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Parametric Modelling of Urban Networks: Assessing the Socio-Economic Integration of Heritage Institutions through the Case of ISBAT, Tunis

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ABSTRACT

This study proposes a parametric modelling framework to assess the socio-economic integration of heritage institutions within urban networks, using the Higher Institute of Fine Arts of Tunis (ISBAT) as a case study. While heritage urbanism has often relied on qualitative interpretation, limited attention has been given to measurable indicators that connect spatial configuration, institutional relationships, and socio-economic urban dynamics. To address this gap, the research combines OpenStreetMap geospatial data, Rhinoceros 3D, and Grasshopper-based parametric modelling to evaluate ISBAT's connectivity, accessibility, and institutional diversity within the urban fabric of Tunis. Three indicators—Connectivity Density, Accessibility Radius, and Institutional Diversity Index—are developed to translate relational urban conditions into measurable variables. The findings show that ISBAT functions as a central urban node, benefiting from short walking-distance accessibility to major institutions, dense spatial connections, and strong interaction with cultural, educational, governmental, and infrastructural systems. The study contributes to heritage-led urban research by demonstrating how parametric modelling can support evidence-based analysis, planning decisions, and sustainable integration of heritage institutions within contemporary urban networks.

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Highlights:

- Proposes a measurable framework for assessing the socio-economic integration of heritage institutions.
- Develops a parametric modelling approach based on urban network connectivity analysis.
- Introduces three spatial indicators: connectivity density, accessibility radius, and institutional diversity.
- Demonstrates ISBAT's role as a central node within Tunis' urban network system.
- Links parametric urban modelling with socio-economic dynamics in heritage urbanism.

Contribution to the field statement:

This study contributes to urban economy, urban design, and heritage by introducing a quantitative, reproducible framework for assessing socio-economic integration of heritage institutions within urban networks. It operationalizes integration through connectivity, accessibility, and institutional diversity, bridging parametric modelling and socio-economic analysis to support evidence-based, connectivity-based strategies for sustainable heritage-led development.

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1. Introduction

A city is not built all at once; rather, it is the cumulative outcome of countless decisions, spatial transformations, institutional practices, and socio-cultural processes that unfold over time (Lynch, 1960). This understanding remains highly relevant for interpreting contemporary urban systems, where spatial configurations are shaped not only by physical form but also by dynamic interactions among institutions, infrastructures, and social actors. From this perspective, cities can be understood as complex urban networks in which connectivity, accessibility, and institutional relationships influence spatial organization, urban performance, and socio-economic dynamics. Such an interpretation is consistent with network-based urban theories, which emphasize that spatial configuration and relational connectivity play a decisive role in structuring urban systems (Hillier, 2007; Porta et al., 2006).

Within these complex networks, heritage institutions occupy a significant position. Their value is not limited to architectural, historical, or symbolic dimensions; rather, they may also function as active urban nodes that support accessibility, cultural production, institutional interaction, and socio-economic exchange. Heritage institutions embedded in dense urban fabrics can therefore contribute to the organization of urban life by linking historical continuity with contemporary spatial and institutional systems. The Higher Institute of Fine Arts of Tunis (ISBAT), founded in 1923 and celebrating its centenary in 2023, represents a relevant case for examining this relationship. Located near the Medina of Tunis and in proximity to major institutional, cultural, and infrastructural nodes, ISBAT is positioned within a dense urban system where historical layers, contemporary infrastructures, and socio-economic processes intersect.

Previous research has increasingly emphasized the role of heritage-led urban development in supporting cultural sustainability, urban resilience, and the adaptive reuse of historic urban environments (Gustafsson & Ripp, 2022; Francini & Rozochkina, 2024). These studies have contributed to a broader understanding of heritage as a dynamic urban resource rather than a passive object of preservation. At the same time, the development of computational and parametric design tools has expanded the scope of urban analysis. Parametric modelling is no longer limited to architectural form generation; it is increasingly used to investigate spatial relationships, connectivity patterns, accessibility structures, and urban network performance within complex urban systems (Zhang & Liu, 2021). This methodological shift offers new possibilities for linking urban morphology with measurable spatial and socio-economic indicators.

Despite these advances, an important research gap remains. Much of the existing research on heritage institutions and urban integration continues to rely primarily on qualitative interpretation, historical description, or morphological reading. While concepts such as socio-cultural integration, spatial integration, accessibility, and institutional interaction are frequently used, they are rarely translated into measurable indicators that allow systematic assessment, comparison, and reproducibility. In particular, the socio-economic role of heritage institutions within urban networks remains insufficiently examined through data-driven and parametric methods. As a result, heritage institutions are often discussed as culturally significant assets, but their measurable contribution to connectivity, accessibility, institutional diversity, and urban socio-economic dynamics remains underexplored.

This limitation is particularly relevant in the case of ISBAT, whose historical and institutional significance is strongly connected to its spatial position within Tunis. Although ISBAT has played a major role in artistic education and cultural production for a century, its role as an urban node within the broader network of Tunis has not been sufficiently assessed through measurable spatial indicators. Understanding this role is essential for moving beyond a purely descriptive interpretation of heritage institutions and toward a more evidence-based understanding of how they contribute to sustainable urban development, institutional interaction, and socio-economic integration.

Accordingly, this study aims to assess the socio-economic integration of heritage institutions within urban networks through a parametric modelling approach, using ISBAT as a case study. The research combines geospatial data, parametric modelling tools, and network-based indicators to evaluate ISBAT's connectivity, accessibility, and institutional diversity within the urban fabric of Tunis. By

doing so, the study shifts the analysis of heritage institutions from a predominantly interpretative framework toward a measurable and reproducible methodology. This approach enables the transformation of relational urban conditions into analytical indicators that can support evidence-based planning and heritage-led urban development.

The contribution of this study is twofold. First, it develops a measurable framework for assessing the socio-economic integration of heritage institutions through three spatial indicators: Connectivity Density, Accessibility Radius, and Institutional Diversity Index. These indicators operationalize socio-economic integration by linking spatial configuration, institutional proximity, and urban accessibility. Second, the study demonstrates how parametric modelling can support urban analysis by revealing the relational structure of heritage institutions and their role in facilitating accessibility, interaction, and institutional connectivity. In this sense, the research contributes to urban network theory, heritage urbanism, and parametric urban analysis by proposing a method through which heritage institutions can be evaluated as active components of contemporary urban systems.

Based on this framework, the study addresses the following research questions:

1. How can the socio-economic integration of heritage institutions be assessed through measurable urban network indicators?
2. What is the level of ISBAT's centrality within Tunis' urban network based on connectivity density and accessibility metrics?
3. How does institutional diversity influence ISBAT's role within urban socio-economic dynamics?

By answering these questions, the study provides a methodological and empirical contribution to the analysis of heritage institutions within contemporary urban networks. It also offers practical insights for urban planners, policymakers, and heritage professionals seeking to integrate heritage assets into sustainable, accessible, and socio-economically responsive urban systems.

2. Research Methodology

This study adopts a computational and data-driven spatial analysis methodology, combining geospatial data processing, parametric modelling, and urban network analysis to assess the socio-economic integration of heritage institutions within the city of Tunis.

Rather than relying on an action-research approach, the methodology is structured as a three-phase analytical framework, ensuring clarity, reproducibility, and alignment with the research objectives. As illustrated in Figure 1, the process establishes a direct link between data acquisition, parametric modelling, and socio-economic interpretation.

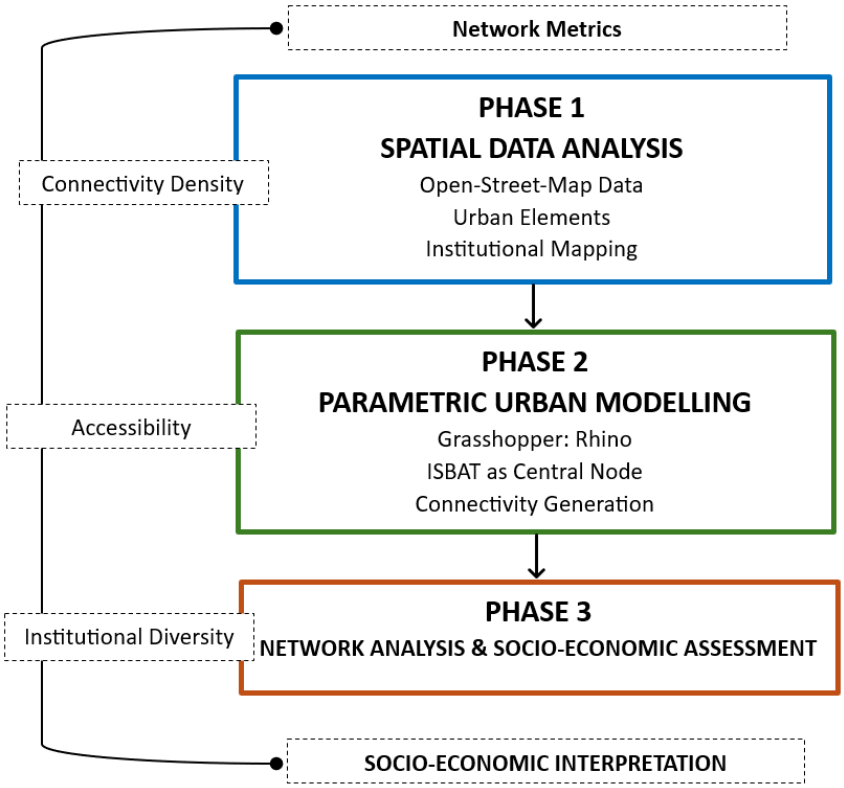

Figure 1. Parametric Urban Network Workflow for Assessing the Socio-Economic Integration of ISBAT in Tunis.

2.1. Research Framework and Workflow

The methodological approach is organized into three interrelated phases:

Phase 1: Spatial Data Analysis and Urban Network Mapping

This phase focuses on the identification and structuring of the urban context. Geospatial datasets are extracted from OpenStreetMap, including building footprints, road networks, and institutional points of interest. Through analytical mapping, ISBAT is positioned within the urban network, and its relationships with surrounding institutions are identified. This step establishes the spatial foundation for subsequent computational modelling and enables the characterization of urban networks in terms of connectivity and distribution.

Phase 2: Parametric Modelling and Network Construction

The second phase translates spatial data into a parametric modelling process using Grasshopper within Rhinoceros 3D. ISBAT is defined as a central node within the urban system, from which a network of connections is generated toward surrounding buildings and institutions. This process allows the construction of a parametric urban network model, where spatial relationships are encoded as measurable geometric and relational parameters. Such approaches align with foundational work in urban network analysis, where spatial structures are examined through graph-based models and relational metrics (Porta et al., 2006; Batty, 2013). The model integrates institutional categorization, enabling the distinction between educational, governmental, cultural, infrastructural, and civic entities. This multi-layered structure supports a more comprehensive analysis of spatial and institutional interactions within the urban environment.

Phase 3: Network Analysis and Socio-Economic Interpretation

In the third phase, the parametric model is used to evaluate ISBAT's position within the urban network through a set of measurable indicators. This phase shifts the analysis from geometric representation to quantitative assessment. Three key indicators are defined:

- Connectivity Density (CD): measures the number and intensity of connections generated from the ISBAT node within the network.
- Accessibility Radius (AR): evaluates walking-distance accessibility between ISBAT and key urban institutions (5–15 minutes).
- Institutional Diversity Index (IDI): quantifies the variety of institutional categories connected to ISBAT. These indicators allow the operationalization of socio-economic integration by translating spatial relationships into measurable variables reflecting accessibility, interaction, and institutional connectivity.

2.2. Methodological Contribution

The proposed methodology establishes a structured link between spatial data, parametric modelling, and socio-economic interpretation. By integrating computational design tools with network analysis, the research provides a reproducible framework for assessing the role of heritage institutions within urban systems.

This approach enhances methodological clarity and responds directly to the need for measurable and evidence-based analysis in contemporary urban research. It also supports the integration of heritage institutions into planning strategies by emphasizing connectivity, accessibility, and institutional interaction as key drivers of socio-economic urban dynamics.

3. A Philosophical-Parametric Framework for Heritage Analysis

As outlined in Figure 2, the theoretical framework of this research is structured as a tripartite system linking philosophical concepts to parametric design operations. To ensure both conceptual clarity and methodological precision, each component of this framework is articulated as a distinct yet interrelated analytical layer. Figure 2 illustrates the translation of philosophical concepts (Debord, Foucault, Deleuze) into parametric modelling processes and network-based analytical dimensions. It establishes a conceptual-operational link supporting the assessment of ISBAT's socio-economic integration within the urban system of Tunis.

3.1. Derive and Deviations (Debord, 1956): Conceptual Parametric Design

Guy Debord's concept of the derive, a practice of urban wandering through which individuals navigate space beyond the constraints of routine, constitutes the conceptual foundation of the first phase of the parametric design process. By emphasizing movement, perception, and the re-appropriation of urban environments, Debord introduces a critical approach in which spatial meaning emerges through exploratory trajectories rather than predefined hierarchies. In parametric terms, this translates into the generation of radiating connectivity lines originating from the ISBAT node toward all identified buildings within the study perimeter. This mono-layer mapping can be interpreted as a form of computational derive: the Grasshopper script systematically traverses the urban fabric from a single point of departure, tracing relational paths without prior categorization. The resulting output is a geometric field of potential connections that reveals the latent structural logic of ISBAT's urban positioning. It constitutes an abstract layer of spatial exploration: a drift rendered computational, where urban wandering is transformed into a measurable and reproducible analytical operation.

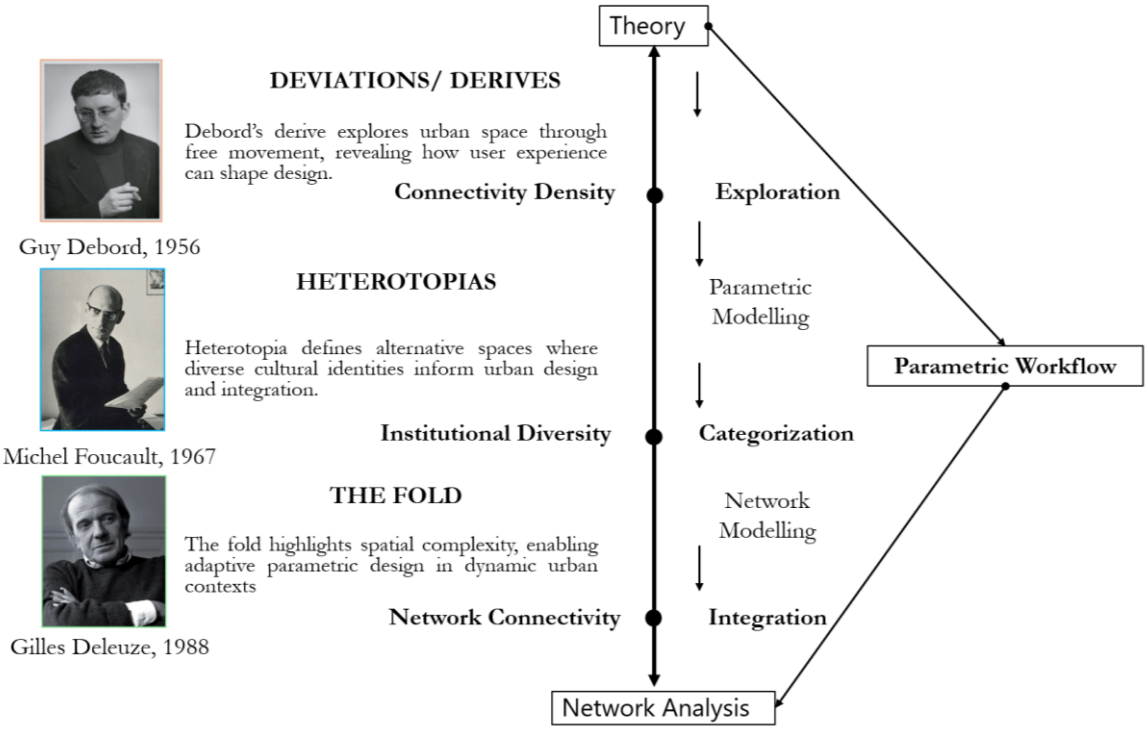

Figure 2. Philosophical-Parametric Framework Linking Urban Theory to Network-Based Analysis of ISBAT (Developed by the Author, 2026).

3.2. Heterotopias (Foucault, 1967): Constructive Parametric Design

Michel Foucault's concept of heterotopias describes real spaces that operate in relation to, yet in tension with, the dominant spatial order. These "other spaces" function as sites of difference, where multiple cultural, institutional, and temporal layers coexist and interact. Within the parametric workflow, this concept structures the transition toward a constructive phase of analysis. The previously generated monolayer map is enriched through a multi-categorical classification system in which each group of institutions is assigned a distinct visual parameter: yellow for governmental entities, blue for the University of Tunis, red for cultural institutions, green for infrastructural networks, and orange for medical and civic facilities. This process transforms an abstract field of connections into a differentiated heterotopic system, making visible the coexistence and interaction of multiple urban identities. The parametric model thus operates as an analytical device that reveals the layered institutional ecology surrounding ISBAT. In this context, ISBAT itself can be understood as a heterotopic entity: simultaneously integrated within the national educational framework and distinct from it; embedded in the urban fabric of Bab Saadoun while operating according to specific cultural and temporal logics; physically anchored in the contemporary city yet bearing the accumulated memory of a century of artistic production.

3.3. The Fold (Deleuze, 1988): Integrative Parametric Design

Gilles Deleuze's concept of the fold provides a framework for understanding spatial complexity as a process of continuous differentiation and integration. Rather than defining fixed boundaries between inside and outside, the fold describes a dynamic system in which relationships are constantly reconfigured. In the parametric methodology, this concept corresponds to the integrative phase of the modelling process. All previously defined layers, structural and categorical, are superimposed and activated simultaneously, generating a dense and composite visualisation of urban connectivity. This integrated output embodies the logic of the fold: ministerial, educational, cultural, and infrastructural relationships are not treated as separate systems but as interdependent dimensions of a single, evolving spatial configuration. The model reveals a multi-scalar and relational urban field in which meanings emerge through interaction rather than isolation.

3.4. Urban Image Theory: (Lynch, 1960)

Kevin Lynch's theory of urban imageability provides an interpretive framework through which the parametric outputs are analysed. By identifying the key elements shaping urban perception: paths, edges, districts, nodes, and landmarks. Lynch offers a structured lens for evaluating the legibility and coherence of urban environments. His later reflections further emphasise the evolving and dynamic nature of urban imageability, highlighting the need to reinterpret spatial perception in response to changing urban conditions (Lynch, 1984). Within this framework, parametric analysis contributes to revealing how ISBAT participates in the spatial and perceptual organisation of the city. Rather than presupposing fixed roles, the modelling process highlights patterns of connectivity, accessibility, and relational positioning that inform the institution's contribution to the broader urban image. In this sense, the analysis does not aim to categorise ISBAT a priori, but rather to provide a spatially grounded interpretation of how its relationships with surrounding educational, cultural, and institutional systems contribute to the legibility and structure of the urban fabric. These dynamics, often implicit in conventional urban analysis, are made explicit through parametric modelling, enabling a more nuanced understanding of ISBAT's role within the evolving image of Tunis.

4. ISBAT in Context: A Century of Institutional and Urban Transformations

The historical trajectory of the Higher Institute of Fine Arts of Tunis (ISBAT), as shown in Figure 3, cannot be understood in isolation from the broader political, spatial, and institutional evolution of Tunis. Rather than a purely chronological narrative, ISBAT's development reflects a series of strategic spatial reconfigurations shaped by major political transitions and urban restructuring processes.

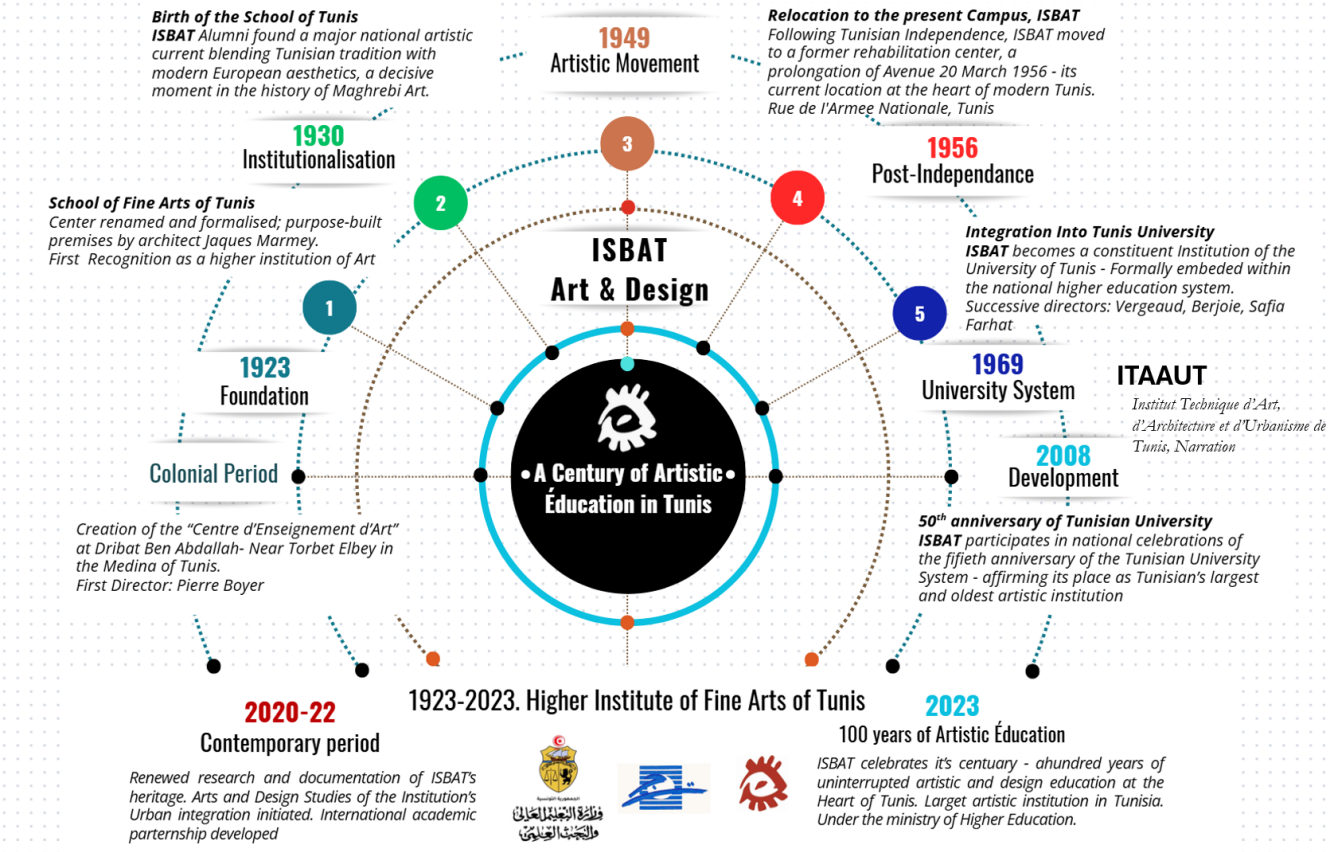

Figure 3. ISBAT-A Century of Artistic Education in Tunis: Circular Timeline of Institutional and Urban Transformations (1923-2023) (Developed by the Author).

As illustrated in Figure 3, which presents a circular timeline of key milestones (1923–2023), ISBAT's evolution can be interpreted through three major urban positioning phases that explain its current role

within the contemporary urban network. Founded in 1923 as the Centre of Teaching Art at Dribat Ben Abdallah, near Tourbet El Bey in the Medina of Tunis, ISBAT was initially embedded within a dense historical fabric. This positioning anchored the institution within a highly interconnected socio-cultural environment, reinforcing its integration within traditional urban networks and local cultural practices. In 1930, the institution was formalized as the École des Beaux-Arts de Tunis, consolidating its academic and spatial presence. A decisive shift occurred in 1949 with the emergence of the École de Tunis movement, which extended ISBAT's influence beyond its physical boundaries into broader cultural and artistic networks, contributing to national identity formation. The year 1956 marked a pivotal turning point, as Tunisian independence was accompanied by a major urban restructuring. ISBAT's relocation to its current site along Avenue du 20-Mars 1956 positioned it within a newly organized urban system characterized by increased accessibility and proximity to key institutional nodes. This spatial transition reflects a shift from a historically embedded institution to a strategically located actor within modern urban networks. In 1969, ISBAT became part of the University of Tunis, reinforcing its role within national educational and institutional systems. This integration enhanced its connectivity within academic and administrative networks, further strengthening its socio-economic relevance on the urban scale. Subsequent milestones, including its involvement in national academic events and its centenary celebration in 2023, confirm ISBAT's continuity as a major institutional actor.

Figure 4. ISBAT Architectural Morphology and Urban Context: Spatial Configuration, Accessibility, and Integration within the Urban Network of Tunis (Developed by the Author).

This longevity reflects not only its historical significance but also its capacity to maintain strong relational connections within evolving urban systems. Beyond a historical narrative, Figure 3 reveals a progressive transformation from a localized cultural institution to a central node within multiple overlapping urban networks, including cultural, educational, and administrative systems. This evolution provides a critical foundation for understanding ISBAT's current spatial centrality and its potential role in shaping socio-economic urban dynamics. Complementing this temporal perspective, Figure 4 presents the architectural and morphological characteristics of ISBAT, emphasizing its physical integration within the urban fabric. It highlights the relationship between the institution's-built form, its surrounding urban structure, and patterns of accessibility. This spatial configuration reinforces ISBAT's role as a connector within the urban network, linking multiple institutional and infrastructural systems.

5. Materials and Methods

This study adopts a computational and data-driven spatial analysis approach, combining geospatial data processing, parametric modelling, and urban network analysis to assess the socio-economic integration of ISBAT within the urban system of Tunis. As outlined in Figure 1, the methodology follows a structured workflow linking spatial data analysis, parametric modelling, and network-based assessment. This approach ensures a clear transition from spatial representation to measurable evaluation, enhancing the reproducibility and scientific rigor of the study. Within this framework, the present section operationalizes the theoretical concepts introduced earlier by translating them into parametric modelling processes and measurable indicators.

5.1. Study Area: ISBAT within the Morphological Context of Bab Saadoun

The study area is in central Tunis, with a focus on the Bab Saadoun sector, where ISBAT is strategically positioned within a dense and heterogeneous urban environment.

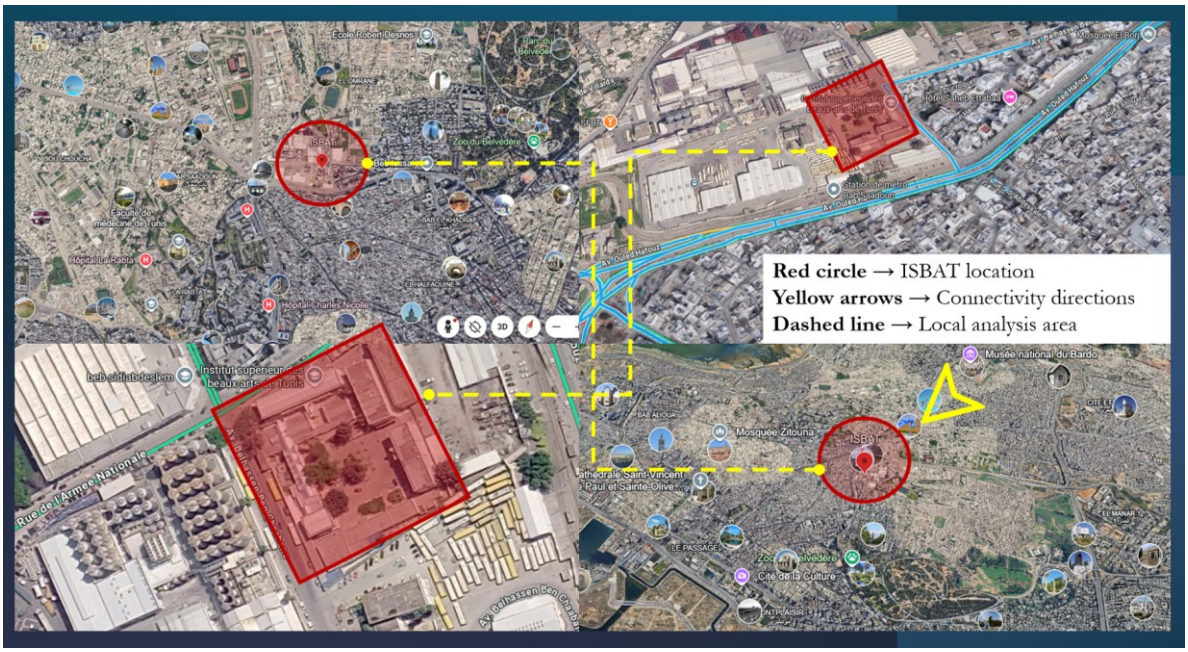

Figure 5. Multi-Scale Spatial Analysis of ISBAT: Urban Context, Accessibility, and Network Connectivity within Tunis.

As illustrated in Figure 5, a multi-scale spatial analysis is conducted to examine ISBAT's positioning within the urban network of Tunis. This approach allows for a comprehensive understanding of connectivity, accessibility, and institutional relationships across different spatial scales.

At the metropolitan scale, ISBAT is embedded within the broader urban structure of Tunis, situated between major geographical and infrastructural elements such as the Lac de Tunis to the east and railway networks to the west. This macro-level positioning highlights its integration within the city's large-scale urban network. At the intermediate scale, the analysis reveals ISBAT's proximity to key institutional nodes, including the Ministry of Higher Education, Bab El Khadra, and Parc du Belvedere, as well as several educational and administrative facilities. These spatial relationships indicate a high level of institutional connectivity, reinforcing ISBAT's role within a dense socio-economic and administrative network. At the local scale, the morphological configuration shows that ISBAT is located at the intersection of major accessibility axes, including primary routes, secondary connections, and transversal links. The connectivity directions illustrated in Figure 5 emphasize patterns of movement and spatial interaction within the urban fabric. This analytical reading can be related to Guy Debord's concept of the derive, understood as a form of exploratory urban movement that reveals latent spatial relationships beyond routine circulation. In this context, the mapping of connectivity

around ISBAT operates as a computational derive, systematically identifying potential paths and interactions within the urban network rather than individual experiential trajectories.
Finally, at the site scale, the architectural footprint and internal organization of ISBAT are highlighted, illustrating the relationship between built form, immediate surroundings, and access points. This multi-scalar framework demonstrates that ISBAT operates as a central node within overlapping urban networks, characterized by high accessibility, strong connectivity, and proximity to strategic institutional systems.

5.2. Parametric Modelling Workflow

The parametric modelling process as detailed in Table 1 and Table 2 was conducted using Grasshopper within Rhinoceros 3D, following a structured and reproducible workflow integrating geospatial data, parametric modelling, and network-based analysis. To enhance methodological clarity, the workflow is organized into two main analytical phases: data foundation and node definition, and connectivity analysis and multi-categorical network modelling. This structure ensures a consistent transition from raw spatial data to measurable indicators supporting the assessment of ISBAT's socio-economic integration.

5.2.1. Data Foundation and Node Definition

Table 1 illustrates the first phase focusing on the integration and structuring of geospatial data to establish the parametric base model.

Table 1: Parametric Workflow: Data Integration and Node Definition.

Stage	Tool / Script	Input Data	Process	Output
Geospatial Data Import	Rhinoceros 3D	OpenStreetMap (buildings, roads)	Data import and geo-referencing	Georeferenced base model of Tunis
Urban Massing	Grasshopper (Extrude)	Building footprints + parameters	3D extrusion of urban volumes	3D urban massing model
Node Definition	Grasshopper (Point)	ISBAT centroid	Definition of central parametric node	Parametric origin point

Geospatial datasets are imported from OpenStreetMap and processed within Rhinoceros 3D to generate a georeferenced urban base model. Building footprints are extruded using Grasshopper to create a three-dimensional representation of the urban fabric. ISBAT is defined as a central parametric node, acting as the origin point for connectivity generation. This phase establishes the structural foundation of the model and corresponds to the conceptual exploration phase, in which spatial relationships are identified and prepared for analysis.

5.2.2. Connectivity Analysis and Multi-Categorical Modelling

The second phase focuses on modelling urban connectivity and structuring the network through institutional differentiation as mentioned in Table 2.

Table 2: Connectivity Analysis and Multi-Categorical Network Modelling.

Stage	Tool / Script	Process	Output	Indicator
Mono-layer Connectivity	Grasshopper (Line Component)	Generate radiating connections from ISBAT	Network of spatial links	Connectivity Density (CD)
Institutional Categorization	Grasshopper (Dispatch + Colour Coding)	Classify institutions by category	Multi-layer network model	Institutional Diversity Index (IDI)
Multi-Scenario Rendering	Rhinoceros 3D	Visualize connectivity patterns	Analytical visual outputs	Spatial interpretation
Integrated Network Model	Grasshopper (Merge)	Superimpose all network layers	Composite network system	CD + AR + IDI

Connectivity is generated by constructing radiating links from the ISBAT node toward surrounding urban elements, creating a mono-layer network that reveals spatial relationships across the study area. This step provides the basis for calculating Connectivity Density (CD).

The network is then enriched through institutional categorization, where urban entities are classified into functional groups (cultural, educational, governmental, and infrastructural). This transformation produces a multi-layer network and enables the calculation of the Institutional Diversity Index (IDI). All layers are integrated into a composite model, allowing simultaneous interpretation of spatial relationships across multiple dimensions. This integrated structure supports a comprehensive evaluation of ISBAT's position within the urban system.

5.2.3. Synthesis and Methodological Contribution

The parametric workflow establishes a direct relationship between spatial data, computational modelling, and analytical interpretation. By combining:

- Connectivity Density (CD)
- Accessibility Radius (AR)
- Institutional Diversity Index (IDI)

The methodology provides a quantitative framework for assessing ISBAT's socio-economic integration within urban networks. This approach ensures reproducibility, improves transparency in the modelling process, and responds to the need for measurable indicators in contemporary urban analysis.

5.3. Accessibility and Network Indicators

To evaluate ISBAT's spatial integration within the urban system of Tunis, this study introduces measurable accessibility indicators based on walking-distance analysis to key urban and institutional nodes.

The accessibility assessment includes the following distances:

- 5 minutes to Bab El Khadra
- 6 minutes to the Ministry of Higher Education
- 8 minutes to the Belvedere area
- 12 minutes to the city center
- 15 minutes to the City of Culture

These values define the Accessibility Radius (AR), which reflects the spatial reach and proximity of ISBAT within the surrounding urban network.

The results demonstrate that ISBAT benefits from a high level of accessibility, positioning it within a short-distance radius of major urban attractors and institutional infrastructures. This proximity enhances opportunities for interaction, mobility, and socio-economic exchange, reinforcing ISBAT's role as a central node within the urban network.

5.4. Institutional Network Structure

Beyond morphological and accessibility analysis, the study examines ISBAT's integration within multiple institutional networks through spatial connectivity patterns illustrated in Figure 6. The figure highlights a set of directional routes linking ISBAT to key urban nodes, corresponding to distinct functional systems:

- Cultural networks (e.g., City of Culture)
- Educational networks (universities, schools)
- Governmental institutions (ministries and administrative entities)
- Medical and civic infrastructures

These spatial trajectories reflect a heterogeneous urban system characterized by overlapping institutional layers. This interpretation can be related to Michel Foucault's concept of heterotopia, which describes spaces where multiple functions and identities coexist and interact. In this context, the network of connections surrounding ISBAT reveals a heterotopic condition, where diverse institutional domains converge within a shared urban framework. To quantify this dimension, the study introduces the Institutional Diversity Index (IDI), which measures the variety and distribution of institutional connections linked to ISBAT. The presence of multiple categories confirms its role as an intersection point between different urban systems.

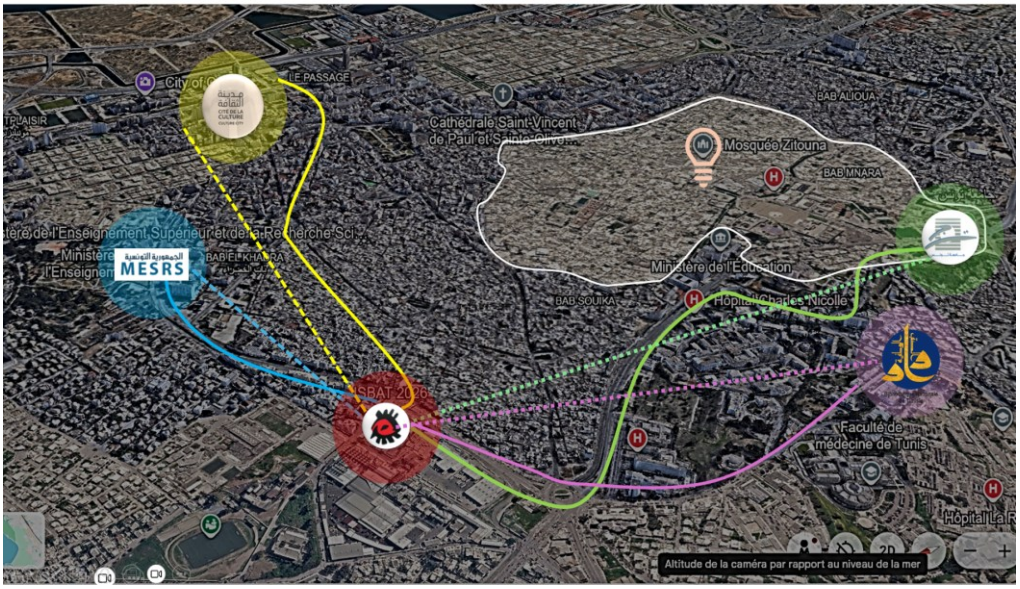

Figure 6. Urban Network Connections of ISBAT: Multi-Directional Linkages between Key Institutional Nodes in Tunis.

5.5. Network-Based Assessment of Socio-Economic Integration

The combined analysis of spatial configuration, accessibility, and institutional relationships allows ISBAT to be interpreted as a central node within overlapping urban networks. This network-based interpretation aligns with the parametric modelling approach, where spatial relationships are not only visualized but translated into measurable analytical indicators.

Three key indicators structure this analysis:

- Connectivity Density (CD): reflects the intensity and concentration of spatial connections surrounding ISBAT
- Accessibility Radius (AR): measures proximity and reach within the urban system
- Institutional Diversity Index (IDI): quantifies the diversity of institutional interactions

Together, these indicators provide a quantitative framework for assessing ISBAT's socio-economic integration within Tunis. The results indicate that ISBAT's spatial centrality is not only a geometric condition but a functional and relational one, driven by connectivity, accessibility, and institutional

interaction. These factors contribute to its role as an active urban node that supports socio-economic dynamics through enhanced mobility, interaction, and network integration.

6. Results

6.1. Conceptual Parametric Modelling: ISBAT as a Structural Node (Debord – Derive)

The first stage of parametric modelling reveals the structural organization of the urban network through a mono-layer connectivity model centered on ISBAT.

The generated radiating network illustrated in Figure 7 highlights clear directional patterns of connectivity, particularly towards the Medina to the east and the institutional axis to the north. The homogeneous distribution of connections indicates a high level of spatial coherence across the study area. This configuration allows ISBAT to be identified as a structurally central node, supported by a continuous and dense field of spatial connections. Such organization reflects a centripetal structure in which spatial relationships converge around the institution.

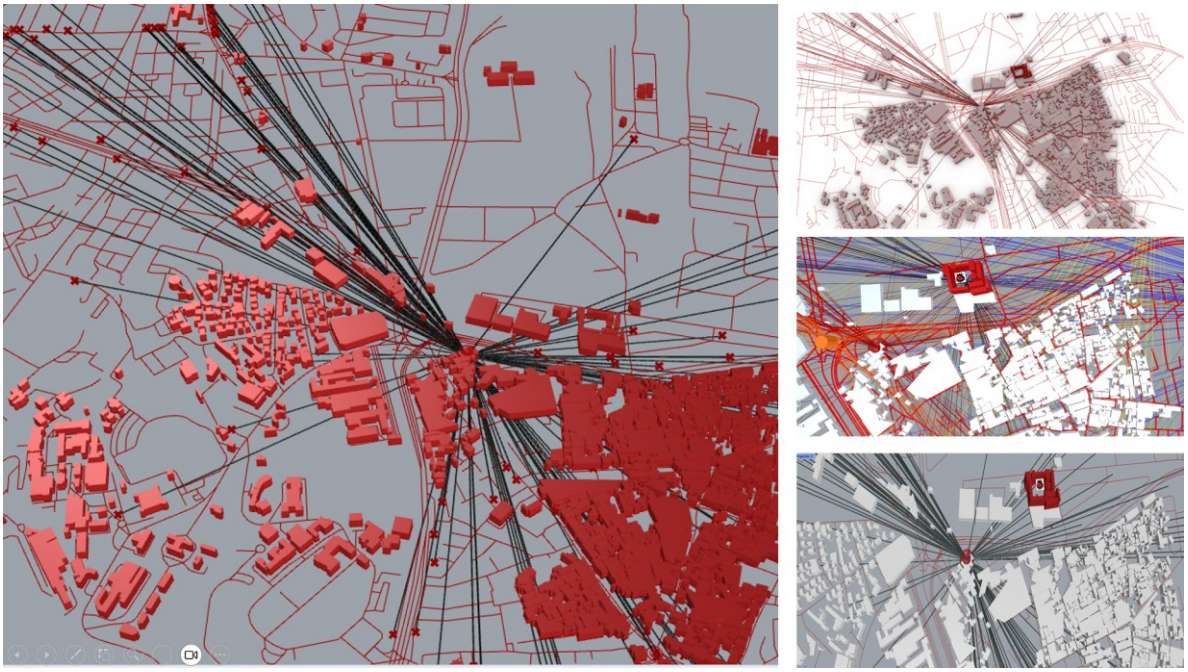

Figure 7. Conceptual Parametric Modelling (Derive): Mono-Layer Connectivity Field Revealing ISBAT's Structural Centrality.

Figure 7 illustrates the radiating connectivity network generated from ISBAT, supporting the analysis of connectivity density and highlighting its role as a central urban node within the network. At this stage, the analysis remains intentionally undifferentiated, focusing on connectivity as a geometric property. This approach corresponds to a computational interpretation of Debord's derive, understood here as a systematic exploration of spatial relationships through network generation.

From a quantitative perspective, this phase supports the evaluation of Connectivity Density (CD), confirming ISBAT's structural centrality. These findings are consistent with recent studies highlighting the role of spatial connectivity in structuring urban systems and influencing urban performance (Zhang, Y., & Liu, C., 2021).

6.2. Constructive Parametric Modelling: Institutional Diversity (Foucault-Heterotopias)

The second stage introduces a differentiated reading of the network through institutional categorization, revealing the diversity of relationships surrounding ISBAT as demonstrated through Figure 8. The distribution of connections across multiple categories: cultural, educational, governmental, and infrastructural demonstrates that ISBAT is embedded within several overlapping institutional systems.

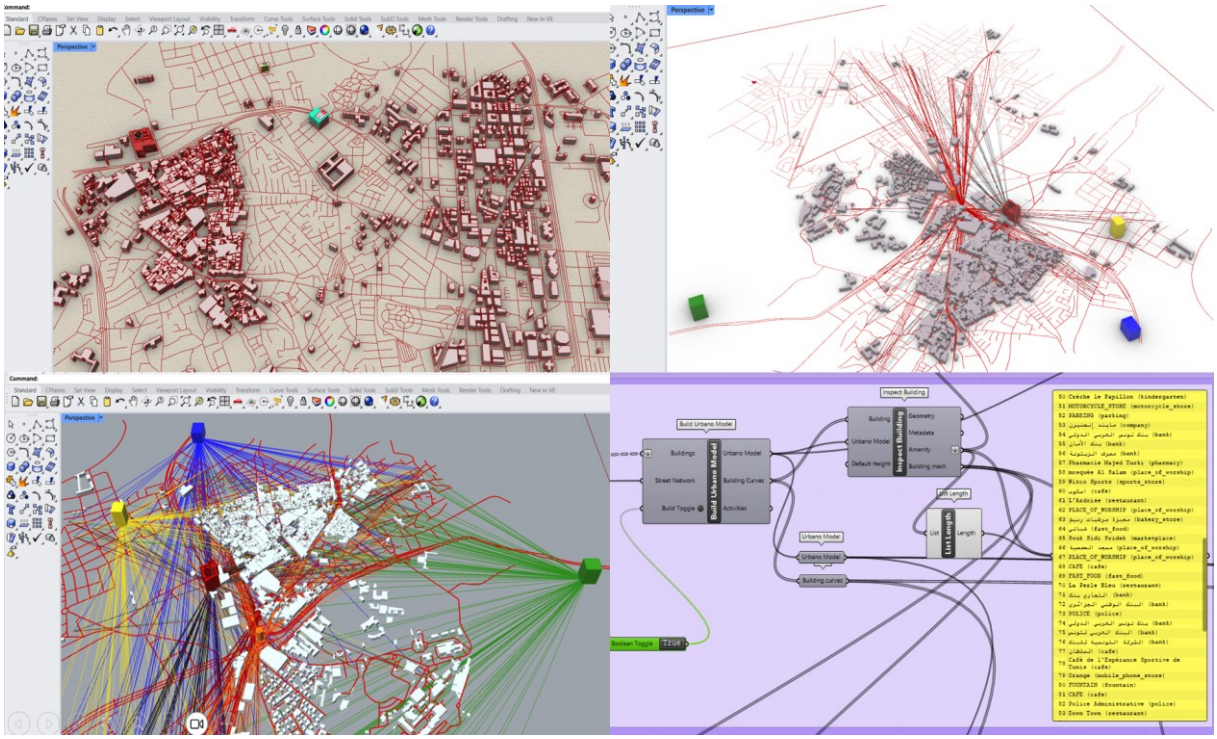

Figure 8. Constructive Parametric Modelling (Heterotopias): Institutional Multiplicity and Multi-Layer Urban Networks around ISBAT.

Figure 8 illustrates the multi-categorical connectivity network generated through parametric modelling. Institutional relationships are differentiated by categories, revealing the diversity of urban systems surrounding ISBAT and supporting the analysis of the Institutional Diversity Index (IDI). This configuration reflects a heterogeneous urban structure, corresponding to Foucault's concept of heterotopias, where multiple functional domains coexist within a shared spatial environment.
From an analytical perspective, this phase supports the calculation of the Institutional Diversity Index (IDI). The presence of multiple categories confirms that ISBAT operates as an intersectional node, linking diverse institutional systems. Such diversity aligns with contemporary research emphasizing the importance of multi-functional urban environments in supporting socio-economic interaction and resilience (Abeynayake et al., 2022; Meenar et al., 2022).

6.3. Integrative Parametric Modelling: Relational Connectivity (Deleuze-Fold)

The third stage synthesises all network layers into a composite parametric model, revealing the cumulative structure of ISBAT's spatial relationships. Figure 9 illustrates the integrated multi-layer connectivity network generated through parametric modelling. The superposition of institutional and spatial systems reveals patterns of interaction and supports the combined analysis of connectivity density (CD), accessibility radius (AR), and institutional diversity (IDI), highlighting ISBAT's role as a central urban connector. The superimposition of connectivity layers generates a dense relational field characterised by strong interaction between cultural, educational, governmental, and infrastructural systems. This configuration highlights the interdependencies between urban subsystems. This relational configuration reflects the principles of complex urban systems, where spatial organization emerges from interconnected networks and dynamic interactions (Batty, 2013). The primary result is the identification of relational integration as a defining characteristic of ISBAT's urban condition. The institution functions not within isolated domains but as a mediator connecting multiple networks. This integrative model combines high connectivity density, strong accessibility radius, and high institutional diversity. Together, these indicators demonstrate that ISBAT acts as a multi-scalar connector within the urban system. These findings are consistent with recent studies showing that

urban centrality emerges not only from spatial position but from relational intensity and network connectivity (Zhang & Liu, 2021; Gustafsson & Ripp, 2022).

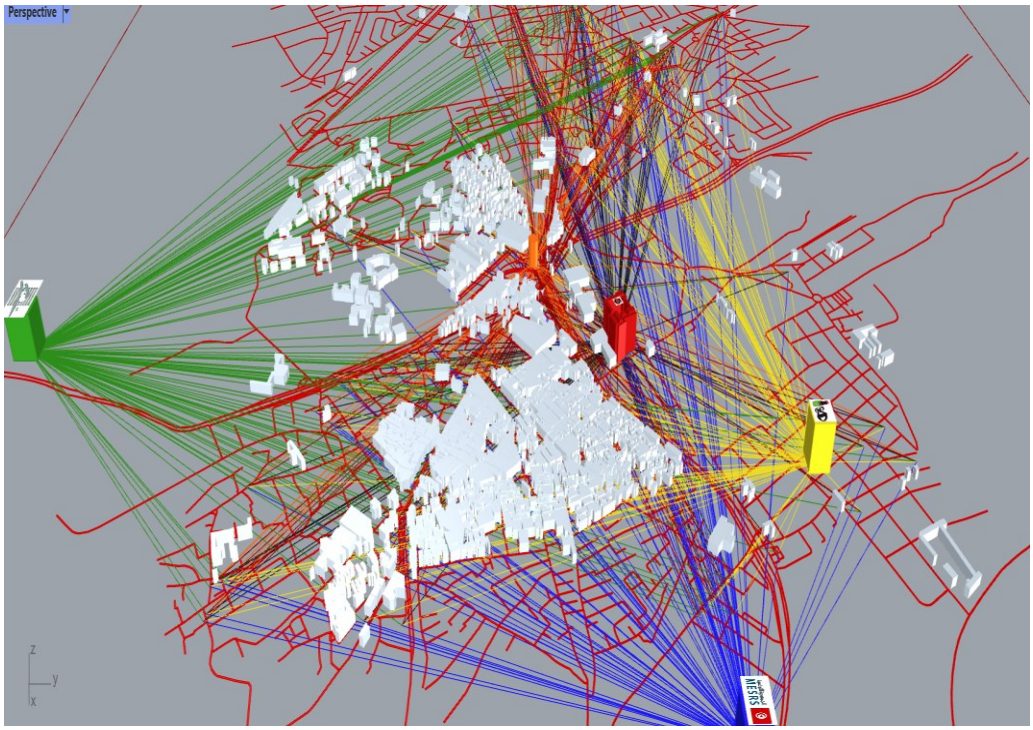

Figure 9. Integrated Parametric Connectivity Model of ISBAT: Multi-Layer Network Synthesis and Relational Integration.

6.4. Integrated Assessment: From Network Structure to Urban Image

The results converge into a unified interpretation in which parametric modelling supports both analysis and interpretation of urban systems. The progression from structural connectivity (Section 6.1) to institutional diversity (Section 6.2) and relational integration (Section 6.3) reflects a transition from geometric centrality to functional complexity and socio-economic integration. Within this framework, Lynch's (1960) theory of urban imageability provides an interpretive layer for understanding spatial organisation in terms of perception and legibility. The analysis demonstrates that ISBAT operates as a multi-dimensional urban entity:

- as a node, concentrating and redistributing spatial relationships
- as a landmark, contributing to urban recognisability
- as a structuring element, organizing a cultural and educational territory

This interpretation aligns with recent research highlighting the role of connectivity, accessibility, and visibility in shaping socio-economic urban dynamics (Meenar et al., 2022; Abeynayake et al., 2022). These findings confirm that the urban significance of heritage institutions is not limited to their physical presence but derives from their capacity to organize and connect spatial and institutional systems (Gustafsson & Ripp, 2022). More broadly, this study demonstrates that parametric modelling functions as a decision-support tool for urban planning, enabling the evaluation of socio-economic integration through measurable spatial indicators.

7. Discussion: Toward a Parametric and Relational Understanding of Urban Heritage

The results of this study support a shift from a form-based interpretation of heritage institutions toward a relational and network-based understanding of urban integration. By linking theoretical frameworks, parametric modelling, and spatial analysis, the research demonstrates that ISBAT's urban significance emerges from its position within interconnected institutional and infrastructural systems rather than from its architectural form alone.

7.1. From Parametric Modelling to Urban Knowledge Production

The findings highlight the dual role of parametric modelling as both an analytical and interpretive tool. Beyond visualization, the modelling process enables the production of spatial knowledge, accessibility, and institutional interaction that are not immediately visible through conventional urban analysis. This approach aligns with contemporary perspectives on cities as data-driven and computational systems, where modelling tools support the interpretation of complex urban dynamics (Batty, 2013; Gün, 2023). This interpretation is reinforced by recent studies emphasizing the capacity of digital tools to enhance the understanding of urban systems and spatial perception (Meenar et al., 2022; Zhang, Y., & Liu, C.,2021). Within this framework, Lynch's (1960) concept of imageability can be reinterpreted as a network-dependent condition, in which urban legibility emerges from measurable spatial relationships rather than solely from morphological features.

7.2. ISBAT as a Multi-Scalar Urban Interface

The analysis of ISBAT as a node, landmark, and structuring element highlights its role not only as a central entity within the urban network, but as a multi-scalar interface connecting different spatial, institutional, and socio-economic systems. Rather than interpreting these roles as fixed attributes, the results suggest that ISBAT operates as a dynamic mediator, linking local accessibility networks with broader metropolitan systems. Its position at the intersection of the historic Medina and modern urban infrastructures enables it to facilitate interactions between distinct urban environments, institutional actors, and social practices. This interface condition reinforces the idea that urban centrality is not solely a function of spatial location but emerges from the intensity and diversity of relational interactions. In this sense, ISBAT can be understood as an active node that continuously reconfigures urban relationships through connectivity, accessibility, and institutional linkage.

Such a reading shifts the interpretation of heritage institutions from static urban markers to relational infrastructures, capable of structuring flows, interactions, and socio-economic exchanges across different urban scales.

7.3. A Relational Approach to Urban Heritage

The study contributes to ongoing debates in heritage urbanism by providing empirical evidence that heritage value is fundamentally relational. This relational perspective also resonates with ecological and spatial resilience approaches, which consider cities as interconnected systems linking spatial morphology, environmental processes, and social dynamics (Marcus & Colding, 2014). As also suggested by Gustafsson and Ripp (2022), heritage should be understood as a dynamic system of interactions embedded within urban processes. This perspective is also consistent with earlier studies on heritage and urban development, which emphasize the role of built cultural heritage in supporting sustainable urban transformation (Tweed & Sutherland, 2007). In the context of urban regeneration, cultural institutions are increasingly recognized as drivers of socio-economic development and spatial restructuring (Evans, 2005; Miles & Paddison, 2005). Urban cultural systems have also been associated with broader socio-ecological dynamics, where social practices, public spaces, and environmental interactions contribute to urban resilience (Barthel et al., 2015). The case of ISBAT confirms this proposition: despite its relatively modest architectural expression, its urban significance is amplified by the density, diversity, and intensity of its connections. This relational perspective aligns with contemporary approaches to cultural sustainability, which prioritize social and spatial resilience over material preservation alone (Francini & Rozochkina, 2024).

7.4. Theoretical Contribution: From Philosophy to Parametric Method

One of the key contributions of this research lies in the operationalization of the Debord–Foucault–Deleuze triad as a generative framework for parametric modelling. Rather than serving as retrospective interpretative references, these concepts are translated into modelling stages:

- Debord's derive computational exploration (connectivity)
- Foucault's heterotopias: categorical differentiation (institutional diversity)
- Deleuze's fold integrative synthesis (network complexity)

This articulation establishes a coherent methodological sequence that links theoretical abstraction to computational implementation, extending previous work on parametric design as an analytical tool (Woodbury, 2010; Sahtout, 2023).

7.5. Implications for Urban Planning and Design

The findings demonstrate that parametric modelling can function as a decision-support tool for urban planning, particularly in the context of heritage-driven urban development. By quantifying:

- connectivity (CD)
- accessibility (AR)
- institutional diversity (IDI)

the approach provides actionable insights into how heritage institutions contribute to urban socio-economic dynamics. This aligns with recent research emphasizing the importance of connectivity-based strategies in enhancing urban performance and resilience (Abeynayake et al., 2022).

More broadly, the study suggests that integrating parametric tools into planning processes can support evidence-based decision-making, enabling a better understanding of the spatial and relational impact of heritage institutions. This interpretation aligns with studies highlighting the role of stakeholder collaboration and cultural strategies in shaping successful urban regeneration processes (Jung et al., 2015). It also resonates with emerging perspectives on smart heritage, where digital tools and data-driven approaches are used to enhance the integration of heritage assets within sustainable urban systems (Song & Selim, 2022).

7.6. Limitations and Future Research

Despite its contributions, the study has several limitations. The parametric model primarily captures spatial and geometric relationships, without fully accounting for experiential, social, and cultural dimensions of urban space. As highlighted in urban theory, the lived experience of cities remains partially irreducible to computational representation (Lynch, 1960; Schön, 1983). Future research should therefore integrate qualitative and participatory approaches, including:

- ethnographic observation
- interviews with ISBAT students and alumni
- participatory mapping practices

These methods would complement the parametric analysis and provide a deeper understanding of the socio-cultural dynamics associated with heritage institutions.

8. Conclusion: Methodological Contributions and Perspectives for Adaptive Heritage Urbanism

This study developed and applied a parametric analytical framework to assess the spatial and socio-economic integration of heritage institutions within urban networks, using the Higher Institute of Fine Arts of Tunis (ISBAT) as a case study. By combining the theoretical perspectives of Debord, Foucault, Deleuze, and Lynch with computational modelling, the research demonstrated that ISBAT should not be understood only as a historical or architectural institution, but as a relational urban node embedded within overlapping spatial, institutional, cultural, and infrastructural networks. The findings show that ISBAT's urban significance emerges from the interaction between connectivity density, accessibility radius, and institutional diversity, confirming its role as a central connector within the urban system of Tunis.

The results also demonstrate that ISBAT contributes to urban socio-economic dynamics through its proximity to major educational, cultural, governmental, civic, and infrastructural nodes. Its short walking-distance accessibility to key urban institutions strengthens opportunities for interaction, mobility, knowledge exchange, cultural production, and institutional collaboration. In this sense, ISBAT's socio-economic role is not defined only by direct economic activity, but by its capacity to connect people, institutions, services, and cultural networks within the city. The study therefore confirms that heritage institutions can support urban socio-economic integration when they operate as accessible and connected nodes within broader urban systems.

The main scientific contribution of this research lies in translating philosophical and urban-theoretical concepts into a measurable and reproducible parametric methodology. Debord's notion of the dérive informed the mapping of exploratory spatial connections, Foucault's concept of heterotopia supported the categorization of institutional diversity, and Deleuze's concept of the fold enabled an integrative interpretation of layered urban relationships. Through this process, parametric modelling was positioned not merely as a representational tool, but as an analytical instrument capable of revealing hidden relational structures within heritage urban environments. This contributes to heritage urbanism, urban network analysis, and parametric urban research by offering a framework through which spatial and socio-economic integration can be evaluated systematically.

The findings also provide practical implications for heritage-led urban planning. They suggest that the long-term relevance of heritage institutions depends not only on conservation policies, but also on their capacity to remain accessible, connected, institutionally active, and socially productive within the contemporary city. In the case of ISBAT, its proximity to educational, cultural, governmental, and infrastructural nodes strengthens its role as a platform for cultural production, institutional interaction, and socio-economic exchange. Therefore, planning strategies for heritage institutions should move beyond physical preservation and address wider relational conditions, including pedestrian accessibility, institutional collaboration, spatial connectivity, cultural programming, and adaptive reuse. Such an approach can support more resilient, inclusive, and socio-economically responsive forms of heritage-led urban development.

Despite these contributions, the study has several limitations. The parametric model primarily focuses on spatial and institutional relationships and does not fully capture experiential, social, symbolic, economic, or affective dimensions of urban space. In addition, the study is based on a single case, which limits the generalizability of the findings across different heritage contexts. Future research should therefore apply the proposed framework to comparative case studies and integrate qualitative and socio-economic methods such as ethnographic observation, interviews, participatory mapping, user-based analysis, institutional surveys, and local activity mapping. These methods would complement computational modelling and provide a deeper understanding of how heritage institutions are experienced, used, and activated by different urban actors.

Overall, this research demonstrates that parametric modelling can move beyond form generation to support evidence-based analysis of heritage urban systems. By revealing the relational complexity of ISBAT, the study advances an adaptive understanding of heritage institutions as active agents within contemporary urban transformation. The proposed framework offers a foundation for future studies seeking to connect digital modelling, heritage analysis, urban socio-economic integration, and network-based planning in a more integrated and scientifically grounded manner.

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Conflicts of Interest

The author reports no conflicts of interest.

Data Availability Statement

The data supporting the findings of this study are based on publicly available geospatial datasets from OpenStreetMap. The parametric models and workflows developed in Grasshopper and Rhinoceros 3D can be made available by the author upon reasonable request.

Institutional Review Board Statement
Not applicable.

Credit Author Statement
Ines Sahtout Gaha was responsible for conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing- original draft, writing- review and editing, visualization, and supervision; the author performed all aspects of the research, including modelling, analysis, and writing, and has read and approved the final manuscript.

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