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Article

The New Urban Paradigm (Synergistic Antifragility): The Role of Complex Systems Theory and Network Theory in Enhancing Urban Synergy and Mitigating Fragility

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Abstract: Cities today are under increasing systemic stressors that expose the limitations of conventional resilience discourses. In answer, this paper proposes an ambitious dual urban model in Synergistic – Antifragile Urbanism that moves beyond mere survival, to enable cities to grow and thrive under uncertainty. Based on Network Theory and Complex Adaptive Systems (CAS), the model represents an integrated schema incorporating six dimensions: interactive-structural, dynamic-functional, transformative-social, inclusive-environmental, participatory-institutional and enabling-digital—by means of three core mechanisms, integration, cooperation and effective interaction. The paradigm envisages urban form as an organic and mobile entity as opposed to a static form, and capable of emerge forces of collective worth (synergy) and growth through disorder (antifragility). The model is applied as an evaluative framework to the public space of Bab al-Sharqi area in Baghdad, historically significant as the location of the Tahrir Square and Al-Umma Park. A structured Likert-scale questionnaire was issued to 41 urban specialists who are simultaneously the users of the site To obtain assessments based on both experience and expertise. The study used SPSS v.26 and Microsoft Excel for the data analysis of the results from the questionnaire and from which the mean, To arrive at descriptive and quantitative statistical analyses. In review, the results show a moderate all-embracing performance, with significant strengths to be found in its physical connectivity, functional multiplicity and social interaction—the results show critical weaknesses also in institutional participation and digital responsiveness. Overall, the results indicate that this particular spatial location displays the prodromal conditions of potential synergies, but has not yet emerged through the complete integrated system dynamics with feedback system of potential antifragility. The research offers An urban diagnostic tool was able to effectively reveal the ineffective dimensions of the urban model in the study area, and to develop an effective strategy for activating a comprehensive urban model capable of addressing current challenges and supporting future development possibilities.

Keywords: Dual urban model; Antifragility; Urban synergy; Network Theory (NT); Complex Adaptive Systems (CAS)

1. Introduction

Contemporary cities face more and more problems as they are overwhelmed by a process of rapid urbanization, climate change, political and technological shocks, which aggravate their structural vulnerabilities and put their sustainability in jeopardy. Here, the resilience paradigm, which focuses on the recovery process and a restoration of some past state, is growing insufficient (Taleb, 2012). It needs a new paradigm that will enable cities not just to survive shocks but to become better and more prosperous with the help of it. Taleb (2012) explains the concept of antifragility and defines systems that become

more robust to stress and turbulence. In contrast to robust systems, which supply strength in shocks, antifragile systems use volatility to enhance their structure and operation. The concept of urban synergy simultaneously highlights both the combination of physical, social, economic, and environmental factors to obtain urban results on the level that goes deeper than aggregate values of the constituents(Capra and Luisi, 2012)(Vankova, Nakamura, and Witthöft, 2018).

Although these ideas have become increasingly popular and appealing, there remains a vast knowledge gap when it comes to the integration of these ideas into an integrated, measurable urban framework, especially in complex and vulnerable urban settings, such as the Middle East. A review of urban literature demonstrates also shows that classic resilience frameworks tend to pursue defensive or passive strategies of endurance, limited to absorbing shocks and bouncing back to a former balance, These models have a knowledge gap of piecemeal dimensions and a sole focus on short-term adaptation from an absence of an integrated framework linking social and institutional dynamics to the spatial morphology (Yamagata and Sharifi, 2018) (Ahern, 2011) (Masnavi,et al, 2018). This paper seeks to fill this gap in the knowledge base through a presentation and analysis of a synergistic-antifragile urban model, which combines the two terms into one unified framework. To implement the model and evaluate the degree of its dimensions realization in the urban structure, the study took the Bab al-Sharqi district of Baghdad, the Tahrir Square, and the Umma Park. Due to the similar trends in the evolution of the site during crises, it is one of the best case studies to consider the subject of urban adaptability and self-organization dynamics (Jameel and Hussien, 2023). Thus, the study aims to:

- Design a conceptual framework for the dual urban model,
- create an initial indicator matrix for its evaluation, and
- test its application via a field survey of public opinions.

The research hypothesis suggests that "Cities can transition from a state of fragility to antifragility through the comprehensive activation of all dimensions of the dual (synergistic–antifragile) urban model. Therefore, this paper makes three main contributions to the scholarship and practice of urban planning. First, on a theoretical level, it supersedes dominant resilience discourses by integrating two well-understood but conceptually divergent frameworks—urban synergy and antifragility—into a single dual urban model. Although these concepts have developed in literature independently, their integration presents a more holistic perspective to consider how cities not only cope with shocks but also thrive in the face of uncertainty. Second, methodologically, the study takes abstract principles from Complex Adaptive Systems (CAS) and Network Theory and translates them into a measurement framework: a structured, quantifiable indicator matrix, consisting of six interdependent dimensions and thirty evaluation items. This operationalization fills a long-standing divide between theoretical frameworks on urban resilience and practical approaches to assess it. Thirdly, the study proves the diagnostic power of the framework at the empirical level by examining a non-Western, post-conflict urban context (Baghdad),where the official planning is lacking, and informal and community-based dynamics are crucial to urban adaptation (Abdulla and Hussein, 2022)(Hinthel, Hussein, and Aldabbagh, 2020). Together, these contributions address scholarly calls for socio-spatial, intervention-oriented frameworks positioning urban resilience between the descriptive idea and urban condition that can be designed and appraised.

2. Theoretical Framework: The Synergistic-Antifragile Urban Model

2.1. Urban Fragility: A Multifaceted Vulnerability

Urban fragility can be described as a vulnerability to the structure of the urban system and its incompetence in carrying out its fundamental functions due to the accumulation of ongoing pressures, and it is open to sudden and rapid failure without necessarily needing a shock(Curci and Chiffi, 2024). Fragility is therefore regarded as a finding indicative of the essential vulnerability of the urban system, the erosion of system flexibility, and the inability to adapt and change(Brage, 2024). The increasing complexity of the urban environment and the variety of interested parties only worsen the fragility, as a lack of integration on various planning levels deteriorates the responsiveness of the city in relation to the sudden appearance of changes and extends the time needed to return to normal (Ansar et al., 2017). In terms of the city, fragility is manifested through the inability to access basic services (water and electricity), high levels of poverty, spatial inequity, poor infrastructure, and unstable institutional decision-making (Bettencourt *et al.*, 2007). As UN-HABITAT (2024) noted, urban centers that were densely populated, exhibited spurts of unplanned development and lacked proper urban planning turned more vulnerable, particularly in case of climate change, epidemics, or political instability(UN-HABITAT, 2024). The abstract concept of urban fragility can be defined as complex and multi-layered phenomenon which includes structure, social and institutional dimensions.

2.2. Antifragility: Progressing Beyond Resilience

Antifragility is defined as the property of systems which not only withstands harm, but also benefits from stress, volatility or disorder (Taleb, 2012). Whereas resilience is a parameter that quantifies the ability of the system to recover from perturbation and return to a pre-existing state, antifragility suggests a system that benefits from adversity. Antifragility of cities means that they use disasters (floods, breakdown of infrastructures, and social turbulence) to transform - rediscovering the way they are governed, modernizing their institutions, and improving their connection with communities. The city systems, which embrace this idea, are founded on three main structural concepts, i.e., decentralization, modularity, and redundancy. Redundancy allows the system to keep operating in times of crisis by offering alternatives, e.g., alternative transportation routes during emergency or congestion, Modularity also works by ensuring the overall failure of the system is reduced due to the presence of units capable of responding to failure, and decentralization also enhances the response because it distributes power, resources, and local coordination, Antifragile systems encourage incremental innovation through small bets, low-risk, iterative interventions which increase learning and adaptation and reduce exposure of the user to big failures (Curci and Chiffi, 2024).

As a result, antifragility provides an alternative vision for urban design and planning in conditions of uncertainty, which, together with the notion of urban synergy, constitutes one of the main characteristics of the Synergistic-Antifragile urban model.

2.3. Urban Synergy: Integration for Collective Advancement

The concept of Urban synergy is realized when the physical, social, economic, and environmental factors have a combined effect that produces greater impacts than the total impact of each factor individually(Wohl, 2018). Based on systems theory, synergy emphasizes interdependence, and nonlinear cooperation as drivers of increased urban effectiveness, flexibility, and creativity (Capra and Luisi, 2012). Synergy is the dynamic interaction between formal institutional planning and spontaneous community self-organization, which results in feedback loops that strengthen urban liveliness and ability to endure (Haken and Portugali, 2021). This process of integration is observed in urban environments, i.e., in the mixed-use neighborhoods, where residential, commercial, and recreational activities are inseparable, thus lowering the mobility requirements, enhancing social interaction, and leading to the efficiency of resources, These areas promote spatial-social integration, which support emergent characteristics that are not possible with isolated interventions(Vankova et al., 2018). Urban synergy is not a design product but an evolutionary dynamic, which increases the ability of a city to adjust to and evolve. This principle is based on participatory governance, shared knowledge and flexible structures that empower the grassroot activities to hone down and supplement the top-down policies.

2.4. Complex Adaptive Systems (CAS) and Urban Dynamics

Cities are Complex Adaptive Systems (CAS), dynamic systems that are made of interrelated components, which interact, adapt, and evolve. In contrast to classical models, which hold that urban order is the outcome of centralized planning, the theory of Complex Adaptive Systems (CAS) underlines the idea of city development as the outcome of ongoing interactions between urban actors (individuals and institutions), physical structures, and environmental forces, This interaction results in self-organization and emergent behaviors, which are the patterns which cannot be predicted or controlled(Haken and Portugali, 2021). Hence, urban planning is rethought in terms of flexibility as opposed to static planning, where cities are learning, experimenting, and evolving through experience (Janković, 2024). Diversity, decentralization and redundancy are three key characteristics of urban systems that survive shocks and successfully adapt to change, thus determining the resilience of an urban community (Abujder Ochoa *et al.*, 2025).

Thus, CAS paints the city as a dynamic system that not only continues to change, but also evolves due to its change. This view is based on behavioral understanding, which fosters adaptive functions in the dual-urban model.

2.5. Network Theory and Urban Connectivity

Network theory is an approach to the study of the complexity of cities in terms of nodes (such as buildings, intersections, and public spaces) and links (including streets, pathways, and digital infrastructures). The resilience and effectiveness of the urban fabric is determined by the configuration and network of these elements (Batty, 2013). Empirical Space Syntax studies have shown that the more the axial lines are connected, the stronger the movement flows and the greater the social interactions that occur, and it leads to greater functional integration (Hillier, 2007). Urban synergy in this sense is achieved

by strong ties that promote interdependence and integration among a variety of urban functions (Meijers, 2007).

Network redundancy (the availability of multiple different paths and redundant connections) increases antifragility by minimizing the fragility of the system that depends on it. As a result, the system is up and running even when a failure occurs (Curci and Chiffi, 2024). According to Ding (2019), in these systems, such complex networks of land-use and transportation systems characteristics allow flows to be adaptable to shocks. Moreover, urban networks may transform themselves, develop in the uncertain conditions, due to their diversification, modularity, and scalability (Batty, 2013). These spatial properties are not only beneficial to the resilience of the system, but also, they aid in performance of the system in times of crisis.

In that way, network theory allows us to apply the principles of synergy and antifragility to urban form. See (Figure 1).

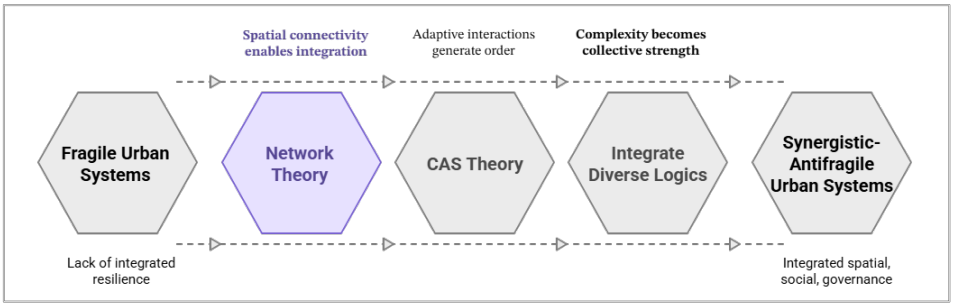


Figure 1. Conceptual Framework for the Transformation of Urban Systems from Fragility to Synergy and Antifragility through Network and Complex Adaptive Systems Theories.

2.6. The Dual Urban Model: Six Interdependent Dimensions

Synergistic-Antifragile Urban Model is a product of the two theoretical approaches related to the Complex Adaptive Systems (CAS) and Network Theory. CAS depicts cities as self-organizing, feedback, and learning systems - in which the city becomes vibrant through diversity and decentralization. Network theory, in its turn, proves the functions of the spatial connectivity, redundancy, and integration to increase the functional efficiency and adaptive capacity. When combined together, they make resilience a passive, endurance-based strategy into an active metamorphosis, in this context, the regenerative seeds of resilience can be exemplified by the provocative statement of Jane Jacobs (1961) that "lively, diverse, intense cities contain the seeds of their regeneration" (Jane Jacobs, 1961).

Based on this premise, the model looks beyond mere description to advocate a code of practice for cities that is both systematic and prospective. An urban-synergy-antifragility model, the present model combines urban synergy (which is a kind of capacity of interdependent systems to realize collective effects surpassing individual action) with antifragility, i.e., the capability to get stronger through disorder(Taleb, 2012) (Blečić and Cecchini, 2017). This " double logic" recasts the city, no longer as a formed body of single planning actions and one-time made, but rather as a processual hybrid: an active synthesis of institutional planning imposed from above and spontaneous self-organization that has developed through cumulative processes of growth and adaptation (Boeing, 2019).

The paper defines the Synergistic-Antifragile Urban Model (SAF-M) as: The model is a systemic urban model based on six mutually reinforcing dimensions that act and interact to produce collective added value (synergy) and transform shocks into opportunities for growth (antifragility): interactive-structural, dynamic-functional, transformative-social, inclusive-environmental, participatory-institutional, and enabling-digital. Based on the concepts of complexity and networks, it operationalizes urban resilience as a dynamic, measurable, and designable process produced through the assembly of top-down governance with bottom-up innovation.

This framework shifts urban design from passive adaptation to **intentionally structuring environments** that thrive on uncertainty. The model is articulated through six interdependent dimensions:

2.6.1. Interactive-Structural Dimension

This Dimension looks at the interconnection of the streets, the buildings, and the public spaces in urban environment, with a view to making access and redundancy possible. It states the spatial rules of network theory which indicate that the robustness of the urban environment is associated with the density and coherence of nodes and links (Xiao et al., 2018). Such robustness forms an important feature of

antifragile systems, which enables the rerouting of the urban network in case of failures while retaining the functionality of the system (Batty, 2013). This feature also occurs when attaching new urban forms to existing spatial patterns and blends in with the old forms without remove them, which ultimately boosts connectivity and spatial identity (Hussein et al., 2019). This dimension is the spatial basis of the dual model which supports synergy through integration, and antifragility through structural redundancy.

2.6.2. Dynamic-Functional Dimension

Dimension assesses the ability of a city to adopt forms that are mixed - use and flexible - able to meet evolving needs. Functional diversity has the benefit of reducing vulnerability by spreading out activities across many nodes and consequently producing resilience in case of emergencies (Moreno *et al.*, 2021). The multifunctional character of cities as well as the provisionality of urban spaces (public halls become shelters) depict the incredible flexibility of towns, which is one of the main characteristics of antifragile cities (Blečić and Cecchini, 2017). This dimension, therefore, captures the transformation of urban systems from rigidity to variability through the changeable activities.

2.6.3. Transformative–Social Dimension

This dimension is around the self-organization of communities and how they influence changes in the cities through collective action and social innovation. It emphasizes the shift from top-down approach of governance to bottom-up, community-based systems that build social capital and alter the way that cities see themselves (Al-Hussaini and Al-Ahbabi, 2020). In emergencies, simple community efforts like: clean-ups, or mutual aid networks, can inspire wider social transformations. Thus, the social dimension represents an important point for achieving the concept of the “right to the city” within the urban space (Hinthel, Hussein, and Aldabbagh, 2020).

2.6.4. Inclusive–Environmental Dimension

This realm deals with the capacity of cities to blend with ecological systems, such as green spaces, sustainable water management and use of renewable energy. Green infrastructure forms the role of "urban acupuncture", requiring minimal input, yet creating tremendous benefits and benefits (Salman and Hussein, 2021). Some paradigmatic examples are community gardens, green roofs and multi-functional parks such as Houtan Park in Shanghai, which integrates stormwater management with recreational activities (Yamagata and Sharifi, 2018). Baghdad parks contribute significantly to the identity of the citizens and have environment health implications (Jameel and Hussien, 2023). This dimension guarantees that ecological benefits are comprehensive and participatory in line with the premise that diversity and material interdependencies are aimed at building resilience (Sonar, 2021).

2.6.5. Participatory–Institutional Dimension

This dimension measures citizen participation in urban governance, which reflects the transition from the process of governing by authority to participatory. Participatory planning, transparency and feedback loops are some of the mechanisms through which institutions can learn and adapt (Healey, 1997). In post-war Iraq, Local collaboration among public authorities in managing the uses of the city has created trust and an identity among urban communities (Abdulla and Hussein, 2022). In Mosul, local knowledge has played a vital role in deciding the long-term rebuild of the area, and the local knowledge has been detailed. Tactical urbanism in Baghdad points out that small-scale, local changes can be one step towards achieving democracy in cities (Hinthel et al., 2020). This dimension is not only procedural but strategic as well, with informal knowledge being used in formal planning for social and spatial justice (Hameed et al., 2020).

2.6.6. Enabling–Digital Dimension

This is a dimension characterized by the deployment of digital systems (smart mobility, digital participation channels, real-time information, Internet of Things, etc.) that will likely enhance urban services and responsiveness. For example, real-time data can deliver instant feedback loops which are required for the "learning from shocks" mechanism, which is a main principle in antifragility (Karavaeva, 2024). It has been stated that a flexible management of energy, water, and traffic practices can be achieved in a tractable manner using digital tools like digital twins, therefore making systems more efficient (Salman and Hussein, 2021). In order to use the concept of digitalization when it comes to planning, in interpolating it is more convenient for institutions to work together and make changes (Romero *et al.*, 2022). This aspect goes further than mere technical aspects; it is a paradigmatic system that changes the interaction between people and urban systems.

2.7. Synergistic–Antifragile Urban Model Mechanisms

While the preceding sections have laid the theoretical groundwork for the Synergistic-Antifragile Urban Model, this section is about how the model works in practice--what are the levers that can be used to bring synergy and antifragility to the urban realm. Integration, cooperation and effective interaction are not just abstract ideas; they are concrete processes that influence the development of urban morphology and the interaction of the top-down planning and bottom-up self-organization (Zuziak, 2017). From the point of view of Complex Adaptive Systems (CAS), cities are dynamic hybrids where material structures and human agency coevolve through a constant interaction (Haken and Portugali, 2021). Within this framework, the three mechanisms act as are the levers that can be used to bring synergy and antifragility to the urban realm.

2.7.1. Integration

Integration is that process through which the various urban systems are formed into unified, synergistic systems. It does this by combining the spatial, functional and institutional characteristics of urban components (e.g. streets, buildings, services and forms of governance) into a coherent and resilient system. Morphologically, integration is in the form of networks of interconnected units, mixed land use, and redundant pathways to ensure continued functioning in the event of a single element's failure (Xiao et al., 2018). Such structural (functional) interdependence makes a system more efficient (able to disperse resources and reduce loading). This results in the system being able to be adaptive and absorb perturbations without systemic failure due to an interaction between functions. This is the case of, for example, the "15-Minute City" plan in Paris, among others, which integrates housing, services and mobility into an interconnected urban fabric. This spatial integration has also resulted in the decrease of car dependence and the increase of quality of life, as well as the efficient use of land (Moreno *et al.*, 2021) (Salih and Hussein, 2021), demonstrating how integration makes urban form a synergy factor and a resilience factor.

2.7.2. Cooperation

Synergy is activated by the same mechanism of cooperation that allocates decision-making power among different urban actors: citizens, institutions, private organizations, and community organizations. It moves urban governance away from centralized control, to participatory frameworks that value local knowledge and collective action. An example of this mechanism is the case of Medellin, where the "social urbanism" approach combines urban design and community involvement in the development of marginal neighborhoods. The most significant urban interventions that were implemented to develop the neighborhood are the installation of Libraries, cable cars, and green corridors, with the objective of improving social connectivity and ecological resilience(Franz, 2017) (Honey-Rosés *et al.*, 2020) (Quinn Coray, 2020). Similarly, the La Mina Neighborhood Development Plan in Barcelona shows how collective action of stakeholders can help to align efforts and better allocation of resources to regenerate the urban fabric and the social fabric (Ulied *et al.*, 2019).These cases provide a that cooperation is an enabler process for creating inclusive and adaptive cities.

2.7.3. Effective Interaction

Effective interaction means that there exists a dynamic balancing of top-down planning and bottom-up emergence. This allows cities to evolve continuously by combining institutional arrangements with bottom-up projects through responsive governance and feedback loops in real time (Rauws, Cozzolino and Moroni, 2020). Morphologically, this mechanism is manifested in the following way: Public space with multi-functional uses (e.g. spaces that can be used as markets or as hubs in emergency situations), Smart infrastructure based on digital platforms for adaptive management, Redundant networks provide functionality even when disrupted (Batty, 2011). For example, the Smart Nation in Singapore uses real-time data to improve services for the city, and the water plazas in Rotterdam are urban areas that are used as recreation spaces in times of dry weather and as basins during periods of heavy rainfall (Jiang, Geertman, 2022) (Pickett et al, 2004). These interventions are examples of cities moving beyond the concept of resilience to antifragile: getting better through stress. The Synergistic-Antifragile Urban Model is operationalized by three fundamental mechanisms. See (Table 1).

Table 1. Interaction Between Mechanisms and Model Dimensions.

Mechanism	Activated Dimensions	Role in The Model
Integration	(Interactive–Structural) (Dynamic–Functional)	Establishes spatial and functional coherence, enabling system continuity and adaptive reuse

		through interconnected networks and mixed-use development.
Cooperation	(Transformative–Social) (Participatory–Institutional)	Fosters social capital, community ownership, and inclusive governance by distributing agency and integrating local knowledge into formal planning.
Effective Interaction	(Inclusive–Environmental) (Enabling–Digital)	Balances design and emergence through adaptive infrastructure and digital responsiveness, allowing cities to learn from and improve through disorder (antifragility).

* Each mechanism activates a pair of interdependent dimensions, demonstrating how integration, cooperation, and effective interaction operationalize the dual model in the urban fabric

2.8. Indicator Matrix for the Dual Model

This research lays the theoretical basis of the dual urban model. It suggests a model for cities that can be shock resilient and resilient to uncertainty. The model is operationalized using six dimensions which draw on Network Theory and Complex Adaptive Systems (CAS). These dimensions do not stand alone, but are interdependent dimensions, which work together, to allow urban systems to generate added value (synergy) and become stronger in the face of disorder (antifragility). See (Table 2).

Evaluation item is classified under one of two outcomes—Synergy or Antifragility—based on its dominant effect. Synergy indicators are those that evaluate processes wherein the interaction/integration of urban elements creates more value than the simply aggregative contributions of elements—such as functional connectivity, mixed-use vitality and social cohesion resulting from spatial integration. Antifragility—If the indicators measure the capacity of the system to thrive under stress; redundancy: an insurance against failure, flexibility: an ability to adapt quickly, decentralization: a distribution of risks, and learning: a system that converts disturbances to development potential. While these two constructs are interdependent such that synergy provides the integrative substrate from which antifragility can arise, these are also differentiated indicators assigned based upon the perceived preponderance of their theoretical effect, as delineated by Taleb (2012) and Complex Adaptive Systems literature.

Table 2. Indicators for Measuring the Synergistic–Antifragile Urban Model.

Dimension	Sub-indicator	Evaluation Item	Primary Outcome	Theoretical Basis: (NT) & CAS	Codin g
Interactive–Structural Dimension	Connectivity and Network Redundancy	Redundancy prevents systemic failure.	Antifragility	NT	Q1
		System continuity under stress.	Antifragility	CAS	Q2
		Integration enhances collective performance.	Synergy	NT	Q3
	Permeability and Spatial Adaptability	Functional flexibility enables rapid adaptation.	Antifragility	CAS	Q4
		Multifunctionality generates added value.	Synergy	NT	Q5
		Spatial permeability enhances resilience.	Antifragility	NT + CAS:	Q6
	Polycentricity and Decentralization	Reduces dependency on a single node.	Antifragility	NT	Q7
		Risk distribution enhances robustness.	Antifragility	CAS	Q8

Dynamic–Functional Dimension	Mixed-Use and Functional Diversity	Networked centers enhance systemic integration.	Synergy	NT	Q9
		Functional integration generates urban vitality.	Synergy	CAS	Q10
		Interaction between uses creates value.	Synergy	NT	Q11
		Spatial efficiency strengthens connectivity.	Synergy	NT	Q12
	Functional Flexibility and Exchange	Rapid adaptation to changing needs.	Antifragility	CAS	Q13
		Functional exchange improves responsiveness.	Antifragility	CAS + NT	Q14
		Learning from disruption through reconfiguration.	Antifragility	CAS	Q15
Transformative–Social Dimension	Community Initiatives and Self-Organization	Self-organization as an adaptive response.	Antifragility	CAS	Q16
		The integration of community agencies enhances collective action.	Synergy	CAS	Q17
		Bottom-up emergence strengthens resilience.	Antifragility	CAS	Q18
	Social Bonds and Integration	Social interaction generates collective capital.	Synergy	CAS	Q19
		Integration fosters social cohesion.	Synergy	CAS	Q20
		Shared identity strengthens urban synergy.	Synergy	CAS	Q21
Inclusive–Environmental Dimension	Green and Blue Infrastructure	Integration of nature enhances multifunctionality.	Synergy	NT.	Q22
		Adaptive response to environmental stress.	Antifragility	CAS	Q23
		Environment as a catalyst for social integration.	Synergy	CAS + NT.	Q24
Participatory–Institutional Dimension	Decentralization and Participatory Decision-Making	Distributed decision-making enhances adaptability.	Antifragility	CAS	Q25

		Institutional responsiveness to local needs.	Antifragility	CAS	Q26
		Decentralization reduces institutional fragility.	Antifragility	CAS + NT.	Q27
Enabling–Digital Dimension	Use of Data and Digital Platforms	Real-time interaction enables rapid adaptation.	Antifragility	CAS	Q28
		Learning from data improves system performance.	Antifragility	CAS	Q29
		Technology enables integration between citizens and institutions.	Synergy	CAS + NT	Q30

Some indicators are grounded in both (NT) and (CAS), as these frameworks are complementary: NT explains the structural connectivity of urban elements, while CAS explains the dynamic, adaptive behaviors of urban agents. However, each evaluation item is classified under one of two outcomes—Synergy or Antifragility—based on its dominant effect.

3. Research Methodology and Case Study

3.1. Research Approach and Design

The study takes the Bab al-Sharqi area in Baghdad and its approaches, Tahrir Square and Al-Ummah Park, as a case study for the effectiveness of the proposed dual model in the theoretical framework of the research to assess the extent to which the region's urban performance aligns with the concepts of synergy and antifragility. This study uses a convergent, mixed-method approach combining quantitative survey data with systematic field observation and spatial analysis to triangulate findings and embed expert perceptions within the visible urban realities of the site. Data were collected by means of a digital survey using Google Forms which is a questionnaire designed based on the six-dimensional framework developed in the theoretical model. The form assesses six major dimensions:

1. Interactive–Structural Dimension;
2. Dynamic–Functional Dimension;
3. Transformative–Social Dimension;
4. Inclusive–Environmental Dimension;
5. Participatory–Institutional Dimension;
6. Enabling–Digital Dimension.

Each dimension is measured by a set of indicators and evaluation items, adopting a scale of 5 levels (from "Weak" to "Excellent", coded numerically on a 5-point Likert scale from 1 to 5) to measure expert perceptions.

This work takes the form of exploratory research on an emerging urban typology. Its six dimensions evaluate the observed performance of the study area against the expert opinions. The model represents a complex of concepts that need the specialized knowledge of an expert community to ensure the technical reliability of the evaluation and for this reason, our research design utilized a targeted sample of experts. The method is in line with standard practice in exploratory urban studies that aim to deeply explore and initially test the tenets of theoretical frameworks before undertaking wider validation(Tousi and Pancholi, 2025) (Naji, 2025) (Yamagata & Sharifi, 2018).The research sample is made up of 46 participants who were selected in a purposive sampling manner. The sample consists of academic researchers (faculty members) and graduate students in the field of urban planning and architecture, in addition to urban specialists who have practical experience in the field of development in Baghdad. All participants are frequent users of Tahrir square and Al-Umma Park and use these places for commuting, or visits. The questionnaire was posted on social media for academic and professional networks, and 46 responses were received initially. Out of these 41 completed surveys were included in the study. and Before taking part, Informed consent was obtained from all participants and they were given:

1. A brief explanation of the research objectives.

2. Visual materials, including AutoCAD maps and on-site photographs of Tahrir Square and Al-Umma Park;
3. The evaluation form has clear definitions of each dimension.

The survey was available for four weeks, and prompts had been sent out for a reminder in order to get more responses. This study was conducted in accordance with the ethical guidelines of the College of Engineering, Al-Nahrain University, which do not require formal ethical approval for this type of research, as the research does not contain sensitive personal information and was conducted with the voluntary and informed consent of the participants.

Data analysis was performed using SPSS 26 and Microsoft Excel. Instrument reliability was assessed via Cronbach's Alpha. As indicators and dimensions were used to evaluate the site performance, descriptive statistics were computed for each indicator and dimension. The nature of inferential statistics was utilized to test sample homogeneity, review inter-dimensional relationships and test the central hypothesis. Relative weights were achieved with Microsoft Excel and performance levels calculated by the interpretation ranges of the Likert scale. The results were triangulated through the combination of systematic field observation with quantitative survey data.

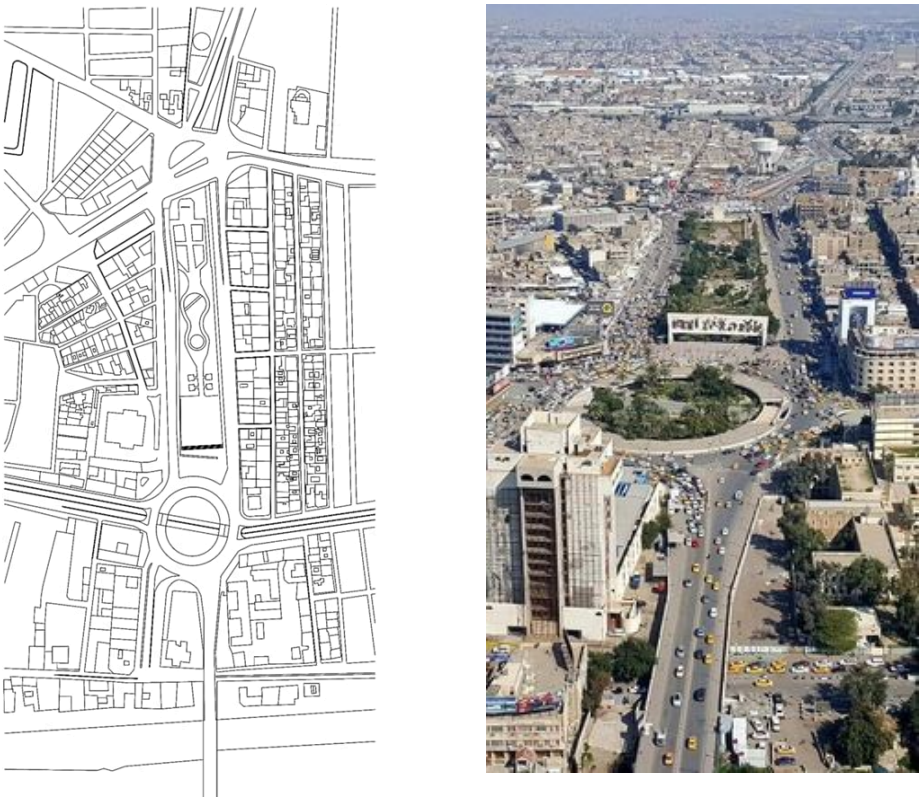
3.2. Case Study: Tahrir Square and Al-Umma Park in Baghdad

Tahrir Square and Al-Umma Park are an important public space in the middle of Baghdad, with an area of about 24,830 square meters. Found in the al-Bab al-Sharqi neighborhood, this site is of historical importance as a symbol of national liberation and civic participation. It has been the site for important political events, such as revolutions, protests, and public assemblies, further solidifying its place as a site of collective memory and democratic voice (Jameel and Hussien, 2023).

Al-Umma Park is a spatial and symbolic buffer between traditional urban fabric of the city and Al-Batawin modern distract. After the July 14, 1958, revolution, the area was redeveloped and renamed Al-Umma Park (the Park was founded in 1937 and its previous name was King Ghazi Park). The park was substantially improved, with larger green areas, fountains and the addition of some distinctive pieces of public art (Al-Saffar, 2024). These include: See (Figure 2) See (Figure 3).

- **The Freedom Monument**: by Jawad Salim, featuring 14 bronze reliefs that symbolize the July 14 Revolution and Iraq's historical narrative from ancient civilizations (Sumerian, Babylonian, Assyrian) to modern liberation, and
- **The Mural of the People**: created by Faiq Hassan in 1960, is a 10 m × 4 m mosaic depicting the unity among Iraqis—soldiers, workers, peasants, women, and children—releasing doves of peace,
- **The Motherhood Statue**, by Khaled Al-Rahal (1961), is a 4.5-metre stone sculpture that symbolizes hope and the future.

The site is surrounded by a vibrant network of markets, cinemas, cafes, and restaurants, contributing to its ongoing social vitality and urban appeal.



(**a**) (**b**)

Figure 2. Urban Context of Tahrir Square and Al-Umma Park in Baghdad: (a) AutoCAD Site Plan (Source: First author, drawn using AutoCAD 2024) and (b) Aerial View (Source: Tamayuz Award website).

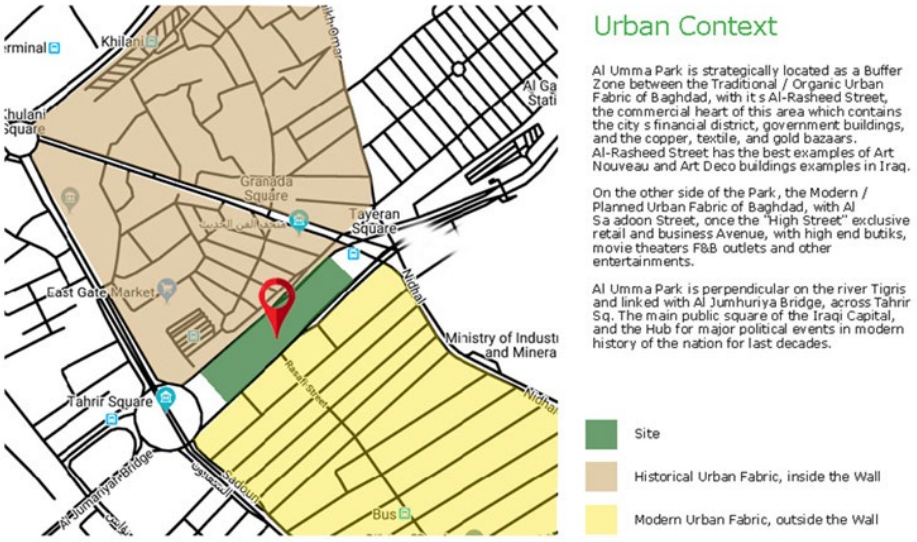


Figure 3. Urban Context of Al-Umma Park and Tahrir Square: A Strategic Interface Between Traditional and Modern Baghdad (Source: Tamayuz Award website).

4. Results

4.1. Response Rate and Demographic Profile

Of the 46 questionnaires sent, 41 were returned completed giving a response rate of 89.1%. All

respondents are professionals who have first-hand knowledge in the concerned discipline. The sample has a high academic level, with 53.7% having a Master's degree, 26.8% having a Ph.D., and 19.5% having a Bachelor's degree. Architects dominate at 34.1% followed by urban designers at 36.6%. Urban planning, however, is only 4.9% while the other related fields make up 24.4%. See (Figure 4). Moreover, all participants highlighted the frequent utilization of Tahrir Square and Al-Umma Park and thus integrated professional background with lived experiences of the study setting.

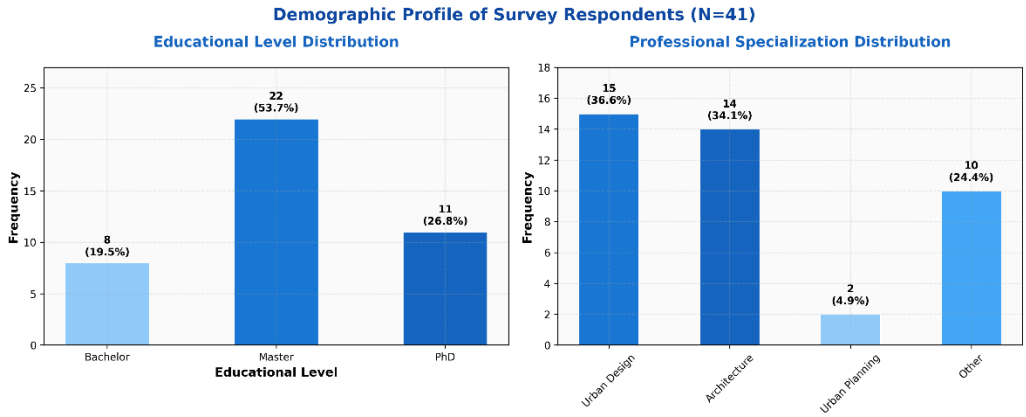


Figure 4. Demographic Profile of Respondents (Educational Level and Specialization).

4.2. Instrument Reliability

Cronbach's Alpha coefficient was used to assess internal consistency of the questionnaire. The reliability values for all dimensions varied between 0.77 and 0.83 with an overall coefficient of 0.80. Well established thresholds indicate values above 0.70 indicate acceptable reliability, which confirms that the instrument has good internal consistency and can be used for data collection. See (Table 3)

4.3. Descriptive statistical analysis of Model Dimensions

Six dimensions of the Synergistic-Antifragile Model were used to evaluate the performance of the study area. Table 3 displays means, standard deviations, and performance level means for the full set of dimensions, indicators, and evaluation items, with scoring based on five-point Likert scale values of Week (1.00–1.79), Moderate (1.80–2.59), Good (2.60–3.39), Very Good (3.40–4.19), and Excellent (4.20–5.00). See (Figure 5)

Figure 5. Radar Chart: Performance Across the Six Dimensions.

Table 3. Comprehensive Descriptive Statistics for All Model Dimensions.

Dimension/ Sub-indicator	Coding	Mean	St. deviation	Weight	Performance	(N)of Indicator	Cronbach's Alpha
Interactive–Structural		**2.73**	**0.51**	**54.74**	Good	9	**0.82**
Connectivity and Network Redundancy		**2.69**	0.73	-	Good		
	Q1	2.85	0.79	-	Good		
	Q2	2.53	0.92	-	Moderate		
	Q3	2.70	1.03	-	Good		
Permeability and Spatial Adaptability		2.87	0.79	-	Good		
	Q4	3.04	1.09	-	Good		
	Q5	2.97	1.01	-	Good		
	Q6	2.60	0.83	-	Good		
Polycentricity and Decentralization		2.63	0.62	-	Good		
	Q7	2.53	0.86	-	Moderate		
	Q8	2.51	0.77	-	Moderate		
	Q9	2.85	0.88	-	Good		
Dynamic–Functional		**2.90**	**0.71**	**58.05**	Good	6	**0.80**
Mixed-Use and Functional Diversity		2.82	0.78	-	Good		
	Q10	2.87	1.07	-	Good		
	Q11	2.90	0.83	-	Good		
	Q12	2.68	0.84	-	Good		
Functional Flexibility and Exchange		2.98	0.88	-	Good		
	Q13	2.70	1.00	-	Good		
	Q14	3.19	1.03	-	Good		
	Q15	3.04	0.92	-	Good		
Transformative–Social		**2.63**	**0.84**	**52.68**	Good	6	**0.78**
Community Initiatives and Self-Organization		2.15	0.95		Moderate		
	Q16	2.24	1.24		Moderate		
	Q17	1.82	0.97		Moderate		
	Q18	2.39	1.06		Moderate		
Social Bonds and Integration		3.11	0.98		Good		
	Q19	3.21	1.10		Good		
	Q20	3.09	0.96		Good		
	Q21	3.02	1.23		Good		
Inclusive-Environmental		**2.02**	**0.82**	**40.49**	Moderate	3	**0.77**
	Q22	2.09	1.11		Moderate		
	Q23	1.46	0.74		Weak		
	Q24	2.51	1.14		Moderate		
Participatory–Institutional		**1.49**	**0.68**	**29.92**	Weak	3	**0.83**
	Q25	1.36	0.79		Weak		
	Q26	1.56	0.74		Weak		
	Q27	1.56	0.97		Weak		
Enabling–Digital		**1.60**	**0.86**	**32.03**	Weak	3	**0.81**
	Q28	1.65	1.01		Weak		
	Q29	1.58	1.02		Weak		
	Q30	1.56	1.00		Weak		
Total		**2.23**	**0.50**		Moderate	30	**0.80**

Source: Author's calculation using SPSS v.26 and Excel, 2025.

Findings indicate a clear tiered ordering in dimensional performance, with the overall model mean of 2.23 (SD = 0.50) positioning the region at a "Moderate" level well below the neutral benchmark of 3.0. Mean scores were also notably higher for the Dynamic-Functional Dimension (M = 2.90, SD = 0.71), reflecting comparative strength in functional richness and functional identity, and capability to adapt

(functional redundancy) (maximum score on any individual item for the entire instrument: M = 3.11 for public space multifunctionality). The second dimension, the Interactive-Structural Dimension, indicated moderate spatial connectivity (M = 2.73, SD = 0.51) while polycentricity indicators scored lower (M = 2.63, SD = 0.62) indicating continued dependence on centralized urban nodes. Transformative-Social Dimension (M=2.63, SD=0.84) showed strong internal variability: indicators of social interactions scored high (e.g., social encounters at M=3.11), while participatory self-organization(Q17) scored low (M=1.82 for resident contribution to decisions), indicating a large distance between informal social capital and formal community agency. The Inclusive-Environmental Dimension (M = 2.02, SD = 0.82) was classified as " Moderate" and climate risk mitigation through green infrastructure obtained(Q23) was the lowest-rated item (M = 1.46) for all items. The Participatory-Institutional Dimension had the lowest overall dimensional mean (M = 1.49, SD = 0.68), where resident involvement in formal planning received the lowest score at 1.36, indicating almost no participatory governance presence. In terms of the Enabling-Digital Dimension (M = 1.60, SD = 0.86), there is virtually no digital infrastructure that undergirds urban management or citizen engagement. See (Figure 6)

4.4. Sample Homogeneity Analysis

In order to ensure that the descriptive results shown above had not been affected systematically by the characteristics of the respondents, One-Way ANOVA was performed across groups of specialisation and educational level (Table 4).

Table 4. ANOVA Results for Effects of Specialization and Educational Level on Total Evaluation.

Variable	Source	Sum of Squares	df	Mean Square	F	Sig.
Specialization	Between Groups	1.245	3	0.415	1.892	0.149
	Within Groups	7.876	37	0.213		
Educational Level	Between Groups	0.842	2	0.421	1.801	0.179
	Within Groups	8.279	38	0.218		

Source: Author's calculation using SPSS v.26 and Excel, 2025.

The significance value for the effect of specialization (Sig. = 0.149) was above the conventional threshold of α = 0.05, suggesting that the four groups (Urban Design, Urban Planning, Architecture, Other) did There are no statistically significant differences in the total evaluation of the study variables among the different specializations. The significance value (Sig. = 0.179) for educational level was also larger than 0.05, indicating no significant differences among the statistically differences between the bachelor's, master's, and doctoral degree holders. Such findings indicate that perceptions of the profession are consistent regardless of educational background or field of expertise. Absence of statistically significant differences strengthens the credibility of these results because it suggests that reported evaluations reflect a professional consensus regarding the study area performance rather than systematic variation by respondent background.

4.5. Inter-Dimensional Correlation Analysis

To examine the structural relationships between the six dimensions, the Pearson correlation coefficients were calculated (Table 5). The analysis aimed to assess whether the dimensions function as a meta-system corresponding to the theoretical model.

Table 5. Pearson Correlation Matrix Among Model Dimensions.

Dimension	Str	Fun	Soc	Env	Inst	Dig
Structural	1.00					
Functional	0.72**	1.00				
Social	0.65**	0.68**	1.00			
Environmental	0.58**	0.61**	0.55**	1.00		
Institutional	0.42**	0.45**	0.50**	0.48**	1.00	
Digital	0.35*	0.38*	0.40**	0.42**	0.60**	1.00

Note: ** $p < 0.01$; * $p < 0.05$.

As the correlation analysis illustrates, there are two distinct clusters of dimensions, supporting the integrative logic of the theoretical framework. The first dimension consists of Structural, Functional, and Social dimensions. These dimensions are highly intercorrelated (r = 0.65–0.72) and comprise the

essential physical-social system that governs everyday urban life. As expected, the Structural and Functional dimensions are the most strongly correlated (r=0.72, $p < 0.01$), indicating that spatial connectivity directly underpins functional diversity and adaptability. The second group is Environmental, Institutional, and Digital and dimensions are relatively inter-correlated (r = 0.42–0.60) to the second group. Such are the groundwork that supports the primary fabric of the city. Institutional and Digital dimensions are particularly correlated with each other (r = 0.60, $p < 0.01$), which infers that these are governance systems that need to be triggered simultaneously.

4.6. Hypothesis Testing

Our narrative undergirding the model is that cities can transition from fragility to antifragility through comprehensive activation of all dimensions of the dual urban model. To confirm this hypothesis, multiple regression analysis was used to evaluate the combined predictive power of the six dimensions, and then one-sample t-test was performed to examine if dimensional performance significantly differs from the neutral line. See (Table 6).

Table 6. Hypothesis Testing: Regression Analysis and One-Sample T-Tests.

Panel A: Regression Model Summary					
R	**R^2**	**Adjusted R^2**	**Std. Error**	**F**	**Sig.**
.861	0.741	0.698	0.301	17.215	<0.001
Panel B: One-Sample T-Test Against Neutral Point (Test Value = 3.0)					
Dimension	**Mean**	**t**	**Sig.**	**Result**	
Interactive-Structural	2.74	−3.242	0.002	Significantly below	
Dynamic-Functional	2.90	−0.868	0.391	Not significant	
Transformative-Social	2.63	−2.783	0.008	Significantly below	
Inclusive-Environmental	2.02	−7.607	<0.001	Significantly below	
Participatory-Institutional	1.50	−14.005	<0.001	Significantly below	
Enabling-Digital	1.60	−10.293	<0.001	Significantly below	
Overall Model	**2.23**	**−9.742**	**<0.001**	**Significantly below**	

With an $R^2 = 0.741$, the six dimensions of the dimensional framework explain 74.1% of variance in an overall evaluation of urban performance (F= 17.215, Sig.= < 0.001), confirming the strong explanatory power that the dimensional framework holds. Results of the one-sample t-tests reveal that the overall mean (M = 2.23) is significantly below neutral (t= -9.742, Sig.= < 0.001), with five of six dimensions significantly below threshold; only the Dynamic-Functional dimension nears adequate performance without significant deviation from neutral. The data have lent credence to the overarching hypothesis: the study area exists in a condition of urban fragility; the lack of full dimensional activation, most importantly the insufficient institutional and digital dimension, inhibits a proper move toward antifragility.

4.7. Contextual Assessment Through Field Observation

In order to triangulate the quantitative findings obtained from the questionnaire survey, systematic field observation was undertaken in order to evaluate the six dimensions of the Synergistic-Antifragile Model in relation to the study area. The observation scale included several visits to the site, photo documentation, and classification of land use. Figure Past presents the current land-use of the subject grant, with photographic documentation of the condition found within (Figure 6).

Interactive-Structural Dimension. Ground survey results showed that the Bab al-Sharqi district is organized by a multi-connected street layout of the primary arterials (Al-Rasheed, Al-Saadoun, and Al-Khulafa Streets) and secondary connections with moderate spatial diversity. Observations, however, identified acute road traffic jams (morning 0800-1000) and afternoon 1100AM – 200 PM) due to lack of smarter mode of transport management. Field observation confirmed that the signals in the study area are not artificially controlled or adaptive-controlled. A great car dependence was also noted where public transport does not exist as an option; even though an underground metro system has been planned, there are currently no functional bus networks or facilities for mass transit in place for the area.

Figure 6. Land use map of the site with photographs illustrating the rich details of the site (prepared by the researcher based on the field survey).

Dynamic-Functional Dimension. Spatial analysis and land-use recording (Figure 6) found a marked degree of mixed use in the district. Commercial mixed with residential on upper floors, religious (Al-Waziriya Mosque), educational (Al-Aqida School) and cultural landmarks such as the Museum of Modern Art and Armenian church were found to express some 62% of building ground-floor frontages. Field visits to the Bab al-Sharqi markets illustrated lively scenes of informal commercial activity involving a range of traders hawking electronics, textiles, second-hand clothing and accessories, cameras, books. The functional diversity observed supports the relatively high evaluation scores of this comparative element. However, it was observed that untitled sector activities, which are economically important have no control system so as to provide maximum returns without floor space encroachment on pedestrian movement at present.

Transformative-Social Dimension. An ironic twist was discovered from observational assessment related to local social dynamics of the site. Signs of the area's historical role as a venue for collective action were recorded, most prominently in remnants of the October 2019 protests based on Tahrir Square (Figure 7). Continuing social activity in the public areas was corroborated by observations made during several site visits. However, systematic observation across multiple visits showed little in the way of resident-initiated activities related to maintenance and improvement or advocacy independent of institutional instigation. This result further supports the survey result reporting low formal self-organization means but high informal social capital.

(**a**) (**b**)

Figure 7. Urban Context (a) A photo illustrating the tactical, community-based practices of pop art on the walls of Tahrir Tunnel following the October Revolution. and (b) The photo shows the Nation's Park empty of people during the day due to the lack of shading. (Source: First author).

Inclusive-Environmental Dimension. Environmental assessment determined that there were valuable ecological assets, such as the Tigris River (west border) and the refurbished Al-Umma Park (rehabilitation finished 2022), as can be observed in (Figure 7-b). However, site visit to the Al-Umma Park exposed a major flaw in the design; insufficient shade was designed for the park even though Baghdad experiences extremely hot temperatures reaching over 50°C which render it almost unusable during daylight hours. The spatial analysis proved that the present and available green spaces are fragmented pieces and neither connected within ecological corridors nor combined with storm water. This is a lost opportunity of rainwater harvesting in a drought-stricken region. The ratio of open space: built-up area (60:40) Which was calculated through documentation of field survey maps of the block and void areas of the site backs up a large ecological underperforming spatial potential.

Participatory-Institutional and Enabling-Digital Dimensions. Institutional analysis-which involved reviewing of documents and consulting with key actors, based on published work-showed that municipal decision-making is characterized by a highly centralized, top-down governance system. It was reported that the redevelopment of Al-Umma Park, implemented by Baghdad Municipality in partnership with a contractor based in Dubai, had occurred without any systematic communication with communities or participatory design sessions and due process of community contributions. Investigation revealed that there are no platforms at a local or national level that can facilitate collaborative decision-making, the integration of citizen feedback or open communications between residents and city institutions. Digital infrastructure analysis corroborated the almost complete lack of technology-enabled urban management: traffic signals run without intelligence, urban services are devoid of data driven optimization, and there is no digital interface between citizens and governance. This institutional-digital vacuum, supported by survey data and field observation, represents the main structural obstacle for the site in heading towards full antifragility (Blečić and Cecchini, 2017), because it prevents feedback loops and adaptive governance mechanisms needed for system's learning from disruption to happen.

Synthesis. The ongoing triangulation of survey evidence with systematic field observation solidifies the validity of research results. Both sources of data consistently evidence that the study region is characterized by activated structural-functional-social dimensions, which generate moderate synergic effects, but environmental capacity results underused and institutional-digital ones critically deactivated. The site consequently presents prodromal preconditions for urban synergy, having failed to attain systemic integration or loops of feedback that are necessary for antifragile urban performance.

5. Discussion

5.1. Interpretation of Findings

The performance mapping of the Bab al-Sharqi district as per Synergistic-Antifragile Model returned a hierarchical order of dimensional performance with an overall mean of 2.23 placing considerably lower than the neutral threshold value. Here, these findings are interpreted with respect to local site conditions and the relevant literature.

The ability of Dynamic-Functional dimension to maintain relatively strong position is mainly due to the historical nature of Bab al-Sharqi as a commercial and cultural center of Baghdad. The field observations of the mixed-use nature, both previous and current, of the built form, illustrating the integration of commercial, residential, religious and cultural functions, speak to decades of organic urban

development prior to formal planning encroachments. The vibrancy of the informal markets demonstrate a type of bottom up economic adaptive capacity that produces synergistic vitality consistent with theoretical postulations by (Batty, 2013) and (Moreno et al., 2021). given the link with functional diversity and systemic redundancy. The apparent correlation of the Structural and Functional dimensions ($r = 0.72$) supports these scholars' claims of the interrelationship of urban morphology and functional performance empirically.

Strong, Moderate performance of the Interactive-Structural dimension reflects district street network legacy, multiple primary arterials running along the edges of the district with many secondary linkages But the lower scores for polycentricity indicators indicate that urban nodes remain reliant on the centralized city. The intense rush hour traffic high during spikes due to lack of intelligent management and alternatives in public transit reveals that even structural connectivity through proximity mean little value without the means for mobility, an insight echoed by (Ding, 2019).

However, the pronounced internal divergence of Transformative-Social needs to be treated with caution. Tahrir Square has traditionally been a place of memory and participation, especially during the October 2019 protests, and therefore scores relatively high on social interaction. But this informal social capital has not been translated into formal community agency, indicated by the low score on resident contribution to decisions. There exists, however, a crucial difference between the Baghdad context and the cases documented in Latin American cities; whilst the former implicates informal social cohesion, the latter relate to formal participatory mechanisms. While the literature developed around Medellín's social urbanism documented the establishment of formal community organizations after investments in infrastructure (Franz, 2017) (Honey-Rosés et al., 2020)(Quinn Coray, 2020), these findings suggest that, in the absence of intentional governance reforms, informal social capital has not been converted into institutional participation.

The significant shortcomings in the two dimensions of Participatory-Institutional and Enabling-Digital reflect on the long-standing institutional legacies of centralized state control contained within Iraq's governance structures (Jameel and Hussien, 2023).The notation of a high correlation for these dimensions ($r = 0.60$), supports the argument put forward by (Rauws, Cozzolino and Moroni, 2020) also point out the role of governance capacity and technological infrastructure as mutually reinforcing enablers of the urban resilience. Close to the (virtual) absence of participatory mechanisms or digital platforms are similar to, as reported by (Hinthel, Hussein, and Aldabbagh, 2020), that tactical urbanism arises from bottom-up rather than top-down initiatives in Baghdad.

The failure of the Inclusive-Environmental dimension of this initial analysis, especially the Lamentable lack of climate risk adjustment via Green Infrastructure as a basic form of ecological under-utilizations in Iraqi urban economies highlight a broader trend. Despite valuable ecological assets, the green spaces identified were poorly connected into ecological corridors and standalone from stormwater management systems. The lack of sufficient shade features in Al-Umma Park; although the outdoor temperatures during summer months reach well above 50°C, with blazing and dry desert winds persisting through much of the season; indicates design failure that severely compromises users' experience and potential for climate adaptability (Salman and Hussein, 2021). stressing the need for a more purposeful incorporation of the green infrastructure design into the processes if urban resilience is to be achieved.

5.2. Theoretical Implications and Hypothesis Substantiation

These results highlight the difference between synergy and the form of antifragility that is the essence of the dual model. The study area showed urban functional unit in structural-functional-social cluster, which diverse factors created urban synergy. At the same time, the commercial vitality of the area, which can be interpreted as a level of resilience, or capacity to absorb disturbance (Masnavi,et al, 2018),is somewhat obvious in its continuity as a commercial area in spite of fluctuation. At the same time, antifragility—ability to become stronger as a result of disorder (Taleb, 2012)—is an attribute that necessitates feedback loops that allow for learning across the system. These institutional-digital deficits prevent this quality-shaping capacity, leading to what we may call prodromal synergy: foundational conditions without infrastructural enabling conditions required for antifragile transformation.

The key hypothesis proposed was that cities can move from fragility to antifragility by activating all model dimensions. The findings substantiate this hypothesis. The latter finding was supported by the regression analysis, where it was found that 74.1% of the variance in urban performance is explained by the six dimensions domain collectively. Results The one-sample t-tests showed that the overall mean is statistically lower than the neutral cut-off ($t = -9.742$, Sig. $= 0.000$) and, consequently, verifying that the study site would be in a fragile situation consistent with incomplete modes activation. Partial activation yields partial results, and full activation is a prerequisite for transitioning to an antifragile state — this is the pattern.

5.3. Practical Implications

The results pinpointed the institutional-digital cluster as the crucial leverage point that would need the three mechanisms theorized to be activated in the dual model. We could establish contact systems and mechanisms to have effective interaction by way of neighborhood consultative forums and digital communication platforms, creating feedback infrastructure providing for citizen-institution dialogue and engagement. Establishing partnerships between municipal authorities, district units, and civil society organizations will activate cooperation mechanisms and will also overcome the fragmented governance structure. Integration mechanisms in the environmental dimension can be activated through connected ecological corridors and stormwater management systems that turn isolated green spaces into functioning infrastructure. Such interventions echo some of the cases previously documented in Medellín (Franz, 2017) (Honey-Rosés et al., 2020) and Singapore (Jiang, Geertman, 2022), but they would need to adapt to the Iraqi institutional context. Using the indicator matrix for a regular reassessment would provide a picture of how much each activation has progressed and the relative success of the different types of intervention.

5.4. Limitations and Future Research

Several methodological limitations are important to point out. Although this investigative study was exploratory in nature and the sample size provided sufficient information, the small sample size limits generalizability of findings. The purposive sampling of architects and urban planners was suitable for early validation of the framework yet this method inevitably limits insights into other stakeholders that may have a different expertise, experience and perception of performance compared to professional stakeholders. We adopted a mixed-method approach combining questionnaire data with systematic field observation, gaining complementary perspectives on urban conditions. On the other hand, both approaches rely on perceptual and interpretive evaluation; the absence of quantitative spatial analysis methods like Space Syntax or GIS-based measurement is a methodological limitation that warrants future research attention. This design of a single case study limits the external validity, since the features of the case of Baghdad as a post-conflict city may limit the potential transferability of its findings. In addition, the cross-sectional nature of the assessment captured conditions at one point in time and did not enable inference on causal transformation pathways. Moreover, the scarce availability of data in the Iraqi context along with time and financial constraints, limited data collection scope and analysis.

Larger and more heterogeneous samples including all relevant stakeholder groups, inclusion of spatial methods integrating perception assessment, comparative multi-case studies across a wider diversity of urban contexts, and longitudinal designs tracking changes in dimensional performance over time relative to interventions would help overcome the limitations of our study and serve as exciting avenues for future work.

6. Conclusion

The present study makes three main contributions to the scholarship and practice of urban planning. Abstract Theoretically, it builds on existing resilience discourses by integrating ideas of synergy and antifragility into a single dual urban model, and operationalizes these more abstract forms of understanding emerging from Complex Adaptive Systems and Network Theory into an empirical indicators matrix with six inter-dependent dimensions. It illustrates methodologically the diagnostic potential of the proposed framework when applied in a post-conflict urban milieu setting where informal planning channels, prevent formal spatial planning mechanisms from being enablers of justice. It identifies activated versus inert dimensions empirically, allowing prioritization of targeted interventions in urban transformation.

The dimensional performance of Tahrir Square and Al-Umma park in Baghdad showed a ranks pattern, with overall mean value of 2.23 that greatly below the neutral point. While the results indicated moderate performance levels for aspects of physical connectivity, functional diversity and social interaction, the site is still considered fragile given important shortfalls in institutional engagement and digital enablement. The regression output analysis also revealed that six dimensions as grouped can explain 74.1% of variance in overall urban performance, thus in good agreement with the coherent rationale behind the integrated framework.

The results validate the core premise that through holistic activation of all dimensions of the model, a city can migrate from fragility to antifragility. The case study showed that the structural-functional-social cluster is somewhat activated by integration and cooperation mechanisms; in contrast, the institutional-digital cluster suffers from drastic shortcomings in the mechanisms of effective interaction. Urban systems must learn from and adapt to disruption and without platforms for citizen feedback, participatory governance, and adaptive management they cannot develop that capacity. It is the lack of

these enabling mechanisms that prevents transition from partial synergy to complete antifragility.

These results have practical implications for urban planners in post-conflict settings. Priority interventions activate effective interaction mechanisms (through forums for neighborhood consultation, or citizen communication digitally), strengthen cooperation across governance levels, and integrate ecological infrastructure. These recommendations offer concrete steps or strategic guidance for urban practitioners looking to expand static resilience paradigms, toward adaptive urbanism.

Finally, This research introduces a paradigm shift in the urban planning discourse from designing cities only to mitigate shocks to planning cities for thriving in uncertainty as defined by an integrated, high level of multi-dimensional activation, institutionalized participation and systemic capacity to adapt to shocks in real time.

Author Contributions

Zainab A. Jabiry: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization; Shaimaa Hameed Hussein: supervision, project administration. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest Statement

The authors declare no conflicts of interest.

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