Justification of the Invariant IQI Core Quality Indicators

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Methodological justification of the invariant Core Quality Indicator architecture of the IQI Infrastructure Quality Standard - Core

INFRASTRUCTURE QUALITY INITIATIVE

Foreword

This paper is a companion to IQI_JQF1 — Justification of the Fourteen Invariant IQI Core Quality Factors.

IQI_JQF1 examined why the IQI Core resolves Infrastructure Quality through fourteen invariant Core Quality Factors. It also identified a separate question that remained outside its scope: the independent justification of the invariant Core Quality Indicators.

This paper addresses that question.

The IQI Core Quality Factors preserve the major quality-relevant dimensions needed for Infrastructure Quality State Determination. The Core Quality Indicators provide the more detailed examination within those dimensions. They identify what must be examined under each Factor. Context-Specific Quality Outcome Criteria and Evidence then provide the basis for determining what the findings mean for the declared Infrastructure Quality Object.

The existence of an Indicator in the present IQI Core does not, by itself, complete its methodological justification. Each established Indicator should be tested to determine whether it preserves a necessary and distinguishable determination function within its parent Quality Factor.

The principal question is therefore not whether an Indicator concerns an important infrastructure subject.

The stronger question is:

What becomes materially less determinable if this Indicator is removed from the invariant Core?

This paper applies that question to the established Core Quality Indicators under all fourteen Quality Factors.

The analysis does not begin with an assumption that the present Indicator set is permanently sufficient. Infrastructure technologies, operating conditions, Boundaries, Interfaces, Failure Modes, Reference Layer requirements, and Evidence differ among Contexts. Continued application of the IQI Core through Context Guides may reveal recurring determination needs that are not adequately represented by the present Indicator set.

Such findings should not automatically produce a new Core Indicator. They should first be preserved and tested. Repetition across sufficiently different infrastructure Contexts may provide Evidence that an additional invariant Indicator should be considered.

The paper therefore treats the Indicator architecture as stable but open.

It also examines a provisional horizontal research question. Indicators may perform different functions in Quality State determination. Some may provide Evidence about the state of the Infrastructure Quality Object itself. Others may concern the capability to determine that state reliably. Still others may concern the capability to preserve, restore, or influence the state.

For this study, these possible functions are examined provisionally as:

Quality-State Indicators;

Quality-State Determination Indicators; and

Quality-State Influence Indicators.

This classification is not introduced as a new normative layer of the IQI Core. It is used as a research lens. Its purpose is to test whether recurring Indicator functions become visible across different Factors and Context Guides, and whether that horizontal comparison reveals gaps, overlap, or other findings relevant to future Core development.

The purpose of this paper is therefore both justificatory and developmental.

It tests why the established invariant Core Quality Indicators are necessary.

At the same time, it keeps the Indicator architecture open to Evidence.

The intended result is not a permanently closed list of Indicators. It is a more clearly justified, stable, testable, and controlled Indicator architecture for determining and communicating the Quality State of energy Infrastructure Quality Objects.

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1. Introduction

1.1 Purpose of This Paper

The IQI Infrastructure Quality Standard — Core (IQC1) establishes fourteen invariant Core Quality Factors and the Core Quality Indicators assigned to them.

IQI_JQF1 separately examines why the fourteen Quality Factors are needed and why they should remain visible as distinct dimensions of Infrastructure Quality State Determination.

The present paper addresses the next level of the IQI Core architecture.

It asks why the established Core Quality Indicators are needed within those Factors.

A Core Quality Factor identifies a major quality-relevant dimension of Function Realization and Quality State determination. A Core Quality Indicator identifies what is examined within that dimension.

The Indicator layer therefore performs a different task from the Factor layer.

The purpose of this paper is to test whether each established Core Quality Indicator preserves a necessary determination function within its parent Quality Factor.

In this study, derivation does not mean reconstructing the Indicator set independently from a blank starting point. It means tracing each established Indicator to the Function Realization, Failure Modes, and determination needs represented by its parent Quality Factor, and then testing whether that function remains necessary and distinguishable.

The analysis does not treat the current Indicator list as justified merely because it is already contained in IQC1.

Each Indicator is tested.

The principal test is whether removal of the Indicator would materially reduce the ability to determine the quality-relevant condition represented by its parent Factor.

The analysis also asks whether an Indicator is sufficiently distinguishable from neighboring Indicators, whether apparent overlap represents useful complementary examination or unnecessary duplication, and whether the Indicator remains meaningful across different infrastructure Contexts and Lifecycle Stages.

The purpose is not to prove that the present Indicator set is permanently complete.

That would require a stronger claim than the available Evidence supports.

An existing Indicator may be necessary while the complete Indicator set may still contain a gap.

The two questions are different:

Is each established Indicator necessary?

and

Are the established Indicators permanently sufficient?

This paper addresses the first question directly.

It keeps the second question open to continued testing.

IQI Context Guides provide an important means for that testing. They apply the invariant Core architecture to Infrastructure Quality Objects with different Intended Functions, Boundaries, Interfaces, operating conditions, Failure Modes, Reference Layer requirements, Quality Outcome Criteria, and Evidence.

Repeated application may therefore strengthen the justification of an existing Indicator.

It may also reveal a recurring determination function that is not adequately represented by the present Indicator set.

Such a finding would not automatically justify revision of IQC1. It would first become a provisional finding for further horizontal comparison across infrastructure Contexts.

The purpose of this paper is therefore to provide a reasoned basis for both stability and controlled development of the IQI Core Indicator architecture.

The established Indicators should remain where their necessity can be demonstrated.

Possible gaps should remain visible where the available Evidence does not justify declaring the Indicator architecture permanently sufficient.

1.2 Relationship to the IQI Core Standard

The IQI Infrastructure Quality Standard — Core (IQC1) is the governing normative basis for the Indicator architecture examined in this paper.

IQC1 establishes the fourteen Core Quality Factors and their Core Quality Indicators as one invariant energy-infrastructure quality architecture.

The Factors and Indicators are applied to the declared Infrastructure Quality Object. They are not intended to operate as a generic organizational checklist.

Within this architecture, the Core Quality Factors and Core Quality Indicators perform different but connected roles.

A Core Quality Factor preserves a major quality-relevant dimension that must remain visible during Infrastructure Quality State Determination.

A Core Quality Indicator identifies what is examined within that dimension.

IQC1 therefore establishes the Indicator layer between the broader Factor level and the more Context-specific levels of Quality Outcome Criteria and Evidence.

This relationship can be expressed simply as:

Core Quality Factor
→ Core Quality Indicator
→ Context-Specific Quality Outcome Criterion
→ Evidence
→ Evidence-Supported Finding
→ Quality Factor Interpretation
→ Infrastructure Quality State.

IQC1 also establishes an important limitation on the meaning of a Core Quality Indicator.

An Indicator identifies what is examined.

It does not, by itself, establish what state is expected or acceptable.

That determination depends on the applicable Quality Outcome Criteria, Reference Layer, Infrastructure Context, and supporting Evidence.

The invariant character of a Core Quality Indicator therefore does not mean that its practical interpretation, Evidence, or expected outcome must be identical in every infrastructure Context.

Different Infrastructure Quality Objects may require different technical criteria, different Evidence, and different context-specific interpretation while continuing to use the same invariant Indicator.

This distinction is essential to the present analysis.

The question is not whether every Indicator can be applied identically to every Infrastructure Quality Object.

The question is whether the determination function represented by the Indicator remains necessary across the intended scope of the IQI Core.

IQC1 is therefore treated in this paper as the established Core architecture to be examined, not as the conclusion of the examination.

The present analysis does not replace or modify IQC1.

It seeks to provide the methodological justification for why the established Core Quality Indicators should remain invariant and to identify, where Evidence supports it, possible findings relevant to future controlled development of the Core.

1.3 Relationship to IQI_JQF1 — Justification of the Fourteen Invariant IQI Core Quality Factors

IQI_JQF1 and this paper address two connected but different levels of the IQI Core architecture.

IQI_JQF1 examines the Quality Factor level.

It asks why the IQI Core requires fourteen major quality-relevant dimensions and why those dimensions should remain separately visible in Infrastructure Quality State Determination.

Its analysis concludes that the fourteen-Factor architecture represents the smallest currently supported Core resolution that preserves the major distinguishable dimensions necessary for sufficiently broad Infrastructure Quality State Determination without unnecessary Context-driven fragmentation.

IQI_JQF1 does not independently justify the number or detailed content of the Core Quality Indicators.

It identifies that task as a separate and more detailed methodological question.

This paper takes up that question.

The relationship between the two studies can be expressed as:

IQI_JQF1
→ Why is this Quality Factor necessary?

This paper
→ Why is each established Core Quality Indicator within that Factor necessary?

The difference is important.

A Factor may be necessary even if the Indicator architecture beneath it requires further development.

Likewise, a weakness or gap at the Indicator level does not by itself demonstrate that the parent Quality Factor is unnecessary or incorrectly defined.

The two architectural levels must therefore be tested at their own methodological resolution.

IQI_JQF1 uses necessity, distinguishability, removal, overlap, cross-Context application, and collective coverage to test the fourteen-Factor architecture.

This paper applies related reasoning at the Indicator level, but it does not assume that the conclusions must be identical.

In particular, IQI_JQF1 addresses both why fewer Factors would create important loss of visibility and why additional Factors are not presently justified.

The Indicator problem is different.

The present paper seeks to determine whether each established Indicator is necessary.

It does not begin with the assumption that the existing Indicator set is permanently sufficient.

This distinction allows two propositions to remain true at the same time:

An established Core Quality Indicator may be necessary.

and

An additional Core Quality Indicator may eventually also prove necessary.

IQI_JQF1 also establishes an important development principle.

The Core should remain stable enough to support consistent interpretation, comparison, and accumulation of Evidence across Contexts and over time.

At the same time, stability does not mean that the Core must be permanently closed to new Evidence.

This paper carries that principle into the Indicator analysis.

Existing Indicators should not be changed merely because a new Context introduces different technical detail.

But repeated Context Guide application may reveal a recurring determination function that the established Indicators do not adequately preserve.

Such findings should be recorded, compared horizontally across Contexts, and tested before any Core revision is considered.

The two papers therefore perform complementary tasks.

IQI_JQF1 justifies the major dimensions of the invariant Core.

This paper examines the more detailed determination functions needed within those dimensions.

Together, they provide a methodological basis for the Factor–Indicator architecture established in IQC1.

1.4 Scope and Limitations

This paper examines the invariant Core Quality Indicators established in IQC1.

Its primary scope is the methodological justification of those Indicators within the fourteen established Core Quality Factors.

The analysis asks whether each Indicator preserves a necessary and distinguishable determination function within its parent Factor.

It also examines whether removal of an Indicator would materially reduce the ability to determine the quality-relevant condition represented by that Factor.

The paper does not redefine the fourteen Core Quality Factors.

Their separate methodological justification is provided in IQI_JQF1.

The paper also does not redefine terms established in WQI Foundational Articles, WQI_VOC1, IQI_VOC1, or IQC1. Those documents remain the governing sources for the concepts used here.

The analysis is conducted at the invariant Core level.

It does not attempt to establish detailed technical requirements for particular infrastructure technologies, assets, facilities, networks, or Lifecycle Stages.

Those requirements may differ substantially among infrastructure Contexts.

A Core Quality Indicator identifies what is examined. The expected or acceptable state is established through applicable Quality Outcome Criteria and supported by relevant Evidence.

The paper therefore does not attempt to create one universal set of technical Quality Outcome Criteria or Evidence requirements for each Core Quality Indicator.

The analysis also does not assume that the present set of Core Quality Indicators is permanently sufficient.

Necessity and sufficiency are treated as different questions.

An existing Indicator may be necessary even if repeated application later reveals an additional determination function that is not adequately represented by the current Indicator set.

For this reason, possible Indicator gaps identified during the analysis are preserved as provisional findings rather than treated automatically as changes to the Core.

Particular attention is given to repeated findings across different IQI Context Guides.

A need arising from one infrastructure Context may be Context-specific.

A similar unresolved determination need appearing across substantially different Contexts may provide stronger Evidence of a possible Core-level gap.

The paper also tests a provisional functional classification of Indicators as Quality-State, Quality-State Determination, and Quality-State Influence Indicators.

This classification is used only as a research tool.

It does not replace the established Factor–Indicator architecture of IQC1 and does not establish a new normative Core layer.

The conclusions of this paper are therefore bounded.

They may support the necessity of established Indicators, identify overlap or possible gaps, and provide Evidence relevant to future Core development.

They do not establish that the present Indicator architecture is permanently complete.

Any future addition, modification, combination, or removal of an invariant Core Quality Indicator should require sufficient accumulated Evidence and controlled revision of IQC1.

1.5 Central Research Question

The central research question of this paper is:

Why is each established IQI Core Quality Indicator necessary within the IQI Core?

The question is narrower than asking whether an Indicator concerns an important infrastructure subject.

Many infrastructure subjects are important.

Importance alone does not justify keeping a subject as an invariant Core Quality Indicator.

The stronger test is whether the Indicator preserves a necessary determination function within its parent Core Quality Factor.

For each established Indicator, the analysis therefore asks:

If this Indicator were removed, what quality-relevant condition or determination function would become materially less visible or less determinable?

A second question follows:

Is that determination function sufficiently different from the functions of the other Indicators within the same Factor?

Indicators may overlap in subject matter or Evidence.

Such overlap does not necessarily mean that they are redundant.

Two Indicators may use related Evidence while asking different determination questions.

Conversely, different Indicator names do not by themselves demonstrate that the Indicators perform different determination functions.

The analysis must therefore test the function of each Indicator rather than rely only on its title.

A third question concerns the complete set of Core Quality Indicators:

Do repeated applications of the IQI Core reveal a quality-relevant determination function that is not adequately represented by the established Indicators?

This question is intentionally kept open.

The present study does not begin by assuming either that additional Indicators are needed or that the existing set is permanently sufficient.

The basic sequence is:

Established Core Quality Indicator
→ identify its determination function
→ test its necessity
→ test what is lost if it is removed
→ test whether it is sufficiently different from other Indicators
→ test its relevance across Lifecycle Stages, Boundaries, Interfaces, and infrastructure Contexts
→ retain the Indicator where its invariant Core function is supported.

At the same time:

Context Guide application
→ possible unresolved determination need
→ provisional finding
→ comparison across different infrastructure Contexts
→ repeated Evidence
→ possible consideration of an additional invariant Core Quality Indicator.

The paper also asks a related question across all fourteen Factors:

Do the established Indicators perform recurring types of determination functions that can provisionally be understood as Quality-State, Quality-State Determination, and Quality-State Influence functions?

This question does not assume that every Indicator belongs exclusively to one type.

An Indicator may perform more than one function.

The purpose is to determine whether this functional view helps explain the existing set of Core Quality Indicators and whether it reveals recurring gaps that are difficult to see when each Factor is examined separately.

The central research problem can therefore be stated in its complete form:

Does each established Core Quality Indicator preserve a necessary and sufficiently different determination function within its parent Quality Factor, and does comparison across Factors and infrastructure Contexts reveal any recurring additional determination function that may need to be considered at the invariant Core Indicator level?

This question guides the analysis that follows.

2. From Quality Factors to Quality Indicators

2.1 Role of a Quality Factor in the IQI Core

A Core Quality Factor identifies a major quality-relevant dimension that must remain visible when the Quality State of an Infrastructure Quality Object is determined.

The fourteen Core Quality Factors do not describe fourteen separate objects.

They provide fourteen different views of the same declared Infrastructure Quality Object.

Each Factor asks a different major question about whether the object can realize its Intended Functions and Intended Results.

For example, one Factor examines whether the required functions have been correctly defined.

Another examines whether those functions have been translated into adequate technical requirements.

Other Factors examine actual integrity, Risk control, environmental interaction, operational reliability, human interaction, competence, compliance, monitoring, traceability, and response to change.

The Factors are therefore not simply headings used to organize Indicators.

Each Factor preserves a determination question that should remain separately visible when Evidence-Supported Findings are interpreted and the Infrastructure Quality State is determined.

At the same time, a Factor is intentionally broad.

It identifies a major dimension of the determination, but it does not identify every condition that must be examined within that dimension.

For this reason, the Factor level requires a more detailed Indicator level beneath it.

The relationship can be expressed simply as:

Infrastructure Quality
→ Core Quality Factor
→ Core Quality Indicators
→ Context-Specific Quality Outcome Criteria
→ Evidence.

The Factor tells us which major quality-relevant dimension is being examined.

The Indicators tell us what must be examined within that dimension.

The Quality Outcome Criteria provide the basis for judging the expected or acceptable condition in the defined Context.

Evidence supports the finding.

This division of roles is important.

If the Factors were made too detailed, the Core would become a long list of technical subjects.

If the Factors were too broad, important differences could disappear inside general categories.

IQI_JQF1 therefore justifies the fourteen Factors as the minimum currently supported set of Core-level distinctions needed to preserve the major quality-relevant dimensions of Infrastructure Quality State Determination.

The present paper begins at the next level.

It accepts the fourteen established Factors as the governing Factor structure and examines whether the Core Quality Indicators within each Factor preserve the more detailed determination functions needed to examine that Factor responsibly.

2.2 Role of a Quality Indicator

A Core Quality Indicator identifies what is examined within a Core Quality Factor.

The Factor establishes the major quality-relevant dimension.

The Indicator makes that dimension more specific by identifying a condition, capability, result, or other subject that must be examined to support determination of the Factor.

An Indicator therefore has a determination role.

It directs attention to something that must remain visible when the Quality State of the Infrastructure Quality Object is examined.

This does not mean that the Indicator itself determines whether the condition is acceptable.

For example, an Indicator may require examination of structural condition, operational performance, personnel competence, monitoring capability, or another quality-relevant subject.

The Indicator identifies the subject to be examined.

The applicable Quality Outcome Criterion establishes the expected or acceptable result for that subject in the defined Context.

Evidence then supports the finding against that Criterion.

The relationship is therefore:

Core Quality Factor
→ identifies the major quality-relevant dimension

Core Quality Indicator
→ identifies what is examined within that dimension

Quality Outcome Criterion
→ identifies the expected or acceptable result

Evidence
→ supports the finding.

The same invariant Indicator may therefore be used in substantially different infrastructure Contexts while its Quality Outcome Criteria and Evidence differ.

For example, the technical means used to demonstrate an Indicator may differ between a pipeline, an underground storage facility, an LNG facility, and another Infrastructure Quality Object.

Those differences do not necessarily require different Core Quality Indicators.

The important question at the Core level is whether the same basic determination need remains.

This is also why an Indicator should not be justified only by the importance of its subject.

A subject may be technically important but still belong within the Context-specific interpretation of another Indicator.

For a subject to justify a separate invariant Core Quality Indicator, it must preserve a determination need that should remain visible across the intended scope of the IQI Core.

The role of the Indicator is therefore more specific than the role of the Factor, but more general than the role of Context-Specific Quality Outcome Criteria and Evidence.

It provides the connection between the major quality-relevant dimension represented by the Factor and the specific determination performed for a defined Infrastructure Quality Object.

This intermediate role is central to the analysis in this paper.

The question for each established Indicator is not simply:

Is this subject important?

The question is:

Does this Indicator identify something that must be examined separately enough that removing it would materially weaken determination of its parent Quality Factor?

2.3 Why a Quality Factor Alone Is Not Sufficient for Quality State Determination

A Core Quality Factor identifies a major quality-relevant dimension.

That level is necessary, but it is too broad by itself to support a sufficiently detailed determination.

Consider Structural and Functional Integrity.

Knowing that integrity must be examined does not yet tell us which conditions must be examined to determine whether integrity is adequately preserved.

The same problem exists for every Factor.

Operational Reliability identifies an important dimension, but the Factor name alone does not identify the different conditions that must be examined to determine whether the Infrastructure Quality Object can perform its Intended Functions reliably.

Competence of Personnel identifies another major dimension, but the Factor alone does not identify the different aspects of competence that must be examined.

Monitoring and Performance Evaluation identifies the need for continuing visibility and evaluation, but the Factor alone does not specify what must be examined to determine whether that capability is adequate.

The Core Quality Indicators provide this additional level of detail.

They divide the broad determination question represented by a Factor into more specific questions that can be examined against applicable Quality Outcome Criteria and Evidence.

The relationship can be expressed as:

Quality Factor
→ What major quality-relevant dimension must be examined?

Quality Indicators
→ What must be examined within that dimension?

Without Indicators, a Factor could remain too general for consistent application.

Different users could interpret the same Factor through substantially different sets of subjects.

Important conditions could be overlooked.

Other conditions could receive excessive attention simply because they are familiar or easy to measure.

The Indicator layer reduces this problem by preserving the more specific determination needs that IQI considers necessary within each Factor.

At the same time, the Indicator layer should not attempt to contain every technical detail relevant to every infrastructure Context.

That detail belongs principally to Context-Specific Quality Outcome Criteria, Evidence, the applicable Reference Layer, and other Context-specific interpretation.

The Indicator level therefore has to maintain a balance.

It must be detailed enough to prevent necessary determination questions from disappearing inside a broad Factor.

It must also remain general enough to apply across different Infrastructure Quality Objects and Contexts.

This gives the Indicator layer its specific role:

Quality Factor
→ preserves the major determination dimension

Core Quality Indicators
→ preserve the necessary more specific determination questions within that dimension

Context-Specific Quality Outcome Criteria and Evidence
→ make those questions sufficiently specific for the actual Infrastructure Quality Object and Context.

A Quality Factor alone is therefore not sufficient for responsible Quality State determination.

The Factor tells us where to look.

The Indicators tell us what within that Factor must be examined.

The remaining question, and the central subject of this paper, is whether the established Indicators identify all presently justified necessary determination questions without assuming that the set is permanently complete.

2.4 Factor–Indicator Relationship

A Core Quality Factor and its Core Quality Indicators perform connected but different roles.

The Factor defines the major quality-relevant dimension that must remain visible.

The Indicators identify the more specific determination questions that must be examined within that dimension.

The relationship is therefore not simply:

Factor
→ list of related subjects.

It is:

Factor
→ major determination question
→ necessary more specific determination questions
→ Core Quality Indicators.

This distinction is important for justifying an Indicator.

An Indicator should not be included under a Factor merely because its subject is related to that Factor.

Its inclusion should be based on the determination function it performs.

The first question is:

What does the parent Factor require us to determine?

The next question is:

What must be examined to make that determination responsibly?

The answers to the second question provide the basis for testing the Indicators.

Several Indicators may be required under one Factor because the Factor cannot be responsibly determined through one narrower question.

Those Indicators may also interact.

Evidence relevant to one Indicator may be relevant to another.

A condition identified through one Indicator may affect the finding under another Indicator.

Such interaction does not automatically make the Indicators redundant.

The important test is whether each Indicator preserves a sufficiently different determination question.

The relationship also works in the opposite direction.

An Indicator should remain within the meaning of its parent Factor.

If an Indicator repeatedly requires examination of a determination question that does not fit the Factor under which it is placed, this may indicate a problem in the Indicator's placement or in the way its function is understood.

The Factor–Indicator relationship should therefore satisfy two conditions:

The Indicator must contribute something necessary to determination of the Factor.

and

The Indicator's determination function must remain consistent with the meaning of that Factor.

This relationship also helps distinguish Core Indicators from Context-specific detail.

A particular technology, Failure Mode, inspection method, technical requirement, or Evidence source may be important within one Context.

But it does not automatically require a separate Core Quality Indicator.

It may instead provide a Context-specific means of examining an existing Indicator.

The Core Indicator should remain at a level that can be interpreted across different Infrastructure Quality Objects while preserving the same basic determination need.

The Factor–Indicator relationship can therefore be summarized as:

Infrastructure Quality State
→ examined through fourteen major quality-relevant dimensions
→ Core Quality Factors

Each major dimension
→ examined through necessary more specific determination questions
→ Core Quality Indicators

Each Indicator
→ interpreted for the declared Infrastructure Quality Object
→ Context-Specific Quality Outcome Criteria and Evidence.

The Indicator layer is therefore neither an unrestricted list of subjects nor a detailed technical checklist.

It is the more specific level at which the broad determination question represented by each Factor becomes sufficiently defined for Context-specific examination.

2.5 Indicators as Means of Making Quality-Relevant Conditions Observable and Determinable

A quality-relevant condition can affect Function Realization without being sufficiently visible for Quality State determination.

The existence of the condition and the ability to determine that condition are not the same thing.

A condition may exist physically, functionally, operationally, environmentally, or through human interaction.

But unless the condition can be examined through relevant Evidence, its significance for the Infrastructure Quality State may remain unknown or uncertain.

Core Quality Indicators help connect these two sides of the determination.

They identify what must become sufficiently observable and determinable within each Core Quality Factor.

In this sense, an Indicator does not merely identify an important subject.

2.6 Distinction Between Indicator, Evidence, and Quality Outcome Criterion

A Core Quality Indicator, Quality Outcome Criterion, and Evidence perform different roles in Infrastructure Quality State Determination.

They should not be treated as interchangeable.

A Core Quality Indicator identifies what is examined.

A Quality Outcome Criterion identifies the expected or acceptable result for the Indicator in the defined Context.

Evidence provides the basis for determining whether that result is achieved.

The relationship can be expressed as:

Core Quality Indicator
→ What is examined?

Quality Outcome Criterion
→ What result is expected or acceptable?

Evidence
→ What supports the finding?

This distinction allows the Core Quality Indicators to remain invariant while their practical application changes across infrastructure Contexts.

The same Indicator may apply to a main pipeline, local distribution network, underground storage facility, LNG facility, or another Infrastructure Quality Object.

However, the applicable Quality Outcome Criteria may differ.

The Evidence needed to support a finding may also differ.

For example, different Contexts may require different measurements, inspections, tests, operating records, calculations, analyses, observations, or other Evidence.

Those differences do not by themselves require different Core Quality Indicators.

They may represent different Context-specific ways of examining the same invariant determination question.

The distinction is also important when testing whether an additional Core Quality Indicator may be needed.

A new technical requirement does not automatically require a new Indicator.

A new Evidence source does not automatically require a new Indicator.

A different acceptance limit does not automatically require a new Indicator.

These may instead represent a new or changed Quality Outcome Criterion, Evidence requirement, or Context-specific interpretation of an established Indicator.

A possible new Core Quality Indicator should be considered only when the underlying determination question itself is not adequately represented by the established Indicators.

This can be expressed as:

Different Evidence
≠ automatically a new Indicator.

Different Quality Outcome Criterion
≠ automatically a new Indicator.

Different Context-specific technical detail
≠ automatically a new Indicator.

Missing necessary determination question
→ possible Indicator gap.

This distinction is important for keeping the IQI Core stable.

It allows Context Guides to provide the technical detail needed for different Infrastructure Quality Objects without continuously expanding the invariant Core Indicator set.

At the same time, it does not prevent identification of a genuine Indicator gap.

If repeated application shows that an important determination question cannot be adequately addressed through the established Indicators, the issue should not be forced into an Indicator simply to preserve the existing list.

It should be recorded and tested as a possible additional Indicator finding.

The Indicator, Quality Outcome Criterion, and Evidence levels therefore perform separate but connected functions.

Keeping these functions separate is necessary both for consistent application of the present IQI Core and for controlled development of the Core Quality Indicator set.

It identifies a determination need.

The basic relationship is:

Quality-relevant condition
→ Core Quality Indicator
→ applicable Quality Outcome Criterion
→ relevant Evidence
→ Evidence-Supported Finding.

Observability does not mean that every condition must be directly measured.

Some conditions can be observed directly.

Others may be determined through inspection, testing, records, calculations, analysis, operating data, demonstrated performance, or other relevant Evidence.

The required means depend on the Infrastructure Quality Object and Context.

The Core Indicator therefore does not prescribe one universal method of observation or determination.

It preserves the question that must be answered.

A large amount of Data does not necessarily make a condition adequately determinable.

Evidence must be relevant to the declared Infrastructure Quality Object, the Indicator being examined, and the applicable Quality Outcome Criterion.

Likewise, the absence of an observed problem does not by itself demonstrate an acceptable condition.

The ability to determine a Quality State depends not only on what is happening to the Infrastructure Quality Object, but also on whether the relevant conditions can be known with sufficient confidence.

This raises an important question for the Indicator analysis.

Some Indicators may primarily concern the actual condition or performance of the Infrastructure Quality Object.

Other Indicators may primarily concern the capability to determine that condition reliably.

Still others may concern the capability to preserve, restore, or influence the condition.

These possible differences are examined later in this paper through the provisional Quality-State, Quality-State Determination, and Quality-State Influence functions.

At this stage, the important point is simpler.

A Core Quality Indicator makes a necessary quality-relevant question explicit.

It identifies something that must be sufficiently observable and determinable for the parent Quality Factor to be responsibly interpreted.

The justification of an Indicator therefore depends partly on what would become insufficiently observable or determinable if that Indicator were removed.

If removal leaves a necessary quality-relevant condition without adequate examination elsewhere in the Factor, the Indicator performs a necessary function.

If another Indicator necessarily preserves the same determination question without meaningful loss, the possibility of overlap or redundancy must be examined.

This connection between Indicator, observability, and determinability provides one of the principal bases for the Indicator necessity tests developed later in this paper.

3. The Different Completeness Problem at the Indicator Layer

3.1 Why the Quality-Factor and Quality-Indicator Problems Are Different

The justification of the fourteen Core Quality Factors and the justification of the Core Quality Indicators are related, but they do not present the same completeness problem.

At the Factor level, IQI_JQF1 asks whether the fourteen Factors provide the major quality-relevant dimensions necessary for sufficiently broad Infrastructure Quality State Determination.

The Factor analysis therefore tests the complete set in two directions.

Could fewer Factors preserve all necessary major dimensions?

and

Is there Evidence that an additional major dimension requires another Factor?

The present conclusion of IQI_JQF1 is that the fourteen Factors provide the minimum currently supported set of Core-level distinctions necessary for the IQI determination task.

The Indicator layer requires a different approach.

Each Core Quality Factor covers a broad quality-relevant dimension.

Several more specific determination questions may be necessary within that dimension.

The first task is therefore to test whether each established Indicator is necessary.

For each Indicator, the question is:

If this Indicator were removed, would a necessary determination question within the parent Factor become materially less visible or less determinable?

If the answer is yes, the Indicator has a basis for remaining in the invariant Core.

But this does not answer a second question:

Are the existing Indicators sufficient to represent every necessary determination question within the Factor?

The two conclusions are not the same.

For example, suppose a Factor presently contains four Indicators.

Analysis may show that all four are necessary.

This establishes:

Indicator 1 is necessary.

Indicator 2 is necessary.

Indicator 3 is necessary.

Indicator 4 is necessary.

It does not automatically establish:

No Indicator 5 can also be necessary.

This is the central difference between the Factor and Indicator completeness problems addressed in these companion studies.

At the Factor level, the present research supports a defined set of fourteen major dimensions.

At the Indicator level, the present research can test the necessity of every established Indicator without claiming that no additional Indicator could later be justified.

This distinction is especially important because Context Guides provide progressively more detailed application of the Core.

Different Infrastructure Quality Objects may reveal determination needs that were not evident when the present Indicator set was established.

Many such findings will remain Context-specific.

They may be addressed through Quality Outcome Criteria, Evidence, Failure Modes, Reference Layer requirements, or other Context-specific interpretation.

But repeated findings across substantially different infrastructure Contexts may reveal something different.

They may reveal a necessary determination question that is not adequately represented by any established Core Quality Indicator.

The Indicator analysis must therefore remain open to that possibility.

This does not weaken the invariant character of the present Core Quality Indicators.

It separates two different claims:

The established Indicator is necessary.

and

The established Indicator set is permanently complete.

The first claim can be tested directly in this paper.

The second should not be made without sufficient Evidence.

For this reason, necessity is the primary test applied to the established Core Quality Indicators, while sufficiency remains open to continued testing through Context Guide application and comparison across infrastructure Contexts.

The Indicator completeness problem is therefore not simply:

How many Indicators should the IQI Core contain?

The more useful questions are:

Which determination questions must remain explicitly represented at the invariant Core Indicator level?

Which established Indicators are necessary to preserve those questions?

And does repeated application reveal another necessary determination question that the present Indicator set does not adequately represent?

These questions provide the basis for the analysis that follows.

3.2 Necessity and Sufficiency in IQI_JQF1

IQI_JQF1 uses necessity and sufficiency to examine the fourteen Core Quality Factors.

Necessity asks whether each Factor preserves a major determination question that must remain visible.

The removal test provides a direct way to examine this.

If a Factor is removed, does another Factor necessarily preserve the same major determination question?

If not, removal creates a loss of necessary quality-relevant visibility.

Sufficiency asks a different question.

Taken together, do the fourteen Factors provide sufficiently broad coverage of the major quality-relevant dimensions needed for Infrastructure Quality State Determination?

IQI_JQF1 tests this question through Factor-by-Factor analysis, Failure-Mode analysis, Reference Layer coverage, and application across different IQI Context Guides.

The two tests work together at the Factor level.

Necessity
→ Why can this Factor not be removed?

Sufficiency
→ Does the complete Factor set leave another major quality-relevant dimension outside the Core?

IQI_JQF1 concludes that fewer than fourteen Factors would presently risk loss of necessary quality-relevant visibility.

It also concludes that an additional Factor is not presently supported by sufficient Evidence of another independent Core-level quality dimension.

This does not mean that the fourteen-Factor set is declared permanently complete.

IQI_JQF1 keeps the Factor set open to continued testing.

Repeated Context Guide application, Failure-Mode analysis, Reference Layer mapping, operating experience, and comparison across infrastructure Contexts may provide new Evidence.

The same general distinction between necessity and sufficiency is useful at the Indicator level, but it must be applied differently.

For an established Core Quality Indicator, necessity asks:

If this Indicator is removed, does a necessary determination question within its parent Factor become materially less visible or less determinable?

Sufficiency asks:

Do the established Indicators, taken together, provide all of the determination questions that need to remain visible within the Factor at the invariant Core level?

The first question can be tested for every established Indicator.

The second requires wider Evidence.

It requires examination not only of the existing Indicators but also of what repeatedly appears during application of the Core.

This is why the present paper does not use sufficiency to mean:

The current Indicator set is complete and no additional Indicator can be needed.

Instead, sufficiency is treated as a continuing research question.

The present Indicators can be shown to be necessary without declaring the set permanently sufficient.

The relationship can therefore be expressed as:

Indicator necessity
→ Does removal create a meaningful loss of determination capability?

Indicator sufficiency
→ Does repeated application reveal a necessary determination question that remains outside the established Indicator set?

This distinction allows the IQI Core to remain stable without treating the current Indicator set as permanently closed.

It also establishes the basis for the next step of this paper:

Necessity is the primary test for each established invariant Core Quality Indicator.

3.3 Necessity as the Primary Test for Invariant Core Quality Indicators

The first question for each established Core Quality Indicator is whether it is necessary.

Necessity does not mean that the subject of the Indicator is important.

Many infrastructure subjects are important.

The question is more specific:

Does the Indicator preserve a determination question that must remain visible within its parent Core Quality Factor?

This distinction prevents the Core from becoming a list of every important technical, operational, human, environmental, regulatory, or information-related subject.

A subject should remain a separate invariant Core Quality Indicator only where its determination function requires separate visibility at the Indicator level.

The necessity test therefore begins with the parent Factor.

For each Indicator, the analysis asks:

What does this Indicator allow us to determine about the parent Factor?

Then:

What happens if the Indicator is removed?

If removal causes a necessary quality-relevant condition to become materially less visible or less determinable, the Indicator has a necessary role.

If the same determination question is necessarily and adequately preserved by another Indicator, the need for a separate Indicator becomes less clear.

The test can be expressed as:

Established Indicator
→ identify the determination question
→ remove the Indicator
→ examine what is lost.

If a necessary determination question is lost
→ necessity is supported.

If no meaningful determination capability is lost
→ possible redundancy or unnecessary separation should be examined.

The test should consider function rather than wording.

Two Indicators may have different names but substantially perform the same determination function.

In that case, their separate necessity requires further examination.

Two Indicators may also appear similar but preserve different questions.

In that case, apparent overlap does not establish redundancy.

Necessity should also be tested across the intended scope of the IQI Core.

An Indicator should not depend for its Core status only on one technology, one Failure Mode, one Lifecycle Stage, or one infrastructure Context.

Its specific application may differ.

Its Quality Outcome Criteria may differ.

Its Evidence may differ.

But the basic determination need represented by the Indicator should remain meaningful across sufficiently different Infrastructure Quality Objects within the intended scope of IQI.

This does not require every Indicator to have the same practical importance in every Context.

An Indicator may become especially important under particular operating conditions, Lifecycle Stages, Boundaries, Interfaces, or Failure Modes.

The question is whether its underlying determination function remains applicable when the Context changes.

Necessity also does not require an Indicator to operate independently from the other Indicators.

Infrastructure conditions interact.

Evidence may support more than one Indicator.

Findings under one Indicator may affect findings under another.

Such interaction is expected.

The relevant question is whether removing one Indicator causes its determination function to disappear or become inadequately represented.

The primary proposition tested for each established Indicator is therefore:

An invariant Core Quality Indicator is necessary when it preserves a quality-relevant determination function within its parent Core Quality Factor that would become materially less visible or less determinable if the Indicator were removed.

This proposition tests the necessity of the established Indicator.

It does not claim that the complete Indicator set is permanently sufficient.

That separate question remains open to Evidence from continued application and comparison across infrastructure Contexts.

3.4 Why Permanent Sufficiency of the Indicator Set Is Not Claimed

The present IQI Core establishes a defined set of invariant Core Quality Indicators.

This paper tests whether those established Indicators are necessary.

It does not claim that the present set contains every Core Quality Indicator that could ever be needed.

There is an important difference between these two conclusions:

Each established Indicator is necessary.

and

No additional Indicator can be necessary.

The first conclusion may be supported by testing the established Indicators.

The second would require much broader Evidence.

The IQI Core applies to different Infrastructure Quality Objects, technologies, Lifecycle Stages, operating conditions, Boundaries, Interfaces, and Failure Modes.

Existing and new Context Guides provide continuing opportunities to test whether the present Indicators remain adequate across these differences.

A new Context may reveal a determination need that was not previously visible.

In most cases, this does not mean that a new Core Quality Indicator is required.

The need may already be represented by an established Indicator and may require only different Context-Specific Quality Outcome Criteria, Evidence, or more detailed Context-specific interpretation.

A finding may also be important only within one particular infrastructure Context.

Such a finding does not justify an invariant Core Indicator.

But another possibility must remain open.

The same determination need may repeatedly appear across substantially different infrastructure Contexts.

It may not be adequately represented by any established Indicator.

Its absence may materially reduce the ability to determine one or more Core Quality Factors.

In that case, the finding may indicate a possible gap in the Core Quality Indicator set.

The appropriate response is not immediate Core revision.

The finding should first be recorded.

It should then be tested against the established Indicators.

Its relationship to the parent Factor should be examined.

Its occurrence across different Contexts should be compared.

Only repeated and sufficiently strong Evidence should support consideration of an additional invariant Core Quality Indicator.

The development sequence is therefore:

Existing Core Quality Indicators
→ Context Guide application
→ possible unresolved determination need
→ test against existing Indicators
→ provisional Indicator finding
→ comparison across different infrastructure Contexts
→ repeated Evidence
→ possible controlled Core revision.

This approach protects two important needs.

The first is stability.

The invariant Core should not change whenever a new technical issue, Failure Mode, requirement, or Evidence source appears.

The second is openness to Evidence.

The Core should not force a repeatedly observed determination need into an existing Indicator when that Indicator does not adequately represent it.

Permanent sufficiency is therefore not claimed because the available Evidence does not justify closing the Indicator set against additional findings.

This is not a weakness of the Core.

It is a controlled limit on the conclusion being made.

The present Indicator set can be justified as necessary while remaining open to Evidence that an additional invariant determination question may need to be represented.

3.5 Stable but Open Indicator Architecture

The IQI Core Quality Indicator set must serve two needs at the same time.

It must be stable enough to support consistent application.

It must also remain open to Evidence that the present set may require development.

Stability is necessary because the Core Quality Indicators are invariant.

The same Indicators provide a common basis for examining different Infrastructure Quality Objects and for developing IQI Context Guides.

If the Core Indicator set changed whenever a new Context-specific issue appeared, comparison across Contexts would become difficult.

It would also become difficult to determine whether a new issue represents a different determination need or simply a different application of an established Indicator.

Stability therefore allows Evidence to accumulate around a common set of determination questions.

But stability does not require permanent closure.

The present Indicator set is based on the current development and application of the IQI Core.

Continued use of the Core may reveal determination needs that require further examination.

The important question is where the new finding belongs.

A new finding may require:

different Evidence;

a different Quality Outcome Criterion;

more detailed interpretation of an established Indicator;

additional Context-specific detail;

or

consideration of an additional invariant Core Quality Indicator.

These possibilities should not be treated as equivalent.

Most new technical detail should not change the Core.

The established Indicator should remain unchanged when it can adequately represent the determination question and the difference can be addressed through Context-specific interpretation.

A possible Core-level gap exists only when the determination question itself is not adequately represented by the established Indicators.

Even then, one finding is not enough to justify a new invariant Indicator.

The finding should be preserved and tested through additional Context Guide work.

Repeated appearance across substantially different Infrastructure Quality Objects provides stronger Evidence that the determination need may be invariant rather than Context-specific.

The process can therefore be expressed as:

New finding
→ Can an established Indicator adequately represent it?

If yes
→ retain the existing Core Indicator and address the needed detail through Context-specific interpretation.

If no
→ preserve the finding as a possible Indicator gap.

Possible Indicator gap
→ test in other infrastructure Contexts
→ compare findings
→ determine whether the same necessary determination question repeatedly appears
→ consider Core revision only when sufficient Evidence supports it.

This approach allows the IQI Core to remain stable without treating the present Indicator set as permanently complete.

The Core is therefore stable in application but open to controlled development based on Evidence.

3.6 Invariance Versus Extensibility

Invariance and extensibility serve different purposes in the IQI Core.

Invariance means that the established Core Quality Indicators remain common across IQI infrastructure Contexts.

A Context Guide does not create an alternative set of Core Quality Indicators for its particular Infrastructure Quality Object.

Instead, it interprets the invariant Indicators through the applicable Context, Quality Outcome Criteria, Evidence, Failure Modes, Boundaries, Interfaces, operating conditions, Lifecycle conditions, and Reference Layer requirements.

This common Core is important.

It allows substantially different Infrastructure Quality Objects to be examined through the same basic set of determination questions.

Extensibility addresses a different issue.

It recognizes that continued application may produce new findings.

Some findings can be addressed within the established Indicators.

Others may reveal a determination question that the present Indicators do not adequately represent.

Extensibility therefore does not mean that individual Context Guides may add new Core Quality Indicators.

A Context Guide may identify a possible gap.

It may preserve and describe that finding.

But the finding does not become an invariant Core Quality Indicator merely because it is important in that Context.

The distinction can be expressed as:

Invariance
→ the established Core Quality Indicators remain common across IQI Contexts.

Context-specific interpretation
→ the Indicators are applied through the conditions, criteria, and Evidence relevant to the declared Infrastructure Quality Object.

Extensibility
→ repeated Evidence may support consideration of an additional invariant Core Quality Indicator through controlled Core revision.

This distinction prevents two opposite problems.

Without invariance, the Core could become different for every Context.

The meaning of the common IQI determination basis would then weaken.

Without extensibility, the Core could remain unchanged even when repeated Evidence shows that a necessary determination question is missing.

Neither result is desirable.

The purpose is therefore not to choose between invariance and extensibility.

The purpose is to control their relationship.

An established Indicator remains invariant unless sufficient Evidence supports Core revision.

A possible additional Indicator remains provisional until its need has been tested beyond the Context in which it was first identified.

The key question is whether the finding represents:

a different way of examining an established determination question;

or

a necessary determination question that is not adequately represented by the established Indicators.

The first normally belongs within Context-specific interpretation.

The second may justify further Core-level research.

Repeated occurrence across substantially different infrastructure Contexts strengthens the second possibility.

The IQI Core Indicator set can therefore remain invariant without being permanently closed.

Invariance provides consistency.

Extensibility provides a controlled way to respond to repeated Evidence.

Together, they allow the Core Quality Indicator set to remain stable, comparable across Contexts, and capable of development when the Evidence supports it.

4. Method for Justifying an Invariant Core Quality Indicator

4.1 Indicator Necessity Test

The justification of an established Core Quality Indicator begins with a necessity test.

The purpose of the test is to determine whether the Indicator preserves a necessary determination question within its parent Core Quality Factor.

The test does not begin by asking whether the Indicator concerns an important subject.

Importance alone is not sufficient.

The test begins with the function of the parent Factor.

First, ask:

What major quality-relevant dimension does the parent Factor require us to determine?

Then ask:

What specific determination question does this Indicator preserve within that dimension?

The Indicator is necessary when that question must remain separately visible for the Factor to be responsibly determined.

The basic test is:

Parent Core Quality Factor
→ identify its major determination question

Core Quality Indicator
→ identify the more specific determination question preserved by the Indicator

Then ask:

Is this question necessary for responsible determination of the parent Factor?

If yes, the analysis continues to determine whether another Indicator already preserves the same question adequately.

If no, the Indicator's invariant Core status requires further examination.

The necessity test must focus on what is being determined rather than on the Indicator title.

An Indicator title may describe a technical subject.

But the justification must identify why examination of that subject is necessary for determination of the parent Factor.

For example:

Subject is important
≠ Indicator is necessarily required in the invariant Core.

Instead:

Subject represents a necessary determination question within the Factor
→ possible basis for invariant Core Indicator status.

The test should also distinguish between a necessary Core determination question and necessary Context-specific detail.

A particular inspection method, technical requirement, Failure Mode, acceptance value, or Evidence source may be necessary in a particular Context.

That does not automatically make it a necessary Core Quality Indicator.

The Core-level question is broader:

Does the determination need remain meaningful across different Infrastructure Quality Objects even when the specific technical means of examining it change?

The Indicator does not need to have equal importance in every Context.

Its detailed interpretation may differ substantially.

But its basic determination function should remain relevant across the intended scope of the IQI Core.

The necessity test therefore considers:

the function of the parent Factor;

the specific determination question preserved by the Indicator;

the relationship of that question to Infrastructure Intended Function realization;

the possible consequences of leaving the question unexamined;

whether the question is already adequately represented by another Indicator;

and

whether the determination need remains meaningful across different infrastructure Contexts.

The result of the necessity test is not yet the final justification of the Indicator.

It establishes the first requirement:

The Indicator must preserve a determination question that is necessary within its parent Core Quality Factor.

The next test strengthens this analysis by asking what actually happens when the Indicator is removed.

4.2 Removal Test

The removal test asks what is lost if an established Core Quality Indicator is removed.

It provides a direct test of necessity.

For each Indicator, the question is:

If this Indicator disappears, does another Indicator within the parent Factor necessarily preserve the same determination question?

If the answer is no, removal creates a gap.

A quality-relevant condition may become less visible.

The ability to determine the parent Factor may become weaker.

Important Evidence may remain available, but there may no longer be a clear Indicator under which that Evidence is interpreted.

The basic test is:

Established Core Quality Indicator
→ remove it
→ examine the remaining Indicators
→ determine whether the same necessary question remains adequately represented.

If the determination question is materially weakened or lost
→ the removal test supports necessity.

If the determination question remains fully and clearly represented by another Indicator
→ possible redundancy should be examined.

The test must consider determination function rather than similar wording.

Two Indicators may concern related subjects but ask different questions.

Removing one may therefore cause a real loss even though another Indicator appears closely related.

The opposite is also possible.

Two differently named Indicators may preserve substantially the same determination question.

If removal of one causes no meaningful loss, their separate Core status requires further examination.

The removal test should also consider whether the lost question could simply be moved into Context-specific detail.

If removal of an Indicator only removes a particular technical method, Evidence source, Failure Mode, or acceptance requirement, a separate invariant Indicator may not be necessary.

Such detail may be adequately addressed through Context-Specific Quality Outcome Criteria, Evidence, or other Context-specific interpretation.

But if removal causes the underlying determination question itself to disappear from the Core, the issue is different.

The distinction is:

Loss of Context-specific detail
≠ necessarily a Core Indicator gap.

Loss of a necessary determination question
→ supports the need for the Core Indicator.

The removal test should be applied across different Infrastructure Quality Objects where practical.

An Indicator may appear unnecessary in one Context because the condition it addresses is simple, uncommon, or indirectly controlled there.

The same Indicator may become essential in another Context.

The test therefore asks whether removal would create a meaningful gap across the intended range of IQI applications, not whether the Indicator is equally important in every individual application.

The removal test also supports comparison among Indicators within the same Factor.

It helps identify whether several Indicators provide complementary views of the Factor or whether they unnecessarily repeat the same determination function.

The result should therefore answer a simple question for every established Indicator:

What becomes materially less visible or less determinable if this Indicator is removed?

A clear answer supports the Indicator's necessity.

An unclear answer does not automatically justify removal.

It identifies the need for further testing of distinguishability, overlap, and the Indicator's relationship to the parent Factor.

The removal test therefore works together with the other tests developed in this Section.

Its specific purpose is to establish whether the absence of an Indicator would create a meaningful loss in the determination of its parent Core Quality Factor.

4.3 Distinguishability Test

The distinguishability test asks whether an established Core Quality Indicator preserves a determination question that is sufficiently different from the questions preserved by the other Indicators within its parent Factor.

This test follows the necessity and removal tests.

An Indicator may address a necessary subject but still overlap strongly with another Indicator.

The question is therefore not only:

Is this determination question necessary?

It is also:

Does this Indicator preserve a sufficiently different determination question to justify separate visibility within the Factor?

The test begins by comparing the Indicator with the other Indicators under the same Factor.

For each pair of closely related Indicators, ask:

What does Indicator A require us to determine?

What does Indicator B require us to determine?

Can one question be answered while the other remains unresolved?

If yes, the Indicators are distinguishable.

For example, two Indicators may examine related conditions and use some of the same Evidence.

But satisfactory Evidence for one may not establish a satisfactory finding for the other.

This indicates that the Indicators preserve different determination questions.

The basic test can be expressed as:

Related Indicators
→ identify the determination question of each
→ compare the questions
→ determine whether one can be resolved without resolving the other.

If yes
→ distinguishability is supported.

If no
→ possible overlap or redundancy requires further examination.

Distinguishability does not require complete separation.

Infrastructure conditions are interconnected.

One condition may affect several Indicators.

One Evidence source may support findings under several Indicators.

One Failure Mode may involve several Indicators.

Such relationships are expected.

The important issue is whether the Indicators ask sufficiently different questions.

The test should therefore avoid a simple subject-matter comparison.

Two Indicators can concern the same physical system while examining different conditions.

Conversely, two Indicators can use different technical language while performing substantially the same determination function.

The distinguishability test should also consider the parent Factor.

A separate Indicator should help divide the broad Factor into useful and necessary determination questions.

If two Indicators cannot be meaningfully distinguished during interpretation of the Factor, keeping them separate may add complexity without adding determination capability.

But Indicators should not be combined merely to make the Core shorter.

Combining them is appropriate only if the distinction between their determination functions does not provide meaningful additional visibility.

The test can therefore be summarized as:

Different names
≠ necessarily different determination functions.

Related subjects
≠ necessarily the same determination function.

Separate Core Indicators are justified when each preserves a necessary determination question that can remain unresolved even when the other has been adequately determined.

The distinguishability test therefore protects both sides of the Indicator set.

It helps prevent unnecessary duplication.

It also prevents necessary differences from being hidden inside overly broad Indicators.

The next test examines this relationship more directly through non-redundancy and overlap.

4.4 Non-Redundancy and Overlap Test

Core Quality Indicators do not need to be completely independent from one another.

Infrastructure Quality is interconnected.

The same condition, Failure Mode, or Evidence may be relevant to several Indicators.

Overlap is therefore expected.

The important question is whether the overlap causes unnecessary duplication.

The non-redundancy and overlap test asks:

Does each Indicator contribute a necessary determination question that is not already adequately preserved by another Indicator?

This requires more than comparing Indicator titles.

The actual determination functions must be compared.

For two Indicators that appear to overlap, the analysis asks:

What does each Indicator require us to determine?

What Evidence may support each determination?

Can one Indicator have an acceptable finding while the other does not?

Would removing either Indicator cause a meaningful determination question to disappear?

If the answers show that each Indicator preserves a different necessary question, the overlap is acceptable.

In that case, the Indicators are complementary rather than redundant.

This can be expressed as:

Shared subject matter
+ different necessary determination questions
→ acceptable overlap.

Shared Evidence
+ different interpretation or determination questions
→ acceptable overlap.

Substantially the same determination question
+ no meaningful loss when one Indicator is removed
→ possible redundancy.

The distinction between shared Evidence and redundant Indicators is particularly important.

One Evidence source may support several findings.

For example, an inspection record, operating record, test result, or analysis may contain information relevant to more than one Indicator.

This does not mean that those Indicators perform the same function.

The Evidence must be interpreted in relation to the particular Indicator and applicable Quality Outcome Criterion.

Overlap may also occur across different Core Quality Factors.

An Indicator under one Factor may affect or provide information relevant to an Indicator under another Factor.

This does not automatically indicate incorrect placement or duplication.

The fourteen Factors examine different major dimensions of the same Infrastructure Quality Object.

A real condition may therefore have consequences for several Factors.

The question remains:

What determination function is being performed in each location?

The test must also guard against excessive separation.

If closely related questions are divided into too many Indicators without preserving meaningful differences, the Core becomes unnecessarily complicated.

The purpose of the Indicator set is not to maximize the number of separately named subjects.

It is to preserve the necessary determination questions at a useful level of detail.

The non-redundancy test therefore works in both directions.

It asks whether combining Indicators would hide a necessary distinction.

It also asks whether keeping Indicators separate adds a meaningful distinction.

The desired result is:

enough separation to preserve necessary determination questions;

but

not so much separation that the same determination function is repeatedly represented under different names.

Where overlap remains uncertain, the issue should be tested through actual Context Guide application.

Different Infrastructure Quality Objects may show whether two apparently similar Indicators produce different findings, require different interpretation, or reveal different Failure Modes.

The non-redundancy and overlap test therefore does not seek complete separation among Indicators.

It seeks meaningful separation.

An invariant Core Quality Indicator should remain separately visible when its determination function adds necessary information that cannot be assumed to be adequately provided by another Indicator.

4.5 Relationship to Intended Function Realization and Failure Modes

A Core Quality Indicator should have a clear relationship to the ability of the Infrastructure Quality Object to realize its Intended Functions and Intended Results.

This relationship may be direct or indirect.

Some Indicators examine conditions that directly affect whether the Infrastructure Quality Object can perform its required function.

Others examine conditions needed to determine, support, protect, or preserve that function.

The necessity of an Indicator should therefore be tested against Function Realization.

For each Indicator, ask:

What part of Function Realization does this Indicator help us determine?

and

What could prevent, degrade, interrupt, or make uncertain that Function Realization if the condition represented by the Indicator were not adequately examined?

Failure Modes provide an important way to test these questions.

A Failure Mode identifies how Function Realization can fail or become unacceptable.

The relationship can be expressed as:

Infrastructure Intended Function
→ required Function Realization
→ possible Failure Modes
→ quality-relevant conditions that must be examined
→ Core Quality Indicators.

This does not mean that every Failure Mode requires a separate Core Quality Indicator.

Failure Modes can be highly specific to the Infrastructure Quality Object and Context.

For example, different technologies may fail through very different physical, operational, environmental, human, or information-related mechanisms.

Those differences can be addressed through Context-specific interpretation of the established Indicators.

The Core-level question is different:

Does the Indicator preserve a determination question needed to identify or evaluate conditions through which Function Realization may fail, degrade, become uncertain, or become unacceptable?

Failure-Mode analysis can therefore test the adequacy of an established Indicator.

If important Failure Modes can be examined through the Indicator, this supports the relationship between the Indicator and Function Realization.

If a Failure Mode repeatedly reveals a necessary determination question that cannot be adequately represented by any established Indicator, a possible Indicator gap may exist.

The distinction is:

New Failure Mode
≠ automatically a new Core Quality Indicator.

Different technical mechanism
≠ automatically a new Core Quality Indicator.

Recurring missing determination question revealed through Failure Modes
→ possible Core Indicator gap.

Failure Modes should also be used to test removal.

If an Indicator is removed, ask whether important ways in which Function Realization can fail would become materially less visible or less determinable.

If yes, the Indicator's necessity is strengthened.

The analysis should not be limited to physical failure.

Function Realization may also be affected by inadequate specification, unreliable conformity determination, loss of monitoring capability, insufficient competence, failure to satisfy applicable requirements, loss of traceability, or inability to respond to changed conditions.

Failure Modes may therefore reveal the need for different types of Indicators under different Factors.

This is consistent with the IQI Core, which derives its Factors and Indicators not from one type of technical failure, but from the wider conditions relevant to Infrastructure Intended Function realization and Infrastructure Quality State Determination.

The relationship to Intended Function Realization and Failure Modes therefore provides an important test of Indicator necessity.

An Indicator should remain in the invariant Core when it preserves a necessary determination question whose absence could allow a meaningful threat to Function Realization, or the ability to determine that realization, to remain insufficiently visible.

4.6 Lifecycle Relevance Test

The IQI Core applies across the Infrastructure Lifecycle.

A Core Quality Indicator should therefore be tested for its relevance across the Lifecycle rather than only at one stage.

This does not mean that every Indicator must have the same importance, Evidence, or practical application at every Lifecycle Stage.

The question is whether the determination function represented by the Indicator remains relevant where that function can affect the Quality State of the Infrastructure Quality Object.

The principal Lifecycle sequence recognized by IQC1 includes:

Design
→ Construction
→ Commissioning
→ Operation
→ Maintenance
→ Repair/Modification
→ Decommissioning/Transition.

Different conditions become important at different stages.

Some Indicators may be especially important during Design.

Others may become more visible during Construction, Commissioning, or Operation.

Still others may become particularly important during Maintenance, Repair/Modification, or transition from service.

An Indicator should not be considered unnecessary merely because its practical importance is limited during one Lifecycle Stage.

The appropriate question is:

Does this Indicator preserve a necessary determination question at one or more Lifecycle Stages where failure to examine that question could materially affect Function Realization or Quality State determination?

The test should also consider continuity between Lifecycle Stages.

Conditions established during one stage may affect later stages.

A design decision may affect construction and operation.

A construction condition may remain important during operation.

Operating experience may affect maintenance or modification.

A modification may change earlier assumptions, requirements, Boundaries, Interfaces, or operating conditions.

Decommissioning may introduce conditions that did not exist during normal operation.

The Lifecycle test therefore examines not only isolated stages but also transitions between them.

The relationship can be expressed as:

Lifecycle Stage
→ relevant determination questions
→ Core Quality Indicators

and

Lifecycle transition
→ changed conditions or transferred information
→ continued or changed Indicator relevance.

The test should distinguish Lifecycle relevance from Lifecycle-specific detail.

A technical requirement that applies only during construction does not automatically require a construction-specific Core Quality Indicator.

A maintenance method does not automatically require a maintenance-specific Core Quality Indicator.

A commissioning test does not automatically require a commissioning-specific Core Quality Indicator.

These matters may be addressed through Context-Specific Quality Outcome Criteria, Evidence, Reference Layer requirements, or other interpretation of an established Indicator.

The Core-level question remains:

Is there a necessary determination function that must remain visible across the Lifecycle where applicable?

The Lifecycle relevance test can also reveal possible gaps.

If repeated Context Guide application shows that an important determination question appears during a particular Lifecycle Stage or transition but cannot be adequately represented by the established Indicators, the finding should be preserved.

One Context-specific example is not sufficient to establish a new invariant Indicator.

Repeated Evidence across different Infrastructure Quality Objects may provide stronger support.

The Lifecycle relevance test therefore helps answer two questions:

Does an established Indicator remain necessary when the Infrastructure Quality Object is considered across its Lifecycle?

and

Does Lifecycle analysis reveal a recurring determination need that the established Indicators do not adequately represent?

An invariant Core Quality Indicator does not need identical application at every Lifecycle Stage.

It must preserve a determination function that remains necessary wherever that function can materially affect Function Realization or responsible determination of the Infrastructure Quality State.

4.7 Boundary and Interface Relevance

A Core Quality Indicator should be tested against the Boundaries and Interfaces of the declared Infrastructure Quality Object.

Quality State cannot be determined responsibly without knowing what object is being examined and where that object begins, ends, and interacts with other objects, systems, organizations, people, information, energy, or materials.

A condition may appear acceptable when examined only inside one part of the Infrastructure Quality Object.

The result may change when a relevant Boundary or Interface is considered.

For this reason, the Indicator necessity test should ask:

Does the Indicator preserve a determination question that remains necessary at or across relevant Boundaries and Interfaces?

The first issue is Boundary relevance.

The Boundary defines what is included in the Infrastructure Quality Object under determination and what remains outside it.

The same physical or functional condition may have different meaning depending on where the Boundary is established.

An Indicator should therefore be interpreted in relation to the declared object rather than applied as an isolated technical subject.

The second issue is Interface relevance.

Interfaces are points or conditions through which important interactions occur.

They may involve transfer of:

materials;

energy;

information;

authority;

responsibility;

Risk;

or consequences.

A condition on one side of an Interface may affect Function Realization on the other side.

The quality-relevant question may therefore concern not only the condition of individual parts but also whether their interaction supports the Intended Functions and Intended Results of the declared Infrastructure Quality Object.

The relationship can be expressed as:

Infrastructure Quality Object
→ declared Boundaries
→ relevant Interfaces
→ conditions affecting Function Realization
→ applicable Core Quality Indicators.

Boundary and Interface analysis can strengthen the justification of an established Indicator.

An Indicator may appear unnecessary when only the internal condition of one component or subsystem is considered.

Its determination function may become clearly necessary when interactions across the wider Infrastructure Quality Object are examined.

Boundary and Interface analysis can also reveal gaps.

A Context Guide may identify an important Interface condition that does not appear to fit clearly under an established Indicator.

This does not automatically justify a new Core Quality Indicator.

The first question is whether the Interface condition can be adequately examined through an existing Indicator.

If yes, the Context Guide should provide the necessary interpretation.

If no, the finding should be preserved for further testing.

The distinction is:

Different Boundary or Interface condition
≠ automatically a new Core Quality Indicator.

Context-specific Interface requirement
≠ automatically a new Core Quality Indicator.

Recurring necessary determination question at or across Boundaries and Interfaces that is not adequately represented by established Indicators
→ possible Core Indicator gap.

This test is particularly important because Boundaries and Interfaces differ substantially among Infrastructure Quality Objects.

A pipeline network, production zone, storage facility, LNG facility, local distribution network, or another infrastructure system may contain very different physical, functional, informational, organizational, and responsibility Boundaries and Interfaces.

The technical details may change.

The Core determination need may remain the same.

The Boundary and Interface relevance test therefore asks whether an established Indicator continues to preserve a necessary determination question when the Infrastructure Quality Object is examined as a bounded object interacting with other parts of the wider infrastructure system.

It also provides another means of identifying recurring determination needs that may not be sufficiently visible when Indicators are examined only within individual components or activities.

4.8 Evidence and Determinability Test

A Core Quality Indicator must identify a determination question that can be connected to relevant Evidence.

An Indicator identifies what is examined.

Evidence provides the basis for determining the condition represented by that Indicator against the applicable Quality Outcome Criterion.

The Evidence and determinability test therefore asks:

Can the condition represented by the Indicator be determined with sufficient support for the intended Quality State determination?

This question is different from asking whether Data or information exist.

IQC1 distinguishes Data and other information from Evidence.

Information becomes Evidence only when its relevance, credibility, Context, traceability, and relationship to the declared Infrastructure Quality Object, Core Quality Indicator, and applicable Quality Outcome Criterion are established.

The basic relationship is:

Core Quality Indicator
→ applicable Quality Outcome Criterion
→ relevant Evidence
→ Evidence-Supported Finding
→ interpretation within the parent Core Quality Factor.

The existence of large amounts of Data does not by itself establish that an Indicator has been adequately determined.

Likewise, completion of an activity, existence of documentation, conformity of an individual component, or absence of an observed failure does not by itself establish an acceptable Infrastructure Quality State.

The Evidence must support the determination question actually represented by the Indicator.

This provides an important test of the Indicator itself.

For each established Indicator, ask:

What must be known to determine this Indicator?

What Evidence could support that determination?

Can the Evidence be connected to the declared Infrastructure Quality Object and applicable Quality Outcome Criterion?

What remains uncertain if the Evidence is incomplete, unreliable, unavailable, or cannot be connected to the actual object under determination?

These questions help identify whether the Indicator preserves a meaningful and determinable question.

They also help distinguish the Indicator from the Evidence used to examine it.

A particular Evidence source should not become an invariant Indicator merely because it is important.

Inspection results, measurements, records, calculations, observations, tests, analyses, or testimony may provide Evidence.

They do not automatically represent separate Core determination questions.

The distinction is:

Evidence source
→ provides information relevant to a determination.

Core Quality Indicator
→ identifies the determination question for which relevant Evidence is required.

The test must also recognize that determinability itself can become a quality-relevant issue.

The actual condition of the Infrastructure Quality Object may exist independently of whether that condition is adequately known.

For example:

Actual condition
≠ necessarily known condition.

Available Data
≠ necessarily sufficient Evidence.

Reported condition
≠ necessarily demonstrated condition.

This distinction becomes important when the ability to determine the actual Quality State is limited by inadequate monitoring, unreliable information, missing records, insufficient traceability, uncertainty, or other Evidence limitations.

Some established Indicators may therefore primarily examine the state or performance of the Infrastructure Quality Object.

Others may contribute more directly to the ability to determine that state reliably.

This possibility is examined later through the provisional distinction between Quality-State Indicators and Quality-State Determination Indicators.

At this stage, no new classification is assumed.

The Evidence and determinability test asks only whether the Indicator preserves a necessary question for which an Evidence-Supported Finding can be responsibly developed, and whether removal of the Indicator would weaken the ability to determine the parent Factor.

The test can also reveal possible gaps.

If repeated Context Guide application shows that the reliability or adequacy of a necessary determination cannot be represented through the established Indicators, the finding should be preserved for further analysis.

It should not automatically become a new Core Quality Indicator.

The first question remains whether the determination need is already adequately represented elsewhere in the Core.

The Evidence and determinability test therefore serves two purposes.

It tests whether an established Indicator provides a meaningful connection between a necessary determination question and the Evidence needed to answer it.

It also helps identify cases where the ability to know the Quality State may itself require further examination within the Core Indicator set.

4.9 Context-Invariance Test

A Core Quality Indicator is intended to remain applicable across different IQI energy-infrastructure Contexts.

The Context-Invariance Test asks whether the determination question represented by an Indicator remains necessary when the Infrastructure Quality Object changes.

Infrastructure Contexts can differ substantially.

They may have different:

Intended Functions and Intended Results;

technologies and configurations;

physical conditions;

operating conditions;

Lifecycle conditions;

Boundaries and Interfaces;

Failure Modes;

Reference Layer requirements;

Quality Outcome Criteria;

and Evidence.

These differences do not automatically require different Core Quality Indicators.

The important question is:

Does the same basic determination need remain when these Context-specific details change?

The existing IQI Context Guides provide a practical basis for this test.

They address substantially different Infrastructure Quality Objects, including production, main pipeline transportation, local distribution, underground storage, and LNG infrastructure.

The technical details differ.

The Indicators should therefore not be tested by asking whether they are applied identically in each Context.

They should be tested by asking whether their underlying determination functions remain necessary.

The test can be expressed as:

Different Infrastructure Context
→ different technical conditions
→ different Quality Outcome Criteria and Evidence

→ same underlying determination question
→ support for Core Indicator invariance.

An Indicator does not fail the Context-Invariance Test merely because it has greater importance in one Context than in another.

Nor does it fail because different technical means are used to examine it.

The required level of Evidence may also differ.

What matters is whether the determination question remains meaningful within the intended scope of the IQI Core.

The opposite result is also important.

Suppose an Indicator repeatedly has no meaningful determination function outside one narrow infrastructure Context.

Suppose its subject can be fully addressed as Context-specific detail under another established Indicator.

In that case, its invariant Core status may require further examination.

The Context-Invariance Test therefore asks:

Does the Indicator preserve a necessary determination question across substantially different Infrastructure Quality Objects?

Can differences among Contexts be addressed through Quality Outcome Criteria, Evidence, and Context-specific interpretation without changing the Indicator?

Would removal of the Indicator create a determination gap in more than one type of infrastructure Context?

The test also works in the opposite direction.

Context comparison may reveal a determination question that repeatedly appears but is not adequately represented by the established Indicators.

One occurrence does not establish a Core-level gap.

A repeated occurrence across substantially different Infrastructure Quality Objects provides stronger Evidence.

The distinction is:

Issue important in one Context
→ may remain Context-specific.

Same necessary determination question recurring across substantially different Contexts
→ possible Core-level significance.

This is why Context Guides serve not only as applications of the IQI Core but also as practical tests of the Core Quality Indicator set.

They allow the invariant Indicators to be examined under different physical, functional, operational, environmental, human, regulatory, and information conditions.

The Context-Invariance Test therefore supports both stability and continued testing.

An established Core Quality Indicator is strengthened when its underlying determination function remains necessary across substantially different infrastructure Contexts even though its detailed interpretation changes.

Repeated Context Guide findings that cannot be adequately represented by the established Indicators should be preserved for horizontal comparison and possible consideration as a Core Indicator gap.

4.10 Conditions for Retaining an Indicator as an Invariant Core Quality Indicator

The preceding tests provide the basis for deciding whether an established Core Quality Indicator should remain separately visible in the IQI Core.

No single test should be used in isolation.

An Indicator should be considered through its relationship to the parent Factor, its determination function, the effect of its removal, its relationship to neighboring Indicators, its relevance to Function Realization and Failure Modes, and its application across Lifecycle Stages, Boundaries, Interfaces, and infrastructure Contexts.

An established Indicator has a strong basis for retention when the following conditions are supported.

First, the Indicator preserves a necessary determination question within its parent Core Quality Factor.

Its purpose can be stated clearly.

It is possible to explain what must be determined through the Indicator and why that determination matters to the parent Factor.

Second, removal of the Indicator would create a meaningful loss.

A necessary quality-relevant condition would become materially less visible or less determinable.

The remaining Indicators would not necessarily preserve the same determination question adequately.

Third, the Indicator is sufficiently distinguishable from neighboring Indicators.

It may overlap with them.

It may use some of the same Evidence.

Its findings may interact with their findings.

But it preserves a determination question that cannot safely be assumed to be answered through another Indicator.

Fourth, the Indicator has a meaningful relationship to Infrastructure Intended Function realization.

The condition examined through the Indicator can affect Function Realization, the ability to determine Function Realization, or another necessary part of responsible Infrastructure Quality State Determination.

Failure-Mode analysis should support this relationship where applicable.

Fifth, the Indicator remains relevant across the Infrastructure Lifecycle where its determination function applies.

Its importance may change between Design, Construction, Commissioning, Operation, Maintenance, Repair/Modification, and Decommissioning/Transition.

Its underlying determination need should remain visible where it can materially affect the Quality State.

Sixth, the Indicator remains meaningful when relevant Boundaries and Interfaces are considered.

Its determination function should apply to the declared Infrastructure Quality Object rather than only to an isolated component, activity, or document unless that narrower item is itself the declared Quality Object.

Seventh, the Indicator can be connected to applicable Quality Outcome Criteria and relevant Evidence.

The Indicator must support a determination that can be examined through Evidence rather than remain only a general statement of importance.

Eighth, the underlying determination function remains meaningful across sufficiently different infrastructure Contexts.

The Quality Outcome Criteria, Evidence, Failure Modes, and technical interpretation may change.

The basic Core determination need should remain.

These conditions can be summarized as:

Necessary determination question
+
meaningful loss if removed
+
sufficient distinction from other Indicators
+
relationship to Function Realization and Failure Modes
+
Lifecycle relevance
+
Boundary and Interface relevance
+
Evidence-supported determinability
+
relevance across different infrastructure Contexts
→ support for retention as an invariant Core Quality Indicator.

Failure to satisfy one test does not automatically require removal.

It identifies a question requiring closer analysis.

For example, apparent overlap may disappear when the determination functions are examined more carefully.

Limited relevance in one Context may be offset by clear necessity across other Contexts.

Unclear Evidence in one application may result from insufficient Context-specific interpretation rather than a weakness in the Indicator itself.

The purpose of these conditions is therefore not to create a mechanical scoring system.

They provide a consistent basis for examining each established Indicator.

The same discipline should apply when a possible additional Indicator is identified.

A new subject should not become a Core Quality Indicator merely because it is important.

It should be tested to determine whether it preserves a necessary and sufficiently different determination question, whether the question remains meaningful across different infrastructure Contexts, and whether existing Indicators cannot adequately represent it.

This creates a common principle for both retention and possible addition:

Invariant Core Indicator status should follow a demonstrated need for a separately visible Core-level determination question.

These conditions provide the method used in the Factor-by-Factor analysis later in this paper.

5. Functional Types of Quality Indicators — A Horizontal Research Question

5.1 Why Indicator Function Should Be Examined Separately from Indicator Subject Matter

The preceding analysis tests each Core Quality Indicator within its parent Core Quality Factor.

A second type of analysis is also useful.

Indicators can be compared across different Factors according to the function they perform in Quality State determination.

This is different from comparing their subject matter.

An Indicator may concern integrity, safety, competence, monitoring, documentation, reliability, or another subject.

The Indicator title tells us what area is being examined.

It does not necessarily tell us what role the Indicator performs in determining the Quality State.

This distinction becomes important when Indicators from different Factors are compared.

Some Indicators may primarily provide information about the actual condition or performance of the Infrastructure Quality Object.

The main question is:

What is the state of the object or of a quality-relevant condition affecting it?

Other Indicators may primarily concern whether that state can be determined reliably.

The main question becomes:

Can the actual condition be adequately observed, identified, measured, evaluated, or otherwise determined?

Still other Indicators may concern the capability to preserve, restore, control, or change a quality-relevant condition.

The main question becomes:

Can the condition be influenced when action is required?

These are different functions even when they concern the same Infrastructure Quality Object.

For example:

Actual condition
→ one determination question.

Capability to determine that condition
→ another determination question.

Capability to influence that condition
→ another possible determination question.

The three questions may interact.

They should not automatically be treated as the same question.

This paper therefore provisionally examines three recurring Indicator functional roles:

Quality-State Indicators;

Quality-State Determination Indicators;

and

Quality-State Influence Indicators.

These terms are used as a research classification in this paper.

They do not replace the established Core Quality Factors or Core Quality Indicators.

They do not create a new required layer in IQC1.

The purpose is to compare Indicator functions horizontally across the existing Core.

This comparison may help answer questions that are difficult to see when Indicators are examined only within their parent Factors.

For example:

Do several Factors contain Indicators that primarily describe the actual state?

Do several Factors contain Indicators that primarily support the ability to determine that state?

Do Indicators concerning the ability to influence the state appear consistently, or only in some Factors?

Does one Indicator perform more than one of these functions?

Does horizontal comparison reveal a recurring determination function that is not adequately represented?

The classification should not be forced.

An Indicator may perform more than one function.

Its function may also depend partly on the Context in which it is applied.

The purpose is not to place every Indicator into one permanent category.

The purpose is to make recurring functions visible and test whether those functions help explain the existing Indicator set.

Subject matter and determination function should therefore be examined separately.

The subject tells us what the Indicator concerns.

The function tells us what the Indicator contributes to determination of the Quality State.

This horizontal view provides an additional test of the established Indicators and a possible means of identifying recurring gaps that may not be visible through Factor-by-Factor analysis alone.

5.2 Quality-State Indicators

The first provisional function is the Quality-State Indicator function.

A Quality-State Indicator primarily helps determine the actual quality-relevant condition of the Infrastructure Quality Object.

Its principal question is:

What is the state of the object or of the condition being examined?

The condition may concern physical integrity, functional performance, operational reliability, environmental interaction, human interaction, compliance, or another quality-relevant aspect represented by the parent Factor.

The important point is that the Indicator directs attention primarily to the condition itself.

The basic relationship is:

Infrastructure Quality Object
→ quality-relevant condition

→ applicable Core Quality Indicator
→ Evidence
→ Evidence-Supported Finding about that condition.

A Quality-State Indicator does not mean that the complete Infrastructure Quality State can be determined from that Indicator alone.

The Indicator addresses one part of the wider determination.

Its finding must still be interpreted within its parent Core Quality Factor and together with findings from the other Factors.

The term also does not mean that the Indicator simply reports whether the object is currently operating.

Current operation and acceptable Quality State are not the same.

An Infrastructure Quality Object may continue to perform while an important quality-relevant condition has degraded or remains insufficiently known.

A Quality-State Indicator therefore concerns the actual condition relevant to Function Realization, not merely the absence of observed failure.

This distinction can be expressed as:

Object is operating
≠ necessarily acceptable quality-relevant condition.

No observed failure
≠ demonstrated acceptable condition.

Reported condition
≠ necessarily actual condition.

The Quality-State Indicator function may apply at different Lifecycle Stages.

During Construction, the relevant state may concern the realized condition of the constructed Infrastructure Quality Object.

During Operation, it may concern present integrity, performance, reliability, or another operating condition.

During Maintenance or Repair/Modification, it may concern the condition before, during, or after intervention.

The technical meaning of the state therefore depends on the Indicator and Context.

The provisional classification does not require that an Indicator perform only this function.

An Indicator that provides information about actual condition may also contribute to determining whether that condition can be reliably known.

It may also be connected to actions that influence the condition.

The classification identifies the primary function being examined, not a permanent exclusive category.

The usefulness of the Quality-State Indicator concept will therefore be tested against the established Core Quality Indicators.

For each Indicator, the analysis may ask:

Does this Indicator primarily tell us something about the actual quality-relevant condition of the Infrastructure Quality Object?

If yes, it may perform a Quality-State Indicator function.

The wider horizontal analysis will then test whether this function appears consistently across the fourteen Factors, how it interacts with other Indicator functions, and whether any important Quality-State determination need remains insufficiently represented.

5.3 Quality-State Determination Indicators

The second provisional function is the Quality-State Determination Indicator function.

A Quality-State Determination Indicator primarily concerns the ability to determine a quality-relevant condition reliably.

Its principal question is:

Can the actual condition of the Infrastructure Quality Object be determined with sufficient confidence?

This question is different from the condition itself.

An Infrastructure Quality Object has an actual condition whether that condition is known accurately or not.

The ability to determine that condition depends on the means through which information is obtained, evaluated, connected to the object, and supported by Evidence.

The basic distinction is:

Actual quality-relevant condition
≠ ability to determine that condition.

This distinction is important for responsible Infrastructure Quality State Determination.

A condition may be acceptable while the available Evidence is insufficient to demonstrate it.

A condition may also be unacceptable while inadequate monitoring, testing, inspection, information, traceability, or evaluation prevents the problem from becoming sufficiently visible.

The Quality-State Determination function therefore concerns the reliability of the path between the actual condition and the finding made about that condition.

This can be expressed as:

Actual condition
→ observation, measurement, inspection, testing, records, analysis, or other information
→ relevant Evidence
→ Evidence-Supported Finding
→ Quality State determination.

Weakness anywhere in this path can affect the reliability of the determination.

The issue is not simply whether information exists.

The information must be sufficiently relevant, credible, traceable, and connected to the declared Infrastructure Quality Object, applicable Indicator, and Quality Outcome Criterion.

Several types of conditions may affect this determination capability.

These may include the adequacy of monitoring;

the reliability of measurement or inspection;

the ability to evaluate performance;

the availability and traceability of necessary information;

the competence needed to make or interpret a determination;

and other conditions that affect whether the actual state can be known with sufficient confidence.

These examples do not establish new Core Quality Indicators.

They illustrate the possible Quality-State Determination function that may already be performed by established Indicators under different Factors.

This function may therefore appear in more than one part of the IQI Core.

For example, Monitoring and Performance Evaluation and Documentation and Traceability clearly contribute to the ability to determine the Quality State.

But the same function may also appear within Indicators under Conformity Assessment, Competence of Personnel, or other Factors.

The horizontal analysis should test this rather than assume it in advance.

A Quality-State Determination Indicator should also not be confused with Evidence itself.

Evidence supports a finding.

The Indicator identifies the determination question being examined.

The question here concerns whether the means and conditions necessary for reliable determination are themselves adequate.

The provisional test is therefore:

Does this Indicator primarily help determine whether a quality-relevant condition can be reliably known, demonstrated, or evaluated?

If yes, it may perform a Quality-State Determination Indicator function.

An Indicator may perform this function together with a Quality-State function.

The functions are not assumed to be mutually exclusive.

For example, an Indicator may provide information about the actual state while also testing whether the means used to determine that state are adequate.

This possible overlap will be examined later.

The importance of the Quality-State Determination function is that responsible Quality State determination requires more than the existence of an actual condition.

It also requires a sufficiently reliable basis for knowing that condition.

Where that basis is inadequate, uncertainty about the Quality State may itself become important to the determination.

The horizontal analysis will therefore test where this function appears within the established Core Quality Indicators, whether it is adequately represented, and whether repeated Context Guide application reveals any determination capability that remains insufficiently visible.

5.4 Quality-State Influence Indicators

The third provisional function is the Quality-State Influence Indicator function.

A Quality-State Influence Indicator primarily concerns the capability to preserve, restore, control, or change a quality-relevant condition when action is required.

Its principal question is:

Can the Infrastructure Quality Object, or the conditions affecting it, be influenced sufficiently to preserve or restore acceptable Function Realization?

This question differs from both the actual condition and the ability to determine that condition.

The distinction can be expressed as:

What is the actual condition?
→ Quality-State function.

Can the actual condition be reliably determined?
→ Quality-State Determination function.

Can the condition be preserved, controlled, restored, or changed when necessary?
→ Quality-State Influence function.

These functions are connected.

A quality-relevant condition may first need to be detected and understood before an appropriate action can be taken.

But determination alone does not ensure that the condition can be influenced.

For example, degradation may be correctly identified.

A Hazard may be recognized.

A performance problem may be detected.

A change in operating conditions may be known.

The remaining question is whether there is sufficient capability to act on that information and influence the resulting Quality State.

The basic relationship may therefore be expressed as:

Quality-relevant condition
→ determination of the condition
→ recognition that action is required
→ capability to intervene
→ preservation, restoration, control, or change of the condition
→ continued or restored Function Realization.

The capability to influence a condition may take different forms.

It may involve prevention.

It may involve control or mitigation.

It may involve maintenance, repair, modification, operational intervention, or adaptation.

It may also involve authority to take necessary action when the condition requires it.

These examples do not establish separate Core Quality Indicators.

They illustrate the possible Influence function that should be tested against the established Indicators.

The function may already appear within several existing Factors.

Process Safety and Risk Mitigation may contain Indicators concerned with prevention or mitigation.

Operational Reliability may include conditions related to maintaining or restoring required performance.

Adaptability and Innovation Readiness may include the capability to respond to changed conditions.

Other Factors may also contain Indicators with an Influence function.

The analysis should determine this from the established Indicators rather than assume it in advance.

The Quality-State Influence function may also be especially important at Interfaces involving responsibility or authority.

An unacceptable condition may be known, but the ability to influence it may depend on whether the responsible person, organization, system, or other decision point can take effective action.

This possibility should be tested through Context Guide application, particularly where responsibility is divided across organizational or system Boundaries.

A Quality-State Influence Indicator should not be confused with the action itself.

A repair, shutdown, adjustment, modification, or other intervention is an action.

The Indicator function concerns whether a necessary capability to influence the quality-relevant condition is adequately represented and determinable.

The provisional test is therefore:

Does this Indicator primarily help determine whether there is sufficient capability to preserve, control, restore, or change a quality-relevant condition when required for Function Realization?

If yes, it may perform a Quality-State Influence Indicator function.

An Indicator may perform this function together with State or Determination functions.

The three functions are not assumed to be mutually exclusive.

The purpose of identifying the Influence function is also not to assume that the present IQI Core lacks such Indicators.

That question must be tested.

The Factor-by-Factor and horizontal analyses will examine where Influence functions are already represented and whether they are represented sufficiently.

If repeated Context Guide application reveals a necessary Influence function that cannot be adequately represented through the established Indicators, the finding should be preserved as a possible Indicator gap.

It should not automatically result in a new Core Quality Indicator.

The Quality-State Influence function is therefore introduced as a provisional research idea.

Its value will depend on whether it helps explain the established Indicators and whether horizontal comparison across Factors and infrastructure Contexts reveals a recurring determination need that would otherwise remain insufficiently visible.

5.5 Relationships and Possible Overlap Among the Three Functions

The provisional Quality-State, Quality-State Determination, and Quality-State Influence functions should not be treated as three isolated categories.

They describe different questions that may be asked about the same quality-relevant condition.

The basic relationship is:

Quality-State function
→ What is the actual quality-relevant condition?

Quality-State Determination function
→ Can that condition be reliably determined?

Quality-State Influence function
→ Can that condition be preserved, controlled, restored, or changed when necessary?

These questions are different.

But they are strongly connected.

Consider a condition affecting Structural and Functional Integrity.

The first question may concern the actual integrity condition of the Infrastructure Quality Object.

The second may concern whether inspection, monitoring, testing, analysis, or other Evidence provides a sufficiently reliable basis for determining that condition.

The third may concern whether degradation can be prevented, controlled, repaired, or otherwise addressed when intervention is required.

The same general relationship can appear under other Factors.

This means that one Core Quality Indicator may perform more than one of the three functions.

For example, an Indicator may directly examine a quality-relevant condition while also providing an important means of determining whether that condition remains acceptable.

Another Indicator may concern both determination and the capability to respond when the determination identifies an unacceptable condition.

The provisional classification should therefore not force every established Indicator into one exclusive category.

Instead, the analysis should ask:

Which function does the Indicator perform?

Does it perform more than one?

Is one function primary and another supporting?

Does its function change depending on the infrastructure Context or Lifecycle Stage?

The possible relationships can be expressed as:

State only;

Determination only;

Influence only;

State + Determination;

State + Influence;

Determination + Influence;

or

State + Determination + Influence.

These combinations are research possibilities.

They are not new IQI Core classifications.

Overlap among the functions may also occur across different Indicators.

One Indicator may primarily examine actual condition.

Another may provide the capability to determine that condition.

A third may concern the capability to influence it.

In such a case, the Indicators may address the same general subject while performing different determination functions.

This type of overlap may be necessary.

It should not automatically be treated as redundancy.

The distinction is:

Same subject
+ different functions
→ potentially necessary complementary Indicators.

Same subject
+ substantially the same function
→ possible redundancy requiring further testing.

The sequence among the three functions should also not be assumed to be strictly linear in every case.

A simple sequence may appear as:

Condition
→ determination
→ decision
→ influence.

But actual infrastructure operation may involve continuing interaction among these functions.

Monitoring may identify change.

Intervention may alter the condition.

Further monitoring may determine whether the intervention was effective.

Changed conditions may require another action.

The relationship may therefore be continuing:

Quality State
→ determination
→ influence
→ changed Quality State
→ renewed determination.

This interaction may occur repeatedly across the Infrastructure Lifecycle.

The three-function view may also help identify a different type of gap.

A Factor may contain several Indicators that describe actual conditions but provide little visibility into whether those conditions can be reliably determined.

Another Factor may contain strong determination functions but limited visibility into whether an identified unacceptable condition can be effectively influenced.

Such a pattern would not automatically demonstrate that an Indicator is missing.

It would identify a question for further analysis.

The existing Indicators under other Factors may already provide the required function.

The function may belong to Context-specific interpretation.

Or repeated analysis may show that a necessary determination function remains insufficiently represented.

The purpose of examining overlap is therefore not to produce a perfectly balanced number of State, Determination, and Influence Indicators.

No such balance is assumed to be necessary.

The purpose is to determine whether the different functions needed for responsible Infrastructure Quality State Determination remain sufficiently visible somewhere in the established Core.

The three-function classification therefore provides a horizontal research tool.

It allows Indicators with different subject matter and different parent Factors to be compared according to what they actually contribute to determining, knowing, preserving, or changing the Quality State.

5.6 Why This Classification Is Provisional Rather Than a New Normative Core Layer

The Quality-State, Quality-State Determination, and Quality-State Influence functions are introduced in this paper as a research tool.

They are not established in IQC1 as a separate normative layer of the IQI Core.

The existing Core remains:

Core Quality Factors
→ Core Quality Indicators
→ Context-Specific Quality Outcome Criteria
→ Evidence.

This paper does not change that structure.

The three proposed functions are used to examine the established Indicators from another direction.

The Factor-by-Factor analysis asks:

Why is this Indicator necessary within its parent Factor?

The functional analysis asks:

What role does this Indicator perform in relation to the Quality State?

These are different questions.

The second question may reveal patterns that are difficult to see when Indicators are examined only within their parent Factors.

But identification of a useful pattern does not automatically justify changing the IQI Core.

Several questions remain open.

First, it is not yet established that every Core Quality Indicator can be meaningfully described through one or more of these three functions.

The Factor-by-Factor analysis must test this.

Second, the boundaries between the three functions may not always be clear.

An Indicator may concern the actual condition while also contributing to the ability to determine that condition.

Another may concern determination while also supporting action that influences the condition.

The three functions may therefore overlap.

Third, it is not yet established that the three-function classification is complete.

Horizontal analysis or Context Guide application may reveal another recurring Indicator function that cannot be adequately described as State, Determination, or Influence.

That possibility should remain open.

The research question is therefore not:

How should all IQI Indicators be divided among three new categories?

The research question is:

Does comparison of the established Indicators through these three possible functions improve understanding of what the Indicators contribute to Quality State determination?

A second question follows:

Does this comparison reveal a recurring function that is insufficiently represented by the present Core Quality Indicators?

The classification should be retained only to the extent that it is useful and supported by the analysis.

It should not be imposed on the Core merely because it provides a convenient way to organize the Indicators.

This distinction is especially important because the IQI Core already preserves different determination questions through its fourteen Factors and their established Indicators.

These functional roles should not duplicate, replace, or reorganize those distinctions without sufficient Evidence.

For this paper, they therefore remain an analytical overlay.

They allow horizontal comparison while leaving the normative Core unchanged.

The relationship can be expressed as:

Established IQI Core
→ remains unchanged.

State / Determination / Influence functions
→ used to examine the established Indicators.

Repeated findings
→ tested across Factors and Context Guides.

Sufficient Evidence of a useful recurring distinction or a possible gap
→ preserved for further Core research.

This approach also allows the classification itself to be tested.

If the three functions prove useful across substantially different Indicators and infrastructure Contexts, confidence in the classification will increase.

If they produce unclear distinctions, unnecessary duplication, or leave important recurring functions outside the classification, the classification should be revised or not retained.

The three-function classification is therefore provisional because it is an object of the research as well as a tool used in the research.

This paper does not assume its final validity.

It tests its usefulness against the established IQI Core Quality Indicators and the Evidence available through IQI Context Guide application.

5.7 Use of the Classification in the Indicator-Justification Analysis

The provisional Quality-State, Quality-State Determination, and Quality-State Influence functions will be used as an additional test during the Indicator-by-Indicator analysis.

They do not replace the necessity, removal, distinguishability, non-redundancy, Lifecycle, Boundary and Interface, Evidence, or Context-Invariance tests developed in Section 4.

They add another question:

What function does this Indicator perform in relation to determination of the Infrastructure Quality State?

For each established Core Quality Indicator, the analysis will first identify the determination question preserved by the Indicator.

It will then consider whether the Indicator primarily concerns:

the actual quality-relevant condition;

the capability to determine that condition;

the capability to preserve, control, restore, or change that condition;

or

more than one of these functions.

The analysis can therefore proceed as follows:

Established Core Quality Indicator
→ identify its determination question
→ test necessity
→ test removal
→ test distinguishability and overlap
→ test relationship to Function Realization and Failure Modes
→ test Lifecycle relevance
→ test Boundary and Interface relevance
→ test Evidence and determinability
→ test Context-invariance
→ examine possible State / Determination / Influence function
→ identify any unresolved finding.

The classification will first be applied vertically.

Each Indicator will be examined within its parent Core Quality Factor.

This will help determine what the Indicator contributes to the determination of that Factor.

The classification will then be applied horizontally.

Indicators under different Factors will be compared according to the functions they perform.

This second step is important.

Two Indicators may concern very different subjects but perform similar functions.

For example, one may concern a technical condition and another may concern personnel or information.

Their subject matter differs.

But both may contribute primarily to determining the actual state, to determining whether that state can be reliably known, or to influencing that state.

Horizontal comparison may therefore reveal recurring functions across the Core.

It may also reveal overlap.

Several Indicators may perform similar functions without being redundant because they apply those functions to different necessary quality-relevant conditions.

The analysis must preserve this distinction.

The classification will also be used to examine possible gaps.

Suppose repeated analysis shows that a necessary Quality-State Determination function appears across several Factors but is not adequately represented by the established Indicators.

Or suppose Context Guides repeatedly reveal a necessary Influence function that cannot be adequately represented through the present Indicator set.

Such a pattern would deserve further examination.

It would not automatically justify a new Core Quality Indicator.

The first questions would be:

Is the function already adequately represented by another established Indicator?

Is the issue actually Context-specific?

Can it be addressed through Quality Outcome Criteria, Evidence, or other Context-specific interpretation?

Does the same unresolved determination need appear across substantially different infrastructure Contexts?

Only after these questions are examined should a possible additional Indicator finding be preserved for further Core consideration.

The classification will also be tested against the analysis itself.

If State, Determination, and Influence functions provide useful and repeatable distinctions across the established Indicators, the research idea gains support.

If Indicators repeatedly cannot be meaningfully examined through these functions, the classification may require modification.

If another recurring function becomes visible, it should be recorded rather than forced into one of the three proposed types.

The classification is therefore used in two directions:

to test the Indicators;

and

to test the classification itself.

This avoids assuming the result before the Factor-by-Factor analysis is performed.

Section 6 now applies the full method to the established Core Quality Indicators under each of the fourteen Core Quality Factors.

6. Factor-by-Factor Justification of the Invariant Core Quality Indicators

6.1 Factor 1 — Functional Specification Quality

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?

IQC1 presently examines this Factor through six invariant Core Quality 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 preserves a necessary and sufficiently different determination function.

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.

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.

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.

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.

IQC1 correctly places those responses principally under other Factors rather than making Indicator 1.4 itself a mitigation requirement.

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.

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.

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 satisfactory determination under one Indicator does not necessarily establish satisfactory determination under the others.

Interim Finding for Factor 1

The analysis supports retention of all six established Factor 1 Core Quality Indicators.

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 present Evidence does not justify treating this as a separate Core Indicator function.

No additional Factor 1 Core Quality 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.

6.2 Factor 2 — Technical Specification Quality

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?

IQC1 presently examines this Factor through seven invariant Core Quality 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.

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.

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.

IQC1 expressly 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.

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.

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 elsewhere in the Core or through Context-specific requirements.

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.

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.

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.

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 Indicator functions 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 Indicator functions across these two Factors are therefore an important finding for later horizontal analysis.

They may show that some Indicator functions recur across different quality-relevant dimensions while remaining necessary within each.

Interim Finding for Factor 2

The analysis supports retention of all seven established Factor 2 Core Quality Indicators.

Each preserves a necessary determination question within Technical Specification Quality.

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 Core Quality Indicator is justified by this analysis at this stage.

This conclusion does not establish 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

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?

IQC1 presently examines this Factor through seven invariant Core Quality 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 Core Indicators preserve the determination questions that must remain visible regardless of which assessment methods are used.

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.

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.

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.

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.

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 Core function 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.

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 Core Indicator serving more than one provisional function.

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.

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 satisfactory performance under one Indicator does not necessarily establish satisfactory performance under the others.

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 retention of all seven established Factor 3 Core Quality Indicators.

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 Core role as the demonstrability bridge 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 Core Quality Indicator is justified at this stage.

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?

IQC1 presently examines this Factor through seven invariant Core Quality Indicators:

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.

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.

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 IQC1 expressly leaves inspection intervals and maintenance techniques outside this Indicator.

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.

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.

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.

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 the complete Core.

Indicator 4.7 primarily performs a Quality-State Determination function.

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

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 mixture of all three provisional Indicator functions.

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.

However, IQC1 does not make inspection, maintenance, or mitigation methods part of Indicator 4.3.

Those actions should therefore not be added to its Core meaning in this analysis.

Interim Finding for Factor 4

The analysis supports retention of all seven established Factor 4 Core Quality Indicators.

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 Core Quality 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 Core Indicator is considered.

6.5 Factor 5 — Process Safety and Risk Mitigation

Factor 5 examines whether hazardous energy, hazardous materials, hazardous processes, Loss-of-Control Scenarios, and relevant Risk are sufficiently identified and addressed.

Its purpose is to support Infrastructure Safety and prevent or limit high-consequence and Cascading Failure conditions.

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 important process safety Risks sufficiently understood, and are the necessary capabilities present to prevent, control, or limit unacceptable consequences?

IQC1 presently examines this Factor through seven invariant Core Quality Indicators:

Indicator 5.1 — Identification of Hazardous Energy, Materials, and Processes

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 recognition of sources of harm to preservation of Risk knowledge and control capability through changing conditions.

Indicator 5.1 — Identification of Hazardous Energy, Materials, and Processes

Indicator 5.1 asks whether the sources and conditions capable of producing harm or functional loss have been explicitly identified.

Its determination question is:

What hazardous energies, materials, processes, and interactions exist within or affect the declared Infrastructure Quality Object?

This question is necessary.

Risk cannot be responsibly examined if the sources of possible harm have not first been recognized.

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

The removal test is:

Remove Indicator 5.1
→ Risk analysis may proceed while an important source of hazardous energy, material, process condition, or interaction remains outside the determination.

Indicator 5.2 cannot replace this function.

Indicator 5.1 identifies what can cause harm.

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 important hazardous conditions are sufficiently known.

Where a hazardous material, energy, or process condition is actually present, the Indicator may also provide information about the Quality State itself.

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.

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.

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.

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.

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.

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 process 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 process-safety and Risk 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.

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 examining Quality-State Influence as a separate provisional Indicator function.

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 establish a new Core layer or require a separate class of Indicators.

Interim Finding for Factor 5

The analysis supports retention of all seven established Factor 5 Core Quality Indicators.

Each preserves a necessary determination question.

Removal of any one would weaken a different part of the process safety and Risk mitigation 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 Core Quality 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 represents a recurring determination need requiring further Core consideration.

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

6.6 Factor 6 — Environmental Protection

Factor 6 examines Environmental Protection as an integral part of Infrastructure Quality.

Its scope includes Environmental Interactions, Exposure Pathways, emissions, discharges, Unintended Releases, Environmental Harm, and cumulative or long-term effects across the Lifecycle.

Factor 6 does not establish universal environmental limits.

Emission and discharge limits, permit conditions, receptor classifications, remediation criteria, and environmental acceptance thresholds remain Context-specific.

Factor 6 therefore asks a broad question:

Are the environmental interactions and consequences of the Infrastructure Quality Object sufficiently understood and controlled to prevent or limit unacceptable Environmental Harm?

IQC1 presently examines this Factor through seven invariant Core Quality Indicators:

Indicator 6.1 — Identification of Environmental Interactions and Exposure Pathways

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

Indicator 6.3 — Environmental Protection 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 different parts of the relationship between infrastructure behavior and environmental consequence.

Indicator 6.1 — Identification of Environmental Interactions and Exposure Pathways

Indicator 6.1 asks whether the ways in which the Infrastructure Quality Object can affect or interact with the environment have been explicitly identified.

Its determination question is:

How can the Infrastructure Quality Object interact with air, water, soil, ecosystems, surrounding areas, or other relevant environmental receptors?

This question is necessary.

Environmental Protection cannot be responsibly determined only from a list of regulatory obligations.

The actual interactions and pathways through which infrastructure behavior may produce environmental effects must first be understood.

The removal test is:

Remove Indicator 6.1
→ environmental requirements may remain known while an important interaction or Exposure Pathway 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, and other relevant environmental relationships.

Indicator 6.1 therefore preserves a necessary and distinguishable determination function.

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.

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 Protection Under Abnormal and Degraded Conditions

Indicator 6.3 asks whether environmental protection provisions remain effective outside normal operation.

Its determination question is:

Do environmental protection provisions continue to perform during foreseeable abnormal, degraded, and transient conditions?

This question is necessary because environmental vulnerability may increase during startup, shutdown, upset, maintenance, temporary configuration, loss-of-containment conditions, or recovery.

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 protection may appear adequate under normal conditions while its effectiveness during foreseeable non-normal conditions remains insufficiently determined.

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 asks whether those provisions remain effective under challenging operating conditions.

The distinction is:

Protection provision exists
≠ protection provision remains effective 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.

Its purpose is to influence environmental consequences by preventing or limiting harm.

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.

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 environmental protection provisions remain aligned when infrastructure configuration, operation, external conditions, or environmental Context changes.

Its determination question is:

When the Infrastructure Quality Object or its environmental Context changes, do the existing protection provisions remain adequate for the changed environmental interactions and Exposure Pathways?

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
→ environmental protection provisions may remain physically present while no longer being aligned with the environmental conditions they are intended to address.

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
→ Does Environmental Protection remain aligned with changed environmental interactions and Exposure Pathways?

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.

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.

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.

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.

Do those provisions remain effective during abnormal, degraded, and transient conditions?

→ Indicator 6.3.

Are cumulative and long-term effects understood?

→ Indicator 6.4.

Does Environmental Protection remain aligned when infrastructure 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 adequate protection during normal operation but inadequate protection during abnormal conditions;

have individually limited environmental effects that become significant cumulatively;

have initially adequate protection that becomes 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 Indicator functions.

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 actual environmental conditions, effects, emissions, discharges, or protection performance.

Quality-State Influence is strongly represented in Indicators 6.2, 6.3, 6.5, and 6.6 because they concern prevention, limitation, continued protection, and alignment of environmental controls.

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 process safety and Risk.

Factor 6 concerns Environmental Protection.

The repeated functional pattern may therefore be significant for the later horizontal analysis.

Interim Finding for Factor 6

The analysis supports retention of all seven established Factor 6 Core Quality Indicators.

Each preserves a necessary determination question.

Removal of any one would leave a different environmental interaction, protection capability, operating condition, cumulative effect, change condition, emission/discharge issue, or information need materially less visible or less determinable.

No additional Factor 6 Core Quality Indicator is justified from this analysis at this stage.

The analysis does, however, strengthen two provisional horizontal findings.

First, the Quality-State Influence function appears repeatedly where the Core examines 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 Core overlap 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?

IQC1 presently examines this Factor through seven invariant Core Quality Indicators:

Indicator 7.1 — Definition 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 — Definition 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.

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.

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.

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.

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.

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.

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.

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 retention of all seven established Factor 7 Core Quality Indicators.

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 later across the complete Core to determine whether they represent necessary repeated application of common functions or possible unnecessary overlap.

No additional Factor 7 Core Quality Indicator is justified from this analysis 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.

6.8 Factor 8 — Workplace Human Interaction and Safety

Factor 8 examines how workplace interaction between people and the Infrastructure Quality Object affects Infrastructure Safety and Function Realization.

Its scope includes Infrastructure Configuration, condition, Interfaces, Human Capabilities and Limitations, Error-Provoking Conditions, Workplace Contextual Pressures, and interaction under normal and non-normal conditions.

Factor 8 therefore asks a broad question:

Does the Infrastructure Quality Object support safe and reliable human interaction during workplace activities?

IQC1 presently examines this Factor through seven invariant Core Quality Indicators:

Indicator 8.1 — Identification of Workplace Human–Infrastructure Interaction Points

Indicator 8.2 — Consideration of Human Capabilities and Limitations in Workplace Interaction

Indicator 8.3 — Error-Provoking Workplace Conditions

Indicator 8.4 — Workplace Safety Under Abnormal and Degraded Conditions

Indicator 8.5 — Alignment Between Infrastructure Design and Human Understanding

Indicator 8.6 — Workplace Contextual Pressures Affecting Safety

Indicator 8.7 — Retention of Workplace Interaction Safety Knowledge.

The seven Indicators examine different ways in which infrastructure can support, complicate, or degrade safe human interaction.

Indicator 8.1 — Identification of Workplace Human–Infrastructure Interaction Points

Indicator 8.1 asks whether the places and conditions where people interact with the Infrastructure Quality Object have been explicitly identified.

Its determination question is:

Where can workplace human 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
→ workplace 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 where interaction occurs.

Indicator 8.2 asks whether the Infrastructure Quality Object accounts for foreseeable human capabilities and limitations at those interactions.

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.

Indicator 8.2 — Consideration of Human Capabilities and Limitations in Workplace Interaction

Indicator 8.2 asks whether infrastructure design and configuration account for foreseeable human capabilities, limitations, and variability.

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 human capabilities that cannot reasonably be assumed under actual workplace conditions.

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 compatible with foreseeable human capabilities and limitations.

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.

Indicator 8.3 — Error-Provoking Workplace Conditions

Indicator 8.3 asks whether infrastructure-related workplace conditions that increase the likelihood of Human Error or unsafe action have been explicitly identified and considered.

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
→ workplace interaction may be examined while infrastructure-created conditions that actively increase error likelihood become insufficiently visible.

Indicator 8.2 cannot fully replace this function.

Human capabilities and limitations concern characteristics and variability of people.

Indicator 8.3 concerns conditions created by the Infrastructure Quality Object that increase the likelihood of error.

The distinction is:

Human limitation
≠ Error-Provoking Workplace Condition.

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.

Indicator 8.4 — Workplace Safety Under Abnormal and Degraded Conditions

Indicator 8.4 asks whether human interaction remains sufficiently safe when the Infrastructure Quality Object is in abnormal, degraded, or transitional conditions.

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
→ workplace interaction may appear safe under normal operation while interaction during foreseeable non-normal conditions remains insufficiently determined.

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 Protection remains effective.

Indicator 8.4 asks whether workplace human interaction remains safe.

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 actual safety of workplace interaction under these conditions and the ability to determine whether assumptions about human action remain valid.

Indicator 8.5 — Alignment Between Infrastructure Design and Human Understanding

Indicator 8.5 asks whether infrastructure design supports correct human understanding and action.

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 supports correct understanding and action.

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.

Indicator 8.6 — Workplace Contextual Pressures Affecting Safety

Indicator 8.6 asks whether workplace pressures arising from infrastructure design or operating conditions that can affect safe human interaction are explicitly considered.

Its determination question is:

Do infrastructure-related time, access, workload, environmental, or competing-task pressures materially reduce the likelihood of safe interaction?

This question is necessary.

Unsafe action may not arise from lack of competence or from one obvious design defect.

It may arise from the combined condition in which infrastructure requires action under severe time pressure, difficult access, environmental exposure, or competing demands.

The removal test is:

Remove Indicator 8.6
→ design and interaction may be examined without sufficiently considering the conditions under which people must actually perform the work.

Indicator 8.6 is distinguishable from broader organizational or management issues.

IQC1 expressly limits this Indicator to pressures arising from infrastructure design or operating conditions.

It excludes organizational policy, labor practices, or management directives.

This Boundary is important.

The Indicator preserves the infrastructure contribution to workplace pressure without turning Factor 8 into a general management-system assessment.

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

The pressure must be identified as part of the actual interaction Context.

Infrastructure conditions can then influence whether safe action remains reasonably achievable.

Indicator 8.7 — Retention of Workplace Interaction Safety Knowledge

Indicator 8.7 asks whether knowledge necessary to understand workplace safety risks arising from human–infrastructure interaction remains available over time.

Its determination question is:

Can known interaction risks, limitations, workarounds, assumptions, and workplace safety issues still be understood later in the Lifecycle?

This question is necessary.

Human–infrastructure interaction knowledge can be lost.

Unsafe workarounds may become normalized.

Lessons from earlier incidents or difficulties may disappear.

Known limitations may no longer be recognized after personnel or configuration changes.

The removal test is:

Remove Indicator 8.7
→ workplace safety issues may be identified at one time while the knowledge needed to recognize repeated or persistent interaction problems is later lost.

Indicator 8.7 is related to Factor 13 and to the Factor-specific information-retention Indicators already identified under Factors 4 through 7.

The same horizontal question therefore appears again.

The present analysis does not establish redundancy.

Indicator 8.7 preserves knowledge specifically needed to understand workplace human–infrastructure interaction.

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

Indicator 8.7 primarily performs a Quality-State Determination function.

Relationship Among the Seven Indicators

The seven Indicators form a connected workplace 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.

Does infrastructure create Error-Provoking Workplace Conditions?

→ Indicator 8.3.

Does workplace interaction remain safe under abnormal, degraded, and transitional conditions?

→ Indicator 8.4.

Does infrastructure design support correct human understanding and action?

→ Indicator 8.5.

Do infrastructure-related workplace pressures make safe interaction more difficult?

→ Indicator 8.6.

Is the knowledge needed to understand workplace interaction safety retained?

→ Indicator 8.7.

The Indicators therefore preserve different questions.

A workplace 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;

be technically understandable but become unsafe under severe Contextual Pressure;

or

be adequately understood today while important safety knowledge is later lost.

These possibilities support separate retention of the seven Indicators.

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 the actual conditions of workplace interaction, especially under Indicators 8.2, 8.3, 8.4, and 8.6.

Quality-State Determination is especially strong in Indicators 8.1, 8.5, and 8.7.

Indicator 8.5 is particularly significant because it concerns whether infrastructure design supports correct human understanding of system condition and behavior.

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, 8.5, and 8.6 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 retention of all seven established Factor 8 Core Quality Indicators.

Each preserves a necessary determination question concerning workplace human–infrastructure interaction.

Removal of any one would leave a different interaction point, human-performance condition, error-provoking condition, abnormal operating condition, understanding problem, Contextual Pressure, or knowledge need materially less visible or less determinable.

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 Core Quality Indicator is justified from the present analysis at this stage.

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?

IQC1 presently examines this Factor through seven invariant Core Quality 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

Indicator 9.7 — Retention of Competence-Relevant Knowledge.

The seven 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.

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.

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.

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.

IQC1 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.

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.

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.

Indicator 9.7 — Retention of Competence-Relevant Knowledge

Indicator 9.7 asks whether information needed to understand competence Assumptions, limitations, and dependencies remains available through the Lifecycle.

Its determination question is:

Can later users still understand where Function Realization depends on particular expertise, judgment, contextual knowledge, or role competence?

This question is necessary.

Important competence dependencies may exist informally.

Knowledge may be concentrated in a small number of people.

Personnel may leave.

Organizations may change.

The reason why a particular role requires particular expertise may then be lost.

The removal test is:

Remove Indicator 9.7
→ competent personnel may exist at one time while later personnel or decision-makers lose the knowledge needed to understand important competence dependencies and limitations.

Indicator 9.7 does not require retention of personnel files or training records.

Its subject is infrastructure-relevant knowledge about competence dependencies.

Indicator 9.7 is related to Factor 13 and to the Factor-specific information-retention Indicators already identified under Factors 4 through 8.

The repeated pattern continues.

The present analysis does not yet establish that these Indicators are redundant.

Each retains information needed for determination of a particular Quality Factor.

Factor 13 provides the wider Documentation and Traceability function.

Indicator 9.7 primarily performs a Quality-State Determination function.

Relationship Among the Seven Indicators

The seven 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.

Is knowledge about important competence dependencies and limitations retained?

→ Indicator 9.7.

The Indicators therefore preserve different 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 seven Indicators.

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. IQC1 expressly includes these roles within Factor 9. □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.

IQC1 itself 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

The analysis supports retention of all seven established Factor 9 Core Quality Indicators.

Each preserves a necessary competence-related determination question.

Removal of any one would leave a different critical-role, competence, non-routine-condition, Authority-limit, Lifecycle-change, competence-Risk, or knowledge-retention 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 Core Quality Indicator is justified at this stage.

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?

IQC1 presently examines this Factor through seven invariant Core Quality Indicators:

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

Indicator 10.7 — Traceability of Compliance Statements.

The seven 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.

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.

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.

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.

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.

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.

Indicator 10.7 — Traceability of Compliance Statements

Indicator 10.7 asks whether Compliance Statements can be traced to the requirements, scope, Lifecycle Stage, and supporting Evidence to which they actually apply.

Its determination question is:

Can the basis and limits of a Compliance Statement be reconstructed and verified?

This question is necessary.

A compliance conclusion may be correct when originally made but become misleading when repeated without its scope, applicable requirements, or Lifecycle context.

The removal test is:

Remove Indicator 10.7
→ valid Compliance Statements may later become over-generalized or separated from the actual requirements and Evidence that supported them.

Indicator 10.7 is related to Factor 3 Indicator 3.7 — Traceability of Conformity Statements and to Factor 13.

The determination questions are similar but applied to different subjects.

Indicator 3.7 preserves traceability of Conformity Statements.

Indicator 10.7 preserves traceability of Compliance Statements.

Factor 13 preserves wider documentation and Evidence continuity.

This repeated traceability pattern should therefore be examined horizontally rather than assumed to be redundant.

Indicator 10.7 primarily performs a Quality-State Determination function.

Relationship Among the Seven Indicators

The seven 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.

Can Compliance Statements be traced to their actual basis?

→ Indicator 10.7.

The Indicators therefore preserve different 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;

or

have a correct Compliance Statement that becomes misleading after separation from its original scope and Evidence.

These possibilities support separate retention of the seven Indicators.

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, 10.6, and 10.7 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 all seven established Factor 10 Core Quality Indicators.

Each preserves a necessary determination question.

Removal of any one would leave a different applicability, integration, conformity, conflict, change, limitation, or traceability issue materially less visible or less determinable.

The analysis also strengthens two horizontal findings.

First, traceability appears repeatedly as a Factor-specific Indicator function in addition to Factor 13.

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 Core Quality Indicator is justified at this stage.

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.

6.11 Factor 11 — Stakeholder and Community Satisfaction

Factor 11 examines whether Infrastructure Quality interpretation accounts for the effects of the Infrastructure Quality Object on affected Stakeholders and Communities.

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?

IQC1 presently examines this Factor through seven invariant Core Quality 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

Indicator 11.7 — Retention of Stakeholder and Community Impact Knowledge.

The seven 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.

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.

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 therefore central to the meaning of Stakeholder and Community Satisfaction in IQC1.

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.

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.

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.

IQC1 defines Responsiveness as evidenced consideration and appropriate treatment, not automatic acceptance.

Indicator 11.5 should also not be reduced to a complaint-handling requirement.

IQC1 expressly excludes complaint-handling processes and engagement mechanisms.

Its Core function 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.

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 Core question remains whether the actual effect and its limitation are represented transparently.

Indicator 11.7 — Retention of Stakeholder and Community Impact Knowledge

Indicator 11.7 asks whether information needed to understand Stakeholder and Community impacts remains available over time.

Its determination question is:

Can later Quality State determinations still understand historical Infrastructure Impacts, sensitivities, assumptions, and observed Community outcomes?

This question is necessary.

Infrastructure–Community relationships can develop over long periods.

Historical issues may recur.

Earlier assumptions may become relevant after modification.

Community effects may only become clear after repeated operation.

Loss of this knowledge can make later impacts appear new or isolated when they are part of a longer pattern.

The removal test is:

Remove Indicator 11.7
→ current observations may remain available while important historical knowledge about Stakeholder and Community effects is lost.

Indicator 11.7 is related to Factor 13 and to the Factor-specific information-retention Indicators identified under Factors 4 through 10.

This recurring pattern is now strong.

The present analysis still does not establish redundancy.

Indicator 11.7 preserves information specifically necessary to understand Stakeholder and Community effects.

Factor 13 preserves wider Documentation and Traceability across the Infrastructure Quality Object.

Indicator 11.7 primarily performs a Quality-State Determination function.

Relationship Among the Seven Indicators

The seven 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.

Is the knowledge needed to understand Stakeholder and Community effects retained?

→ Indicator 11.7.

The Indicators therefore preserve different 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

have repeated historical effects whose earlier Evidence and context are later lost.

These possibilities support separate retention of the seven Indicators.

Relationship to Other Core 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, 11.6, and 11.7 strongly support the ability to determine and interpret those effects.

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.

But IQC1 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

The analysis supports retention of all seven established Factor 11 Core Quality Indicators.

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 Core Quality Indicator is justified from this analysis at this stage.

Repeated Context Guide Evidence should continue to test whether important Stakeholder or Community determination functions remain outside the present seven Indicators, particularly where external observations provide early or independent visibility of infrastructure conditions not sufficiently visible through internal information paths.

6.12 Factor 12 — Monitoring and Performance Evaluation

Factor 12 examines whether the behavior, Infrastructure Results, and Infrastructure Outcomes of the declared Infrastructure Quality Object remain sufficiently observable and interpretable.

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 changes in infrastructure condition and behavior be detected, understood, and related to Intended Functions and Intended Results before they lead to unacceptable consequences?

IQC1 presently examines this Factor through seven invariant Core Quality 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

Indicator 12.6 — Interpretation of Infrastructure Behavior in Relation to Intended Results

Indicator 12.7 — Retention of Monitoring and Performance Knowledge.

The seven 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.

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.

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.

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.

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 Core.

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.

Indicator 12.6 — Interpretation of Infrastructure Behavior in Relation to Intended Results

Indicator 12.6 asks whether observed infrastructure behavior is interpreted in relation to Infrastructure Intended Functions and Infrastructure Intended Results.

Its determination question is:

What does the observed behavior mean for actual Function Realization?

This question is necessary.

An Infrastructure Quality Object can be operating without adequately realizing its Intended Functions.

Data can show continued activity while performance margins decline.

A system can remain physically active while its Intended Result is no longer being achieved.

The removal test is:

Remove Indicator 12.6
→ infrastructure behavior may be monitored and interpreted technically while its significance for Intended Function Realization remains insufficiently determined.

Indicator 12.3 cannot replace this function.

Indicator 12.3 asks whether monitoring information is interpreted correctly in its operating Context.

Indicator 12.6 asks what the observed behavior means in relation to Intended Functions and Intended Results.

The distinction is:

What does the observed signal mean under these conditions?

≠

What does the observed behavior mean for Function Realization?

Indicator 12.6 therefore preserves a necessary and distinguishable determination function.

Its provisional classification strongly combines Quality-State and Quality-State Determination.

Actual Function Realization concerns the Quality State.

Observed behavior provides Evidence through which that state is determined.

Indicator 12.7 — Retention of Monitoring and Performance Knowledge

Indicator 12.7 asks whether information needed to understand monitoring assumptions, trends, limitations, blind spots, and interpretations remains available over time.

Its determination question is:

Can later determinations still understand what was monitored, what the information meant, and what the monitoring could not reliably reveal?

This question is necessary.

A monitoring record without its interpretation basis may become misleading.

Historical trends may be lost.

Known blind spots may be forgotten.

A later user may assume that absence of recorded abnormality demonstrates absence of an abnormal condition.

The removal test is:

Remove Indicator 12.7
→ monitoring data may remain available while the knowledge needed to interpret their meaning, limitations, and historical Context is lost.

Indicator 12.7 is related to Factor 13 and to the information-retention Indicators repeatedly identified under earlier Factors.

The present analysis again does not establish redundancy.

Indicator 12.7 preserves knowledge specifically necessary to understand monitoring and performance Evidence.

Factor 13 addresses wider Documentation and Traceability across the Infrastructure Quality Object.

Indicator 12.7 primarily performs a Quality-State Determination function.

Relationship Among the Seven Indicators

The seven Indicators form a connected 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.

Can observed behavior be interpreted in relation to Intended Functions and Intended Results?

→ Indicator 12.6.

Is the knowledge needed to understand monitoring and performance retained?

→ Indicator 12.7.

The Indicators therefore preserve different 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;

understand observed behavior without relating it to actual Function Realization;

or

retain data while losing the knowledge needed to understand what those data mean.

These possibilities support separate retention of the seven Indicators.

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 Core Quality Factors

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.

Interim Finding for Factor 12

The analysis supports retention of all seven established Factor 12 Core Quality Indicators.

Each preserves a necessary determination question concerning what is observed, whether it can be detected adequately, whether it is interpreted correctly, whether developing Risk can be recognized, whether monitoring remains relevant after change, whether observed behavior is connected to Function Realization, and whether monitoring knowledge remains available over time.

Removal of any one would weaken a different part of the Quality-State determination path.

No additional Factor 12 Core Quality Indicator is justified from 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;

connection to Intended Results;

and retention of monitoring knowledge.

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 Core Indicator unless repeated cross-Context Evidence demonstrates that an invariant determination function 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?

IQC1 presently examines this Factor through seven invariant Core Quality 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

Indicator 13.7 — Prevention of Documentation Substitution for Quality.

The seven 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.

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.

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.

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 overlaps with Indicator 3.7 and Indicator 10.7.

But the scopes differ.

Indicator 3.7 concerns traceability of Conformity Statements within Factor 3.

Indicator 10.7 concerns traceability of Compliance Statements within Factor 10.

Indicator 13.4 preserves broader traceability of assessments, evaluations, and Conformity Statements across the infrastructure quality determination.

This strengthens the horizontal question already identified:

When is Factor-specific traceability necessary, and when is the broader Factor 13 traceability function sufficient?

The present analysis does not decide that question in advance.

Indicator 13.4 primarily performs a Quality-State Determination function.

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.

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.

Indicator 13.7 — Prevention of Documentation Substitution for Quality

Indicator 13.7 asks 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 test is:

Remove Indicator 13.7
→ the Documentation and Traceability Factor itself can create a false positive if documentary completeness is interpreted as proof of Infrastructure Quality.

This Indicator is therefore unusual but important.

It limits the meaning of the Factor in which it appears.

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.

Indicator 13.7 therefore strongly performs a Quality-State Determination function.

It protects the validity of the overall determination from a category error.

Relationship Among the Seven Indicators

The seven 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?

→ Indicator 13.7.

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 seven 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 retention of all seven established Factor 13 Core Quality 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 Core Quality Indicator is justified from this analysis at this stage.

The present seven 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 — Adaptability and Innovation Readiness

Factor 14 examines whether the declared Infrastructure Quality Object can undergo responsible Adaptation and Innovation without losing required Function Realization, Infrastructure Safety, Structural or Functional Integrity, Operational Reliability, Environmental Protection, Evidence, Critical Infrastructure Conditions, or claim validity.

Its purpose is not to promote Innovation for its own sake.

It examines whether change can occur intentionally and safely rather than through ad hoc or reactive modification.

Factor 14 therefore asks a broad question:

Can the Infrastructure Quality Object adapt or incorporate Innovation without weakening the quality basis that must remain preserved?

IQC1 presently examines this Factor through seven invariant Core Quality Indicators:

Indicator 14.1 — Identification of Adaptability-Relevant Constraints and Opportunities

Indicator 14.2 — Preservation of Safety and Integrity During Adaptation

Indicator 14.3 — Compatibility with Functional Intent, Boundaries, and Interfaces

Indicator 14.4 — Treatment of Uncertainty Introduced by Innovation

Indicator 14.5 — Reversibility and Recoverability of Adaptation

Indicator 14.6 — Learning from Adaptation and Innovation Results and Outcomes

Indicator 14.7 — Retention of Adaptation and Innovation Knowledge.

The seven Indicators examine different conditions needed for responsible change.

Indicator 14.1 — Identification of Adaptability-Relevant Constraints and Opportunities

Indicator 14.1 asks whether the conditions that limit or enable responsible Adaptation have been explicitly identified.

Its determination question is:

What physical, technical, operational, Interface, capacity, or dependency conditions affect the ability of the Infrastructure Quality Object to adapt responsibly?

This question is necessary.

An Infrastructure Quality Object may appear adaptable until an important constraint becomes visible.

Physical configuration may prevent modification.

An Interface may limit compatibility.

Spare capacity may be insufficient.

A dependency may make a seemingly local change affect the wider system.

The removal test is:

Remove Indicator 14.1
→ Adaptation or Innovation may proceed without sufficient understanding of the conditions that make the change feasible, constrained, or potentially unsafe.

Indicator 14.2 cannot replace this function.

Indicator 14.1 asks what enables or constrains Adaptation.

Indicator 14.2 asks whether safety and integrity are preserved when Adaptation occurs.

The two questions are different.

Indicator 14.1 therefore preserves a necessary and distinguishable determination function.

Its provisional function is primarily Quality-State Determination.

It establishes the conditions within which responsible Adaptation can be considered.

Indicator 14.2 — Preservation of Safety and Integrity During Adaptation

Indicator 14.2 asks whether Adaptation or Innovation preserves Structural Integrity, Process Safety, Workplace Safety, and Environmental Protection.

Its determination question is:

Does the proposed or implemented Adaptation preserve the critical safety and integrity conditions of the Infrastructure Quality Object?

This question is necessary.

A change may improve one aspect of performance while weakening another.

Innovation may improve efficiency while reducing an existing safety margin.

A modification may solve a local problem while creating an integrity or environmental problem elsewhere.

The removal test is:

Remove Indicator 14.2
→ Adaptation may be assessed for usefulness or technical feasibility while its effects on safety and integrity remain insufficiently visible.

Indicator 14.2 overlaps with several earlier Factors.

But its function is not to replace Factors 4, 5, 6, or 8.

Those Factors determine Structural and Functional Integrity, Process Safety, Environmental Protection, and Workplace Human Interaction directly.

Indicator 14.2 asks whether Adaptation preserves those established quality conditions.

The distinction is:

Earlier Factors
→ determine the relevant safety and integrity conditions.

Indicator 14.2
→ tests whether Adaptation compromises them.

Indicator 14.2 therefore preserves a necessary cross-change determination function.

Its provisional classification strongly combines Quality-State and Quality-State Influence.

It concerns the resulting safety and integrity state and whether change can be controlled so that those conditions remain acceptable.

Indicator 14.3 — Compatibility with Functional Intent, Boundaries, and Interfaces

Indicator 14.3 asks whether Adaptation remains compatible with the Infrastructure Quality Object's Functional Intent and declared Boundaries and Interfaces.

Its determination question is:

Does the changed Infrastructure Quality Object still correspond to what it is intended to do and to the system relationships within which that function must be realized?

This question is necessary.

Innovation can introduce new capability while unintentionally changing the meaning, extent, or Interfaces of the declared Infrastructure Quality Object.

The modification may technically work while becoming inconsistent with the original or current Functional Intent.

The removal test is:

Remove Indicator 14.3
→ Adaptation may preserve individual technical performance while creating misalignment with Intended Functions, Boundaries, or Interfaces.

Indicator 14.2 cannot replace this function.

Safety can remain acceptable while functional alignment is lost.

Likewise, functional alignment can remain while a safety condition becomes unacceptable.

Indicator 14.3 is therefore necessary and distinguishable.

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

The continued alignment must be determined.

Adaptation must then remain bounded by that alignment.

Indicator 14.4 — Treatment of Uncertainty Introduced by Innovation

Indicator 14.4 asks whether new Uncertainty introduced by Adaptation or Innovation has been explicitly identified and considered.

Its determination question is:

What is not yet sufficiently known about the changed technology, material, configuration, operating mode, or Interface?

This question is necessary.

Novelty can create uncertainty in behavior, interaction, degradation, Failure Modes, or performance.

A new solution may appear promising while its limits remain poorly understood.

The removal test is:

Remove Indicator 14.4
→ Innovation may be treated as equivalent to established technology even when important behavior, interactions, or Failure Modes remain uncertain.

Indicator 14.1 cannot replace this function.

A constraint may be known while the behavior of the new solution remains uncertain.

Indicator 14.2 also cannot replace it.

Safety and integrity evaluation may itself depend on uncertain information.

Indicator 14.4 therefore preserves a necessary and distinguishable determination function.

Its provisional function is strongly Quality-State Determination.

It protects the determination from false confidence where novelty reduces certainty.

Indicator 14.5 — Reversibility and Recoverability of Adaptation

Indicator 14.5 asks whether there is practical capability to reverse an Adaptation or recover acceptable Function Realization if unintended consequences occur.

Its determination question is:

If the Adaptation produces an unacceptable result, can the Infrastructure Quality Object return to a previously acceptable condition or otherwise recover acceptable Function Realization?

This question is necessary because not every effect of Innovation can be predicted in advance.

Where practical, responsible Adaptation should avoid unnecessary lock-in to a configuration that cannot be corrected.

The removal test is:

Remove Indicator 14.5
→ an Adaptation may satisfy the initial evaluation but leave no practical means to recover if its actual effects become unacceptable.

Indicator 14.5 is one of the clearest Quality-State Influence Indicators in the present Core.

It directly concerns the capability to move the Infrastructure Quality Object away from an unsatisfactory changed state and toward acceptable Function Realization.

It also contains a Quality-State Determination component because the feasibility and limits of reversal or recovery must first be understood.

The Indicator is not absolute.

IQC1 states "where practicable."

This Boundary is important.

Not every infrastructure change can be physically reversed.

Recoverability may therefore be more relevant than exact reversal in some Contexts.

Indicator 14.6 — Learning from Adaptation and Innovation Results and Outcomes

Indicator 14.6 asks whether the actual Results and Outcomes following Adaptation or Innovation are evaluated and used to inform later infrastructure decisions.

Its determination question is:

What did the Adaptation actually produce, including unintended effects, and what should that Evidence mean for later infrastructure decisions?

This question is necessary.

The quality of an Adaptation cannot be determined only from the assumptions made before implementation.

Actual infrastructure behavior may confirm, weaken, or contradict those assumptions.

The removal test is:

Remove Indicator 14.6
→ Adaptation may be implemented repeatedly without systematic use of Evidence from observed Results and Outcomes.

Indicator 14.4 cannot replace this function.

Indicator 14.4 concerns uncertainty before or during Innovation.

Indicator 14.6 concerns what is learned after implementation from actual behavior and outcomes.

Indicator 14.6 therefore preserves a necessary and distinguishable determination function.

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

Observed Results and Outcomes concern actual state.

Their interpretation provides Evidence for later determination and decisions.

It may also support Quality-State Influence by changing how later Adaptations are selected or bounded.

Indicator 14.7 — Retention of Adaptation and Innovation Knowledge

Indicator 14.7 asks whether information needed to understand Adaptation and Innovation decisions, Assumptions, Results, Outcomes, Uncertainty, and limitations remains available.

Its determination question is:

Can later users understand what was changed, why it was changed, what was uncertain, what actually happened, and what limitations remain?

This question is necessary.

Innovation knowledge can be lost.

A successful local trial may later be repeated in a different Context without its original limitations.

An unsuccessful approach may be attempted again because the earlier Evidence was not retained.

The removal test is:

Remove Indicator 14.7
→ Adaptation may occur and be evaluated while the knowledge needed to avoid unsafe replication, inappropriate scaling, or repeated error is later lost.

Indicator 14.7 is related to Factor 13 and to the Factor-specific information-retention Indicators already identified throughout Section 6.

Again, the present analysis does not automatically establish redundancy.

Indicator 14.7 preserves information specific to Adaptation and Innovation.

Factor 13 preserves wider Documentation and Traceability.

This relationship should be examined horizontally in Section 7.

Indicator 14.7 primarily performs a Quality-State Determination function.

Relationship Among the Seven Indicators

The seven Indicators form a connected Adaptation determination.

They ask:

What constrains or enables responsible Adaptation?

→ Indicator 14.1.

Are safety and integrity preserved during change?

→ Indicator 14.2.

Does the Adaptation remain compatible with Functional Intent, Boundaries, and Interfaces?

→ Indicator 14.3.

What new Uncertainty has been introduced?

→ Indicator 14.4.

Can the Infrastructure Quality Object reverse or recover if the Adaptation produces unacceptable effects?

→ Indicator 14.5.

What do the actual Results and Outcomes of Adaptation show?

→ Indicator 14.6.

Is the knowledge needed to understand and reuse those findings retained?

→ Indicator 14.7.

The Indicators therefore preserve different determination questions.

An Infrastructure Quality Object can:

have an unrecognized constraint to Adaptation;

adapt successfully in one respect while weakening safety or integrity;

preserve safety while becoming misaligned with Functional Intent;

introduce Innovation whose behavior remains insufficiently understood;

implement a change that cannot be practically corrected after an unacceptable result;

complete an Adaptation without adequately evaluating what actually happened;

or

learn from an Adaptation but later lose the knowledge needed to apply that learning responsibly.

These possibilities support separate retention of the seven Indicators.

Relationship Between Factor 14 and the Change-Related Indicators in Other Factors

Factor 14 creates another important horizontal question.

Many earlier Factors contain Indicators addressing change.

Examples include Functional Changes, Technical Specification Changes, preservation of Integrity through change, Risk mitigation alignment under change, Environmental Protection alignment under change, Reliability under change, continued Compliance validity, and Monitoring relevance under change.

Factor 14 then examines Adaptability and Innovation as a wider quality dimension.

This does not automatically establish duplication.

The Factor-specific change Indicators ask:

When change occurs, is this particular quality condition preserved?

Factor 14 asks a wider question:

Does the Infrastructure Quality Object possess the demonstrated capacity to undergo responsible Adaptation and Innovation while preserving the necessary quality basis?

The distinction can therefore be expressed as:

Factor-specific change Indicator
→ effect of change on one Quality Factor.

Factor 14
→ capacity for responsible change itself.

This appears to be a meaningful distinction.

However, the repeated change pattern should still be tested horizontally in Section 7.

The removal test should ask whether any Factor-specific change Indicator becomes unnecessary because Factor 14 adequately preserves the same determination question.

That conclusion should not be assumed in advance.

Relationship to the Provisional State / Determination / Influence Functions

Factor 14 provides particularly strong support for the provisional Quality-State Influence function.

Adaptation itself is an intentional attempt to change the Infrastructure Quality Object or its capability.

Indicator 14.5 makes this especially clear.

Reversibility and Recoverability concern the ability to move the Infrastructure Quality Object away from an unacceptable changed condition and restore acceptable Function Realization.

Indicators 14.2 and 14.3 also contain strong Influence functions because change must remain bounded by safety, integrity, Functional Intent, Boundaries, and Interfaces.

Quality-State Determination is also strongly represented.

Indicators 14.1 and 14.4 concern constraints and Uncertainty.

Indicator 14.6 concerns interpretation of actual Results and Outcomes.

Indicator 14.7 preserves the knowledge needed for later determination.

Quality-State functions appear where the actual post-Adaptation condition and Results are examined.

Factor 14 therefore provides another strong case where State, Determination, and Influence functions interact within one Factor.

Interim Finding for Factor 14

The analysis supports retention of all seven established Factor 14 Core Quality Indicators.

Each preserves a necessary determination question concerning constraints and opportunities, preservation of safety and integrity, functional compatibility, Innovation-related Uncertainty, reversibility and recovery, learning from actual Results and Outcomes, or retained Adaptation knowledge.

Removal of any one would weaken a different part of the ability to determine whether Adaptation or Innovation is responsible and compatible with Infrastructure Quality.

The Factor also strongly supports the provisional Quality-State Influence concept.

Unlike Factors that primarily ask what the state is or whether it can be determined, Factor 14 directly examines the capability to intentionally change the Infrastructure Quality Object while preserving or restoring acceptable Function Realization.

No additional Factor 14 Core Quality Indicator is justified from this analysis at this stage.

However, two horizontal questions should be carried forward.

First, the relationship between Factor 14 and the numerous Factor-specific change Indicators should be tested for necessity and possible overlap.

Second, repeated Context Guide Evidence should test whether the existing Indicators adequately represent the full path from recognizing the need for Adaptation, through responsible implementation, to recovery when the changed state proves unacceptable.

These questions should remain open rather than being resolved before the horizontal analysis is performed.

7. Horizontal Analysis Across the Fourteen Quality Factors

7.1 Recurring Indicator Functions Across Different Factors

Section 6 examined the invariant Core Quality Indicators vertically.

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 Core Indicators first establish the subject that 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 important to this question because it examines the wider capacity for responsible Adaptation and Innovation.

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;

Process Safety and Risk Mitigation;

Environmental Protection;

Operational Reliability;

Workplace Human Interaction and Safety;

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.

Factor 14 applies the same general function specifically to Uncertainty introduced by Innovation.

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 repeatedly throughout the Core.

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 present Core.

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;

Reversibility and Recoverability;

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 cross-Indicator function.

The Core frequently examines:

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 Core 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 Indicator functions 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 create another normative IQI Core layer.

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 Core

The provisional Quality-State Indicator function 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 Core 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 in the Core.

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 Process Safety and Risk Mitigation

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 Workplace Human Interaction and Safety

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 Stakeholder and Community Satisfaction

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 Monitoring and Performance Evaluation

Factor 12 is dominated by Quality-State Determination.

However, Indicator 12.6 provides a strong connection back to State.

Observed Infrastructure Behavior must be interpreted in relation to Intended Functions and Intended Results.

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 precisely why Indicator 13.7 is necessary.

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 Adaptability and Innovation Readiness

Factor 14 again contains clear State functions.

An Infrastructure Quality Object may or may not possess the actual capability to adapt responsibly.

Safety and integrity may or may not remain preserved after Adaptation.

A changed configuration may or may not remain compatible with Functional Intent.

Reversibility or Recoverability may or may not actually exist.

Results and Outcomes following Innovation may be satisfactory or unsatisfactory.

Factor 14 therefore examines actual capabilities and resulting conditions as well as the determination and Influence functions needed to manage change.

Horizontal Pattern

Across the Core, 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 Indicator function.

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 Core 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 Core Quality Factors.

They are especially strong where the Core directly examines:

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 normative 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 Core

The provisional Quality-State Determination Indicator function 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.

Indicator 13.7 adds another important limit:

Documentation
≠ Quality State.

The existence of information does not establish that the information demonstrates an acceptable condition.

Quality-State Determination in Factor 14

Factor 14 requires determination of:

constraints on Adaptation;

effects of Adaptation on safety and integrity;

compatibility with Functional Intent, Boundaries, and Interfaces;

new Uncertainty introduced by Innovation;

Reversibility and Recoverability;

and

actual Results and Outcomes after Adaptation.

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 Core 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 Core 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 Indicator function across the IQI Core.

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 Core Quality 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 Core

The provisional Quality-State Influence Indicator function 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 IQI Core.

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 normative Core layer.

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 Core 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 Indicator function.

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 provides perhaps the clearest direct expression of Quality-State Influence together with Factor 5.

Adaptation is intentional change.

Indicator 14.2 asks whether safety and integrity remain preserved during that change.

Indicator 14.3 asks whether Adaptation remains compatible with Functional Intent, Boundaries, and Interfaces.

Indicator 14.5 concerns Reversibility and Recoverability.

Indicator 14.6 requires learning from actual Adaptation Results and Outcomes.

Indicator 14.5 is particularly important.

It asks whether an unsatisfactory changed condition can be reversed or whether acceptable Function Realization can otherwise be recovered.

The relationship is directly:

changed state
→ unacceptable result identified
→ reversal or recovery capability
→ movement toward acceptable Function Realization.

Factor 14 therefore strongly supports the provisional Influence classification.

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 Core 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 IQI Core 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 IQI Core, 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 Indicator function across the IQI Core.

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 Core Quality 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 Indicator functions:

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 Core Quality 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.

Reversibility and Recoverability under Factor 14 show the same relationship.

The capability exists as part of the present state of the Infrastructure Quality Object.

Its purpose is to influence the state if Adaptation produces an unacceptable result.

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 Core.

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 existing Core 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 Core definition of 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 normative IQI Core structure.

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 Core Quality 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 Core Quality 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 Core Quality Indicators.

This is a demanding test.

An apparent gap is not automatically a missing Core 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 existing Core 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 Core 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 Core 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 Core may already represent it through the interaction of Factors 5, 8, 9, 12, and 14.

Context Guide evidence is needed before any Core addition 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 Core 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 normative IQI term or Core Indicator.

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 Core 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 IQI Core 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 existing Core 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 the IQI Core should contain one Indicator for 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 existing Core leaves any recurring function materially uncovered.

Why Apparent Gaps Are Not Yet Core Gaps

The distinction between an apparent gap and a demonstrated Core gap 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 Core gap requires stronger Evidence.

The candidate function should:

be necessary to reliable Infrastructure Quality State Determination;

not already be sufficiently represented by existing Core Indicators;

remain distinguishable from existing Indicator functions;

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 present IQI Core 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 Core revision.

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 Core Indicator from a Context-Specific Need

The identification of an apparent Indicator gap does not establish that an invariant Core Quality 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 IQI Core 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 Core Quality Indicator?

Context-Specific Need

A finding should normally remain Context-specific when an existing Core Quality 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 Core 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 Core gap exists.

Greater Detail Does Not Establish a Missing Indicator

Context Guides normally operate at a smaller resolution than the Core.

They examine the Infrastructure Quality Object in greater detail.

Greater detail will naturally reveal conditions that do not appear explicitly in the invariant Core wording.

This is expected.

It does not mean that every newly visible condition requires another Core Indicator.

For example, a Context Guide may identify several different physical degradation mechanisms.

The Core 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 Core 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 Core 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 Core Indicator.

Fourth, the function must not merely represent a preferred method.

The IQI Core 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 Core.

Repeated appearance across substantially different Infrastructure Quality Objects provides stronger evidence that the function may be invariant.

Sixth, the function must remain meaningful at Core 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 Core-level resolution.

Testing Against the Existing Core Before Proposing Addition

Before a new Core Indicator is proposed, the candidate function should be tested against the complete existing Core.

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-Factor Core?

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 Core 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 Core 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 Core 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 Core 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 Core should not be expanded merely because different Contexts use different means to realize an already established function.

Threshold for a Missing Core Indicator

A candidate should therefore move from a Context-Specific finding toward a possible invariant Core 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 existing Core;

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 Core.

Even then, the finding should first be recorded as provisional.

Core revision should not follow 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 Core function.

A possible Core gap 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 IQI Core to remain stable without declaring the present Indicator set permanently sufficient.

It also provides the methodological bridge to Section 8.

The next Section examines how IQI Context Guides can be used not only as applications of the invariant Core, but also as research and test cases for evaluating the continuing adequacy of the Core Indicator set.

8. Testing the Indicator Architecture Through IQI Context Guides

8.1 Context Guides as Applications and Research/Test Cases

IQI Context Guides apply the invariant IQI Core to a declared infrastructure Context.

They do not create a separate quality model for each type of infrastructure.

The fourteen Core Quality Factors and their invariant Core Quality 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 invariant Core Indicator set.

These two roles should remain distinct but connected.

Context Guide as an Application of the Core

As an application, a Context Guide begins with the established Core.

It does not begin by independently creating a new set of Quality Factors and Indicators.

The basic relationship is:

IQI Core
→ 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 function may remain the same.

The Context Guide therefore provides greater detail without automatically changing the Core.

Context Guide as a Test of the Core

Application of the Core also tests it.

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 function?

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 perform the same function?

Does an important quality-relevant determination question appear that no existing Indicator adequately represents?

These questions cannot always be answered at the abstract Core 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 Core itself.

Testing Necessity Through Context

Section 6 applied a general removal test to the established Core 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 Core 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 Indicator Functions

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 functions 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 Core 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 New Indicator Functions

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 Core.

It should then be tested.

The first test is:

Can an existing Indicator reasonably represent this function?

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 missing Indicator function.

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 existing Core Indicators

→ testing in additional Context Guides

→ horizontal comparison across different infrastructure Contexts

→ determination of whether the function is Context-specific or invariant

→ possible Core revision.

This sequence prevents immediate Core modification after every new Context finding.

At the same time, it prevents the Core 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 a missing function 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 Indicator set increases.

This does not prove permanent sufficiency.

A new infrastructure Context may later reveal another function.

But the accumulated evidence strengthens the practical basis of the Core.

Likewise, if a provisional candidate repeatedly disappears when tested against existing Indicators, that finding should be recorded.

It may demonstrate that the existing Core is broader than initially apparent.

Context Guides as Controlled Core Development

The combined application and research roles of Context Guides therefore support controlled development of the IQI Core.

The Core remains 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 Core revision.

This relationship can be summarized as:

stable invariant Core

→ multiple Context-Specific applications

→ accumulated Evidence

→ horizontal research

→ provisional Core findings

→ controlled revision only when justified.

Interim Finding

IQI Context Guides can serve two legitimate purposes at the same time.

They apply the invariant IQI Core to specific Infrastructure Quality Objects.

They also provide practical research and test cases for evaluating the continuing adequacy of the invariant Core Quality 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 Core Indicators can be tested against increasingly detailed infrastructure conditions.

The next Section examines the Evidence already available from existing IQI Context Guides:

8.2 Evidence from Existing IQI Context Guides

The existing IQI Context Guides already provide an initial practical basis for testing the invariant Core Quality 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 Core Quality 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_JQF1 examined the existing Context Guide family as part of the justification of the fourteen invariant Core 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 functions 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 function.

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:

invariant Indicator function

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 function 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 of Intended Function Realization.

This provides practical evidence for the distinction:

Failure Mode
→ Context-specific manifestation of possible Function Realization failure.

Core Indicator
→ invariant subject or determination function through which the quality-relevant condition 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 Core 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 Core 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 function does not.

This supports the separation between:

Core 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 function.

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 Core-revision finding.

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 Indicator set 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 function that cannot be adequately represented through the existing Core Indicators?

If the answer is uncertain, the finding should remain provisional.

Evidence from one Context should not be used to redesign the Core prematurely.

What the Existing Context Guides Demonstrate

The existing Context Guide evidence supports several conclusions.

First, the invariant Core 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 Indicator function 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 possible missing functions that deserve further testing.

What the Existing Context Guides Do Not Demonstrate

The existing Context Guide family does not demonstrate that the present Indicator set is permanently sufficient.

The number and variety of infrastructure Contexts remain limited.

New Contexts may reveal relationships or determination functions 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 Core Indicator set as a workable invariant basis for continued application and testing.

It does not establish permanent closure of that set.

Interim Finding

The existing IQI Context Guides provide practical evidence supporting the use of invariant Core Quality 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 Core.

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 more closely how one invariant Indicator can retain the same Core meaning while being interpreted differently across infrastructure Contexts:

8.3 Interpretation of Invariant Indicators in Different Infrastructure Contexts

An invariant Core Quality 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 Core Quality Indicator
→ context-specific interpretation
→ Context-Specific Evidence
→ Context-Specific Quality Outcome Criterion.

The Core 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 Core 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 Core question 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 of required 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 function.

Therefore:

different Failure Mode
≠ different Core 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 Core does not need to prescribe one universal Evidence type.

Its purpose is to identify the quality-relevant determination subject.

This distinction protects the Core 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 Core Indicator and Quality Outcome Criterion are separate.

The Core determines what is examined.

The Context determines what condition is expected or acceptable.

Different Resolution

Context Guides also operate at a smaller resolution than the Core.

This means that one invariant Indicator may require several detailed Context-Specific questions.

For example:

one Core 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 Core Indicator set.

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 Core gap.

If a necessary quality-relevant determination function repeatedly cannot be represented by the established Indicator set, it should not be artificially placed under the nearest existing Indicator merely to preserve the current Core.

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 give the Indicator an unrelated function.

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 function.

Interpretation and Apparent Overlap

context-specific interpretation can also help resolve apparent overlap among Core Indicators.

At the Core level, 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 Core 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 Core Quality 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 Core Indicator.

This distinction allows the Core 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 genuinely missing invariant function.

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 Core Quality 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:

Core Quality 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 Core Indicator set.

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 Core 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 Core.

If every Context-Specific acceptable value or condition were placed directly into the Core 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 Core 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 Core.

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 Core 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 function must first be identified.

The research sequence is:

new Evidence
→ previously insufficiently visible condition
→ identification of the underlying determination function
→ test against existing Core 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 Core 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 Core 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 function makes this criterion necessary?

That function should then be tested against the existing Core.

Only after that analysis could a possible additional Core 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 Core 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 Core 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 invariant Indicator function.

Interim Finding

Context-Specific Evidence and Quality Outcome Criteria are essential to applying the invariant Core Quality Indicators, but they perform different functions.

The Core 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 Core Indicator should be considered only where the underlying necessary determination function cannot be adequately represented by the established Core Indicator set.

This distinction is important for keeping the IQI Core 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 function repeatedly appears across different Infrastructure Quality Objects and remains insufficiently represented by the established Core Quality Indicators.

This Section therefore focuses on recurrence.

The basic research sequence is:

Context Guide finding
→ identification of the underlying determination function
→ test against the existing Core
→ 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 function.

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 function?

If yes, the evidence for a possible invariant Core gap becomes stronger.

Recurring Technical Detail Is Not Enough

A recurring technical feature does not automatically justify a Core 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 missing invariant quality function.

The Core 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 Core Indicator already represents that function, no Core gap 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 Core determination function.

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 function appears in more than one Context.

Second, the Contexts are materially different.

Third, the function is necessary for responsible Infrastructure Quality State Determination or Influence.

Fourth, the function cannot be adequately represented by the existing Core Indicator set.

Fifth, omission of the function creates a material loss of visibility or determinability.

Sixth, the function can be stated at a Core-level resolution without depending on one technology or sector.

The relationship can be expressed as:

different infrastructure Contexts
→ different physical manifestations
→ same unresolved determination function
→ possible invariant Core significance.

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 function 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 Core.

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 function already represented in the complete Core?

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 Core gaps.

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 existing Core 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 Core Indicator set.

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 Core 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 function remains.

The research method should permit all of these outcomes.

Threshold Before Escalation

A provisional finding should become a stronger Core-revision candidate only after repeated testing.

At minimum, the research should establish that:

the function recurs;

the recurrence is not merely technical similarity;

the function remains necessary;

the function remains unresolved after testing against the complete Core;

the function is distinguishable from existing Indicators;

and

the function can be expressed at invariant Core 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 function appear again in a materially different Context and remain insufficiently represented by the current Core?

This distinction protects both sides of the IQI Indicator structure.

It protects the Core from unnecessary expansion.

It also protects the Core from artificial closure.

Repeated Context Guide evidence can therefore strengthen confidence in the present Indicator set or identify a legitimate candidate for later controlled Core revision.

The next Section addresses the threshold for that transition:

8.6 When a Context-Guide Finding May Support a New Invariant Core Indicator

A Context Guide may reveal an important quality-relevant condition that is not explicitly visible in the present Core Indicator set.

That finding should not automatically result in a new invariant Core Quality Indicator.

The threshold must be higher.

The Core is intended to remain invariant across different infrastructure Contexts.

A new Core Indicator should therefore represent a necessary determination function 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 Core Quality Indicator?

The Starting Point — A Context-Guide Finding

The process begins with application of the existing Core.

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 Core 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 Core Indicator set should be examined.

The question is:

Can an established Indicator reasonably and sufficiently represent this determination function?

The test should not be limited to the Quality Factor under which the finding first appeared.

The function may already be represented elsewhere in the Core.

If an existing Indicator adequately covers the function, a new Core Indicator is not justified.

The Context Guide may require more detailed interpretation.

But:

need for greater detail
≠ missing Core 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 function, 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 function must be identified before any Core addition 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 invariant Core should normally identify the required determination function rather than one method used to realize it.

Therefore:

necessary Context-Specific method
≠ necessarily an invariant Core Indicator.

The research should ask:

What underlying function makes this method necessary?

That function, rather than the method itself, is the possible Core candidate.

Test 6 — Does the Finding Result from an Incomplete Boundary or Interface?

Before identifying a Core gap, the declared Infrastructure Quality Object must also be checked.

An apparent missing function may result from exclusion of 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 Core Indicator set.

Test 7 — Is the Function Necessary?

If the finding remains unresolved, the necessity test should be applied.

The question is:

If this determination function 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 invariant Core status.

If removal creates a meaningful blind area, the case becomes stronger.

The removal test can be expressed as:

candidate function removed
→ important quality-relevant condition no longer sufficiently determined
→ possible necessity established.

Necessity alone is still not sufficient.

Test 8 — Is the Function Distinguishable?

The candidate must also preserve a determination question that is meaningfully different from the established Indicators.

Two functions may use different words while asking substantially the same question.

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 Function 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 function 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 function.

This is stronger evidence of invariance than simple repetition of the same technical problem within one infrastructure sector.

Test 10 — Can the Function Be Stated at Core Resolution?

A candidate invariant Indicator must also be expressible at the same general level as the existing Core 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 Core.

The Core-level wording should identify the common quality-relevant function.

The Context Guide should provide the smaller-resolution realization.

The relationship should remain:

invariant function
→ 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 function remains meaningful during relevant stages such as:

Design;

Construction;

Commissioning;

Operation;

Maintenance;

Repair/Modification;

and

Decommissioning/Transition.

A function that appears only because of one highly specific Lifecycle activity may be more appropriately handled through context-specific interpretation.

A function 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_JQF1 justified the fourteen invariant Core 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 function 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_JQF1.

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 function 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 function remain visible?

This makes Context diversity important to Core development.

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 Core.

It helps explain what the candidate contributes.

A candidate whose function cannot be clearly stated may not yet be sufficiently developed for Core consideration.

From Context Finding to Core Candidate

The complete process can therefore be expressed as:

Context Guide finding

→ identify the underlying determination function

→ test against existing Core 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 Core resolution

→ identify its relationship to an existing Quality Factor

→ record as a provisional Core Indicator candidate.

Even at this point, Core revision does not automatically follow.

Provisional Candidate Is Not a Core Indicator

This distinction must remain explicit.

A candidate may satisfy enough tests to deserve continued study without having sufficient support for normative Core inclusion.

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 Core.

Only after sufficient support exists should controlled Core revision be considered.

Interim Finding

A Context-Guide finding may support consideration of a new invariant Core Quality 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 underlying function must be:

quality-relevant;

necessary;

distinguishable;

non-redundant;

meaningful at Core 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 Core to develop when Evidence requires development.

At the same time, it prevents Context-specific findings from producing unnecessary Core expansion.

Section 8 therefore establishes the practical research mechanism:

Context Guides apply the Core.

Application tests the Indicators.

Repeated findings are compared horizontally.

Unresolved recurring functions are preserved provisionally.

Only sufficiently supported invariant findings become candidates for controlled Core revision.

The next Section provides the formal place for preserving those findings without prematurely changing IQC1:

9. Provisional Additional Indicator Findings

9.1 Purpose of Provisional Indicator Findings

The analysis in Sections 6 through 8 does not establish that additional invariant Core Quality 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 Core revision.

At the same time, they should not be inserted into IQC1 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 function that may not be sufficiently represented by the present Core Indicator set.

Its purpose is to preserve the finding for continued testing.

It is not an additional Core Quality Indicator.

It does not modify IQC1.

It does not create a new requirement for IQI Context Guides.

It does not establish that the present Core is deficient.

The distinction can be expressed simply:

possible unresolved function
→ Provisional Additional Indicator Finding;

repeated supporting Evidence
→ stronger Core candidate;

sufficient justification
→ possible controlled Core revision.

Why Provisional Findings Are Needed

The present paper applies two different standards of proof.

For an established Core 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 function 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 Core.

Without a provisional category, two undesirable results are possible.

The first is premature Core expansion.

Every important Context Guide finding could produce another Core Indicator.

The Core would gradually become a collection of Context-specific details.

The second is artificial closure.

A finding that does not immediately justify Core revision 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 normative Core.

What Should Be Recorded

A Provisional Additional Indicator Finding should identify the underlying function 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:

Is there a recurring quality-relevant function concerning the ability to connect Quality-State determination to effective intervention within the available time?

This formulation allows the same function 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 function 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 existing Core Indicators tested against it;

why existing coverage may be insufficient;

the consequence of removing the function from the determination;

its possible Quality-State, Quality-State Determination, or Quality-State Influence function;

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 Function-Based

The distinction between function and method 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 Core Indicators.

The research should ask what common function 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 functional level.

Relationship to the Existing Core

Every provisional finding should remain linked to the existing Core.

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 function;

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 Core revision.

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 function is not represented, what becomes materially less determinable?

If no meaningful loss can be identified, the finding should not progress toward Core status.

The function may still be useful.

But usefulness alone is not enough.

The invariant Core should contain necessary determination functions, not every function 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 function 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 Core Indicator.

Repeated appearance of the same underlying function 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 Core-level resolution.

The finding can then be closed.

This prevents the provisional research record from becoming an informal second Core.

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 function.

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 functional level.

The opposite is also possible.

One broad provisional finding may later prove to contain two distinguishable necessary functions.

The research structure must allow both results.

Relationship to the Three Provisional Indicator Functions

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 Core;

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 functions.

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 actually parts of one larger function.

However, the S/D/I classification remains provisional.

A candidate should not be retained merely because it fits one of these three functions.

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 Core Quality Indicator.

The established Indicators remain the governing Core set.

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 function.

They should therefore not yet be formulated as proposed new Core Indicators.

Their proper status is provisional research findings.

Research Without Premature Core Revision

The provisional category allows IQI development to follow Evidence rather than assumptions.

The Core does not need to be revised whenever a new question appears.

Nor does the Core need to be declared permanently complete.

The relationship is:

stable Core
+
open research
→ controlled development.

This is particularly important at the Indicator layer.

The fourteen Quality Factors provide the invariant dimensions established in IQI_JQF1.

The Indicator layer operates at a smaller resolution.

Repeated Context Guide work may therefore reveal determination functions that were not sufficiently visible when the present Indicator set was first established.

Keeping this possibility open is not a weakness in the Core.

It is a controlled way of testing the Core against increasing practical Evidence.

Interim Finding

Provisional Additional Indicator Findings provide a formal research space between a Context-Specific observation and an invariant Core revision.

They allow a possible missing function to be:

identified;

recorded;

tested against the existing Core;

compared across Context Guides;

examined horizontally;

strengthened;

combined;

rejected;

or

eventually supported for controlled Core revision.

At the present stage, no provisional finding identified in this paper should be treated as an additional IQI Core Quality Indicator.

The next Section establishes the 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 IQC1, but it should still be controlled.

The purpose is to preserve a potentially important determination function 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 function not sufficiently visible in the present Core Indicator set.

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 function 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 Core coverage.

A candidate may be worth recording precisely because its relationship to the existing Core is not yet fully resolved.

For example, the function 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 functional 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 function.

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 function does this Evidence support?

If that function is already represented, the finding remains Evidence.

If the Evidence reveals a previously insufficiently represented function, that function 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 function 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 Core research.

The eleventh criterion is Core-level wording.

The candidate should be capable of being expressed at a level consistent with the existing Core 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 Core.

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 Core.

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 Core Quality Factor or Factors;

Existing Indicators tested against the finding;

Reason present coverage may be insufficient;

Possible consequence if the function is omitted;

Possible State / Determination / Influence function;

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 existing Core;

Context-specific;

Method-specific;

Combined with another provisional finding;

Rejected as non-necessary;

or

Candidate for controlled Core review.

These are research statuses.

They do not create normative classifications in IQC1.

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 a Core Indicator.

The wording should remain neutral.

For example:

Possible determination-to-intervention continuity function.

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 Core-level determination function may remain insufficiently represented.

The candidate should be:

quality-relevant;

function-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 Core revision.

But it is high enough to keep the provisional research record focused on findings that may materially affect the continuing adequacy of the IQI Core Indicator set.

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 Core Quality 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 existing Core Indicators rather than from one isolated Factor.

They should therefore be examined horizontally.

Finding 1 — Continuity from Quality-State Determination to Intervention

The existing Core 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 function can be expressed as:

Quality-State determination
→ communication
→ decision
→ Authority
→ action.

The present Core addresses 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 function 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 function 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 invariant function.

The possible function 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 IQC1.

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 function is therefore not:

shutdown whenever uncertainty exists.

The provisional function 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 existing Core already includes Recovery Capability under Operational Reliability and Reversibility and Recoverability under Adaptability and Innovation Readiness.

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 Core 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 Core appears to contain substantial coverage of this function.

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 Core 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 functional break remains insufficiently visible when the Core is 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 functions;

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 Core Quality 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 Core coverage must be tested before any new Indicator is proposed.

Interim Finding

The present Core clearly contains Quality-State Influence functions.

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 Core 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 Core already contains strong Determination functions.

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

Adaptability and Innovation Readiness.

The present analysis therefore does not suggest that Quality-State Determination is absent from the Core.

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 Core addresses 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 function may be described provisionally as:

Quality-State Information Integrity.

This term should remain a research term.

It is not presently proposed as a new normative IQI term.

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 Core 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 function 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 Core 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 function 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 normative vocabulary at this stage.

The present analysis does not establish that this condition requires a separate Core 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 Core.

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 Core appears to contain 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;

Quality State cannot presently be determined with sufficient confidence.

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 sufficiently preserve an indeterminate Quality State where the available Evidence cannot support either an acceptable or unacceptable 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 state 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 IQI Quality State model and vocabulary before any new Core 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 Core 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 function 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 function:

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 produce an indeterminate 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 Core Quality 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 Quality State;

and

timeliness of the complete determination process.

These subjects should be tested through Context Guides before any Core revision is considered.

Interim Finding

The existing Core contains extensive Quality-State Determination functions.

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 functions that may become important when the Core 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 Core contains 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 functional break 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 Core appears to contain 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 Quality State and Influence

Section 9.4 distinguished three possible determination conditions:

acceptable Quality State demonstrated;

unacceptable Quality State demonstrated;

and

Quality State cannot presently be determined with sufficient confidence.

The third condition creates an important Cross-Function Finding.

An indeterminate Quality State is a Determination result.

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 Quality State
≠ universally unacceptable physical state;

but also:

indeterminate Quality State
≠ 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?

The invariant Core 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-function 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 function.

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-function 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 functions 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 functions 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 Core contains Indicators addressing many parts of this path.

The research question is not whether every step needs a separate Core Indicator.

It is:

Does the existing Core, 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 Core Quality Indicator.

They demonstrate that the three provisional functions 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 functions 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 examines how these provisional findings should be handled without prematurely changing the established IQI Core:

9.6 Why Provisional Findings Do Not Yet Justify Core Revision.

9.6 Why Identification Does Not Automatically Require Core Revision

The identification of a Provisional Additional Indicator Finding does not automatically require revision of IQC1.

This distinction is necessary to preserve both stability and continued research.

The present IQI Core contains the established fourteen invariant Quality Factors and their Core Quality Indicators.

A provisional finding has a different status.

It identifies a question that deserves further testing.

It does not establish that the existing Core 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 Core gap;

demonstrated Core gap
≠ automatic Core revision;

sufficient accumulated justification
→ possible controlled Core revision.

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 Core requirement.

Existing Core Coverage Must Be Tested First

Before revision is considered, the finding must be tested against the complete existing Indicator set.

This test should not be limited to the Factor where the issue was first identified.

Horizontal analysis may show that the function 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 function is missing.

The correct test is functional:

Can the existing Core sufficiently determine the condition when its relevant Indicators are applied together?

If yes, Core revision 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 Core Indicator is intentionally general.

The Context Guide provides the detail.

Therefore, absence of specific technical wording in IQC1 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 Core revision.

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.

Core revision should not be used to correct an incomplete Context definition.

Repeated Evidence Is Required

A stronger case begins when the same underlying determination function appears repeatedly.

Even then, repetition alone is not sufficient.

The research must determine whether the function recurs across materially different Infrastructure Quality Objects.

The physical manifestations may differ.

The underlying function 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 Core.

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 Core from becoming dominated by the needs of one infrastructure sector.

Necessity Must Be Demonstrated

A candidate should not enter the Core merely because it improves description.

The removal test remains necessary.

The research must ask:

If this candidate function is not represented, what material part of Infrastructure Quality State Determination is lost?

If the answer is unclear, the case for revision is weak.

If repeated Context Guide analysis shows that omission consistently creates a material blind area, the case becomes stronger.

The Core should contain necessary invariant determination functions.

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 Indicator set.

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 Remain at Core Resolution

A provisional finding may be necessary and recurring but still belong below Core resolution.

This is possible where the function 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 Core Indicator.

The Core candidate must be capable of being stated independently of those particular realizations.

The relationship must remain:

invariant determination function
→ different Context-Specific realizations.

If that relationship cannot be established, the finding should remain below Core level.

Provisional State / Determination / Influence Functions Do Not Change the Core

The Quality-State, Quality-State Determination, and Quality-State Influence functions examined in this paper are research tools.

Their usefulness does not itself justify revision of IQC1.

The present Core Indicators may perform one or more of these functions 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 function appear weak?

Does a possible gap recur across Factors or Contexts?

The classification should therefore support analysis.

It should not predetermine Core structure.

A Provisional Finding May Strengthen the Existing Core Without Changing It

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 existing Core.

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 Core Revision

Core revision becomes a legitimate question only after a substantially stronger case has developed.

The research should support that:

the function is quality-relevant;

the function is necessary;

removal materially weakens Quality-State determination;

existing Core Indicators do not sufficiently represent it;

the function 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 function recurs across materially different infrastructure Contexts;

and

the function can be stated at invariant Core resolution.

Only then does the question change from:

Should this finding continue to be researched?

to:

Should this function be considered for inclusion in the invariant IQI Core?

Even this stronger finding begins the Core-revision question.

It does not answer it automatically.

Why This Caution Is Necessary

The invariant Core serves a different purpose from a Context Guide.

The Context Guide should become detailed.

The Core should remain general enough to apply across infrastructure Contexts.

If every important Context finding changed the Core, the distinction between the Core and Context Guides would gradually disappear.

The opposite error must also be avoided.

If the present Indicator set were treated as permanently closed, repeated evidence of a genuinely missing invariant function could not be incorporated.

The required position is therefore neither constant revision nor permanent closure.

It is:

stable Core
+
continued testing
+
preserved provisional findings
+
controlled revision 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 Indicator set need not be claimed.

Interim Finding

Provisional Additional Indicator Findings provide evidence for continued research.

They do not themselves provide sufficient grounds for changing IQC1.

A finding should first be tested against:

existing Core coverage;

context-specific interpretation;

Evidence and Quality Outcome Criteria;

Boundary and Interface definition;

necessity;

distinguishability;

Context recurrence;

and

Core-level applicability.

The finding may then be:

resolved through the existing Core;

retained for additional research;

combined with another finding;

rejected;

or

eventually supported as a candidate for controlled Core revision.

This separation allows IQI to preserve a stable invariant Core without declaring the present Indicator set permanently sufficient.

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 present Core Quality Indicators are necessary to the invariant IQI Core at the present stage of development.

Second:

the present Indicator set should not be declared permanently closed.

These conclusions are not contradictory.

Necessity concerns the established Indicators individually.

Closure concerns whether no additional invariant Indicator could ever be justified.

The present research can support the first conclusion without claiming the second.

Necessity of the Established Indicators

The Factor-by-Factor analysis examined the established Core Quality 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 several recurring functions appear 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 horizontal function 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 function 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 make those dimensions sufficiently observable and determinable.

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 Core Quality 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 function remains available and meaningful when the applicable infrastructure Context requires it.

The Context Guide provides the smaller-resolution interpretation.

Necessity Does Not Mean Every Indicator Performs Only One Function

The horizontal analysis also showed that one Indicator may contribute to more than one provisional function.

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 functions 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 Indicator set must be more limited.

The present analysis can examine the established Indicators and ask whether each remains necessary.

It cannot demonstrate that no additional invariant determination function 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.

Smaller-resolution analysis may expose functions that were hidden at Core resolution.

For these reasons, permanent sufficiency would be a stronger claim than the present Evidence supports.

The appropriate conclusion is therefore:

the present Indicator set is supported as necessary and presently adequate as a basis for continued application and testing;

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 Core Indicator set provides a workable invariant basis for current IQI application and continued Context Guide development.

Permanent closure would mean that no additional invariant Indicator could ever be justified.

The present study does not make that claim.

This distinction allows the Core to remain stable without becoming conceptually closed.

Context Guides Provide the Continuing Test

The principal mechanism for testing continuing adequacy is the IQI Context Guide family.

Each Context Guide applies the same invariant Core to a more specific Infrastructure Quality Object.

This produces a repeated test.

The relationship is:

stable Core
→ 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 Indicator set.

Repeated unresolved findings may identify a possible Core gap.

Both results are useful.

Evidence Supporting the Core 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 functions, the Evidence supporting the present Core becomes stronger.

The research sequence may therefore produce:

new Context
→ apparent issue
→ existing Indicator found sufficient
→ stronger evidence supporting existing Core 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 Supporting Revision Can Also Accumulate

The opposite result must remain possible.

A Context Guide may identify a determination function 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 function 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
→ Core-resolution test
→ possible controlled Core review.

This process allows revision to follow Evidence rather than assumption.

Why Immediate Revision Would Be a Weakness

Immediate Core revision after every important Context finding would create several problems.

The Core 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 Core.

The distinction between the two levels would weaken.

A stable Core 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 Indicator set were declared permanently complete, new Evidence could not meaningfully test its sufficiency.

Context Guides would then become only applications of the Core.

They could no longer serve as research/test cases for Core development.

A necessary determination function 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 normative Core.

A finding can be:

recorded;

tested;

compared;

combined;

refined;

rejected;

or

eventually supported for controlled Core review.

This creates a separation between:

research finding;

and

Core requirement.

That separation is important for disciplined development of the Indicator layer.

The Three Provisional Functions 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 the fourteen-Factor Core.

It does not reorganize the Core Indicators.

Its purpose is to make horizontal functions 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?

Are any necessary functions repeatedly weak or missing?

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 IQI Core Indicator set.

2. Apply it through Context Guides.

3. Interpret the Indicators at smaller Context-specific resolution.

4. Identify appropriate Evidence and Quality Outcome Criteria.

5. Record apparent gaps without immediately changing the Core.

6. Test those findings against the complete existing Indicator set.

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 function.

10. Consider controlled Core revision 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.

The present analysis supports retention of the established Core Quality Indicators because removal of their distinguishable determination functions would materially weaken the ability of the corresponding Quality Factors to support Infrastructure Quality State Determination. This supports the necessity of the preserved functions within the present Core architecture; it does not establish that the exact current wording, decomposition, or placement of every Indicator is uniquely optimal.

Horizontal overlap does not invalidate that necessity.

Different Indicators may perform similar functions while preserving different determination subjects.

At the same time, the present research does not establish that the Indicator set is permanently sufficient.

Such a conclusion would require knowledge of all relevant infrastructure Contexts and all determination functions that may become visible through continuing application.

That Evidence does not exist.

The defensible position is therefore:

The present analysis supports the necessity of the IQI Core Quality Indicator set as the current invariant basis for Infrastructure Quality State Determination.

Its continuing adequacy should be tested through Context Guide application and horizontal comparison.

Possible additional invariant functions should be preserved as provisional findings and incorporated into the Core only when their necessity, distinguishability, non-redundancy, and Context invariance are sufficiently demonstrated.

In shorter form:

necessary
≠ permanently exhaustive;

stable
≠ closed;

open to justified revision
≠ continuously changing.

The following Subsections consolidate the results of this analysis, distinguish what the present research supports from what it does not establish, and state the present status of the IQI Core Indicator set.

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 IQI Core Quality 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 function 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 Indicator set.

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;

Core Quality 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 make Functional Specification Quality determinable through the necessary elements of the Functional basis.

Under Factor 2, the Indicators make Technical Specification Quality determinable through the technical basis needed to realize the required functions.

Under Factor 3, the Indicators make Conformity Assessment determinable through Evidence-supported evaluation of whether applicable requirements have been fulfilled.

Under Factor 4, the Indicators make Structural and Functional Integrity determinable through the conditions affecting the ability of the realized infrastructure to maintain required physical and functional integrity.

Under Factor 5, the Indicators make Process Safety and Risk Mitigation determinable through identification and treatment of conditions that may lead to Loss-of-Control or other unacceptable consequences.

Under Factor 6, the Indicators make Environmental Protection determinable through the conditions affecting Environmental Interaction, prevention, limitation, and resulting Environmental Effects.

Under Factor 7, the Indicators make Operational Reliability determinable through actual Function Realization, disturbance tolerance, degradation, Recovery Capability, and related operating conditions.

Under Factor 8, the Indicators make Workplace Human Interaction and Safety determinable through the quality-relevant conditions at the human–infrastructure Interface.

Under Factor 9, the Indicators make Competence of Personnel determinable for Infrastructure-Critical Roles, including competence under relevant normal, abnormal, degraded, and non-routine conditions.

Under Factor 10, the Indicators make Regulatory and Standards Compliance determinable through identification, application, maintenance, and change of Applicable Requirements.

Under Factor 11, the Indicators make Stakeholder and Community Satisfaction determinable through quality-relevant Infrastructure Effects, supported observations, and resulting conditions affecting Stakeholders and Communities.

Under Factor 12, the Indicators make Monitoring and Performance Evaluation determinable through observation, detection, interpretation, and continuing relevance of information about infrastructure performance and condition.

Under Factor 13, the Indicators make Documentation and Traceability determinable through preservation, linkage, accessibility, and continuity of Quality-Critical Information and Evidence.

Under Factor 14, the Indicators make Adaptability and Innovation Readiness determinable through controlled change, preservation of Functional Intent and Integrity, Reversibility or Recoverability, and evaluation of actual 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 invariant Core status.

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 make determinable?

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 Indicator set.

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 function 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 function 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 functions.

Results of the Context-Invariance Test

The existing Context Guide evidence supports continued treatment of the established Indicators as invariant Core 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 functions remain meaningful.

This supports the proposition:

invariance belongs to the determination function, not to identical physical realization.

The present Context Guide evidence is not sufficient to demonstrate permanent completeness of the Indicator set.

But it supports continued use of the established Indicators as the invariant Core basis.

Results of the Three-Function 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 functions.

This functional 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-function classification therefore remains useful as a horizontal research tool.

The analysis does not support introducing it as a new normative Core 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 Core 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 Indicator set is also permanently sufficient.

The present research does not make that stronger claim.

Overall Result

The Indicator necessity tests support retention of the established IQI Core Quality Indicators.

The principal reason is functional.

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:

The established IQI Core Quality Indicators are supported as necessary components of the present invariant Core Indicator set.

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 IQI Core Quality Indicators.

These conclusions should be stated carefully.

The purpose is not to claim more than the analysis demonstrates.

The principal conclusion is that the established Indicators are necessary components of the present IQI Core Indicator set.

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 Core Quality Indicators identify the smaller determination questions needed to make that Factor sufficiently observable and determinable.

The relationship is:

Quality Factor
→ major quality-relevant dimension;

Core Quality 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 performs a necessary determination function.

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 Core status 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 Core 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 make determinable?

The same horizontal function 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 Core 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 function.

Therefore:

invariant Indicator
≠ identical physical condition in every Context.

This allows the same Core Indicator to be interpreted through different Context Guides without changing its Core meaning.

5. context-specific interpretation Does Not Change the Core Indicator

The analysis demonstrates the importance of separating:

Core Indicator;

context-specific interpretation;

Evidence;

and

Quality Outcome Criterion.

The relationship is:

Invariant Core Quality 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 Core.

This separation allows the Core 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 function 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 Core 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 Core 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 Core 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 functions.

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 Quality State Is Distinguishable from an Acceptable or Unacceptable State

The analysis demonstrates an important logical distinction.

The following conclusions are not equivalent:

acceptable Quality State demonstrated;

unacceptable Quality State demonstrated;

Quality State cannot presently be determined with sufficient confidence.

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 Influence response to an indeterminate state remains Context-specific.

14. Human Participation May Extend Across Several Quality Functions

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:

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 Core

The analysis supports the conclusion that Context Guides have two compatible functions.

They apply the invariant Core to specific Infrastructure Quality Objects.

They can also provide practical Evidence for testing the continuing adequacy of the Core.

The relationship is:

Core
→ Context Guide application
→ smaller-resolution findings
→ 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 IQC1.

It means that repeated Context Guide application can provide Evidence relevant to later Core research.

16. Provisional Findings Can Be Preserved Without Changing the Core

The analysis supports the usefulness of maintaining Provisional Additional Indicator Findings.

This allows a possible unresolved function to remain visible without prematurely becoming normative.

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 provides a controlled connection between Core stability and continued research.

17. The Three Provisional Functions Are Useful for Horizontal 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.

The three functions can help identify:

recurring determination functions;

possible overlap;

possible gaps;

connections between information and action;

and

relationships among different Factors.

The analysis does not demonstrate that these three functions should become a new normative layer of IQC1.

Their present value is analytical.

18. The Present Core Indicator Set Is Supported for Continued Use

Taken together, the analysis supports continued use of the established Core Quality 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 Core 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 present analysis supports the conclusion that the established IQI Core Quality Indicators perform necessary and distinguishable functions in making the fourteen invariant Quality Factors sufficiently observable and determinable.

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 Indicator set;

continued Context Guide application;

horizontal comparison of recurring Indicator functions;

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 necessity of the established Core Quality Indicators and their continued use as the present invariant Indicator set.

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 Permanent Completeness of the Indicator Set

The analysis does not demonstrate that the present Core Quality 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 function.

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 functions 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 Core 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 Core Indicator Is Presently 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 Core.

In particular, the present analysis does not yet demonstrate that any provisional function is simultaneously:

necessary;

distinguishable;

non-redundant;

insufficiently represented by the existing Core;

recurring across materially different infrastructure Contexts;

and

expressible at invariant Core resolution.

Therefore, no additional Core Quality 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 function 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 Core 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 function.

For example, an Indicator may describe an actual infrastructure capability while also supporting determination of that capability and its effectiveness.

The three-function model should therefore remain a research tool at this stage.

The analysis does not demonstrate that IQC1 should be reorganized around these three functions.

7. The Analysis Does Not Establish Quality-State Information Integrity as a New Normative Indicator

Quality-State Information Integrity emerged as an important provisional research subject.

However, the present analysis does not demonstrate that it requires a separate Core Indicator.

Its underlying functions may already be substantially represented through existing Indicators concerning:

Conformity Evidence;

Workplace Human Interaction;

Personnel Competence;

Monitoring;

Documentation and Traceability;

and

other relevant Core 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 functions 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 function 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 Core-Revision Documents

Context Guides provide Evidence for testing the Core.

They do not independently modify IQC1.

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 Core review could determine whether the normative Core should change.

Therefore:

Context Guide finding
≠ Core revision.

This separation preserves the respective functions of the Core and its Context Guides.

17. The Analysis Does Not Demonstrate That Core Revision Is Currently Necessary

Taken together, the present findings do not provide sufficient grounds for immediate revision of the IQI Core Indicator set.

The established Indicators remain supported for continued use.

The provisional findings provide a research agenda.

They do not establish a current normative deficiency requiring correction.

The appropriate present approach is therefore:

maintain the Core;

continue Context Guide development;

preserve provisional findings;

compare them horizontally;

and

reconsider the Core only when accumulated Evidence justifies reconsideration.

Overall Limitation

The present analysis is a justification and testing study.

It supports the necessity of the established Core Quality 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 Core Indicators.

It does not convert provisional research concepts into normative IQI requirements.

The conclusion should therefore remain deliberately bounded:

The present IQI Core Quality Indicator set is supported as the current invariant basis 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 Core Indicator set:

10.4 Present Status of the Core Indicator Set

The analysis in this paper supports retention of the established IQI Core Quality Indicator set in its present form.

At this stage, the research does not provide sufficient justification to:

add a new invariant Core Quality Indicator;

remove an established Core Quality Indicator;

combine established Indicators;

reorganize the Indicators into a different Core structure;

or

revise the established fourteen Quality Factors.

The appropriate present status is therefore:

Core Indicator set retained
+
continued Context Guide testing
+
horizontal Indicator research
+
provisional findings preserved separately.

This position does not mean that the Core 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 Core Quality Indicators remain the invariant Indicator set 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 interaction and recurring functions among 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.

Possible horizontal functions 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 form an additional normative Core layer.

They do not require restructuring of the existing Factor–Indicator relationship.

The present structure remains:

Quality Factor
→ Core Quality Indicators
→ context-specific interpretation
→ Quality Outcome Criteria
→ Evidence.

Status of the Three Provisional Functions

The three provisional functions 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 perform 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 fourteen-Factor structure remains the Core structure.

The three-function 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 Core 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 existing Core already contains relevant functions 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 Core 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 Quality State

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 IQI 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 Core.

Their primary function remains application of the Core to specific Infrastructure Quality Objects.

At the same time, their accumulated findings can provide Evidence for Core 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 invariant Core remains adequate at smaller Context-specific resolution.

The second function does not give an individual Context Guide authority to modify the Core.

It provides Evidence for later horizontal research.

Status of Provisional Additional Indicator Findings

Provisional Additional Indicator Findings should remain outside the normative Core.

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 existing Core;

Context-specific;

Combined with another finding;

Rejected;

or

Candidate for controlled Core review.

Only the last status would justify beginning a formal review of possible Core change.

Even then, Core revision would require separate justification.

Present Research Direction

The most useful next research step is therefore not immediate revision of IQC1.

It is continued application.

New Context Guides should apply the established Core without assuming either:

that a new Indicator must be found;

or

that the present Indicator set must always be sufficient.

Where an apparent gap occurs, it should first be tested against:

the complete existing Indicator set;

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 function remains.

Horizontal comparison can follow as the Context Guide family grows.

Present Core Position

The present Core position can therefore be stated simply:

The fourteen invariant Quality Factors remain unchanged.

The established Core Quality Indicators remain unchanged.

No additional invariant Core Quality 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 functions remain research tools.

The provisional findings identified in this paper remain outside the normative Core.

Context Guides remain the principal practical means for continued testing.

Future Core revision remains possible only where accumulated Evidence demonstrates a necessary, distinguishable, non-redundant, and Context-invariant function not adequately represented by the existing Core.

Overall Finding of Section 10

Section 10 therefore reaches a deliberately balanced conclusion.

The present Core 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 IQI Core 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 IQI Core development:

11. Research Findings and Implications for IQI Core Development

The analysis in this paper produces findings that extend beyond the necessity test of individual Core Quality Indicators.

The Factor-by-Factor analysis, horizontal comparison, and Context Guide research method together provide a basis for continuing development of the IQI Core without requiring immediate revision of IQC1.

The principal implication is that Core development should proceed through accumulated Evidence.

The present Core should remain stable while Context Guides continue to test it at smaller resolution.

This creates a continuing relationship:

IQI Core
→ Context Guide application
→ Context-Specific findings
→ horizontal comparison
→ stronger justification of the existing Core

or, where appropriate,

→ provisional unresolved finding
→ additional testing
→ possible later Core review.

11.1 Context Guides as Applications and Research/Test Cases

IQI Context Guides have a primary practical function.

They interpret the invariant Core 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.

They can operate as research/test cases for the continuing adequacy of the Core.

These two functions are compatible.

Application of the Core

For application purposes, the Context Guide begins with the established Core.

It does not begin by creating a new Indicator structure.

The relationship remains:

Core Quality Factor
→ Core Quality Indicator
→ context-specific interpretation
→ Quality Outcome Criterion
→ Evidence
→ Quality-State finding.

This provides consistency across different infrastructure Contexts.

The same invariant Core questions are applied even though their physical realization may differ substantially.

Testing Through Application

Every application also creates an opportunity to test the Core.

At the smaller Context Guide resolution, questions may become visible that were not obvious at the invariant Core 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 function not clearly represented by the existing Indicator set.

Most such findings will not require Core revision.

Their value is that they test whether the existing Core 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 Core Indicators, this provides practical support for the existing Indicator set.

The research result may therefore be:

new Context
→ detailed application
→ no unresolved invariant function
→ existing Core coverage supported.

This is important.

Context Guide research should not be designed primarily to discover missing Indicators.

A Context Guide that reveals no Core gap 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 Core 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 Core research issue.

This prevents unnecessary movement from Context detail to Core revision.

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 function 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 function.

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 function 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 Core 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 Core 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 functions.

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 existing Core 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 function 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 existing Core first.

Only an unresolved function should be preserved for later horizontal comparison.

Preserving Provisional Core-Revision Findings

Where a Context Guide reveals a plausible unresolved invariant function, the finding should be preserved separately from the normative Context Guide requirements.

The record should identify:

the originating Context;

the underlying determination function;

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 Core.

No Immediate Core Revision Is Required

The present research therefore supports continued Context Guide development before any broad revision of the IQI Core Indicator structure.

This sequence has an important methodological advantage.

If the Core remains stable while materially different Context Guides are developed, the same Indicator set can be tested repeatedly.

If the Core 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 IQI Core.

Each new Context Guide should be treated simultaneously as:

an application of the established Core;

and

a test of its continuing adequacy.

Provisional Core-revision findings 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 IQI Core and the diversity of real Infrastructure Quality Objects.

Their detailed application tests whether the established Core remains meaningful at smaller resolution.

Repeated successful application strengthens the practical support for the Core. Because Context Guides are developed through application of IQC1, they provide structured application and test Evidence rather than fully independent validation of the Core. 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 Core Quality Indicator realized in this particular infrastructure Context?

It is:

What recurring Indicator functions become visible when materially different infrastructure Contexts are compared?

This comparison can strengthen the justification of the existing Core Indicators.

It can also reveal possible overlap, relationships among Indicators, and possible determination functions requiring further research.

Vertical and Horizontal Research

The two directions of research should remain distinct.

Vertical research moves from the invariant Core into one specific Context:

Core Quality Factor
→ Core Quality 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 function is removed?

How does the function 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 Core Indicator Across Contexts

The first horizontal research method is to compare one established Core 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 Core Indicator
+
different Context-Specific realizations
→ evidence supporting invariant function.

Comparing Functions 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 functions 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 function to different subjects;

unnecessary duplication;

or

a broader relationship not sufficiently visible in the present Core structure.

This research should not begin with an assumption that repetition is a problem.

Recurring Indicator Functions

A particularly useful research direction is classification of recurring Indicator functions.

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 Core.

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 Core structure.

It provides a way to compare determination functions 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 functions easier to compare.

Cross-Function Horizontal Research

The most important horizontal findings may occur between the three provisional functions.

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 functions.

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 existing Core Indicators adequately represent the reliability of these different information paths.

The research should focus on function rather than requiring 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 existing Core interpretation;

within Context-Specific Quality Outcome Criteria;

or

eventually within a broader invariant function.

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 function 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 functions.

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 Quality State

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 existing Core 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 Indicator set.

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 functions 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 existing Core coverage appears sufficient;

and

the present research status.

This creates an accumulating evidence base for later Core review.

The record should include negative findings as well.

If a suspected gap is repeatedly resolved through existing Indicators, that result strengthens the Core.

Research Sequence

The horizontal research program can therefore follow this sequence:

develop a Context Guide;

apply the established Core;

identify smaller-resolution findings;

separate Context-specific detail from possible invariant functions;

preserve unresolved findings;

repeat the process in another Context;

compare the underlying functions;

test recurrence;

apply removal and distinguishability tests;

evaluate existing Core coverage;

and

retain, combine, reject, or strengthen the provisional finding.

This process should continue across a sufficiently diverse Context Guide family before broad Core revision 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 functions;

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 Core development.

Importantly, the research remains useful even if no new Core Indicator is identified.

Demonstrating that the existing Core 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 functions—

Quality State;

Quality-State Determination;

and

Quality-State Influence—

provide one useful way to organize that comparison without changing the established fourteen-Factor Core.

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 rather than converted prematurely into new Core requirements.

The next Subsection establishes how findings from that research should be preserved and evaluated over time:

11.3 Provisional Core-Revision Findings and Evidence Accumulation

Horizontal comparative research may identify findings that remain unresolved after application of the existing Core.

These findings should be preserved without immediately changing IQC1.

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 function 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 Core-revision finding
→ additional Context testing
→ accumulated Evidence
→ horizontal evaluation
→ finding retained, combined, rejected, or strengthened
→ possible controlled Core review.

Provisional Core-Revision Finding

A Provisional Core-Revision Finding is not a proposed amendment to IQC1. It represents a later research stage than an initial Provisional Additional Indicator Finding: the initial finding has survived preliminary testing and has sufficient continuing relevance to be preserved in the formal Core-development research record.

It is a research record identifying a possible issue concerning the continuing adequacy of the Core.

Such a finding may concern:

a possible missing invariant Indicator function;

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 require Core-level consideration.

The term provisional is essential.

The finding remains subject to further Evidence.

Evidence Accumulation

Evidence should accumulate through actual Core application rather than through repetition of the same theoretical argument.

A provisional finding becomes more significant when independent Context Guide applications reveal the same underlying function.

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 function remains unresolved, the Evidence supporting possible invariant significance becomes stronger.

The research should therefore record both:

similarity of the underlying function;

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 Core revision.

Evidence for invariant significance becomes stronger where the same function appears across Infrastructure Quality Objects that differ materially 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 function remains, the stronger the evidence of possible invariance.

Evidence Supporting Existing Core Coverage

Evidence accumulation should not be understood only as accumulation of support for revision.

It may instead strengthen the existing Core.

A provisional finding may appear in one Context.

A later Context Guide may show that an established Indicator already represents the function adequately.

Further applications may confirm that conclusion.

The research sequence may therefore be:

provisional finding
→ additional Context testing
→ existing Core coverage demonstrated
→ provisional finding closed
→ justification of existing Core 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 functional level.

The same words do not need to appear in different Context Guides.

The question is:

Does the same quality-relevant determination function 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 function 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 function 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 Indicator set does not sufficiently preserve?

If yes, the case for a separate invariant function strengthens.

If no, the finding should be resolved through the existing Core.

Evidence Concerning Core Resolution

A recurring function may still remain below Core 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 function 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 function 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 an unresolved recurring function should remain as a Core-revision finding.

Accumulating Evidence for Determination-to-Intervention Continuity

The same approach applies to the possible determination-to-intervention function.

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 function remains, its Core significance 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 existing Core Indicators.

The common function, 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 function:

reliability of Quality-State Determination;

not a predetermined technical solution:

mandatory redundancy.

This distinction should remain throughout Evidence accumulation.

A Living Research Record

The provisional Core-revision record should therefore be treated as a living research record.

For each finding, it should preserve:

working name;

underlying function;

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 Core Coverage Under Review

→ Likely Covered by Existing Core

→ Closed

or

Initial Finding

→ Recurring Finding

→ Necessary Function Supported

→ Distinguishability Supported

→ Cross-Context Invariance Supported

→ Candidate for Controlled Core Review.

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 function;

and

adequacy of testing against the existing Core.

Therefore, no fixed numerical threshold is proposed.

Threshold for Controlled Core Review

A provisional finding should move toward controlled Core review only when accumulated Evidence supports, at minimum, that:

the function is quality-relevant;

the function is necessary;

removal creates a material determination loss;

the function is distinguishable from established Indicators;

existing Core 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 function recurs across materially different Infrastructure Quality Objects;
and
the function can be stated at invariant Core resolution.
Only then is the question of Core revision 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 Core Review.
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 Core;
or
a new invariant Indicator is justified.
The Evidence should determine the outcome.
Implication for IQI Core Development
This approach provides a practical mechanism for developing the IQI Core without making it unstable.
The Core remains 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 Core level for formal consideration.
The development cycle can therefore be expressed as:
Core
→ application
→ Evidence
→ Provisional Additional Indicator Finding
→ repeated testing and horizontal comparison
→ Provisional Core-Revision Finding where warranted
→ Candidate for Controlled Core Review where sufficiently justified
→ controlled review
→ Core retained, clarified, or revised
→ renewed application
→ additional application
→ horizontal comparison
→ accumulated Evidence
→ controlled review where justified

→ Core retained, clarified, or revised

→ renewed application.

The process is iterative.

But Core revision remains controlled rather than continuous.

Interim Finding

Provisional Core-revision findings provide the bridge between practical Context Guide research and possible later development of the invariant Core.

Their purpose is not to create a waiting list of future Indicators.

Their purpose is to preserve unresolved functions long enough for Evidence to determine their significance.

Evidence may strengthen the existing Core.

It may close a provisional finding.

It may combine several findings.

Or it may eventually justify controlled Core review.

The important principle is:

Core development 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 Core:

11.4 Conditions for Controlled Core Revision

The preceding analysis establishes that the IQI Core should remain stable while Context Guide application and horizontal comparative research continue.

Stability, however, does not mean that the Core cannot be revised.

Revision should remain possible where accumulated Evidence demonstrates that the established Core no longer provides sufficient coverage of a necessary invariant quality-relevant function.

The important question is therefore:

Under what conditions should a provisional finding move from continuing research to controlled Core review?

The threshold should be deliberately high.

A Core revision affects every Context Guide and every later application of the IQI Core.

A Context-Specific problem should therefore not become an invariant Core requirement without sufficient justification.

The following conditions provide the basis for deciding when controlled Core review may be appropriate.

Condition 1 — A Material Quality-Relevant Function Has Been Identified

The finding must concern a function 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, Core revision is not justified.

Condition 2 — Necessity Has Been Demonstrated

The candidate function must pass the removal test.

The research should ask:

If this function is not represented, what becomes materially less observable, less determinable, or less capable of appropriate Influence?

The consequence of removal should be identifiable.

A function may be useful without being necessary.

Core status requires the stronger conclusion.

Therefore:

useful function
≠ necessary invariant function.

The necessity finding should be supported by Evidence from actual Context application rather than only by theoretical possibility.

Condition 3 — Existing Core Coverage Has Been Tested

Before revision is considered, the candidate must be tested against the complete established Core Indicator set.

The analysis should not ask only:

Does one existing Indicator contain this exact wording?

It should ask:

Can the necessary function be adequately determined through one or more existing Core Indicators when they are properly applied?

This distinction is important because the Core Indicators interact.

A possible function 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 invariant Core intentionally operates at a larger resolution than a Context Guide.

Therefore, the absence of technical detail in IQC1 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 Core-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 function.

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 function not adequately represented by the established Indicators should Core-level research continue.

Condition 7 — The Finding Is Not Merely a Method

A candidate should not be moved into the Core 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 Core question is different:

What underlying function 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 Core revision 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 Core Indicator set should not be changed.

This test is especially important for distributed infrastructure.

Condition 9 — The Function 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 Indicator set?

If no clear answer exists, the candidate has not demonstrated sufficient distinguishability for Core revision.

Condition 10 — The Function Is Non-Redundant

Distinguishability and non-redundancy are related but not identical.

A candidate may appear distinguishable when considered against one Indicator but become redundant when the entire Core is considered.

The research must therefore test whether several existing Indicators together already preserve the necessary function.

The appropriate comparison is:

candidate function

against

complete relevant Core 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 function 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 function 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 strength of the Core-level case increases where the same function appears across Infrastructure Quality Objects differing materially 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 Core 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 function 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 Function Can Be Stated at Invariant Core Resolution

A candidate may be necessary and recurring but still remain too Context-specific for Core inclusion.

Before controlled review begins, the function 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 Core-level suitability.

Condition 15 — Possible Placement Within the Existing Factor Structure Has Been Examined

A candidate Core Indicator should be examined against the established fourteen Quality Factors.

The research should determine:

which Factor most directly represents the candidate function;

whether the function is already represented through interaction among several Factors;

and

whether placement under one Factor would preserve its intended meaning.

A function appearing horizontally 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

A Core 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 Indicator-level Core consideration.

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 function should remain meaningful wherever the relevant quality condition can arise.

If the function 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-function classification 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 functions.

This does not determine where the candidate belongs in the Core.

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 function is Quality-State Influence.

A proposed information requirement may instead concern reliability of Quality-State Determination.

Clarifying the function helps prevent method-specific wording from entering the Core.

Condition 19 — The Consequences of Adding the Candidate Have Been Examined

Core revision 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 Core 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 Core.

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 Core is left unchanged?

If the answer is clear, repeated across materially different Contexts, and not resolved through existing Core provisions, the case for controlled review becomes strong.

Threshold for Beginning Controlled Core Review

No single condition above should automatically trigger Core revision.

The conditions work together.

A candidate becomes suitable for controlled Core review where accumulated Evidence supports that it is:

quality-relevant;

necessary;

distinguishable;

non-redundant;

not adequately represented by the existing Core;

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 Core resolution;

and

capable of materially improving Infrastructure Quality State Determination by closing a demonstrated gap.

At that point, the status may change from:

Provisional Core-Revision Finding

to

Candidate for Controlled Core Review.

Beginning Review Does Not Mean Approving Revision

This distinction should remain explicit.

Candidate for Controlled Core Review
≠ approved Core revision.

The controlled review may conclude that:

no revision is required;

existing Core wording is sufficient;

an existing Indicator requires clarification;

Context Guide guidance should be improved;

two or more provisional findings represent one existing function;

or

a new invariant Indicator is justified.

The purpose of controlled review is to make that determination.

Possible Forms of Core Development

If accumulated Evidence eventually justifies Core development, 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 Core text;

or

addition of a new Indicator where a genuinely missing invariant function 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.

Core Revision Should Be Version-Controlled

Any approved change to the invariant Core 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 Core;

and

whether existing Context Guides require review.

This preserves Traceability of Core development.

It also allows later research to determine whether the revision produced the intended improvement.

Revision Itself Should Be Tested

A revised Core provision should not be treated as proven merely because it has been adopted.

It should return to the Context Guide research cycle.

The revised function 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 Core 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;

indeterminate 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 Core revision.

The present Core should therefore remain unchanged while these findings are tested through additional Context Guides.

Interim Finding

Controlled Core revision should begin only after a provisional finding survives repeated attempts to explain it through the existing Core and demonstrates a necessary unresolved function 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 function that the present Core does not adequately represent?

Only when that question can be supported affirmatively should controlled Core review begin.

This preserves both requirements of continuing IQI development:

Core stability;

and

openness to Evidence-supported improvement.

The next Subsection brings these research implications together into a practical continuing development approach:

11.5 Continuing IQI Core Research Program

The findings of this paper provide a practical basis for continuing research on the IQI Core Indicator layer.

The immediate purpose of this research should not be to revise the Core.

It should be to continue testing the established Core 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 functions across different Contexts.

Together they provide the Evidence needed for continued justification or, where eventually necessary, controlled development of the Core.

Maintain the Present Core as the Common Research Basis

The established fourteen Quality Factors and their Core Quality Indicators should remain the common basis for continuing research.

This is important for comparison.

If the Core structure changes repeatedly while Context Guides are being developed, later horizontal comparison becomes more difficult.

A stable Core provides a common reference.

The research sequence should therefore begin with:

present Core
→ repeated Context Guide application
→ accumulated findings
→ horizontal comparison.

Core revision 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;

Reference Layer;

context-specific interpretations of the Core Indicators;

Quality Outcome Criteria;

and

Evidence.

The purpose is first to produce a useful Context Guide for the particular Infrastructure Quality Object.

Core research follows from that application.

This order is important.

A Context Guide should not be designed around the search for Core deficiencies.

It should apply the Core as it presently exists and allow any 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 Core Indicator functions remain necessary and sufficient 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:

Core Quality 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 Core-Supporting Findings

The research record should preserve findings that support the existing Core, 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 Core-level findings should remain separate from the normative Context Guide requirements.

This separation protects both documents.

The Context Guide remains an application of the established Core.

The provisional research record preserves questions concerning possible Core development.

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 functions?

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 is to test whether an unresolved function remains after the existing Core 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 existing Core Indicators already provide sufficient coverage.

The objective is not to establish the provisional term as a new normative concept.

The objective is to determine whether the underlying function 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 function 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 existing Core coverage;

identified as Context-specific;

rejected;

or

strengthened for additional cross-Context testing.

Only sufficiently developed findings should move toward controlled Core review.

No automatic revision schedule is necessary.

Review should follow the accumulation of meaningful Evidence rather than a calendar date.

Preserve Traceability of Core Research

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 Core decision.

This is important whether the final decision is to revise or retain the Core.

A decision to make no change should be traceable to Evidence just as a decision to revise should be.

Core development itself should therefore follow the same Evidence discipline that the Core 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 Indicator set.

It may clarify the meaning or application of existing Indicators.

It may improve Context Guide methods.

It may identify recurring horizontal functions without requiring Core revision.

It may close provisional findings.

It may eventually identify a necessary invariant function not sufficiently represented by the present Core.

The research program should remain open to all of these outcomes.

Its success should not be measured by the number of Core revisions produced.

Research Priority

At the present stage, the highest priority is continued development of Context Guides under the stable existing Core.

This provides the practical Evidence needed for all later horizontal research.

The immediate research sequence should therefore remain:

stable Core

→ additional Context Guides

→ detailed Context-Specific application

→ provisional findings where justified

→ horizontal comparison

→ accumulated Evidence

→ controlled Core review only where justified.

This sequence allows the Indicator layer to develop from actual application rather than from theoretical expansion.

Overall Finding

The continuing IQI Core research program should combine stability with systematic testing.

The established Core 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.

Core revision should occur only when a necessary, distinguishable, non-redundant, and Context-invariant function remains insufficiently represented after serious testing against the existing Core.

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 IQI Core 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 Core Quality Indicators used within the fourteen invariant IQI Quality Factors.

The principal purpose was to answer two related but different questions:

Why are the established Core Quality Indicators necessary?

and

Can the present Indicator set 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.

Core Quality 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;

Core Quality 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 Core Quality 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 as the current invariant Core Indicator set.

12.3 Similarity Does Not Establish Redundancy

Horizontal analysis identified recurring functions across the Indicator set.

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 function 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 Function

The analysis supports an important distinction between invariant function and Context-Specific realization.

An invariant Core Quality 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 function.

This relationship can be expressed as:

invariant determination function
→ different Context-Specific realizations.

This allows the Core 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 Indicator set.

These are different conclusions.

Permanent completeness would require demonstrating that no materially different infrastructure Context could reveal another necessary invariant determination function.

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 Core to a specific Infrastructure Quality Object at smaller resolution.

This application can produce two useful results.

First, the existing Core may successfully represent the new Context.

This strengthens the practical justification of the established Indicator set.

Second, the application may reveal a possible unresolved determination function.

That finding can then be preserved for additional research.

The relationship is:

stable Core
→ Context Guide application
→ Context-Specific findings
→ horizontal comparison
→ accumulated Evidence.

Context Guides therefore serve both as applications of the Core and as research/test cases for its continuing development.

12.7 Horizontal Comparison Provides the Test of Possible Invariance

A finding from one Context does not establish an invariant Core requirement.

Horizontal comparison across materially different Context Guides is required.

The comparison should focus on the underlying quality-relevant function rather than identical technical realization.

The research question is:

Does the same necessary unresolved determination function recur despite material differences among Infrastructure Quality Objects?

If yes, the case for possible invariant significance becomes stronger.

If the finding is resolved through existing Core coverage, context-specific interpretation, Evidence, Quality Outcome Criteria, or Boundary and Interface treatment, no Core revision is required.

12.8 Three Provisional Horizontal Functions Were Identified

The analysis identified a potentially useful horizontal distinction among:

Quality-State;

Quality-State Determination;

and

Quality-State Influence.

These functions do not replace the fourteen Quality Factors.

They do not presently form another normative IQI Core layer.

They provide a research method for examining what role different Indicators perform.

Quality-State functions concern the actual quality-relevant condition or capability of the Infrastructure Quality Object.

Quality-State Determination functions concern the capability and reliability of determining that condition.

Quality-State Influence functions concern the capability to preserve, restore, limit, or intentionally change the condition where required.

Many established Indicators contribute to more than one of these functions.

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 a new normative Core 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 Core 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 State Must Not Be Confused with an Acceptable 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

Quality State cannot presently be determined with sufficient confidence.

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 normative 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 Core

Possible unresolved functions should be preserved as Provisional Core-Revision Findings.

Their purpose is to maintain research continuity.

They should not automatically become Core requirements.

A provisional finding may later be:

resolved through the existing Core;

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 provides a controlled means of keeping the Core open to research without making it unstable.

12.15 Core Revision Should Follow Accumulated Evidence

Controlled Core review should begin only where a provisional finding demonstrates a substantially stronger case.

The Evidence should support that the function is:

quality-relevant;

necessary;

distinguishable;

non-redundant;

not adequately represented by the existing Core;

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 invariant Core resolution.

Even then:

Candidate for Controlled Core Review
≠ approved Core revision.

The review may support retention, clarification, refinement, or revision.

12.16 Present IQI Core Position

The present research supports the following position.

The fourteen invariant IQI Quality Factors remain unchanged.

The established Core Quality Indicators remain unchanged.

The established Indicators are supported as necessary components of the present invariant Core.

No additional invariant Core Quality 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 functions remain research tools.

The provisional findings identified in this paper remain outside the normative Core.

Context Guides should continue to provide the principal practical tests of Core adequacy.

Horizontal comparative research should continue as the Context Guide family expands.

Core revision should occur only where accumulated Evidence provides sufficient justification.

Final Conclusion

The derivation and justification of Core Quality 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 IQI Core can therefore remain stable without being closed.

Its Indicator set 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 IQI Core development is:

retain what is supported;

apply it consistently;

test it through different Contexts;

preserve what remains unresolved;

and

change the invariant Core only when accumulated Evidence demonstrates that change is necessary.

This allows the IQI Core to develop through Evidence rather than assumption while preserving the stability required for consistent Infrastructure Quality State Determination.

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