World Journal of Information and Knowledge Management
Print ISSN: 2960-0111
Online ISSN: 2960-012X
DOI: https://doi.org/10.61784/wjikm3029

FROM MANDATE TO MOTIVATION: INCENTIVE COMPATIBILITY IN DIGITAL INFRASTRUCTURE GOVERNANCE

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Abstract: Digital infrastructure is often treated as a technical investment problem, although implementation depends equally on sustained cooperation among agencies, districts, project teams, and operators. This paper develops a conceptual explanation for uneven implementation in capable cities. It combines Hurwicz's incentive-compatibility approach with Herzberg's distinction between motivators and hygiene factors. The resulting framework separates four incentive functions—mission-based, administrative-advancement, economic, and career-development incentives—from two sets of conditions: official traits and project location. It also defines an incentive gap between formally announced rewards and the strength perceived by implementing actors. Three mechanisms enlarge that gap: implementation lag, criterion ambiguity, and attribution ambiguity. Nanjing's digital transportation transformation is used as an illustrative case, not as an empirical test. The analysis shows why data sharing, long project horizons, and citywide spillovers can weaken otherwise credible mandates. Six propositions specify when incentive portfolios should motivate cooperation and when they may instead encourage symbolic compliance, project selection, or competition for credit. The framework implies that effective design requires shared contribution records, project-specific evaluation, differentiated incentive portfolios, and shorter feedback cycles.
Keywords: Digital infrastructure; Incentive compatibility; Digital transportation; Mechanism design; Incentive gap; Nanjing

1 INTRODUCTION

Digital infrastructure has become a central component of urban development. Transport systems increasingly depend on data platforms, intelligent roads, smart hubs, digital freight services, and interoperable control systems. In August 2021, the Ministry of Transport issued a national action plan for new transportation infrastructure, emphasizing digital transformation and intelligent upgrading [1]. Nanjing subsequently released a transportation digital-transformation plan for 2022-2025. Its nineteen tasks were organized around digital foundations, smart facilities, data-enabled governance, digital services, and integrated technology application [2]. These documents define an ambitious technical agenda, but they also create a demanding organizational problem.

Nanjing is an analytically useful setting because it combines strong transport assets with substantial digital capacity. The city functions as an international comprehensive transport hub and integrates aviation, rail, highways, inland shipping, urban transit, and freight platforms. Resource scarcity or technological backwardness cannot explain every implementation difficulty. Even in a capable city, formal plans do not automatically produce integrated databases, common standards, reusable interfaces, or reliable lifecycle maintenance. Visible pilots may advance quickly while data cleaning, cybersecurity review, and routine interagency exchange receive less attention.

The underlying problem is distributed cooperation. A transport bureau values system-wide interoperability, but a district unit bears immediate coordination costs. A data-holding agency may be expected to share information while remaining accountable for security and accuracy. Technical staff may work on a multi-year platform whose benefits appear after the annual appraisal cycle. Contractors can meet delivery milestones without optimizing long-term maintainability. Each actor can satisfy formal requirements yet withhold information, effort, or organizational adjustment that the wider system needs.

Existing studies show that digital infrastructure can affect productivity, innovation, labor allocation, low-carbon development, and regional integration [3-7]. This literature establishes why digital investment matters. It says less about how implementing actors interpret the rewards and risks attached to cooperative behavior. Recommendations to strengthen incentives often treat incentives as a single variable. Such treatment leaves four questions unresolved: Which reward function is expected to work? Which actor values it? How quickly and credibly will it follow contribution? Under what conditions can an apparently strong reward undermine joint production?

Digital infrastructure makes those questions unusually important. Its value is generative: later users recombine platforms and data in ways that were not fully specified at the construction stage [8]. It is layered and path dependent: new components must interoperate with legacy databases, devices, contracts, and routines [9]. Its benefits depend on complementary adoption, which means that one unit's return may remain low until other units also participate [10-11]. These characteristics make contribution difficult to measure and credit difficult to assign. They also separate project completion from system value.

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This paper asks how incentive compatibility can explain the distance between a digital-infrastructure mandate and the cooperation needed to realize it. The paper makes four contributions. First, it adapts mechanism-design reasoning to the organizational setting of urban digital infrastructure. Second, it distinguishes four incentive functions from the recipient and location conditions that shape their strength. Third, it specifies an incentive-gap mechanism linking formal design to perceived consequences. Fourth, it derives six propositions and applies them to Nanjing as an illustrative case. No survey, interview, or causal estimate is claimed.

2 THEORETICAL FOUNDATIONS

2.1 Incentive Compatibility

Hurwicz reversed the conventional direction of analysis. Instead of asking only how actors behave under existing rules, mechanism design asks which rules can generate a desired collective outcome when actors possess private information and pursue their own objectives [12]. A mechanism is incentive-compatible when the action needed for the designer's objective is also a defensible response for each participant. Later work formalized implementation conditions, but the central insight remains: a desirable outcome does not follow merely because an authority announces it [13].

The urban digital setting contains nested principal-agent relations. A city authority sets targets and allocates resources; bureaus, districts, project units, and operators possess superior information about feasibility, effort, data quality, and local risk. A bureau may be an agent in relation to city leaders and a principal in relation to a contractor. Multiple evaluation signals therefore operate at once. They may reward delivery speed, budget execution, safety, innovation, or service continuity, even when system integration requires a different ordering of priorities.

Technical complexity enlarges information asymmetry. An evaluator may be unable to determine whether delay reflects genuine interoperability problems, vendor dependence, weak data quality, or strategic underinvestment. Completion indicators can be satisfied while reuse remains poor. Conversely, a team may invest heavily in standards, security, or maintenance without creating a visible asset. When effort and outcome are only loosely connected in the evaluator's information set, implementing actors cannot be confident that costly cooperation will be recognized.

This paper uses incentive compatibility as an institutional diagnostic rather than a claim that urban administration can be reduced to a complete game. The diagnostic identifies actors, information, feasible actions, consequences, and attribution rules. It then asks whether the expected value of cooperation is credible relative to formal compliance, delay, selective implementation, or protection of organizational credit.

2.2 Motivators and Hygiene Factors

Herzberg, Mausner, and Snyderman distinguished factors that generate satisfaction and positive motivation from conditions whose absence produces dissatisfaction [14]. Achievement, recognition, responsibility, advancement, and meaningful work operate mainly as motivators. Pay, working conditions, supervision, and organizational rules often operate as hygiene factors. Correcting a hygiene deficiency may remove dissatisfaction without producing discretionary effort.

This distinction complements incentive compatibility. Mechanism design examines whether rules align individual action with collective outcomes. Two-factor theory explains why instruments with similar administrative or monetary value can carry different motivational meanings. A modest allowance may restore fairness but may not compensate for the reputational and coordination risk of opening a database. Responsibility for a visible pilot, credible advancement credit, or access to scarce digital skills can change the meaning and future value of the work.

Economic resources remain essential. Teams cannot maintain digital systems without stable budgets, staffing, and procurement support. Yet additional funding does not automatically reward interoperability, shared data, or stewardship. If payment is late or weakly contingent on contribution, even its hygiene function deteriorates. Conversely, a mission narrative or honorary recognition becomes ceremonial when it is disconnected from authority, resources, and appraisal.

2.3 Digital Infrastructure as a Coordination Object

Digital infrastructure differs from conventional public works in four respects. First, it is generative. Platforms, common standards, and sensing layers enable later applications that the original designer may not anticipate [8]. This creates social option value but weakens ex ante measurability. Second, it is layered. Legacy systems and prior contracts constrain later design choices, so current effort affects future flexibility [9]. Third, production is distributed across asset owners, data custodians, service providers, regulators, and users [15]. Fourth, network effects make early participation individually uncertain even when collective value depends on broad adoption [10-11].

These features change the incentive problem. Construction milestones are observable, but integration quality, reuse, maintainability, and data stewardship are harder to verify. Benefits may appear after personnel rotation or outside the unit that supplied the enabling input. Failure, by contrast, can be immediately visible and assigned to a specific actor. This negative-risk asymmetry makes cautious compliance rational. Table 1 summarizes how the two theoretical foundations address this setting.

Table 1 Theoretical Foundations and Their Analytical Roles

Foundation	Core question	Contribution to the framework	Main limitation
Incentive compatibility	Do institutional rules make cooperation individually defensible?	Connects actions, information, consequences, and collective outcomes	Does not by itself explain why actors value different consequences
Two-factor theory	Does an instrument motivate effort or merely prevent dissatisfaction?	Separates motivational functions of recognition, advancement, pay, and learning	Functions vary with context and should not be treated as fixed labels
Digital-infrastructure theory	Why are value, contribution, and completion difficult to align?	Identifies generativity, layering, distributed production, and network effects	Describes structural conditions rather than actor response
Integrated framework	When does a formal incentive become a credible perceived consequence?	Links functional incentives and heterogeneity through the incentive gap	Requires later empirical testing of perceptions and behavior

3 ANALYTICAL FRAMEWORK

3.1 Functional Incentives and Heterogeneity

The framework separates what an incentive does from the conditions under which it is received. Four functional types form one dimension. Mission-based incentives connect work to public value, professional identity, responsibility, and recognition. Administrative-advancement incentives operate through appraisal weight, appointment prospects, leadership attention, and honorary recognition. Economic incentives include allowances, project resources, welfare improvements, and operating support. Career-development incentives include technical training, secondment, cross-unit exchange, and opportunities to lead complex projects.

Two sets of conditions form the second dimension. Official-trait conditions include career stage, education, technical confidence, work experience, role, and access to organizational networks. Demographic variables should be treated as possible proxies for these mechanisms rather than as deterministic preferences. Project-location conditions include fiscal capacity, geography, engineering complexity, installed systems, and the distribution of local costs and citywide benefits.

Table 2 presents the resulting structure. Each cell is an interaction, not a separate instrument. Training remains a career-development incentive even if its perceived value varies with age, technical role, or local institutional capacity. Similarly, a common reward can have different credibility in a well-resourced district and in a location facing high engineering risk.

Table 2 Two-Dimensional Incentive Framework

Incentive function	Principal instruments and logic	Official-trait conditions	Project-location conditions
Mission-based	Public value, professional responsibility, meaningful assignment, recognition	Stronger when professional identity and desire for achievement are salient	Stronger in visible or socially meaningful projects; weaker when success seems unattainable
Administrative-advancement	Appraisal weight, appointment prospects, leadership attention, honors	Varies with rank, remaining career horizon, role, and access to decision networks	Weakened when benefits spill across districts or contribution cannot be assigned
Economic	Allowances, welfare, project resources, stable operating support	Fairness expectations and household constraints shape dissatisfaction	Credibility depends on fiscal capacity and reliable lifecycle funding
Career development	Training, exchange, secondment, project leadership, portable expertise	Often valuable when new skills can be used in later assignments	Stronger where quality training and repeated digital projects are available

The four functions should not be added mechanically. A diverse portfolio can still be incoherent. An organization may praise data sharing while scoring managers only on proprietary service targets. It may fund a platform but deny staff time for training. It may reward rapid procurement while later demanding interoperability. Portfolio diversity improves motivation only when instruments point toward compatible behavior.

Heterogeneity is a design constraint, not an invitation to stereotype officials or favor stronger districts. Equal formal treatment can produce unequal motivational force when actors face different costs, risks, time horizons, and feasible actions. The appropriate objective is equivalent credibility: each actor should be able to see a plausible relationship among contribution, evidence, and consequence.

3.2 The Incentive-Gap Mechanism

The incentive gap is the divergence between formal incentive design and perceived incentive strength. Formal design consists of announced rewards, appraisal rules, responsibilities, sanctions, and opportunities. Perceived strength is an actor's belief that a specified action will lead, with reasonable probability and acceptable delay, to a valued consequence. Behavior responds primarily to the second.

Three mechanisms widen the gap. Implementation lag discounts a reward and increases uncertainty about whether the same evaluator, budget, or appointment opportunity will still exist. Criterion ambiguity prevents actors from knowing which outcomes matter and how trade-offs will be judged. Attribution ambiguity weakens the connection between individual contribution and collective output, especially when one unit provides data or standards that enable another unit's visible result.

These mechanisms interact. Long projects produce staff turnover, which makes contribution records more important. Ambiguous criteria encourage actors to select visible subprojects. Weak attribution makes shared work appear risky, which can increase delay. A formally strong instrument may therefore have little motivational force by the time it reaches the actor.

Table 3 links each mechanism to its likely behavioral response and to evidence that can support later empirical testing.

Table 3 Incentive-Gap Mechanisms and Observable Indicators

Mechanism	How the formal signal weakens	Likely behavioral response	Evidence for later testing
Implementation lag	Reward follows contribution after a long or uncertain interval	Preference for short-cycle outputs and reduced maintenance effort	Time from contribution to recognition; staff rotation; delayed reimbursement
Criterion ambiguity	Appraisal rules do not specify the weight of integration, reuse, or stewardship	Symbolic compliance and selection of easily measured tasks	Indicator definitions; staff understanding; consistency across evaluators
Attribution ambiguity	Joint output cannot be linked to enabling contributions	Data protection, credit competition, or reluctance to support other units	Contribution logs; co-signed milestones; cross-unit credit allocation
Portfolio inconsistency	Different instruments reward contradictory actions	Gaming of the strongest signal and neglect of shared objectives	Alignment among budgets, appraisals, recognition, and training

3.3 Propositions

Proposition 1. The effectiveness of an incentive instrument depends on its compatibility with the coordination demands of the project. A reward for visible unit-level completion will be weak or counterproductive when value depends on shared standards and broad adoption.

Proposition 2. Incentive effectiveness varies systematically across official traits and project locations. Uniform designs therefore produce uneven perceived strength even when their formal value is identical.

Proposition 3. Mission-based and administrative-advancement incentives generally function as motivators in capable public agencies, while modest economic rewards mainly function as hygiene factors. Economic deficiencies can sharply reduce effort, but marginal bonuses alone are unlikely to induce high-risk cooperation.

Proposition 4. Implementation lag, criterion ambiguity, and attribution ambiguity create a systematic incentive gap. The gap will be largest for long-horizon, technically complex, and cross-unit tasks.

Proposition 5. Instrument diversity increases perceived effectiveness only when the instruments are mutually reinforcing. A smaller coherent portfolio can outperform a larger portfolio containing contradictory signals.

Proposition 6. Incentive-compatible design requires alignment at both individual and interagency levels. An individually attractive reward can reduce system performance when it encourages credit competition, data control, or selection of stand-alone projects.

The sixth proposition is deliberately counterintuitive. Stronger administrative-advancement rewards can mobilize effort, but when assessment is individual and production is joint, a higher prize can intensify competition for ownership. The relevant design problem is therefore not simply reward magnitude. It is the unit, timing, and evidence of contribution.

4 NANJING AS AN ILLUSTRATIVE CASE

4.1 Policy Context and Analytical Scope

Nanjing's transport strategy provides a demanding context for the framework. The 2022-2025 plan links digital foundations, smart facilities, data-enabled coordination, digital services, and integrated technology application [2]. A later hub-development plan emphasizes multimodal information exchange and coordination among transport, planning, commerce, finance, customs, maritime, and postal authorities [16]. These objectives require more than separate technical projects. They depend on common standards, data exchange, aligned operating routines, and continuous maintenance.

The case is illustrative rather than confirmatory. Public documents establish goals, institutional responsibilities, and selected capacity-building activities. They do not reveal detailed personnel appraisals, internal contribution records, staff perceptions, or project-level budget contingencies. The analysis therefore identifies plausible incentive risks and the evidence needed to test them. It does not claim that a particular Nanjing unit has delayed, obstructed, or manipulated implementation.

4.2 Incentive Diagnosis

Mission-based incentives are visible in the city's modernization narrative. Digital transport is connected to safer mobility, efficient logistics, better services, and an internationally connected hub. Such framing can make technical work meaningful, especially for teams attached to visible pilots. Its limitation is uneven salience. Interface maintenance, data cleaning, and cybersecurity review are essential, yet they rarely receive the recognition attached to a new control center or smart terminal.

Administrative-advancement incentives are less observable in public sources. Strategic plans demonstrate leadership attention, but formal mention is not equivalent to a credible appraisal contingency. Implementing actors need to know whether interoperability, reuse, maintenance, and cross-unit contribution affect evaluation and appointment. If those rules remain unclear, a strong mandate may be interpreted as symbolic or temporary.

Economic incentives operate through project allocation, procurement, allowances, and operating resources. Nanjing has the capacity to mobilize investment, but funding construction does not necessarily reward data sharing or lifecycle stewardship. A platform can be delivered on time while incentives for reuse remain weak. Stable operating support can remove a hygiene deficiency without changing the comparative value of cooperation.

Career-development incentives receive clearer support. Digital transformation creates demand for expertise that bridges transport operations, procurement, cybersecurity, data management, and emerging analytical tools. Training and project leadership can reduce technical asymmetry and create portable human capital. Their motivational effect depends on access, task relevance, and recognition in later assignments.

Project conditions vary across the city. River crossings, port logistics, dense central districts, and peripheral road networks create different engineering and coordination demands. Fiscal capacity, installed systems, and access to specialized personnel also vary. A standard citywide instrument therefore need not produce standard effort. Table 4 converts these observations into a concise diagnostic agenda.

Table 4 Nanjing Diagnostic Matrix

Documented condition	Potential incentive risk	Design response	Evidence required
Multimodal data exchange across many agencies	Enabling units bear risk while visible benefits appear elsewhere	Shared milestones and contribution records	Internal appraisal rules, data-sharing logs, interviews
Long platform and maintenance horizons	Present effort is separated from later recognition	Interim appraisal and milestone-based recognition	Project timelines, personnel rotation, reward timing
Uneven project visibility	Flagship assets crowd out foundational maintenance	Separate indicators for reuse, uptime, standards, and stewardship	Maintenance records, audit results, reuse statistics
Variation in district capacity and engineering complexity	Uniform targets create unequal feasibility and credibility	Risk-adjusted targets and differentiated support	District budgets, technical constraints, staffing profiles
Training for digital tasks	Learning becomes ceremonial if disconnected from assignments	Task-linked training and documented skill use	Training access, assignment history, later project roles

Three misalignments deserve particular attention. The first concerns data sharing. A unit may remain accountable for security and accuracy while another unit receives the visible service benefit. Without shared credit, cautious and conditional exchange can be individually rational. The second is temporal. Standardization and maintenance generate future value, while annual appraisal favors immediately observable outputs. The third is spatial and fiscal. District actors may carry disruption, preparation, and operating costs while congestion reduction or freight efficiency accrues citywide. Stronger districts can absorb experimentation more easily; weaker locations may wait for clearer support.

The city's explicit call for multimodal information exchange is evidence that integration is a central task, not evidence that it has failed [16]. The framework directs later inquiry toward contribution records, appraisal timing, indicator clarity, risk allocation, and perceived credibility. Those variables can be examined through document coding, surveys, interviews, and process data.

5 DISCUSSION

5.1 Theoretical Contributions

The framework changes how incentives are represented in digital-infrastructure analysis. Instead of a generic enabling variable, incentives are separated by function. A bonus can prevent perceived unfairness; advancement credit changes the future value of effort; recognition adds meaning; training changes capability and later options. The same package can therefore produce different responses across actors and locations.

The incentive-gap mechanism adds a process explanation. Formal rules do not act directly on behavior. They pass through beliefs about timing, criteria, attribution, and credibility. This middle layer is where information asymmetry becomes motivational. Flexible appraisal may help evaluators respond to changing technical conditions, but it also weakens commitment when actors cannot anticipate how contribution will be judged.

The analysis also gives incentive consequences to familiar properties of digital infrastructure. Generativity delays measurement; layering disperses responsibility; network effects create incentives to wait; rapid obsolescence reduces the value of delayed recognition. Institutional design should therefore be treated as part of infrastructure design. Platform architecture and contribution-allocation rules jointly shape adoption.

Finally, the framework qualifies high-powered advancement incentives. Clear targets can mobilize resources, but joint digital production cannot always be decomposed into independent and rankable contributions. If assessment remains individual while production is collective, increasing reward intensity can encourage credit protection. Stronger incentives are beneficial only when attribution and cross-unit alignment are improved at the same time.

5.2 Policy Design

Five design principles follow. First, appraisal should recognize outcomes beyond expenditure and installation, including interoperability, verified reuse, uptime, maintenance, and enabling contribution. Second, project-specific indicators should reduce criterion ambiguity without reducing every outcome to one score. A layered scorecard can combine milestones, user evidence, technical audit, and peer review.

Third, cross-unit projects need shared-credit mechanisms. Joint milestones, contribution logs, co-signed evaluations, and team-based recognition can record enabling work without erasing individual accountability. Fourth, incentive portfolios should vary with career stage, technical role, district capacity, and project complexity. Differentiation is justified when actors face different risks and feasible actions. Fifth, feedback cycles should be shortened. Interim appraisal, prompt reimbursement, timely training, and milestone recognition reduce the discounting caused by long implementation horizons.

Operationally, a city can begin with a limited portfolio of cross-unit projects. At each milestone it can record enabling contributions, verify interoperability and reuse, and compare formal rewards with perceived strength. Short interviews can reveal whether participants understand the criteria and trust the promised consequences. The city can then revise indicators, remove contradictory signals, and scale arrangements that make cooperation more credible.

The framework has clear boundaries. It is most applicable to capable, multiagency digital projects with delayed and uncertain outcomes. Economic incentives may become genuine motivators where baseline compensation or fiscal reliability is low. Conventional milestones may work well when outputs are standardized and directly observable. Shared-credit mechanisms may add unnecessary cost in projects controlled by one unit. Design complexity should remain proportional to production interdependence.

This study is theoretical. Its propositions have not been tested, and public silence cannot establish that an internal incentive is absent. Future work should compare formal and perceived incentives across units and districts, contrast clearly measurable tasks with integration tasks, and track contribution and recognition over time. Mixed methods are appropriate: document coding can identify formal rules, surveys can measure perceived strength, interviews can trace ambiguity, and process records can examine timing and attribution.

6 CONCLUSION

Digital infrastructure is a continuing pattern of cooperation under asymmetric information, not merely a technical asset financed through public investment. The framework developed here links four incentive functions to official-trait and project-location conditions. It explains why apparently sound designs weaken when implementation is delayed, criteria are vague, contribution is difficult to assign, or instruments point toward conflicting behavior.

Nanjing illustrates the practical value of this approach. Its digital transportation agenda depends on data exchange, long-horizon maintenance, and benefits that cross organizational and spatial boundaries. These features create predictable incentive risks even in a capable city. The appropriate response is not simply to increase reward intensity. It is to clarify contribution, align individual and interagency consequences, differentiate portfolios, and shorten feedback cycles.

The six propositions provide an agenda for empirical work. Surveys and interviews can measure the distance between formal design and perceived strength; project records can trace timing and attribution; comparative studies can test how fiscal capacity and engineering complexity alter incentive credibility. Incentive-compatible design will determine whether digital infrastructure remains a set of completed projects or becomes durable urban capacity.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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