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Gate Retention and Custodial Continuity in Public Infrastructure Project Governance

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Abstract

Public infrastructure projects gain authorization on account of strategic promises that must stay understandable even after the project has undergone front-end formulation, design, construction, commissioning, and operational use. This paper explores how phase gates adjacent to one another affect the visibility and custodianship of discontinuity modes in a change programme for a public infrastructure project and what owner-side continuity obligations are implied. The dataset consists of a fixed phase-mode ledger of a Norwegian public infrastructure authority comprising twenty coded cases: seven in the front-end, one in design, nine in construction, and three in operation. Mode distribution includes one personnel case, seven information cases, five measurement cases, and seven strategy cases. Four calculated criteria are used for analysis: Boundary-Weighted Continuity Potential (BWCP), Directional Gate-Retention Analysis (DGRA), Custody-Span Orphan Test (CSOT), and Continuity Activation Score (CAS). The results demonstrate that construction bears the heaviest discontinuity burden and the front-end shows the widest variety of discontinuity modes. Information and strategy prove the most frequent modes (35% each), although measurement boasts the highest boundedness-weighted priority due to four of its five cases occurring in construction. The design-construction gate features the lowest retained profile share ($R = 0.222$), followed by front-end-design ($R = 0.286$), although construction-operation maintains a higher aggregate profile share ($R = 0.556$) but loses measurement completely. CSOT reveals that measurement stands out as the sole mode that reaches an orphan rate of $\Omega = 1.000$, while information appears visible in all phases yet demonstrates a major change in relative salience ($A = 0.646$). According to CAS, measurement takes the first place (0.672), followed by strategy (0.460), information (0.323), and personnel (0.190). Therefore, the research question receives an exact answer: strategic continuity is not lost exclusively at final handover; it gets filtered at design-construction, reconstructed in construction, and jeopardized at operation when the custody of measurement is not continued. The owners of public infrastructure must consider measurement covenanting, strategic custody, evidence harmonization, and role backup as separate continuity obligations and not as a checklist.

Keywords: public infrastructure; strategic continuity; gate retention; custody span; boundary objects; performance measurement; project governance; project handover

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1. Introduction

Public infrastructure projects are organizational temporary arrangements designed to generate assets which will deliver value for years ahead. It is because the road, hospital, railway, water infrastructure, school estate, or other civic infrastructure project is commissioned in anticipation of delivering public value to the future rather than being deliverable within any period of contracts. This issue is important as the evidence and assumptions underlying the decision to invest are usually generated well before the start of the actual delivery of the asset. Front-end work converts needs, policies, and interests into the preferred reason to proceed; design converts the reason into the technical form; construction converts the technical form into a tangible asset; operation converts the asset into the service, maintenance, and experience. Each transformation can keep, narrow, reframe, or abandon the strategic content.

The central challenge of organizing public projects is that such projects should transform themselves yet keep their meaning. Major infrastructure programmes rely on temporary alliances, professional specialisms, procurement packages, contracts, and stage reviews [1]. The governance of such programmes relies on the temporary and interorganizational character of the project coalitions [2]. The project owner thus needs to govern a chain of knowledge environments undergoing transformations rather than a single stable organization. The research in project-based learning has considered how to retain the knowledge across temporary organizations [3]. The research on transitioning between project and operations has shown that the continuity of the process requires how the knowledge can be transferred into the later organizational environment [4]. More recently, the project literature has recognized that major projects are an intervention in the wider systems of public and operations [5]. The related literature recognizes that the major projects need to be interpreted through their broader institutional and developmental consequences [6]. Similarly, the systems-oriented project research connects delivery with the environment in which the asset is supposed to perform [7]. The studies of megaproject performance have also shown that value could be renegotiated as the result of evolving governance structures [8]. Non-market stakeholders and independent actors further shape the decision-making space [9]. These debates have made continuity an administrative concern. The continuity is the condition allowing the project to remain linked to the public value which justifies its implementation.

The literature on handover is pertinent yet insufficient by itself. The handover of the asset information is typically seen as a construction-to-operations problem, and the recent guidance has rightfully pointed out the need for well-organized asset information process providing operation and maintenance staff with decision-ready evidence [10]. The risk-prioritization literature on infrastructure handover has also shown that there are gaps in the perception of the risk at the critical moments of transition into the operations [11]. Yet, this study addresses an earlier and broader issue. If the criteria of strategic value, measurement obligations, and interpretive responsibility are already filtered away before the end of construction, the final handover would only be able to pass what was kept during earlier gates. A well-designed handover process would not remedy the filtering away of the logic of measurement or strategic justification in the transformation between design and construction.

Project governance literature is the second foundation of the argument. Governance is typically considered in terms of organizational structures, roles, decision rights, and accountability arrangements. Yet, governance also operates through situated practices and governance work [12]. Translations and reviews across organizational levels are another part of the governance process [13]. The governance arrangements provide an initial link between organizational intentions and project delivery. The strategy implementation literature has further seen governance as the line of sight linking strategic priorities and the delivery decisions [14]. Front-end governance adds an early control of the needs, effects, and concepts which the delivery should keep [15]. The public infrastructure magnifies this requirement as a public owner needs to maintain the strategic traceability in the technical, contractual, and operational realms. Thus, the continuity is seen as a custody problem: it is not only a question of existence of the knowledge but of assigning the custody and governance of this knowledge to a phase of the process.

The empirical base of this research is the phase–mode ledger of observations of the discontinuities in the implementation of a strategic change programme by a Norwegian public infrastructure agency [16]. The coded ledger includes four ordered phases of the project: front-end, design, construction, and operation. It also includes four discontinuity modes: personnel changes, information transfers, absence of performance measurement, and the misalignment of long-term strategic goals. The ledger consists of twenty discontinuity observations: seven in the front-end, one in design, nine in construction, and three in operation. There are one observation of personnel discontinuity, seven observations of information discontinuity, five observations of measurement discontinuity, and seven observations of strategy discontinuity. As the ledger is small and structured, the analysis does not aim at generalization. Instead, it is used for generating the auditable interpretation of how discontinuity profiles are transformed through the adjacent gates.

The research question is: *When coded discontinuity observations are read as a phase-gate sequence, which discontinuity modes are retained, lost, imported, or left without continuous custody, and what does this imply for public-owner intervention priorities?* It is different from the conventional frequency question. While the frequent mode could be easily visible and governable through the evidence standards, the infrequent one could be more dangerous in case of disappearing and reappearance without the named custodian. It also differs from the usual handover question in that it asks about the gate filtering of continuity before the operation commences.

This study makes a contribution of the focused diagnosis of the continuity of public infrastructure owners. It utilizes BWCP to characterize phase load, mode prevalence, entropy, boundedness, boundary friction, and ablation; DGRA to identify signed loss, import burden, and retained profile share at adjacent gates; CSOT to test the mode visibility across repeated presence-absence transitions; and CAS to rank the intervention intensity. The value of the analysis is in the interpretation of the four calculations as the diagnosis of custody problem: it reveals why the measurement is the first continuity obligation despite the higher frequency of information and strategy, why the design-construction boundary is the sharpest profile filter, and why the handover reaction is already too late when custody breaks have happened.

2. Theoretical Orientation

2.1 Strategic continuity as durable organizational interpretation

Strategic continuity in infrastructure is the ability to keep a project-specific line of reasoning relevant and usable as the project proceeds through phase transitions, actor team changes, evidence form changes, and shifts of managerial focus. The line starts at public need and public authorization, but it must survive through the phases and the associated forms of justification, design choices, construction controls, commissioning evidence, and operational performance. Documentation preservation is necessary but not sufficient. A receiving phase also has to understand the reason why the decision was made, the assumptions that have made it credible, the evidence that could have contested it, and the authority to protect or revise it.

Strategy-as-practice research is helpful because it understands strategy as the enactment of strategic aims through routines, artefacts, talk, meetings, and situated judgment, not as a plan moved from one part of an organization to another [17]. The strategic artefacts and their practical use add another mechanism to the process of strategic translation [18]. The view fits well the world of public infrastructure projects, where strategic aims are constantly translated into technical requirements, procurement clauses, delivery controls, and asset management routines. Organizational learning literature also makes the same point from a slightly different angle. Organizational learning involves a constant tension between exploitation of existing knowledge and exploration of new possibilities [19]. A phase gate must not lock everything in the assumptions of an early phase, but it must preserve enough interpretive context to distinguish adaptation from drift.

The dynamic capability literature shows clearly why continuity can be both stable and flexible [20]. Organizational routine literature also explains how stable patterns can be performed differently depending on the circumstances [21]. Routines are not just repetitive sequences, they are patterns that can change while the recognizable sequence is preserved [22]. The interplay of ostensive and performative elements of routines is particularly helpful to understand such continuity [23]. Review articles on routine dynamics emphasize the role of routines in both stability and change [24]. Enabling formalization literature makes another related point: a formal system can be enabling rather than coercing if it helps to make sense of work processes [25]. Such systems also help actors identify and solve problems rather than follow the procedures blindly [26]. As far as the infrastructure governance is concerned, this lesson is immediately applicable. A continuity obligation should not be designed as a rigid document management requirement. It must be an enabling tool that helps the later phase to make sensible judgments.

2.2 Boundary objects, gate filtration, and custody breaks

There are many occupational and organizational boundaries in infrastructure projects. Planners, designers, constructors, public servants, finance specialists, sustainability experts, and operators often apply different criteria for assessing the project status. Boundary object literature explains how the artefacts can be meaningful for different communities [27]. Boundary objects can also help with transforming the knowledge across professional domains [28]. Boundary spanning depends on how actors negotiate and use such artefacts in practice [29]. Infrastructure literature extends this idea to cross-boundary collaboration in public projects [30]. Specifications, design records, risk registers, benefits maps, asset data models, commissioning evidence, and performance measures can all be seen as boundary objects in construction and infrastructure. Their usefulness depends on how they preserve the meaning in the communities of practice [32]. Cross-occupational coordination also depends on how different groups interpret the shared objects [33]. Knowledge is also preserved in situated practice where artefacts are used in work [34].

A phase gate is a special type of boundary in infrastructure because it is both temporal and organizational. It does not connect two teams, but translates one phase concerns into the basis of work for the other phase. Front-end decisions must be turned into design criteria. Design criteria must be turned into construction requirements. Construction evidence must be turned into operational knowledge. Governance-as-practice literature explains how the formal governance arrangements are translated as they are enacted in a particular project [12]. Translation is inevitable, but it can also involve filtering out the parts of the strategic intent. Gate retention focuses on what remains, what disappears, and what appears in the receiving phase without adequate preparation in the sending phase.

Custody break occurs when a discontinuity mode is present in one phase, absent in the next one, and reappears or persists unresolved without continuous responsibility. It is not the case that each mode must be equally present in all phases. Personnel discontinuity, for example, may be rare, but still significant if it affects tacit interpretation. Measurement discontinuity may be mostly present in construction, because construction produces the evidence that is easier to measure. Strategy discontinuity may be mostly present where the high-level goals conflict with delivery concerns. What matters for governance is whether there is an owner who explains the importance of the mode in the next phase.

2.3 Measurement as an enabling continuity device

Measurement is a special case of continuity because it converts the strategic claims into observable criteria. Performance measurement systems can be coercive and discipline organizational attention [35]. They can be enabling and facilitate learning when they are designed this way [26]. In infrastructure, measurement connects front-end justification, design requirements, construction evidence, commissioning acceptance, and operational performance. When measurement is strong in construction but weak in design or operation, it is just a delivery stage artefact, not an enabling continuity device.

This distinction is important in public infrastructure because the public value is realized through long-term use. A project can meet construction milestones and still lose the evidence for evaluating service performance, environmental commitments, resilience claims, and asset management readiness. Systems integration literature in the context of infrastructure projects similarly emphasizes the importance of configuration control, testing, commissioning, and client authority for successful integration [36]. Asset information handover literature also considers the handover process that starts before project closeout [10]. This custody-oriented reading extends the insight into the discontinuity modes: measurement must be an obligation of custody before construction produces its own criteria.

2.4 Project governance and the public owner role

The public owner is a special case because it is the owner responsible for preserving the public purpose in temporary arrangements of the projects' delivery [1]. The capability of public owner also depends on how the public organization coordinates the fragmented delivery system [37]. Front-end governance literature emphasizes that the early definition is critical for success because the problem, need, effect, and feasible concept are already defined at the front end [15]. Project governance reviews stress that the governance must enable strategy implementation rather than monitor delivery performance [14]. Governance practices affect the translation of strategic intent into project activities [13]. Studies of major projects show that the performance problems often arise from changes in governance structure and stakeholders' alignment [9]. Value distribution can also change as the project coalition evolves [8]. Institutional complexity provides another potential source of discontinuity [38]. Major projects may change due to changes in the institutional logics and organizational arrangement [39].

Therefore, the public owner must not think about continuity as a universal control requirement. There are different modes of discontinuity and different governance responses are required. Information needs a consistent evidence format and traceability. Measurement requires a continuity covenant binding early criteria to the construction evidence and operational performance. Strategy requires named custody of value claims and authorized changes in strategic interpretation. Personnel discontinuity requires role back-up, transition safety, and decision-rationale documentation to minimize the dependence on tacit memory [40]. These are governance-oriented interpretations of the mode-specific findings.

3. Materials and Methods

3.1 Phase-mode ledger and analytical variables

The empirical data set includes twenty discontinuity observations that have been coded in the public infrastructure agency case studied by Minoretti et al. [16]. The four phases of the case are front-end (F), design (D), construction (C), and operation (O). Their counts are $F = 7$, $D = 1$, $C = 9$, and $O = 3$. Discontinuity modes include personnel (P), information (I), measurement (M), and strategy (S), with mode counts $P = 1$, $I = 7$, $M = 5$, and $S = 7$. Personnel means discontinuity resulting from change of responsibility or loss of tacit interpretation. Information refers to any transfer, availability, or interpretability problems. Measurement implies lack of performance feedback. Strategy indicates misalignment and weakening of strategic aims.

The analysis draws on three related ledgers. The first is an observation ledger with twenty entries, corresponding to twenty discontinuities that have been coded based on their phase and mode. This ledger allows for analysis of phase load, mode prevalence, normalized entropy, boundedness, boundary friction, and ablation. The second is a directional gate ledger with twelve entries that arise from cross-referencing three neighboring gates (front-end–design, design–construction, construction-operation) with four modes. The third is a mode-custody ledger with four entries for each discontinuity mode. It allows for persistence span, zero-crossing, directional shift, and activation ranking.

This design of the ledgers in Table 1 ensures transparency in the approach. Every calculation derives from few observable phase-mode combinations, and every calculation has an explicitly defined governance meaning. The format proves helpful for a small-N analysis because it does not appear statistically precise yet allows one to trace continuity loss in reasoning.

Table 1. Analytical ledger structure

Ledger	Unit of analysis	Records	Diagnostic purpose
Observation ledger	coded phase–mode observation	20	Measures phase load, mode prevalence, entropy, boundedness, boundary friction, and ablation.
Directional gate ledger	adjacent boundary–mode transition	12	Measures signed loss, import burden, and retained discontinuity-profile share at each phase gate.
Mode-custody ledger	discontinuity mode	4	Measures phase span, zero-crossing orphan rate, average directional shift, and continuity activation.

The phase-gate map in Figure 1 explains why the very same empirical material is readable at three different levels. The top corridor reflects the sequence of the projects, gate seams show the three moments when continuity might be filtered out, and the bottom lines illustrate how BWCP, DGRA, CSOT, and CAS interpret the same empirical material. The design phase is shown narrowly because there is only one coded observation on the information level; this narrowness explains the future result showing the strongest retention filter is design-construction.

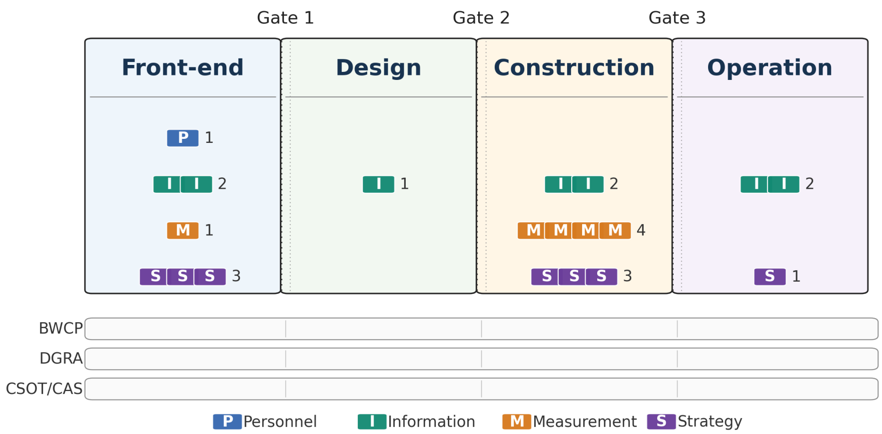

Figure 1. Phase-gate ledger structure.

3.2 Boundary-weighted continuity potential layer

Let $\mathscr{P} = \{F, D, C, O\}$ be the ordered phase set and $\mathscr{M} = \{P, I, M, S\}$ be the mode set. For observation i, p_i denotes the phase and m_i denotes the mode. The phase–mode count matrix is

$$N_{pm} = \sum_{i=1}^{n} \mathbf{1}(p_i = p, m_i = m), \tag{1}$$

where $n = 20$. Phase exposure and mode prevalence are

$$\rho_p = \frac{\sum_{m \in \mathscr{M}} N_{pm}}{n}, \qquad \pi_m = \frac{\sum_{p \in \mathscr{P}} N_{pm}}{n}. \tag{2}$$

The within-phase profile is

$$r_{pm} = \frac{N_{pm}}{\sum_{m \in \mathscr{M}} N_{pm}}, \tag{3}$$

for phases with nonzero observations. Internal variety within each phase is measured with normalized entropy:

$$H_p = -\frac{1}{\ln |\mathscr{M}|} \sum_{m \in \mathscr{M}} r_{pm} \ln r_{pm}, \tag{4}$$

with no terms left out. Entropy acts as an index for describing mixture and not causally as a parameter [41]. Numbers closer to one suggest a wide range of modes in the phase, numbers closer to zero mean a concentration in just one mode.

Explanation of Eqs. (1)–(4) is simple. Counts tell us where coded information is, prevalences tell us how much the weight of each mode is, and entropy tells us whether the phase has several kinds of discontinuity or one dominating issue. This does not provide directional losses yet, but they create the empirical ground on which the gate analysis starts.

Mode boundedness is calculated as

$$\beta_m = \frac{\max_{p \in \mathscr{P}} N_{pm}}{\sum_{p \in \mathscr{P}} N_{pm}}, \tag{5}$$

and the BWCP priority coefficient is

$$\Gamma_m = \pi_m \beta_m. \tag{6}$$

The frequency and concentration are combined into the coefficient. High concentration of the mode is considered as a lower priority, and infrequent mode with highly concentrated occurrence in only one phase could be considered as a higher priority, as it reflects the continuity weakness within the phase.

Adjacency phase friction is based on the Jensen–Shannon divergence of the smoothed and normalized profile. The smoothed profile is

$$q_{pm} = \frac{N_{pm} + \alpha}{\sum_{m \in \mathscr{M}} N_{pm} + \alpha |\mathscr{M}|}, \qquad \alpha = 0.5. \tag{7}$$

For adjacent phases p and $p+1$, the boundary friction is

$$B_{p,p+1} = \frac{1}{\ln 2} \left[\frac{1}{2} D_{KL}(q_p \| z) + \frac{1}{2} D_{KL}(q_{p+1} \| z) \right], \qquad z = \frac{q_p + q_{p+1}}{2}. \tag{8}$$

Normalization ensures that the value falls within the range of zero and one, with higher values showing a more abrupt change in the profile. Jensen-Shannon distance is selected due to its symmetry and boundedness, unlike its underlying non-symmetric counterpart, the Kullback-Leibler divergence [42]. The contribution of a mode to total boundary friction is determined by:

$$\Delta_m = 100 \times \frac{\sum B(N) - \sum B(N^{(-m)})}{\sum B(N)}, \tag{9}$$

where $N^{(-m)}$ is the count matrix with mode m suppressed.

The friction and ablation measures remain descriptive, but they are significant in that they redirect attention from the total to the boundary of the phase. A high friction coefficient indicates that the receiving phase does not have the same discontinuity pattern as the sending phase. A high ablation measure shows that one particular mode carries the responsibility for the discontinuity in the phase pattern. It is especially crucial in the phase-mode matrix, since measurement is not the most dominant mode in terms of frequency but contributes most to structure.

3.3 Directional gate-retention analysis

BWCP measures the size of the profile change, whereas DGRA measures the direction of the change. Signed displacement of each mode between two consecutive phases is

$$\delta_{b,m} = r_{p+1,m} - r_{p,m}, \qquad b = (p, p+1). \tag{10}$$

A negative value represents loss between the sender and receiver phases. A positive value represents the import burden, whereby the receiver phase is more dominated by the mode than the sender phase was. The gate-level loss, import burden, and retention are

$$L_b = \sum_{m \in \mathscr{M}} \max(-\delta_{b,m}, 0), \qquad E_b = \sum_{m \in \mathscr{M}} \max(\delta_{b,m}, 0), \qquad R_b = \sum_{m \in \mathscr{M}} \min(r_{p,m}, r_{p+1,m}). \tag{11}$$

As each phase profile totals one, $L_b = E_b$ and $R_b = 1 - L_b$. Small retention suggests very little commonality between the receiver profile and sender profile. In terms of substantive understanding, this implies that the gate has been a good filter for the information.

The diagnosis of DGRA is not based on the assumption that all imports are bad and all losses are preventable. A receiver phase may have legitimate reasons for raising new issues during more detailed elaboration of tasks. What matters is to differentiate prepared import from unowned import. In case a mode dominates the receiving phase after a gate, the public owner should wonder whether the receiving phase possesses enough reason and information for handling the mode.

3.4 Custody-span orphan test

By CSOT we ask whether each mode is visible through phases or passes back and forth between presence and absence. The custody-span of mode m is

$$\phi_m = \frac{1}{|\mathscr{P}|} \sum_{p \in \mathscr{P}} \mathbf{1}(N_{pm} > 0). \tag{12}$$

A mode has a zero crossing at a boundary when it is present on one side and absent on the other:

$$Z_m = \sum_{b=(p,p+1)} \mathbf{1}\left[(N_{pm} > 0) \oplus (N_{p+1,m} > 0)\right], \qquad \Omega_m = \frac{Z_m}{|\mathscr{P}| - 1}, \tag{13}$$

where $\oplus$ refers to the exclusive OR operator. The orphan rate Ω_m is understood to represent a custody break measure. If Ω_m is large, then this suggests that the mode is not visible throughout the ordered project process and hence requires a continuity obligation.

The orphan test does not require that the mode appears in equal measure at all stages. What it seeks to detect is the pattern of appearance and disappearance. That the orphan rate is high is a problem since with every disappearance there is increased probability that the next appearance will have to be pieced together by unstable responsibility. Hence the mode may be rare compared to information and strategy and yet require more governance concern.

3.5 Continuity activation score

The CAS represents a combination of directional instability and presence absence instability. The average absolute directional change for mode m is

$$A_m = \frac{1}{|\mathscr{P}| - 1} \sum_{b=(p,p+1)} |\delta_{b,m}|. \tag{14}$$

The activation score is then

$$CAS_m = \frac{A_m + \Omega_m}{2}. \tag{15}$$

CAS is not a probability, causal estimate, nor risk metric. Rather, it is an index for deciding continuity requirements, which in the present application are assigned as follows: scores greater than or equal to 0.60 correspond to a mode that requires a continuity covenant; scores between 0.40 and 0.60 correspond to named strategic custody; scores between 0.30 and 0.40 correspond to evidence harmonization; and scores less than 0.30 correspond to local role-backup protection. These are interpretation conventions for the small-N study at hand and should not be taken to apply generally.

The utility of CAS is its ability to distinguish two types of instability: a mode may be continuously present but directionally unstable, like information in the present ledger; another may be intermittently present and therefore subject to a potential custody break, like measurement. The combined score allows a public owner to avoid considering all discontinuities as an equally problematic handover problem.

4. Results and discussion

4.1 Observation-level structure and phase load

The phase-mode count matrix of Table 2 exhibits a very unbalanced observation structure. Construction is involved in nine of twenty records, the front-end is involved in seven, operation in three, and design in one. Already, this structure undermines any simple final-handover perspective. Discontinuity is already present at the front-end stage and reaches its maximum concentration in the construction phase. Design emerges as an important but relatively rare transition mode as it represents the link between initial intention and delivery control.

Table 2. Phase–mode counts and entropy

Phase	P	I	M	S	Total	H_p
Front-end	1	2	1	3	7	0.921
Design	0	1	0	0	1	0.000
Construction	0	2	4	3	9	0.765
Operation	0	2	0	1	3	0.459
Total	1	7	5	7	20	–

Moreover, from the tabled figures, the front-end phase displays the highest normalized entropy value $(H = 0.921)$, suggesting a wide range of personnel, information, measurement and strategy discontinuities at the early stages of project life cycle. The second highest entropy value is recorded at the construction phase $(H = 0.765)$, indicating a mixed delivery-stage phase that is dominated by measurement and strategy discontinuities. On the other hand, operation phase displays a relatively narrow profile $(H = 0.459)$ while design phase exhibits zero entropy as it consists of only one information-coded observation. In summary, early strategic development phase is not just a planning phase and construction is more than just production phase since both phases include several continuity problems.

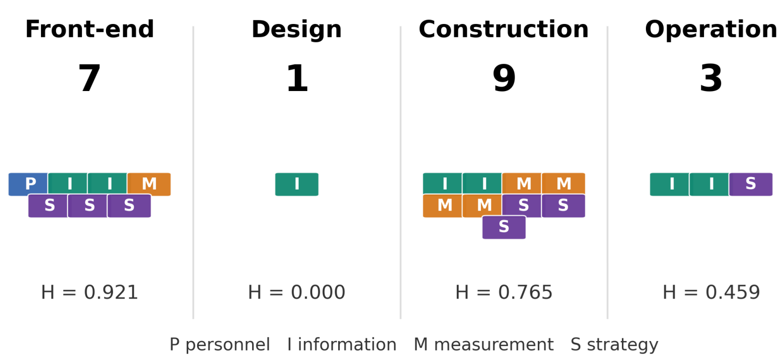

Figure 2. Observation load by phase.

The tile plot presented in Figure 2 enables an audit of the small empirical structure. Specifically, each tile is representative of one coded observation, which means that the higher observation load of construction phase cannot be due to any scaling issue. The comparison between one tile of design and nine tiles of construction is very helpful in appreciating the fact that the influence of design is not based on the number of discontinuities, but rather the transition into design.

4.2 Prevalence, boundedness and priority

The mode-level results in Table 3 distinguish frequency from concentration. Information and strategy both have seven observations out of twenty ($\pi = 0.350$). On the other hand, measurement accounts for five observations ($\pi = 0.250$), whereas personnel has only one observation ($\pi = 0.050$). In other words, frequency would suggest that information and strategy should be the first choice. However, BWCP reverses the order of priority using boundedness: measurement has $\beta = 0.800$ as four of its five occurrences belong to construction stage and thus the highest priority coefficient ($\Gamma = 0.200$).

Table 3. Mode prevalence and priority

Mode	Count	Prevalence π_m	Boundedness β_m	Priority Γ_m
Personnel (P)	1	0.050	1.000	0.050
Information (I)	7	0.350	0.286	0.100
Measurement (M)	5	0.250	0.800	0.200
Strategy (S)	7	0.350	0.429	0.150

Given the priority values, the fact that the largest discontinuity prevalence is not the most phase sensitive does not surprise. Information is present in all four phases, hence it gets a relatively low value for boundedness. Strategy, like information, has a relatively high prevalence, but slightly less concentrated. Measurement has a lower prevalence than both information and strategy. But the concentration in the construction phase makes measurement structurally significant. Supporting systems for measurement help to achieve continuity since performance evidence can still be used [26]. Research in systems-oriented infrastructure emphasizes that the connection between project evidence and later asset operations is important [36]. Public infrastructure research puts additional stress on information and responsibility continuity across lifecycle transitions [10].

Information and strategy have the highest values of prevalence, but after adjustment with the boundedness factor, measurement ranks first. Therefore, an owner must not rely only on frequency to determine the priorities for continuity management. A concentrated mode in one phase needs special attention since it will probably be seen as a phase-specific issue and lost in the next gate.

4.3 Boundary friction and measurement ablation

The values of the boundary friction presented in Table 4 show the sharpest changes in the profile of discontinuity between adjacent phases. Front-end–design friction equals 0.056, design-construction equals 0.120, and construction-operation equals 0.118. Both the largest values are associated with the boundaries around the construction phase. This means that construction phase is not only the phase with the most observations; it is also the place where discontinuity composition changes most dramatically.

Table 4. Boundary friction and ablation

Diagnostic item	Value	Interpretation
Front-end $\to$ Design friction	0.056	The mixed front-end profile narrows into a single information-coded design profile.
Design $\to$ Construction friction	0.120	The design information profile gives way to construction measurement and strategy.
Construction $\to$ Operation friction	0.118	The construction profile loses measurement and becomes more information-oriented.
Total friction, all modes retained	0.294	Reference value for the BWCP boundary layer.
Total friction after removing M	0.209	Measurement removal reduces total friction by 28.8%.

The boundary friction ablation helps to understand the interpretation better. Boundary friction with all modes included is 0.294, while with the removal of measurement it is 0.209; this is 28.8% reduction in boundary friction. However, this does not imply that measurement causes discontinuity in any causal manner; this implies that measurement plays an important role in bringing about the composition change through the phase sequence. In governance terms, this means that construction produces the measurement-intensive profile that is not carried through to operation, which is exactly what a public owner ought to find out before the handover.

The top panel in Figure 3 shows the near-equivalence of the design–construction and construction–operation boundary frictions, while the bottom panel highlights the effect of measurement. This becomes significant since the final hand-over will consider primarily the latter one. What the figure indicates is that design–construction is just as important. Continuity of measurement should thus be addressed before construction, not after.

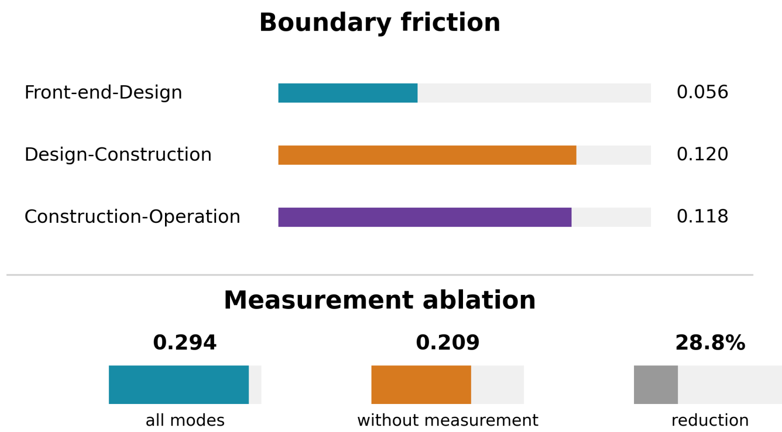

Figure 3. Boundary friction and ablation.

4.4 Directional gate-retention results

The values in Table 5 tell us which components lose or gain their shares as the project proceeds through each gate transition. The front-end–design transition sees loss of personnel (-0.143), measurement (-0.143) and strategy (-0.429) while gaining information ($+0.714$). The design–construction transition sees a loss of information (-0.778) while gaining measurement ($+0.444$) and strategy ($+0.333$). The transition from construction to operation loses measure (-0.444) and gains information ($+0.444$), while personnel and strategy remain at their signed shares. These numbers indicate that the transition sequence does not represent a seamless flow of the same issue. The issue varies at each gate.

Table 5. Directional gate retention

Gate	δ_P	δ_I	δ_M	δ_S	Loss L_b	Import E_b	Retention R_b
Front-end $\rightarrow$ Design	-0.143	0.714	-0.143	-0.429	0.714	0.714	0.286
Design $\rightarrow$ Construction	0.000	-0.778	0.444	0.333	0.778	0.778	0.222
Construction $\rightarrow$ Operation	0.000	0.444	-0.444	0.000	0.444	0.444	0.556

The retention values answer an important part of the research question. Design-construction has the lowest retention value ($R = 0.222$), which means that 22.2% of the design discontinuity profile remains in construction. The front-end-design has a relatively low value of retention ($R = 0.286$), whereas the construction-operation retains a higher aggregate portion of the profile ($R = 0.556$). Those values do not mean that the operation phase will be secure. It means that the construction-operation has a visible aggregate profile despite losing all measurement values.

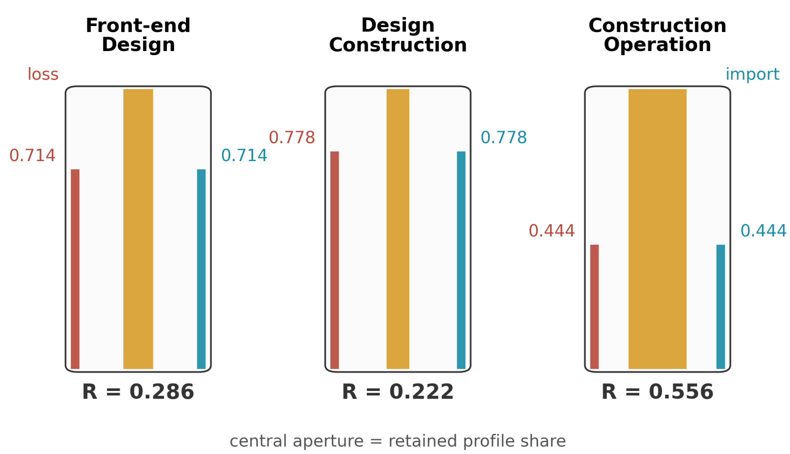

Figure 4. Gate-retention profile.

The visualization of the gate-retention in Figure 4 shows that design-construction has the narrowest gate. Such visualization form helps to avoid the equalization of all boundaries as review points. The first gate filters a mixed strategic front-end into information, the second gate turns design information into measurement and strategy, the third gate loses the measurement when operation becomes more informative. In this way, the public owner faces a succession of gate-tasks instead of a single gate task as an end point of transition.

The signed displacement plot in Figure 5 explains why aggregate values of gates should not be interpreted independently. Positive information displacement at the front-end-design is a different issue than the negative one at design-construction. The former means the domination of design profile with information values, the latter means that there is no such profile in construction. Measurement moves in the opposite direction: it is imported into construction and then disappears at the operation stage. This migration of measurement proves the fragility of the custody problem in the ledger.

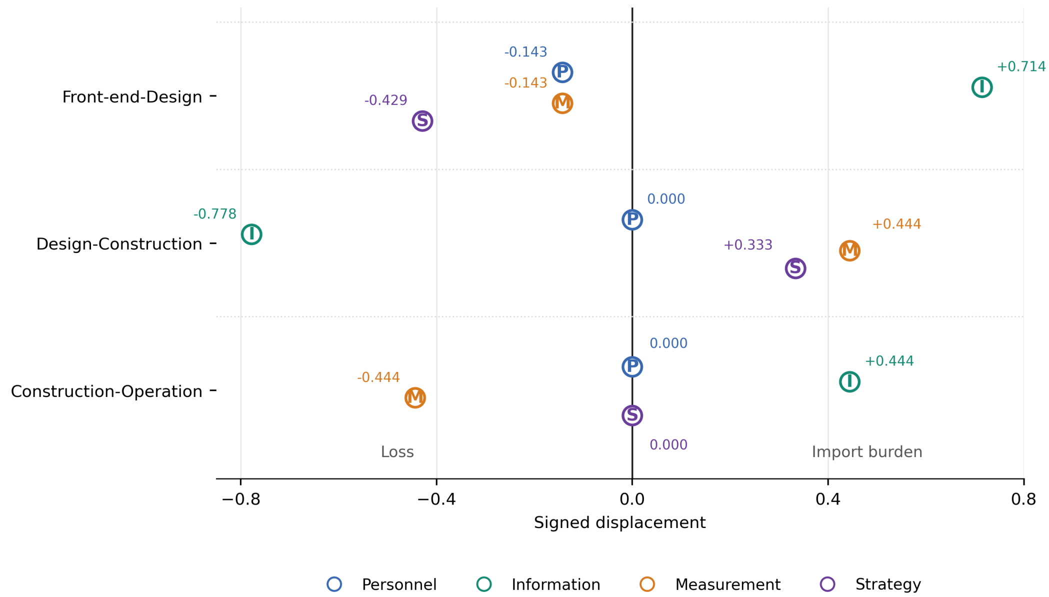

Figure 5. Signed mode displacement.

4.5 Custody span, zero crossings, and activation ranking

CSOT and CAS values in Table 6 help to define how each mode behaves during the full phase sequence. Information has full custody span ($\phi = 1.000$) and zero zero-crossings, but its average directional shift is the largest ($A = 0.646$). Measurement has a span of 0.500, three zero-crossings, and full orphan rate ($\Omega = 1.000$). Strategy has a span of 0.750 and orphan rate 0.667. Personnel has low span (0.250) and low activation score (0.190) since it operates only in front-end phase and does not produce a lot of directional shifts.

The most significant difference in Table 6 is between continuous presence and stable custody. Information is present throughout all the phases, but its salience varies drastically at all the gates. This implies that information cannot be treated as a resolved continuity issue just because of its omnipresence; it needs evidence harmonization, i.e., the receiving phase should be aware of the decision-relevant information and how it should interpret it. Measurement faces an opposite problem: it does not have a stable presence in all the phases but crosses visibility barriers at all adjacent gates. This calls for more drastic measures since the measurement criteria might get lost by the time the asset is received for operation.

Table 6. Custody span and activation

Mode	Count	Span ϕ_m	Zero crossings Z_m	Orphan rate Ω_m	Shift A_m	CAS_m
Personnel (P)	1	0.250	1	0.333	0.048	0.190
Information (I)	7	1.000	0	0.000	0.646	0.323
Measurement (M)	5	0.500	3	1.000	0.344	0.672
Strategy (S)	7	0.750	2	0.667	0.254	0.460

The pattern in Figure 6 visualizes the orphaning result without involving any formulae. Information forms an unbroken presence line, while measurement is presented at the front-end, disappears at the design phase, reappears at the construction phase, and vanishes once again at the operation phase. Strategy gets interrupted at the design phase but then appears again.

Personnel stays at the front-end only. Thus, this pattern allows for differentiation of the governance response: continuity efforts should not be implemented through a unified document transfer process because of different custody patterns in modes.

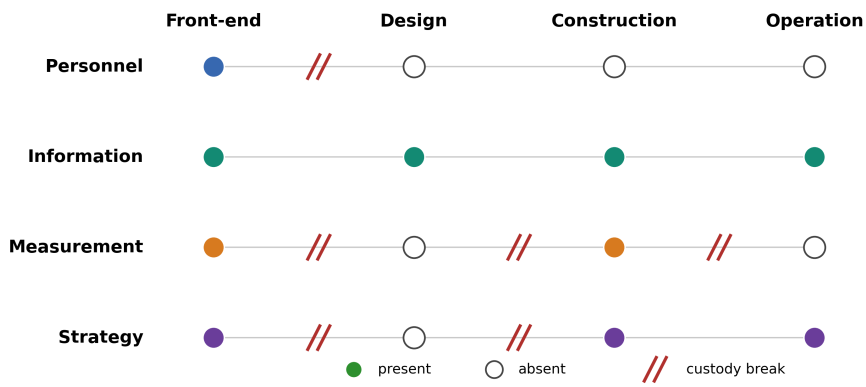

Figure 6. Custody-span breaks.

The ranking in Figure 7 translates the numerical results into intervention intensity. Measurement exceeds the 0.60 threshold and thus demands a continuity covenant. Strategy belongs to the named custody category. Information belongs to the evidence harmonization category. Personnel belongs to the role backup category. This ranking is consistent with the recent research on infrastructure handover [11] that shows risk blindness of operations phase transition but extends it by showing that some risk blindness could be discovered earlier by observing phase gates as retention points.

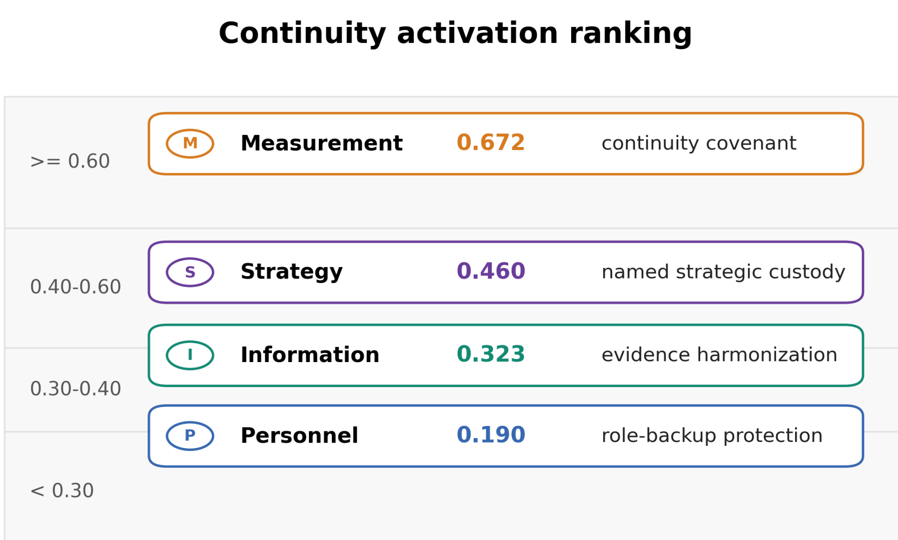

Figure 7. Activation and response.

4.6 Diagnostic-to-governance translation

The governance translation in Table 7 translates each of the results into an appropriate action of public owner. The highest intervention is required for measurement because it is not continuously visible and bounded to construction. Strategy also needs a named custody because the ambition gets expressed in several phases but it is not continuously visible. Information does not need anything more powerful than evidence harmonization since it is present at all phases but changes drastically in salience. Personnel needs role backup and decision rationale recording because of a single personnel-coded observation signaling tacit memory exposure rather than a phase-specific pattern.

This table must be understood as a mode-specific governance specification rather than a generic set of recommendations. A measurement covenant will ensure that every phase defines how the performance criteria are inherited, amended, tested, and transferred to operations. Named strategic custody will make sure that there is an accountable actor or entity to preserve the public-value claim when pressures related to design or construction force change. Evidence harmonization will regulate how information, when crossing phases, is formatted and interpreted. Role backup will help avoid dependence on personal memory in case of personnel changes.

Table 7. Governance response by mode

Mode	CAS	Diagnostic meaning	Governance response
Measurement	0.672	Repeatedly orphaned and strongly construction-bounded.	Establish a continuity covenant linking front-end criteria, design requirements, construction evidence, and operational performance.
Strategy	0.460	Frequent but intermittently visible across gates.	Assign named custody for strategic premises, value claims, and authorized changes to strategic interpretation.
Information	0.323	Present in every phase but highly unstable in salience.	Harmonize evidence formats and define which information must retain traceable meaning across phases.
Personnel	0.190	Low-frequency mode with potential tacit-knowledge exposure.	Use role backup, transition interviews, and decision-rationale records for strategic memory.

4.7 Implications for public infrastructure project governance

The findings above challenge four assumptions about infrastructure governance common in the literature. First, it shows that handover is not enough continuity model. The highest discontinuity rate happens at design-construction phase when an asset has not yet been prepared for operational handover. Early front-end governance literature stresses the importance of early value definition for long term value creation [15]. The literature on project governance emphasizes the necessity to translate strategic intent into delivery mechanisms before construction begins. If the public owner waits until close-out to impose continuity controls, it accepts the risk that design and construction have filtered strategic meaning.

Second, the findings above show that presence of information does not mean continuity of information. Information is present in all phases, but its average directional shift is the highest among all four modes. Hence, the organization has documents or information-coded concerns at all stages of the process, but its relative role changes dramatically. As seen in the boundary object literature, artefacts can cross communities only after being translated [28]. Boundary spanning is based on people who understand the artefacts and interpret them in the new community [29]. Therefore, evidence harmonization should focus on meaning retention, not only storage or transferring.

Third, the findings show that measurement is a complex problem, which cannot be solved by establishing key performance indicators. Measurement mode has the highest BWCP priority, the biggest ablation effect, and the highest CAS. Hence, the problem is not reduced to absence of a key performance indicator. It is the discontinuity in the process from strategic promise to operational evaluation. Public owners need a measurement covenant to ensure that the value claims will be translated into design requirements, construction verification, and operational monitoring.

Fourth, the findings about the strategy show that strategic intentions are often expressed, but intermittently visible. Strategy has seven records, a 0.750 phase span, two zero crossings, and a CAS of 0.460. Hence, the response here is named custody, not a general measurement covenant. Strategic custody implies assignment of the responsibility for the authorized interpretation of public-value claims and for recording when those claims are changed. Governance structures and value distribution can change during the lifecycle of a major project [8]. Changes in stakeholder expectations and institutional relations can also alter the strategic intentions behind the project [9].

The findings also have implications for how to use small coded ledgers responsibly. A twenty-record ledger cannot be used to prove a universal claim statistically, but it can support a disciplined diagnostic if the calculations and interpretations stay close to observed counts. The figures and tables above work as audit devices in that sense: they show the observed counts, gate shifts, custody breaks, and activation ranking. It is quite appropriate for public-owner setting where governance decisions have to be made based on structured but incomplete evidence, and organizational change programmes can reshape the logic of projects over time [43].

4.8 Scope and interpretive limits

The analysis in this paper is based on a single coded phase-mode ledger from a Norwegian public infrastructure agency. Hence, the findings above must be understood as a structured case diagnostic rather than a universal distribution of discontinuity modes. The low number of design observations is especially significant for it. It does not prove that design is unimportant; on the contrary, the gate analysis shows that the small design profile makes it a structurally important gate because design-construction transition has the smallest retained share.

The calculations in the paper rely on the four-mode coding of personnel, information, measurement, and strategy. Other projects may require other coding categories and more detailed mode definitions. However, the method works when the categories are clear and tied to project evidence. Here, the main strength of the analysis is that a small ledger can reveal various modes of discontinuity: frequency, concentration, boundary friction, directional displacement, custody breaks, and activation priorities.

5. Conclusion

The paper addressed the research question: what discontinuity modes are retained, lost, imported, or left without continuous custody when coded observations from a public infrastructure change programme are read as a phase-gate sequence, and what are implications for public-owner intervention priorities? Hence, the answer here is not a broad statement about the importance of better handover practices in infrastructure projects. The evidence identified a specific continuity mechanism: strategic continuity is filtered at adjacent gates, and the most important filter in this ledger is design-construction transition.

The twenty-record ledger shows that construction contains the highest discontinuity load (nine records), while the front-end contains seven records, operation three records, and design one record. Information and strategy modes are the most frequent (each of them represents 35% of records). Measurement is less frequent (25%), but it has the highest boundedness-weighted priority since four of its five records happen in construction. The highest boundary friction occurs at design-construction (0.120) and almost the same at construction-operation (0.118) gate transitions. Removal of measurement reduces the total boundary friction from 0.294 to 0.209, and it confirms that measurement is crucial for the profile instability.

Directional retention analysis provides the final answer to the research question. The design-construction gate has the smallest retained profile share ($R = 0.222$), which means that design is a strong filter rather than a neutral connector. Front-end-design transition is also a weak one ($R = 0.286$). Construction-operation transition has a higher aggregate retained share ($R = 0.556$), but it loses measurement mode entirely. The custody-span analysis helps to understand why it matters: measurement has three zero crossings and a complete orphan rate ($\Omega = 1.000$), while information stays in all phases but it has the largest directional shift ($A = 0.646$). Therefore, CAS ranks measurement as the first priority, strategy as the second one, information as the third one, and personnel as the fourth one.

The practical implication is that public owners must replace the idea of single end-of-project handover with the mode-specific continuity obligations along the phase corridor. Measurement requires a covenant linking front-end criteria, design requirements, construction evidence, and operational performance. Strategy requires the custody of value claims and the authorization of changes in interpretation. Information requires evidence harmonization so that continuously present documents retain the traceable meaning. Personnel discontinuity requires role backup and rationale documentation. All these actions should be implemented before final handover since filtration happens before the operation receives an asset.

The research contribution of the paper is thus the identification of gate filtration as the continuity mechanism in public infrastructure governance. The calculations stay inside BWCP, DGRA, CSOT, and CAS frameworks. Their contribution is in showing that the same small ledger can answer a more precise governance question: not only where the discontinuities appear but which modes lose custody as strategic intent is transferred across project phases.

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