A STAGE-SENSITIVE COMPETENCY READINESS FRAMEWORK FOR LEADERSHIP OF URBAN DIGITAL INNOVATION IN SMART CITIES

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Urban digital innovation in smart cities depends on more than technical procurement. It requires local authorities, infrastructure managers, and delivery partners to align strategic intent, collaborative governance, data capability, and responsible innovation across the full life cycle of a project. This article presents a stage-sensitive competency readiness framework that translates the Digital Cities for Change competency framework (DC2-CF) into an auditable model for planning, implementation, and governance in urban development and smart-city practice. The framework is grounded in the empirical base reported by Bastidas et al., namely a four-phase qualitative research programme conducted over five years, incorporating two structured literature reviews, a Cambridge city-scale digital twin case, an initial focus group with 12 experts, a two-day workshop with more than 40 participants, and subsequent validation activities involving a six-person international focus group, a one-to-one discussion with a UK local-government programme manager, and a two-hour workshop with 10 participants in the Republic of Ireland.

The manuscript consolidates the original process model, task structure, competency architecture, and role portfolios into a transparent readiness instrument centred on task-competency-role triplets. Rather than relying on synthetic performance claims, the paper specifies how readiness should be assessed across the three process stages of plan*,* test*, and* embed*, together with the supporting environment of* enable*. The resulting framework provides a rigorous basis for diagnosing capability gaps, sequencing organisational investment, and improving governance assurance in city-scale digital programmes.*

Three conclusions are central. First, competencies tied to stakeholder engagement, socio-technical scoping, participatory governance, communication, trust formation, and risk awareness are not peripheral to implementation; they are constitutive conditions of successful smart-city delivery. Second, competency salience changes across the innovation process, making stage-sensitive assessment essential for urban digital governance. Third, organisational readiness depends on role continuity as much as individual expertise: sponsors, champions, catalysts, and implementers must be aligned if cities are to move beyond isolated pilots toward legitimate and durable public-value outcomes. The article therefore offers a publication-ready framework for capability stewardship in urban development and smart cities.

Index Terms — smart cities; urban development; public value; digital innovation; competency framework; local government; socio-technical systems

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INTRODUCTION

Cities increasingly rely on digital systems to address congestion, environmental pressure, service fragmentation, infrastructure strain, and unequal access to opportunity. Yet the success of these initiatives is rarely determined by technology alone. Urban digital innovation is a socio-technical undertaking that combines governance design, organisational coordination, public legitimacy, data capability, and implementation discipline. For journals focused on urban development and smart cities, this raises a foundational question: how can local authorities build the leadership capacity required to convert digital experimentation into accountable public value?

A strong foundation for answering this question is provided by the Digital Cities for Change competency framework (DC2-CF), introduced by Bastidas et al. as a socio-technical framework for leading digital innovation in the urban built environment [1]. That study set out a digital innovation process, identified stage-relevant tasks, organised competencies across digital and technical, governance and management, and ethics and responsible innovation domains, and grouped roles into sponsor, champion, catalyst, and implementer portfolios [1]. Its principal contribution was to show that smart-city leadership depends on cross-disciplinary capability rather than on technical expertise in isolation.

What city administrations still require, however, is a practical way to translate that framework into operational capability management. Urban leaders need a structured basis for determining which competencies must be present at project inception, which become decisive during pilot activity, which are indispensable when scaling or terminating interventions, and how responsibility should move across organisational roles. Without such a device, smart-city programmes can remain over-concentrated on pilot delivery while underdeveloping the governance, trust, and embedding capacities needed for sustainable adoption.

This article addresses that need by presenting a stage-sensitive competency readiness framework that converts the DC2-CF into an auditable model for local-government use. The framework is designed for the core concerns of urban development and smart-city governance: institutional readiness, delivery sequencing, democratic legitimacy, and public-value protection. Its purpose is not to replace the original framework, but to render it actionable for capability diagnosis, staffing, procurement oversight, and implementation review.

The study makes three contributions. First, it consolidates the empirical and conceptual architecture reported in the original DC2 research programme into a coherent analytical base for readiness assessment. Second, it formulates a transparent readiness model anchored in the task-competency-role structure of the DC2-CF. Third, it demonstrates how the model can be applied using the transport engagement scenario presented in the underlying study, thereby aligning conceptual clarity with practical urban-governance use.

RESEARCH BASIS AND ANALYTICAL MATERIALS

Empirical foundation

The readiness framework is grounded in the research design reported by Bastidas et al., who describe a qualitative programme conducted over four phases and five years [1]. This research basis is important because the DC2-CF was not derived from a single workshop or a purely conceptual review. It emerged from a layered process that combined literature synthesis, case analysis, expert deliberation, and validation across several institutional settings.

The first phase reviewed relevant literature in two complementary streams. One review examined the limitations of dominant smart-city and digital-city narratives and established the need for a socio-technical

perspective. A second review mapped competency gaps and identified 22 competency frameworks comprising 27 competency areas across three dimensions: 10 in digital and technical, 13 in governance and management, and 4 in ethics and responsible innovation [1]. This literature base clarified both the fragmented nature of existing competency models and the need for a more integrated urban framework.

The second phase combined a qualitative case study of a Cambridge city-scale digital twin prototype with the first design of the Digital Innovation Process (DIP) model [1]. The case work was used to examine the overlapping character of the three competency dimensions, the multiplicity of actors involved in city management, and the limits of purely technical approaches to digitalisation. The initial DIP model was then presented to a focus group of 12 city-management professionals, built-environment practitioners, and academic experts engaged in city-scale digitalisation, providing structured feedback for refinement [1].

The third phase refined the framework through a two-day workshop involving more than 40 local and international participants, including academics, built-environment professionals, technology developers, and city managers working with local authorities [1]. Participants were asked to identify tasks, competencies, and role types across four policy dimensions: improving air quality, emergency response and management, planning for liveability, and city-wide information environments. The outputs were analysed through qualitative discourse analysis and network analysis, allowing the researchers to structure tasks, distinguish action-based and knowledge-based competencies, and visualise the relationships among competencies, tasks, and roles [1].

The fourth phase focused on validation. Bastidas et al. report three distinct validation activities: an in-depth 2.5-hour focus group with six experienced international participants (three practitioners and three academics) from the UK, Germany, Austria, Canada, and Egypt; a one-hour discussion with a digitalisation programme manager in a UK local authority; and a two-hour workshop with 10 participants from the Republic of Ireland, including local-government officers, city-management professionals, technology suppliers, planners, and researchers [1]. These activities confirmed both the practical relevance of the framework and the continuing importance of multi-disciplinary capability in real projects.

Analytical unit

The operational unit used in this manuscript is the *task-competency-role triplet*. Each triplet links:

1. a task located within a particular component of the digital innovation process,
2. the action-based and knowledge-based competencies needed to perform that task, and
3. the role portfolio through which those competencies are most plausibly mobilised.

This triplet is the smallest analytically useful unit for readiness assessment because it preserves process location, capability content, and organisational responsibility in a single structure.

FRAMEWORK ARCHITECTURE

Process logic

The readiness model follows the structure of the DC2-CF Digital Innovation Process. In the original framework, the objective is to create public value through responsible digitalisation in the urban built environment [1]. To support that objective, the process is organised around three process stages—*plan*, *test*, and *embed*—together

with a supporting environment, *enable*, that sustains and connects multiple digital-innovation cycles [1]. This distinction matters for urban development because capability needs do not remain static over the course of a smart-city programme.

The *plan* component is concerned with vision setting, public-value framing, priority definition, participation design, and boundary setting. The *test* component centres on experimentation, prototyping, pilot delivery, and implementation monitoring. The *embed* component governs the decision to upscale, reframe, or terminate interventions and addresses institutional integration, democratic oversight, and ongoing risk management. The *enable* environment supports these cycles through system monitoring, stakeholder engagement, and the evolution of information infrastructure and evidence bases [1].

Readiness dimensions

The framework assesses readiness across four mutually reinforcing dimensions:

1. **Stage adequacy**: whether a city possesses the competencies required for the current process component.
2. **Cross-dimensional balance**: whether digital and technical, governance and management, and ethics and responsible innovation capabilities are represented together.
3. **Role continuity**: whether sponsors, champions, catalysts, and implementers can sustain coordination across hand-offs.
4. **Public-value assurance**: whether the city can detect, communicate, and manage risks to legitimacy, inclusion, and accountability.

Operational model

Let C_s denote the set of competencies associated with process component s, where $s \in \{P,T,E,N\}$ represents *plan*, *test*, *embed*, and *enable*. Let $a_{mc} \in [0,1]$ denote the audited attainment of competency c within municipality m, scored on an ordinal rubric translated to a continuous scale (0 = absent, 0.33 = emerging, 0.67 = functional, 1 = institutionalised). Let ω_{cs} denote the salience of competency c in component s, derived from its explicit association with tasks in the DC2-CF and adjusted locally where context requires additional emphasis.

Stage readiness is defined as:

$$R_{ms} = \frac{\sum_{c \in C_s} \omega_{cs} a_{mc}}{\sum_{c \in C_s} \omega_{cs}}. \tag{1}$$

Overall readiness is then expressed as a weighted aggregation across the three process stages and the enabling environment:

$$\mathrm{CRI}_m = \lambda_P R_{mP} + \lambda_T R_{mT} + \lambda_E R_{mE} + \lambda_N R_{mN}, \tag{2}$$

where $\lambda_P + \lambda_T + \lambda_E + \lambda_N = 1$ and the weighting profile is set by the adopting authority to reflect programme priorities. This formulation avoids arbitrary synthetic values while retaining an analytically transparent audit structure.

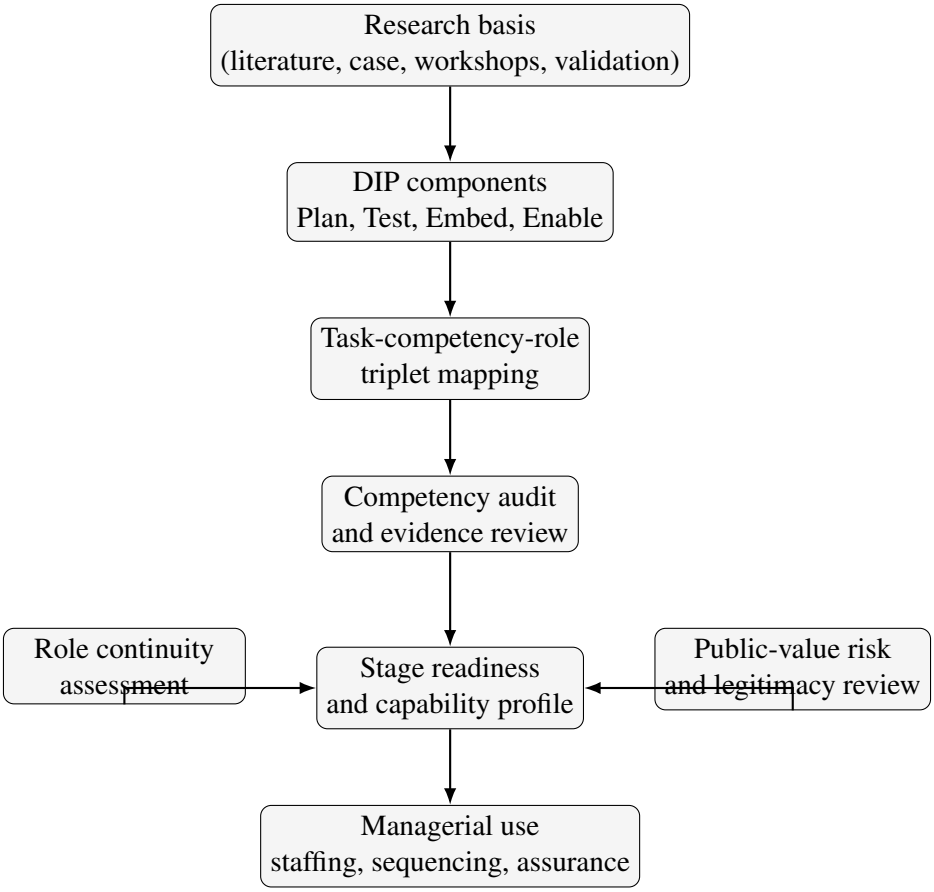

Figure 1: Analytical workflow for the stage-sensitive competency readiness framework.

Algorithm 1 Stage-sensitive readiness assessment for an urban digital initiative

Require: Task-competency-role map T, local audit evidence E, weighting profile λ

for all process components $s \in \{P, T, E, N\}$ **do**
    identify competency set C_s from the DC2-CF task map
    for all competencies $c \in C_s$ **do**
        derive salience ω_{cs} from task association and local programme priorities
        score attainment a_{mc} using documentary, staffing, and governance evidence
    end for
    compute stage readiness R_{ms} using Equation 1
end for
compute overall readiness CRI_m using Equation 2
interpret gaps by stage, competency cluster, and role portfolio
return $\{R_{mP}, R_{mT}, R_{mE}, R_{mN}, \mathrm{CRI}_m\}$

SOURCE-DERIVED TASK AND COMPETENCY STRUCTURE

Stage-specific task structure

A readiness framework is only useful if it remains anchored in the process logic of the underlying model. Table 1 restates the key task architecture reported in the DC2-CF and converts it into a concise audit matrix suited to urban digital-governance review.

Table 1: Core task structure across the DC2-CF process components

Task family	Plan	Test	Embed
Public-value analysis	Analyse the mechanisms through which public value may be created.	Test whether the assumed value-creation mechanisms hold during experimentation.	Review how value-creation mechanisms perform under real-world conditions and whether learning supports continuation.
Problem framing	Frame social needs, opportunities, and desired public outcomes.	Frame pilot experiments against defined public-value goals and priorities.	Evaluate experiments and consolidate learning for city-wide decisions.
Boundary setting	Define scope and constraints by considering possible harm to public value.	Define the scope of pilot experimentation in light of risk and potential harm.	Assess city-wide context and determine whether an intervention should be embedded, reframed, or terminated.
Implementation logic	Align objectives and possible solution pathways with public-value priorities.	Run pilots and prototypes while documenting operational performance.	Implement the chosen embedding, redesign, or closure decision.
Participation and collaboration	Create incentives for deliberation, co-creation, and broad participation.	Manage stakeholder participation and collaboration during delivery.	Maintain or redesign inclusive implementation mechanisms and democratic oversight.
Communication	Translate innovation proposals into understandable public-value terms.	Communicate the experimentation process and interpret pilot outputs.	Translate realised outputs into accountable public outcomes and institutional learning.

The enabling environment

The original framework explicitly treats *enable* as a supporting environment rather than a conventional stage [1]. This distinction should be preserved in smart-city readiness assessment. The enabling environment contains three recurrent activities:

1. assess, manage, and monitor urban socio-technical systems;
2. engage stakeholders and citizens while demonstrating value; and
3. evolve information infrastructure and the evidence base for decision-making.

For local authorities, these activities are not ancillary. They provide the institutional conditions that allow repeated digital-innovation cycles to begin, mature, and remain accountable over time.

Competency architecture

The DC2-CF distinguishes between **action-based competencies** (what practitioners must be able to do) and **knowledge-based competencies** (what they must understand) [1]. This distinction is particularly important for urban development and smart-city projects because governance failures often stem from treating technical know-how as sufficient in the absence of participatory, legal, or ethical literacy.

Knowledge-based competencies are organised into three clusters:

1. **Governance and management**, covering topics such as governance networks, accountability, data ownership, citizen participation, co-creation, transparency, and privacy;
2. **Digital and technical**, covering topics such as digital tools, boundary spanning, system performance, and cybersecurity; and
3. **Ethics and responsible innovation**, covering topics such as public value, bias, conflict resolution, empowerment, and risk management.

The operational implication is direct: a city may possess substantial technical capacity yet still remain unready if governance and ethical competencies are weak or disconnected from delivery.

TRANSPORT APPLICATION AS A READINESS TEMPLATE

The transport example reported by Bastidas et al. provides a concrete illustration of how the framework should be used in practice [1]. In that scenario, a local authority seeks to improve environmentally sustainable transport networks through new bus routes, expanded service hours, cycling infrastructure, and a sustainable travel zone. The public-value objective is to empower citizens as active stakeholders in infrastructure planning while avoiding exclusion caused by the digital divide [1]. For the purposes of readiness assessment, this example is especially useful because it makes visible the interaction between technical design, engagement capability, and democratic legitimacy.

Task-centred competency mapping

Within the *plan* component, the key task is *creating incentives for participation and collaboration*. In the underlying framework, this task is defined as engaging diverse publics and encouraging active deliberation and co-creation [1]. Table 2 presents the source-derived competency snapshot for this task and demonstrates how a city can convert the DC2-CF into an audit template.

Table 2: Transport scenario: competency snapshot for participation and collaboration

Task	Action-based competency	Knowledge-based competency	Cluster
Creating incentives for participation and collaboration: engaging diverse publics and creating incentives for deliberation and co-creation	AC-15 Assess stakeholder engagement needs	1.3.8 Engagement methods and mechanisms (stakeholders)	G&M
		2.1.1 Landscape of digital tools and technologies	D&T
		2.4.2 Boundary spanning and management	D&T
		3.3.4 Consensus seeking and conflict resolution	E&RI
		3.4.1 Empowerment for responsiveness	E&RI
		3.4.2 Risk management concept	E&RI
		3.2.5 Macro environment of culture and practices	E&RI
	AC-16 Translate and communicate complex technical knowledge	1.3.7 Storytelling	G&M
		1.4.5 Co-creation methods and good practices	G&M
		2.4.1 System performance indicators	D&T
		3.1.3 Public value concept	E&RI
	AC-18 Build trust with stakeholders and citizens	1.1.3 Legislative and regulatory landscape	G&M
		1.3.7 Engagement methods and mechanisms (citizens)	G&M
		1.4.4 Transparency of governance processes; 1.4.7 Privacy (concept, value); 2.5.1 Cybersecurity policy, governance and people; 2.5.3 Cybersecurity data administration; 3.1.2 Bias in data collection and sampling	Mixed

This example shows why a readiness model for smart cities cannot be reduced to digital maturity in a narrow technical sense. The action-based competencies in the transport scenario depend simultaneously on engagement design, communication, system understanding, regulatory literacy, trust formation, cybersecurity, bias awareness, and public-value reasoning. A city that lacks any one of these elements may still launch a consultation platform, but it will do so with a heightened risk of exclusion, mistrust, or poor uptake.

Role portfolios and capability responsibility

The DC2-CF groups roles into four portfolios: **sponsor**, **champion**, **catalyst**, and **implementer** [1]. The distinction is not merely descriptive. It provides a practical basis for capability governance in local authorities.

Table 3: Role portfolios and their governance function in readiness assessment

Portfolio	Core function	Illustrative organisational location
Sponsor	Provides formal legitimacy, deploys resources, and authorises collaboration and strategic direction.	Mayor, cabinet member, senior local-government executive
Champion	Mobilises organisational capacity, coordinates actors, and sustains momentum across departments.	Chief information officer, programme manager, smart-city lead
Catalyst	Creates constructive disruption, challenges inherited assumptions, and opens room for innovative approaches.	Infrastructure portfolio lead, strategic transformation lead
Implementer	Converts plans into operational delivery and maintains the practical routines needed for execution.	Digital service manager, engagement specialist, delivery manager

For readiness assessment, these portfolios answer a crucial question: *who is institutionally capable of carrying the competencies required by a given task?* A city may possess isolated expertise yet remain operationally weak if no role portfolio can mobilise that expertise at the right moment or carry it across process hand-offs.

VALIDATION SIGNALS AND MANAGERIAL USE

What the validation activities show

The validation activities reported in the original study offer direct guidance for how the readiness framework should be interpreted. First, the international six-person focus group helped refine the visual representation of the delivery structure and the knowledge-based competency map, reinforcing the importance of clearly tracing the connections among roles, competencies, and tasks [1]. Second, the UK local-government interview confirmed the need for a framework that is usable within real administrative settings rather than only in academic analysis [1]. Third, the Republic of Ireland workshop highlighted two findings of immediate relevance to readiness assessment: participants considered the multi-disciplinary emphasis highly relevant, and they identified the *champion* role as especially important to project accountability and coordination [1].

The same workshop also showed that practitioners tend to prioritise competencies aligned with their own backgrounds: planners emphasised public-engagement capability, while computer-engineering specialists prioritised digital and technical competencies [1]. This observation strengthens the case for a structured readiness instrument. Without such a model, smart-city teams risk overvaluing familiar competencies and underinvesting in the cross-disciplinary capacities that actually sustain implementation.

Readiness bands for local-government use

To support practical application, the following interpretive bands can be used after computing stage and overall readiness scores:

Table 4: Interpretive readiness bands for urban digital-governance use

Range	Band	Interpretation
0.00–0.39	Foundational deficit	Core competencies are absent or weak across one or more process components; pilot activity may be possible, but institutional risk is high.
0.40–0.59	Pilot-capable	The authority can frame and run bounded experiments, yet gaps in embedding, trust, or governance make sustained adoption uncertain.
0.60–0.79	Operationally ready	The authority can plan, test, and integrate initiatives with reasonable confidence, but continued strengthening is needed for long-term adaptability.
0.80–1.00	Strategically adaptive	The authority demonstrates strong cross-dimensional capability, credible role continuity, and a robust basis for accountable scaling and learning.

These bands are intentionally conservative. In urban development practice, a city should not be classified as mature merely because it can procure tools or launch pilots. Readiness must also include the capacity to justify, govern, communicate, and, where necessary, halt digital interventions in the public interest.

Implementation guidance

For local authorities and delivery partners, the framework supports four immediate uses:

1. **Capability audits**: identify missing competencies before procurement, procurement during piloting, and accountability risks before scaling.
2. **Staffing and reorganisation**: determine whether gaps are best addressed through recruitment, internal development, cross-functional teaming, or external support.
3. **Programme sequencing**: align investments with the actual component of the process rather than overinvesting in technical build capacity too early.
4. **Governance assurance**: incorporate inclusion, transparency, cybersecurity, privacy, and bias awareness into delivery review rather than treating them as late-stage compliance add-ons.

DISCUSSION

The manuscript makes a conceptual and practical contribution to research at the intersection of urban development, smart-city governance, and public-sector innovation. Conceptually, it provides a process-sensitive method for interpreting competency needs in city-scale digital programmes. The core significance lies in shifting the focus from generic digital maturity to a socio-technical understanding of readiness. This is important because urban digital projects do not fail only when software underperforms; they also fail when participation is narrow, accountability is unclear, roles are fragmented, or public trust is undermined.

A second contribution is the preservation of the three-dimensional competency architecture within an operational model. The literature on digital transformation often recognises the importance of organisational and human capability, yet practice still tends to privilege technical delivery [3, 4, 11]. By keeping governance and

management, digital and technical, and ethics and responsible innovation in active relation, the framework offers a more realistic basis for understanding smart-city delivery in institutional context.

A third contribution concerns role orchestration. The sponsor-champion-catalyst-implementer structure is especially valuable for urban governance because smart-city projects almost always move across political, administrative, technical, and collaborative boundaries. Readiness therefore depends not only on whether competencies exist somewhere in the organisation, but also on whether they are carried by roles with the authority and continuity to use them at the right time.

Several limitations remain. The model is grounded in a robust qualitative evidence base, but it is not a substitute for prospective field testing across multiple city administrations. Local calibration is necessary when assigning salience weights and interpreting readiness thresholds. In addition, because urban digital projects are highly context-sensitive, the framework should be used as a disciplined diagnostic instrument rather than as a universal ranking device. These limitations do not weaken its practical value; they clarify the conditions under which it should be applied responsibly.

CONCLUSION

Leadership of urban digital innovation depends on disciplined capability stewardship. For smart-city and urban-development practice, the central question is not whether a city can deploy a digital tool, but whether it can align public-value goals, task design, multi-dimensional competencies, and role continuity across planning, experimentation, embedding, and the wider enabling environment.

The framework presented here offers a practical answer. Grounded in the empirically developed DC2-CF, it translates a socio-technical competency architecture into a usable readiness model for local authorities and delivery partners. It shows that the decisive competencies of urban digital innovation are not purely technical; they include stakeholder engagement, socio-technical boundary setting, communication, trust-building, transparency, cybersecurity, bias awareness, and adaptive governance. It also shows that these competencies only become effective when they are connected to roles capable of carrying them through real organisational processes.

For the field of urban development and smart cities, this matters because the long-term value of digital programmes depends on legitimacy, coordination, and institutional learning as much as on technological sophistication. A stage-sensitive readiness framework helps cities make those conditions visible before failure becomes embedded in delivery. In that respect, capability assessment is not an administrative afterthought. It is part of the essential infrastructure of responsible smart-city governance.

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