision levels.

Horizontal comparison can test whether the current Indicators adequately represent the reliability of these different information paths.

The research should focus on the determination question rather than require identical arrangements.

Horizontal Research on Independent or Parallel Information Paths

Another research subject is whether materially different Contexts reveal recurring dependence on a single Quality-State information path.

The question is not whether every infrastructure system requires redundancy.

It is:

Under what conditions does failure of one information path materially weaken the ability to determine a Critical Infrastructure Condition?

Comparison across Contexts may show that:

one reliable path is sufficient in some cases;

independent confirmation is necessary in others;

parallel paths are useful but not necessary in others;

or

different Evidence sources provide sufficient independence without technical duplication.

This can help determine whether the issue belongs:

within current Indicators interpretation;

within Context-Specific Quality Outcome Criteria;

or

eventually within a broader invariant question.

Horizontal Research on Timeliness

Time should also be compared horizontally.

Different Infrastructure Quality Objects may have very different rates of physical change.

Horizontal research can compare:

time required for detection;

time required for determination;

time required for communication;

time required for decision;

time required for Influence;

and

time available before an unacceptable Result or Outcome.

The relevant question is not whether the numerical times are identical.

They will not be.

The question is whether the same functional relationship recurs:

required determination-and-influence time
≤
available time for effective response.

If this relationship repeatedly proves necessary across materially different infrastructure Contexts, its significance can be examined further.

The specific numerical criterion would remain Context-specific.

Horizontal Research on Authority

Authority should also be examined comparatively.

Different Context Guides may realize Authority through:

local operators;

remote operators;

supervisors;

technical specialists;

automatic systems;

pre-authorized actions;

or

other arrangements.

The methods differ.

The horizontal question is:

Can a supported determination of a Critical Infrastructure Condition lead to appropriate action within the available conditions and time?

This allows the question to be studied without assuming one organizational structure.

Horizontal Research on Remote Workplaces and Communication Interfaces

Distributed infrastructure provides another important comparison subject.

Some Infrastructure Quality Objects may depend strongly on remote operation.

Others may depend primarily on local human interaction.

Some may use remote technical specialists only under unusual conditions.

Horizontal comparison should examine when a remote workplace or communication path materially participates in:

Function Realization;

Quality-State Determination;

Quality-State Influence;

or

more than one of these categories.

This can strengthen the method for determining:

what belongs inside the Infrastructure Boundary;

what belongs at the Boundary;

and

what should be treated as an external Interface.

The research should remain functional rather than geographic.

Horizontal Research on Indeterminate Findings

Another useful comparison concerns situations where the available Evidence does not support a sufficiently confident acceptable or unacceptable finding.

Different Contexts may respond differently.

One may require additional inspection.

Another may increase Monitoring.

Another may permit restricted operation.

Another may require a protective HOLD or another safe-state response.

The Influence response differs.

The common Determination question is:

How is the Quality State represented when the available Evidence does not support a stronger conclusion?

Horizontal comparison may help determine whether the current Indicators and IQI vocabulary already represent this condition sufficiently.

This question should be researched before any new normative classification is introduced.

Horizontal Research on Change

Change is already one of the clearest recurring functions across the Indicators.

A change may affect:

Functional Requirements;

Technical Specifications;

Risk;

Environmental Interaction;

Operational Reliability;

Monitoring relevance;

Documentation;

Personnel Competence;

or

Adaptation.

Horizontal Context Guide research can examine whether these repeated change-related Indicators remain distinguishable.

The research question is:

What different quality-relevant subject is being protected against the effects of change?

This may strengthen the present Indicator structure.

It may also reveal where some change-related questions can be described more consistently without combining their distinct determination subjects.

Horizontal Research on Traceability and Retention

Traceability and retention also recur.

Different Context Guides can test what information must remain connected to:

the Infrastructure Quality Object;

the applicable configuration;

the Lifecycle Stage;

the original Assumptions;

the applicable requirements;

the Evidence;

and

the resulting Quality-State finding.

This may help distinguish:

general Documentation and Traceability functions

from

subject-specific retention functions under other Factors.

Again, the purpose is not automatic consolidation.

It is to understand why each occurrence is necessary.

Recording Horizontal Findings

Horizontal findings should be recorded separately from the individual Context Guides.

A useful research record should identify:

the recurring function;

the Context Guides in which it appears;

the different physical manifestations;

the relevant established Indicators;

the possible State, Determination, or Influence role;

the consequence of omission;

whether current Indicators coverage appears sufficient;

and

the present research status.

This creates an accumulating evidence base for later invariant Indicators review.

The record should include negative findings as well.

If a suspected gap is repeatedly resolved through existing Indicators, that result strengthens the Indicators.

Research Sequence

The horizontal research program can therefore follow this sequence:

develop a Context Guide;

apply the established Indicators;

identify smaller-resolution findings;

separate Context-specific detail from possible invariant questions;

preserve unresolved findings;

repeat the process in another Context;

compare the underlying questions;

test recurrence;

apply removal and distinguishability tests;

evaluate current Indicators coverage;

and

retain, combine, reject, or strengthen the provisional finding.

This process should continue across a sufficiently diverse Context Guide family before a broad addition to or change in the invariant Indicators is considered.

Expected Research Value

Horizontal comparative research can produce several useful results.

It can:

strengthen justification of existing Indicators;

clarify why apparently similar Indicators remain separate;

identify recurring Indicator roles;

improve consistency of Context Guide interpretation;

improve Boundary and Interface analysis;

reveal relationships among State, Determination, and Influence;

identify provisional gaps;

and

provide Evidence for later controlled development of the Indicators.

Importantly, the research remains useful even if no new invariant Indicator is identified.

Demonstrating that the current Indicators continues to represent materially different infrastructure Contexts is itself an important result.

Interim Finding

Horizontal comparative research across Context Guides provides the principal method for moving from individual Context-Specific observations toward stronger conclusions about Indicator invariance.

The method does not search for identical technical conditions.

It searches for recurring quality-relevant functions beneath different physical realizations.

The three provisional categories—

Quality State;

Quality-State Determination;

and

Quality-State Influence—

provide one useful way to organize that comparison without changing the established fourteen-Factor invariant Indicators.

The strongest research questions presently concern:

the reliability of Quality-State information;

the complete determination path;

the connection from determination to Influence;

timeliness;

Authority;

remote human and communication Interfaces;

and

re-determination after Influence.

These questions should be tested through the expanding Context Guide family before they are used to justify additional Indicators.

The next Subsection establishes how findings from that research should be preserved and evaluated over time:

11.3 Provisional Findings and Evidence Accumulation

Horizontal comparative research may identify findings that remain unresolved after application of the current Indicators.

These findings should be preserved without immediately changing the established Indicators.

The purpose is to allow Evidence to accumulate across different Context Guides and over time.

A finding may begin with one infrastructure Context.

Its significance at that stage is limited.

The same underlying question may later appear in another Context with a completely different physical realization.

Repeated comparison may then strengthen, weaken, combine, or eliminate the original finding.

The research process therefore requires continuity.

The basic relationship is:

initial Context finding
→ provisional finding about a possible Indicator addition or change
→ additional Context testing
→ accumulated Evidence
→ horizontal evaluation
→ finding retained, combined, rejected, or strengthened
→ possible controlled review of the Indicator set.

Provisional Finding About a Possible Indicator Addition or Change

A provisional finding about a possible Indicator addition or change is not a proposed amendment. It records a later stage of research: the initial finding has survived preliminary testing and remains relevant enough to preserve for further study of the Indicator set.

It is a research record identifying a possible issue concerning the continuing adequacy of the Indicators.

Such a finding may concern:

a possible omission of a determination question that an Indicator needs to address;

possible overlap among established Indicators;

possible ambiguity in Indicator meaning;

a recurring difficulty in context-specific interpretation;

a recurring Boundary or Interface issue affecting Indicator application;

or

another finding that may eventually justify considering an additional invariant Indicator.

The term provisional is essential.

The finding remains subject to further Evidence.

Evidence Accumulation

Evidence should accumulate through application of the established Indicators, not through repetition of the same theoretical argument.

A provisional finding becomes more significant when independent Context Guide applications reveal the same underlying question.

The physical conditions do not need to be the same.

For example:

one Context may reveal a problem through Monitoring;

another through inspection;

another through human observation;

another through remote operation.

If the same underlying determination question remains unresolved, the Evidence supporting possible invariant significance becomes stronger.

The research should therefore record both:

similarity of the underlying question;

and

difference of the physical Contexts in which it appears.

Context Diversity as Evidence

Context diversity is particularly important.

Repeated findings within closely related infrastructure systems may justify improvement of a Context Guide family.

They do not necessarily justify addition or change to an invariant Indicator.

Evidence for invariant significance becomes stronger when the same determination question recurs across Infrastructure Quality Objects that differ in:

Intended Function;

technology;

physical configuration;

scale;

Boundary;

Interfaces;

Failure Modes;

operating conditions;

human participation;

rate of Quality-State change;

and

Reference Layer requirements.

The greater the differences in physical realization while the same necessary determination question remains, the stronger the evidence of possible invariance.

Evidence Supporting Existing invariant Indicators Coverage

Evidence accumulation should not be understood only as accumulation of support for revision.

It may instead strengthen the current Indicators.

A provisional finding may appear in one Context.

A later Context Guide may show that an established Indicator already represents the question adequately.

Further applications may confirm that conclusion.

The research sequence may therefore be:

provisional finding
→ additional Context testing
→ current Indicators coverage demonstrated
→ provisional finding closed
→ justification of current Indicators strengthened.

This is an important research result.

The purpose of evidence accumulation is to determine whether revision is justified, not to produce revision.

Evidence Against a Candidate

Evidence may also weaken a provisional finding.

For example, later research may show that the finding is:

technology-specific;

sector-specific;

method-specific;

limited to one Failure Mode;

caused by an incomplete Boundary;

caused by an omitted Interface;

already represented by an established Indicator;

or

not necessary for Quality-State determination.

Such Evidence should be recorded.

A provisional finding should not accumulate only supporting observations while contradictory findings are ignored.

The research record should preserve both.

This helps prevent confirmation bias.

Evidence of Recurrence

Recurrence should be evaluated at the question level.

The same words do not need to appear in different Context Guides.

The question is:

Does the same quality-relevant determination question recur?

For example, one Context may reveal delayed transmission of an abnormal condition.

Another may reveal delayed technical interpretation.

Another may reveal delayed decision Authority.

Another may reveal delayed intervention.

These may initially appear to support several different findings.

Horizontal comparison may show that they are parts of one broader function concerning the continuity and timeliness of the determination-to-intervention path.

Alternatively, further research may show that they are distinguishable.

The Evidence should determine which interpretation is stronger.

Evidence of Necessity

Recurrence alone is insufficient.

The function must also remain necessary.

The removal test should therefore be repeated as Evidence accumulates.

For each Context, the question is:

If this question is omitted, what becomes materially less observable, less determinable, or less capable of appropriate Influence?

If omission repeatedly creates a material loss across different Contexts, the necessity case becomes stronger.

If the question can be omitted without meaningful loss, the case weakens.

Evidence of Distinguishability

The same process applies to distinguishability.

A provisional finding may initially appear different from the established Indicators.

Additional Context Guide applications may show that the distinction disappears.

Alternatively, the distinction may become clearer.

The research should ask:

Does the candidate repeatedly preserve a determination question that the established Indicators do not sufficiently preserve?

If yes, the case for a separate invariant question strengthens.

If no, the finding should be resolved through the current Indicators.

Evidence Concerning invariant Indicators Resolution

A recurring function may still remain below selected methodological resolution.

For example, the same specialized technical requirement may appear in several related Context Guides.

This does not necessarily make it invariant.

The candidate must be capable of being expressed without dependence on:

one technology;

one equipment type;

one particular organizational structure;

one jurisdiction;

or

one Context-Specific method.

The research should therefore progressively remove unnecessary Context-specific detail from the candidate wording.

The objective is to determine whether an invariant question remains.

Evidence Concerning Factor Placement

A provisional Indicator finding should also be tested against the established fourteen Quality Factors.

As Evidence accumulates, the research should ask:

Does the question clearly belong under one existing Factor?

Does it operate across several Factors but still belong primarily under one?

Is it already represented through interaction among existing Factors?

Or does it appear not to fit the established Factor structure?

The last result would be more significant.

It should not automatically produce another Factor.

It would require separate Factor-level research using the derivation and justification method applicable to the Quality Factor layer.

The present Indicator research should record the issue without exceeding its scope.

Accumulating Evidence for Quality-State Information Integrity

Quality-State Information Integrity provides an example of the process.

The present analysis identifies a possible recurring function concerning preservation of the meaning and reliability of quality-relevant information through the determination path.

Future Context Guides may test whether this issue appears in:

local Monitoring;

remote Monitoring;

human observation;

inspection;

technical evaluation;

control centers;

communication paths;

or

other arrangements.

The research should then determine whether the observed problems are already adequately represented through existing Indicators concerning:

Conformity Evidence;

Workplace Human Interaction;

Personnel Competence;

Monitoring;

Documentation and Traceability;

and

related functions.

Only a recurring unresolved determination question should remain as a provisional finding about a possible Indicator addition or change.

Accumulating Evidence for Determination-to-Intervention Continuity

The same approach applies to the possible determination-to-intervention question.

Different Contexts may contain very different intervention paths.

One may use a local operator.

Another may use remote control.

Another may rely on automatic protection.

Another may require technical escalation.

Another may require coordinated action among several workplaces.

The methods differ.

The horizontal research question remains:

Does a supported Quality-State determination have an adequate path to appropriate Influence under the applicable conditions and available time?

If existing Risk, Monitoring, Competence, human-interaction, Reliability, and Adaptability Indicators consistently provide sufficient coverage, the provisional finding can be closed.

If a recurring unresolved determination question remains, the case for treating it as invariant becomes stronger.

Accumulating Evidence for Timeliness

Timeliness should also be tested through different physical rates of Quality-State change.

The Evidence should compare:

how quickly the relevant condition can develop;

how quickly it can be detected;

how quickly its significance can be determined;

how quickly the necessary decision can be made;

and

how quickly effective Influence can occur.

The numerical values will differ.

The research concerns the recurring functional relationship.

If the same relationship repeatedly proves necessary across very different Contexts, its invariant significance may become clearer.

Accumulating Evidence for Authority

Authority should be examined in the same manner.

The research should not search for one preferred organizational arrangement.

It should examine whether the applicable arrangement allows an identified Critical Infrastructure Condition to produce appropriate action within the necessary time.

Evidence may show that:

local Authority is necessary in one Context;

rapid escalation is sufficient in another;

automatic protection is appropriate in another;

or

the issue is already adequately represented through current Indicators.

The common question, if one exists, should emerge from comparison.

Accumulating Evidence for Independent or Parallel Information Paths

The need for independent or parallel information paths should also be tested rather than assumed.

Future Context Guides may show that a single path provides adequate reliability in some conditions.

Other Contexts may demonstrate that failure of one path would eliminate the ability to determine a Critical Infrastructure Condition.

The research should examine the question:

reliability of Quality-State Determination;

not a predetermined technical solution:

mandatory redundancy.

This distinction should remain throughout Evidence accumulation.

A Living Research Record

The record of provisional findings about possible Indicator additions or changes should therefore be updated as research continues.

For each finding, it should preserve:

working name;

underlying question;

originating Context;

additional Contexts tested;

relevant established Indicators;

supporting Evidence;

contrary Evidence;

removal-test result;

distinguishability result;

possible Quality Factor placement;

possible Quality-State / Determination / Influence role;

present interpretation;

and

current status.

The record should be updated as new Context Guides are completed.

This provides continuity across separate research projects.

Status Changes

A provisional finding may move through several statuses.

For example:

Initial Finding

→ Additional Testing Required

→ Recurring Finding

→ Existing invariant Indicators Coverage Under Review

→ Likely Covered by Existing invariant Indicators

→ Closed

or

Initial Finding

→ Recurring Finding

→ Necessary Function Supported

→ Distinguishability Supported

→ Cross-Context Invariance Supported

→ Candidate for Controlled Review of a Possible Indicator Addition or Change.

These paths are illustrative.

They should not become rigid procedural requirements at this stage.

Their purpose is to show that a finding can develop in more than one direction.

No Fixed Number of Context Guides

The present research should not establish an arbitrary rule such as:

a finding appearing in three Context Guides becomes invariant.

The number alone is insufficient.

Three nearly identical Contexts may provide weaker evidence than two substantially different Contexts.

The strength of the finding depends on:

Context diversity;

quality of Evidence;

necessity;

distinguishability;

consistency of the underlying question;

and

adequacy of testing against the current Indicators.

Therefore, no fixed numerical threshold is proposed.

Threshold for Controlled invariant Indicators Review

A provisional finding should move toward controlled review of possible additional Indicators only when accumulated Evidence supports, at minimum, that:

the question is quality-relevant;

the question is necessary;

removal creates a material determination loss;

the question is distinguishable from established Indicators;

current Indicators coverage remains insufficient;

the finding is not merely context-specific interpretation, Evidence, a Quality Outcome Criterion, or a method;

the issue is not resolved through correct Boundary or Interface treatment;

the question recurs across materially different Infrastructure Quality Objects;

and

the question can be stated at invariant selected methodological resolution.

Only then is the question of addition or change to an invariant Indicator sufficiently developed for separate formal consideration.

Controlled Review Is Still Not Automatic Revision

Even at that stage, the finding should be treated as:

Candidate for Controlled Review of a Possible Indicator Addition or Change.

The review may still conclude that:

existing wording should be clarified;

an existing Indicator should be interpreted more precisely;

two existing provisions together are sufficient;

the candidate belongs in guidance rather than the Indicators;

or

a new invariant Indicator is justified.

The Evidence should determine the outcome.

Implication for derived Factors and Indicators Development

This approach provides a practical mechanism for developing the derived Factors and Indicators without making it unstable.

The established Indicators remain the common reference point.

Context Guides continue to apply it.

Research findings accumulate separately.

Horizontal comparison tests those findings.

Only sufficiently supported results return to the level of the Indicators for formal consideration.

The development cycle can therefore be expressed as:

invariant Indicators

→ application

→ Evidence

→ Provisional Additional Indicator Finding

→ repeated testing and horizontal comparison

→ provisional finding about a possible Indicator addition or change, where warranted

→ Candidate for Controlled Review of a Possible Indicator Addition or Change where sufficiently justified

→ controlled review

→ invariant Indicators retained, clarified, or revised

→ renewed application

→ additional application

→ horizontal comparison

→ accumulated Evidence

→ controlled review where justified

→ invariant Indicators retained, clarified, or revised

→ renewed application.

The process is iterative.

But addition or change to the Indicators remain controlled rather than continuous.

Interim Finding

Provisional findings about possible Indicator additions or changes provide the bridge between practical Context Guide research and possible later development of the invariant Indicators.

Their purpose is not to create a waiting list of future Indicators.

Their purpose is to preserve unresolved determination questions long enough for Evidence to establish their significance.

Evidence may strengthen the current Indicators.

It may close a provisional finding.

It may combine several findings.

Or it may eventually justify controlled review of possible additional Indicators.

The important principle is:

development of the Indicators should follow accumulated cross-Context Evidence.

It should not follow isolated findings or assumptions of permanent completeness.

The next Subsection considers when accumulated Evidence would be sufficient to begin controlled revision of the Indicators:

11.4 Conditions for Adding or Changing an Indicator

The preceding analysis establishes that the derived Factors and Indicators should remain stable while Context Guide application and horizontal comparative research continue.

Stability, however, does not mean that the Indicators cannot be revised.

An addition or change should remain possible if accumulated Evidence shows that the established Indicators no longer adequately address a necessary invariant determination question.

The important question is therefore:

Under what conditions should a provisional finding move from continuing research to controlled review of possible additional Indicators?

The threshold should be deliberately high.

An addition or change to an invariant Indicator affects every Context Guide and every later application of the Indicators.

A Context-Specific problem should therefore not become an invariant Indicator requirement without sufficient justification.

The following conditions provide the basis for deciding when controlled review of possible additional Indicators may be appropriate.

Condition 1 — A Material Quality-Relevant Determination Question Has Been Identified

The finding must concern a question that materially affects determination of the Infrastructure Quality State.

It should not be based merely on:

additional technical detail;

preferred practice;

administrative convenience;

a particular technology;

or

a useful but non-essential method.

The research question is:

Does the finding concern something that must be known, determined, preserved, restored, or appropriately influenced in order to support Infrastructure Quality State Determination?

If not, addition or change to the Indicators is not justified.

Condition 2 — Necessity Has Been Demonstrated

The candidate question must pass the removal test.

The research should ask:

If this question is not represented, what becomes materially less observable, less determinable, or less capable of appropriate Influence?

The consequence of removal should be identifiable.

A determination question may be useful without being necessary.

status as an invariant Indicator requires the stronger conclusion.

Therefore:

useful determination question
≠ necessary invariant question.

The necessity finding should be supported by Evidence from actual Context application rather than only by theoretical possibility.

Condition 3 — Existing invariant Indicators Coverage Has Been Tested

Before revision is considered, the candidate must be tested against the complete established Indicators.

The analysis should not ask only:

Does one existing Indicator contain this exact wording?

It should ask:

Can the necessary determination question be adequately addressed through one or more current Indicators when they are properly applied?

This distinction is important because the invariant Indicators interact.

A possible question may already be represented through the combined application of several Indicators.

If existing coverage is sufficient, no additional Indicator is required.

Condition 4 — context-specific interpretation Is Insufficient

The research must also demonstrate that the finding cannot be adequately addressed through context-specific interpretation of an existing Indicator.

The established Indicators operate at a larger methodological resolution than a Context Guide.

Therefore, the absence of technical detail in the established Indicators is not itself a deficiency.

The relevant question is:

Can an established Indicator reasonably support the necessary Context-Specific determination without changing its invariant meaning?

If yes, the issue belongs in the Context Guide.

If no, the case for invariant Indicator level consideration becomes stronger.

Condition 5 — The Finding Is Not Merely Evidence

A new Evidence source does not justify a new Indicator.

The candidate should therefore be tested to determine whether it represents:

what must be determined;

or

how an established determination is evidenced.

For example, a new:

sensor;

inspection technique;

test;

record;

calculation;

observation;

or

data source

may improve determination without creating a new invariant determination question.

If the finding is Evidence, it should remain at the Evidence level.

Condition 6 — The Finding Is Not Merely a Quality Outcome Criterion

The same separation is required for Quality Outcome Criteria.

A new:

limit;

threshold;

response time;

performance level;

recovery condition;

margin;

or

acceptable result

does not automatically establish a new Indicator.

The research should ask:

Does this criterion evaluate an existing Indicator?

If yes, it remains a Quality Outcome Criterion.

Only where the criterion reveals a necessary determination question not adequately represented by the established Indicators should invariant Indicator level research continue.

Condition 7 — The Finding Is Not Merely a Method

A candidate should not be moved into the Indicators because one technical or organizational method has proved effective.

Examples may include:

a particular Monitoring arrangement;

a particular communication system;

a specific reporting route;

a particular organizational position;

automatic shutdown;

a specific redundancy arrangement;

or

a particular inspection method.

These may be appropriate in a Context.

The question addressed by the invariant Indicator is different:

What underlying question makes the method necessary?

The candidate must be capable of being stated independently of the particular method.

Condition 8 — Boundary and Interface Issues Have Been Resolved

An apparent Indicator gap may result from an incomplete Infrastructure Quality Object Description.

Before an invariant Indicator addition or change is considered, the research should determine whether the issue is actually caused by omission of a quality-relevant:

physical element;

supporting system;

building;

communication connection;

remote workplace;

Infrastructure-Critical Role;

or

external Interface.

If correcting the Boundary or Interface treatment resolves the problem, the Indicators should not be changed.

This test is especially important for distributed infrastructure.

Condition 9 — The Determination Question Is Distinguishable from Existing Indicators

A candidate must preserve a determination question that is meaningfully different from those already represented.

Different wording is insufficient.

Different examples are insufficient.

Different technical realization is insufficient.

The question is:

What becomes determinable through this candidate that is not sufficiently determinable through the existing Indicators?

If no clear answer exists, the candidate has not demonstrated sufficient distinguishability for addition or change to an invariant Indicator.

Condition 10 — The Determination Question Is Not Redundant

Distinguishability and non-redundancy are related but not identical.

A candidate may appear distinct when compared with one Indicator but become redundant when compared with the full set of Indicators.

The research must therefore test whether several existing Indicators together already preserve the necessary function.

The appropriate comparison is:

candidate question

against

complete relevant invariant Indicators coverage.

Only a remaining material determination gap supports further consideration.

Condition 11 — Recurrence Has Been Demonstrated

A candidate identified in one Context should normally remain provisional.

Stronger justification requires recurrence.

The same underlying question should appear through additional Context Guide applications.

Recurrence should be functional.

Identical technical manifestations are not required.

The research should ask:

Does the same necessary determination question continue to appear despite differences in physical realization?

If yes, the evidence for possible invariant significance increases.

Condition 12 — Recurrence Extends Across Materially Different Contexts

Frequency alone is not enough.

A finding appearing repeatedly within one narrow infrastructure family may remain sector-specific.

The case for treating an Indicator as invariant strengthens when the same determination question recurs across Infrastructure Quality Objects that differ in:

Intended Function;

technology;

physical configuration;

scale;

Boundary;

Interfaces;

Failure Modes;

Lifecycle conditions;

human participation;

operating environment;

and

rate of Quality-State change.

The important relationship is:

different Contexts
+
different physical realizations
+
same necessary unresolved function
→ stronger evidence of invariance.

No fixed number of Contexts should substitute for this test.

Condition 13 — Contrary Evidence Has Been Considered

Controlled invariant Indicators review should not be based only on Evidence supporting the candidate.

The research record should also include cases where:

the candidate was unnecessary;

existing Indicators were sufficient;

the issue did not recur;

the question was resolved through Boundary or Interface treatment;

or

a different interpretation better explained the finding.

Contrary Evidence is important.

A candidate that survives serious attempts to resolve or reject it has a stronger justification than one supported only by selected examples.

Condition 14 — The Determination Question Can Be Stated at the Selected Methodological Resolution

A candidate may be necessary and recurring but still remain too Context-specific for inclusion as an invariant Indicator.

Before controlled review begins, the question should be expressible without dependence on:

one technology;

one equipment type;

one jurisdiction;

one organization;

one specific Failure Mode;

one technical solution;

or

one Context-Specific Quality Outcome Criterion.

The wording should identify:

what must be determined;

not

how one particular Context determines it.

This is one of the most important tests of invariant Indicator level suitability.

Condition 15 — Possible Placement Within the Existing Factor Structure Has Been Examined

A candidate invariant Indicator should be examined against the established fourteen Quality Factors.

The research should determine:

which Factor most directly represents the candidate question;

whether the question is already represented through interaction among several Factors;

and

whether placement under one Factor would preserve its intended meaning.

A determination question that appears across several Factors does not automatically require another Quality Factor.

If the candidate cannot reasonably be placed within the existing Factor structure, that finding should be recorded separately.

It may indicate a more fundamental research question requiring Factor-level analysis.

The Indicator study should not resolve such a question automatically.

Condition 16 — The Candidate Improves Determination Rather Than Merely Description

An invariant Indicator should contribute materially to determining the Infrastructure Quality State.

It should not be added merely because it provides a more complete description of infrastructure.

The research should therefore ask:

Does the candidate make a necessary quality-relevant condition observable and determinable?

or

Does it simply provide additional descriptive information?

Only the first supports further consideration of an additional invariant Indicator.

Condition 17 — The Candidate Remains Necessary Across Applicable Lifecycle Conditions

The candidate should also be examined in relation to the Infrastructure Lifecycle.

This does not mean that it must have equal importance during every Lifecycle Stage.

However, the proposed invariant question should remain meaningful wherever the relevant quality condition can arise.

If the question exists only during one highly specialized activity or one narrow technical phase, it may belong more appropriately in a Context Guide.

Lifecycle analysis therefore provides another test of the appropriate level of the finding.

Condition 18 — The Candidate's Relationship to State, Determination, and Influence Has Been Examined

The provisional three-category analysis can assist controlled review.

The candidate should be examined to determine whether it primarily concerns:

the actual Quality State;

Quality-State Determination;

Quality-State Influence;

or

a relationship among these categories.

This does not determine where the candidate belongs in the Indicators.

It helps clarify what function the candidate actually performs.

For example, a proposed technical control may initially appear to concern the Quality State.

Further analysis may show that its underlying question is Quality-State Influence.

A proposed information requirement may instead concern reliability of Quality-State Determination.

Clarifying the question helps prevent method-specific wording from entering the Indicators.

Condition 19 — The Consequences of Adding the Candidate Have Been Examined

addition or change to the Indicators should also consider what happens after a candidate is added.

A new invariant Indicator would affect interpretation of every Quality Object to which its parent Factor applies.

The review should therefore ask:

Does the candidate remain meaningful across different Contexts?

Would its wording unintentionally impose one technical solution?

Would it duplicate requirements already produced by other Indicators?

Would it create confusion between Indicator, Evidence, and Quality Outcome Criterion?

Would it require changes to existing Context Guides?

Would it alter the meaning of neighboring Indicators?

These questions concern the integrity of the Indicators as a whole.

Condition 20 — The Consequences of Not Adding the Candidate Have Been Demonstrated

The opposite test is equally important.

The strongest justification for revision is not that the candidate would improve the Indicators.

It is that leaving the candidate out would preserve a material and recurring determination gap.

The final question should therefore be:

What necessary quality-relevant determination remains insufficient if the Indicator set is left unchanged?

If the answer is clear, repeated across materially different Contexts, and not resolved through current Indicators provisions, the case for controlled review becomes strong.

Threshold for Beginning Controlled invariant Indicators Review

No single condition above should automatically trigger addition or change to an invariant Indicator.

The conditions work together.

A candidate becomes suitable for controlled review of possible additional Indicators where accumulated Evidence supports that it is:

quality-relevant;

necessary;

distinguishable;

non-redundant;

not adequately represented by the current Indicators;

not merely context-specific interpretation;

not merely Evidence;

not merely a Quality Outcome Criterion;

not merely a method;

not caused by an incomplete Boundary or Interface analysis;

recurring across materially different infrastructure Contexts;

expressible at invariant selected methodological resolution;

and

capable of materially improving Infrastructure Quality State Determination by closing a demonstrated gap.

At that point, the status may change from:

Provisional Finding About a Possible Indicator Addition or Change

to

Candidate for Controlled Review of a Possible Indicator Addition or Change.

Beginning Review Does Not Mean Approving Revision

This distinction should remain explicit.

Candidate for Controlled Review of a Possible Indicator Addition or Change
≠ approved addition or change to an invariant Indicator.

The controlled review may conclude that:

no revision is required;

current Indicators wording is sufficient;

an existing Indicator requires clarification;

Context Guide guidance should be improved;

two or more provisional findings represent one existing determination question;

or

a new invariant Indicator is justified.

The purpose of controlled review is to make that determination.

Possible Forms of invariant Indicators Development

If accumulated Evidence eventually justifies development of the Indicators, revision does not necessarily mean adding another Indicator.

The appropriate result may be:

clarification of an existing Indicator;

refinement of Indicator wording;

clarification of the relationship among existing Indicators;

additional explanatory text to clarify an Indicator;

or

addition of a new Indicator where a determination question not represented by an invariant Indicator has been demonstrated.

Removal or consolidation of existing Indicators should also remain theoretically possible if later Evidence demonstrates redundancy.

The form of revision should follow the demonstrated problem.

Any Addition or Change to an Indicator Should Be Version-Controlled

Any approved change to the Indicators should be identifiable.

The revision should record:

what changed;

why it changed;

which Evidence supported the change;

which Context Guide findings contributed;

how the revised provision relates to the earlier invariant Indicators;

and

whether existing Context Guides require review.

This preserves Traceability of development of the Indicators.

It also allows later research to determine whether the revision produced the intended improvement.

Revision Itself Should Be Tested

A revised Indicator provision should not be treated as justified merely because it has been adopted.

It should return to the Context Guide research cycle.

The proposed Indicator should be applied across relevant Contexts and tested for:

clarity;

necessity;

non-redundancy;

Context applicability;

and

its contribution to Quality-State determination.

The development cycle therefore continues:

provisional finding
→ accumulated Evidence
→ controlled review
→ justified revision where required
→ renewed Context Guide application
→ further Evidence.

This allows the Indicators to develop without losing the research discipline used to justify it.

Present Application of These Conditions

Applying these conditions to the provisional findings identified in this paper leads to a clear present result.

The findings concerning:

Quality-State Information Integrity;

independent or parallel information paths;

timeliness;

Authority;

determination-to-intervention continuity;

an indeterminate finding about the Quality State;

and

re-determination after Influence

remain appropriate subjects for continued research.

They have not yet accumulated sufficient cross-Context Evidence to justify controlled addition or change to an invariant Indicator.

The present Indicators should therefore remain unchanged while these findings are tested through additional Context Guides.

Interim Finding

A controlled review of a possible Indicator addition or change should begin only after a provisional finding remains unresolved after repeated testing against the current Indicators and shows a necessary determination question across materially different infrastructure Contexts.

The central threshold is not:

Would this addition be useful?

It is:

Does accumulated Evidence demonstrate a necessary invariant determination question that the present Indicator set does not adequately represent?

Only when that question can be supported affirmatively should controlled review of possible additional Indicators begin.

This preserves both requirements of continuing IQI development:

invariant Indicators stability;

and

openness to Evidence-supported improvement.

The next Subsection brings these research implications together into a practical continuing development approach:

11.5 Continuing Research on the Derived Factors and Indicators

The findings of this paper provide a practical basis for continuing research on the IQI invariant Indicator layer.

The immediate purpose of this research should not be to revise the Indicators.

It should be to continue testing the established Indicators through application to materially different Infrastructure Quality Objects and to preserve Evidence concerning its continuing adequacy.

The research program should therefore maintain two parallel activities:

continued Context Guide development;

and

horizontal comparative research across completed Context Guides.

The first provides detailed application.

The second tests recurring determination questions across different Contexts.

Together they provide the Evidence needed for continued justification or, where eventually necessary, controlled development of the Indicators.

Use the Established Indicator Set as the Common Research Basis

The established fourteen Quality Factors and their invariant Indicators should remain the common basis for continuing research.

This is important for comparison.

If the Indicators structure changes repeatedly while Context Guides are being developed, later horizontal comparison becomes more difficult.

A stable set of invariant Indicators provides a common reference.

The research sequence should therefore begin with:

present Indicators
→ repeated Context Guide application
→ accumulated findings
→ horizontal comparison.

addition or change to the Indicators should occur only where the accumulated Evidence meets the conditions established in Section 11.4.

Continue Development of the Context Guide Family

The principal source of new research Evidence should be continued Context Guide development.

Each Context Guide should define the applicable:

Infrastructure Quality Object;

Intended Function;

Boundary;

Interfaces;

Lifecycle Stages;

Failure Modes;

categories of relevant Reference Layer sources;

context-specific interpretations of the invariant Indicators;

Quality Outcome Criteria;

and

Evidence.

The purpose is first to produce a useful Context Guide for the particular Infrastructure Quality Object.

invariant Indicators research follows from that application.

This order is important.

A Context Guide should not be designed around the search for invariant Indicators deficiencies.

It should apply the Indicators as they presently exist and allow unresolved findings to emerge from the application.

Increase Context Diversity

As the Context Guide family grows, diversity should become an important research consideration.

Closely related Infrastructure Quality Objects are useful for testing consistency within one infrastructure family.

Materially different objects are useful for testing invariance.

The research program should therefore gradually include Contexts differing in:

physical scale;

technology;

geographic distribution;

operating environment;

rate of Quality-State change;

human participation;

remote operation;

Failure Modes;

Lifecycle characteristics;

and

external Interfaces.

The objective is not diversity for its own sake.

The objective is to determine whether the same determination questions remain necessary and adequately addressed across substantially different physical realizations.

Preserve a Stable Context Guide Method

Horizontal comparison will be stronger if Context Guides use a sufficiently consistent research method.

This does not mean that every Context Guide should contain identical technical content.

It means that each should consistently distinguish:

invariant Indicator;

context-specific interpretation;

Quality Outcome Criterion;

Evidence;

and

Quality-State finding.

The same discipline should be applied to:

Boundaries;

Interfaces;

Lifecycle Stages;

Failure Modes;

and

Reference Layer requirements.

A stable method makes later comparison more reliable.

Record Findings That Support the Indicators

The research record should preserve findings that support the current Indicators, not only possible gaps.

For example, where an apparent issue is successfully represented through an established Indicator, this should be recorded.

Where several Indicators together provide sufficient coverage of a complex function, this should also be recorded.

Where a provisional finding fails the removal or distinguishability test, that result should be preserved.

This creates a balanced Evidence base.

The research program should therefore accumulate:

Evidence supporting existing Indicators;

Evidence clarifying Indicator relationships;

Evidence resolving apparent gaps;

and

Evidence supporting unresolved provisional findings.

Record Provisional Findings Separately

Possible findings about invariant Indicators should remain separate from Context Guide requirements.

This separation protects both documents.

The Context Guide remains an application of the established Indicators.

The provisional research record preserves questions concerning possible development of the Indicators.

A provisional finding should identify at least:

the originating Context;

the underlying quality-relevant function;

the relevant existing Indicators;

the reason existing coverage may be insufficient;

the consequence of omission;

and

the Evidence needed for additional testing.

This record can then follow the finding across later Context Guide projects.

Maintain Horizontal Indicator Research

At appropriate stages, completed Context Guides should be compared horizontally.

The comparison should examine both:

the same Indicator across different Contexts;

and

recurring functions across different Indicators.

The first tests Indicator invariance.

The second tests the relationships among Indicators.

Horizontal research should pay particular attention to functions already identified in this paper, including:

change;

Uncertainty;

traceability;

retention of quality-relevant information;

abnormal and degraded conditions;

recovery;

Quality-State information reliability;

timeliness;

and

relationships among Determination and Influence.

These subjects should remain research questions.

They should not be treated as predetermined gaps.

Continue Testing the Three Provisional Functions

The provisional classification into:

Quality-State;

Quality-State Determination;

and

Quality-State Influence

should continue to be tested across Context Guides.

For each established Indicator, horizontal research may ask:

What part of the actual Quality State does this Indicator make visible?

How does it contribute to determining that state?

Does it provide or evaluate capability to preserve, restore, limit, or change that state?

Does it participate in more than one of these categories?

This comparison may help identify recurring functional patterns without changing the fourteen-Factor structure.

The classification itself should remain open to refinement or rejection if later research shows that it does not provide sufficient analytical value.

Research the Complete Quality-State Determination Path

One continuing research subject should be the complete path through which an actual infrastructure condition becomes a supported Quality-State determination.

A general representation is:

actual condition
→ observation
→ Evidence
→ information
→ communication
→ interpretation
→ Evidence-Supported Finding
→ Quality-State determination.

Different Context Guides may contain different versions of this path.

The research should examine whether existing Indicators sufficiently determine the reliability of the applicable path.

Particular attention should be given to conditions where information passes through:

multiple technical systems;

multiple human participants;

remote workplaces;

or

several organizational or decision points.

The purpose is not to establish a new information-path Indicator in advance.

It tests whether an unresolved question remains after the current set of Indicators is applied.

Research the Determination-to-Influence Path

A second continuing subject should be the connection between a supported Quality-State determination and effective Influence where Influence is required.

A general representation is:

Quality-State determination
→ communication
→ decision
→ Authority
→ action
→ resulting Quality State.

The physical and organizational realization may differ substantially among Contexts.

The research should determine whether existing Indicators concerning Risk, Operational Reliability, Workplace Human Interaction, Personnel Competence, Monitoring, Documentation, and Adaptability sufficiently represent this relationship.

The important question is not whether every Context uses the same intervention arrangement.

It is whether the necessary path remains adequate for the applicable condition.

Research Time as a Cross-Function Condition

Time should continue to be examined across Context Guides.

The relevant relationship may include:

rate of Quality-State change;

time required for observation;

time required for determination;

time required for communication;

time required for decision;

time required for Influence;

and

time required to determine the resulting state.

Different Contexts will produce different values.

The horizontal research question is whether the complete determination-and-influence process remains compatible with the time available before an unacceptable Result or Outcome may occur.

Specific time requirements should remain Context-specific unless later research demonstrates a stronger invariant conclusion.

Research Quality-State Information Reliability

The provisional Quality-State Information Integrity concept should continue to be tested.

The research should examine whether quality-relevant information remains sufficiently faithful to the actual observed condition through the applicable determination path.

This may involve questions of:

accuracy;

completeness;

Traceability;

availability;

preservation of Context;

and

preservation of meaning.

The research should also examine whether current Indicators already provide sufficient coverage.

The objective is not to establish the provisional term as an additional Indicator.

The objective is to determine whether the underlying question is already adequately represented.

Research Independent or Parallel Information Paths Where Relevant

Context Guides should also provide opportunities to test whether reliance on one information path creates a material determination weakness.

This research should remain risk- and Context-based.

It should not assume that multiple paths are always required.

The research question is:

If one information path becomes unavailable, incorrect, delayed, or materially changed, can the relevant Quality State still be determined with sufficient reliability where such determination is necessary?

The answer may differ among Contexts.

Those differences are themselves useful Evidence.

Research Authority in Relation to Available Decision Time

Authority should continue to be examined as part of the connection between Determination and Influence.

The relevant question is not which organizational position should hold Authority.

It is:

Can the necessary action be initiated within the conditions and time available after the relevant Quality State has been determined?

Different Contexts may use:

local Authority;

remote Authority;

rapid escalation;

pre-authorized action;

automatic protective action;

or

another arrangement.

Horizontal comparison can determine whether a broader invariant question remains after these Context-specific methods are removed.

Research Re-Determination After Influence

The research program should also examine whether the resulting Quality State is adequately determined after intervention.

The relationship is:

determined condition
→ Influence
→ resulting condition
→ Evidence
→ renewed determination.

This is important because completion of an action does not demonstrate successful Function Realization.

Context Guide research should test whether existing Indicators concerning Monitoring, Reliability, Risk Control effectiveness, Documentation, and Adaptation Results already provide sufficient coverage.

Research Distributed Infrastructure Boundaries and Interfaces

Continuing Context Guide development should also test the treatment of distributed Infrastructure Quality Objects.

Modern infrastructure may involve quality-relevant functions distributed among:

physical facilities;

equipment;

supporting systems;

communication connections;

local workplaces;

remote workplaces;

control centers;

and

external infrastructure Interfaces.

The research should determine the appropriate treatment of each element as:

inside the Quality Object Boundary;

at the Boundary;

or

outside the Boundary as a quality-relevant Interface.

This is particularly important where remote humans or communication systems materially participate in Quality-State Determination or Influence.

Correct Boundary treatment should be tested before an apparent Indicator gap is preserved.

Periodically Review Provisional Findings

Provisional findings should not accumulate indefinitely without review.

At suitable points in the Context Guide research program, the findings should be compared and their status reconsidered.

A finding may be:

retained;

refined;

combined with another finding;

resolved through current Indicators coverage;

identified as Context-specific;

rejected;

or

strengthened for additional cross-Context testing.

Only sufficiently developed findings should move toward controlled review of possible additional Indicators.

No automatic revision schedule is necessary.

Review should follow the accumulation of meaningful Evidence rather than a calendar date.

Preserve Traceability in Research on the Indicators

The continuing research program should preserve Traceability between:

the original Context finding;

later Context applications;

horizontal comparisons;

supporting and contrary Evidence;

changes in provisional status;

and

any eventual invariant Indicators decision.

This is important whether the final decision is to revise or retain the Indicators.

A decision to make no change should be traceable to Evidence just as a decision to revise should be.

development of the Indicators itself should therefore follow the same Evidence discipline that the Indicators requires for Infrastructure Quality State Determination.

Expected Research Outcomes

The continuing program may produce several legitimate outcomes.

It may strengthen the justification of the established Indicators.

It may clarify the meaning or application of existing Indicators.

It may improve Context Guide methods.

It may identify recurring horizontal functions without requiring addition or change to an invariant Indicator.

It may close provisional findings.

It may eventually identify a necessary invariant question not sufficiently represented by the present Indicators.

The research program should remain open to all of these outcomes.

Its success should not be measured by the number of Indicators added or changed.

Research Priority

At the present stage, the highest priority is continued development of Context Guides under the stable current Indicators.

This provides the practical Evidence needed for all later horizontal research.

The immediate research sequence should therefore remain:

stable invariant Indicators

→ additional Context Guides

→ detailed Context-Specific application

→ provisional findings where justified

→ horizontal comparison

→ accumulated Evidence

→ controlled review of possible additional Indicators only where justified.

This sequence allows the Indicator layer to develop from actual application rather than from theoretical expansion.

Overall Finding

The continuing derived Factors and Indicators research program should combine stability with systematic testing.

The established Indicators should remain the common basis for Context Guide development.

Context Guides should provide increasingly diverse applications.

Their findings should be compared horizontally.

Possible gaps should be preserved provisionally.

Supporting and contrary Evidence should accumulate.

addition or change to the Indicators should occur only when a necessary, distinguishable, non-redundant, and Context-invariant question remains insufficiently represented after serious testing against the current Indicators.

The resulting research cycle is:

apply
→ determine
→ compare
→ test
→ accumulate Evidence
→ retain or revise when justified
→ apply again.

This provides a practical path for continuing derived Factors and Indicators development without assuming either permanent completeness or continuous change.

The next Section presents the overall conclusions of the paper:

12. Conclusions

This paper examined the derivation and justification of the invariant Indicators used within the fourteen invariant IQI Quality Factors.

The principal purpose was to answer two related but different questions:

Why are the established invariant Indicators necessary?

and

Can the present Indicators be considered permanently complete?

The analysis supports a clear distinction between these questions.

The established Indicators can be justified as necessary without claiming that no additional invariant Indicator could ever be identified.

12.1 The Indicator Layer Is Necessary

The fourteen invariant Quality Factors identify the major dimensions required for Infrastructure Quality State Determination.

The Factors alone, however, operate at a larger resolution.

invariant Indicators provide the smaller determination questions necessary to make each Factor sufficiently observable and determinable.

The relationship is:

Quality Factor
→ identifies a major quality-relevant dimension;

invariant Indicators
→ identify what must be examined within that dimension;

context-specific interpretation
→ identifies how the Indicator applies to the particular Infrastructure Quality Object;

Quality Outcome Criterion
→ establishes the expected or acceptable result;

Evidence
→ supports the resulting finding.

The Indicator layer is therefore not merely additional description beneath the Quality Factors.

It is necessary for practical Quality State determination.

12.2 The Established Indicators Are Supported as Necessary

The Factor-by-Factor analysis applied the removal test to the established invariant Indicators.

The central question was:

What becomes materially less observable or determinable if the Indicator is removed?

The analysis supports retention of the established Indicators.

Each preserves a quality-relevant determination question whose removal would weaken the ability to determine the condition represented by its parent Quality Factor.

The analysis did not identify sufficient grounds to:

remove an established Indicator;

combine established Indicators;

or

replace the present Indicator structure.

The present Indicator set is therefore supported for continued use.

12.3 Similarity Does Not Establish Redundancy

Horizontal analysis identified recurring functions across the Indicators.

These include:

change;

Uncertainty;

Traceability;

retention of information and knowledge;

abnormal and degraded conditions;

Monitoring;

recovery;

and

evaluation of Results and Outcomes.

Such recurrence does not by itself establish duplication.

The same kind of question may apply to different quality-relevant subjects.

The relevant test is:

What becomes insufficiently determinable if this particular Indicator is removed?

Where a distinguishable determination question is lost, the Indicator remains necessary even if it shares a horizontal function with other Indicators.

12.4 Invariance Belongs to the Determination Question

The analysis supports an important distinction between an invariant determination question and its Context-Specific realization.

An invariant Indicator does not require identical:

equipment;

technology;

Evidence;

Failure Modes;

Quality Outcome Criteria;

Lifecycle application;

Boundaries;

or

Interfaces

across all Infrastructure Quality Objects.

Its physical realization may differ substantially.

The invariant element is the necessary determination question.

This relationship can be expressed as:

invariant determination question
→ different Context-Specific realizations.

This allows the Indicators to remain applicable across materially different infrastructure Contexts.

12.5 The Present Indicator Set Is Not Declared Permanently Complete

The analysis supports necessity of the established Indicators.

It does not demonstrate permanent completeness of the Indicators.

These are different conclusions.

Permanent completeness would require demonstrating that no materially different infrastructure Context could reveal another necessary invariant determination question.

The present Evidence cannot support such a claim.

Therefore:

necessary
≠ permanently exhaustive;

presently adequate
≠ permanently complete;

stable
≠ closed.

The appropriate position is to retain the present Indicator set while continuing to test its adequacy through application.

12.6 Context Guides Provide the Continuing Test

Context Guides provide the principal practical means for continued testing.

Each Context Guide applies the invariant Indicators to a specific Infrastructure Quality Object at a more specific methodological resolution.

This application can produce two useful results.

First, the current Indicators may successfully represent the new Context.

This strengthens the practical justification of the established Indicators.

Second, the application may reveal a possible unresolved determination question.

That finding can then be preserved for additional research.

The relationship is:

stable invariant Indicators
→ Context Guide application
→ Context-Specific findings
→ horizontal comparison
→ accumulated Evidence.

Context Guides therefore serve both as applications of the Indicators and as research cases for their continuing development.

12.7 Horizontal Comparison Provides the Test of Possible Invariance

A finding from one Context does not establish an invariant Indicator requirement.

Horizontal comparison across materially different Context Guides is required.

The comparison should focus on the underlying determination question rather than identical technical realization.

The research question is:

Does the same necessary unresolved determination question recur despite material differences among Infrastructure Quality Objects?

If yes, the case for possible invariant significance becomes stronger.

If the finding is resolved through coverage by the current Indicators, context-specific interpretation, Evidence, Quality Outcome Criteria, or Boundary and Interface treatment, no addition or change to the Indicators is required.

12.8 Three Provisional Horizontal Categories Were Identified

The analysis identified a potentially useful horizontal distinction among:

Quality-State;

Quality-State Determination;

and

Quality-State Influence.

These categories do not replace the fourteen Quality Factors.

These horizontal categories do not constitute another layer of Indicators.

They provide a research method for examining what role different Indicators perform.

The Quality-State category concerns the actual quality-relevant condition or capability of the Infrastructure Quality Object.

The Quality-State Determination category concerns the capability and reliability of determining that condition.

The Quality-State Influence category concerns the capability to preserve, restore, limit, or intentionally change the condition where required.

Many established Indicators contribute to more than one of these categories.

The classification should therefore remain provisional and analytical.

12.9 Determination and Influence Form a Continuing Relationship

The horizontal analysis also identified a recurring relationship:

Quality State
→ Quality-State Determination
→ Quality-State Influence where required
→ resulting Quality State
→ renewed Quality-State Determination.

This relationship is important because reliable determination alone does not guarantee effective Influence.

Likewise, Influence capability alone does not guarantee that it will be applied appropriately.

And completion of an Influence action does not demonstrate that the resulting Quality State is acceptable.

Therefore:

condition observed
≠ condition necessarily determined correctly;

condition determined correctly
≠ appropriate Influence necessarily available;

action performed
≠ acceptable resulting Quality State demonstrated.

The complete relationship should remain a subject of Context Guide research.

12.10 Quality-State Information Reliability Requires Continued Research

The analysis identified a provisional research subject concerning the reliability of quality-relevant information through the determination path.

A general path may be represented as:

actual condition
→ observation
→ Evidence
→ information
→ communication
→ interpretation
→ Quality-State determination.

Information may be technically available while still becoming:

incomplete;

delayed;

changed in meaning;

separated from important Context;

or

interpreted beyond what the Evidence supports.

The provisional concept of Quality-State Information Integrity was used to examine this issue.

The present research does not establish it as an additional invariant Indicator.

Existing Indicators may already provide sufficient coverage.

Additional Context Guide testing is required.

12.11 Timeliness Requires Cross-Function Research

Time emerged as another recurring research subject.

The relevant issue is not one universal response time.

Different Infrastructure Quality Objects change at different physical rates.

The important relationship is among:

rate of Quality-State change;

time required for determination;

and

time required for effective Influence.

A technically correct determination may become outdated if the physical condition changes before action can occur.

An effective Influence capability may also become ineffective if it cannot be applied within the available time.

Specific numerical requirements remain Context-specific.

The horizontal function should continue to be tested.

12.12 Authority and Information Paths Remain Provisional Research Subjects

The analysis also identified questions concerning:

Authority;

independent or parallel information paths;

remote workplaces;

communication Interfaces;

and

continuity from determination to intervention.

None presently justifies a new invariant Indicator.

Different infrastructure Contexts may use very different arrangements.

The appropriate invariant question, if one ultimately exists, must be separated from the particular technical or organizational method.

These subjects should therefore remain provisional findings for continued Context Guide research.

12.13 An Indeterminate Finding Must Not Be Confused with an Acceptable or Unacceptable State

The analysis also identified an important distinction concerning the limits of Evidence.

The following conclusions are different:

acceptable Quality State demonstrated;

unacceptable Quality State demonstrated;

and

The available Evidence does not presently support a sufficiently confident determination of the Quality State.

Therefore:

absence of Evidence demonstrating an unacceptable state
≠ Evidence demonstrating an acceptable state.

At the same time:

insufficient Evidence demonstrating an acceptable state
≠ proof of an unacceptable physical state.

The appropriate Influence response depends on the particular Context.

The present paper does not establish a new Quality State classification.

It establishes the narrower principle that the Quality-State conclusion should not exceed what the available Evidence supports.

12.14 Provisional Findings Should Remain Separate from the Indicators

Possible unresolved questions should be preserved as provisional findings about possible Indicator additions or changes.

Their purpose is to maintain research continuity.

They should not automatically become invariant Indicators requirements.

A provisional finding may later be:

resolved through the current Indicators;

shown to be Context-specific;

identified as Evidence or a Quality Outcome Criterion;

resolved through Boundary or Interface correction;

combined with another finding;

rejected;

or

strengthened through accumulated cross-Context Evidence.

This allows the Indicator set to remain open to research without making it unstable.

12.15 Any Addition or Change to the Indicators Should Follow Accumulated Evidence

A controlled review of a possible Indicator addition or change should begin only when a provisional finding has stronger support.

The Evidence should support that the question is:

quality-relevant;

necessary;

distinguishable;

non-redundant;

not adequately represented by the current Indicators;

not merely context-specific interpretation;

not merely Evidence;

not merely a Quality Outcome Criterion;

not merely a technical method;

not caused by incomplete Boundary or Interface treatment;

recurring across materially different infrastructure Contexts;

and

expressible at the selected methodological resolution for an invariant Indicator.

Even then:

Candidate for Controlled Review of a Possible Indicator Addition or Change
≠ approved addition or change to an invariant Indicator.

The review may support retention, clarification, refinement, or revision.

12.16 Present Status of the Derived Factors and Indicators

The present research supports the following position.

The fourteen invariant IQI Quality Factors remain unchanged.

The established invariant Indicators remain unchanged.

Each established Indicator is necessary within its Quality Factor because it preserves a distinct determination question.

No additional invariant Indicator is presently justified.

No established Indicator is presently justified for removal or combination.

The provisional Quality-State, Quality-State Determination, and Quality-State Influence categories remain research tools.

The provisional findings identified in this paper remain outside the established Indicators.

Context Guides should continue to test the adequacy of the established Indicators.

Horizontal comparative research should continue as the Context Guide family expands.

addition or change to the Indicators should occur only where accumulated Evidence provides sufficient justification.

Final Conclusion

The derivation and justification of invariant Indicators cannot reasonably end with a claim that the present Indicator set is permanently complete.

A stronger and more defensible approach is to demonstrate why the established Indicators are necessary and to establish a disciplined method for testing whether they remain sufficient.

The present study provides that basis.

The derived Factors and Indicators can therefore remain stable without being closed.

The Indicators can remain invariant for current application while continuing to be tested against materially different Infrastructure Quality Objects.

Context Guide research provides the Evidence.

Horizontal comparison tests recurrence and invariance.

Provisional findings preserve unresolved questions.

Controlled review provides the path for justified change.

The resulting principle for continuing derived Factors and Indicators development is:

retain what is supported;

apply it consistently;

test it through different Contexts;

preserve what remains unresolved;

and

change the invariant Indicators only when accumulated Evidence demonstrates that change is necessary.

This allows the derived Factors and Indicators to develop through Evidence rather than assumption while preserving the stability required for consistent Infrastructure Quality State Determination.

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