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Regional Institutional Capacity as a Potential Mediator of Infrastructure Capitalization: A Conceptual and Geospatial Framework

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Abstract

Major infrastructure investments alter accessibility and urban development patterns, yet their impact on housing prices varies significantly across regions. The prevailing interpretation attributes this heterogeneity to supply differences or regulatory constraints, treating land use regulations as exogenous variables. Nevertheless, even two regions with a nominally similar regulatory framework may produce substantially different outcomes in the housing market, depending on the effectiveness of rule implementation. This paper argues that this approach overlooks a critical variable: the ability of regional authorities to coordinate, regulate, permit, and implement spatial development in a predictable and timely manner. In line with this, a conceptual framework is developed, grounded in the literature on spatial and multi-level governance, in which regional institutional capacity is proposed as a potential mediator of capitalization around project milestones (announcement, funding, construction, operation), rather than as a backdrop. This capacity shapes outcomes through three interrelated dimensions: the responsiveness of supply, which depends on administrative capacity and regulatory consistency; the coherence of governance across jurisdictions within functional urban areas; and the management of land value through land value capture instruments. From this framework, testable propositions are derived regarding the intensity, timing, and spatial distribution of price effects. The study does not empirically estimate changes in housing prices, nor does it test the propositions put forward. Instead, it develops the conceptual framework and organizes the spatial and institutional units of observation required for a subsequent empirical test. The framework is specified spatially through Section A, Line 4 of the Athens Metro to organize the project's spatial units, administrative jurisdictions, land uses, and milestones for future analysis. The contribution is threefold: conceptual, as it elevates regional institutional capacity from a contextual to an explanatory variable; theoretical, in that it bridges urban economics with the governance literature; and policy-relevant, since it repositions the reform of regional governance as a constituent element of housing policy and as a factor that may shape sustainable spatial development outcomes.

Keywords: spatial governance; regional institutional capacity; housing prices; infrastructure capitalization; accessibility; land use regulation; permitting frictions; value capture

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1. Introduction

1.1. The Heterogeneity of Effects on Property Values

The distribution of real estate prices in urban areas is one of the most visible manifestations—though not the only one—of the way in which institutions, markets, and spatial interventions interact. It reflects the ability of institutions to regulate land use, coordinate development, and manage spatial interventions to produce predictable and socially acceptable outcomes. Contemporary literature on strategic spatial planning has shifted the discussion from the production of plans to a broader conception, in which the quality of the outcome depends not only on the rules but also on the capacity to implement them [1,2]. In this regard, large-scale spatial interventions (e.g., the expansion of transportation networks, neighborhood regeneration, and climate adaptation infrastructure) serve as diagnostic events: they are expected to be reflected in property values because they alter accessibility, environmental conditions, and expectations about the area's future development. Empirical literature not only confirms the existence of this capitalization but also highlights a systematic, unresolved issue: its magnitude varies dramatically across comparable interventions and locations.

Synthetic analyses of capitalization in railway projects document effects ranging from negligible to double-digit growth rates, with these variations persisting even after controlling for infrastructure type and methodology [3,4]. In neighborhood regeneration, the very nature of the effects is disputed. While some studies document strong positive externalities that multiply the value of public investments [5], others find that the benefits remain localized to the directly benefiting property owners without wider diffusion [6]. In climate adaptation infrastructure, the effects are strongly localized, with gains concentrated in close proximity to the project [7], whereas in emerging markets, the discounting effects systematically observed in mature institutional frameworks are entirely absent, a divergence attributed to institutional uncertainty surrounding implementation [8].

This heterogeneity is not statistical "noise". It appears consistently across various types of spatial interventions, methodological approaches, and geographical contexts. Its persistence raises an interpretive question at the heart of spatial governance: why does the "same" spatial intervention result in radically different outcomes in the housing market?

1.2. Explanation and Blind Spot

The prevailing interpretation of heterogeneity focuses on differences in housing supply and regulatory constraints on development. The argument is simple: when land use regulations constrain supply, an increase in demand cannot be met with new construction. Thus, demand is reflected in the prices of existing homes rather than in an expansion of the housing stock [9,10]. The quantification of this approach is based on regulatory stringency indices (a prime example being the Wharton Residential Land Use Regulatory Index [11]), which systematically record codified land use regulations by jurisdiction. Combined with measures of geographically available land [12], these indices provide a robust analytical framework for explaining why some markets exhibit higher capitalization than others.

Despite its undeniable interpretive power, this framework contains a systematically limiting assumption: it treats regulatory constraints as formulated rather than as applied. This distinction is not insignificant. The empirical literature on spatial planning has repeatedly documented that incorporating specific principles or rules into formal plans is not systematically associated with the production of corresponding spatial outcomes [13]. Even if two regions have a nominally equivalent regulatory framework, they can produce significantly different outcomes in the housing market, depending on the speed and predictability of the permitting process, the consistency of rule enforcement, and the capacity for collaboration among the relevant authorities. Meanwhile, the limitation is also method-

ological: when regulatory constraints, geographic scarcity, and high prices are spatially concentrated, it can be difficult to distinguish between what is produced by the rule itself and what is produced by the way the rule is applied [12,14]. Thus, a critical aspect of the observed diversity remains unaddressed: not the existence of regulations, but how they are implemented on the ground.

1.3. Regional Institutional Capacity as a Mediator

An alternative interpretation focuses not on what the rules state, but on what the competent authorities can accomplish. The concept of regional institutional capital, introduced as a multidimensional resource that combines knowledge, relationships, and the ability to mobilize, provides the theoretical basis for understanding differences in the production of spatial outcomes [2]. At the subnational level, the capacity of regional authorities to coordinate, regulate, license, and implement spatial development in a predictable and timely manner is unevenly distributed: it exhibits systematic variation within states and regions to an extent that national-level measures do not capture [15]. When this variation is considered alongside the heterogeneity of capitalization phenomena, the hypothesis emerges that regional institutional capacity may function not merely as a passive backdrop to capitalization, but as a potential mediator that can shape the intensity, timing, and spatial distribution of impacts surrounding a project's milestones: the announcement, financing, construction, and operation. This mediation is exercised through three interrelated channels: the responsiveness of supply, the coherence of governance across jurisdictions, and the management of land value. The theoretical foundation of each dimension is developed in Section 2, while its analytical integration is presented in Section 3.

1.4. Geospatial Framing

For regional institutional capacity to be more than just an abstract concept, it must be observable. This requires spatial analysis, not as an additional tool, but as an essential component of observation. As mentioned above, the capacity of authorities may vary significantly between regions, between administrative units within the same region, and even within functionally integrated urban areas [15]. This variation is expressed in ways that are essentially spatial: permit processing times that change abruptly when crossing administrative boundaries, areas where the implementation of urban planning schemes is systematically delayed, and instances where the interface between multiple authorities creates friction and delays. Indicators that aggregate such observations at the national or regional level obscure precisely this variation that lies at the heart of the matter. In this context, geospatial information functions not as a simple mapping of space but as a fundamental infrastructure for spatial governance [16,17]. Tools developed in Geographic Information Science [18] (indicators of spatial association, geographically weighted approaches, spatial autocorrelation analysis, and detection of discontinuities in administrative boundaries) enable the conversion of capacity into measurable metrics, thereby identifying where and how institutional friction occurs. This development aligns with the broader transition toward smart land governance, in which the quality of institutional functioning is assessed not only by technology but also by the synthesis of technology, transparency, and institutional participation [19]. The point, therefore, is not merely that geospatial tools are valuable for analyzing capitalization. It is that without spatial analysis, regional institutional capacity itself cannot be observed as a differentiated variable.

This paper is a conceptual article that develops a theoretical framework rather than an empirical assessment of Line 4's effects on housing prices. It develops the argument in three stages: first, it formulates a theoretical framework that treats regional institutional capacity as a mediating factor of capitalization; second, it translates the framework into

measurable dimensions and testable propositions; and third, it uses the case of Line 4 of the Athens Metro as an illustrative geospatial application for organizing future units of observation. The maps do not constitute an empirical test of the propositions, nor do they document that changes in values have already occurred. They define the spatial, administrative, and temporal scope within which such a test can be carried out in a subsequent research phase.

2. Theoretical Framework

2.1. The Capitalization of Spatial Interventions on Property Values

The theoretical basis for the study of capitalization stems from the tradition of urban structure models, in which land value is determined by variations in accessibility to the metropolitan center and the resulting cost–benefit trade-offs in location decisions (bid-rent theory) [20,21]. Given this background, a spatial intervention that alters accessibility or local characteristics is expected to be reflected in measurable shifts in real estate values [22,23]. Modern empirical approaches express this logic through hedonic pricing models, which analyze a property's value as the sum of the individual contributions of its characteristics (e.g., accessibility, environmental quality, neighborhood quality, public services), assigning an indirect marginal value to each [24]. Despite a common theoretical starting point, the mechanisms by which spatial interventions translate into changes in value differ substantially by intervention type. For instance, transportation infrastructure acts primarily by altering accessibility, with effects manifesting gradually around distinct milestones (announcement, funding, construction, operation) and accompanied by both positive and negative externalities, depending on the distance from the station [8,14,22,23,25]. Neighborhood regeneration operates through quality externalities: the upgrading of the built environment can generate spillover benefits for surrounding properties or, conversely, be limited to the owners who benefit directly [5,6]. Climate adaptation infrastructure capitalizes on the reduction in perceived risk, with effects that decline sharply with distance from the project [7]. Green infrastructure operates through a combination of environmental and social factors, with outcomes that depend heavily on the local context [26]. However, when estimated effect sizes are aggregated in meta-analyses, a systematic pattern emerges: the effect sizes exhibit striking dispersion, with deviations that persist even after controlling for intervention type, methodology, and key contextual characteristics [3,4]. The same dispersion is observed in specific externalities, as evidenced by the mixed effects at airports, where noise and accessibility zones exert conflicting pressures on values [27]. This heterogeneity poses a broader challenge to theory: which characteristics of the place explain why the same category of spatial intervention produces such different outcomes? The conventional answer focuses on housing supply and regulatory constraints on development, the subject of the next section. At the same time, measuring these effects is complicated by spatial correlation in omissions and endogeneity that traditional parametric models struggle to address, necessitating more flexible spatial methods [14].

Capitalization in housing prices is not exclusively a result of changes in accessibility or the institutional environment. Prices are simultaneously influenced by changes in income and employment, interest rates, the availability of mortgage and development financing, inflation, construction costs, investor expectations, demographic trends, property taxes, demand for short-term rentals, the overall housing supply, and other local or metropolitan interventions. These factors may coincide with the milestones of an infrastructure project and cause price changes that cannot be attributed exclusively to the infrastructure or to regional institutional capacity.

2.2. Land Use Regulation and Supply Responsiveness

The conventional response to heterogeneity focuses on differences in housing supply and regulatory constraints on development. According to this approach, land use regulations create a kind of "regulatory tax" on construction: the difference between the market value of a built space and its construction cost does not reflect the natural scarcity of land, but the artificial scarcity imposed by the urban planning framework [9]. When supply is constrained in this way, any increase in demand—whether due to improved accessibility, urban renewal, or a broader macroeconomic change—leads to higher prices for existing properties rather than an expansion of the housing stock. Quantification of this logic has relied on regulatory stringency indices, with the Wharton Residential Land use Regulatory Index (WRLURI) serving as the most systematic measurement tool, recording codified regulations and procedural barriers to construction across thousands of jurisdictions [11]. When combined with measurements of geographically available land derived from satellite data [12], this approach provides estimates of supply elasticity and forecasts of the extent to which an exogenous shift in demand will be reflected in prices. The empirical validity of the framework is significant: studies in England estimate that housing prices would be approximately 35% lower in the absence of the British planning system [10].

Despite its interpretive power, the framework is based on two restrictive assumptions. First, it treats regulations as exogenous, whereas Saiz [12] himself has highlighted reverse causality: geographical scarcity and high prices trigger stricter regulations, as existing owners have an incentive to protect their investments through exclusionary policies. Secondly, and more critically for this paper, these indices record the rules as they are formulated in official texts, not as they are applied in practice. Two regions with equivalent WRLURI scores can produce radically different outcomes in the housing market, depending on the speed and predictability of permitting, the consistency of rule enforcement, and the coordination capacity of the relevant authorities. This difference between regulation as written and regulation as implemented is precisely where regional institutional capacity comes into play.

The response to the supply also depends on economic and financial conditions that are beyond the direct control of local authorities. Even a predictable and efficient permitting system does not necessarily lead to new construction when financing costs are high, developers' access to credit is limited, construction costs are rising, or expected demand is insufficient. Similarly, strong investment demand and favorable financing conditions can accelerate development even in administratively challenging environments. Thus, administrative indicators must be analyzed in conjunction with market conditions and not as self-sufficient determinants.

2.3. Multilevel Governance and Regional Institutional Capacity

The idea of regional institutional capacity as a mediating mechanism, introduced in Section 1, draws on three distinct but complementary traditions: first, Healey's concept of institutional capital: a multidimensional resource that combines knowledge, relationships, and mobilizing capacity, which provides the basis for understanding differences in the production of spatial outcomes [2]. At the same time, the literature on multilevel governance has shown that spatial interventions rarely unfold within a single jurisdiction: they involve both permanent, general-purpose administrative structures and flexible, task-specific bodies that operate in parallel and often overlap [28]. The quality of coordination between these structures, not simply their existence, determines the actual capacity for intervention in the field. Empirically, the variation in institutional quality is striking not only between countries but also within them, and it has been documented that it exerts a decisive influence on the performance of public investments: beyond a certain funding threshold, the quality of governance becomes a

more critical factor than the sheer volume of resources [15,29]. In that vein, regional institutional capacity is not a uniform national characteristic but a spatially distributed quality that influences both nature and the intensity of the effects of spatial interventions on real estate markets. Despite this clear theoretical and empirical foundation, the link between governance and capitalization literature remains unaddressed.

Regional institutional capacity is therefore introduced as a conditional mediating or moderating mechanism, rather than as the primary determinant of changes in housing prices. Its expected effect depends on the magnitude of the change in accessibility, local market characteristics, financing conditions, supply responses, and the broader macroeconomic environment. The empirical question is whether differences in institutional capacity account for additional heterogeneity in the results after accounting for these economic, spatial, and social factors.

2.4. Geospatial Shift and Identification of the Gap

A third argument is developed in the literature on land administration and Geographic Information Science, with the central premise that geospatial information functions not merely as a recording tool but as a constitutive infrastructure of spatial governance. In this context, the fundamental functions of land ownership, value, use, and development are treated as interconnected dimensions of an integrated geospatial system, within which the quality of institutional functioning becomes visible and measurable [16,17]. Meanwhile, Geographic Information Science has developed a methodological toolkit for studying spatially distributed phenomena characterized by autocorrelation, boundary discontinuity, and scale heterogeneity [18]. Contemporary approaches to smart land governance integrate these elements by proposing frameworks that link technology, institutions, and participation into functional management systems [19]. Despite the maturity of all three traditions (the capitalization of spatial interventions, supply and regulations, and the institutional dimension in conjunction with geospatial governance), their convergence remains uncommon. The heterogeneity documented by the first tradition is not adequately explained by the regulatory terms of the second, while the conceptual and methodological tools of the third are rarely utilized to understand capitalization. This is precisely where the theoretical gap lies.

3. The Capacity as a Mediator: Conceptual Framework and Geospatial Translation

3.1. Regional Institutional Capacity as an Analytical Category

The concept of regional institutional capacity has been drawn upon across the literature of spatial planning, economic geography, and infrastructure governance, without, however, acquiring a fixed analytical meaning. In most of its applications, it is intertwined with related but distinct categories: state capacity, administrative competence, quality of governance, and good governance, thereby diminishing its explanatory value. Its utilization as a mechanism for mediating capitalization, as proposed in this framework, therefore requires a preliminary clarification: which properties of the institutional environment constitute capacity as understood here, and how it differs from its closely related constructs.

State capacity, as developed in comparative political science, refers to the ability of the nation-state to mobilize resources, extend its authority throughout its territory, and enforce binding decisions. It is defined and measured primarily at the national level. Administrative capacity, by contrast, refers to a narrower scope: the technical and managerial skills of public organizations in carrying out established procedures, such as drafting regulatory acts, processing files, or executing budgets. The tradition of quality governance, in turn, evaluates the institutional environment, synthesizing elements of impartiality, low corruption, and the rule of law into a normatively charged construct. Finally, the

rhetoric of "good governance" frameworks functions normatively rather than analytically: it prescribes desirable characteristics rather than explaining variation in outcomes among comparable jurisdictions.

In contrast to these approaches, capacity as understood from this perspective has three distinct characteristics. First, it is not a homogeneous national characteristic but a spatially distributed feature: it varies within states, within regions, and even within metropolitan areas to an extent that national-scale measurements cannot capture [15]. Secondly, it is functionally specialized rather than evaluatively diffuse: it focuses on capabilities related to producing spatial outcomes, not on governance in general. Thirdly, it is operationally observable through measurable manifestations (such as the time elapsed until the issuance of a building permit, the consistency with which equivalent cases are handled by the same authority, and the degree to which neighboring jurisdictions coordinate within functionally unified urban areas) rather than through abstract institutional virtues. Based on the above, regional institutional capacity is defined here as the spatially distributed ability of subnational authorities to coordinate, regulate, permit, and implement spatial development with predictability and in a timely manner. Institutional implementation credibility should be distinguished from the three operational channels of capacity. It is neither a fourth independent channel nor synonymous with overall institutional quality. It is a cross-cutting and perceived attribute of the implementation framework: the degree to which market actors believe that a project's announced commitments, funding decisions, timelines, and successive milestones are likely to be realized. This perception is shaped by observable factors, such as consistency between announced and actual milestones, securing funding, contracting, continuity of intergovernmental coordination, predictability of administrative procedures, and the track record of completing comparable projects. Therefore, credibility serves as the temporal mechanism by which the operational dimensions of capacity influence the pricing of expectations.

This definition parallels the work of Healey [2], who introduced the concept of institutional capital as a multidimensional resource comprising cognitive, relational, and motivational dimensions. The connection is substantial but not identical. Healey's formulation is situated within the collaborative production of design; the present reading shifts the emphasis to the capacities specifically involved in the production and distribution of phenomena of capitalization. Healey's three-dimensional function, in this light, is an underlying condition. The operational capacities specified below constitute the channels through which these conditions are translated into spatial outcomes.

Two additional qualitative specifications are necessary. Capacity, as understood in this context, is unevenly distributed across functions: a jurisdiction may demonstrate efficiency in licensing while lacking coordination with neighboring authorities, or vice versa. This internal heterogeneity is not merely an empirical observation but a critical analytical property: it allows the framework to address cases in which the same intervention is filtered differently by different dimensions of capacity within the same administrative space. Second, capacity is not exogenous to the phenomenon it shapes; prolonged capitalization pressures can, over time, either trigger institutional adaptation or, conversely, entrench institutional weaknesses through politico-economic mechanisms that protect existing owners. The analytical priority given here to capacity in terms of capitalization is therefore analytical in nature; it does not constitute a claim of temporal exogeneity at the empirical level.

From this starting point, capacity ceases to function as an evaluative criterion and assumes an analytical role: it becomes a candidate explanatory variable for understanding why the same spatial intervention produces markedly different results in jurisdictions with comparable regulatory frameworks. Its explanatory power, however, does not rest on a uniform quality

of the institutional environment but on specific functional dimensions through which the intervention is filtered before it manifests as a change in housing market prices.

For empirical purposes, regional institutional capacity should not be captured by a single, general index without first examining its internal structure. The three functional dimensions must be measured separately at first, as a jurisdiction may perform well in one dimension and poorly in another. Comparisons between regions must therefore be based on a transparent system of individual indicators, with a common definition, a common time period, a comparable unit of reference, and an explicit distinction between the institutional availability of a tool and its actual implementation.

3.2. Channels of Institutional Mediation

The first dimension through which capacity filters a spatial intervention concerns the responsiveness of supply: the ability of the local administrative apparatus to convert new demand pressures into new construction within a reasonable timeframe, rather than allowing them to be absorbed as a price increase in the existing stock. The conventional approach to regulatory constraints treats the rule as an independent factor, but spatial planning practice shows that two jurisdictions with formally equivalent frameworks can produce markedly different rates of new development, depending on the speed, predictability, and internal consistency of the administrative procedures that translate intent into implementation. This weakness has been recognized even by the most systematic indicators of regulatory stringency: the codified letter is measured with precision, but its translation into timeframes and outcomes remains unmeasured [11]. The relevant planning literature has, moreover, documented the discrepancy between adopted principles and actual spatial outcomes as systematic [13], while the asymmetrical distribution of responsibilities without a corresponding allocation of resources has been identified as a mechanism that undermines the responsiveness of subnational authorities [30]. The geospatial manifestation of this dimension is evident in the distribution of licensing times by administrative unit, the time lag between license issuance and construction completion, and the variation in licensing outcomes for equivalent cases within the same jurisdiction. The responsiveness of the supply side can be operationalized through indicators such as the median time from submission to issuance of a building permit, the variation in processing times for comparable cases, the percentage of applications requiring review or additional information, the number and floor area of new residential permits per unit of existing housing stock, the time between permit issuance and the start or completion of construction, and the change in new housing stock following each project milestone.

Beyond the response times of a single administrative apparatus, there is a second operational dimension: that of governance coherence, which becomes critical when an intervention extends beyond a single jurisdiction. Large-scale spatial interventions rarely unfold within the boundaries of a single administrative unit; they cross jurisdictions with incompatible priorities and asymmetrical capacities while often involving flexible special-purpose entities, such as development companies or project oversight authorities. The coexistence of permanent general-purpose structures with specialized agencies has been recognized as a structural feature of contemporary spatial governance [28], and the quality of coordination between them, not merely their existence, determines whether the intervention produces spatially uniform or fragmented outcomes. The empirical literature has documented that institutional quality is distributed highly unevenly not only across states but also within them, and that beyond a certain funding threshold, it becomes more decisive than the level of resources itself [15,29]. When this uneven distribution intersects with an intervention spanning multiple jurisdictions, the discontinuities in administrative capacity are reflected in the outcomes themselves: some parts of the project mature more

quickly, the application of rules varies as the project moves from one administrative boundary to another, and the final spatial distribution of impacts takes on an anisotropy that cannot be explained by the physical characteristics of the intervention. The geospatial pattern is evident in the spatial fragmentation of jurisdictions within a functional urban area, in discontinuities in measurable outcomes across administrative boundaries, and in the presence or absence of institutional mechanisms for interregional cooperation. The coherence of governance can be reflected in the existence and effective functioning of inter-municipal or intergovernmental coordination mechanisms, consistency in the application of comparable urban planning regulations, the frequency of conflicting or successively revised administrative decisions, differences in the timelines and outcomes of administrative procedures on either side of the border, and the existence of common protocols for data exchange and project monitoring.

The first two dimensions concern the generation of these effects; the third, that of land value management, concerns their distribution. The fundamental observation goes back to the classic analysis of the benefits of public transportation investments. The increase in land value triggered by such investments does not constitute a net social benefit but rather reflects the actual benefits of reduced transportation costs [23]. When this surplus value is fully absorbed by private landowners without any public return, the investment itself becomes a mechanism for wealth transfer rather than a generator of public value. The public sector's ability to capture a portion of the surplus value through tools such as improvement levies, compulsory land acquisition, transferable development rights, or financing through increased tax revenues varies radically across institutional frameworks and constitutes a distinct functional characteristic, recognizable both in its institutional availability and in its actual implementation. Even in successful urban regeneration policies, the benefits may be concentrated among the owners who benefit directly, rather than being dispersed as broader spatial externalities [6]. Therefore, the ability to manage value appreciation concerns both institutional availability and the actual implementation of mechanisms through which part of the privately capitalized value is returned to the public sector or funds broader social and spatial benefits. Its geospatial representation can be based on recording, by jurisdiction, the existence of relevant tools, the frequency of their application, and the spatial distribution of the public returns resulting from them. The capacity to manage land value uplift can be measured by separately recording the legal availability and actual application of each tool, the number and value of relevant transactions, the level of public return associated with the value generated, the time required to activate the mechanisms, and the spatial distribution of revenues or compensatory benefits.

A distinct yet related issue is the point in time at which the market incorporates the expected value of the infrastructure. This time lag is not a specific feature of land value management. It depends on the institutional credibility of implementation, that is, on the extent to which market participants believe that announcements, financial commitments, contracting, and successive project milestones will be consistently carried out. When this credibility is high, the expected value of the intervention may be incorporated into prices before completion or even before work begins [31]. Conversely, in environments where implementation credibility is low, early discounting may be limited or absent, with capitalization shifting toward the start of construction or the project's operation [8]. Institutional implementation credibility is therefore treated as a cross-cutting characteristic of the implementation framework rather than as a fourth operational channel or as a sub-dimension of land value management.

3.3. Observed Behavior of Capitalization: Five Propositions

Before breaking down the framework into testable propositions, a preliminary observation is in order. The three functional dimensions do not operate on the same aspect of the phenomenon: the responsiveness of supply and the coherence of governance primarily shape the production of effects (how intensely and how uniformly they manifest across space and time), while land value management shapes the distribution of the benefits produced. From this dual function, propositions emerge referring to four distinct qualities of capitalization: its intensity, its duration, its spatial distribution, and the social distribution of the benefits it generates. The five propositions that follow do not constitute an exhaustive list of potential cases, but rather the smallest sufficient set that captures these four qualities, using the three channels as sources.

In the following propositions, comparability does not imply complete similarity between regions. It refers to comparisons in which the effect of the institutionally mediated supply response is, as far as possible, isolated from other factors that influence prices. Relevant empirical applications must control for at least the initial state of the local housing market, the composition and characteristics of the housing stock, land uses, available development land, pre-existing accessibility, distance from stations and the metropolitan center, the characteristics of the infrastructure itself, local socioeconomic conditions, and common temporal or macroeconomic shocks. Therefore, the propositions outline conditions under which a relationship is expected to be observed, rather than independent or unconditional causal effects.

Proposition 1 (Intensity). Given comparable exposure to infrastructure and, after taking into account differences in the initial state of the housing market, the characteristics of the housing stock, land uses, pre-existing accessibility, local socioeconomic conditions, and common temporal or macroeconomic shocks, areas with lower supply responsiveness are expected to experience greater price increases in the existing housing stock following infrastructure milestones than areas with higher supply responsiveness. The expected mechanism is that, when new demand cannot be absorbed in a timely manner through new construction, land-use conversion, or an increase in the available stock, a larger portion of the adjustment is passed on to prices.

Proposition 2 (Duration). In the same jurisdictions, the observed effects are expected to persist longer after the project's main milestones, as the gradual adjustment of supply, which, in a highly responsive environment, mitigates initial price increases, occurs with significant delay or is absent.

Proposition 3 (Spatial Distribution). In functional urban areas characterized by low governance cohesion among the relevant jurisdictions, the effects of a spatial intervention are expected to be distributed anisotropically across the area, exhibiting distinct discontinuities at administrative boundaries that cannot be explained by the intervention's physical characteristics or the geometry of accessibility.

Proposition 4 (Social Distribution). In jurisdictions with weak capacity for land value management, the surplus value generated by a public spatial intervention is expected to flow primarily to private landowners, without a corresponding public return, intensifying the spatial concentration of wealth that the intervention itself produces.

Proposition 5 (Timing). With a comparable expected improvement in accessibility and considering broader market conditions, capitalization is expected to occur earlier in the project lifecycle when institutional implementation credibility is higher. In environments where financing is secured, contracting is complete, milestones are being met, and the relevant entities have a consistent track record, a larger portion of the expected value may be incorporated into prices at the time of the announcement, financing, or contracting.

When the same data are uncertain or inconsistent, the adjustment is expected to shift toward the start of construction or operation.

The five propositions are analytically distinct but empirically interrelated. Proposition 1 and Proposition 2 concern the same dimension of capacity from different perspectives (one regarding scope, the other regarding temporal persistence) and are expected to coincide empirically: where one manifests, there is an increased likelihood that the other will also manifest. Proposition 3 introduces a vertical spatial reading that can coexist with the first two without depending on them, as the coherence of governance is functionally distinct from the responsiveness of supply within a single jurisdiction. Proposition 4 is directly linked to the third operational channel, namely the ability to manage land value appreciation. In contrast, Proposition 5 refers to a cross-cutting feature of the implementation framework: institutional credibility, consistency, and proven functioning of the relevant institutional processes. Credibility is not added as a fourth operational channel but explains the temporal manner in which information about project implementation is transformed into market expectations.

Taken together, the propositions are designed to be falsifiable. Each requires observable covariance between a measurable property of the capacity and a measurable characteristic of the effects, with a clear prediction regarding the direction of the relationship. The systematic absence of such covariance in empirical applications would constitute an indication in favor of revising the framework. This testability also accounts for the dependence of each proposition on sufficient empirical data: their value depends on the ability to observe both the capacity and the phenomena of capitalization on a common spatial and temporal basis, an issue discussed in the next section. The propositions, along with their geospatial implementation framework, are presented in Table 1.

Table 1. The five propositions and their geospatial implementation.

Proposition	Theoretical Framework	Outcome Variable	Institutional Capacity Indicator(s)	Key Control Variables	Indicative Greek Sources
P1: Intensity	Limited supply response	Change in transaction prices or asking prices for housing per spatial unit and distance from the station	Number and surface of new building permits, ratio of new construction to existing stock, time to issue a permit, percentage of revision or delays	Initial price level and trend, property characteristics, land use, density, available land, pre-existing accessibility, income, and common time effects	e-Permits from the Technical Chamber of Greece for administrative acts related to construction work; real estate market or transaction data, provided that access to sufficient spatial resolution is ensured; objective value maps as a supplementary spatial reference for administratively assessed values, not as a substitute for transaction prices

Table 1. *Cont.*

Proposition	Theoretical Framework	Outcome Variable	Institutional Capacity Indicator(s)	Key Control Variables	Indicative Greek Sources
P2: Duration	Delayed adjustment of supply	Duration and decline of price changes following each project milestone	Time sequence of permit issuance, commencement of work, and building completion; time between application, approval, and implementation.	Pre-existing price trends, interest rates, inflation, general market cycle, local construction activity, and property characteristics	Time-stamped records from e-Permits, ELSTAT construction activity time series
P3: Spatial Distribution	Low governance coherence between neighboring jurisdictions	Discontinuities in price changes, construction activity, or administrative performance across municipal boundaries	Differences in permitting times, enforcement of urban planning regulations, availability of digital services, and inter-municipal coordination mechanisms	Distance from a station, land use, topography, natural barriers, density, initial characteristics of the housing stock, and pre-existing accessibility	Administrative boundaries and official geospatial data for municipalities; e-Permits and data from competent Building Authorities; decisions and planning agreements of municipalities and public bodies; Urban Atlas land use data
P4: Social Distribution	Limited capacity for public management or recovery of the surplus value generated	Ratio of the value generated that remains as private capital gain relative to the value returned to public infrastructure, services, or redistributive interventions	Legal availability and actual implementation of land or cash contributions, urban planning obligations, expropriations, transfer of development rights, special development agreements, or other public value recovery mechanisms	Ownership status, urban planning status, development scale, initial land values, and nature of public investment	Current urban planning legislation; municipal regulatory decisions, technical programs, and budgets; decisions posted on the Diavgia portal; implementing acts; and available land registry or expropriation data

Table 1. *Cont.*

Proposition	Theoretical Framework	Outcome Variable	Institutional Capacity Indicator(s)	Key Control Variables	Indicative Greek Sources
P5: Timing	Cross-cutting attribute of the implementation framework: institutional implementation credibility	Time taken for price changes to materialize in relation to the announcement, financing, contract signing, start of construction, and operation	Deviation of actual timelines from announced timelines, securing of financing, completion of bidding and contracting, frequency of postponements or revisions, continuity of construction progress, and track record of completing comparable projects	General real estate market trends, interest rates, inflation, credit conditions, income changes, and other local projects	Hellenic Metro for official milestones and project progress; financing, award, and contracting decisions; Diavgia portal and official public procurement documents

The sources listed in Table 1 identify the administrative and statistical systems from which the required information can be obtained or requested; they do not imply that all data are already available as open, fully geocoded, and time-series datasets. Prior to practical implementation, it will be necessary to verify the spatial resolution, temporal coverage, the ability to link sources, and any access restrictions or personal data protection requirements. Where microdata are unavailable, aggregate data should not be treated as an equivalent substitute, particularly when the analysis concerns discontinuities within or between municipalities.

Indicators should be calculated for a common time period and, where possible, at a spatial level smaller than the municipality. Before any aggregation, it is necessary to check the completeness, comparability, temporal consistency, and direction of the individual variables. The indicators can initially be standardized and analyzed separately for each of the three functional dimensions. A composite index of regional institutional capacity should be used only if empirical analysis shows that the individual indices reflect a coherent latent construct. Otherwise, the three dimensions must be entered separately into the analytical model so as not to obscure different or conflicting institutional effects.

3.4. Geospatial Composition: Capacity as an Object of Observation

The aforementioned propositions cannot be adequately observed with tools that fail to account for the phenomenon's spatial and administrative variations. Each of them requires a comparative measurement of both capacity and capitalization phenomena on a common spatial and temporal basis, where the unit of observation is smaller than the state, often smaller than the region, and positioned to enable linkage to the milestones of a specific project. National institutional quality indicators, even when methodologically sound, obscure precisely the variation that the present framework seeks to explain, that which manifests itself within states and within regions, at the interfaces between jurisdictions, and in the spatial discontinuities of administrative outcomes [15]. The issue of observation is therefore not a method to be applied to an already defined empirical field. It is an

epistemological prerequisite of the empirical field itself: without a geospatial conception, the variable proposed here as mediating simply does not manifest itself in a way that allows for the testing of hypotheses.

In future empirical implementation, institutional capacity indicators should be linked to market outcomes on the same spatial and temporal scale. The core analytical model will need to include an infrastructure exposure index, the three distinct dimensions of regional institutional capacity, and interaction terms between infrastructure exposure and each of these dimensions. The interaction terms are critical, because the framework does not assume that institutional capacity independently causes changes in prices. It assumes that it modifies how exposure to infrastructure translates into the intensity, duration, timing, spatial distribution, and social distribution of outcomes. The model must also include control variables for real estate and housing stock characteristics, land uses, baseline accessibility, socioeconomic conditions, and broader economic and financial changes, as well as appropriate spatial and temporal fixed effects.

This observation defines the context in which Geographic Information Science tools play a pivotal role. The recognition of spatial dependence as a structural property of geographically distributed phenomena [18] transforms spatial statistical methods from corrective tools of econometric estimation into modes of observation. Decisive in this case is the shift from global spatial correlation indices, which synthesize the information of a phenomenon into a single measure, to local indices, which pinpoint exactly where in space clusters occur, discontinuities, or deviations from the general pattern [32,33]. The shift is necessary since the phenomenon under consideration here is essentially local: regional institutional capacity is not something a country has or does not have, but something that manifests differently across its territory and interacts differently with different components of a spatial intervention. For Propositions 1 and 2, the empirical analysis should compare areas with similar exposure to improved accessibility but different supply responses. The comparison should be conducted by examining initial price levels and trends, housing stock characteristics, density and land uses, available development land, local socioeconomic characteristics, and common temporal changes. The supply response can be captured by the number of new building permits and the surface area they cover, the time required for permitting, permit revisions, the completion of new housing units, and the ratio of new construction to the existing housing stock. For Proposition 3, which concerns the spatial distribution of effects, empirical testing requires methods that detect discontinuities along administrative boundaries under conditions of high spatial autocorrelation, precisely where traditional parametric models fail to distinguish the signal from the noise [14]. Regarding Propositions 4 and 5, which concern social distribution and timing, the analysis requires simultaneous mapping of the institutional availability of land value management tools by jurisdiction and the spatially differentiated distribution of capitalization around the project's milestones. In all cases, the methodological approach is the reverse of what is usually attempted: we do not use geospatial data to validate a non-spatial model but rather construct a model whose variables are defined as geospatial from the outset.

These requirements highlight the need for a geospatial observation protocol. It organizes three distinct types of information on a common spatial basis: the project's milestones and spatial spheres of influence; capacity indicators by functional dimension and jurisdiction; and the spatiotemporal distribution of capitalization phenomena. The methodological approach for mapping institutional arrangements as measurable spatial variables draws on the land management literature [16,17]. Its analytical value does not rest on any of the three types of information in isolation, but on their intersections, where the project's zones of influence intersect with different regional institutional capacities. It is precisely at

these intersections that the framework predicts recognizable patterns of outcomes, which otherwise remain invisible or uninterpreted.

This framework serves two distinct diagnostic functions, depending on whether a global pattern of spatial correlation exists in each empirical domain. When capacity is distributed without an apparent global pattern, local indicators serve as tools for identifying clusters: they reveal areas where capacity is systematically low or high in ways that the overall picture obscures. Conversely, when there is a strong global pattern, the same indicators function as tools for identifying local instability: they identify exceptions or points where the relationship between capacity and outcomes systematically deviates from the general trend [32]. This dual function is essential in the present context, as the expected empirical picture varies with the spatial composition of the respective national or regional context, and it allows the same conceptual framework to be applied to both countries with uniformly distributed institutional quality and countries with marked subnational contrasts.

This approach is part of the broader movement towards smart land governance, in which the use of geospatial infrastructure is combined with institutional transparency and interdisciplinary collaboration as interdependent prerequisites for effective governance [19]. Its application to a specific intervention, however, requires not only methodological design but also data with appropriate spatial and temporal resolution and a strong connection to the institutional conditions of the relevant jurisdiction. The geospatial operationalization of the framework through Line 4 serves as an observational structuring of the framework within a specific institutional and spatial context while simultaneously highlighting the limitations of the available data and directions for further research.

4. Illustrative Geospatial Operationalization of the Framework: The Case of Athens Metro Line 4

4.1. Operational Logic

This section presents a spatial structuring of the framework, using Section A of the Athens Metro Line 4 as the spatial field of observation. The aim is to demonstrate how the spatial levels required for the future observation of the three dimensions of institutional capacity can be organized. Specifically, this section serves three purposes: first, it defines the spatial zone within which the impact of Line 4 may be observed in the future; second, it shows that this zone is intersected by different municipal jurisdictions; and third, it captures the functional heterogeneity of the urban space within the same zone. The use of the term "operationalization" in this section refers to the organization of the required units and levels of observation, rather than to the measurement or empirical verification of institutional capacity and capitalization. Consequently, the case of Line 4 is not treated as a confirmatory case study, but as an illustrative application of the development of a future empirical protocol.

Line 4 of the Athens Metro was selected because it is a major metropolitan transportation project in Greece, featuring clear linear geometry, distinct access points, and development across multiple municipal jurisdictions. This case demonstrates how an infrastructure project can be transformed from a technical object into a spatial field of observation, where accessibility, administrative boundaries, land uses, and the temporal milestones of implementation intersect.

The analysis is limited to Section A of Line 4, Alsos Veikou-Goudi, which is the section currently under construction. According to Hellenic Metro, this section is approximately 12.8 km long and includes fifteen underground stations, as well as intermediate or terminal shafts. The broader Line 4 includes subsequent sections, but these are not included in the present geospatial operationalization because the analytical focus is on the section that has already moved from the design phase to the construction phase [34].

This choice has methodological significance. The capitalization of an infrastructure is linked not only to its final operation but also to the development of the project's institutional credibility over time. The contract for the commencement of work on Section A was signed in 2021, between the then Attiko Metro and the AVAX–Ghella–Alstom consortium. This serves as a critical institutional milestone, reducing uncertainty surrounding the project's implementation and moving Line 4 from planning to construction.

4.2. Data and Geospatial Preparation

This section follows the three-level structure outlined in Section 3.4, tailored to the conditions of Line 4. Each level corresponds to a distinct information base: the project geometry, the zone of potential spatial exposure, and the area's administrative and operational composition.

The first level concerns the project's geometry. The fifteen stations of Section A were recorded as point data, and the alignment of the line was recorded as linear data. This mapping is not treated as an official geodetic representation of the project, but as a working cartographic representation, sufficient for the indicative geospatial specification of the theoretical framework.

The second level concerns the zone of potential direct spatial exposure to the intervention. The 800 m distance is used as the initial walking access zone, as it corresponds approximately to a 10 min walk and is frequently used in the literature on subway station catchment areas. However, it does not constitute a universal or empirically proven limit of influence on housing prices. The actual catchment area may vary depending on road network connectivity, topography, natural or artificial barriers, station entrances, land uses, and the travel patterns of the local population. For this reason, the 800 m zone is used in this mapping as an indicative unit for organizing the analysis and not as a predetermined boundary of causal impact.

The third level concerns the administrative and functional composition of the area. The 800 m zone intersects the boundaries of the municipalities to map the administrative geography of the intervention. In addition, the Urban Atlas land use categories [35] were used to capture functional heterogeneity within the same zone. The Urban Atlas layer used refers to 2018 and therefore predates the signing of the construction contract in 2021 by three years. In this implementation, it is used as a spatial representation of the area's functional composition prior to the contractual milestone, rather than as an updated record of land uses during construction. Consequently, the mapping exercise establishes the spatial framework upon which such an impact could be observed in the future.

In a comprehensive empirical application, the spatial sensitivity of the results must be tested using alternative zones, such as 400, 600, 800, and 1000 m, as well as, where possible, using zones calculated based on the actual distance within the pedestrian network rather than exclusively using Euclidean circular buffers. Comparing different radii will allow us to examine whether the results are stable, show a gradual attenuation with distance, or depend on a specific spatial delimitation. Therefore, 800 m constitutes the baseline scenario for cartographic observation, and not the only acceptable spatial scale.

4.3. Key Milestones and Their Significance

The spatial layout of Line 4 should be read in conjunction with the project's lifecycle. In the theoretical framework of this article, project milestones are critical, as the property market may incorporate not only actual changes in accessibility but also expectations regarding the future completion of infrastructure. Therefore, the observation protocol for Line 4 is not limited to the question of "where" the potential impact lies but is also

structured around "when" the infrastructure becomes reliable enough to alter expectations. These timings are presented in Table 2.

Table 2. Indicative milestones of Section A of Line 4 and their role in the context.

Phase	Milestone	Context
Planning and Maturation	Inclusion of Section A, Alsos Veikou-Goudi, in the long-term planning for Line 4	Early setting of expectations, but with high uncertainty
Funding	Financial support for Section A	Enhancing implementation reliability and reducing uncertainty
Contracting	Signing of the contract to commence work in 2021	Reduction in institutional uncertainty and transition from planning to implementation
Construction	Development of construction sites, progress on tunnels, and civil engineering works	Visibility of the project and increased confidence in implementation
Future operation	Handover and commencement of operations on the section	Actual change in accessibility and ability to measure impacts ex post

The significance of these milestones is qualitative. They are not used here to prove that prices have already shifted, but to establish time points around which future empirical analysis could be organized. The same 800 m zone may have different significance before contracting, during construction, and after operations begin. In this framework, this is directly linked to the proposition about the timing of capitalization: in environments with higher implementation reliability, the market may discount the benefits of the infrastructure earlier, whereas in environments with greater uncertainty, the adjustment may be shifted toward construction or operation.

4.4. Line 4 as a Spatial Observation Field

Map 1 (Figure 1) determines the primary field of observation. Line 4 is treated as a set of access points that generate zones of potential spatial change around them, rather than an underground linear infrastructure. The 800 m zone serves as an analytical framework within which changes in accessibility can be correlated with the characteristics of the urban structure, municipal jurisdictions, and, in a subsequent phase, with market or construction activity data.

This mapping is crucial, since it defines the spatial scope of the analysis. In the absence of such a geometric representation, regional institutional capacity would remain a general concept, while capitalization would be viewed merely as the market's average response to a given infrastructure. In contrast, spatial delineation allows for more specific questions to be posed: which stations fall within which administrative units, which parts of the catchment area are located near municipal boundaries, and which land uses predominate around access points.

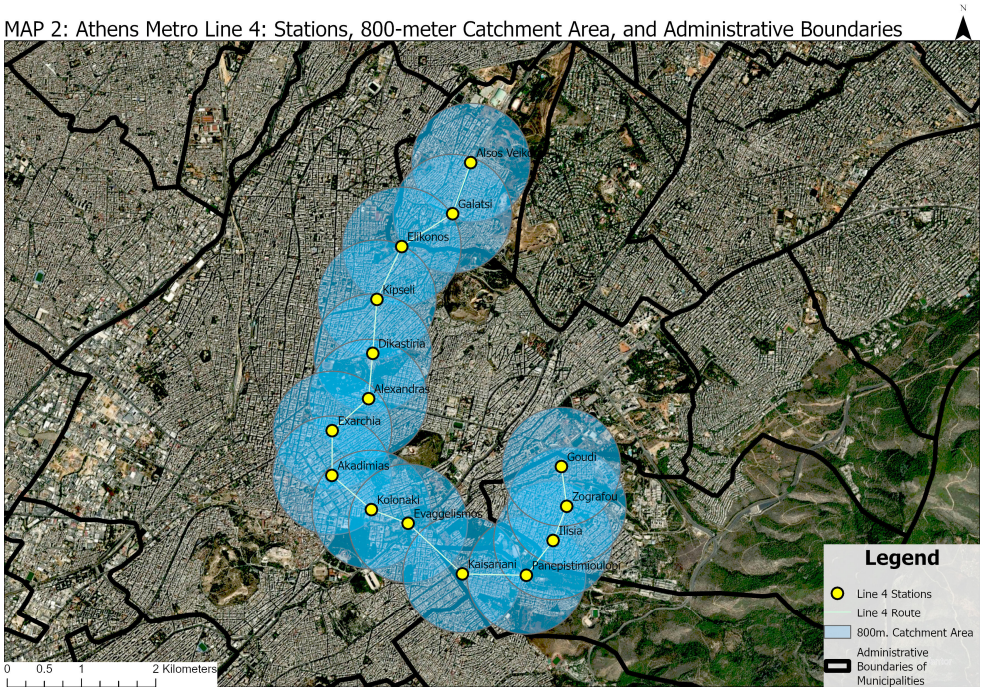


Figure 1. Map 1: Athens Metro Line 4, stations, 800 m catchment area, and administrative boundaries.

4.5. Administrative Division of the Catchment Area

The intersection of the 800 m zone and municipal boundaries indicates that the area directly exposed to Line 4 spans multiple administrative jurisdictions. As shown in Map 2 (Figure 2), the catchment area intersects five municipalities: Athens, Galatsi, Zografou, Kaisariani, and Vyronas. Stations are in four of these: Galatsi, Athens, Kaisariani, and Zografou. Administrative division defines the units for future comparison, but does not, in itself, prove that municipalities differ in their institutional capacity. To examine actual administrative variations, certain common indicators are required regarding the duration and predictability of permitting procedures, the consistency of urban planning rule enforcement, the existence of coordination mechanisms, the issuance and implementation of building permits, and the intensity of new development. This mapping identifies where this comparison should be made, but it does not replace the collection of the relevant administrative data.

The Municipality of Vyronas does not include a station in this section, but it is within the 800 m zone, indicating that spatial exposure to the intervention does not necessarily coincide with station locations. The unique location of the Municipality of Vyronas provides a useful case study for comparative analysis. Part of the municipality lies within an 800 m radius of stations located in neighboring jurisdictions, while the municipality itself does not host a station within the area under consideration. Vyronas can therefore be used in a future analysis as a case of cross-boundary exposure, through which it will be examined whether proximity to the same infrastructure produces different results when spatial exposure and administrative jurisdiction do not coincide.

This case is particularly relevant to Proposition 3. A future analysis could compare neighboring spatial units on either side of the Vyronas–Athens or Vyronas–Kaisariani boundaries, which are similarly distant from the nearest station but fall under different municipal and urban-planning administrative conditions. Any inconsistency in price changes, construction activity, or the duration of administrative procedures would be consistent with the prediction of Proposition 3 only if it cannot be explained by land use, physical barriers, initial differences in the housing stock, or other changes in accessibility.

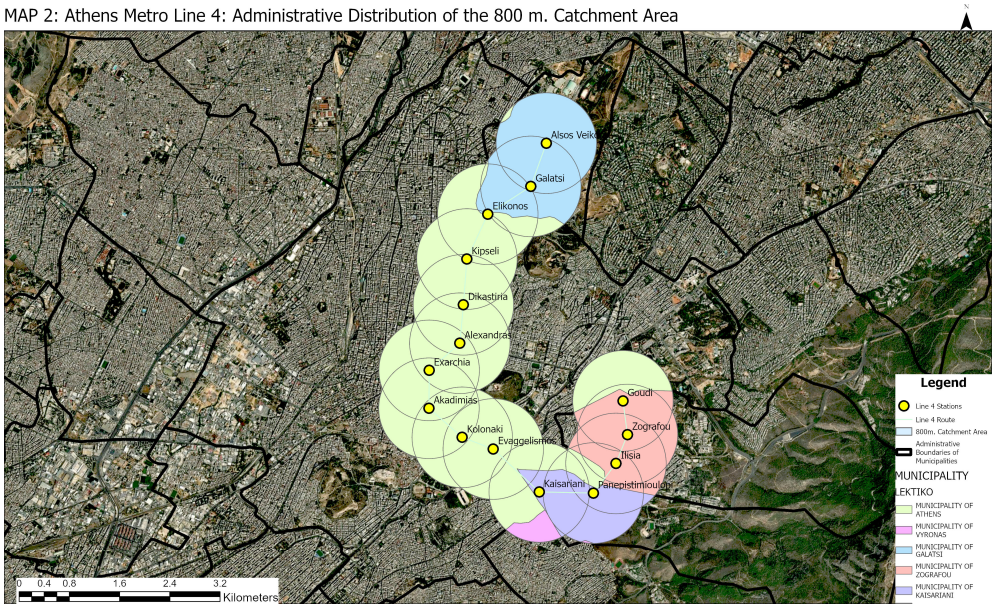


Figure 2. Map 2: Athens Metro Line 4, administrative distribution of the 800 m catchment area.

This administrative division is not used here as a direct indicator of regional institutional capacity. However, it has analytical significance in indicating that the same sphere of influence extends to municipalities with different urban planning histories, administrative practices, and potential pathways of institutional renewal. Therefore, municipal jurisdiction should not be treated as a mere cartographic boundary, but as a potential level of differentiation in the application of rules, coordination, and the future absorption of infrastructure impacts.

In terms of the theoretical framework, this map transforms the coherence of governance from an abstract concept into a spatially observable problem. If, in the future, different rates of change in property values are observed around stations with similar positions within the network, the question will not only be whether the stations differ in accessibility, but also whether they are subject to different administrative and institutional conditions.

4.6. Land Use of the Catchment Area

Map 3 (Figure 3) shifts the analysis from administrative geography to the functional composition of urban space. The overlay of the Urban Atlas land use categories within the 800 m zone reveals that the area directly accessible to Line 4 is not functionally homogeneous. It includes continuous urban fabric, discontinuous urban development of varying densities, green urban areas, public or special-use areas, road infrastructure, and sports or recreational areas. These categories reflect the functional composition as of 2018. They do not account for changes in land use, developments, or restructuring of the urban fabric that may have occurred between 2018 and the signing of the contract or during the construction period. For this reason, the map should be interpreted as a baseline prior to the main construction milestone and not as a contemporary representation of the current situation.

An increase in accessibility does not necessarily result in the same outcome across all types of urban space. In densely populated areas, adaptation may primarily take the form of changes in property values within the existing stock, especially when the potential for new development is limited. In areas with public, university, green, or special-use zones, the potential for direct private capitalization may be more limited or operate through different mechanisms. Therefore, land uses function as a spatial substrate within which the channels of regional institutional capacity can manifest themselves with varying intensities.

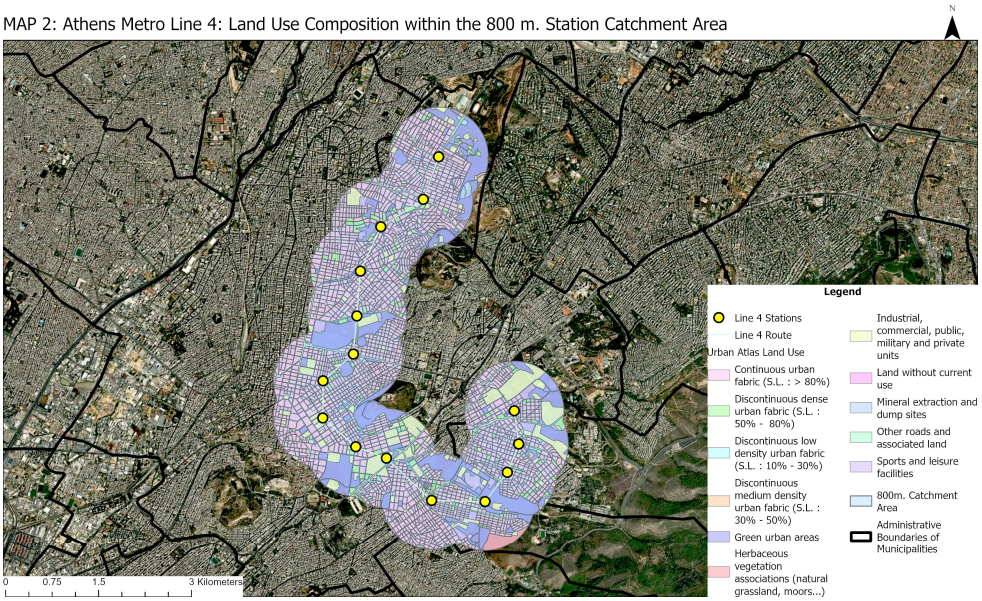


Figure 3. Map 3: Athens Metro Line 4, land use composition within the 800 m catchment area.

The operational heterogeneity of the urban fabric is particularly linked to the channel of supply responsiveness. Whether a new expectation of accessibility will translate into new development, renovation, a change in use, or simply an appreciation of the existing stock depends on the regulatory framework, the feasibility of obtaining permits, existing land uses, and the actual potential to alter the built environment. The spatial mapping of land uses thus allows for the avoidance of a simplistic interpretation of the zone of influence as a homogeneous area. Therefore, land use mapping is a prerequisite for determining whether a future change in property values is due solely to proximity to the station or also to the form of the urban space into which the new accessibility is integrated.

Land uses must be considered in future comparative planning, both as factors that restrict or facilitate development and as control variables. Differences in the extent of continuous urban fabric, public or special-purpose land uses, green spaces, and available developable land can result in varying degrees of building density even in the absence of differences in administrative capacity. For this reason, observed development should not automatically be interpreted as a measure of institutional performance.

4.7. From Mapping to a Verifiable Protocol

The geospatial operationalization in Line 4 generates something that precedes and is necessary for this: a geospatial structure within which capitalization can be observed in a theoretically consistent manner. The three maps function as successive levels of operational translation of the framework. The first defines spatial exposure to the intervention. The second shows that this exposure is administratively fragmented. The third shows that the same field is functionally heterogeneous.

The result is an observation protocol with three basic requirements. First, the distance from the station alone is not sufficient. It must be combined with the administrative jurisdiction to which each part of the zone of influence belongs. Second, the zone of influence cannot be considered homogeneous. Land uses and the existing form of urban fabric influence whether an improvement in accessibility can translate into new development, a change in land use, or simply an appreciation of the existing stock. Third, spatial analysis needs to be linked to the project's milestones, because the market may react differently to the announcement, financing, contracting, construction, and operation of the infrastructure.

By this means, the analysis transforms the theoretical propositions of the previous section into testable empirical hypotheses. To examine the intensity of capitalization, price changes within and outside the catchment area must be compared, controlling for land use and administrative location. To examine duration, these changes need to be monitored against the project's successive milestones. To examine spatial distribution, it is necessary to check for discontinuities at administrative boundaries or between areas with different functional compositions. Examining the social distribution of benefits will require linking to property data, value capture tools, or mechanisms for the public return of benefits. For Proposition 3, the administrative district of Vyronas offers a concrete example of the proposed protocol. The empirical unit would not be the municipality as a single entity, but rather small neighboring spatial units on either side of an administrative boundary, matched in terms of distance from the station, land uses, density, housing stock characteristics, and pre-existing accessibility. This comparison would allow for an examination of whether administrative discontinuity exists beyond the geometry of access.

The comparative analysis can be organized on two complementary levels. At the first level, the five municipalities that intersect the observation zone can be compared using a common framework of indicators for administrative procedures, urban planning regulations, intergovernmental coordination, and development intensity. Then, small spatial units within and outside the zone of influence, or on either side of administrative boundaries, can be compared based on common characteristics such as accessibility, land use, density, and housing stock. The first level captures institutional differences between jurisdictions, while the other reduces the risk that municipal averages will mask internal spatial heterogeneity.

Thus, the contribution of this observation protocol lies in the transition from a general argument about regional institutional capacity to a specific research framework. Line 4 shows that the institutional dimension of capitalization cannot be added ex post as a general indicator of governance quality. Instead, it needs to be built into the very spatial design of observation: which zone is being studied, which administrative jurisdiction it belongs to, what kind of urban space it encompasses, and to which project milestone the observation refers.

4.8. Limitations and Requirements for a Full Empirical Implementation

This study does not constitute a preliminary empirical test of the five propositions. It does not utilize data on changes in housing prices, microdata on building permits, or comparable administrative performance indicators at the municipal level. Consequently, the maps do not allow for an assessment of the magnitude, direction, or statistical significance of the relationship between regional institutional capacity and capitalization. The contribution of this section is limited to organizing the spatial and temporal scope within which the propositions can be tested in a subsequent empirical phase.

The analysis is deliberately limited in scope. It relies on spatial data rather than transaction data, asking prices for property, geocoded building permits, or direct indicators of permit processing times and administrative efficiency. Furthermore, while tax-assessed property values are a useful institutional indicator of spatial variation in values, they are not incorporated as a map layer because no exportable geospatial file of price zones suitable for direct analysis was available. Using an average price per municipality would be insufficient, as the municipalities in the study area encompass multiple value zones.

An initial pilot implementation could be limited to Propositions 1 and 3, as these can be directly linked to the administrative jurisdictions that intersect the zone of influence. For Proposition 1, time-series data on property prices and building permits would be required for small spatial units both within and outside the access zones, along with an analysis of

housing stock characteristics, land uses, initial price trends, and local socioeconomic conditions. For Proposition 3, neighboring spatial units on either side of municipal boundaries could be compared, such as Vyronas–Athens and Vyronas–Kaisariani, which are similarly distant from the nearest station but fall under different administrative jurisdictions. This approach would require an examination of pre-existing spatial differences and could not rely solely on municipal averages.

The reason this pilot analysis was not conducted in the present study is the lack of a unified dataset that, at the required spatial and temporal resolution, links property values, building permits, administrative processing times, land uses, and project milestones. References to existing administrative or statistical systems do not imply that the corresponding microdata are open, time-series, fully geocoded, or directly interoperable. The creation of this integrated dataset is a prerequisite for a valid assessment of the framework's interpretive power.

Although Vyronas is identified as a potentially useful case for cross-border comparison, this mapping application does not demonstrate that the neighboring areas on either side of the municipal boundaries are empirically comparable. Its use as a comparative case requires fine-scale spatial data and a matching or boundary identification process that accounts for pre-existing spatial and socioeconomic differences.

An additional temporal limitation concerns land-use data. The Urban Atlas 2018 predates the signing of the construction contract in 2021 and does not allow for the observation of changes that may have occurred before or after that contractual milestone. This temporal gap is acceptable for the present illustrative mapping exercise, since the layer serves as an initial spatial baseline. However, a full empirical application would require more recent or longitudinal data on land use, construction activity, and changes in the building stock to distinguish pre-existing conditions from changes associated with the project's development.

The use of uniform circular zones also imposes limitations, because it equates geometric distance with actual walking distance. It does not fully account for topography, road network structure, crossings, fences, large facilities, and other obstacles that can substantially affect accessibility. Future applications should compare Euclidean zones with network-based walksheds and examine the sensitivity of the results at different spatial scales.

These limitations do not invalidate the approach, but they define the next empirical step. A full test of the framework would require spatiotemporal data on housing prices, building permits, and administrative timeframes, linked to the stations' catchment areas and the project's milestones. The contribution of this observation protocol is that it identifies exactly where and how this data should be integrated.

5. Discussion

The conceptual framework developed above supports the hypothesis that the capitalization of infrastructure in housing prices should not be viewed solely as a function of distance from the project or changes in accessibility. This study does not empirically test this hypothesis. Accessibility remains the primary mechanism by which a transportation intervention can influence property values, yet it alone does not explain why comparable interventions yield such different outcomes across locations. The paper argues that this heterogeneity must be understood in terms of the institutional and spatial structures within which the intervention is implemented. In other words, the critical question is not merely whether an infrastructure improves access, but into which administrative, urban planning, and operational environment it is embedded.

The proposed institutional analysis does not replace the established economic and financial explanations for housing price dynamics. Changes in affordability, housing supply,

incomes, interest rates, credit availability, construction costs, demographic demand, and investment expectations remain direct determinants. Regional institutional capacity is assumed to alter the manner and speed with which these pressures translate into prices, new construction, spatial variations, or public value capture. Thus, the empirical value of the framework will be judged by whether the institutional indicators and their interactions with infrastructure exposure add explanatory power beyond the economic, social, and spatial reference characteristics.

The contribution of the framework lies in its proposal to shift the focus of analysis from rules as formal data to rules as applied practices. Regulatory stringency and supply constraints remain critical factors, but the framework assumes that their effects may depend on the speed, consistency, and predictability of their implementation. Regional institutional capacity is therefore treated as a potential mediating mechanism that may alter the intensity, timing, and spatial distribution of capitalization. The strength and direction of these relationships remain to be empirically tested.

The geospatial dimension is of decisive importance because regional institutional capacity is not a uniform national characteristic. It manifests within specific administrative boundaries, zones of influence, land uses, and project stages. The case of Line 4 was not used to demonstrate that price changes have already occurred, but to show how the scope within which such changes could be examined might be organized. The mapping of the 800 m zone, its intersection with the municipalities, and land use mapping illustrates that the spatial field within which potential effects would be examined is not homogeneous. It unfolds in a field where distance from the station intersects with municipal jurisdiction, urban form, land uses, and the milestones of the project's lifecycle.

From this perspective, the article proposes a different starting point for empirical research. Before assessing whether an infrastructure has affected property values, the geospatial context in which that effect can be understood must be defined. Distance from infrastructure should be combined with the area's administrative status, the functional composition of the urban fabric, and the project's stage of development. Only in this way can it be determined whether an observed transformation simply reflects improved accessibility or whether it is reinforced, delayed, weakened, or redistributed by institutional factors.

This article, therefore, concludes with a methodological and theoretical proposal, rather than a confirmed empirical conclusion: the capitalization of infrastructure can be studied as a spatiotemporal and institutionally mediated phenomenon. Regional institutional capacity needs to be made observable before it can be used as an explanation. This requires a geospatial protocol that combines project geometry, zones of influence, administrative boundaries, land uses, implementation milestones, and, in a subsequent stage, data on prices, permits, and administrative performance. Without this intermediate step, there is a risk of attributing accessibility or regulatory stringency effects that could partly reflect regional institutional capacity and its spatial variation.

6. Conclusions

This study does not provide empirical confirmation that regional institutional capacity affects housing prices. It provides a conceptual framework, a set of testable propositions, and a geospatial protocol for future examination of this hypothesis. The next stage of the research must link time-series data on property prices and construction activity with measurable indicators of administrative performance, station access zones, municipal jurisdictions, and successive project milestones. Only through such an application will it be possible to assess whether institutional capacity has additional explanatory power beyond accessibility, housing supply characteristics, and broader economic and financial conditions.

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The study builds on a recurring finding in empirical literature: comparable categories of infrastructure projects are associated with heterogeneous changes in real estate prices. The existing literature has suggested accessibility, supply responsiveness, regulatory stringency, and other market characteristics as important explanations for this heterogeneity. This paper suggests that the manner of rule enforcement, administrative predictability, and coordination among competent authorities may provide an additional explanation, without claiming that this relationship has already been empirically confirmed.

The central argument is that regional institutional capacity can be viewed as a potential mediating mechanism for capitalization. In order to make it testable, it is broken down into three operational channels (supply response, governance cohesion, and surplus management), and linked to five propositions regarding intensity, duration, spatial distribution, social distribution, and timing of expected outcomes. These propositions constitute theoretical predictions rather than empirically verified findings.

Key to this transition is the geospatial dimension. Regional institutional capacity is not a uniform national characteristic but a spatially distributed quality that must be observed where spatial outcomes are produced: around stations, along administrative boundaries, and within spheres of influence. For this reason, the paper proposed a geospatial protocol that treats geographic information systems not as an auxiliary visualization tool, but as a means of constituting the observation unit itself. The Line 4 case demonstrated how an infrastructure project can be organized as a field of observation through its geometry, access zones, municipal jurisdictions, land use composition, and implementation phases, even before price or permit data are collected.

This approach is subject to clear limitations that define the next step in research. The indicative operationalization defines the scope of the analysis before hypothesis testing, since a full empirical assessment would require transaction data, geocoded building permits, and direct indicators of administrative efficiency. A comprehensive empirical analysis would require spatiotemporal data on prices, building permits, and administrative processing times, linked to station catchment areas and project milestones on a common spatial and temporal basis. Identifying this need precisely, where and how the data should be integrated constitutes the bridge from the conceptual framework to its empirical application.

The contribution is, therefore, threefold. First, it offers a theoretical bridge between urban economic analysis of capitalization and the literature on spatial governance. Second, it proposes a methodological approach to observing regional institutional capacity at fine spatial and temporal scales. Third, it suggests that infrastructure, housing, and land management policies should not be considered in isolation: when public investments alter expectations and values, the authorities' capacity to manage these effects may become a relevant component of the very outcome of the infrastructure.

The empirical validity of the framework remains an open research question. Future studies should examine whether regional institutional capacity indicators are systematically linked to market outcomes after controlling changes in accessibility, initial market conditions, housing stock characteristics, land uses, incomes, financial conditions, investment expectations, and common temporal changes. The absence of the predicted relationships or the prevalence of alternative explanations would constitute grounds for revising, limiting, or rejecting specific elements of the proposed framework.

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