EFFECTS OF URBAN PLANNING ON SPATIAL COMPLEXITY: HISTORICAL ANALYSIS OF IZMIR METROPOLITAN AREA

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submitted by **MUSTAFA RAŞİT ŞAHİN** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in City and Regional Planning, Middle East Technical University** by,

Prof. Dr. Halil Kalıpçılar
Dean, Graduate School of **Natural and Applied Sciences** _____

Prof. Dr. Serap Kayasü
Head of the Department, **City and Regional Planning** _____

Prof. Dr. Emine Yetişkul Şenbil
Supervisor, **City and Regional Planning, METU** _____

Assoc. Prof. Dr. M. Anıl Şenyel Kürkçüoğlu
Co-Supervisor, **City and Regional Planning, METU** _____

Examining Committee Members:

Assoc. Prof. Dr. Olgu Çalışkan
City and Regional Planning, METU _____

Prof. Dr. Emine Yetişkul Şenbil
City and Regional Planning, METU _____

Prof. Dr. Burcu Çıngı Özüduru
City and Regional Planning, Gazi University _____

Prof. Dr. Çiğdem Varol Özden
City and Regional Planning, Gazi University _____

Assoc. Prof. Dr. A. Burak Büyükcivelek
City and Regional Planning, METU _____

Date: 19.06.2023

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name Last Name: Mustafa Raşit Şahin

Signature:

ABSTRACT

EFFECTS OF URBAN PLANNING ON SPATIAL COMPLEXITY: HISTORICAL ANALYSIS OF IZMIR METROPOLITAN AREA

Şahin, Mustafa Raşit
Doctor of Philosophy, City and Regional Planning
Supervisor: Prof. Dr. Emine Yetişkul Şenbil
Co-Supervisor: Assoc. Prof. Dr. Müzeyyen Anıl Şenyel Kürkçüoğlu

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This study aims to examine the effects of planning decisions on the complexity level of urban systems, specifically focusing on the Izmir metropolitan area. By integrating fractal analysis and complexity theories into urban planning, the study seeks to deepen our understanding of urban systems' intricate relationships and dynamics. The research questions address various aspects of the effects of planning decisions on complexity, including the impact of land use decisions, master plans, emergent activities, system components, and complexity analysis as a monitoring criterion. The methodology involves data preparation, fractal dimension calculations, and analysis techniques such as difference analysis, cluster analysis, Moran's I, and hotspot analysis. The findings from this study can notify more informed and sustainable urban planning practices, leading to resilient and adaptive urban environments.

The structure of the study consists of seven chapters, each building upon the previous to provide a comprehensive exploration of the topic. The chapters cover background information on urban planning theories, fractal analysis frameworks, planning processes in Izmir, methodology, complexity analysis of the Izmir metropolitan area,

and a concluding chapter that summarizes the research findings and suggests future directions.

Overall, this study contributes to understanding urban complexity and the relationship between planning decisions and the complexity level of urban systems. It highlights the importance of considering the interdependencies and dynamics within urban systems to develop more effective and sustainable planning strategies.

Keywords: Complexity, Fractal Analysis, Sub-fractal Analysis, Urban Planning, Urban Morphology

ÖZ

KENT PLANLAMASININ
MEKÂNSAL KOMPLEKSİTE ÜZERİNDEKİ ETKİLERİ:
İZMİR METROPOLİTAN ALANININ TARİHSEL ANALİZİ

Şahin, Mustafa Raşit
Doktora, Şehir ve Bölge Planlama
Tez Yöneticisi: Prof. Dr. Emine Yetişkul Şenbil
Ortak Tez Yöneticisi: Doç. Dr. Müzeyyen Anıl Şenyel Kürkçüoğlu

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Bu çalışma, özellikle İzmir metropol alanına odaklanarak, planlama kararlarının kentsel sistemlerin karmaşıklık düzeyine etkilerini incelemeyi amaçlamaktadır. Fraktal analizi ve karmaşıklık teorilerini kentsel planlamaya entegre ederek, çalışma kentsel sistemlerin karmaşık ilişkilerini ve dinamiklerini daha derinlemesine anlamamızı hedeflemektedir. Araştırma soruları, planlama kararlarının karmaşıklık üzerindeki etkilerinin çeşitli yönlerini ele almaktadır, bunlar arasında arazi kullanım kararlarının, ana planların, ortaya çıkan faaliyetlerin, sistem bileşenlerinin ve karmaşıklık analizinin bir izleme kriteri olarak etkisi yer almaktadır. Yöntem, veri hazırlığı, fraktal boyut hesaplamaları ve fark analizi, küme analizi, Moran's I ve hotspot analizi gibi analiz tekniklerini içermektedir. Bu çalışmanın bulguları daha bilinçli ve sürdürülebilir kentsel planlama uygulamalarına katkıda bulunabilir ve dirençli ve uyarlanabilir kentsel ortamlara yol açabilir.

Çalışmanın yapısı, konuyu kapsamlı bir şekilde araştırmak için birbirini tamamlayan yedi bölümden oluşmaktadır. Bölümler, kentsel planlama teorileri hakkında arka plan bilgisi, fraktal analiz çerçeveleri, İzmir'deki planlama süreçleri, metodoloji,

İzmir metropol alanının karmaşıklık analizi ve araştırma bulgularını özetleyen ve gelecek yönelimler öneren bir sonuç bölümünü kapsamaktadır.

Genel olarak, bu çalışma kentsel karmaşıklığı anlama ve planlama kararları ile kentsel sistemlerin karmaşıklık düzeyi arasındaki ilişkiyi vurgulamaktadır. Kentsel sistemler içindeki bağımlılıkları ve dinamikleri dikkate almanın daha etkili ve sürdürülebilir planlama stratejileri geliştirmek açısından önemini vurgulamaktadır.

Anahtar Kelimeler: Karmaşıklık, Fraktal Analizi, Alt-fraktal Analizi, Kentsel Planlama, Kent Morfolojisi

To my beloved cats (fındık & yuu-mi)

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In closing, I would like to dedicate this acknowledgment to raising awareness about autism spectrum disorder (ASD). While not directly related to this research, it is essential to recognize and support individuals with ASD, their unique perspectives, and their contributions to our society. We can create a more inclusive and accepting academic and professional environment by fostering inclusivity and understanding.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

ABMs: Agent-Based Models

BC: Box-Counting

DFA: Detrended Fluctuation Analysis

DLC: Local Connected Fractal Dimension

FACS: Free Agents in Cellular Space

IMM: Izmir Metropolitan Municipality

IPA: İzmir Planning Agency

IRN: Inter-Representation Network

LCFD: Local Connected Fractal Dimension

MFDFA: Multifractal Detrended Fluctuation Analysis

PBMs: Pattern-Based Models

PSFA: Periodic Sub-Fractal Analysis

CHAPTER 1

INTRODUCTION

"Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line."

Benoit B. Mandelbrot

The quote by Mandelbrot highlights the fundamental concept of fractal geometry and its relevance to complexity theories. Fractal geometry explores the irregular, intricate, and self-repeating patterns in nature and various complex systems, challenging traditional notions of symmetry and linearity. In the context of urban complexity, this quote serves as a reminder that cities are not homogeneous and uniform entities. They are dynamic and heterogeneous systems comprising diverse elements, interactions, and scales. Urban complexity theory recognizes that cities are not reducible to simple, linear models but rather exhibit nonlinear and emergent behaviors, much like natural phenomena.

Urban settlement systems have undergone significant paradigm shifts in their conceptualization, recognizing their inherent complexity and exhibiting characteristics of self-organization, emergence, non-linearity, and openness (Batty & Longley, 1994; Portguali, 2000; Batty, 2012). As Mandelbrot's quote reminds us, urban morphology must be more complex and conform to traditional shapes. Instead, it is shaped by a combination of top-down (global) and bottom-up (local) processes (Batty, 2010), reflecting the intricate and diverse nature of urban systems.

In order to understand and model urban complexity, non-conventional mathematics and modeling techniques have been incorporated into the urban planning and research realm. This integration of various methodologies and theories has expanded

the tools of urban modeling. Chaos theory, focusing on the sensitive dependence on initial conditions and the emergence of complex behavior, provides insights into the unpredictable dynamics of urban systems. Cellular automata and agent-based modeling simulate the interactions and behaviors of individuals, capturing the complexity that arises from their collective actions. Artificial intelligence and neural networks offer powerful tools for pattern recognition, prediction, and decision-making within urban contexts. Spatial metrics allow for quantifying and analyzing spatial patterns and relationships, shedding light on the underlying structure of urban systems. Fractal analysis, as alluded to in the quote, recognizes the self-repeating and intricate patterns that can be found in urban forms and structures.

By integrating these non-conventional mathematical and modeling techniques into urban analysis, researchers and planners gain a more comprehensive understanding of urban complexity. They can explore the interplay between different scales, uncover emergent behaviors, and assess the impacts of planning decisions on the urban system. This multidisciplinary approach allows for a more nuanced examination of urban dynamics, bridging the gap between theory and practice.

Urban complexity theory emphasizes the interplay between macro and micro scales within urban systems. It acknowledges that a city's overall behavior and characteristics emerge from the interactions and dynamics of its individual components, such as neighborhoods, buildings, infrastructure, and social networks. These components, in turn, influence and shape the larger urban structure.

By considering the macro-micro dynamics, researchers can assess how planning decisions cascade through the urban system, affecting various aspects such as spatial configuration, social dynamics, economic activities, and environmental sustainability. Fractal geometry and complexity theories provide valuable tools for comprehending the intricate relationships and feedback loops that emerge from these interactions. The importance of understanding macro-micro changes in the urban system lies in achieving holistic and sustainable urban development. It allows planners and policymakers to go beyond simplistic and linear approaches to urban

design and decision-making. Instead, they can embrace the complex and interconnected nature of cities, considering urban residents' diverse needs, aspirations, and behaviors.

By recognizing the fractal nature of cities, planners can adopt more adaptive and resilient strategies. They can foster self-organizing systems encouraging innovation, collaboration, and diversity within neighborhoods and communities. This approach acknowledges the uniqueness of each urban context while still striving for overall coherence and functionality. Furthermore, understanding the macro-micro dynamics helps to anticipate unintended consequences and identify potential trade-offs associated with planning decisions. It enables planners to assess different interventions' equity implications, social cohesion, and environmental impacts. By taking a comprehensive view of urban complexity, decision-makers can make informed choices that promote inclusive and sustainable urban development.

In the study aiming to examine the effects of planning decisions on the complexity level of the urban system, the quote by Mandelbrot resonates strongly. It reminds researchers that cities are intricate and multifaceted entities influenced by many factors and processes. The study recognizes the need to explore the fractal patterns, feedback loops, and emergent behaviors that arise from planning decisions and their interactions with the urban fabric. By adopting a complexity perspective, the study acknowledges that planning decisions have far-reaching effects, shaping the urban system at various scales. It emphasizes the importance of understanding the interdependencies between macro-level policies and micro-level dynamics, recognizing that changes in one aspect can reverberate throughout the entire system.

1.1 Aim of the Study and Problem Statement

The main aim of this study is to examine the effects of planning decisions on the complexity level of urban systems. In addition, the study aims to investigate the effects of micro and macro-level changes on the entire urban system, explore the

impact of top-down deterministic approaches in urban planning, and observe the effects of the parts of the system on the entire system.

The problem revolves around the limited understanding of the intricate relationship between planning decisions and the complexity of urban systems. In this context, there is a need for comprehensive research and knowledge regarding the dynamic, non-linear, and emerging structure of cities and their adaptive capacities in land-use planning. The following specific issues highlight the research gaps:

- *The need to investigate the effects of planning decisions on the complexity level of urban systems:* Despite the significant influence of planning decisions on cities, there needs to be a more in-depth understanding of how these decisions impact the complexity dynamics of urban systems. This knowledge gap hinders the development of effective and sustainable urban planning strategies.
- *The necessity to explore the effects of micro and macro level changes on the entire urban system:* Urban systems consist of interconnected elements ranging from individual buildings to neighborhoods and the city. Understanding how micro and macro changes interact and propagate within the urban system is crucial for comprehending the complexity dynamics. Currently, there is limited research on this interplay and its implications for urban planning.
- *The importance of assessing the impact of top-down deterministic approaches in urban planning:* Traditionally, urban planning has often relied on centralized decision-making processes, imposing predetermined solutions onto the urban fabric. However, the effectiveness of such top-down approaches in addressing the complexity of urban systems is questionable. Examining the outcomes and consequences of these approaches is essential for developing more adaptive and responsive planning strategies that account for the inherent complexity of cities.

- *The need to observe the effects of the parts of the system on the entire system:* Urban systems consist of multiple interconnected components, such as land use patterns, transportation networks, social structures, and economic activities. Changes in one component can have cascading effects on other parts of the system, leading to emergent behaviors and complexity. Understanding the relationships and interdependencies between these components and their collective influence on the overall system behavior is crucial for effective urban planning.

By addressing these research gaps and focusing on the aim and co-aims mentioned above, this study aims to deepen our understanding of the effects of planning decisions on the complexity level of urban systems. By doing so, it seeks to contribute to the development of more informed and sustainable urban planning practices that consider the intricate dynamics of cities, leading to improved urban environments that are resilient, adaptable, and responsive to the needs of their inhabitants.

1.2 Research Questions

The research questions presented are closely related to the problem statement and aim of the study, as they address specific aspects of the effects of planning decisions on the complexity level of urban systems. Here is how each research question relates to the problem:

- ***Research Question:*** *How to evaluate a city's complex, dynamic, nonlinear, constantly changing, self-adapting, and emergent patterns and analyze its response to comprehensive master plans?*

The main research question addresses the critical need to evaluate and understand a metropolitan city's complex patterns and dynamics, taking into account its dynamic, nonlinear, and emergent nature. It aims to investigate how comprehensive master plans influence these patterns and assess the city's response to such planning

interventions. By studying the interplay between urban complexity and master plans, the research seeks to develop effective and sustainable urban planning strategies responsive to metropolitan cities' inherent complexities. Through this inquiry, the research aims to contribute to the knowledge gap by providing insights into the complex dynamics of urban systems and their relationship to comprehensive master plans.

- ***Sub-RQ1:*** *What are the trends of complexity change identified through fractal dimension analyses?*

Fractal dimension analyses are a quantitative method used to measure the intricacy and self-similarity of complex systems, such as urban systems. By examining the trends of complexity change, researchers can identify patterns and fluctuations in urban complexity over time. This question aims to understand how planning decisions impact these trends. For example, are there periods of increased complexity following specific planning interventions, or do certain decisions lead to a more stable or predictable complexity pattern?

- ***Sub-RQ2:*** *What is the relationship between the parts of the system and the whole in terms of complexity?*

Complexity in urban systems arises from the interactions and interdependencies of various components, such as transportation networks, land-use patterns, social dynamics, and economic activities. This question seeks to explore the relationship between these individual parts and the overall complexity of the urban system. By understanding how changes in specific components influence the complexity of the entire system, researchers can identify critical elements that disproportionately impact urban complexity.

- ***Sub-RQ3:*** *What is the adaptive capacity range of the entire system?*

Adaptive capacity refers to the ability of a system to adjust and respond to internal and external changes while maintaining its fundamental functions and structures. This research question focuses on determining the adaptive capacity range of the

urban system. By evaluating the system's ability to adapt to different planning decisions, researchers can identify the limits and potentials of urban resilience. This knowledge is crucial for sustainable land-use planning, as it helps ensure that the system can withstand and adapt to future challenges and uncertainties.

- ***Sub-RQ4:*** *How does the complexity change with reference to the master plans of Izmir?*

explicitly examines the impact of master plans on the complexity of Izmir, a specific city. Master plans are comprehensive urban planning documents that outline the long-term vision and strategies for land use, transportation, infrastructure, and other aspects of urban development. By analyzing how complexity changes in relation to different master plans, researchers can assess the effectiveness of specific planning interventions in managing and shaping urban complexity.

- ***Sub-RQ5:*** *Which Master Plan of İzmir had the most significant impact on the level of complexity?*

Building upon the previous research question, this inquiry aims to identify the master plan that had the most significant influence on the complexity level of Izmir. By comparing the outcomes of different master plans, researchers can determine which planning approach or strategies were particularly effective in addressing complexity dynamics. This understanding can guide future planning efforts, enabling decision-makers to prioritize approaches that substantially impact urban complexity.

- ***Sub-RQ6:*** *To what extent do major land use decisions affect the level of complexity, and which of them are more distinct in master plans?*

focuses on major land use decisions and their impact on urban complexity. Land use decisions, such as zoning regulations or the allocation of space for residential, commercial, or industrial purposes, can significantly shape urban areas' physical and functional characteristics. By evaluating the extent to which these decisions affect the complexity and identifying which ones have a more pronounced effect,

researchers can provide insights into which land use choices have the most significant impact on urban complexity patterns.

- ***Sub-RQ7:*** *How can complexity analyses be used as a criterion for monitoring and forecasting tools in master planning?*

explores the practical application of complexity analyses in the context of master planning. Complexity analyses provide valuable insights into urban systems' dynamics and emergent properties. By integrating complexity analysis methods into monitoring and forecasting tools, decision-makers can better understand the evolving patterns of urban complexity. This knowledge can inform the development of more effective and adaptive master planning strategies, ensuring that plans are responsive to the dynamic nature of urban systems.

By addressing these research questions, researchers can bridge the knowledge gap regarding the relationship between planning decisions and the complexity of urban systems. The findings will provide valuable insights for policymakers, urban planners, and stakeholders involved in land-use planning processes, enabling them to make informed decisions and develop more sustainable and resilient cities.

1.3 Methodology

The methodology employed in this study consists of several steps. Initially, the study presents its purpose and research questions, outlining the specific objectives it aims to achieve. The case study area is introduced and discussed, providing relevant background information and context.

Next, that part of the study focuses on data preparation, which involves gathering and organizing the necessary data required for the analysis. In this case, the data includes information related to the case study area, such as spatial data, demographic data, or other relevant data sets.

Once the data is prepared, the study calculates fractal dimensions using various methods. These methods may include box-counting analysis, local connected fractal dimension analysis, and sub-fractal analysis. These techniques allow for quantifying the fractal characteristics of the study area, providing insights into its spatial patterns and complexities. The results obtained from the fractal dimension calculations are then evaluated using different analysis techniques. Difference analysis compares the obtained fractal dimensions across different spatial units or periods, highlighting any variations or changes in the fractal patterns. Cluster analysis, on the other hand, groups spatial units with similar fractal characteristics together, identifying clusters or patterns of similarity.

Moran's I spatial autocorrelation technique is employed to assess the spatial autocorrelation and identify any spatial clusters of high or low fractal dimensions. This analysis helps understand the spatial relationships and patterns of the fractal dimensions within the study area. Additionally, hotspot analysis is conducted to identify areas with significantly higher or lower fractal dimensions, indicating areas of particular interest or concern.

Overall, the findings derived from these analyses provide valuable insights for informed decision-making by city planners. By understanding the complexity and resilience of the city's spatial patterns through fractal analysis, planners can make more informed decisions regarding urban development, resource allocation, and future planning endeavors.

1.4 Structure of the Study

The main objective of this thesis is to investigate and analyze the impact of major planning decisions on the complex pattern of the urban system, with a specific focus on the Izmir metropolitan area. The thesis consists of seven chapters, each addressing different aspects and building upon the previous chapters to understand the topic comprehensively.

Chapter 2 serves as a background to the study, exploring the evolution of urban planning theories over time. It examines the critiques of comprehensive planning and the emergence of the "communicative action" era in planning. The chapter further discusses contemporary approaches in urban planning, shedding light on new perspectives and methodologies. Additionally, it introduces the concept of complex-cities and the significance of complexity theories in understanding and analyzing urban systems.

Building upon the foundation laid in the previous chapter, Chapter 3 delves into contextual frameworks for fractal analysis. It clearly defines fractals and explores various subjects related to fractal analysis, including multi-scale fractal structures, and self-affine fractal structures. The chapter also highlights the applications of fractal geometry in urban planning, particularly in urban morphology and urban geography. Furthermore, it offers an overview of existing research on the applications of fractals, underscoring their relevance to the field.

Chapter 4 shifts the focus to the planning processes of the Izmir city. It investigates unimplemented and implemented plans throughout the city's history, presenting notable proposals from various periods. By analyzing the planning decisions and their outcomes, the chapter provides insights into the development and evolution of the Izmir metropolitan area.

In Chapter 5, the methodology used in the study is detailed. It elucidates the aim of the research and presents the research questions that guide the investigation. The chapter justifies the use of urban road network data for fractal analysis and the methods employed for data preparation. It further describes the tool used for fractal calculation and elaborates on the analysis methods, including fractal dimension analysis and overlapping outputs. The evaluation methods used, such as difference and cluster analysis with Moran's I, are also explained.

Chapter 6 focuses on the complexity analysis of the Izmir metropolitan area. It explicitly examines periodic fractal dimension analysis concerning plan boundaries. The chapter describes various techniques employed in the analysis, such as periodic

box-counting analysis, periodic local connected fractal dimension analysis (DLC), and periodic sub-fractal analysis using overlapped visuals. The results obtained from the fractal dimension analysis are subjected to difference analysis, providing insights into the variations caused by planning decisions. Additionally, cluster analysis with Moran's I is employed to evaluate the outputs further and uncover spatial autocorrelation patterns.

Finally, Chapter 7 concludes the thesis by providing a general evaluation of the research findings. It discusses the study's implications and highlights the contributions to the planning and fractal analysis literature. The chapter explores the theoretical and technical limitations associated with complexity theories, presenting potential future research directions. Moreover, it emphasizes the importance of fractal analysis in urban planning and its relevance for planning professionals. Furthermore, the chapter examines how fractal analysis methods can contribute to parametric urban design studies, shaping the future of the urban design era.

In summary, this thesis aims to examine the effect of major planning decisions on the complex pattern of the urban system in the Izmir metropolitan area. It covers various topics such as urban planning theories, complex-cities, fractal analysis, and planning processes. Through a comprehensive analysis, the study contributes to understanding urban complexity and provides insights into urban planning practices.

RESEARCH DESIGN

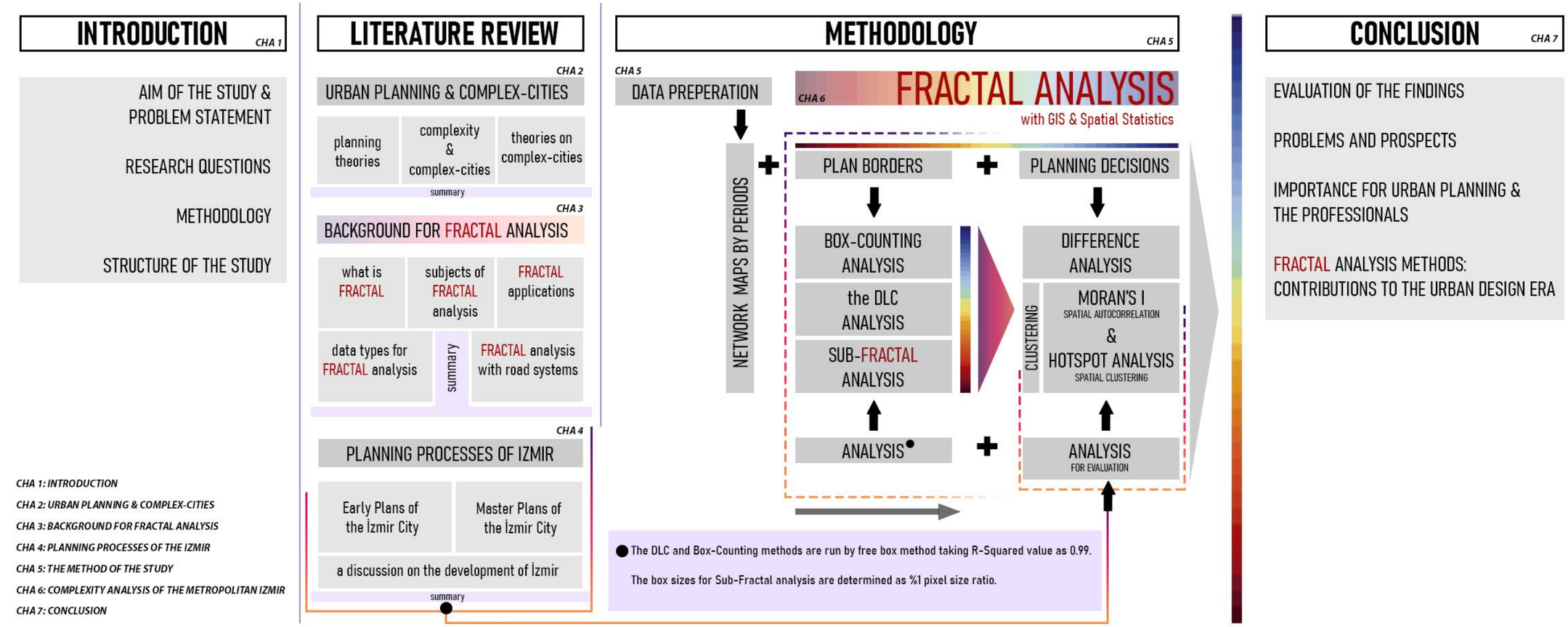


Figure 1.1 Research Design Algorithm for the Study

CHAPTER 2

BACKGROUND: URBAN PLANNING AND *COMPLEX*-CITIES

Different political movements and shifts have influenced planning theories over time, such as the influence of the Chicago School in the 1950s, postmodernism in the 1980s and 1990s, and an increasing interest in complexity in the 21st century (Hillier, 2010a). Therefore, planning has had to adapt to changing social and political contexts, responding to current-era discussions. In the 21st century, traditional assumptions of planning theory have been strongly criticized due to uncertainty and complexity. Planning practices are continuously evolving, shifting from rigid and formulated approaches to more flexible ones based on communication and interaction (De Roo, 2010).

The idea that cities should be viewed as dynamic, nonlinear, open, and complex systems and processes that can adapt to changing conditions and continue to develop in this manner is becoming increasingly accepted. Furthermore, planning involves a world where fundamental and direct interactions are transformed into complex situations, and technical and communicative rationality overlap.

In such a complex, continuously evolving, and unpredictable world, straightforward policy-making cannot be efficient as the results are also unpredictable (Morçöl, 2012). Therefore, it is necessary to engage planning theories with complexity theory by being aware of cities' self-organization and adaptation capacity, given the complex, nonlinear, and open structure of policy-making and planning. Complexity theory can help accommodate cities' uncertain and nonlinear nature (Hillier, 2010a; De Roo, 2010; Morçöl, 2012).

Accordingly, this chapter consists of two main sections. The first section discusses the evolution of traditional planning approaches and critiques of the traditional

approach. The second section describes the theoretical backgrounds of how complexity theories are used in different forms to understand the dynamic and non-linear structure of cities.

2.1 Evolution of Urban Planning Theories

Although cities are inherently complex, historical urban planning practices have often sought to simplify them (Marshall, 2012). The emergence of reformist urban utopias following the Industrial Revolution in the late 19th century shaped urban spaces in the 20th century. These utopias, characterized by a top-down modernist approach, focused primarily on the physical aspects of cities (Fishman, 1977). However, criticisms arose, with Jacobs (1961) arguing that the utopians' approach did not align with the functioning of cities. The dominance of a hermeneutic-descriptive planning culture during that period led to the sacrifice of cities (Jacobs, 1961). The utopians' attempts to create ideal urban societies often resulted in imposing standardized spaces, homogeneity, and control, reproducing injustices (Monno, 2012).

In response to the disorder caused by industrialization in the mid-19th century, early 20th-century urban planning approaches primarily focused on improving cities' physical and spatial aspects. The reformist city utopias of the late 19th century spurred the development of new planning approaches in the early 20th century, aiming to address the challenges of the Industrial Revolution. Planning transformed into a scientific discipline with new directions during the 1950s and 1960s, characterized by comprehensive and long-term planning visions (Kaiser & Godschalk, 1995).

The rational comprehensive planning approach gained prominence during this time. It was characterized by instrumental rationality, emphasizing a positivist lens and the concept of public interest. However, critics argued that this approach was too expert-driven and top-down (Fainstein, 2000). Jacobs (1961) criticized traditional urban

planning for neglecting the complexities of real cities and focusing primarily on aesthetics. She advocated for a more self-critical and observational approach that recognized the unique qualities of each city and emphasized the importance of social relationships in shaping urban environments (Marshall, 2012).

Recognizing the limitations of rational comprehensive planning, alternative approaches that embraced a more holistic and participatory perspective emerged (Altshuler, 1965; Rittel & Webber, 1973). These new approaches aimed to address the deficiencies of the earlier models and encourage a more inclusive understanding of urban development.

2.1.1 Critiques of Comprehennsive Planning

Comprehensive planning has faced critiques over the years, leading to the emergence of alternative approaches such as incremental planning and advocacy planning. Scholars like Lindblom, Etzioni, and Davidoff have questioned the effectiveness of rational comprehensive planning and highlighted the need for considering social, political, and environmental complexities.

- Lindblom (1959) criticized rational comprehensive planning for relying heavily on data without considering complex analysis.
- Etzioni (1967) introduced the mixed-scanning approach as a third method that combines rational and incremental planning elements.
- Etzioni and Davidoff (1965) proposed a hybrid technique for evaluating problems with limited data, advocating for planners to consider social and political ideals.
- Krumholz and Forester (1990) argued for planners to focus on achieving more significant equity in response to growing inequalities.
- Friedmann (1993) suggested a shift towards transactive planning, prioritizing normative considerations and creative solutions.
- Jacobs (1961) criticized the reductionist approach to urban planning.

- Healey (1996) identified two paradigm shifts in planning theories, from instrumental rationality to understanding power relations and from object-oriented to context-oriented management.
- Innes (1983) emphasized the importance of negotiation, facilitation, and collaborative decision-making in planning.

These critiques and shifts have influenced the development of planning theories, including the modernist and qualitative-constructivist approaches. The communicative approach, focusing on collaboration and inclusive development, has emerged as an essential framework for addressing complex urban issues.

2.1.2 The Era of *"Communicative Action"* in Planning

The transition from technical to communicative rationality in planning has revolutionized the understanding of complex dynamics and social relations. Jürgen Habermas's theory of communicative action (1984) has played a pivotal role in establishing the foundations of collaborative rationality. It highlights the importance of deliberation and the role of socially constructed knowledge in shaping power relations.

Forester (1980) applied Habermas's critical communication theory to planning practice, emphasizing the need for participatory labor and mutual understanding. Planning is seen as an activity of making sense together, relying on communication behaviors to establish common ground and shared knowledge. This critical approach aims to democratize and organize planning practice.

The shift to communicative rationality has enabled planners to understand intricate dynamics and explore economic and social linkages. It promotes interactive discussions based on inclusionary arguments, fostering participatory and discursive democracy. Innes (1995) argues that this shift recognizes planning as a communicative and collaborative process.

Communicative rationality challenges the limitations of science and instrumental reasoning. It encourages working together to reach common agreements among stakeholders, moving away from a top-down approach. Fainstein (2000) suggests that communicative planning considers broader social structures and benefits, embracing interdisciplinary approaches. However, communicative planning is not without challenges and criticism. It faces complexities in practice and must navigate its own set of issues.

2.1.3 Contemporary Approaches in Urban Planning

The communicative planning theory faced criticism in the 1990s for its idealistic nature, neglect of power dynamics, and unequal distribution of resources (Habermas, 1984; Flyvbjerg & Richardson, 2002). Total inclusiveness was deemed unachievable, and decision-making often relied on voting rather than consensus (Purcell, 2009). The influence of neoliberalism and the dark side of planning, characterized by inequalities and dominance, challenged the theory (Fainstein, 2000). Fainstein further argued that communicative planning overlooked unjust outcomes and the potential benefits of paternalism (Fainstein, 2000). To address these critiques, contemporary approaches in urban planning have emerged.

New approaches like collaborative planning, strategic planning, and new urbanism principles have been proposed to overcome the limitations of traditional planning (Portugali, 2012c). Collaborative planning emphasizes open dialogue, collaboration, and consensus building while addressing localized power relations (Albrechts, 2004). Strategic planning anticipates future changes and involves planners in decision-making, promoting inclusiveness (Healey, 1996). New urbanism focuses on design and public participation but differs from communicative planning (Fainstein, 2000).

Collaborative processes have been recognized as means to enhance adaptability and resilience through collective and individual learning (Innes & Booher, 2010).

Effective communication, face-to-face interaction, and stakeholder engagement are crucial for generating shared knowledge and finding solutions (Innes & Booher, 2010). However, power imbalances and incomplete stakeholder engagement can hinder collaborative policy dialogue (Innes & Booher, 2010).

In addressing the complexities of a changing world, Innes and Booher (2010) propose a collaborative model within the complexity science framework. This approach recognizes the adaptability and creativity required in uncertain environments. The shift from technical to communicative rationality in mainstream planning theory acknowledges the complexity of planning and the need for evolving collaborative practices (Jacobs, 1961).

2.2 Understanding Cities with Complexity Theories

In the 1950s and 1960s, the quantitative approach was predominant in planning discussions, followed by critical approaches in the 1970s. However, De Roo (2010) argued that traditional processes were deemed inadequate and replaced by socially constructed nonlinear processes. This shift from a top-down and static equilibrium view of cities as general systems to a dynamic theory approach with bottom-up and out-of-equilibrium approaches was a result of the criticism of centralized models, as well as the influence of Darwin's Origins of Species (1859), which had a lasting impact on the top-down approach. In the late 19th century, there was a theoretical concern for cities, as highlighted by Portugali (2011).

Pioneers in discussing complexity in planning and emphasizing the necessity of developing urban life from the bottom up include Geddes (1915), who criticized the mechanical perceptions of urban elements during the early 19th century. Hillier (2010a) noted that Darwinism was too restrictive to discuss urban planning, but Geddes applied this biological approach to planning. Jacobs and Alexander also criticized the modernist approach during the early 1960s, strongly arguing for the complexity of cities. Rittel and Weber (1973) defined planning problems as wicked,

and De Roo et al. (2012) assert that wicked and fuzzy problems open space for the sciences of complexity.

In summary, complexity theory provides a new perception of cities, and there is a need to rethink planning theory and practice in the light of nonlinearity, resilience, adaptivity, complexity, and complexity thinking.

2.2.1 The Complexity

Complicated and complex are two related terms but with distinct meanings:

- ***Complicated*** *refers to something made up of many interconnected parts or elements but can be understood through analysis and breaking it down into simpler components. A complicated system may be difficult to understand or operate, but it can be broken down into smaller pieces and analysed step-by-step to determine how it works. The relationships are more predictable and linear.*
- ***Complex****, on the other hand, refers to something made up of interdependent parts that cannot be fully understood by analysing them in isolation. A complex system may exhibit emergent behaviours or properties that cannot be predicted from the behaviour of its components. Complex systems often involve feedback loops, nonlinear dynamics, and interactions among many components that are difficult to understand fully. The relationships are unpredictable and non-linear.*

In short, while a complicated system can be understood through analysis and breaking it down into simpler components, a complex system is characterized by emergent behaviours and interdependence among its parts, making it difficult to understand and predict its behaviour fully.

The quest for certainty and clarity in science creates a reductionist approach that ignores complexity, according to Cilliers (2005). Complexity theories initially emerged in the 1960s in physical-material systems, highlighting emergence, self-

organization, and history. Later, the interest in complexity theories grew due to work on the dynamical properties and structural transformation of nonlinear, "far-from-equilibrium" systems (Martin & Sulley, 2007). Technological advancements further contributed to the interest in complexity theories (Cilliers, 2002), which started being applied to social sciences (Portugali, 2012d).

> ***Non-linearity*** *is when the relationship between two or more variables is not directly proportional or does not follow a straight line. In other words, when changes in one variable do not result in a constant or predictable change in another variable, the relationship between them is non-linear. Non-linearity is often observed in complex systems where small changes in one component can significantly and unexpectedly affect the overall system. Non-linear relationships are characterized by their non-constant rates of change, curvature, and sensitivity to initial conditions.*

Various schools of thought have developed different conceptualizations of complexity theory, and there is no complete framework to define it (Hillier, 2010c). Therefore, it is necessary to clarify concepts within their application areas (Morçöl, 2012). Even though there is no broad agreement on the definition of complexity, Martin and Sunley (2007) identify the distributed nature and representation, openness, nonlinear dynamics, emergence and self-organization, adaptive behaviour and adaptation, and non-determinism and non-tractability as the inherent components of complex systems. Unlike equilibrium situations, complex systems emphasize temporality (De Roo et al., 2012).

Therefore, a multifaceted system undergoes a process of evolution over a period of time and enhances our comprehension of advancement, alteration, and growth. According to Cilliers (2005, p. 257), there exist specific fundamental attributes of intricate systems, which can be outlined as follows:

- Complex systems exhibit characteristics of open systems.
- The system functions in a non-equilibrium state.

- Complex systems are comprised of numerous components. The constituents in question must be more flexible (or amenable to being regarded as such).
- The result produced by various constituents relies on the input variables. At least some of these functions must exhibit nonlinearity.
- The determination of the state of a system is contingent upon the values of its inputs and outputs.
- Tangible input-output relationships characterize interactions and are dynamic, wherein the intensity of the interactions undergoes fluctuations over time.
- On average, components interact with a multitude of other components. Various pathways can be taken to connect components, which are facilitated through various means. Specific patterns of interaction may offer feedback pathways, regardless of their length.
- The behaviour exhibited by complex systems is a product of the interplay between their constituent components rather than being determined by the inherent properties of the components in isolation. The phenomenon under consideration is occasionally referred to as emergence.
- The internal dynamic processes of complex systems facilitate the development, maintenance, and adaptation of asymmetrical structures in terms of temporal, spatial, and functional organization. The structure's maintenance persists despite replacing or renovating its constituent elements.
- Complex systems exhibit behaviour across a wide range of divergent timescales. The system must adapt to its surroundings. The ability to rapidly adapt to environmental changes is a crucial factor for sustainability; however, the system can only maintain its viability if a portion of it changes at a slower pace than the changes occurring in the environment. This component may be regarded as the system's memory.
- It is possible to generate multiple depictions of a complex system, each involving a distinct system decomposition. Distinct characterizations may exhibit varying levels of intricacy.

Complex systems, also known as complex adaptive systems, are characterized by adaptability, self-organization, and openness. The concept of adaptability is closely associated with the capacity of the systems to self-organize, which distinguishes them from non-adaptive complex systems (Morçöl, 2012). However, Morçöl argues that adaptability is unnecessary for a system to attain complexity. The principal notion characterizing complex systems is nonlinearity, which is not typically accounted for in linear thinking commonly used in scientific thought. Nature's norm is nonlinearity and openness, despite scientific thought's linear foundations (Morçöl, 2012). Nonlinearity does not necessarily imply randomness and conflict, as it can engender constructive patterns.

Additionally, complex systems are far from equilibrium states and are highly susceptible to external stimuli. Emergence is closely related to complex systems, where the whole system is more than the sum of its components. Macro transformations arise from local and micro-interactions, as proposed by Hillier (2010a). The phenomenon of self-organization arises from the interplay of relationships among actors and their opposition to centralized command and control. Complex systems are often perceived as coevolutionary phenomena, where the system and its environment co-evolve. However, Batty and Marshall (2012) argue that the definition of complex systems cannot be considered optimal due to unpredictable exogenous changes, lack of closed solutions, and absence of certainty.

Cilliers (2002) and Morçöl (2012) offer contrasting viewpoints on the determinants of complexity in complex systems. While Cilliers suggests that a system's complexity arises from the significant number of elements it contains, Morçöl posits that the interactions among these elements lead to complexity. Even small changes in these interactions can significantly change the system's behaviour (Morçöl, 2012). Both authors agree that comprehending the entirety of a complex system by analysing its components is unattainable. The dynamic interdependence among the system's components undergoes continual transformation through self-organizing processes, making it challenging to comprehend the entire system's intricate configuration (Cilliers, 2002).

Morçöl (2012) further suggests that, without a comprehensive understanding of a system's components, forecasting its future behaviour remains impossible. Thus, a complete understanding of a complex system is unachievable, and one can only grasp a particular scope of knowledge, as Cilliers (2005) suggested. Hillier (2010c) also argues that complexity involves multidisciplinary thinking and the interplay between order and chaos arising from unforeseeable occurrences and emergence.

2.2.2 The Complex-Cities

Since the opening of the 21st century, the approach to cities has changed. In the traditional approach that advocates the hierarchy of parts and the organization of the system, cities were seen as controlled systems that maintain equilibrium, and the city models developed based on this approach were generally deterministic models for a single point in time.

- ***The Logic of Deterministic Models***

  Socio-physical models developed from Newton's Law of Gravity and based on microeconomic theory, such as rent and population density models, are typical examples of this approach (Batty, 2009). Gravity models, which calculate spatial interaction in proportion to the size of regions or sub-regions, such as population and fundamental workforce, and inversely proportional to distance, determine the distribution of service workforce or daily travel.

  The first example of these models, which determine the attractiveness of settlements or urban development based on the interaction between population and workforce, was developed by Lowry in 1964. The journey production model in urban transportation planning also distributes travel quantities mathematically between socio-economic variables such as journey characteristics, population size, number of workers and students, and income status using the gravity model. The ease of operation and the researcher's

complete control over the structural elements have made these types of socio-physical models widely used.

Another example of the traditional approach to cities is microeconomic theory, which is an economic model that determines urban land distribution. These models, which were applied to the urban housing market by Alonso in 1964, developed from land rent theory and calculate housing demand based on household income and utility maximization. Household preferences for housing size and the cost of housing-office travel explain the change in land prices from the centre to the periphery and indicate urban density.

The location, land use, and transportation models described above are operated for a single time period only. This is unrealistic in urban life, where change is constant (de Roo, 2010)."

In the early 1960s, Jacobs and Alexander argued about how cities are complex, which criticized the modernist approach that favoured simplistic order. Rittel and Weber (1973) described planning problems as wicked, while De Roo et al. (2012) claimed that wicked and fuzzy problems offer opportunities for the sciences of complexity, and spatial planning is moving towards a new phase that involves a nonlinear understanding of planning. Innes (1983) argued that planning theories must comprehensively explain the complex nature of planning and the various contexts in which it occurs. Therefore, there is a need to reconsider both the theory and practice of planning in the context of nonlinearity, resilience, adaptivity, complexity, and complexity thinking. Hillier (2010a) argued that spatial planning theory should confront complexity and uncertainty. At the same time, Portugali (2011) believed that the complexity theory offers a fresh perspective on urban areas and can help clarify intricate issues.

The cities of the future will be different from today's cities, and our past experiences may be insufficient to guide us in facing urban problems. In her famous book, "The Death and Life of Great American Cities," Jane Jacobs discusses cities not by debating how they should always be but by understanding their self-organizing

power. She emphasizes that despite a large number of variables in urban problems, they are not random but rather interrelated in an organic whole. *Jacobs* applied this approach in the design of a neighbourhood park as follows:

> *"The extent to which a park is used is partially dependent on the design of the park. However, the partial effect of park design on park usage is also dependent on who uses the park and when they use it, which is, in turn, dependent on the non-park uses of the city. In addition, the composition of activities and creatures around the park will depend on factors such as the mix of building ages, the size of the surrounding building blocks, and so on. Everything changes if you make the park dimensions too large or redesign it to separate and fragment users instead of bringing them together. New sets of influences come into play both in and around the park. We have moved far away from simple problems such as the ratio of open space to population; parks behave like organized complex problems, which they are. The same is true for all other elements of the city. The internal relationships of many factors can be complex, but how these factors influence each other is not random or irrational (Jacobs, 2009, p. 443)."*

The implication drawn from the text resembles what has been observed in other domains of social complexity. Throughout the 1990s, many scientific breakthroughs have trended towards more sophisticated qualitative approaches and complex systems, impacting the social sciences. Multi-agent systems have made it feasible to simulate a system's behaviour and consecutive changes at the macro level by utilizing techniques grounded in individual accounting for each agent in the system (Sawyer, 2005). Each multi-agent system encompasses hundreds or even thousands of agents interacting with one another. As such, researchers can produce synthetic societies and establish analogous complex systems by modifying the agents' properties or diversifying their communication languages.

- ***The Butterfly Effect:***

Edward Lorenz's article "Predictability: Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?" is a significant work in the field of chaos

theory, and it introduced the concept of the butterfly effect. In the paper, Lorenz (1972) presented a simplified model of weather patterns that demonstrated how small changes in the initial conditions could have significant impacts on the final outcome. This finding had important implications for weather forecasting, as even minor errors in measuring initial conditions could lead to major discrepancies in predicted weather patterns (Lorenz, 1972).

The butterfly effect refers to the idea that small changes in one part of a complex system can have far-reaching and unpredictable consequences in other parts of the system (Lorenz, 1972). This idea has since been applied to various phenomena, such as the spread of diseases, the behaviour of financial markets, and the development of social trends. The concept highlights how small events can lead to significant and unexpected outcomes, making it challenging to predict the behaviour of complex systems.

Complexity is situated at the edge of chaos, as coined by Kauffman (1991), between cosmos and chaos, or order and disorder. If a system is non-linear, a small change can result in significant changes and lead to new situations. This "butterfly effect" can create unexpected outcomes, while a large change may not have a significant effect. Similar unexpected situations can arise in dynamic systems, and chaos theory investigates these sensitive systems (Gleick, 1987). However, chaos does not only represent random behaviours but is also made up of interlocking cycles. Cycles arise from continuous interaction between behaviours attempting to become cosmos and other behaviours that influence them as they search for a new order (Waldrop, 1993). Traffic congestion arises at a certain point in time and space, then suddenly disappears, and a new state of order arises (Johnson, 2009). Complex systems are evolving systems that adapt themselves to their environment and demonstrate organizational behaviour when adopting. The concept of self-organization was developed in the 1960s. In complexity theory research, the organized and patterned behaviour of systems with many interacting components has been referred to as self-organization (Portugali, 2009).

- ***The Heisenberg's Uncertainty:***

One of the most basic principles in quantum physics is known as the Heisenberg uncertainty principle. This concept asserts that the more accurately the location of a particle can be known, the less precisely its momentum can be known, and vice versa. This principle arises from the wave-particle duality of matter, where the position and momentum of a particle are described by wave functions that can interfere with each other (Feynman et al., 1965).

An analogy for the Heisenberg uncertainty principle in the context of complexity and urban systems can be made with the relationship between the position and speed of an electron in an atom. The position of an electron can be determined by measuring its energy level or the probability of finding it in a particular location. In contrast, its speed can be determined by measuring the frequency of light it emits or absorbs. However, the more precisely we measure one property, the less precisely we can measure the other property due to the uncertainty principle (Feynman et al., 1965).

In urban systems, many variables and factors interact in complex and unpredictable ways, resulting in a high degree of uncertainty. For example, changes in transportation infrastructure can affect the local economy, social interactions, and environmental quality in unpredictable ways, making it difficult to make accurate predictions about the outcomes of such changes (Holling & Walters, 1978).

Therefore, the Heisenberg uncertainty principle reminds us that there are inherent limits to our ability to measure and predict complex systems accurately. As such, it is crucial to approach urban systems with humility, recognize the limitations of our knowledge, and adopt an experimental and adaptive approach to management and decision-making.

Another characteristic of complex systems is the emergence of patterns or unexpected behaviours (emergence) resulting from the tension between order and

disorder (Waldrop, 1993; Holland, 1998). These behaviours arise from the collective actions of the micro-level components of a complex system, revealing their patterns, structures, and entities. The most significant example in social sciences is language transformation in communication. Changes are not determined by any management or external force. For example, language transformation arises from countless daily conversations among individuals in society and develops entirely on its own (Sawyer, 2001). In a social system, the micro-level actions of individuals and their relationships, such as daily conversations, form the macro-level language. Another example is Adam Smith's "invisible hand," which organizes the market. At the micro-level, individuals and firms learn from the behaviour of others to maximize their interests and profits, maintaining market equilibrium at the macro-level. In fact, the macro-level order of complex systems is composed of relatively complex micro-level components, individuals, relationships, and actions. Predicting instant fluctuations in the stock market or market bubbles and crashes at the macro-level is challenging as they are difficult to explain with micro-level components (Mitchell, 2009).

- ***The Analogy of Heraclitus:***

Heraclitus was a pre-Socratic Greek philosopher known for his emphasis on change and impermanence. He famously said, "You cannot step into the same river twice." This statement expresses the idea that everything is in a constant state of flux and that nothing remains the same.

The analogy of Heraclitus has been used in the context of complexity theory and city systems to emphasize the dynamic and evolving nature of cities. Like the river that is constantly changing, cities are also complex systems that are always in a state of flux. They are influenced by a multitude of factors, including social, economic, cultural, and environmental variables, and these factors are constantly interacting and evolving (Capra, 1996).

Complexity theory delivers a framework for understanding the behaviour of complex systems, such as cities, and the interactions between their individual

components. By embracing the idea of constant change and impermanence, complexity theory recognizes that cities are not static entities but rather dynamic and evolving systems (Strogatz, 2001).

In this context, the analogy of Heraclitus highlights the importance of understanding the complexity and interdependence of city systems. It prompts us cities are not just the sum of their individual parts, but rather a complex and evolving network of interactions that require a holistic approach to management and development (Cilliers, 1998).

In the new approaches, *cities are seen as dynamic, nonlinear, constantly changing, and self-adapting complex systems.* The organization and structure of the system emerge from the relationships between the components. This is also to think of cities as evolving systems rather than designed or planned structures. Social science theorists adapt the language of complexity from natural sciences such as physics, chemistry, and biology. Urban theorists and planners such as Batty (2005) and Portugali (2000; 2011), who conduct more comprehensive urban research based on complexity theory, have been influenced by thermodynamics and chaos theory in natural sciences and have adopted a new approach based on complexity by developing traditional quantitative urban models. In this approach, cities are accepted as self-organizing complex systems.

2.3 Introducing the Models on *Complex-Cities*

Even though the systems examination dependent on the General Systems Theory gave a way to deal with take a gander at urban communities impressively, it is basically static and is restricted in the capacity to manage dynamic development marvels. In a cataclysmic framework, basic qualities of framework boundaries exist at which some irregular conduct of the system can happen. Both the calamity and bifurcation hypotheses are worried about these basic qualities. Studies in the Chaos

Theory uncover that even the least difficult physical systems that comply with deterministic laws can concede eccentric unpredictability (Robinson, 1998).

> ***Bifurcation*** *refers to a crucial point in a system where even a slight change or disturbance can result in the system behaving completely differently or transitioning to an entirely different state. This means that at the bifurcation point, the system becomes unstable and can move in multiple directions. This concept is often studied in complex systems like weather patterns, ecosystems, and social networks. Bifurcation can make a system behave unpredictably, but it is also crucial to understand how complex systems evolve and adjust over time (Robinson, 1998).*

Ongoing studies on complex systems have shown that chaos can sometimes lead to order, despite the presence of bifurcation and disorder (Deranged and Longley, 1994). At the Brussels School, researchers investigated physical and chemical systems and applied their findings to urban planning (Prigogine & Stengers, 1984). They found that in an open system, where energy and materials are exchanged with the environment, the flow of energy or materials can cause the system to move towards a state that is "far from equilibrium" (Prigogine & Stengers, 1984, p. 141). When different components of the system interact in a nonlinear way, they can create opportunities for bifurcation that may disrupt the overall state of the system and lead to "order from fluctuations" (Prigogine & Stengers, 1984, p. 178). This nonlinear interaction can destroy the existing order and lead to the emergence of a new order beyond another bifurcation. These ideas suggest that complex systems have a self-organizing capacity and that small changes in local behaviour can ultimately lead to big changes in global patterns (Wu, 1998a, p. 732).

Recent investigations have brought to light the open system theory's impact on urban development. Cities can be seen as complex and comprehensive self-organizing systems, constantly exchanging goods and energy with surrounding cities and their hinterlands. This system has evolved from localized processes and can lead to global occurrences, even in unfavourable regional dynamics. Therefore, metropolitan

growth can be viewed as a spatially dynamic process, displaying distinct vital attributes of a self-organizing system. The expansion of metropolitan areas into rural areas is similar to the spread of disease or fire. Past metropolitan structures continue to influence the present and future ones. Therefore, it is more effective to use a ground-up approach and self-organizing perspective to study the local behaviour of the system in order to model urban development. This has led to the creation of new simulation models, such as diffusion-limited aggregation, geo-simulation based on automata, and agent-based models (Benenson & Torrens, 2004; Wu, 1998a; Wacko, 1997, 1995; White & Engelen, 1994, 1993; Couclelis, 1985).

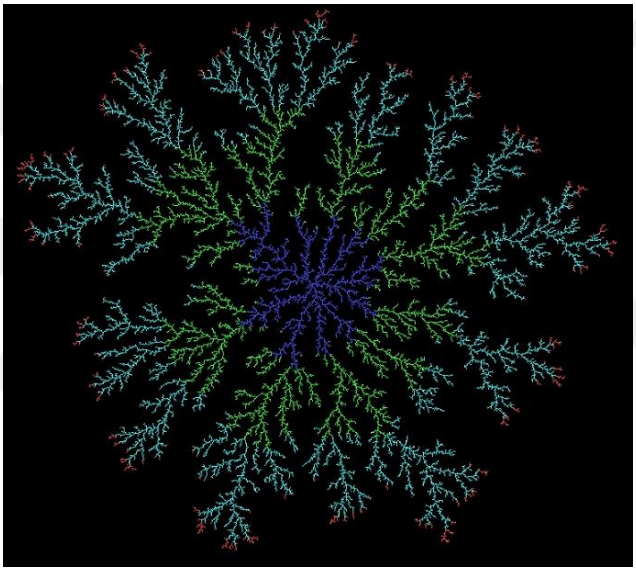


Figure 2.1 This image depicts a Diffusion Limited Aggregation (DLA) pattern of approximately 33,000 particles. The pattern was formed by allowing random walkers to adhere to a seed at the center. The different colors in the image indicate the different arrival times of the random walkers (Wikipedia, 2019).

Diffusion-limited aggregation (DLA) is a model that explains the complex structure of a system that has the same level of irregularity on all scales, which is called self-similarity. DLA's growth process is simple and involves accumulating at the boundary. For instance, a DLA model starts with a fixed seed in plane space, and a particle is released from a random position far away from the seed. The particle is allowed to diffuse into the space, and if it touches the seed, it is immediately immobilized and becomes part of the aggregate. Then, similar particles are released

one by one, and each stop after hitting the aggregate group (Wu, 1998a). DLA is considered one of the main models of fractal growth, based on principles of fractal mathematics that describe the irregular pattern of a system.

Urban models based on the automata approach have also emerged under a self-organizing system, with cellular automata being the simplest yet most popular in practice. An automaton is an entity with its own spatial and non-spatial attributes and a mechanism for processing information based on its attributes, rules, and external data. Cellular automata are individual automata arranged in a regularly patterned space, such as a regular grid (Benenson & Torrens, 2004). The processing and sharing data between neighbouring cells are possible using cellular automata. This approach has been employed in advanced computing for quite some time, as pointed out by Macrae in 1992. However, after the late 1980s, it was utilized to study self-organizing systems and urban development modelling. Various researchers, including Wu and Webster in 2000 and 1998, Deranged, Xie, and Sun in 1999, and Clarke and Gaydos in 1998, have utilized this technique to examine urban development.

Another type of automata, multiple agent systems (MAS), has also been adopted for urban modelling (Torrens & Benenson, 2005; Benenson, Omer, and Hatna, 2002; Benenson, 1999, 1998). Multiple agent systems are designed as a collection of interacting autonomous agents, each with its abilities and goals, but they relate to a typical environment. This type of model works on similar principles as the cellular automata model. Each agent is considered an autonomous agent automaton (Torrens, 2003), and their states generally represent some agent-based characteristics. However, there are differences between cellular automata and multi-agent systems in various ways. One difference is that in the multi-agent system, the basic unit of movement is the collection of agents representing people, engineers, planners, or government leaders. The agents are autonomous in that they are capable of making independent actions, their activities are directed toward achieving defined tasks or goals, and their impact on the environment can be at different scales (Torrens &

Benenson, 2005; Benenson, Omer and Hatna, 2002; Benenson, 1999, 1998; Torrens, 2003).

Another difference between cellular automata and multi-agent systems is that they have fixed cells in the CA grid. In contrast, agents in multi-agent systems are dynamic and versatile entities that can move within the areas they occupy (Torrens, 2003). These agents can process and transmit the information as they move through their areas and pass the information from one agent and environment to another. Thus, the local connections in agent automata are also different: when individual agents change their positions in space, their local connections also change. This modelling approach offers greater flexibility as their agents not only convey the internal dynamics of the automata and the mechanism of communicating information to its neighbours, but they also represent the behavioural characteristics or even simulate "intelligence" (Torrens, 2003). Therefore, this modelling approach also offers attractive features in urban modelling (White & Engelen, 2000). However, in practice, agent-based models are less popular compared to CA-based models in urban simulation, and most of the agent-based models developed in urban modelling were actually conceived as CA and later rethought as multi-agent systems (Benenson & Torrens, 2004; Torrens, 2003; Benenson, Omer, and Hatna, 2002).

Self-organization and Chaos

Self-organization can be understood as a theory explaining how chaotic systems achieve order through internal mechanisms. Synergetics proposes that this is due to cooperation between the different parts of the system, while the theory of dissipative structures suggests that this is due to dispersion. According to this perspective, self-organization is a scientific theory that explains the concept of Order Out of Chaos, as highlighted in Prigogine and Stengers' (1985) book. This implies that self-organization is a fundamental concept that helps explain how complex systems, such as cities, achieve order and structure. Self-organizing urban areas refer to cities where self-organization explains how their current demand state was generated.

However, this conclusion is only partially accurate, as it is just one example of a broader scenario where self-organized planned cities may exhibit chaos. To fully comprehend this, it is essential to differentiate between two types of chaos: local or microscopic chaos and global, macroscopic, or deterministic chaos. This implies that self-organization can lead to order and chaos in urban areas. Comprehending the different types of chaos is essential to develop effective strategies for managing urban systems (Prigogine & Stengers, 1985).

In a complex system, isolated components' erratic movement or behavior can result in local chaos. This can be observed in various scenarios, such as the movement of cars on an empty highway, the behavior of people in an empty plaza, or the motion of gas particles. These situations involve unpredictable and disordered movements by the individuals involved. This is a typical starting phase for a self-organizing system, where the behavior of individual components can affect the system's overall behavior.

Sequential chaos occurs when the movement or behavior of several components in a complex system becomes erratic and disordered. However, due to self-organization, a few attractors or order parameters suddenly bring these individual pieces together, leading to structured movement.

This new state appears to be orderly, but it is not truly so because the order parameters that control the system are often turbulent. These order parameters can suddenly switch back and forth between different attractive forces in a chaotic manner. This behavior is known as "deterministic chaos" because the predictable control of a chaotic system characterizes it. This label emphasized how easily and precisely chaotic behavior can be controlled through order parameters (Prigogine & Stengers, 1985).

Dendrinos & Sonis (1990) have conducted a comprehensive study that explores the relationship between chaos theory and socio-spatial components. The study provides a foundation for future research that will apply chaos theories to the specificity of

urban areas and urbanization. While these examinations are yet to be conducted, it may be helpful to outline some possible directions for such research.

Urban areas can be viewed as self-organizing systems and exhibit turbulence in various aspects. The process of self-organization in urban areas involves a cycle of stability followed by fluctuations or disorder. This cycle is similar to the behavior of open and complex systems. The urban system reaches a "steady state" or equilibrium, experiences a brief period of instability and fluctuation, then transitions to a new level of equilibrium and stability. This pattern repeats continuously in the self-organizing process of urban development (Portugali, 2002).

A common way to explain the self-organization process in cities is by using a bifurcation diagram. This diagram shows how a city moves from one stable state to another through bifurcations. At each developmental step, the city shifts from a relatively stable state to a slightly chaotic one before transitioning to a new, predominantly stable state. This process is necessary because it distinguishes the "new" concept of a far-from-equilibrium underlying structure of a self-organized city from the "old" stable city structure discussed in location theory (Portugali, 2002).

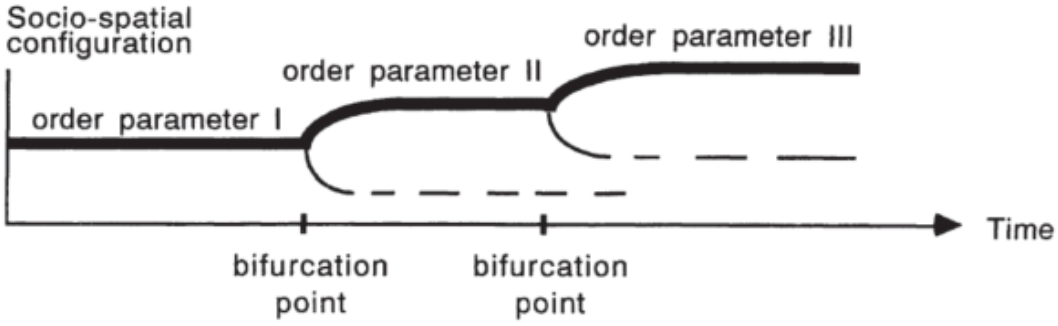


Figure 2.2 Stratigrafic Change (Portugali, 2002)

As previously mentioned, self-organizing cities can exhibit phenomena of deterministic chaos, where sudden and chaotic jumps occur between the order parameters that dominate the city when in a stable state. One example is conflicts between residential and commercial activities or sociocultural order characteristics. Interestingly, neighborhoods can observe chaotic behavior while the city develops

gradually. Some unstable and chaotic areas can be present within an otherwise orderly city.

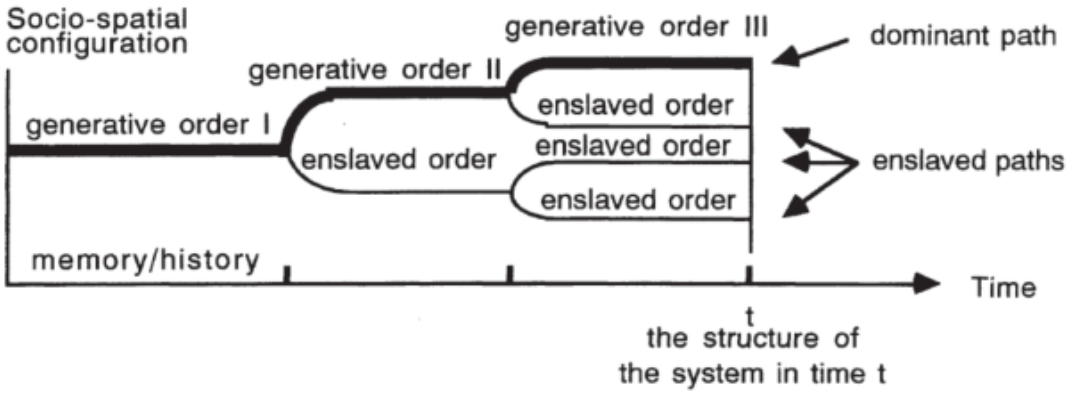


Figure 2.3 Furcative Change (Portugali, 2002)

According to a cellular automata model, these adjacent islands of instability are necessary to maintain the overall global stability of the city. This is known as the captive principle, and it is suggested that it complements Haken's slaving concept. The captive principle involves spatially isolating small chaotic elements threatening the city's stability while maintaining global order (Dendrinos & Sonis, 1990). The daily and long-term growth of cities can display a balance between chaos and order. This balance is reflected in the movement of people and vehicles, which can transition between unstable and stable movements. For instance, the movement of cars on the freeway can vary between randomly circulating speeds during off-peak times to regularly dispersed speeds during peak times, indicating a shift from chaos to order. Similarly, sudden changes in the speed of large groups of moving cars during busy times can demonstrate deterministic chaos. This interplay between chaos and order is an area of interest for researchers studying self-organization in urban areas (Dendrinos & Sonis, 1990).

> *The term "chaos" should be taken with care, as there are differences between its meaning in everyday language and its technical definition in numerical hypothesis. Therefore, it is crucial to use the concept of chaos correctly when discussing it in the context of self-organizing systems such as cities.*

2.3.1 Agent-Based Models (ABMs)

Agent-Based Models are computational models that simulate the behavior and interactions of individual entities, called agents, within a more extensive system. Agents can represent various elements, such as individuals, organizations, or objects. Each agent follows a set of rules or behaviors and can interact with other agents and the environment. When combined, individual agents' interactions and behaviors give rise to emergent properties and patterns at the system level. ABMs are particularly useful for understanding complex systems where the interactions and behaviors of individual entities play a crucial role in shaping the overall system dynamics.

2.3.1.1 Dissipative Cities

Dissipative cities are created by applying Prigogine's hypothesis of dissipative structures to the study of urban areas and systems of urban communities by Allen and colleagues (Allen, 1981; Allen & Sanglier, 1981; Allen et al., 1985). The term "dissipative" refers to the emphasis on dispersal's role in Prigogine's self-organization theory. Prigogine's argument is based on integrating Boltzmann's organization principle with the Benard experiment, demonstrating a coherent particle movement. According to Boltzmann's principle, this self-organized movement is unlikely to occur as it is stochastic. However, it does occur. The explanation is;

> *"In situations that are far from equilibrium, the concept of probability underlying Boltzmann's structural standard is not applicable, and traditional thermodynamics suggests the creation of balanced structures like crystals. However, the Benard cell structure is an exception. The idea of "dissipative constructs" is introduced to highlight the connection between structures and dispersion or waste in non-equilibrium situations. In the Benard cell, the heat transfer that was previously considered waste in classical thermodynamics becomes a source of order. The emergence of new conditions, such as dissipative constructs, can be attributed to the system's interaction with the*

external environment and its placement in non-equilibrium conditions. Dissipative structures, including the Benard cell, reflect the global non-equilibrium that gave rise to them (Prigogine & Stengers, 1984, p. 142-144)."

Those who know location theory would notice the striking similarity between the hexagonal shape of Benard cells and the hexagonal landscapes of focus points developed by Christaller (1966/1933) and Lösch (1954). This similarity prompted Allen and his colleagues to explore a connection between the two through a series of studies. They modified Christaller and Lösch's static central place theory to Prigogine's dissipative structures (Allen, 1981; Allen & Sanglier, 1981; Allen et al., 1985).

To describe their theoretical approach to hierarchical landscapes of central places, Allen and his team constructed a range of models for urban systems at a local level, followed by models for individual cities within metropolitan areas. They also applied their models to perform detailed case studies of Brussels and the surrounding regions of Belgium, as seen in Sanglier and Allen (1989), Sanders (1987), Saint-Julien, Pumain, and others.

Allen and Sanglier (1981) studied central place theory and received both positive and negative criticism. The positive criticism focused on factors such as economies of scale and regular foundation, while negative criticism addressed issues such as congestion and pollution. They developed a model, illustrated in the figure, that depicts a hypothetical location represented by a rectangular grid of homogeneous regions. By incorporating chance factors such as the timing and location of different movements and initiatives, the model generates a series of balance breakings that result in an uneven distribution of population and businesses. As a result, new metropolitan cities emerge, grow, and transform the entire provincial arrangement of central points. The evolution of the system leads to some regions growing, others shrinking, or even disappearing, creating a unique history for the area (Allen & Sanglier, 1981).

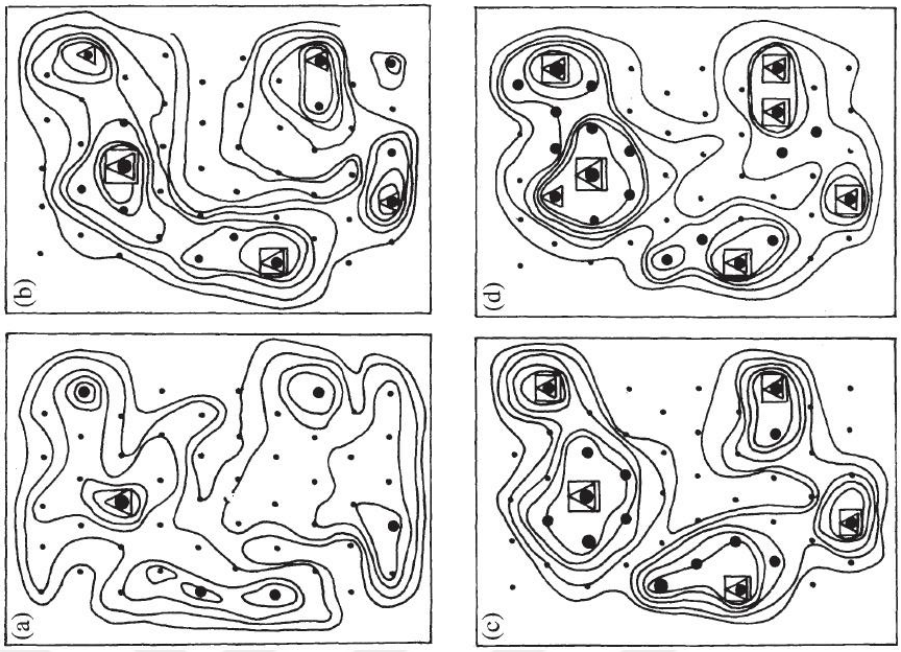


Figure 2.4 Dissipative system of cities by Portugali (2009)

When Allen and his colleagues applied the concept of dissipative structures to develop a new hierarchical system of central places, they found that it differed from the traditional static approaches of Christaller and Lösch. Although both the old and new approaches led to the formation of urban centers as a result of economic activities and collaborations, the new system was "greater than the sum of its parts" and reflected a non-equilibrium situation, unlike the traditional definitions that described an equilibrium condition that is the streamlined sum of the qualities of the many economic Powers (Portugali, 2009). Thus, the new system used connections and fluctuations to acquire, maintain, and then vary the progressive spatial order among the central places, while on the other hand, scattering (as in the Benard cells) was also used (Allen, 1981; Allen & Sanglier, 1981; Allen et al., 1985).

2.3.1.2 Cellular Automata Cities

A typical two-dimensional cellular automaton (CA) represents a matrix where each cell can have various states and attributes. The CA model is constructed through a sequence of iterations, where each cycle utilizes a new set of rules to determine the

status of every cell in the matrix. The principles used in this model are local and consider the connections and relationships between neighboring cells. The primary objective of a CA model is to investigate how interactions and connections between cells affect global characteristics, processes, and overall system behavior. These models can generate complex global structures and behaviors, making them attractive research and exploration tools. It is important to note that CA models have different concepts and principles of chaos than those used in everyday language and must be approached cautiously (Wolfram, 1983).

The cellular automata (CA) model has its roots in the concepts of self-replicating machines proposed by Alan Turing, the demonstration of such devices by John von Neumann, and John Conway's Game of Life, which was a simple form of a CA game (Gardner, 1971). These early ideas formed the foundation for developing the CA model, which has become a powerful tool for exploring complex systems and their emergent behaviors.

The cellular automata (CA) model is often used in studies related to self-organization and has been applied in various fields such as organic chemistry (Langton, 1986), physical science (Manneville et al., 1989), neuroscience and computer sciences (Demongeot et al., 1985), and the study of artificial life (Langton, 1986). The book "Laws of the Game" by Eigen and Winkler (1983) provides a comprehensive overview of the CA model, while for further exploration, references such as Wolfram (1984) and Toffoli & Margolus (1987) can be consulted.

Using differential equations in modeling self-organization often leads to repetitive calculations, making it less appealing. In contrast, cellular automata models are attractive for studying self-organization due to their ability to generate complex patterns and structures through local cell interactions.

> *"In the current scenario, where individuals are more interested in subjective outcomes, using complex mathematical equations to model self-organization may be avoided. Instead, more straightforward frameworks represented by cellular automata models are preferred. These models provide a more*

accessible way to study self-organization and its patterns (Mikhailov, 1990).”

In studying self-organization, there is a difference between differential equations and cellular automata (CA). When using differential equations, numerical models express the fundamental concepts of self-organization, such as order parameters or attractors. In contrast, these concepts are inferred or derived from the simulation's output when using CA. The evolution of attractors or order parameters is not calculated during the simulation itself but is instead calculated post-factum from the results of the CA game (Kuznetsov, 1998).

The use of Cellular Automata (CA) models in studying urban societies is a logical choice due to the fundamental similarities between the building blocks of natural urban communities and the CA models. The spatial units in natural urban communities, such as homes, lots, and city blocks, can be represented as discrete spatial units called cells in CA models. These cells' attributes are often resolved similarly to their neighboring cells, reflecting how spatial units in actual urban areas also share standard features with their neighbors. This similarity makes CA models a reliable tool for intuitively and mathematically simulating urban cycles. Tobler (1979) suggested that CA models could be used for "Cellular Geography," which involves modeling metropolitan and geological phenomena using CA models. Research utilizing CA modeling to investigate urban societies has become more prevalent in recent years.

The iterative design of CA algorithms helps generate fractal structures, which has been demonstrated by Batty (1997) in the context of urban communities. Batty showed that CA models could produce "fractal urban communities," unique and realistic urban environments. This is important because it connects the concepts of fractal urban communities with CA urban regions, creating a link between the two distinct features of various self-organizing urban communities.

2.3.1.3 FACS and IRN Cities

A simulation of a city can be developed with two layers. The first layer represents a conventional cellular automata (CA) city with a two-dimensional grid. The second layer is a superstructure of individual free agents who can move between cells in the city, have memories of the past and plans for the future, and move with purpose. These free agents are aware of recent events and their surroundings, and their perception is influenced by cognitive maps, which guide their decisions and actions. Essentially, each free agent is a virtual person who self-organizes as a system (Portugali, 2002).

The FACS (free agents on a cellular space) model is a city simulation consisting of two layers: a foundation layer representing a traditional CA city and a superstructure layer with individual free agents. The free agents move with purpose, have memories of the past and plans for the future, and their perception is emotional and influenced by cognitive maps. Each free agent is a self-organizing system that shapes the city, and the entire city functions as a self-organizing framework. The cyclical causality between the two self-organizing sub-systems at different scales produces a solitary arrangement of inner and outer representations. This model allows a better understanding of how individual actions shape the city and influence behavior. IRN (Inter-Representation Network) depicts the components of this model (Portugali, 2002).

The purpose of this new approach is to enable the assessment of self-organization at both the individual and global levels of a city to understand better how individuals' self-organization contributes to the overall self-organization of the city and how this, in turn, affects the self-organization of individuals. This technique goes beyond traditional self-organization studies that focus solely on the macro-level self-organization of the city while ignoring the micro-level self-organization of individuals or focusing solely on micro-level examples without considering their relationship to the larger scale. The aim is to provide a more comprehensive understanding of self-organization in urban systems (Portugali, 2002).

2.3.2 Pattern-Based Models (PBMs)

Pattern-Based Models focus on identifying and analyzing recurring patterns or structures within a system. These models explore the spatial or temporal arrangements of elements or components in a system and study their relationships. Patterns can be identified through various analytical methods such as statistical, fractal, or visual examination. Pattern-Based Models help reveal underlying principles or processes that generate or influence these patterns. By studying patterns, researchers can gain insights into complex systems' organization, dynamics, and emergent properties.

2.3.2.1 Sandpile Cities

> *"Consider building a sandpile where sand is added one piece at a time. As the pile grows, larger and more spectacular avalanches occur until a stable state is reached, where all avalanches happen, and the correlation length becomes infinite. This state is analogous to the equilibrium thermodynamic systems in its significance. The criticality of the state is self-organized since external fields do not need to be adjusted to bring the system to a critical state. This concept is known as self-organized criticality (SOC) and has been observed in various natural and artificial systems (Bak et al., 1987)."*

The sandpile system is characterized by two distinct features that remain constant throughout various locations, despite its instability. These features include more extensive and spectacular avalanches as the sandpile grows, ultimately leading to a stable state in which avalanches of all sizes occur and the system reaches a state of criticality. While the neighboring sand arrangements and other specific features may change due to these avalanches, the fundamental characteristics, such as the size distribution of the avalanches, remain remarkably constant (Bak, Chen, & Creutz, 1989). A well-known instance of self-organized criticality is the formation of sand piles. According to Bak, Chen, and Creutz (1989), Bak and Chen (1991), Batty

(1995, 1996), and Batty and Xie (1999), self-organized criticality theory is more precise, restricting, and detailed than other "grand" theories of self-organization such as dissipative structures and synergetics. The system is governed by a particular order parameter, which in the standard model mentioned above, is represented by the angle of the sandpile, with the control parameter being the addition of sand grains beyond a particular critical threshold. In this way, the internal dynamics of self-organized systems are altered during their steady-state phases. The theory becomes interesting because it reveals the potential complexity and richness of internal dynamics in a steady-state situation.

The observation that "the size distribution of avalanches remains essentially the same" reminds geographers of the old "rank-size rule." This rule states that the size distribution of urban settlements remains similar, even under conditions of continuous population growth. The rank-size rule is one of the few human geography examples exhibiting such quantitative consistency. Therefore, self-organization could provide a theoretical basis for spatial consistency, such as the rank-size rule, which has previously been criticized for lacking a theoretical foundation.

Batty and Xie (1999) proposed that self-organized criticality could help understand the dynamics of human environments in urban regions, which can be difficult to depict accurately with traditional methods. They suggested using a simple CA game called "Game of Life" to demonstrate the potential of self-organized criticality in urban studies. The study showed that the CA model produced self-organized criticality and a fractal interaction with a dimension of around 1.7 in the Game of Life (Bak, Chen & Creutz, 1989; Alstrom & Leao, 1994). The essence of self-organized importance is not the final quantifiable size distribution but the preceding cycle.

Batty and his colleagues proposed using self-organized criticality to study urban communities. They suggested that combining cellular automata and fractal urban places could provide detailed information on the finer-grained aspects of urban areas. However, they acknowledged that experimental investigations of the natural world

are necessary to obtain the quantitative data needed for these models. Deranged is currently using this theory to study Buffalo's development from 1750 to 1990 by focusing on more dynamic models (Batty et al., 1999).

In his work, Deranged claims that real-world urban communities exhibit the characteristics of self-organized criticality over time but acknowledges that there are technological challenges to applying the theory effectively. Batty and Xie (1999) similarly suggest that a combination of CA modeling and fractal analysis can provide quantifiable information about urban dynamics, but note that further developments are necessary for the theory to be successfully applied. A CA model was used to generate and study fractal urban structures, which were analyzed in the context of the self-organized criticality theory.

2.3.2.2 Fractal Cities

Mandelbrot's fractal calculation theory is based on self-similarity and fractal dimensions. Mandelbrot's theory proposes that simple repeating patterns may generate extremely complex geometrical structures. Batty and Longley apply these ideas to show how fractals can be used to model the intricate processes of urban structure, growth, and change on intra-metropolitan and inter-metropolitan scales.

The idea of self-organization is linked to fractal calculations through the concept of chaos. Boltzmann's strange attractor, which is a vital characteristic of chaos, has been observed to have self-similar directions that can be represented by a fractal of a size between 2 and 3. Fractals can also constitute a portion of the attractors or order parameters that regulate a self-organized system in its stable state. They create complex, self-similar shapes using fundamental iterative principles and have a fractal dimension (Mandelbrot, 1983).

Understanding how self-organizing urban environments work is based on the property of consistent state and order parameters. This means a city may have a specific ordering principle that guides its development and change rather than being

in equilibrium and stability, as described in Christaller's and Lösch's central place theories. Batty and Longley's book, "Fractal Cities," provides examples of how fractal urban communities may be used to understand this complex development and change. Batty and his colleagues have also developed express models using cellular automata models to create fractal metropolitan regions and analyze them regarding self-organized importance.

2.4 Chapter Summary

This part of the study examines the evolution of urban planning theories, starting with the critique of comprehensive planning in the mid-20th century. Comprehensive planning faced criticism for its top-down approach and inability to address cities' complex and unpredictable nature. The era of "communicative action" in planning emerged, emphasizing community involvement and diverse perspectives.

Contemporary approaches in urban planning are discussed, focusing on adaptive and flexible planning to accommodate the ever-changing nature of cities. The concept of complexity is introduced, along with complexity theory's contribution to understanding cities as complex adaptive systems.

The study introduces complex cities, characterized by non-linearity and unpredictability, and their impact on urban planning. The theories of dissipative, synergetic, and cellular automata approaches are explored, providing insights into working with the inherent complexities of cities.

Overall, the chapter highlights the shift towards more inclusive and responsive planning approaches that recognize and embrace the complexities of urban environments.

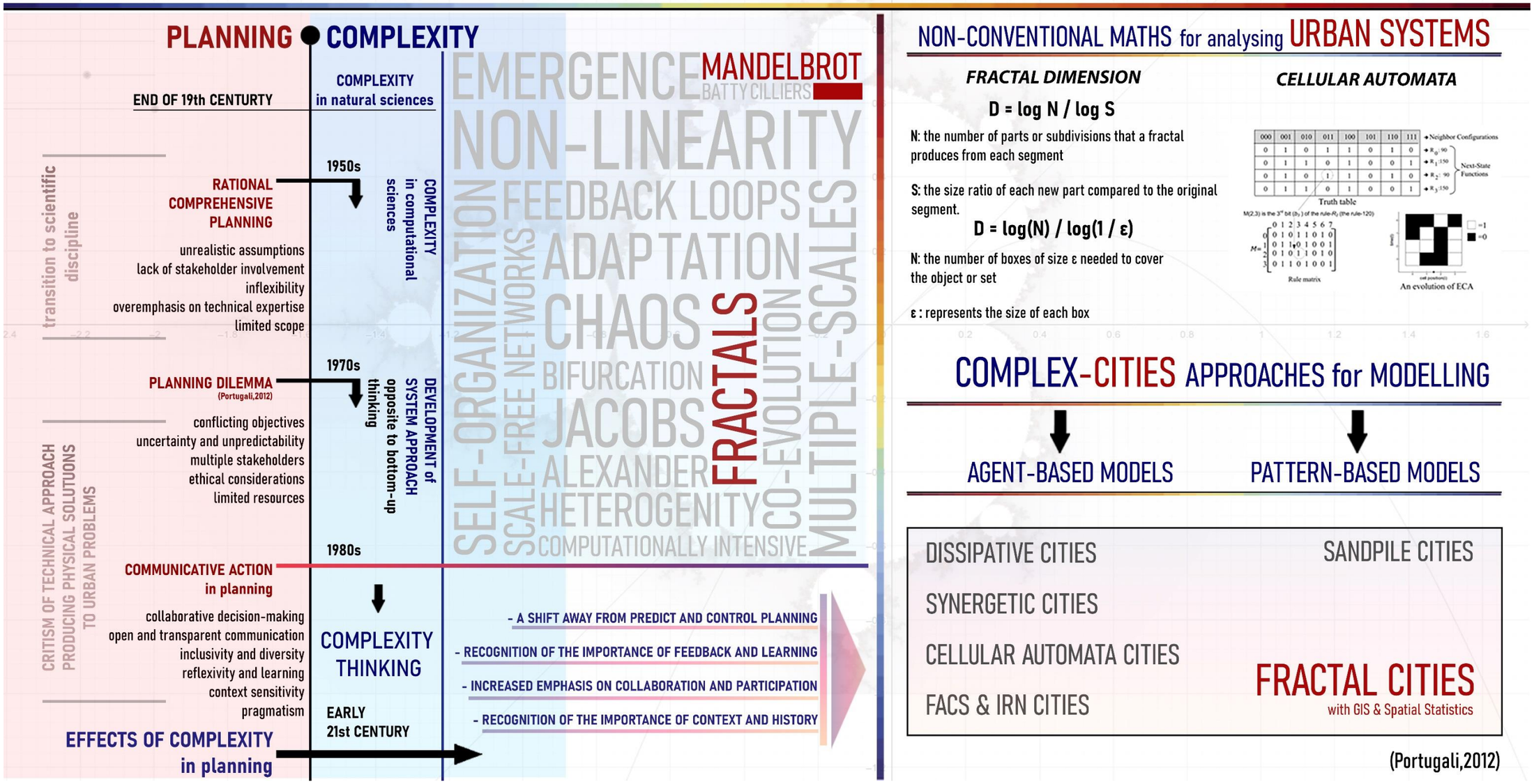


Figure 2.5 Progress of Urban Planning Theories

CHAPTER 3

CONTEXTUAL FRAMEWORKS FOR FRACTAL ANALYSIS

Fractals are complex geometric shapes that are self-similar at different scales. They have been used in a wide range of fields, including mathematics, physics, and engineering. This part of the study is starting with an introduction which is about the importance of fractal analysis for urban planners.

This chapter will also explore the definition of fractals and the subjects of advanced fractal analysis. Additionally, it will delve into the various applications of fractal geometry in urban planning and the analysis of road and city systems.

The use of fractals in these fields can provide new insights and solutions to complex problems. The chapter will demonstrate the significance of fractals in these areas and why they are an important topic of study. Finally, the chapter will be summarized.

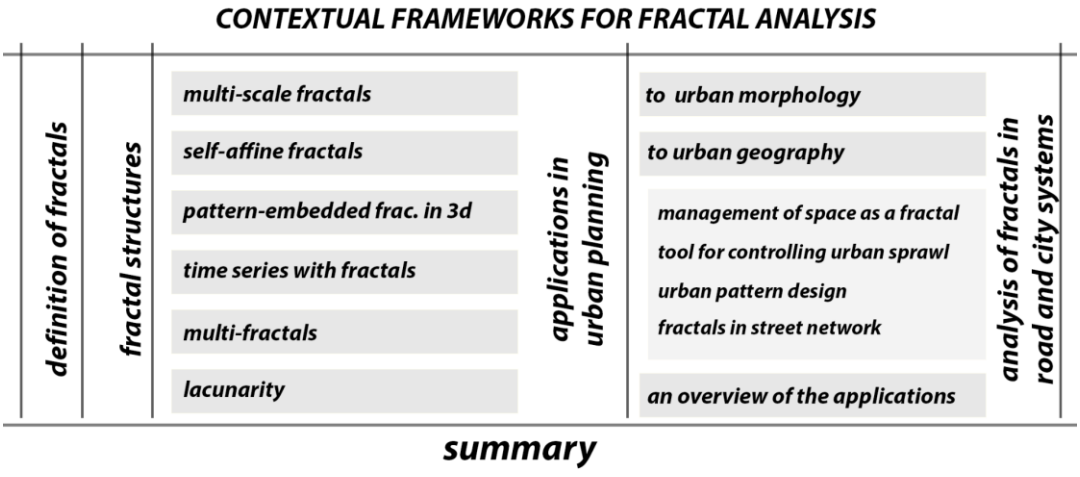


Figure 3.1 The Research Scheme for Fractal Analysis

3.1 Definition of Fractals

In physics, the main factors characterizing an item, space, or mass are time and space. Fractal is defined by Baranger (2001) as an object that is chaotic in space. Fractality is linked to quantum mechanics and relativity, according to Baranger (2000). Both theories are used to examine "elementary particles" with the goal of discovering fundamental laws of physics and the universe. Even though they originated as atoms, when seen at a microscopic scale, they are now composed of nuclei and electrons. As soon as the scale was improved, protons and neutrons took the place of atoms, and they were detected and classified as elementary particles. A few decades later, it is found that they are also formed of gluons, which are said to be produced in an infinite process, and quarks of various flavors. This turns particle physics into a significant fractal in space. Due to chaotic systems' ability to modify their configuration over time as a dynamical system, chaos in time has also been observed in addition to chaos in space. A distinguishing trait of time and chaos is "sensitivity to starting conditions." The butterfly effect was coined by E. Lorenz, the discoverer of sensitivity to beginning conditions. Because any slight uncertainty in the initial condition may occur, reductionism could not handle those systems. It has the potential to develop exponentially over time and become very enormous. The relationship between time-chaos and space-chaos is so strong that fractals might be considered as a probable outcome of time-chaos' protracted action. Complex systems are distinct from chaotic systems, despite the fact that they share some characteristics. Both systems, for example, have nonlinearity. Complex systems, on the other hand, have additional characteristics, such as;

- Complex systems are interrelated, and the total of the parts does not equal the whole.
- Complex systems have a structure that spans numerous scales, and a structure may be found at every scale.
- Global interactions in complex systems, which are emergent and self-organized, are the source of emergent behavior, which is scale-related and a

product of these interactions. It leads to self-organization by altering the structure and establishing a new structure. Complex adaptive systems have the capability of adapting to a changing environment. Complexity is only detectable in a chaotic environment. Simple fractals are chaotic while being uncomplicated. The interplay of chaos and non-chaos occurs at different scales in a complex system (Baranger, 2001).

Euclidean dimensions, which are based on Newtonian physics of deterministic natural sciences, might not apply to complex objects in the actual world. By examining the change in measurement result of length, area, or volume as a relation of numeric value or scaling factor, fractal analysis (Kaya & Bölen, 2017) is a novel method for measuring the amount of complexity instead of utilizing specific Euclidean parameters.

The word "fractal" was first used by Mandelbrot in 1983 to refer to entities whose shapes are intrinsically asymmetrical, size invariant, and self-similar. Fractal geometry is a spatial manifestation of chaos theory. According to Baranger (2001), fractals are chaotic things that do not get simpler when divided into ever-smaller pieces. According to Batty & Longley, a coastline, which is never linear and comprises space with twists and turns, is the prototypical example of a fractal (1994). Richardson's (1961) work on determining the length of coastlines and national boundaries prompted Mandelbrot to expand the idea via shoreline in his paper "How Long is the Coast of Britain" (1967). They have a Euclidian parameter of 1 to 2 and are shorter than a plane but longer than a straight line. Mountains have a fractal dimension of 2 to 3, which is greater than a surface but less than a volume, like the other natural fractal example.

Alternatively, the idea of fractal parameters contradicts reason. The article claims that instead of the conventional measurements of 0 (point), 1 (line), 2 (plane), and 3 (cube), fractals instead contain shattered proportions like 0.35 (an item that is more than a juncture but less than a connection) or 1.6 (more than a connection but less than a plain) (Portugali, 2011).

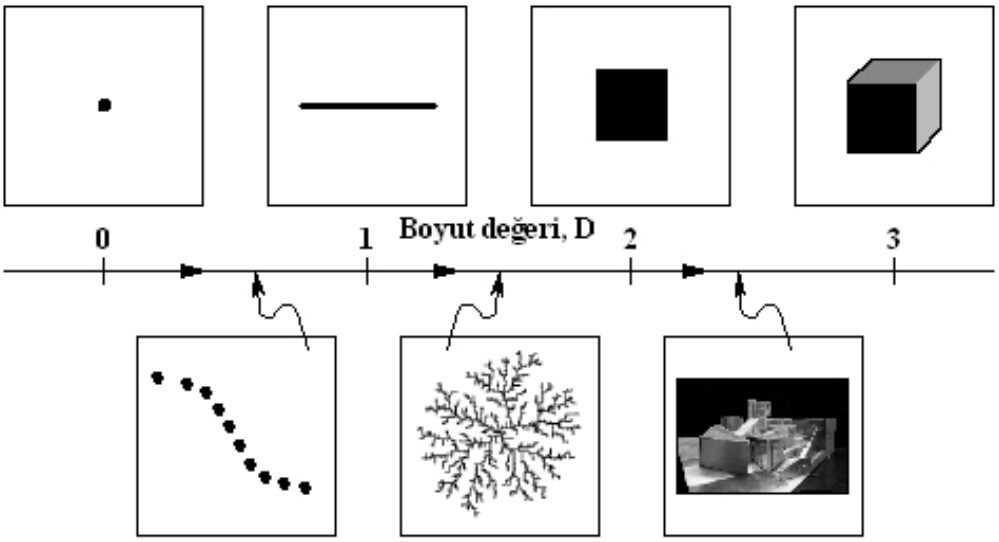


Figure 3.2 Euclidian and fractal dimensions (Kaya, 2003, p. 46)

The three main fractal principles are as follows (Batty & Longley, 1994);

- Fractals have always been self-similar; regardless of scale, they have the same structure or level of irregularity.

- Fractals are defined by a hierarchical order of self-similar elements such as trees, roads, and settlements.

- In terms of calculus, fractals are irregular and non-differentiable.

In nature, fractals have been encountered. A portion of the coast, a mountain range, trees, the physical figure, ferns of leaves, the layout of seismic fractures, the sky on a partially overcast day, and the waves on the ocean's surface are examples of natural fractals (Batty, 1995). They are pretty similar to one another and do not become more basic when seen through stronger lenses (Baranger, 2001).



Figure 3.3 Fractal self-similarity and iterative mechanisms (Yale, 2014; referenced in Erdoğan, 2014)

Fractal objects may be created artificially in addition to natural fractals. The fundamental aspects of fractal creation/generation and analysis are as follows:

- a material
- an initiator or generator
- the emerging shape (Mandelbrot, 1983; cited in Batty & Longley, 1994; McAdams, 2007).

By connecting the generator and initiator through a sequence or downscale, one may create straightforward fractals like the Koch Curve. By applying the generator again and again, the process went on forever, eventually reaching the limit. In 1904, Helge von Koch created the famous theoretical fractal known as the Koch Curve by using four copies of the original that were each one-third of its length as the generator and a linear connection as the initiator.

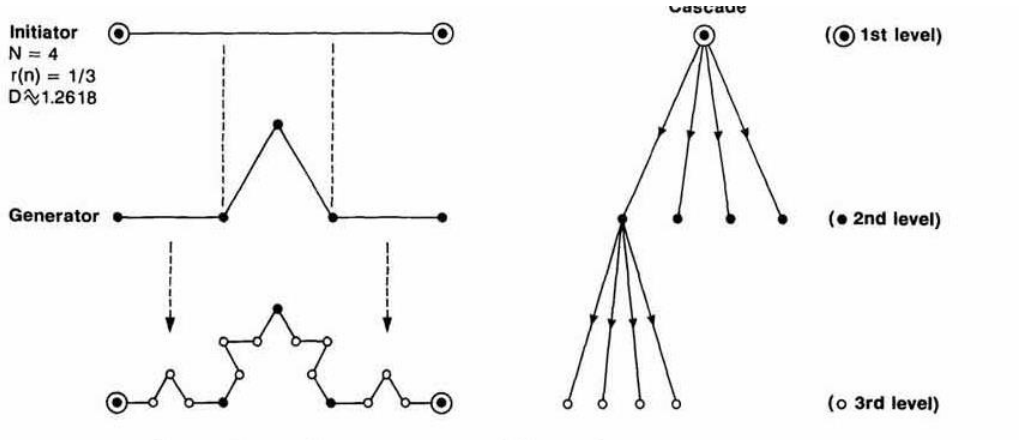


Figure 3.4 Development of the Koch Curve (Batty & Longley, 1994, p. 62)

The standard Koch curve has a fractal aspect of ‘1.262’. The Sierpinski's plate, the Dragon Curve, and the 'C' curve are examples of other theoretical fractals. The fractal aspect of a Sierpinski blanket is ‘1.585’. Particularly in the context of computer development, many fractals are purposely constructed to simplify repetitive operations.

3.2 The Subjects of Fractal Analysis

> *“The fundamentals of fractal geometry are easily understood and are now familiar to many middle schoolers. However, as one moves farther from the center, the visuals get more complex and the issues more confusing. They often do synchronize, low-to-high cliff dives (Mandelbrot, 2002, p.10).”*

In this part of the study, it is desired to go beyond the basic techniques and expand on the previously presented essential ideas to create a complete picture of various available concepts and strategies. The literature on fractals and their study is extensive. The majority of published material consists of mathematics and statistics. Numerous strategies have been created and used for a variety of phenomena. This chapter will introduce some of these essential types of fractal analysis. It also investigated *three-dimensional fractals, self-affinity, fractal time series, multifractals, and lacunarity.* In order to avoid overwhelming novices, it is tried to explain these concepts briefly naturally and skip specific mathematics. It is impossible to provide an exhaustive exegesis in the allotted area since some of these topics are substantial and might fill volumes.

> *“Complex systems do have structure, even if it may not be shallow or hierarchical. Hierarchy exists in a shallow structure. The most accessible approach would be via the structure of all sizes and interactions between structural elements. The self-organized criticality of complex systems could provide light on this component (Cilliers, P., 2000).”*

3.2.1 Multi-Scale Fractal Structures

Basic Definition: *A multiscale fractal is a fractal that exhibits self-similarity at multiple scales. This means that the fractal has the same overall shape at different levels of magnification, with each level revealing more detail and complexity. Multiscale fractals are commonly used in computer graphics and image processing, as well as in other fields such as physics and biology.*

A fractal design with various power law exponents controls different domain portions. These are called multiscaling fractals, and the figure below shows a sketch of such a graph. The double-log plot has two parallel lines with different slopes. Due to the link between line slope and fractal dimension, the fractal dimension alters at a critical point. This graph proposes numerous processes or mechanisms since the scaling link varies from regime to regime. Further study may reveal why the object's fractal behavior differs at that size or scale. Knowing the scaling regimes may change sample sizes and help explain the events (Burrough, 1981).

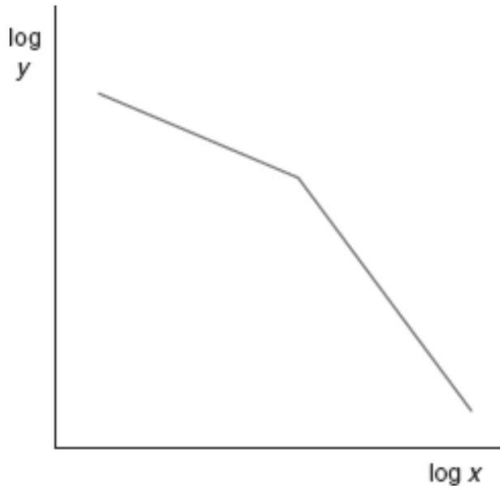


Figure 3.5 The graph showing two fractal dimensions in various areas of a hypothetical fractal connection (Burrough, 1981).

A basic illustration of ancient projectile tip morphologies is provided by Kennedy and Lin (1988). Stone arrowheads, spear tips, dart points, and other armatures are all referred to as "projectile points" in the field of archaeology. To create these tools,

pebbles like flint (chert), obsidian, quartz, and others are chipped down to the correct size and shape. The design and sophistication of a civilisation might be shown by its projectile points. Surprisingly, there is a wide variety of projectile shapes. Among the shifts are novel hafting techniques and interesting twists on the old ones. The blade and haft combine to form the tip of the projectile. Depending on preference, the blade may have concave or convex angles. Surfaces on hailing components might be stemmed, notched, flat, or concave. The shape of the weapon may be exposed if the projectile tip were to chip. Large, parallel chips run the length of some blades. Shorter chips down the spine that come together at the center are a feature of certain knives. Using fractal analysis, Kennedy and Lin discovered two fractal dimensions on the flat faces of projectile tip edges. There are two dimensions that best represent the processes responsible for the line's varying slants. It was Kennedy and Lin's opinion that fractal analysis was able to capture the scaling qualities of the tool's overall form at larger sizes and the chipping pattern at smaller scales. The fractal dimension provided a quantitative measure of the pattern's distinctive scaling qualities, which manifested themselves in the "structure" at large sizes and the "texture" at small sizes.

An object or phenomenon may have more than two fractal dimensions working at many scales. As the number of distinct scaling regimes increases, the log-log plot will curve. As their number grows, so does their importance. In social science, it is rare to discover a phenomenon spanning more than a few orders of magnitude. It can be represented to find fractal scaling behavior across at least one or two orders of magnitude in each occurrence to confirm self-similarity and scale invariance. Thus, for diverse scaling regimes, the practical top limit for fractal dimensions is 3 or 4. When the number of fractal dimensions increases in one instance, its interpretation may become murkier. Thus, many scaling regimes may be challenging to describe convincingly. If this explanation becomes complicated and unlikely, the fractal model loses its appeal as short and intelligent.

Note that*;* multi-scaling should be distinct from multifractals, which will be covered in the next section. As an added note, by saying "various fractal dimensions," it is

meant to values of the Hausdorff dimension and not to the information dimension or the correlation dimension, both of which exist and are relevant to the study of multifractals.

In urban planning, traditional fractal analysis, which only takes into account a single scale, is inadequate for studying patterns in the built environment, whereas multiscale fractals can. To better comprehend the interconnected nature of the built environment's many components, multiscale fractal analysis may examine these components at several sizes.

For instance, the multiscale fractals of a city's street network may help planners determine which parts of the network are the most and least efficient, which can then be used to guide investments in new transportation infrastructure and changes to zoning laws. Moreover, similarly, zoning and land use choices may be informed by evaluating the multiscale fractals of a city's land use patterns to determine where specific land uses are more strongly or weakly associated.

In summary, multiscale fractals may give a richer and more complex knowledge of the built world by evaluating patterns of many sizes. Urban planners may utilize this data to understand better the strengths and weaknesses of correlations between various land uses and the potential effects of actions on the overall system. Further, by studying the fractal dimension, planners may zero in on the sizes at which actions are most likely to have a domino impact.

3.2.2 Self-Affine Fractal Structures

Basic Definition: *A self-affine fractal is a fractal that is self-similar and has a different scale factor in different directions. This means that the fractal looks the same at different levels of magnification, but the scaling factor is not the same in all directions. This creates a fractal pattern that is anisotropic, or directionally dependent. Self-affine fractals are commonly found in natural phenomena such as*

coastlines, mountains, and river networks, and are used in fields such as geomorphology and image processing.

Inquiring into self-affinity is a logical next step when considering three-dimensional fractals. If every fractal were perfectly self-similar, the cosmos would seem complex but incredibly dull and predictable. Most fractals in the actual world exhibit statistical self-similarity rather than strict self-similarity. There are many more layers of complexity to the fractal behavior of certain occurrences. Fractals may manifest in the actual world in a wide range of surprising forms.

It is conceivable for the fractal activity of phenomena to be of one kind in one direction and another type in another. It is essential to remember that not all scales are created equal; consider topographic relief. The landscape is isotropic, meaning it is statistically identical in two distinct horizontal orientations. The average fractal dimension of a coastline or contour line is thus 1.26. The horizontal and vertical components are fractal. However, the vertical component has a somewhat lower scaling factor. Topographic maps may occasionally exaggerate the vertical dimension to emphasize relief when portraying a vertical slice or profile of the terrain. The vertical exaggeration is a result of several natural scaling considerations. In contrast to "self-similarity," an instance of "self-affinity" occurs when different characteristics of a phenomena scale in opposing directions.

In urban planning, self-affine fractals can be used to study patterns in the built environment that are not well captured by traditional fractal analysis, which only considers a single fractal dimension. By analyzing the built environment at multiple scales and identifying different degrees of roughness or roughness exponent, self-affine fractal analysis can provide a more detailed and nuanced understanding of how different elements of the built environment are interrelated.

For example, by analyzing the self-affine fractals of a city's street network, planners can identify areas where the network is more or less efficient, and use this information to inform decisions about transportation infrastructure investments and land use regulations. Similarly, by analyzing the self-affine fractals of a city's land

use patterns, planners can identify areas where different land uses are more strongly or weakly correlated, which can inform decisions about zoning and land use regulations.

In summary, self-affine fractals can provide a more detailed and nuanced understanding of the built environment by identifying patterns that have different degrees of roughness or roughness exponent at different scales. This information can inform urban planning decisions by identifying areas where interventions are more likely to have a ripple effect across the entire system and by identifying areas where different land uses are more strongly or weakly correlated.

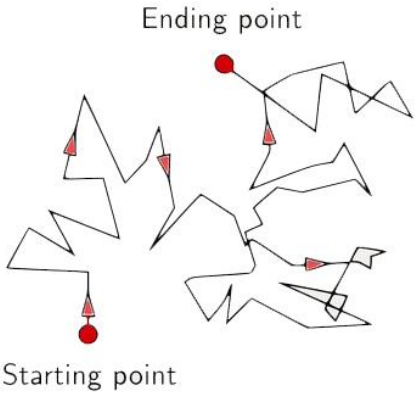
3.2.3 Time Series with Fractal Characteristics

Basic Definition: *A fractal time series is a type of time series data that exhibits self-similarity at multiple scales. In other words, the patterns that appear in the data at a given time scale are similar to the patterns that appear at other time scales. This means that the same patterns repeat in the data at different levels of granularity, creating a fractal-like structure.*

Fractal time series are common in many natural phenomena such as weather, stock market prices, and heart rate variability. They can be analyzed using fractal analysis techniques such as detrended fluctuation analysis (DFA) and multifractal detrended fluctuation analysis (MFDFA). These techniques can reveal information about the complexity and long-term statistical properties of the fractal time series, as well as help in forecasting future patterns.

In the discipline of statistics, the examination of time series is a separate subject that covers a vast amount of ground. The situation is similar in fractal statistics. It can briefly be discussed a few of the most fundamental ideas in this part of the study, which does not honestly do the topic credit; it indeed calls for its book. Because fractal time series are often self-affine, it is decided to discuss them after presenting the idea of self-affinity to avoid confusion.

One single variable, *y*, is tracked in a time series at discrete *t* intervals. These timespan specifications are rigidly enforced. However, there are specific approaches to assessing time series when the time intervals are left unspecified (not be covering any of them here). The study focuses on exploring other methods. Typically, the t-axis will be drawn horizontally when graphing time series, whereas the y-axis will be drawn vertically. When y is a random variable, whose values are drawn randomly from a normal distribution, the resulting signal will be uniformly distributed "white noise." Periods will progress independently of one another because of this circumstance. In addition, since positive and negative shifts cancel one another out, the average deviation from the mean will be zero.



$$P(x,t) = P_0 \frac{e^{-\frac{x^2}{4Dt}}}{2\sqrt{\pi Dt}}$$

Figure 3.6 Brownian Motion: Particle motion probability in a medium with a diffusion coefficient of D, given as a one-dimensional vector with respect to time (Falconer, 2003).

Brownian motion is a valuable model for analyzing time series. Particle motion in a colloid is explained by Brownian motion, so called after the botanist who first observed it. Brown (1828) observed the unpredictable motion of pollen particles suspended in water using a microscope. Pollen's movability lent credence to the idea that it has consciousness. Brown also grounds up various materials, including different kinds of stone, and looked at the resulting powders under the microscope. Even though the stone was not made of living stuff, he once again saw the unexpected motion of tiny particles. So, he realized he had observed a physical

process but thought incorrectly that he had seen the molecules that made up the different components of these things in motion.

The modern concept of Brownian motion may be traced back to Albert Einstein's contributions to statistical mechanics. Even though one of his most influential articles was published in 1905, Einstein is best known for his ideas of relativity (Einstein, 1956). In one of his first works, he suggests that minuscule particles' Brownian motion results from random collisions with molecules or atoms. The link between heat and diffusion is shown, lending credence to the atomic explanation of the matter. Moreover, he demonstrates that these changes are in keeping with standard Gaussian statistics (Einstein, 1956, p. 16).

Numerous approaches developed throughout time have been used to study the scaling characteristics of fractal time series. For instance, the variogram technique may be used simultaneously in studying surfaces and time series. The variogram is geostatistic that is often used. It establishes how much the average squared distances between the point amplitudes vary in relation to the horizontal distance separating the points. The comparison to the Hurst exponent is evident since this measure directly relates to how the variance changes over time in time series. Other methods include a roughness-length technique, a variance analysis method, a zero-crossing analysis method, and a detrended fluctuation analysis (Peng et al., 1994; Malinverno, 1990). These techniques were all individually created (Liebovitch & Yang, 1997). Numerous scholars, such as Liebovitch and Yang (1997), Liebovitch, Penzel, and Kantelhardt (2002), Bassingthwaighte and Raymond (1994), and Klinkenberg (1994), have compared and contrasted a variety of methods. However, it should be noted that the rescaled range method is sensitive to the length of the time series data available for analysis; lengthy series are highly desired for an accurate estimate.

In urban planning, Brownian motion can be used to model the random movement of people, vehicles, and goods within a city. By analyzing patterns of human mobility, planners can gain a deeper understanding of how different parts of the city are connected, and how changes to the transportation network, land use patterns, or

other elements of the built environment will impact the movement of people and goods.

For example, by analyzing the Brownian motion of people within a city, planners can identify areas where transportation infrastructure investments are most likely to have the greatest impact on reducing congestion, or identify areas where land use regulations could be modified to promote more sustainable patterns of development. Additionally, by analyzing the Brownian motion of goods within a city, planners can identify areas where logistics infrastructure investments are most likely to have the greatest impact on reducing congestion and improving the efficiency of the city's supply chain.

In summary, the movement of random particles may be studied using a mathematical model called Brownian motion. This model can be used to analyze a variety of phenomena, including human mobility, automotive traffic, and the movement of products in cities. By highlighting locations where actions are more likely to have a system-wide impact and by highlighting regions where various land uses are more strongly or weakly connected, understanding the patterns of these movements may help guide urban planning choices.

3.2.4 Multi-Fractal Structures

Basic Definition:

- *Multifractal is a term used to describe complex systems or patterns that exhibit self-similarity across multiple scales. This means that the system or pattern looks the same at different levels of magnification, but the scaling factor is not the same in all directions.*
- *Multifractals are characterized by a range of different fractal dimensions, rather than a single fractal dimension as in traditional fractals. This gives them a greater level of complexity and irregularity.*

- *Examples of multifractals include natural phenomena such as coastlines, mountains, and river networks, as well as man-made systems such as* ***urban areas****, financial markets, and internet traffic. They can be found in a wide range of fields such as physics, geomorphology, computer science, image processing and biology.*
- *Multifractal analysis is the process of quantifying and characterizing the multifractal nature of a system or pattern, and it can be used to understand the underlying dynamics and complexity of the system.*

Multifractals allow for the extension of fractal theory from sets to measures. A set's membership has a binary or Boolean feature. A measure differs from a set in that it is fundamentally based on quantity or size. As a consequence, measure in mathematics is more general than set. Multifractals are produced when the concept of self-similarity and related fractal technologies are applied to quantitative study (Evertsz & Mandelbrot, 1992).

As a result, multifractals do not deal with problems of presence or absence but rather with quantity, density, and concentration. Because all the boxes in the covering will be complete in the standard fractal dimension, they are helpful when the quantity of something being measured varies between locations. Therefore, they are applicable when something is present globally yet in varied quantities. Multifractals account for the current quantity by use of a quantifier.

To define a multifractal, it is sufficient to examine a number of related dimensions. The fractal dimension is the lowest dimension imaginable, whereas all other dimensions are just higher-order moments of the fractal dimension. When all dimensions are same, we refer to a fractal as homogenous. A phenomenon is multifractal if its dimensions vary with time in accordance with well-defined power laws. According to Turcotte (1997, pp. 113-129), a phenomenon is not multifractal if its dimensions do not adhere to power laws.

Although the multifractal technique has been used to analyze a wide range of natural phenomena (Turcotte, 1997, p. 129), the multifractal method has still found few

followers among social scientists. The calculations may seem challenging, or the procedures have not made their way from their origins in mathematics and physics into social research. Because multifractal analysis is not noticeably more challenging than monofractal analysis, analysts who work in the field should not be too dissuaded from trying to use it. However, on the other hand, the multifractal analysis does provide a few difficulties or drawbacks. The simplicity of expression offered by monofractal analysis is one of the method's most compelling selling points. Its classiness cannot be denied.

In urban planning, multifractal structures can be used to study patterns in the built environment that are not well captured by traditional fractal analysis, which only considers a single fractal dimension. By analyzing the built environment at multiple scales and identifying different levels of self-similarity, multifractal analysis can provide a more detailed and nuanced understanding of how different elements of the built environment are interrelated.

For example, by analyzing the multifractal dimension of land use patterns, planners can identify areas where different land uses (e.g., residential, commercial, industrial) are more strongly or weakly correlated, which can inform decisions about zoning and land use regulations. Similarly, by analyzing the multifractal dimension of transportation networks, planners can identify areas where transportation infrastructure investments are more likely to have a ripple effect on the rest of the network.

In summary, multifractal analysis of urban structures can offer a more comprehensive and sophisticated comprehension of the built environment, which can aid in making informed urban planning decisions by pinpointing regions where interventions are more likely to have a widespread impact on the system and by identifying areas where different land uses are more closely or loosely related.

3.3 Different Fractal Geometry Applications in Urban Planning

The mathematical notion of fractal geometry may be used to represent the self-similarity and complexity of natural systems, including urban landscapes. Among its applications in urban planning are:

- to examine the spatial arrangement of urban areas in order to detect patterns in the distribution of buildings, roadways, and other elements.
- to map the connectedness of a city and to identify places where citizens have easy access to services and facilities, as well as more secluded locations.
- to analyze the resilience of a city's infrastructure and identify regions that may be more susceptible to interruption, such as in the event of a natural catastrophe.
- to optimize the structure of transportation networks, including bus and subway systems, in order to increase accessibility and decrease travel times.
- *to estimate how a city will develop over time and to determine which regions are likely to see the most growth and change.*

Urban planners may employ fractal geometry to better comprehend and create more efficient, sustainable, and livable cities.

3.3.1 The use of fractal geometry to urban morphology

Urban morphology examines urban genesis, evolution, and change (Chen, 2014). This evolution is caused by natural and climatic factors. Over time, social, economic, and technical factors interact in metropolitan settings, transforming them (Mcadams, 2007). Fractal dimension helps explain space-filling and urban development (Y.-G. Chen, 2018). The fractal dimension may describe how space fills up. Hence, it can provide insight into how cities have changed over time (Chen, 2018). Fractal geometry is regarded as one of the cutting-edge approaches to studying urban morphology. Furthermore, as a novice in this field, two issues may arise after reading about the applications of fractals in urban morphology. First, what do "fractal" and

"fractal" usages for urban objects mean? A complicated geometric form known as a fractal seems self-similar at various sizes. Two criteria must be met for an item to be regarded as a fractal:

- power-law distribution and
- scale-free distribution (Kim et al., 2007).

The system's power law shows that it is scale-free and self-similar. Scale-free distribution indicates that items seem the same at various scales of observation. For instance, if we magnify a tiny portion of an item to an infinite level, the object's form stays similar across sizes (Kim et al., 2007; Lu et al., 2016). Traditional mathematics uses characteristic lengths (length, density, area, volume) to measure and compare things. However, an urban area is vast, with buildings and roads. Due to its concealed physical complexity, urban areas cannot be measured with such a typical scale (Chen, 2020). Urban areas are scale-free; therefore, physical attributes are measured relative to scale. It is scale-free since it has no characteristic length (Chen et al., 2017; Chen, 2018, 2020). Fractal geometry helps scale cities (Fankhauser,1998). Thus, fractal parameters may define urban form.

However, several empirical investigations have shown that cities are more like pre-fractals than actual fractals. While a pre-fractal has a restricted hierarchy, a fundamental fractal may be replicated to various levels (Chen, 2020). Numerous empirical investigations have demonstrated that, within a specific scaling range, a city exhibits fractal characteristics. Using fractals to display urban form and define urban growth requires fractal dimension. Numerous academics have used numerous forms of fractal dimensions; nevertheless, the box-counting methodology and match dimension are the most often employed ways for calculating fractal dimension. The box size is the most appropriate for expressing the spatial structure and systems of a city, whereas the others are utilized to depict scale-free distribution. Generally, fractal dimension values vary among 0 and 2 (Ariza-Villaverde et al., 2013).

3.3.2 The use of fractal geometry to urban geography

Using Euclidean geometry, researchers first described the intricacy, diversity, and irregularity of urban space. In its urban form, it was unsuccessful. Cities are complex physical configurations, not simple geometric forms. While scanning the coastline, Mandelbrot (1997) invented urban geography fractals. Mandelbrot discovered that the length of a shoreline increases with proper measuring scales, and on varied viewing scales, each component seems identical to the whole (Mandelbrot, 1967). After then, a number of academics used fractal theory to depict complex urban planning (Fankhauser, 1998, 2008). Depending on a city's creation, it may have begun in a central region and expanded outward. As the city develops outward from its core, it fragments. Due to a center-periphery imbalance, urban layouts are diverse. Self-similarity argues that both uninhabited and inhabited locations undergo continual change at different geographical scales (Arlinghaus, 1985; Shen, 2002). As a result, urban masses are neither dense nor sparse in terms of space. The farther one goes from the city's core, the lower the urban element density. Fractal geometry complements urban studies. Urban areas exhibit hierarchy (at the local, regional, and city levels), irregularity, and self-similarity as a result of their land-use structures, demographic structure, service density, and open spaces, among other characteristics, respectively (Tannier and Pumain, 2005).

Current studies of urban structure in several cities have shown that it exhibits multifractal properties (Man & Chen, 2020). Because of their multifractal nature, various parts of a city have varying fractal dimension values. Furthermore, as we go from the center of a fractal to its edges, the value of the fractal dimension decreases, providing a clear sign of urban development (Man & Chen, 2020).

- ***Management of space as a fractal:***

All too often, urban areas serve as the epicenter for a wide range of unwanted phenomena (such as air, noise, and water pollution). Humans cause nuisances when they interfere with or alter the natural environment. It not only has a negative effect

on people's health but also makes their day-to-day lives miserable. As a result, this suggests that many cities' dwellers value proximity to parks and other green spaces. As a result, the problem is intrinsically linked to issues of space administration and design. It is generally agreed that cities are complicated organisms. The intricate creation process is what gives rise to the phenomenon's inherent complexity. Cities take on their own forms as a result of the cumulative impact of several regional influences. Cities are often analyzed using fractals because of their complexity and irregularity. The "Fractal Dimension" measures a fractal's capacity to be complex, compact, and spatially heterogeneous all in one number (Jevric & Romanovich, 2016; Man & Chen, 2020). The value of fractal dimension tends to change depending on the abundance of green space in a given place. It's been shown that the value of the fractal dimension decreases as the amount of open space increases in an urban setting. Alternatively, dense urban centers will have a greater value (Shen, 2002; Wang et al., 2011).

The fractal dimension of urban boundaries is just as crucial for space management as urban regions. Planning for cities suggests making them denser by improving public utilities, preserving green spaces, and discouraging sprawl. A parameter for spatial development choices might be the fractal dimension value of the urban border and urban region. The fractal dimension value should be high in urban cores and low in urban peripheries for optimal spatial design. Denser, more uniform development with a propensity to provide more open space is indicated by a rise in metropolitan area FD and a fall in urban border FD (Jevri, Kneevi, Kalezi, et al., 2014). When the tendency goes in the other direction, it represents urban sprawl. There has been some research on this topic (Chen, 2011; Jevric & Romanovich, 2016).

- ***Fractals as a tool for controlling urban sprawl:***

Every vantage point reveals urban dynamics to be an intricate and ever-changing system. If urban sprawl is considered, these difficulties multiply. Although the term "urban sprawl" has been defined in a variety of ways by various experts, most definitions agree that it involves the spread of development outward, a lack of

density, the dispersion of land use, and the presence of breaks in continuity (Frenkel & Ashkenazi, 2008; Kaya & Terzi, 2008). Researchers have utilized various approaches across time and techniques to quantify urban sprawl. Sprawl index and density gradient are two of the most used techniques (Banai & DePriest, 2010). Several scholars in the last decade have put up fractal theory to quantify urban development (Terzi & Kaya, 2008, 2011). The notion of fractals is often used to characterize the spatial distribution of urban items. In terms of geometry, a city is a fractal. When cities expand outward, their built environments tend to cover the available land in a patchwork of directions and orientations. Therefore, several growth patterns are possible (Terzi & Kaya, 2011). The results indicate that the spread of urbanization reduces the fractal dimension (Terzi & Kaya, 2011). Values of fractal dimensions shift as cities grow. The value of the fractal dimension is often more excellent for localized growth. Using fractal dimension as a tool for quantifying sprawl seems promising (Terzi & Kaya, 2008, 2011).

- ***Urban pattern design using fractals:***

Cities often have both planned and unplanned sections, and their overall shapes are seldom uniform or precisely geometrical. When urban features (such as buildings, roads, and open spaces) are dispersed in a way that is not uniform, the result is irregularity (Jevri et al., 2014). The geographical distribution of urban components follows a power-law distribution, even if the underlying structural arrangement of items may look asymmetrical. The fractal dimension estimates the varying spatial extents of things. In metropolitan areas, the fractal dimension value changes depending on the pattern of item distribution. In a perfectly homogeneous city, the value is close to 2.

Additionally, if all of the people in a city were to congregate in one spot, like the downtown area, then the value would be zero (Kim et al., 2003). Space constraints and increasing urbanization pose significant difficulties for innovative urban pattern design. Most people need to be able to go to some green area right away. In light of this, cities should provide an equal amount of green space across the city. Here, we

may use fractal geometry to plan a landscape with a consistent distribution of green areas across many zoom levels. An increase in metropolitan area FD and a decrease in urban border FD are both indicative of more compact, uniform growth that tends to provide room for more greenery. Dispersed development, shown by the opposite tendency, indicates urban sprawl. As a result, this concept has the potential to contribute to improved city planning. Different options for urban patterns may be pursued depending on the amount of planning undertaken (Fankhauser, 2004, 2008; Jevri et al., 2014).

New studies show that the variety of city layouts results from local elements interacting through time to produce a globally coordinated pattern. As a result of the interplay of local forces, it exhibits a distinct hierarchical order when viewed at different length scales. Several kinds of research have shown that a little shift in local elements might result in a radical shift in urban patterns. Therefore, for the urban pattern to be fractal, the components inside it must be composed in a spatially hierarchical order (e.g., city center, sub-center, rural region) and distributed uniformly over various observation scales (Fankhauser, 2015).

- ***Using Fractals for Street Network:***

Almost all major cities have both organized and unorganized areas, and their overall shapes are seldom uniform or precisely geometrical. Urban areas need to be more organized because of the haphazard placement of their components (such as buildings, streets, and parks) (Jevric et al., 2014). Despite what may seem to be an ad hoc grouping of items, the geographical distribution of urban features follows a power-law distribution.

Fractal dimension measures the extent to which an item occupies space at different magnifications of an area's fractal dimension value shifts as its object distribution changes. When city characteristics are spread out evenly, the value is close to 2. Also, if all of a city's residents live in one area, like the downtown area, the value would be zero (K. S. Kim et al., 2003). Space constraints and growing populations are two of the biggest obstacles to developing innovative urban patterns. Most people

need to be able to go to some green areas quickly. As a result, cities need to provide more parks and other green spaces to their residents.

Fractal geometry is proper here because it allows us to create a landscape with a consistent distribution of green areas across several scales of observation. As was said before, an increase in metropolitan area FD and a decline in urban border FD suggest more compact, homogeneous development with a propensity to create more open space.

Urban sprawl, characterized by fragmented development, is shown by the inverse trend. Urban planners may benefit from this approach as a result. Several important considerations must be made at each planning stage, resulting in various potential outcomes for urban layouts (Fankhauser, 2004; 2008; Jevri et al., 2014). fractal, the components inside it must be composed in a spatially hierarchical order (e.g., city center, sub-center, rural region) and distributed uniformly over various observation scales (Fankhauser, 2015).

Multiple recent research (Long & Chen, 2021; Murcia et al., 2015; Pavón-Domnguez et al., 2018) have demonstrated that urban roadway networks exhibit multifractal properties. One of the main reasons why multifractal analysis is used is because a single fractal dimension is insufficient to deal with the local density fluctuation of a street network (Long & Chen, 2021; Murcia et al., 2015). As a result, it may be wondered, "what is multifractal?" According to the definition provided by Murcia et al. (2015), a multifractal is an object that displays a variety of fractal qualities over a range of sizes and locations. In contrast to popular belief, Pavón-Dominguez et al. (2018) found no correlation between road density and a road network's multifractal features. The distribution of road networks within an area and the connectivity of (national or regional) subnetworks are more critical factors. Long and Chen's (2021) study shows that road networks exhibit multifractal rather than fractal properties. However, multifractal properties (such as global vs. local fractal dimension) are not universal but are restricted to specific scaling ranges. In addition, the results of this investigation imply that the street system is not fractal but rather a fractal-like

system. Multifractal analysis' primary use is in identifying spatial issues within a system's architecture. When the desired growth level is compared to the actual development level, it may be seen as the root cause of the primary spatial gap or issue (Long & Chen, 2021).

The issue may be remedied by reorganizing the roadway network's physical layout to make the most use of available real estate (Masucci et al., 2013). Several factors, including the organization's hierarchical structure and the ever-changing land use character, make this process more complicated than it would otherwise be. Fractally shaped geometries are the key to this puzzle's solution (Long & Chen, 2021).

3.3.3 An overview of the research on the applications of fractal

The creation of cities and the dispersion of their parts have been shown in several studies to follow the fractal principle. The roadway network, land-use pattern, and element distributions in cities have all been proven to be hierarchical, self-similar, and diverse (Fankhauser, 1998a; Jevri et al., 2014, and others). Due to their importance in fractal geometry, they may be readily reduced to a single number by measuring their "fractal dimension." The "fractal dimension" is also a function of the capacity of urban objects to fill the space allocated to them (Kim et al., 2003a; Sreelekha et al., 2017a). Following the discoveries made in fractal geometry, urban geographers and analysts have looked for ways to implement the theory in real-world urban environments.

The qualities of fractal geometry are readily apparent in the urban form if it is examined it in light of these principles (Batty et al., 1989; Batty & Longley, 1994; Fankhauser, 1998a, 1998b; Salingaros, 2003). In addition, the form and structure of cities may be accurately described, and urban expansion can be quantified using fractal dimensions (Batty, 1991; Batty & Longley, 1987; Feng & Chen, 2010; Shen, 2002). Nevertheless, a few years later, it was found that cities take on multifractal properties (Chen, 2015; Chen & Wang, 2013; Frankhauser et al., 2018). Urban

hierarchies and road systems are excellent examples of multifractal patterns (e.g., local, regional, and national-level planning). However, one of the most pressing concerns is still up for debate: how can we include the fractal dimension in our decision-making? Unlike the distribution of streets, the FD-based explanation of the distribution of urban form features is more complex.

Table 1 An overview of the researches based on the applications of fractals

FIELD OF STUDY	RESEARCH SUB-FIELDS	RESEARCHERS	NUM.
urban formation	the morphology of urban lan use	(Batty & Longley, 1988; Feng & Chen, 2010; Purevtseren et al., 2018)	3
	urban growth and form	(Batty et al., 1989; Batty, 1991; Batty & Longley, 1994; Y. Chen et al., 2017; Man & Chen, 2020)	4
	urban morphology	(Batty et al., 1993; Y. Chen, 2020; Y.-G. Chen, 2018; Frankhauser, 1998a)	4
	urban pattern	(Frankhauser, 1998a, 2004, 2008; Jevrić et al., 2014b; Tannier et al., 2012)	5
sprawl management	urban border	(Jevric & Romanovich, 2016)	1
	urban agglomeration	(Frankhauser, 1998b)	1
	urban sprawl	(Terzi & Kaya, 2008b, 2011)	2
	urbanized area	(Y. Chen, 2015; Shen, 2002)	2
street network	urban road network analysis	(Benguigui, 1995; Dasari & Gupta, 2020; Kim et al., 2003b; Lu & Tang, 2004; Mo et al., 2015; Mohajeri et al., 2012; Rodin & Rodina, 2000; Sreelekha et al., 2017b; Sun et al., 2012; Wang et al., 2017; Zhang et al., 2021; Zhang & Li, 2012)	10
	multifractal characterization of road network	(Long & Chen, 2021; Murcio et al., 2015; Pavón-Domínguez et al., 2017, 2018)	4

Having an FD of 0 implies that the city's physical characteristics radiate out from a central location, while an FD of 2 shows that they are dispersed evenly across the urban area (Kim et al., 2003). It has been found by Sreelekha et al. (2017) that the most negligible value of the fractal dimension reflects the outer suburban zone, while the most significant value symbolizes the central business district. When urbanites scramble to replace unused land with new dwellings, the local government supports the region's burgeoning residential community. It increases traffic, noise, and air pollution in a city. They are incorporating fractal geometry into city planning and adding more green space. An increase in metropolitan area FD and a drop in urban border FD are indicators of more compact, homogenous development with a

propensity to provide more open space (Jevric, Kneevi, Kalezi, et al., 2014). If the tendency goes in the other direction, then urban sprawl is happening. Table 1 summarizes fractal applications in the built environment.

3.4 Data Types for Fractal Analysis of Cities

According to the research that has been conducted, fractal analysis of cities may be performed in one of three distinct methods, depending on the goals that are being sought to be achieved within urban planning.

- ***With the Macro-form Stain***

Fractal analysis is valuable for studying the built environment, particularly in urban macro form. This analysis focuses on cities' overall shape and structure, providing insights into their growth patterns and factors influencing urban development. By examining the macro form, researchers can track the evolution of cities over time, identifying trends and predicting future growth (Chen & Huang, 2018). This analysis helps uncover the underlying causes of changes in urban form and supports informed decision-making in urban planning.

One aspect of the fractal analysis is the assessment of urban compactness, which measures the degree of urban development and empty spaces within a city. Understanding the compactness of cities is crucial for evaluating environmental sustainability and resource efficiency. By examining the fractal characteristics of urban macro form, researchers can identify factors contributing to compactness, such as land use patterns, transportation infrastructure, and zoning regulations (Chen & Huang, 2018). This knowledge enables policymakers to make informed decisions about urban design, density, and land use to promote sustainable and livable cities.

Overall, fractal analysis of the urban macro form provides valuable insights into cities' growth, structure, and sustainability. It aids in understanding the dynamics of urban development, predicting future trends, and identifying strategies for efficient and well-designed cities. By incorporating fractal analysis into urban planning

processes, decision-makers can better address urbanization's complex challenges and opportunities (Chen & Huang, 2018).

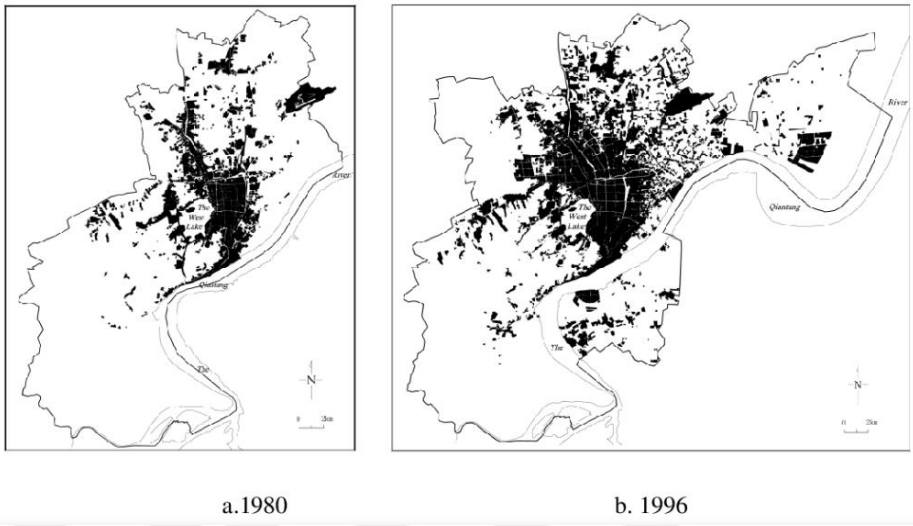


Figure 3.6 The example of Fractal Analysis by using Urban Macro-form Stain (Chen & Huang, 2018)

- ***With the Urban Road Network***

The second is the analysis carried out on the road systems of the cities. It aims to observe the changes in the cities, which is a dynamic system, over time, through the road system (Zhang, Hong & Lan, Tian & Li, Wen. 2021). With this method, the development direction of cities, areas of development, and change can be observed.

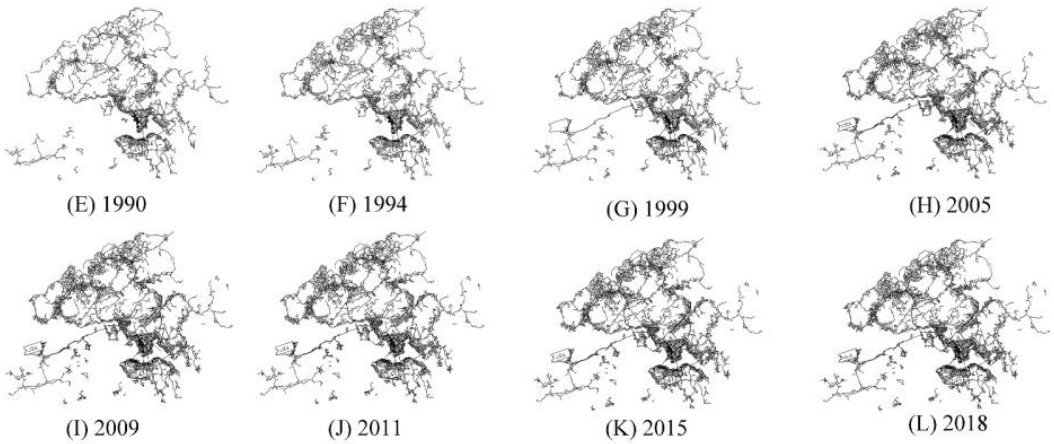


Figure 3.7 Honkong Street Network by Years, (Zhang, Hong & Lan, Tian & Li, Wen. 2021)

- ***With the Built Environment of City Structure***

The third, fractal analysis can also be done by using elements such as buildings, roads, and green areas in the built environment. For this, the lacunarity method is generally used. Lacunarity is a concept, as mentioned before, used in fractal analysis to describe the distribution of empty spaces in a fractal structure, such as the built environment (Lagarias & Prastacos, 2020). In general, fractal analysis of the built environment using lacunarity involves the following steps:

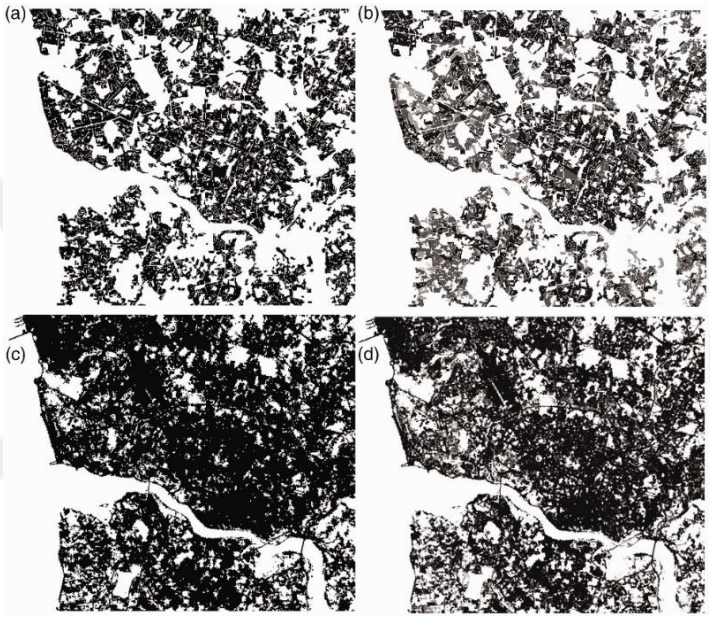


Figure 3.8 An Example from Southern Europeans Cities for Lacunarity analysis (Lagarias & Prastacos, 2020).

Defining the region of interest: This involves selecting the part of the built environment desired to analyze.

Identifying the voids: It involves finding empty spaces in the region of interest, such as spaces between buildings or roads.

Calculating lacunarity: This involves using a mathematical formula to quantify the variability of the size and distribution of the voids in the region of interest.

Analyzing the results: This involves interpreting the lacunarity values to understand the spatial arrangement of building elements in the region of interest.

The result of the fractal analysis can provide insights into the structure of the built environment, such as the distribution of empty spaces and the arrangement of building elements (Lagarias & Prastacos, 2020).

3.5 Analysis of Fractals in Road and City Systems

The urban transport network is a classic fractal system that may be used to assess complexity and expansion. That is to say, an urban transport system is a common fractal framework, and researches characterizing a city's road system using fractal geometry have proved to be useful (Batty & Longley, 1994), (Shen, 1997; Chen and Luo, 1998; Shen, 2002; Lu&Tang, 2004; Avineri, 2010; Thomas et al., 2011; Thomas&Frankhauser, 2013; Wang et all, 2016, Sreelekha et all, 2015; Lu et all, 2016, Lan et al., 2019). The formula for determining the complexity of road networks is as follows:

$$D_{L_i} = -\ln\left(\frac{N_i}{N_{i-1}}\right) \Big/ \ln\left(\frac{L_i}{L_{i-1}}\right)$$

where N_i is the number of cells with streets for the grid's ith level, and L_i denotes the cell size. From left to right, the D values for the four graphs demonstrate that how fractal dimension may represent space filled by distinct linear features on a continual scale (Lu &Tang, 2004).

Urban zonings are complex, according to McAdams (2007), and remote-sensing datasets may not capture the intricate or multi-layered network of geographies. The spatial structure of the roadways and their complexity parameters, in addition to the total length of the transport network, can be linked to urban expansion (Lu & Tang, 2004). The findings show that fractal dimension of urban networks conform power-law (Chen, 2008, Thomas & Frankhauser, 2013) while in a self-organized critical condition and exponential law otherwise (Chen & Jiang, 2016).

A basic linear structure is a metropolitan road network. For fractal analysis of line characteristics, there are commonly three sets of techniques:

- First, *the technique of line-walking is as follows:* A base line is defined for each step by measuring the length while maintaining the geometrical form of a line feature. There are several approaches that differ from one another based on the beginning juncture of the starting lane (Batty & Longley, 1994).

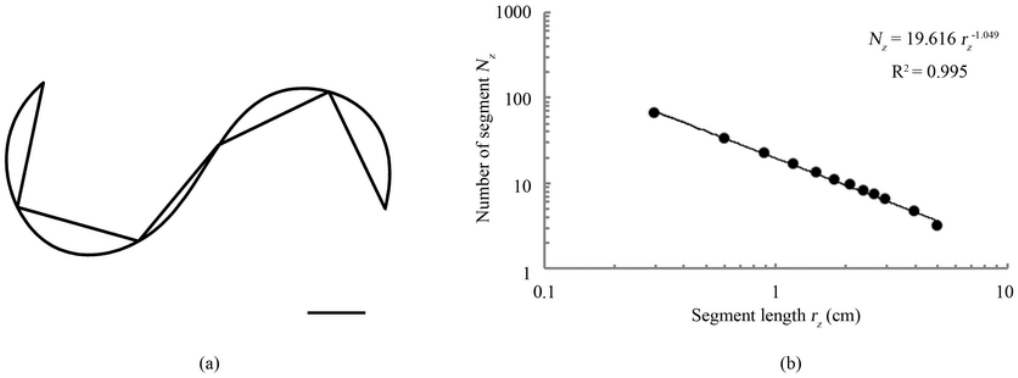


Figure 3.9 The fractal aspect analysis approach of lane walking (Losa, et al., 2016)

- Second, *the technique of calculating the length-area relationship is as follows:* The approach focuses on determining the link between line feature lengths and the regions they encompass. This is used to show the link between line feature lengths and the regions they cover or service. The supposition that there is a single centre dot that could be evaluated as the lanes' distribution zone is the major flaw. Additionally, achieving a service area based on road size may result in deficiencies (Lu & Tang, 2004).

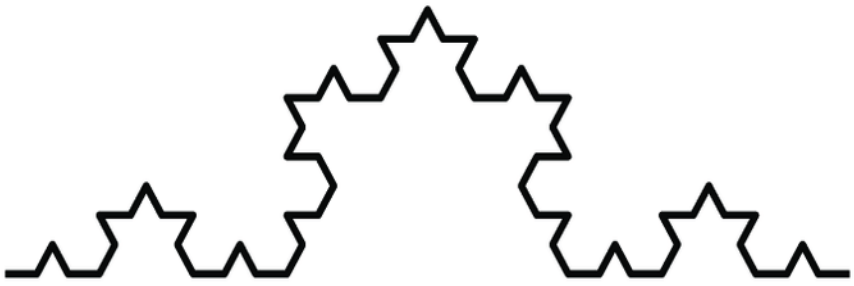


Figure 3.10 A Koch Curve's length area measurement technique (Yale, 2014)

- Third, *the box-counting (or cell-counting) approach consists of the following steps:* Its purpose is to cover the research area with a homogenous square netting whose dimension is determined by a limited set of values. A regression function is used to calculate the size of the cell and the number of cells containing the line characteristic. This approach necessitates the detection and change of cell sizes. The following is an explanation of the box-counting approach for assessing the fractal structure of transport networks:

$$\ln N_s = A + D \ln\left(\frac{1}{s}\right) + E_s ,$$

A stand for the intersection, *E* for the error term, and *D* for the fractal degree of the line characteristic being studied.

The method is continued for larger and larger squares until the experimental curve is suited to a theorized curve that corresponds to a fractal rule. A pseudo-R2 is used to determine the quality of fitness (Lu&Tang, 2004).

The lower fractal aspect of the street connectivity corresponds the intensity of the systems and achieved through core locations, according to research based on urban macroforms. In suburban regions, on the other hand, fractal dimension rises as you go closer to more central locations (Le et al., 2016), (Sun et al., 2007), (Thomas & Frankhauser, 2013). According to Shen (1997), bigger cities have a greater fractal scale. According to the findings, heavily inhabited locations have larger network fractal dimensions According to Shen (1997), bigger cities have a greater fractal scale. The findings, heavily inhabited locations have larger network fractal dimensions (Rodin&Rodina, 2000), (Shen, 2002), (Sun et al, 2007), (Thomas&Frankhauser, 2013). The outcomes might be read as a positive association between the network's fractal dimension and density, similar to what has been found in urban border or solid-void investigations. The outcomes might be read as a positive association between the network's fractal dimension and density, similar to

what has been found in urban border or solid-void investigations. Another discovery may be viewed as higher fractal dimension values being shown by more established and greater cities with a more developed transportation infrastructure (Lu & Tang, 2004), (Lu et al, 2016). Whereas network frequency has been shown to have a positive relationship with fractal dimension (Thomas & Frankhauser, 2013; Lu et al., 2016; Wang et al., 2017), it is still unknown if the distance of a transport network as a whole is related to how complex the connection structure is (Lu & Tang, 2004).

The fractal dimensions of systems and built environments might change due to topological variations. According to Thomas & Frankhauser (2013), networks are more hypertrophic than built form because;

- The distribution of buildings along the transportation network is not necessarily constant.
- Streets not only link buildings on a local level, but they also integrate people to the rest of the globe (containing transit streams),
- Access to unurbanized regions must also be provided through streets (open areas, agricultural areas and forests),

According to Thomas and Frankhauser's research, the fractal diameter of the street network is higher than the fractal diameter of the urban fabric in Antwrep, with mean values of 1.525 and 1.690, accordingly. Conversely, the fractal diameter of the transport network in Greater Montreal (1.732) is lower than the fractal aspect of the metropolitan limit (1.858). In the matter of regional research, it is predicted that the results at the city scale will fall between 1 and 2. Lu and Tang examined at the transport network in the Dallas municipal area, which included eleven districts. It is noted that around 50% of the towns have a fractal diameter of 1.2 to 1.4, and 81% have a fractal diameter of 1.1 to 1.5. In lower and higher orientations, the fractal parameter of the same town's macroform or transportation network might vary. Conversely, it is also claimed that fractal aspect for city systems might be estimated between 0 and 1 (François era lii, 1995; cited in Myint & Lam, 2005),

(Lu&Tang, 2004), (Thomas & Frankhauser, 2013). By way of explanation, a mixture of multiple forms of fractal tendencies at various sizes might be noticed in an intra-urban spatial arrangement.

3.6 Chapter Summary

This part of the study provides an in-depth examination of the use of fractals in urban planning, including the definition, applications, and the most recent advancements in this field. After discussing the importance of fractal analysis as a tool to understand the cities and their complex structure for planning proffesionals, the chapter starts with a detailed explanation of fractals, which are mathematical patterns that repeat at different scales, and their importance in understanding patterns in the built environment. This part then delves into the subjects of advanced fractal analysis, including techniques such as, multifractals, and self-affine fractals, which provide a more detailed and nuanced understanding of the built environment. These techniques allow for the quantification of fractal patterns and methods for studying their spatial and temporal dynamics.

This part of the study also discusses different fractal geometry applications in urban planning, including analyzing land use patterns, transportation networks, and building layouts. The different fractal dimensions, and multifractal analysis can be applied to these elements. It provides insight into how they are interrelated and how changes to one element may impact the others. The chapter also provides examples of how these techniques can inform decision-making and support sustainable urban planning.

This study discusses for what purposes and in which forms fractal analysis can be used at the scale of metropolitan cities. The first of these methods is using the city's macro-form stain to analyze the complexity of urban sprawl, growth, and compactness. Secondly, it is aimed to use the road network of cities for fractal analysis and to observe the development direction of cities, which are a dynamic

system, over time, and the level of complexity of development and change areas. Third, how fractal analysis can be applied to urban systems with the lacunarity method over the built environment is given.

The chapter also covers the use of fractals in road and city systems. It explains how the fractal analysis calculations will be made in the following parts of the study.

Overall, this chapter provides a comprehensive overview of the use of fractals in urban planning and the recent advancements in this field. It provides a detailed explanation of the various fractal analysis techniques and their applications in different aspects of urban planning and highlights their potential for informing decision-making and promoting sustainable urban development.

CHAPTER 4

PLANNING IN THE IZMIR CITY

Izmir has become one of Turkey's largest cities and has served as one of the first examples of Turkish urban planning. The planning processes in Izmir developed in parallel with critical milestones in Turkey's political and social history and, with some delay, followed the emerging planning procedures created in the West. Throughout the Republican era in Izmir, seven metropolitan planning strategies were executed. Each corresponded to a different period in Turkey's history, carried out by separate institutions, and based on distinct theoretical methods.

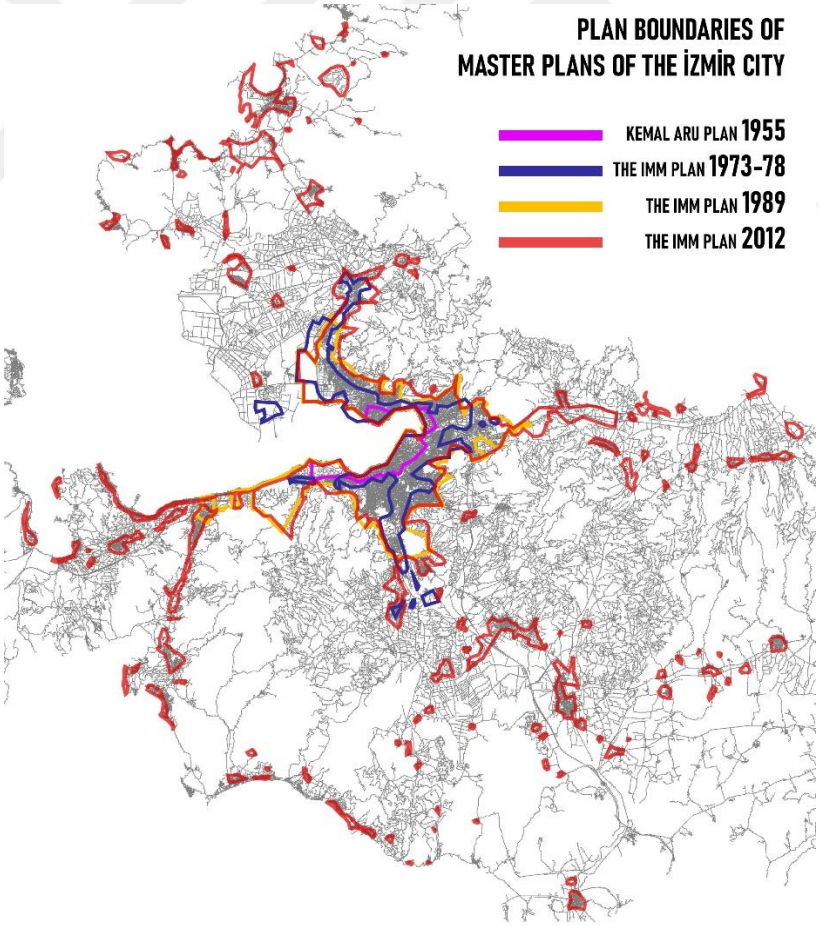


Figure 4.1 The Plan Boundaries of the Master Plans of İzmir City

1. The Danger and Prost plan, which was authorized in 1925 and amended by city employees in 1933.
2. Le Corbusier's proposal was finished in 1949 but not accepted.
3. Aru, Özdeş, and Canpolat developed a competition proposal in 1952, which was refined by the planning department of the Municipal government of İzmir with Aru's help and authorized in 1955.
4. In 1960, the Ministry of Development and Settlement finished and assessed Albert Bodmer's design, but it was not accepted.
5. Metropolitan Planning Office's plan was finished in 1972, authorized in 1973, and amended in 1978.
6. In 1989, the Metropolitan Municipality authorized a plan.
7. The Environmental Plan of the Metropolitan Municipality of İzmir in 2012.

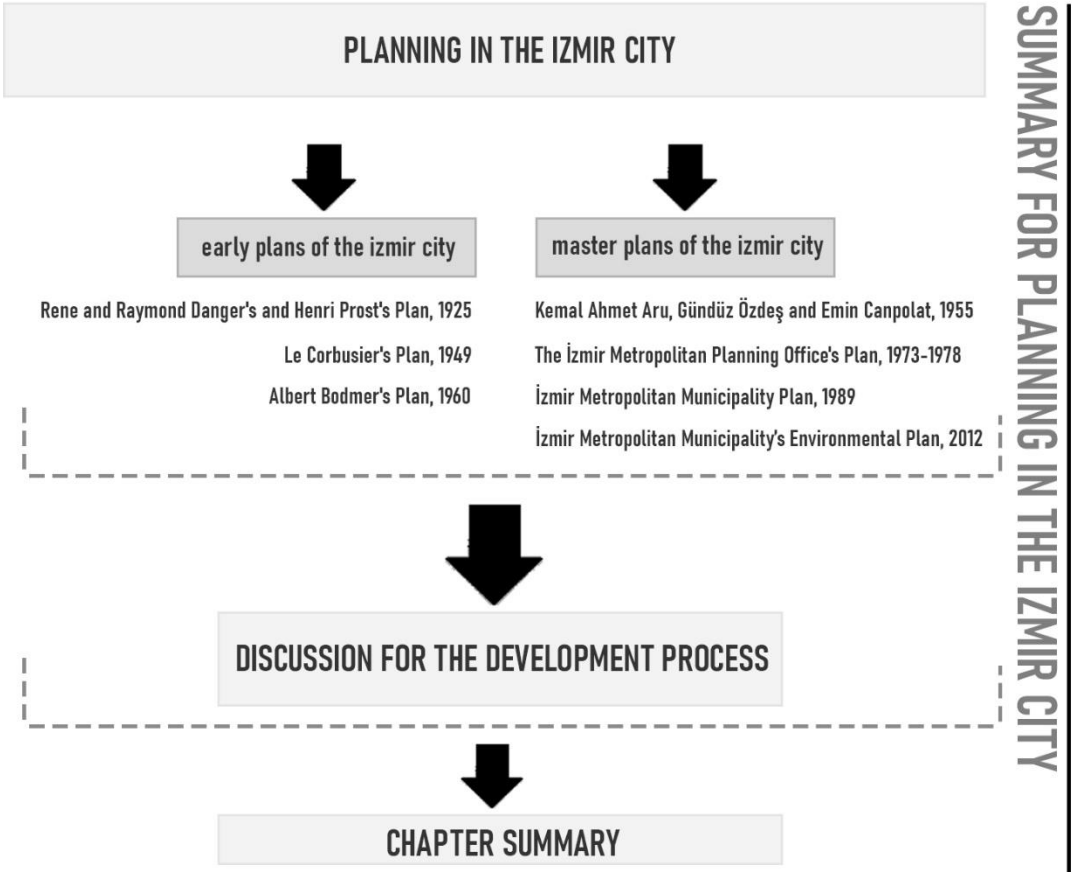


Figure 4.2 Flow Chart for Planning Processes of the İzmir City

4.1 Early Plans of the Izmir City

4.1.1 Rene and Raymond Danger's and Henri Prost's Plan, 1925

The establishment of the Republic of Turkey in 1923 marked a turning point in urban planning. The government prioritized the planning and design of cities, starting with a master plan for İzmir in 1925. International experts contributed modernist planning ideas. The plan consisted of two stages: analyzing existing conditions and formulating a strategic vision, followed by a revision in 1933 to accommodate changing economic and social factors. The revised plan focused on integrating transportation systems, developing industries, and commercial centers.

The Early Republican Period's Spatial Structure in İzmir

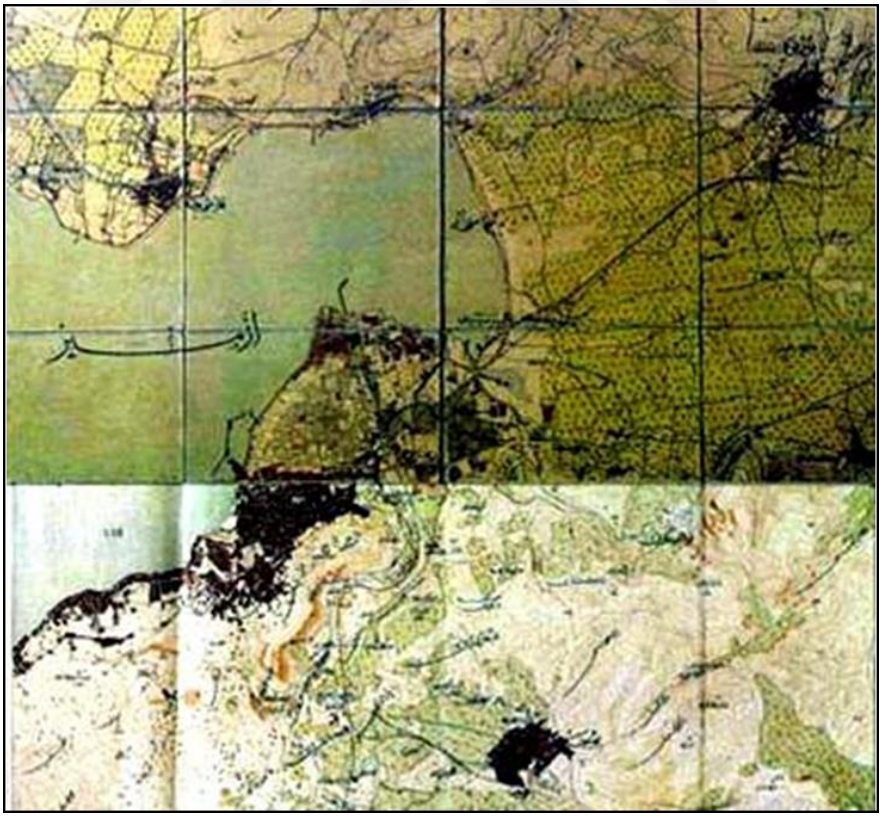


Figure 4.3 İzmir in the early twentieth century (Archives of the İzmir Metropolitan Municipality)

The metropolis's populace was around 150.000 at the time of the first metropolitan planning attempt. It was divided between a core section, which included the areas of Konak, Alsancak, and Güzelyalı, and a subcenter, Karşyaka, which was linked to the core by water transport; Agamemnon geothermal facilities and İnciraltı beach as leisure sites; Bornova and Buca as suburbs linked to this center section by railroad transit. This area had three townships: the Town of İzmir, founded in 1871; the Town of Bornova, founded in 1881; and the Town of Buca, founded in 1923.

The 1925 Master Plan: Planning Process and Preparation

There was no broad attempt to plan İzmir until the Republican era, as there was for the rest of Turkish towns. Instead, there were piecemeal actions in arranging the urban area for new necessities.



Figure 4.4 Alsancak District after IndependenceWar, 1923, (YA, 09.09.1964)

During the Independence War, İzmir and other Aegean communities suffered extensive damage. The federal and municipal governments sought assistance from European specialists to aid in their reconstruction. Minister Şükrü Kaya, the former mayor of İzmir, played a vital role in connecting with French architects, including Henri Prost, who recommended René and Raymond Danger. René Danger was contracted in 1924 to draft an urban plan for İzmir, with advisory support from Prost. The plan aimed to rebuild war-damaged areas, develop İzmir as a regional economic center, and meet the needs of modern society (Tekeli, 1980).

At the outset of the plan development process, a panel consisting of architects, engineers, and doctors from the municipal government, in collaboration with René Danger, established the primary criteria for the city. The plan encompassed the following key objectives:

- Consolidating the two railway stations in a location away from the downtown area.
- Relocating the harbor infrastructure and constructing a new harbor that would directly connect to the railroad and industrial sectors.
- Identifying new residential zones to reduce population density in existing urban areas.
- Improving the city's transportation routes and access.
- Constructing the new city on previously damaged land, despite the suggestion being rejected by René Danger. However, the committee persisted in advocating for this approach (Bilsel, 1997).

Within the municipal boundaries, the plan incorporated the primary İzmir areas of Alsancak, Konak, and Karataş but excluded the sub-center of Karşıyaka. Upon completing the planning activities, the Ministry of Reconstruction approved the proposal in 1925.

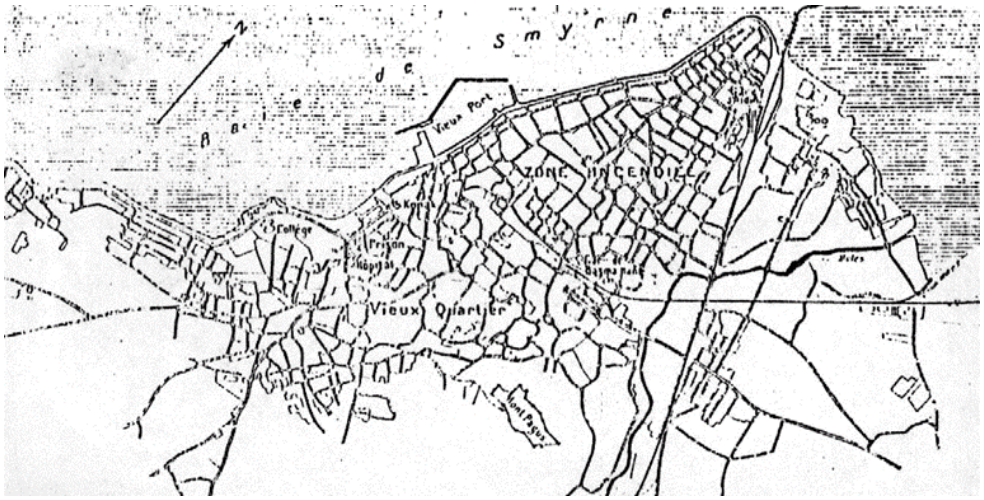


Figure 4.5 İzmir City Map from the 1920s, (Bilsel, 1996)

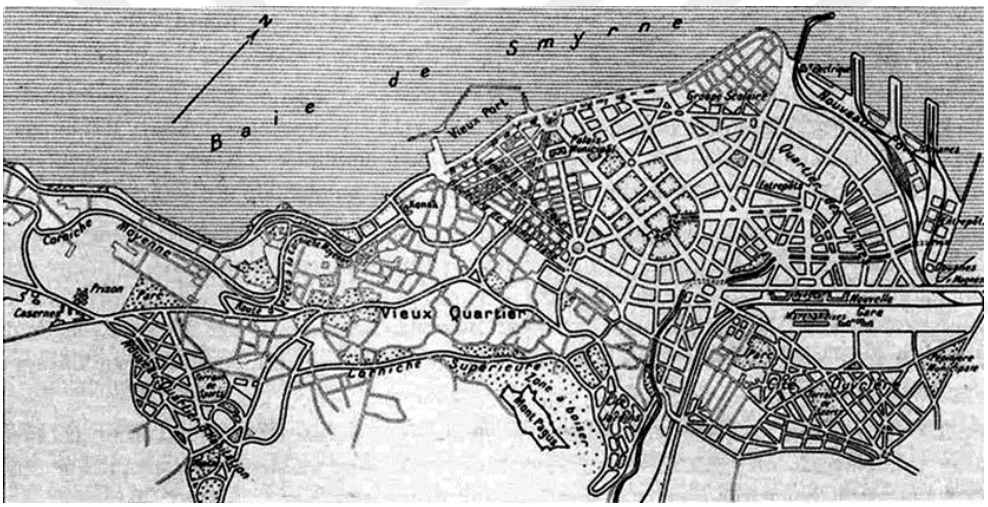


Figure 4.6 Danger and Prost's Proposal, 1925

(İzmir Metropolitan Municipality Archives)

Revision Plan of 1933: Planning Process and Preparation

After the Great Depression, Turkey faced economic challenges, leading to state-controlled fiscal policies. In 1933, a five-year growth plan focused on industrial development was adopted. İzmir was selected to host a global trade fair in 1934 to boost the economy. In preparation, the Danger plan was revised, allocating a 43-

hectare parkland surrounded by residential areas in Alsancak. The parkland was expanded later on.

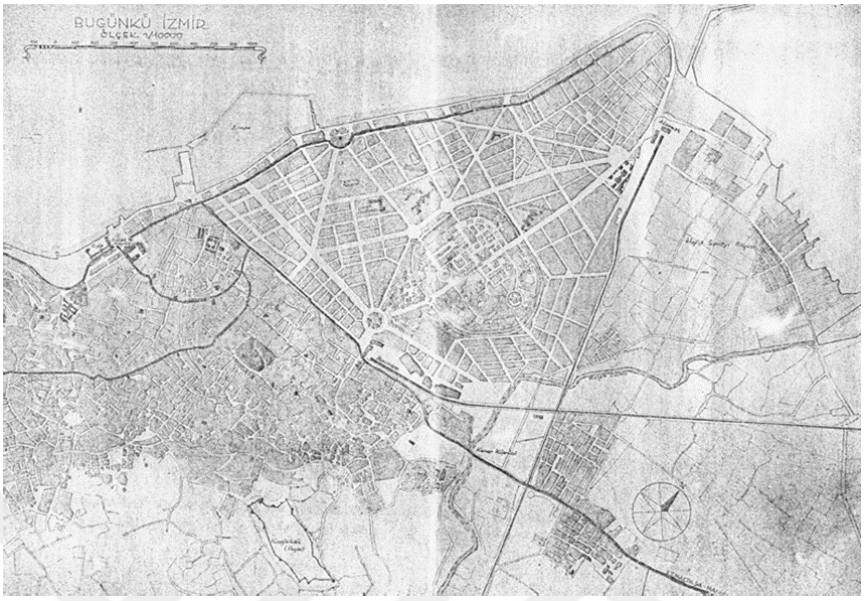


Figure 4.7 In 1933, the Danger Revision Plan for the Alsancak and Çankaya Districts (Canpolat, 1954)

Theoretical Fundamentals and Implementation

The Danger and Prost plan for İzmir aimed to introduce a modern planning system and cater to the bourgeoisie class. Inspired by the French model, it focused on the spatial arrangement of the city and employed a radial layout with boulevards, civic structures, and public spaces. The plan aimed to regenerate areas affected by the fire while preserving traditional neighborhoods. The allocation of distinct areas for different functions did not emphasize rigid zoning regulations, as the focus was on creating an environmentally sustainable city with a low-rise, low-density urban fabric. The plan aligned with Turkey's modernization aspirations and societal reorganization efforts (Tekeli, 1980).

During Mayor Behçet Uz's tenure (1931-1941), there was progress in implementing the Danger and Prost plan in İzmir. Key developments included the construction of fire agency buildings, the installation of the Atatürk statue in Cumhuriyet Plaza, the

transformation of the Dokuz Eylül Festival site into a fair relocated to Kültürpark, and the development of surrounding areas of Kültürpark. Some cemeteries were transformed into eco-friendly spaces, such as Faik Ener Park and Cumhuriyet Grove, and recreational areas and playgrounds were established.

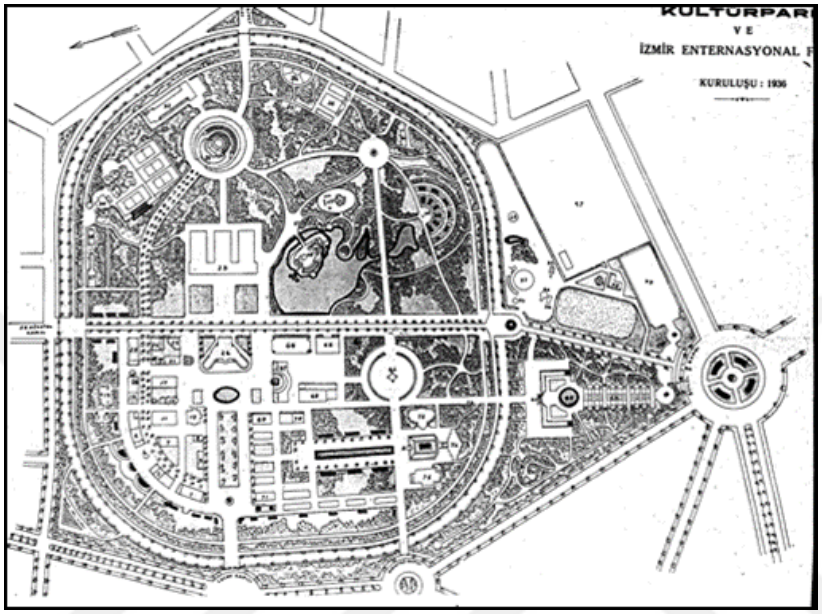


Figure 4.8 Kültürpark, 1936 (İzmir City Guide, 1943)

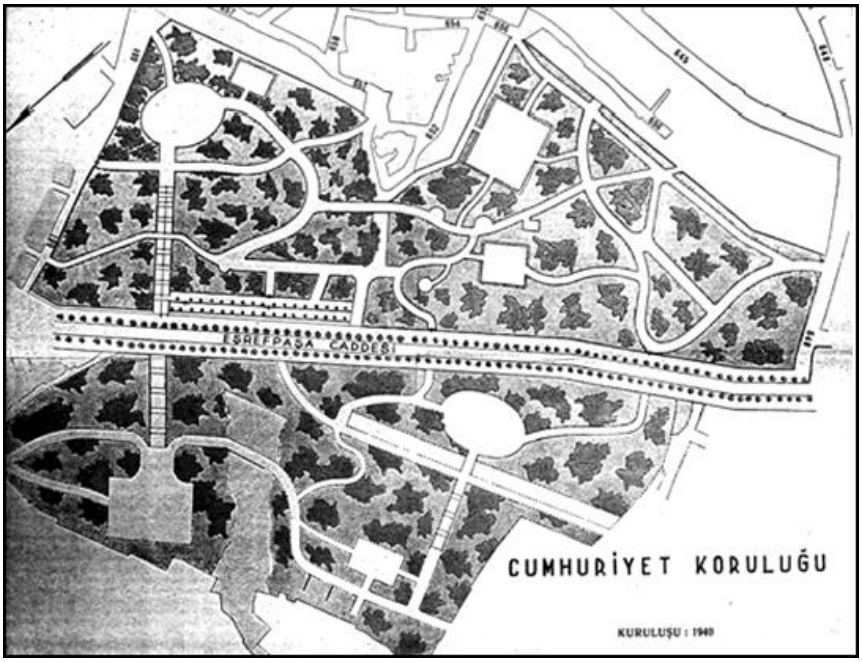


Figure 4.9 Cumhuriyet Grove, 1940 (İzmir City Guide, 1943)

Numerous infrastructure projects were carried out during Mayor Behçet Uz's tenure (1931-1941) in İzmir. This included the construction of 15 main streets and avenues, 20 smaller streets, and an asphalt road connecting İkiçeşmelik, Eşrefpaşa, and Kadifekale. Establishing İsmetpaşa main street replaced the previous yard sale location, improving connectivity between the city's old and new sections. Efforts were made to renovate existing routes and sewer lines, enhancing the overall infrastructure. Additionally, Kadifekale underwent a significant restoration process to preserve and revitalize its historical significance and architectural heritage (Izmir City Neighborhood Names and Street Numbers Guide, 1939, pp. 188-184).



Figure 4.10 Cumhuriyet Plaza, 1930s (İzmir Municipality Archives)

After the barracks and jail demolition in 1941, the municipal administration of İzmir planned to create a green corridor along the seafront and Kadifekale as part of a five-year improvement program. However, the implementation of this plan was never realized, and the city's remaining green areas were reduced due to new development projects. In the 1950s, settlement and construction initiatives continued, but previous work under the plan was reconstructed to accommodate new building regulations allowing taller structures. The road network in the Alsancak, Çankaya, and Kahramanlar regions followed the 1925 Danger Plan and its subsequent amendment in 1933. Plans to merge the railroad terminals were not implemented, and financial constraints hindered the completion of additional policies and investments.

4.1.2 Le Corbusier's Plan, 1949

Similar to the first, the second planning process in İzmir unfolded in two stages. The first stage spanned the period prior to World War II and involved the search for an approach and a planner to undertake the preparatory work for the planning process. The second stage encompassed the post-war period and concluded with the submission of the plan to the Municipality of İzmir.

İzmir's Spatial Structure in the 1930s

In the 1930s, the municipality of İzmir experienced significant population and size growth. Alongside incomplete adaptations of the Danger and Prost plans, the emergence of slums became a prominent geographical feature during this period. The formation of early slums in İzmir can be attributed to the severe financial difficulties resulting from the 1929 World Economic Depression. Limited efforts were made to develop civic structures, parks, and roadways under the choices outlined in the Danger and Prost Plan. While the town center and planned zones were still under construction, new slum areas such as Kadriye, Yeni İstiklal, Zeytinlik, and Yeşildere neighborhoods along the Basmane-Buca axis, as well as the Cumhuriyet and Naldöken areas along the Basmane-Çiğli axis, emerged around the downtown area of the city between 1928 and 1935.

İzmir's Post-World War II Spatial Structure

Due to the sluggish economy resulting from the war, the city's architectural layout underwent minimal changes between 1939 and 1948. Significant neighborhoods such as Güzelyalı, Göztepe, Karantina, Karataş, Bostanlı, Karşıyaka, Turan, Bayraklı, Salhane, and Alsancak, along with the suburbs Bornova and Buca, remained intact. However, in the post-war period, new slum areas emerged, including 2. Kadriye, Gürçeşme, Kadifekale, Boğaziçi, Gültepe, and Ferahlı regions.

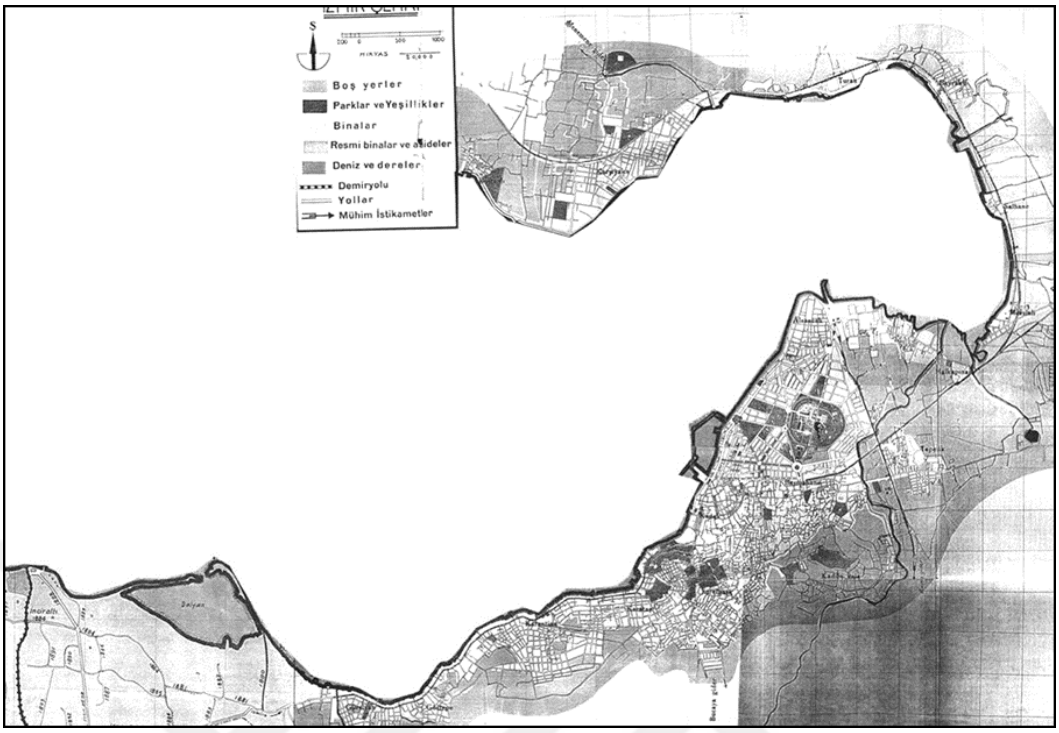


Figure 4.11 İzmir City Map, 1943 (İzmir City Guide, 1943)

During the war, there needed to be more new planning or development initiatives in the city. Even the construction of civic facilities came to a halt. The reconstruction of the city hotel was suspended due to the war, and the progress of the retail market and municipal structure was delayed. However, there were a few exceptions, such as the completion and inauguration of the Behçet Uz Pediatric Hospital in 1946 and the dedication of the partially constructed central bus station in Basmane during the war. In the postwar period, efforts were made to expand the port, complete the airport in Cumaovası, establish the city hostel, and finish the bus station.

Planning Process of İzmir After World Word II

After World War II, İzmir faced a rapid influx of migrants and population growth, prompting the development of a master plan. Mayor Reşat Leblebicioğlu invited Le Corbusier to visit İzmir and continue the planning investigations that had been initiated before the war. Le Corbusier developed a conceptual diagram and proposal

outlining the city's growth prospects and strategic planning investigations. In 1949, he presented these plans to the municipal government of İzmir. The plan covered a 50-year timeframe and included recommendations at various scales, addressing population density, transportation, land use, and detailed designs for residential and industrial facilities. The proposal aimed to provide a comprehensive framework for the city's future development.

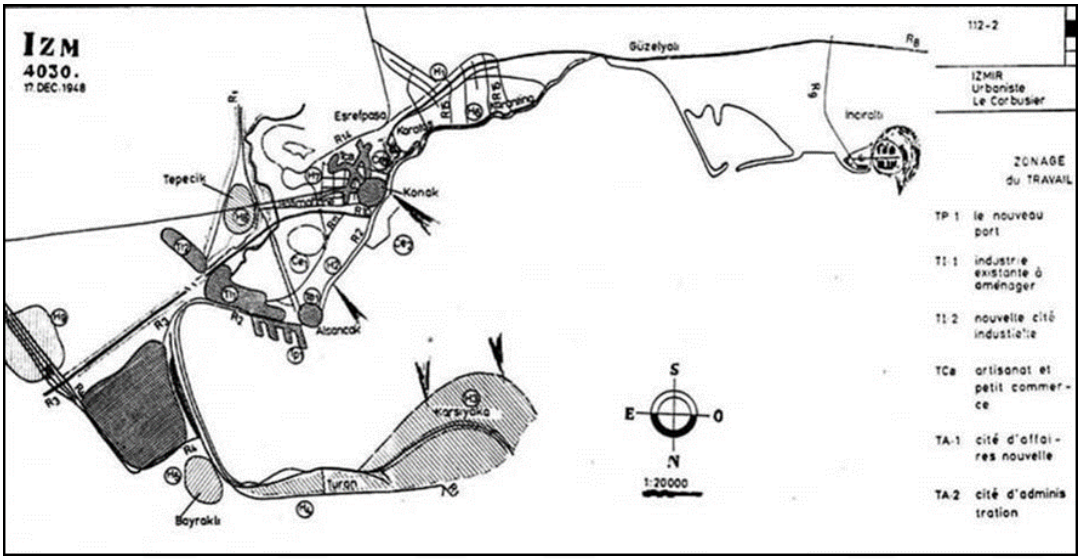


Figure 4.12 Le Corbusier's Plan, 1949; Conceptual design in 1/20.000 scale (İzmir Meropolitan Municipality Archives)

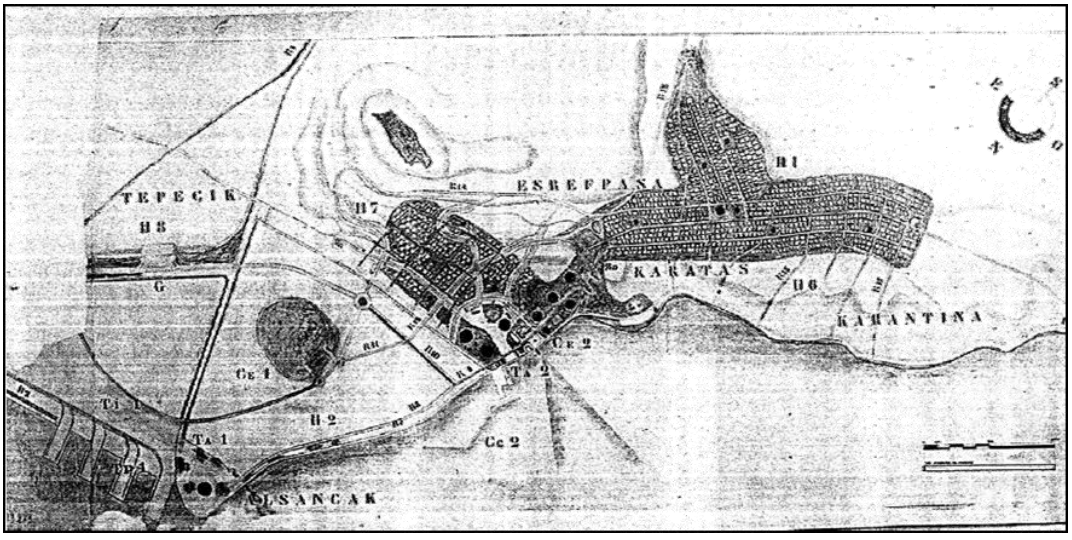


Figure 4.13 Core and New Housing Zones Request (Bilsel, 1996)

The plan's main decisions are:

- In Accordance with demographic report of 1945, the town's inhabitants were 198.000 residents. For the plan year 2000, the demographic data reported to the planner was estimated to be 400.000.
- Several of the initial plan's unenforced recommendations, such as combining train stations and expanding the port in the Alsancak area, were approved.
- The following new land-use choices were suggested:

- The Le Corbusier plan proposed a vibrant commercial district in Alsancak and an institutional and cultural core in Konak.
- The plan aimed to create a central area in Konak with theaters, museums, and contextual buildings surrounding Konak Plaza.
- New housing projects were initiated in elevated areas like Karataş and Karantina, blending with the natural surroundings.
- The housing developments were designed as self-contained units with all necessary amenities within the complexes.
- Each housing unit was recommended to have a minimum of 5 hectares of open land, accommodating up to 10,000 individuals.

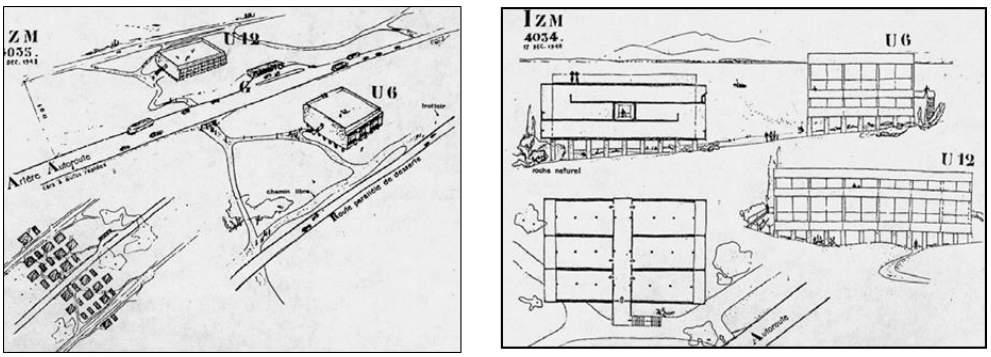


Figure 4.14 Residential Units Suggestions (Beyru, 1994)

- A significant industrial zone, strategically connected to rail and highway networks, was designated in the Mersinli and Bayraklı areas. Additionally, the initial proposal included industrial areas in Halkapınar and along Şehitler Street.

- In İnciraltı, a comprehensive sports center was already established, catering to various sporting activities and events.
- A 120-hectare facility was planned.
- The proposed urban layout aimed to transform the organic arrangement into a uniform grid pattern, featuring wide thoroughfares and expansive green spaces, thus rejuvenating the older residential and commercial districts. Special attention was given to preserving and protecting the heritage structures within the Kemeraltı zone (İzmir Master Plan, 1950).

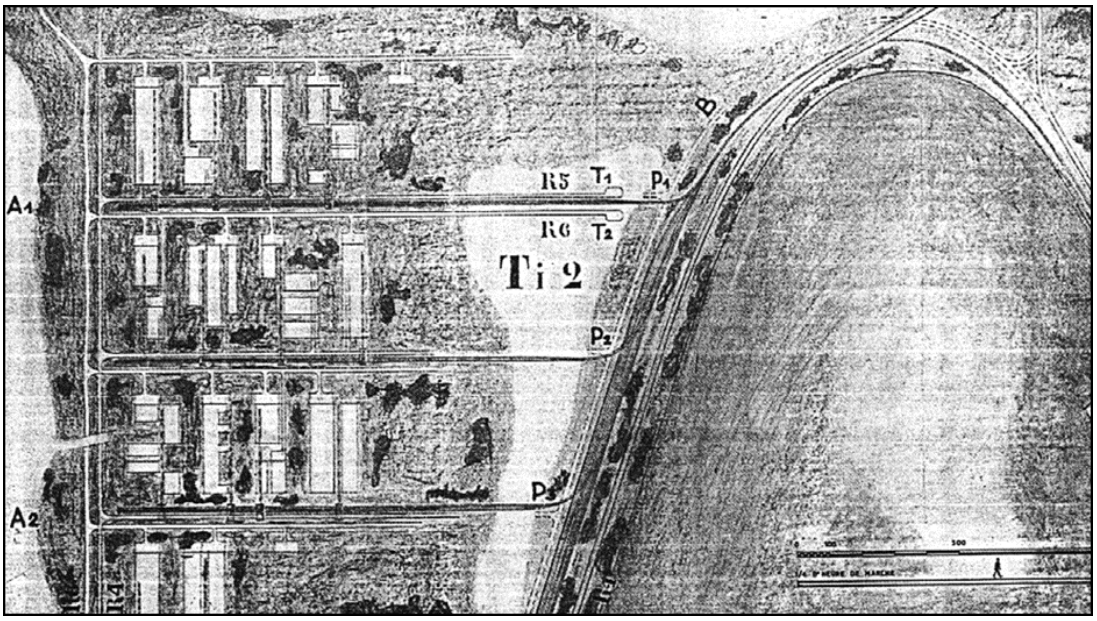


Figure 4.15 Industrial Areas Proposal (Bilsel, 1996)

The program was devised solely by Le Corbusier, rather than in collaboration with the municipality's expert personnel, as originally intended before the war. However, the municipal authorities deemed the concept impractical due to the extensive modifications it would entail in the city's existing framework. Consequently, the second planning endeavor for İzmir could not progress beyond formulating a plan and assessment, serving as a blueprint for future planning initiatives (İzmir Master Plan, 1950).

Theoretical Fundamentals and Implementation

The shift in urban planning concepts after the Great Recession led to a more practical and utilitarian approach in Western countries, influencing Turkish urban planning. Initially considering an international competition, the municipality hesitated to collaborate with foreign designers due to growing resistance. The planning process for the post-war plan was led by Le Corbusier, with limited involvement from other stakeholders and little consideration for public input. Le Corbusier adopted a utilitarian approach influenced by CIAM principles and modernist urban design ideas.

His plan aimed to create distinct zones with efficient connectivity and a grid layout. He proposed vertical construction to increase population densities and improve mobility by separating vehicular and pedestrian circulation. These ideas were influenced by Tony Garnier's concepts for industrializing cities.

The municipal administration deemed the idea proposed by Le Corbusier as unfeasible and therefore did not implement it. The reasons behind this decision included diverse perspectives within the administration and limited financial resources, which made it challenging to execute all of Le Corbusier's revolutionary and utopian development choices in the postwar context. Instead, the new municipal administration considered using the proposal as a guide for future planning rather than adopting it as an operational plan.

One notable partial implementation of the design was the construction of the Varyant roadway in the 1950s, which aimed to connect the higher districts surrounding the city center to Konak Square. However, it is essential to note that despite the proposal not being officially approved and adopted as a formal declaration, it does not carry any legal implications for the current urban layout.

4.1.3 Albert Bodmer's 1960 Plan

The 1955 plan, designed with a focus on low density and small scale, faced requests for changes after its implementation. The municipal planning department initially handled operational areas and adjustment plans. However, resource constraints led to a new revision plan being developed by the municipal leadership within a year of adopting the Aru plan in 1955.

The Spatial Structure Throughout the 2nd Half of the 1950s

In the 1950s, despite some efforts to implement the Aru plan, the overall layout of İzmir remained unchanged. Requests for plan changes from private landowners and limited funds allocated to high-budget projects led to incomplete construction projects and limited modifications to the city's spatial organization. The drafting of İzmir's fourth planning profession marked a shift in the planning approach.



Figure 4.16 İzmir's central districts, late 1950s (Metropolitan Municipality archieves)

Initial Studies: 1957-1959

In 1956, Mayor Enver Dündar Başar announced the intention to revise the municipal administration's five-year growth and confiscation plan (YA, 15.02.1956). A panel of 23 municipal officials was formed to investigate the matter (YA, 12.07.1956), and connections were established with international specialists to gather their opinions on the proposed adjustments (YA, 18.10.1957). Swiss planner Albert Bodmer was invited to İzmir and collaborated with the municipality's expert office to assess the necessary revisions (YA, 18.10.1957). After completing his evaluation, Bodmer prepared a comprehensive report and presented it to the Ministry of Development (YA, 01.11.1957).

However, Bodmer did not meet the specified deadline, and the municipal authorities explored alternative approaches in collaboration with the Bank of Provinces (YA, 14.03.1958). Prof. Luigi Piccinato also provided recommendations for the city's future growth (Beyru, 1991, p. 79). Plans were initiated to establish a planning department with representatives from the ministry, the Bank of Provinces, and the municipal government (YA, 24.10.1958).

The Master Plan Preparation: 1959-1960

In 1959, Albert Bodmer returned to İzmir as the advisor to the planning department tasked with conducting revisions (YA, 29.07.1959). Alongside Harbi Hotan, the municipal deputy manager of the Development Agency, Bodmer worked on the required adjustments to the plan, including converting green and underdeveloped regions into improvement zones and addressing slum areas (YA, 29.07.1959). The Bank of Provinces established the Regional Planning Department, with Hotan as the office manager and Bodmer as the designer (YA, 08.11.1959).

Bodmer focused on the issue of slums and proposed the establishment of organizations by slum dwellers under the municipal government's jurisdiction (YA, 31.07.1959, 09.08.1959). He conducted investigations in slum regions, observing the

living conditions of slum inhabitants (YA, 31.07.1959, 09.08.1959). Bodmer emphasized the importance of addressing the slum issue and proposed an eight-year rehabilitation plan (YA, 26.09.1959).



Figure 4.17 1960s Slum Area in İzmir, (YA, 08.08.1963)

Based on their research and the existing regulations, the authorities decided to restore and revise slum areas that harmed the city's aesthetics or created challenges for the community. These slum areas had been established prior to 1953. The primary objective was to identify and register the residents living in these slums. Subsequently, slum division plans were developed and presented to the Ministry of Development and Settlement. The ministry expressed satisfaction with the proposed ideas.

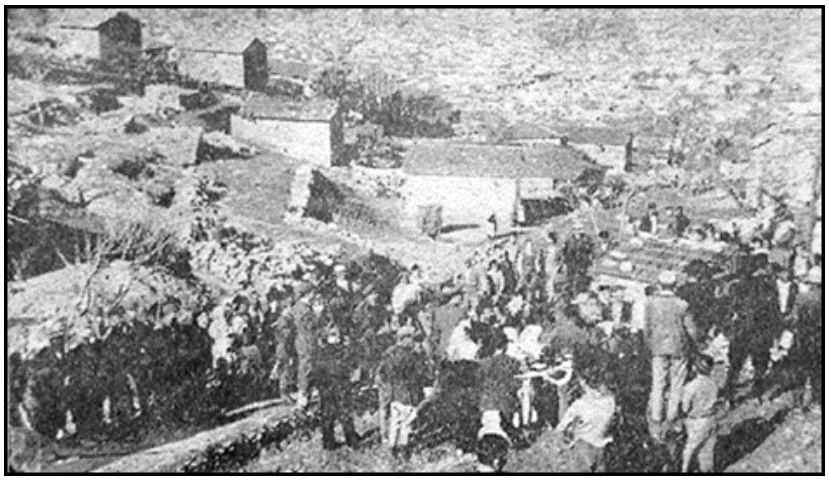


Figure 4.18 1960s Gültepe Slums, (YA, 22.12.1960)

In 1959, proposals were made to allocate 20 million TL of state funding to the municipality for partitioning properties, constructing 2000-2500 dwellings annually, eliminating slums, preserving green spaces, and restricting urban sprawl (YA, 14.10.1959). Bodmer recommended relocating the manufacturing district to reduce pollution and discourage migration to the city (YA, 21.11.1959, 04.10.1975).

A planning department was established with Bodmer and a municipal committee, focusing on tasks like creating subsection plans for slums, developing road plans, and protecting green spaces (Municipal Council meeting, December 24, 1959). The department designed plans for Şemikler and other regions (YA, 05.04.1960, 24.06.1960).

In 1960, military control led to changes in the government, but the planning department completed the master plan, which included proposed changes from 1955 and covered new precincts (YA, 1960). The finalized plan was submitted to the Ministry of Development and Settlement.

The following were the plan's key determinations:

- According to research, the city's population was estimated to be 900,000 by the year 2000.
- The central districts of Konak and Alsancak were identified, with manufacturing zones located south of the Alsancak seaport.
- Limited manufacturing activities were observed in the Halkapınar, Mersinli, and Salhane regions.
- A railway connection was established between the port and the extensive manufacturing area situated in the Işıklar and Pınarbaşı areas.
- Residential neighborhoods were developed north of the Karşıyaka region, south of Üçkuyular and Hatay precincts, and along the Bornova-Buca axis, including the massive manufacturing region.
- An extensive green network was planned to create a system of recreational spaces and delineate different districts.

- The transportation network underwent renovations, and proposals were made for a new peripheral road that would integrate the city's northern and southern halves and additional links to facilitate transportation to the extensive manufacturing area.

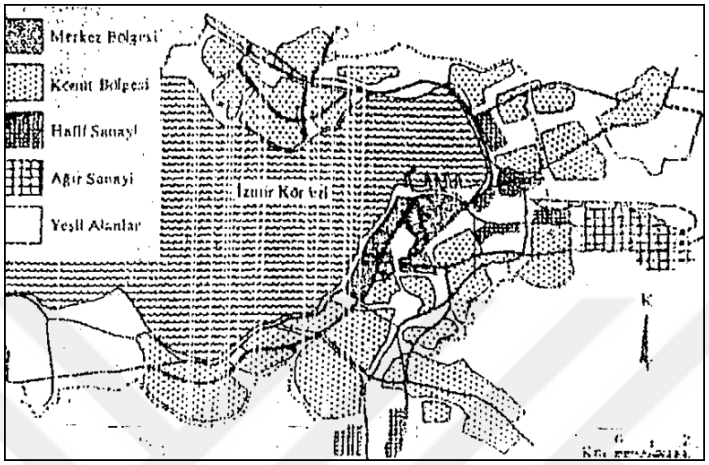


Figure 4.19 The Bodmer Plan, 1960 (İzmir Municipality Archive)

The government rejected the plan and requested the municipal government to make adjustments. While acknowledging the plan's comprehensive coverage of neighboring communities such as Buca, Bornova, and other suburban expansions, the government insisted on revisions and preparing a report that included the accompanying assessments of the planning endeavor. The report aimed to address the deficiencies in the previous master plan and provide a rationale for the proposed changes and new requirements. It included the following aspects:

- Assessment of the prior master plan's shortcomings and reasons for the proposed modifications.
- Clear objectives of the new plan.
- Demographic projections, including population distribution within the city and demographic concentrations.
- Classification of various types of employment.
- Evaluation of commercial establishments.
- Design and implementation of the primary transportation network.

Enhancements Before Bodmer's Dismissal, 1960-1963

After the 1960 coup, Safa Poyraz became the mayor of İzmir Municipality and formed a committee to oversee planning efforts (YA, 01.07.1960). They aimed to address shortcomings of the master plan, revise density recommendations, open blocked minor roads, adjust green spaces, and prevent undesirable growth around city gateways (YA, 03.08.1960).

Bodmer's presence in İzmir was mentioned in 1962, indicating that he stayed and received a salary from the Swiss government (YA, 19.01.1962). The municipality prepared a four-year development plan and began operations before the ministry's approval, leading to instructions for compliance with the existing master plan (YA, 19.11.1960, 01.09.1961). Bodmer returned to the Technical Works Office, and the major manufacturing zone was relocated to Çiğli and Bornova-Pınarbaşı (YA, 23.01.1962). The master plan boundaries expanded to include Buca, Bornova, Balçova, and Bozyaka (YA, 15.11.1962).

Following his departure, the municipal government kept working on the revising investigations till the Metropolitan Planning Department was established in 1968. Initially, a committee was constituted to supervise planning activities during the mayor Rebii Başol's tenure (1963). The committee held sessions over the course of a week and came to the following conclusions:

a. Current property use maps and provisional plans would be promptly generated in order to convert underdeveloped area encircling the city into a population zone.
b. The building criteria decided at the construction lot scale will be specified at the block size to promote harmonious relationship among the construction lots in a block.
c. The municipal council will debate the partly modification of the master plan once a month, and speculation on the plan changes will be avoided.

d. If difficulties arose during the Technical Works Department's drafting of plan revisions, a Development Department would be formed to perform the plan adaptations.
e. The committee's ideas would be submitted to the Ministry of Development and Settlement for authorization (YA, 18.07.1963).

In the 1960s, housing regulations and urban planning decisions were made. The municipal government aimed to include slum areas within settlement limits to address housing needs. Plans were announced to develop these zones, potentially accommodating 200,000 people pending ministry approval. A slum test zone was established on the Kadifekale hillside, and infrastructure development for a social housing area in Üçkuyular was initiated. Collaboration between the central administration and the municipal government of Bornova led to the construction of 10,000 social housing units in the Dağdibi district, mirroring the approach in the Cumhuriyet district (YA, 16.08.1963; YA, 06.02.1965).

Theoretical Fundamentals and Implementation

In the fourth planning endeavor in İzmir, a comprehensive planning approach was employed, reflecting a shift in Turkey's spatial organization strategies. This transition was facilitated by new planning legislation in 1957 and the establishment of a new ministry in 1958. The municipal government of İzmir embraced this strategic approach, with Mayor Başar participating in research on optimal demographic arrangements. Unlike previous initiatives, Bodmer's plan extended beyond municipal borders to include neighboring communities, emphasizing the need for a comprehensive planning strategy. The plan incorporated extensive research and recommendations, addressing both land use and the socio-economic composition of the town. A functionalist approach was adopted, defining distinct areas and integrating green spaces. Bodmer and the planning department actively engaged with the public during the investigation process, incorporating their requests and reflecting their concerns and interests (YA, 11.06.1957).

Despite its comprehensive nature, Bodmer's plan for İzmir focused on partial modifications to the master plan until 1963 without being officially authorized or documented as a formal report. The demographic forecast provided to the planner proved ineffective as population growth exceeded expectations in the 1980s. Societal changes may have influenced the plan's acceptance and implementation. Although the Bodmer plan was not formally accepted or published, its property use determinations influenced subsequent planning efforts, particularly in residential and manufacturing areas. The Aru plan, which followed Bodmer's plan, incorporated some of its property use determinations and remained in effect until the late 1970s. The planning attempts during Bodmer's research can be seen as a continuation of the previous planning process rather than a completely new approach.

4.2 Master Plans of the Izmir City

4.2.1 The Proposal of K. Ahmet Aru, G. Özdeş and E. Canpolat, 1955

Following the submission of Le Corbusier's second proposal for İzmir in late 1949, the municipal authorities deemed it unfeasible and sought alternative approaches to initiate the planning process for İzmir. The third planning endeavor in İzmir emerged within a unique sociopolitical and socioeconomic context, occurring at a crucial juncture in Turkey's urbanization trajectory.

Izmir's Spatial Structure and Improvements in the 1950s

The municipal boundaries of İzmir encompassed the coastal zone around the bay, extending from the Yenikale area in the southwest to the Ahirkuyu area in the north. However, the need to expand these boundaries arose during municipal council sessions to accommodate new construction sites and emerging districts such as Bozyaka, Karabağlar, and Kançeşme (Gürçeşme), which had predominantly developed informally (Municipality council meeting, 26.2.1950). The central

activities of the city revolved around Konak Plaza, with key avenues like Varyant, Eşrefpaşa, İkiçeşmelik, Fevzipaşa, and 2nd Kordon radiating from it, along with Karşıyaka and Güzelyalı in the subcenter. With a growing population and increasing number of vehicles, the city's main axial areas, including Konak Square and the Kemeraltı district, characterized by one to three-story traditional buildings, became congested.

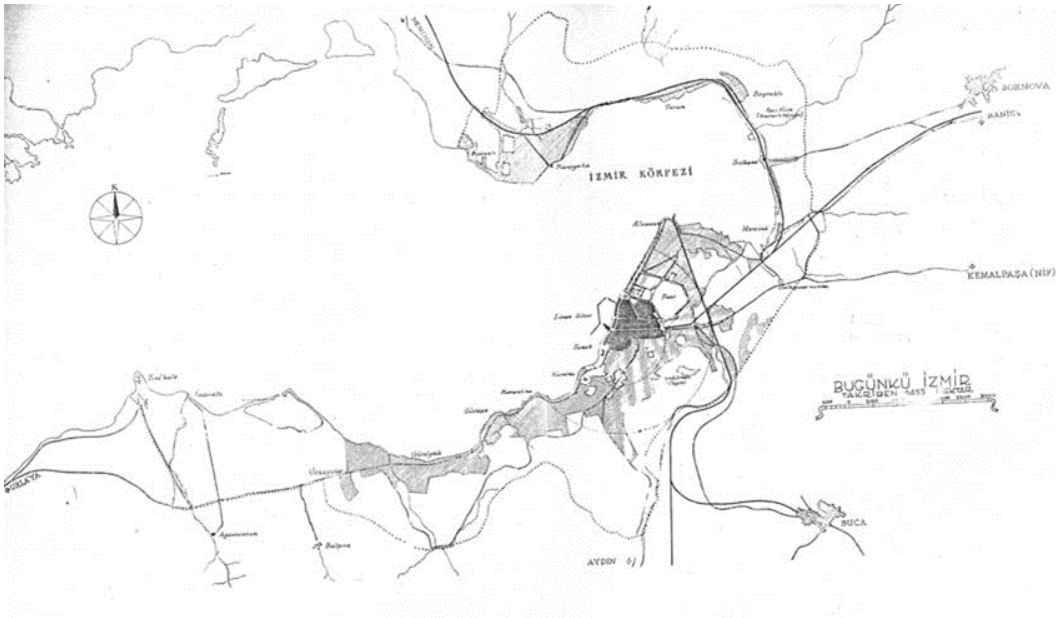


Figure 4.20 İzmir City Map from 1950 (Canpolat, 1954)

During this period of rapid development, İzmir's socio-cultural amenities were insufficient to meet the population's growing demands. There was a significant need for a theater, sports and entertainment facilities, and a university campus. Consequently, various medical, educational, and sports institutions and industrial facilities began to establish themselves in the neighboring villages of Bornova and Buca, which had not yet been integrated into the city proper. Unfortunately, apart from minimal efforts in tree planting, there were no initiatives to create new recreational spaces. Additionally, the green areas of essential parks such as Kültürpark, Cumhuriyet Grove, Bahribaba Park, İnciraltı coastlines, and the outskirts of Kadifekale, which had existed since the early Republican era, gradually

diminished as they were encroached upon by both legal and illegal constructions (YA, 03.08.1950; 14.12.1951).

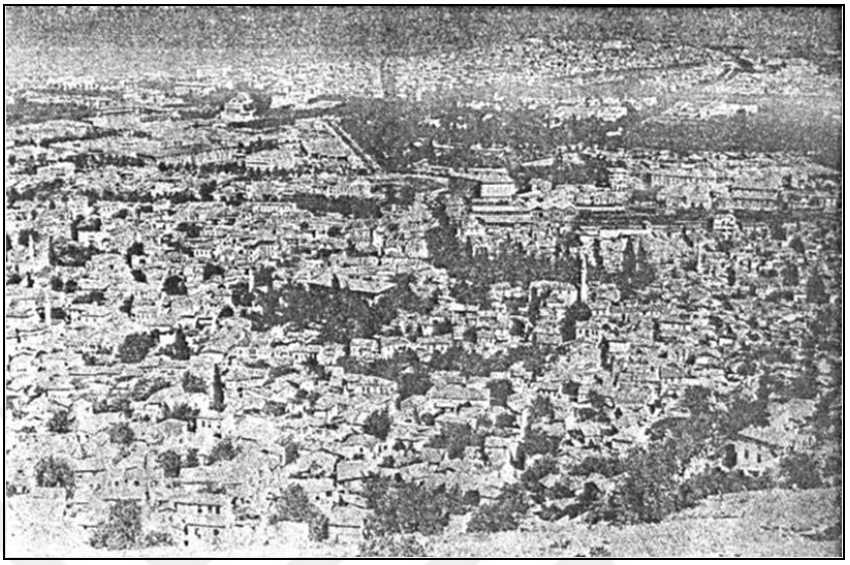


Figure 4.21 İzmir's central districts in the 1950s (Canpolat,1954)

In the 1950s, contamination in the gulf led to the closure of public coastlines and shutdowns of coastal areas in central districts (YA, 02.07.1950). Excavations led by Ekrem Akurgal from the Research Institute of West Anatolia began in Bayraklı in 1947. Restoration of the Agora was decided in 1951, and the reconstruction of the Kadifekale fortifications commenced in 1952 (YA, 1951; 1952).

In 1945, with the establishment of the Bank of Provinces and the need for localities to create their basic maps, İzmir entered into an agreement with Kemal Söylemezolu from the Academy of Fine Arts for mapping data revision. Alongside map production, preliminary planning investigations were conducted by Söylemezoglu and municipal employees. Geological maps of the city were produced between 1950 and 1951 by Dr. Ervin Lahn from the Ministry of Reconstruction, redefining the seismic zone of the Göztepe and Kadifekale area from first-degree to second-level, allowing for the construction of less expensive projects (YA, 10.02.1950; YA, 24.03.1951).

Competition Project Preparation: 1951-1952

A meeting organized by the municipal government in İzmir involved approximately 100 participants, including delegates from various organizations and interest groups, to discuss planning choices. Proposed options included designating İzmir as a center for business and trade, focusing on the upper sections of Karantina for expansion, transforming Alsancak into a commercial port, preserving the Alsancak stadium, replacing barracks with leisure zones around Konak Square, and considering various other ideas such as residential placement, worker districts, tourism aspects, campus site, recreational facilities, historical landmark preservation, and relocation of the slaughterhouse (YA, 23.11.1950). The municipality also emphasized the opportunity for public feedback and engagement while developing the contest materials (YA, 25.11.1950).

After reaching conclusions about the project, the employees of the Bank of Provinces began to prepare the necessary paperwork for the contest. This contest would serve as the basis for the master plan. On April 20, 1951, the bank initiated the "International Contest for the Master Plan of the City of İzmir."

The Contest Contract outlined several key provisions, including the following:

- The contest was open to both Turkish and international planning specialists.
- Participants had to spend at least 15 days in İzmir during the first three months of the contest (01.05-01.12.1951) to familiarize themselves with the city.
- The winner of the first prize would be responsible for incorporating necessary adjustments as requested by the committee.
- If the municipal administration could negotiate with the first-place contestant for subsequent planning efforts, the contestant would serve as an advisor in the planning department and receive compensation according to international standards. If a contract could not be reached, the administration would enter

into a contract with the following contestants, who would implement the recommendations of the original project.

- Proposals would be evaluated based on their feasibility and compatibility with the town's characteristics and needs.
- The winning projects would become the property of the municipal administration, and the municipal council would have the right to use the assets.
- The Union of International Architects (UIA) could serve as the arbitrator in a scientific dispute.
- Contestants were provided with various documents, including the program, base maps at a 1/5000 scale, base maps for Konak and Alsancak regions at a 1/1000 scale, a concept plan at a 1/20000 scale, the Development Commission document, an image illustrating the urban limits with the agreement. Contestants were required to submit the city-wide master plan at a 1/5000 scale, transportation network, and regional plan, action region plans for Konak and Alsancak regions at a 1/1000 scale, an analysis of the Development Commission, and a map showing the urban limits (Master Plan Contest Report).

The Contest's Program;

- The following factors were to be considered by the contestans:

• Characteristics of the town: The plan should consider İzmir's significance as the primary seaport in West Anatolia.
• Demographic estimates: The city had a population of 230,000 people in 1950, and it was projected to reach 400,000 by the year 2000.
• Plan boundaries: The plan's boundaries encompass the area surrounding Yenikale in the west, Bozyaka and Karabağlar in the south, Çamdibi district in the east, and Ahırkuyu in the north.

- Development areas: The higher sections of Karantina would serve as the primary focus for urban development, and there would also be designated development areas in Karşıyaka.
- Expressways: The plan includes the following expressway routes: İnönü Street and its extensions towards Seferihisar, Urla, Eşme, and Karaburun; Eşrefpaşa Road and its extension towards Kızılçullu-Karabağlar-Cumaovası-Aydın-Denizli; the route connecting Kızılçullu intersection with Bornova and Manisa; the Gaziler Road connecting Uşak-İzmir-Kemalpaşa-Turgutlu-İzmir; the route connecting Halkapınar, Mersinli, Bornova, Manisa, Turgutlu, and Akhisar; and the road connecting Alsancak, Menemen, Balıkesir, Bandırma, and Bursa.
- Railroads: Existing railroad routes would be maintained, and connections between commuter and commercial terminals, the seaport, and various parts of the city would be established.
- The Port: The plan involves transforming the Alsancak seaport into a container port. In contrast, the current port would be repurposed as a commuter port, in line with the Ministry of Reconstruction's recommendations (Master Plan Contest Report).

- The contenders were required to submit suggestions for the preceeding issues, some of these were featured in the state's plan to be implemented:

- Link of the Hatay road to the south of Güzelyalı.
- Link of the Hatay road to the Hacı Ali Road.
- Link of the Hacı Ali Road to Kemer-Gaziler road.
- Link of the Karantina - 9 Eylül road to İnönü road.
- Proposal of the 2nd periphery route as a touristic route.
- Proposal of the link among İnönü and Eşrefpaşa road.

- At the mentioned instances, the contestants were to submit suggestions:

- Because the Alsancak Field would be demolished, a plan for a stadium deal and other sports facilities has been made.
- Rearrangement of current parks and ideas for additional greenery.

- Proposed locations for future health facilities.
- Suggestions for new services and constructions in the area surrounding Konak Square, where shelters and army structures once stood.
- A main campus suggestion.
- A 1/1000 scale detailed design depicting the roadways connecting Alsancak train station, 26 Ağustos Square, and the seaport sector.
- Suggestions for rearranging and repair of unpleasant districts.
- The Danger plan, Le Corbusier plan, aerial images, town guidebook, and galleries on the history of İzmir may be used by the contestants.

The Contest's Outcomes:

The contest proposals were presented to the municipal commitee in December 1951, and the court examined them over the course of a week beginning on January 8, 1952. As shown in the jury's decision, the aforementioned contestants were awarded prizes:

- The First Prize: Prof. Kemal Ahmet Aru, Gündüz Özdeş, and Emin Canpolat (all from Istanbul)
- The Second Prize: Alexander Freiker von Branca and Reinhold Wierl, his assistant (Munich)
- Third Prize: Rauf Beyru (Ankara)
- Mentions:

Richard Braun, Anna Braun, Otto Grün (Vienna) Leo Hofner, Nuri Yüksel (Switzerland)

Doç.Dr. Eyüp Kömürcüoğlu, Ertuğrul Menteşe, their assistant Reha Erkızan (İstanbul)

Harika Söylemezoğlu, Doç. Kemali Söylemezoğlu (İstanbul)

Fritz Jelpke, Willi Schütte, 8 assistants (Germany)

The committee wrote a paper outlining the strong and weak features of the initial plan, recommending that the other winning proposals be used, as well as certain adjustments to be made throughout the master plan's creation. The contest's outcomes were published in papers, and the people was very interested in the proposals (YA, 17.01.1952, 18.01.1952).

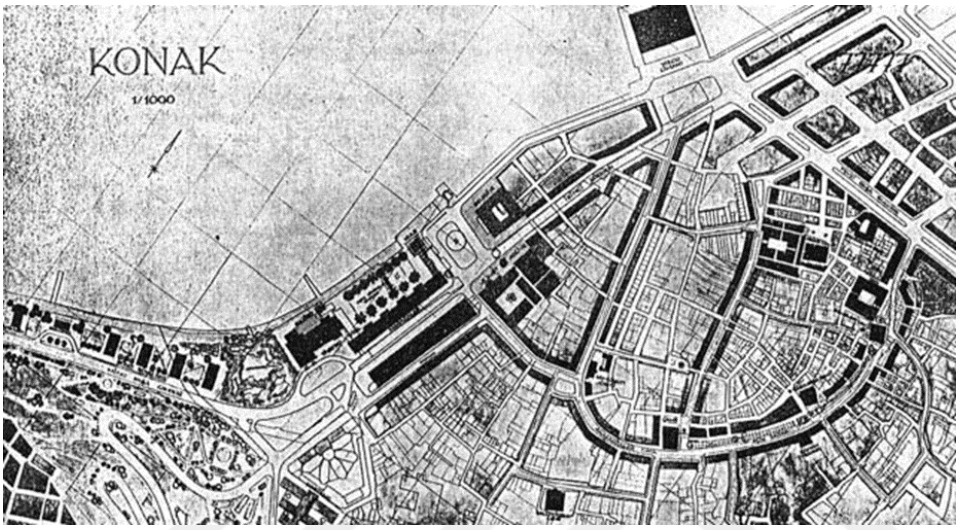


Figure 4.22 Environs of Konak Square and Kemeraltı Operational Zone Plan

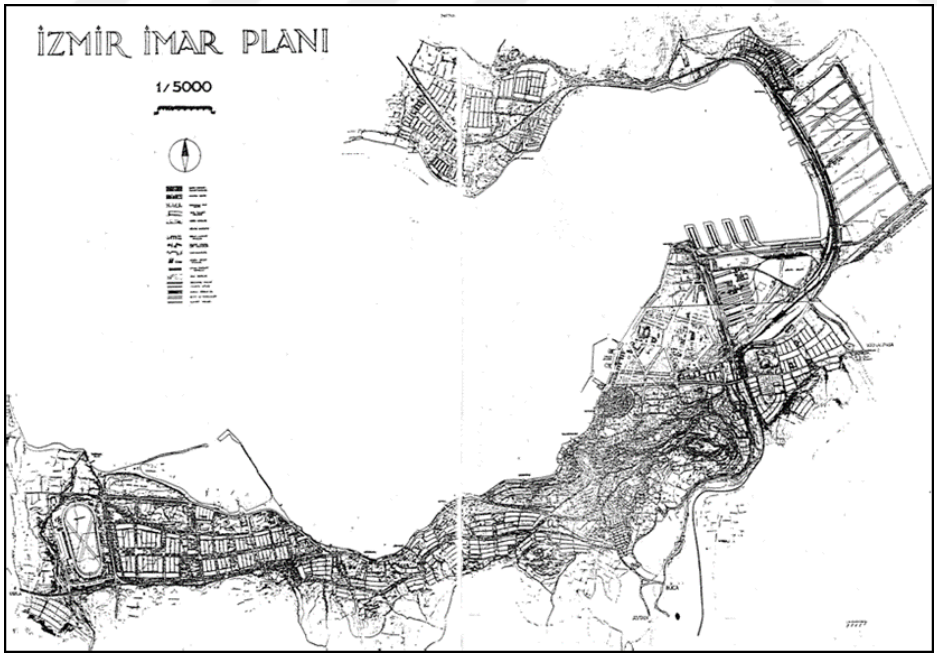


Figure 4.23 K. Ahmet Aru's Proposal, Emin Canpolat, Gündüz Özdeş, 1952
(Master Plan Contest Report)

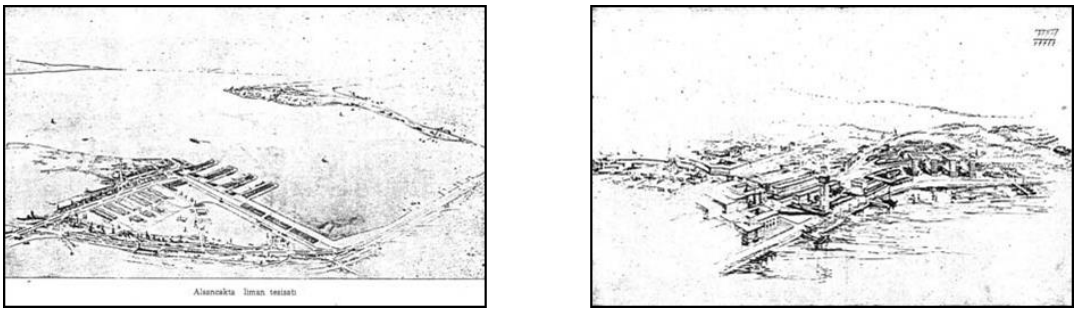


Figure 4.24 New Port and Konak Square: Future Prospects

Preparation of the Master Plan: 1952-1955

After the release of the jury 's final decision, the municipal government attempted to establish a planning department for the production of the master plan by developing the contest proposal by incorporating concepts from other winning concepts and revising it to meet new criteria and requests.

The municipal administration initially authorized the master plan just for the Anafartalar, Eşrefpaşa, and Karantina sections, along with the Varyant road. Simultaneous to this effort, the municipal government developed a five-year improvement plan, with the following topics being prioritized:

- Accomplishment of the master plan, action area plans for the major roads and collectivization actions after their permission, operation zone plans for Konak Square and Deniz Bostanls, and reorganizing the important squares.
- Accomplishment of army building structures to be constructed in exchange for Sarıkışla Structure, Şark café, Eşrefpaşa bazaar, Karşıyaka shoreline, new structures in Alsancak and Karşıyaka markets, slaughterhouse, refrigerating halls, commodity market, Şehitler bridge, water recycling in Yelkenkaya, a pool, a restaurant, and a recreation and demonstration house in Kültürpark, Repair of Fevzipaşa, Cumhuriyet, and Gaziler roads, acquisition of Agamemnon geothermal spa, construction of a sports complex in Halkapınar,

and distribution of construction sites to communities for the construction of low-cost housing.

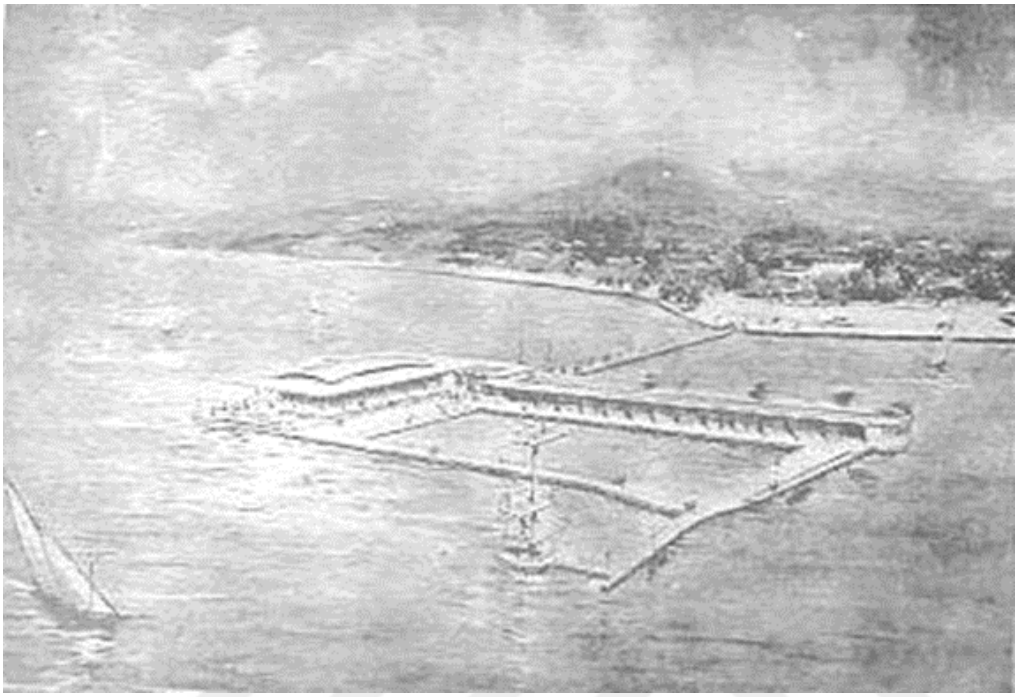


Figure 4.25 Karşıyaka Beach's Project (YA, 28.02,1953)

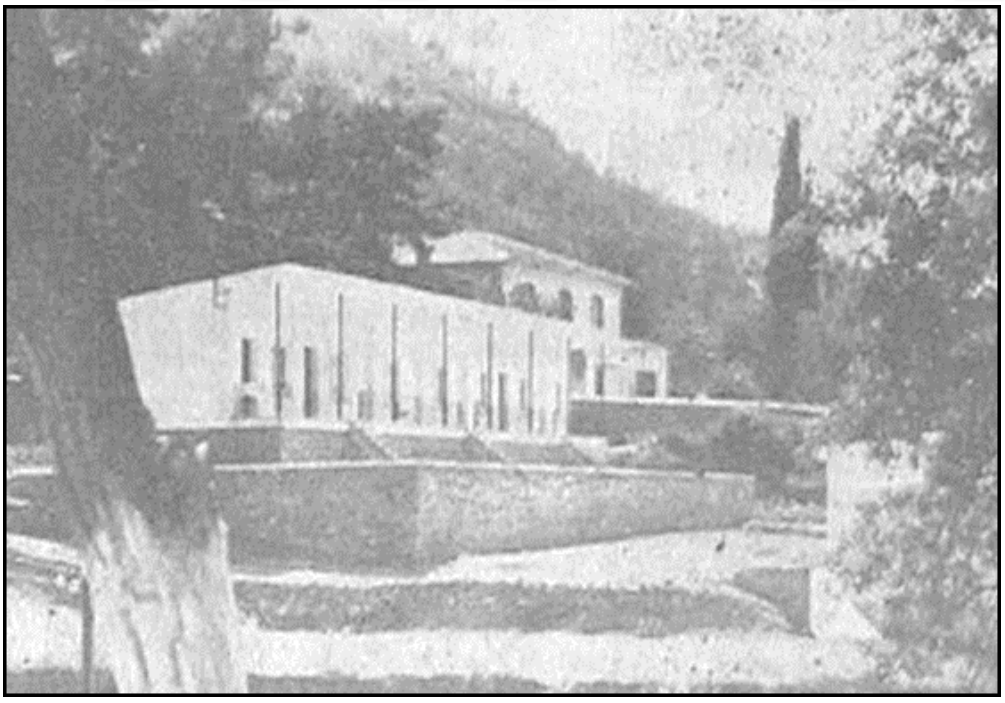


Figure 4.26 Thermal Baths of Agamemnon (YA, 13.04.1954)

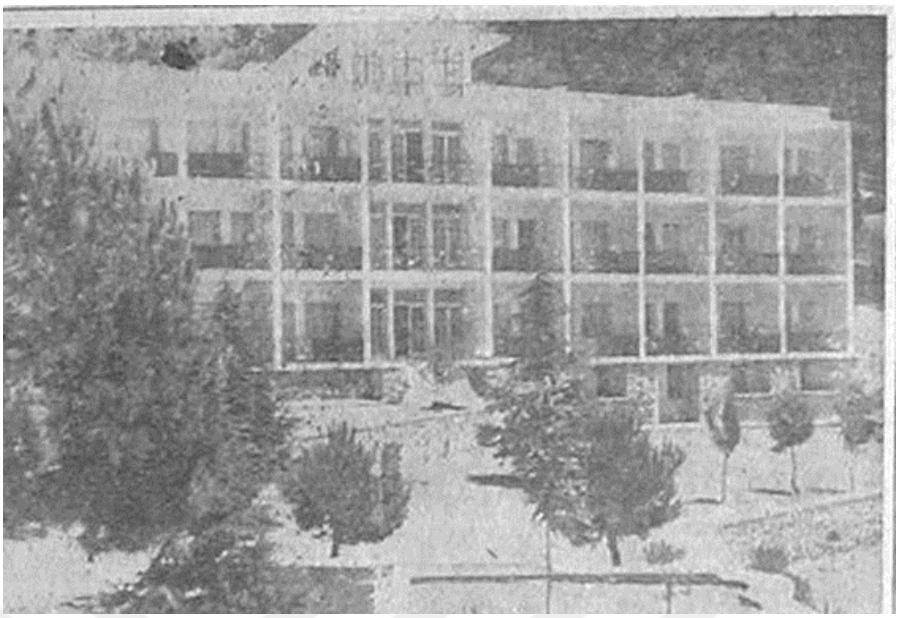


Figure 4.27 Resort Yamanlar (YA, 21.07.1965)

In 1955, the municipal administration reviewed the master plan, which consisted of 81 tiles of 40x60 cm^2 and constructed at 1/2000 scale. (YA, 21.02.1955) The statement of plan was released in the paper –Yeni Asır for 10 days in between 23rd of February and the 4th of March, 1955, until it was confirmed by the Ministry of Reconstruction.

The master plan's key features were:

- İzmir is Tukey's largest entrance in the Eastern Mediterranean, second in significance in case of international trading ports, a cultural and recreational city with a large countryside in aspects of agricultural activities and economy, and its citizenry has doubled in the last twenty-five years; all of these variables indicate that the city will be the first-degree major city in the long term.
- In 1950, the populace of the city was 230.000, with a projection of 400.000 in the year 2000. Among Üçkuyular and Karşıyaka Bostanlısı, the town encompassed 1455 hectares, with a gross population of 158 people for every hectare in the constructed regions. The master plan covered 4300 hectares and had a total intensity of 93 people for each hectare.

- Decisions on land use and transportation systems:

- Gümrük seaport was changed into a civilian seaport, while Alsancak seaport was enhanced to be a container and commerce port, based on proposals developed by the Ministry of Reconstruction and to be finished afterwards.
- Current commerce sectors were recognized and enhanced in all of the town's areas. The region among Gümrük and Konak squares, and even the region around Alsancak harbor, has been set aside for large retail shops and office complexes.
- Apart from a few highways that were extended to facilitate traffic, constructed zones were conserved.
- Since the minor industries and stores in the Gümrük seaport are likely to be relocated to the new seaport, land near Alsancak port has been set aside for these purposes. The manufacturing zones around Alsancak seaport were approved, and a new manufacturing area was established on the gulf among Mersinli and Bayraklı.
- Alsancak train station was decommissioned, and Basmane station was designated as the primary station for two lanes, with a railway link to Alsancak seaport.
- The west axis of Karataş, Karantina, Göztepe, Güzelyalı, and Üçkuyular areas, as well as the north and west of Karşyaka, were used to establish new housing zones. Among Güzelyalı and İnciraltı, agrarian land is somewhat urbanized but generally preserved. On the east side of the İnciraltı seashore route, two summer resort zones were approved. Surrounding Tepecik, Eşrefpaşa-Beştepeler district, across Buca route, and to the south of Bayraklı, residences for railroad, seaport, and industrial employees are envisaged.
- The region among Gümrük and the Social Hub enclosing Konak Square was designed as a business, institutional, and cultural hub. Main routes in Kemeraltı were expanded to relieve congestion and facilitate connectivity. Offices, retail houses, stores, an opera hall, and a theater were housed in the barracks Provincial building, Municipal building, and Judiciary. The retail

and office structures on this site would be 25.80m and 19.80m tall, respectively.

- It was predicted that the city will require 66 elementary schools over the plan period. To the extant three intermediate and 4 high schools, the Plan added 31 schools to the current 38 schools and two high schools – one in Güzelyalı and the other in Karşıyaka. A university site was established on a section of the property utilized by the military academy in Güzelyalı.
- In the Halkapınar district, an athletic sports site and a culture hub were planned, as well as recreational grounds around Halkapınar Lake.
- The civic shoreline at İnciraltı was extended, and additional beach homes, resorts, restaurants, and recreational amenities were suggested.
- Resort, dining, and leisure facilities might be built inside green spaces. Playgrounds and smaller green spaces were conserved and integrated with green axis at Kültürpark, Bahribaba park, Cumhuriyet grove, at the base of Kadifekale, and across the constructed region.
- It was suggested to plant trees at the bottom of Kadifekale.
- The designed zone's cemeteries were turned into parks.
- Different divisions and purposes were divided from one another by spontaneous common green space and advancement-controlled regions, whereas social structures might have been built in such locations if necessary.
- The fast route connecting Buca and Şemikler (Altınyol), the Konak-İnciraltı coastline route, the Ballıkuyu Varyant route, and a green path connecting Naldöken and Bostanlı were among the significant new connections planned under the proposal. Many of the town's principal roadways have been enlarged, including the Konak-Varyant route street-Kizilçullu-Buca linkage, the Fevzipaşa boulevard-Basmane-Gaziler road linkage, and the Fevzipaşa boulevard-Basmane-Gaziler road linkage, Hatay road (Eşrefpaşa-Üçkuyular link), Mithatpaşa road (Konak-Güzelyali-Urla linkage), İkiçeşmelik road (Mezarlikbaşi-Eşrefpaşa linkage), Tilkilik road (Mezarlıkbaşı-Basmahane link), Halilrifatpaşa road (Konak-Karantina connection), Kemeraltı road

(Konak-Fevzipaşa connection), 2nd Kordon road, Halilrifatpaşa road (Konak-Karantina linkage), Çamdibi road (Mersinli-Gaziler roads linkage), Ballıkuyu street, Naldöken-Bostanlı coastline, Alsancak-Şehitler road - Bornova road connection and Alsancak- Şehitler street-Karşıyaka-Menemen linkage. A 4,5 m walkway would be built on 1st Kordon once the 2nd Kordon roadway was widened, with the goal of being predominantly utilized by walkers.

- Housing and farming utilities were allowed to be built in economically underdeveloped regions inside the plan limits, that were largely made up of farmland, besides a base plot size of 5.000 m^2 and a maximal building area of 5% of the overall plot size and a height limit of 6,5 m.

The master plan was accepted by the municipal administration in February 1955, the provincial government in April 1955, and eventually the Ministry of Reconstruction in June 1955, rendering the preceding designs developed at 1/1000 and 1/5000 scales insufficient (YA, 04.06.1955).

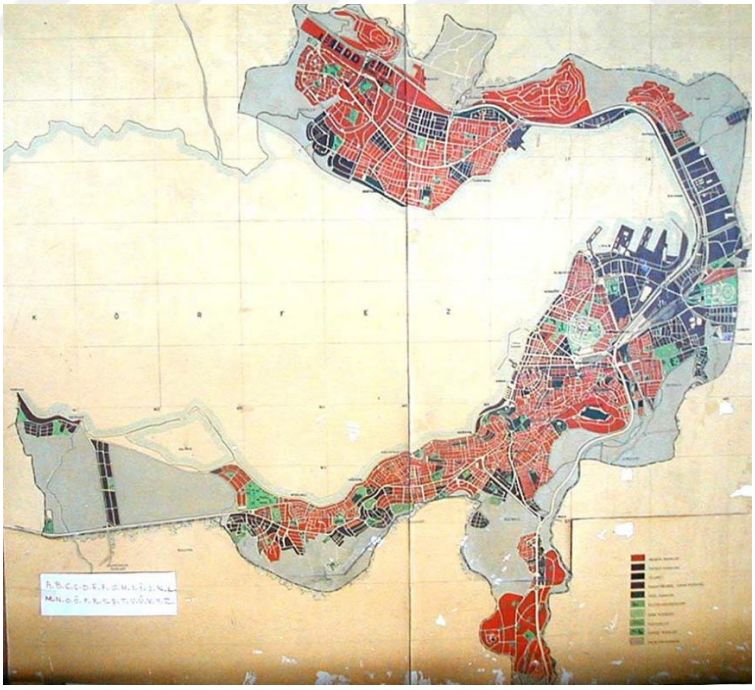


Figure 4.28 İzmir Master Plan, 1955 (Archives of the İzmir Metropolitan Municipality)

Improvements After the Plan's Authorization: 1955-1957

Following the execution of the plan, a five-year program is created depending on the master plan. The municipal planning department proceeded to work on the modification and descriptive plans. The processing of intervention zone plans and implementation of planning determinations, especially for Altınyol, Konak square, the Konak-İnciraltı coastline route, collectivisation and development of the route among Eşrefpaşa market and Cumaovası airport, collectivisation of Hatay and Ballıkuyu streets, and the adjustment of the Karşıyaka shoreline, were the primary issues of the following planning attempts. In the long run, they also chose to evict the slums and replace them with cooperative housing (YA, 08.10.1955, 06.06.1956).

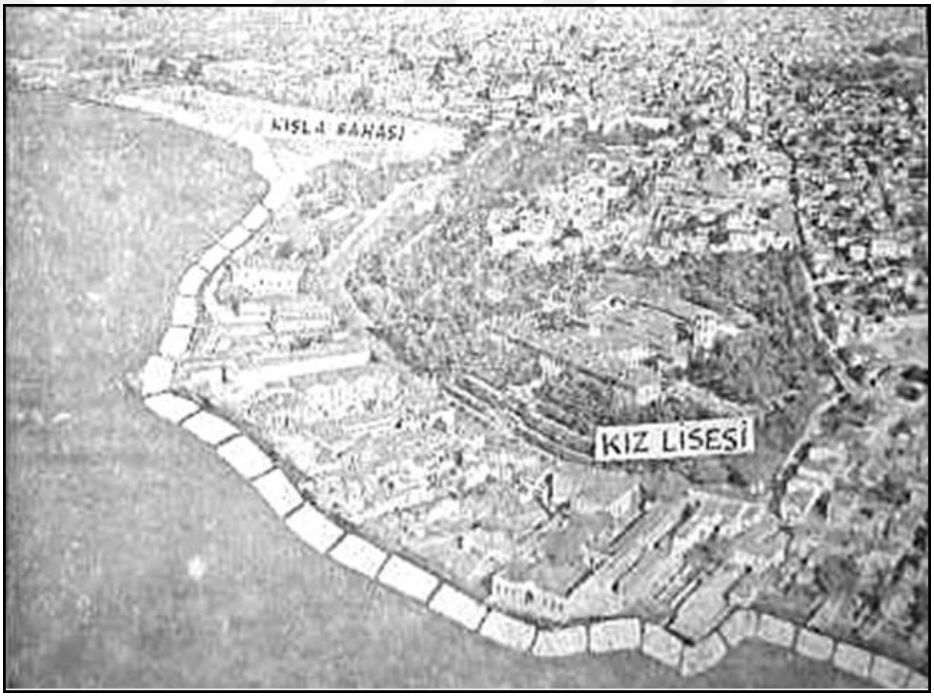


Figure 4.29 Konak–İnciraltı Coastline Construction Development

(YA, 18.10.1956)

To address the housing shortage and slum dwellers' problem, the İzmir municipal administration partnered with the Bank of Estate and Credits to build moderate garden dwellings on municipally held property and sell them to people without

homes. The proceeds from these sales would fund the eviction of slums and the construction of new dwellings (YA, 08.10.1955). The Bank of Estate and Credits created divisional plans and blueprints for 1,000 garden dwellings in Karşıyaka Denizbostanlsı, and construction began on 80% of the 10,000 units by the Workers Insurance Institution (YA, 20.02.1955).

While drafting operational district plans and execution of plan choices, there were doubts and criticism of the master plan. The planner, Aru, decided to stop working on plan changes after its approval and left his position in the local authority. Requests for plan changes were considered at municipal board sessions, with 398 lawsuits filed against the municipal government between 1951 and 1956, mainly related to planning delays and analytical issues. Participants in the council suggested that a new plan be prepared due to the perceived failure of the existing plan, citing requests for increased building heights, integration of manufacturing industries, additional housing and commerce zones, and the transformation of green spaces into housing neighborhoods as common requests for plan changes (YA, 20.02.1955). The central government has agreed to a number of requests, including the protection of constructed districts;

- Evolution of green spaces into education or other public purposes in some locations.
- Relocating the university from Güzelyalı to Bornova, as well as the bus station from Basmane to Halkapınar.
- Evolution of the housing zones into green spaces in Asansör district.
- Integration of several nearby regions into the municipal territory, including as Örnekköy, Yamanlar, and Şemikler, as well as manufacturing zones towards Bayraklı and Bornova, the land in Çamdibi and its southern section, as well as the area in Balçova along Urla route, the region around the Serinkuyu Flow, the areas of Gürçeşme and Samantepe, and the classification of Buca as a sub-centre (YA, 21.05.1955, 19.01.1956, 20.10.1956, 07.03.1957).

Because majority of the requests for plan changes were for new housing and business structures, they were mostly denied.

Theoretical Fundamentals and Implementation

From the early Republican era until the 1950s, international planners were involved in the initial planning procedures of major Turkish cities such as İzmir, Istanbul, and Ankara. However, in the 1950s, Turkish professionals began engaging in city planning activities. Although a global planning contest was held, a Turkish group eventually won, but the officials continued to collaborate with international specialists and sought inspiration from Western examples. For instance, British specialist Brian Lewis lectured on British planning observations in İzmir, and a group of practitioners from the United States visited İzmir to understand the planning operations. Mayors and their delegations also traveled to the United States and Europe to learn from their planning expertise (YA, 18.2.1951; YA, 09.05.1951).

Influenced by European precedent, the Aru plan aimed to organize the city's property functions and transportation network through a structural-functional land use plan. It aligned with Le Corbusier's concepts but with less drastic choices. The plan primarily focused on practicality and utilized a survey-analysis-plan technique, with most surveying and analysis conducted during the contest procedures. However, the plan did not address socio-economic and demographic challenges or consider the issues of rapid urbanization, neighboring population growth, and slums. It needed more community engagement, relying on technical experts, administrators, and intellectuals. Nevertheless, the plan was modified during the execution phase to accommodate public requests.

Turkey needed to catch up in implementing comprehensive plans due to the limitations in the organizational system needed to address the rapidly developing and merging cities and their surroundings (YA, 18.2.1951; YA, 09.05.1951). Aru affirmed with this in his thoughts on the plan:

"We were to design one of Turkey's largest port cities. The goal was to take into account the city's location inside the municipal limits. The planners were provided little analytical data; there was no knowledge on the country or area, and no study of population projections or planning timeframes. Anyway, the acknowledgment of the agreement and the program of the contest on which the all-inclusive strategy was based by the Union of International Architects demonstrated that the circumstance was not really not the same as Turkey (Aru, 1-9)."

Despite the fact that the demographic projections were surpassed in the 1960s and planning attempts lagged underneath the city's expansion, the plan was amended progressively via updates and affected the urban landscape for over 30 years.

By comparing the plan to the 1989 city map, it is clear that many of the town's core areas have been molded in conformity with the plan's land-use objectives.



Figure 4.30 İzmir City Map from 1989

The Aru plan had flaws in base maps and data accuracy, and it needed to prioritize ecological and historical conservation. Renovations were required, mainly for road

enlargement, and some farmland was used. The plan's effectiveness depended on the funding and developmental strategies of the ruling party. Due to financial constraints, investments were delayed, and some projects were only completed in the 1990s. However, many options from the plan were implemented, including traffic determinations, enhancements to the Alsancak seaport, railroad stations, Halkapınar sports facility, and the establishment of housing and manufacturing zones.



Figure 4.31 Sports Facility Halkapınar (YA,05.10.1971)

The plan's inacceptable and modified recommendations included the expansion of roadways in Kemeraltı, which was halted by the Conservation Act in the 1970s.

The plan's inacceptable and modified determinations included the expansion of streets in Kemeraltı, that was canceled throughout the 1970s by the Conservation Act, Konak square, that was rethought several times but never completed, the university were established in Güzelyalı, that was relocated to Bornova, the leisure zone about Halkapınar pond, the forests of Kadifekale's foothills, and active and inactive green spaces in other sections of the town that were transformed into constructed zone by revitalization or illegal constructions.

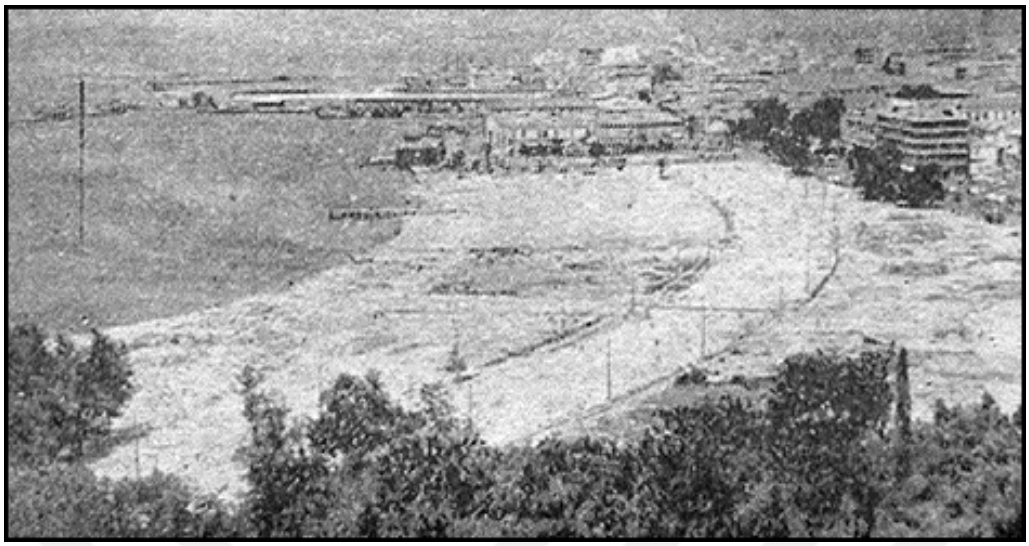


Figure 4.32 Konak, 1958 (YA, 27.06.1958)



Figure 4.33 Konak, 1972 (YA, 16.03.1972)

4.2.2 The İzmir Metropolitan Planning Office's Plan, 1973-1978

Consequently, the fast urbanization trend of the 1950s and 1960s, İzmir began to merge with its environs and transform into a metropolitan town. The prior approaches for planning attempts were inadequate to address the city's issues. There was a necessity to create a plan that took into account the town and its environs, as

well as the administration's five-year growth objectives. İzmir's fifth planning exercise took place in a new economic and political context and with a various institution.

Turkey's Political and Socioeconomic Structure in the 1960s

In the 1960s, Turkey experienced a transition in its political and socio-economic structure following a military coup. The State Planning Organization was established, and five-year growth plans were developed with a focus on industry-based advancement. To address the challenges of rapid urbanization and the integration of surrounding settlements, metropolitan planning departments were established in major cities like İzmir, Istanbul, and Ankara.

The Bank of Provinces played a significant role in collecting and analyzing data for urban planning. The Act of Squatters was enacted to address slum dwellers' issues, including slum recovery and deportation plans. In terms of education, the Department of City and Regional Planning at METU was established, and the Chamber of Turkish City Planners, Architects, and Engineers was formed to institutionalize city planning as a discipline.

İzmir's Spatial Structure in the 1960s

As İzmir grew into a densely populated urban center, surrounding communities like Güzelbahçe, Narlıdere, Balçova, Yeşilyurt, Çamdibi, Gültepe, Altındağ, Pınarbaşı, Işıkkent, and others established their municipal government organizations due to increasing land values and development.

Kemeraltı was considered the historic center, while the new Central Business District (CBD) was located in the Gümrük-Basmane-Atatürk Statue area, catering to various commercial activities. The CBD was expected to expand in different directions, serving different income groups and types of businesses.

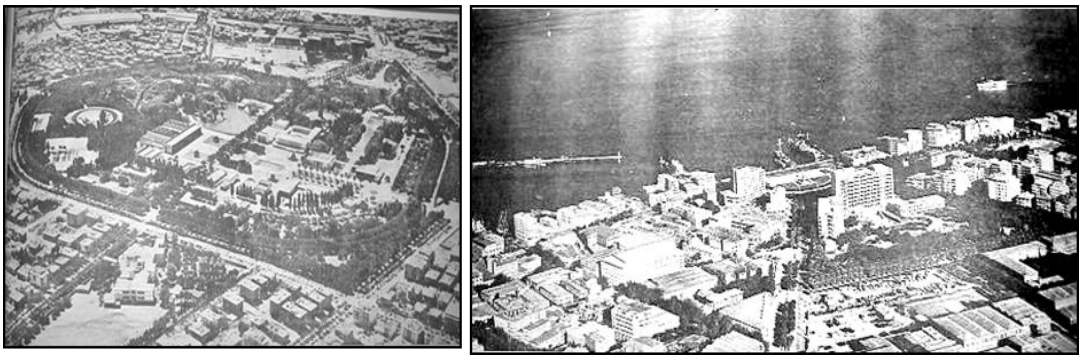


Figure 4.34 İzmir's central districts in the 1960s (YA, 09.08.1967, 18.03.1968)

Housing zones were formed in the city as high-income groups around the bay, such as Alsancak, Karşıyaka, Göztepe, and Güzelyal areas, and in recent years in Hatay, middle-income groups in historic regions and Karşıyaka, and low-income groups in slum settlements established surrounding the center city. High income housing districts were bordered by other urban activities, and because these regions lacked development sites, they rose vertically and in intensity.



Figure 4.36 1960s Housing zones near Güzelyalı (YA, 03.12.1968)

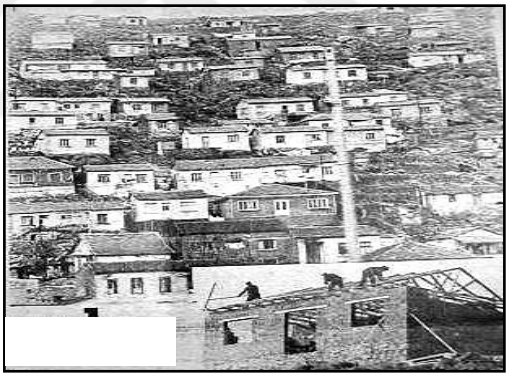


Figure 4.35 1960s squatter settlements (YA, 17.01.1968)

The number of industrial facilities in Izmir has expanded as a result of the administration's improvement strategies. Aside from the manufacturing regions positioned surrounding the Alsancak port, Halkapnar, Mersinli, and partly forward into Bayraklı, new manufacturing functions are being developed in the Karabağlar, Kemalpaşa, and Çiğli precincts.

The principal transportation associations of the city to the external parts were given through Ankara, Bornova-Manisa, Karşıyaka-Menemen-Çanakkale and Çeşme routes; Basmane-Balıkesir-Bandırma, Basmane-Menemen-Afyon and Alsancak-Aydın rail routes; Pasaport travelers port and Alsancak cargo port; and Gaziemir and Çiğli military and Cumaovası common air terminals. In this era serious issues of the city were gridlock, water shortage, contamination of the bay and extension of the slums.

Master Plan Preparation: 1968-1973

The İzmir Metropolitan Planning Department, established in 1968, created the city's sixth master plan. The department, formed through collaboration between the Municipal government of İzmir, the Ministry of Development and Settlement, and the Bank of Provinces, began its research and analysis in 1965. The agency comprised a diverse team of professionals, including new graduate city planners and international experts (Beyru, 1991). The planning process involved a roadmap, methodology, and timetable, and despite the research not being fully completed, the plan was presented to the municipal committee for discussion and required changes in 1971. The plan was then submitted to the government in 1972 with the understanding that it was subject to further amendments. Finally, in 1973, the plan was accepted (YA, 1971; YA, 1972).

The plan was evaluated in three stages:

- The provinces of İzmir, Manisa, Aydın, Denizli, and Muğla were included in the Aegean Region. This framework's examination involves the role of İzmir at global, national, regional, and urban sizes, as well as the transport system (Master Plan, 1972, pp. 13-22). Proposals for agricultural production, manufacturing, entertainment, and infrastructure were presented under this framework (Master Plan Report, 1972, pp. 76-90).

- Main İzmir, Karşıyaka, Bornova, Karaburun, Çeşme, Urla, Seferihisar, Selçuk, Torbalı, Bayındır, Kemalpaşa, Menemen, Foça, Dikili, Bergama, Kuşadası, and pivotal Manisa sub-provinces were incorporated in the Metropolitan Zone. Physical environment, social, economic, and demographic elements are all examined at this scale (Master Plan Report, pp. 23-35, 1972). For this casing a plan arranged at 1/250.000 scale in which the workplace decided the significant qualities of the settlements in the metropolitan region and decentralized a portion of the focal capacities or distributed new capacities to these settlements was adopted. Principal decisions of the plan:

- Aliağa, Torbalı, Turgutlu, Kemalpaşa, and Manisa would be the fastest expanding and most populous cities.
- The communities of Çeşme, Karaburun, Seferihisar-Sığacık, Gümüldür, Ahmetbeyli, Selçuk, Kuşadası, Foça, Yeni Foça, Dikili, Çandarlı, and Bergama would become tourism destinations due to its ecological, historical, and heritage potential.
- Menemen and Cumaovası would develop as polar subsidiary zones on the northern and southern axes, respectively, while Urla and Güzelbahçe would develop on the eastern and western axes.
- Activity locations for advanced manufacturing, sociocultural, and technological infrastructural expenditures would be identified.
- Productive farmland as well as rural regions would be protected and promoted.
- A public park green area and a snow sports complex are suggested for Bozdağ, in addition to leisure places on Samsun peak, Sipil highlands, Efes, Bergama, and Dilek peninsula.
- Oil industry and related industries would be established in the Aliağa area.
- Alternative energy and water resources would be discovered as part of regional technological infrastructure initiatives.

- The suburb railroad lines Aliağa-Menemen-Manisa and Aliağa-Menemen-zmir-Cumaovası-Torbalı would be energized as a result of the aforementioned improvements.
- The harbors of Alsancak, Çeşme, and Dikili could be enlarged, a marina would be built in Kuşadası, and agrarian ports would be built at Urla, Sığacık, and Çandarlı (Master Plan Report, 1972, 91-95).
- Next to this arrangement in 1974 the specialists of Ministry of Development and Settlement, Ministry of Tourism and Bank of Provinces chose to set up a construction plan for the beach front districts inside the metropolitan region, the plan arranged at 1/250.000 scale, finished in 1976 and supported in 1981. (Master Plan Report, 1976)

- Major (Whole) City comprised the towns of core İzmir, Bornova, Buca, Gültepe, Çamdibi, Altındağ, Yeşilyurt, Balçova, Narlıdere, Güzelbahçe, Çiğli, Gaziemir, Pınarbaş, and 31 surrounding villages: Kaynaklar, Çatalca, Gölcükler, Görece, Kısık, Uzundere, Çamiçi, Çiçekli, Doğanlar, Eğridere, Gökdere, Işıklar, Karaçam, Kavaklıdere, Kayadibi, Kurudere, Naldöken, Sarnıç, Yaka, Doğançay, K. Çiğli, Örnekköy, Asarlık, Sancaklı, Yamanlar, Harmandalı, Balatçık, Koyundere, Kaklıç, Sasallı, Ulucak. It was 76.000 hectares in size. Natural characteristics, terrain, elevation, geology, flora, soil capacity, weather, property pattern, social system, urban property use, public transit, circulation, heritage places, and major investment programs were all examined (Master Plan Report, 1972: 35-75).

These presumptions guided the concepts made at this scale:

- The metropolis will keep expanding at a rapid pace.
- It will serve both global and regional purposes.
- As family sizes decrease, the need for hotel spaces increases.
- The younger generation will grow, causing an expansion in the service industry.

- Minor manufacturing groups will aim to combine, increasing the demand for large manufacturing sites.
- New workplace relationships will lead to an expansion in automobile owning.
- The demand for community transportation will expand.
- Despite funding resources for implementing plan choices are restricted, there are efficient entities and organizations in İzmir that will facilitate the execution of planning initiatives (Master Plan Report, 1972, 96-107).

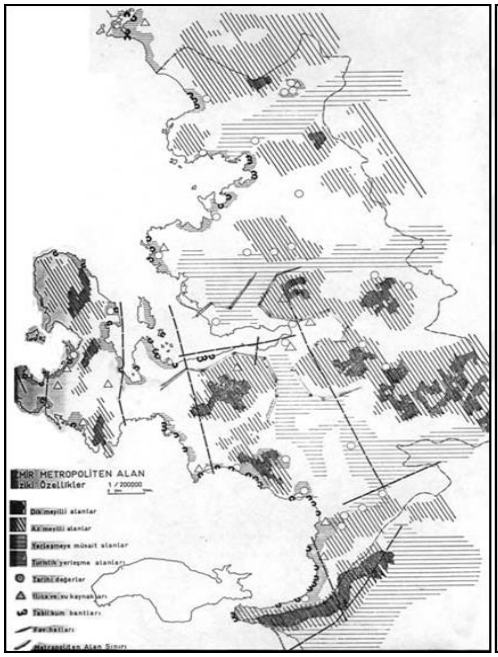


Figure 4.38 Metropolitan Area's Physical Structure (Master Plan Report, 1972)

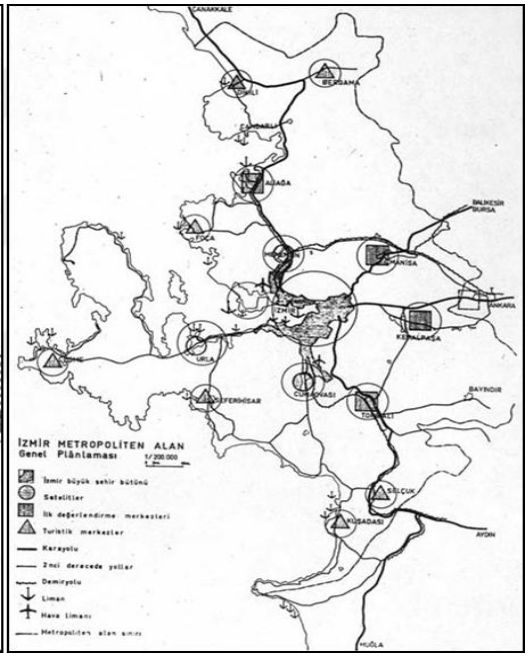


Figure 4.37 Metropolitan Area ‘s Master Plan ((Master Plan Report, 1972)

Based on these estimations, the Metropolitan Planning Department created four optional conceptual layouts. They chose the alternative that suggests a straight morphology along a north-south path after evaluating the options.

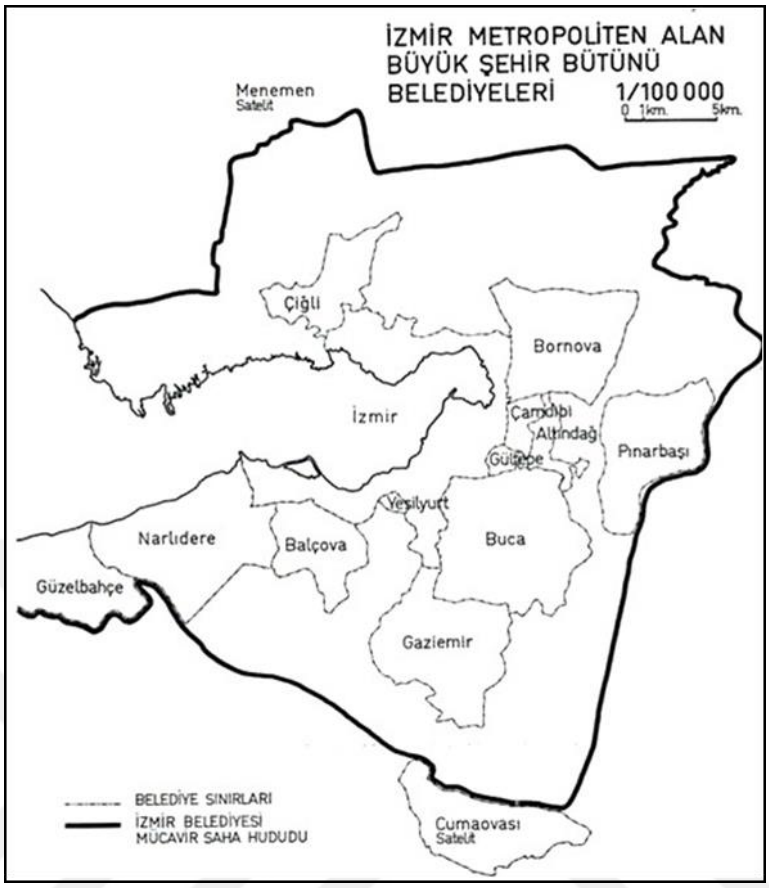


Figure 4.39 City Limits of the Metropolitan Area (Master Plan Report,1972)

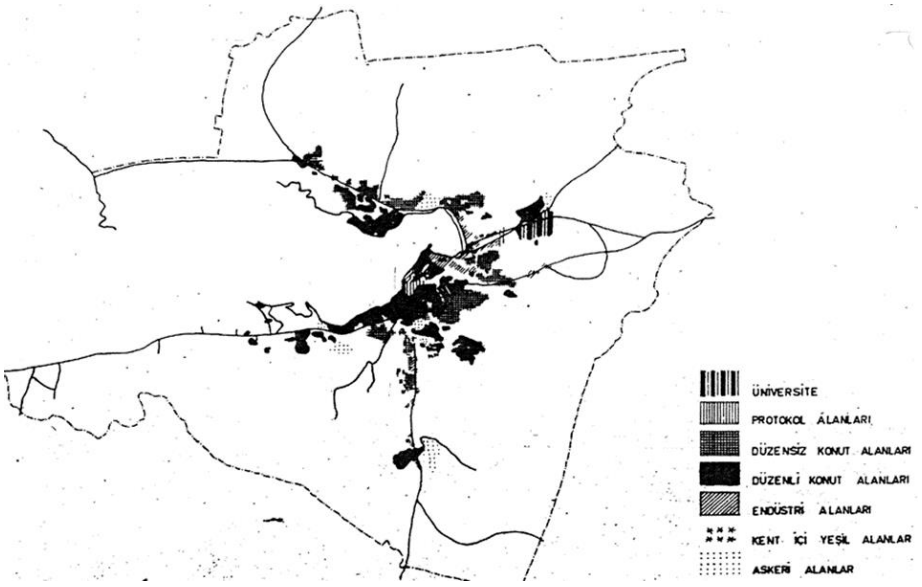


Figure 4.40 Current Land Use Map, 1970 (Metropolitan Planning Department, 1985)

The following were the major actions recommended by and accepted in the plan:

- The populace was anticipated to be 1.466.000 in 1985 and 2.024.000 in 1995.
- Macroform: The plan's main idea was to produce a linear macroform, which would be achieved through a linear transport network and manufacturing areas on both ends of the straight axis. This sort of macroform was selected because of its benefits in terms of maximizing transit options and seating capacity while minimizing trip length and infrastructural expenses. The north-south direction of the linear macroform was chosen with the goal of preserving farmland on the east and west directions and preventing expansion on the east axis due to inadequate land features.
- Urban Land-Use:

- In the old center, instances of civil architecture would be conserved in the areas of Kadifekale, Alsancak, Bayraklı, and Güzelyalı; Kemeraltı and other ancient areas would be totally conserved; and the Kadifekale zone would be started cleaning of substandard annexure.
- New CBD was situated at the intersection of significant streets, it would incorporate exercises connected with port, fundamental bus stop, discount market and distribution centers.
- All communities' current commercial occurrence areas would be enhanced.
- A region of 1280 ha. was suggested for manufacturing purposes, with the majority of it lying on two dimensions: the Şemikler-Aliağa direction to the north and the Karabağlar-Cumaovası direction to the south. Regulated manufacturing areas in the present structure might be preserved provided they are not contaminating their environs, but modest manufacturing and storage facilities would be relocated to expansion routes, and nearby towns would have their own manufacturing complexes. Industrial growth on the east direction was constrained due to the contamination of underground aquifers.

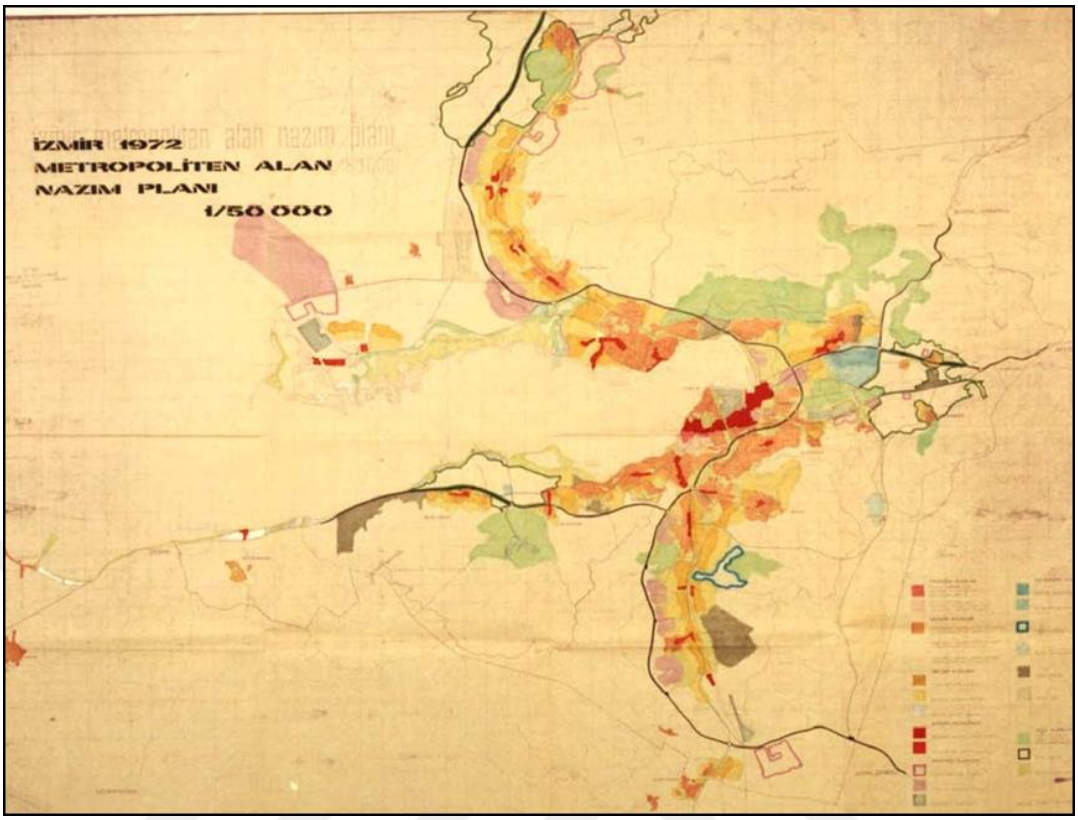


Figure 4.41 Metropolitan Planning Office Master Plan, 1973 (by Semahat Özdemir)

- The proposal envisioned an overall dwelling territory of 9723 hectares, incorporating the current 3695 hectares of constructed land, with a gross intensity of 110 people per hectare. Old neighborhoods like as Kemeraltı, Tilkilik, and Bayraklı would be conserved, as would newer areas such as Kordon, Cumhuriyet Square, Karşıyaka Yalı Street, Konak-Üçkuyular seashore, and Hatay Road. Additional zones would be restructured by altering the layout, intensity, and infrastructure to some extent. Slum settlements would be repaired and reconstructed. Summertime vacation communities would be built along the west spine. In nearby locations, restricted uses have been suggested. New residential neighborhoods are being developed in accordance with industrial growth zones.
- The location of Çiğli-Çamaltı Tuzla has been recommended as a venue for an international fair.

- The proposal called for a raise in entertainment and sporting spaces of up to 3,4 m²/person. The leisure zones of Kavacık-Çatalkaya and Yamanlar-Karagöl will be evaluated under a new proposal. Farmlands would be kept. İnciraltı and the fair area in Çiğli would be reforested, and portions of the beachfront would be extended for community access by infill.

- Transportation: All types of transport systems had the common purpose of providing efficient public transit.
- To produce a linear macroform, a direct route was planned as the spine of the urban system, involving nearly all of the modern advancements across it. This spine united the west and east directions.
- Because a quick railway system was deemed unfeasible due to the city's geographical circumstances and heavy investment costs, extant trains would be improved by linking north and south lanes and electrifying them. In Halkapınar, a multi-function railway terminal was built to merge the intercity services of the Basmane and Alsancak terminals. Main motorway intersections and road-railroad linkages were envisaged.
- Alsancak seaport would be extended, and a modern manufacturing port in the Çamaltı Tuzla zone suggested, with the bay in the Gümrük-Pasaport area changed into a touristic port. Yacht amenities and cabins have been suggested in Bostanli, İnciraltı, and Güzelbahçe.
- To tackle harbor contamination, a purification facility was suggested at Çiğili as part of the major canal construction (Master Plan Report, 1972, 108-132).

Turkey's New Developments in the 1970s

In the 1970s, Turkey faced financial and sociological challenges due to the World Economic Crisis and the strains of Welfare State programs. This led to social uprisings and a shift towards a more participatory and liberal society. The political party in power, CHP, aimed to implement social democratic ideals and introduced new measures for local government, residential regulations, and slum

redevelopment. Municipal administration regulations were also revised to improve efficiency, and the Ministry of Local Governments and the Consultation of Environment was established. A coordination committee involving various ministries was formed to facilitate planning and investment decisions. However, the progress was halted by a military takeover in 1980.

Revision Plan Preparation 1973-1978

In 1973, İzmir's master plan was presented to the ministry before its complete examination, leading to subsequent adjustments and revision investigations until 1978. The plan had flaws, disregarding existing urban expansions and prior planning determinations. Funding determinations for the linear macroform were also lacking. The mayor of İzmir Municipality, İhsan Alyanak, expressed a desire to engage former mayors and council delegates for planning investigations, but this was not effectively implemented. After adopting the master plan, the core and neighboring towns established a planning department in the municipal government for modification and subsectional plans. Private planning bureaus created and submitted master plans for linked municipalities, while the İzmir Metropolitan Planning Department improved the 1973 plan based on unforeseen changes and new needs (YA, 1973, 1974, 1975). The plan's last conclusions were made in 1978. The following were the revision plan's major considerations:

- The seaport suggestion in 1973 was rejected, and the plan in 1978 was not evaluated inside the confines of Metropolitan City.
- The CBD envisioned by the 1973 master plan was oriented north-eastward.
- Salhane region, that was intended as a manufacturing region in 1955 and a recreational zone in 1973, was incorporated into CBD in 1978.
- The extant manufacturing zones on the east corridor, which were ignored in the 1973 plan, were approved in the 1978 plan.

- Manufacturing zones among both the current route and the rapid roadway on the south direction were not built as anticipated in the 1973 plan and were instead positioned along the extant roadway in the 1978 plan.
- In the 1978 design, the rapid route on the west axis was relocated to the south of the towns.
- In Kaklıç, a civilian airfield is envisioned.

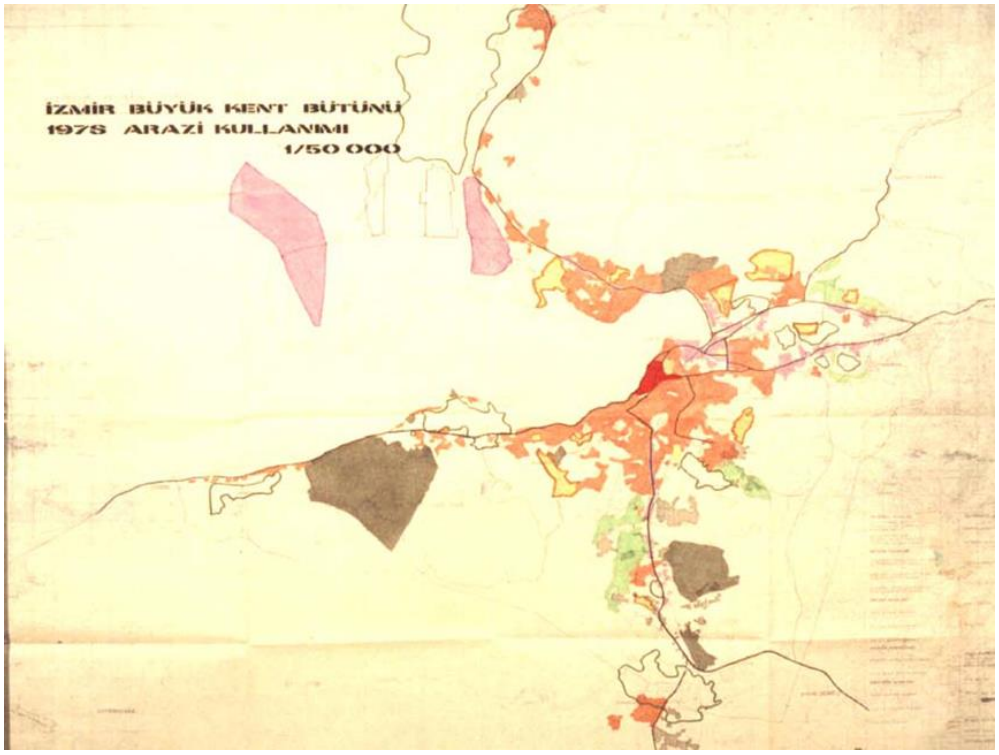


Figure 4.42 Existant Property Use Map, 1978 (by Semahat Özdemir)

The revising plan was distributed to the planners of the neighboring municipal governments, who produced their plans in accordance with it. The majority of the district designs were produced between 1982 and 1983, with others finished subsequently. Following the military coup in 1980, the neighbouring municipal governments became divisions of the Municipality of İzmir.

Metropolitan planning offices were suspended by the Greater City Municipalities Act (Act number 3030) in 1984, thereby ending the office's planning activities. The

professional personnel have been assigned to several departments of the Metropolitan Municipality of İzmir.

Aside from these master plans, various reaction zone initiatives have been created for the city's key areas, including Konak Square.

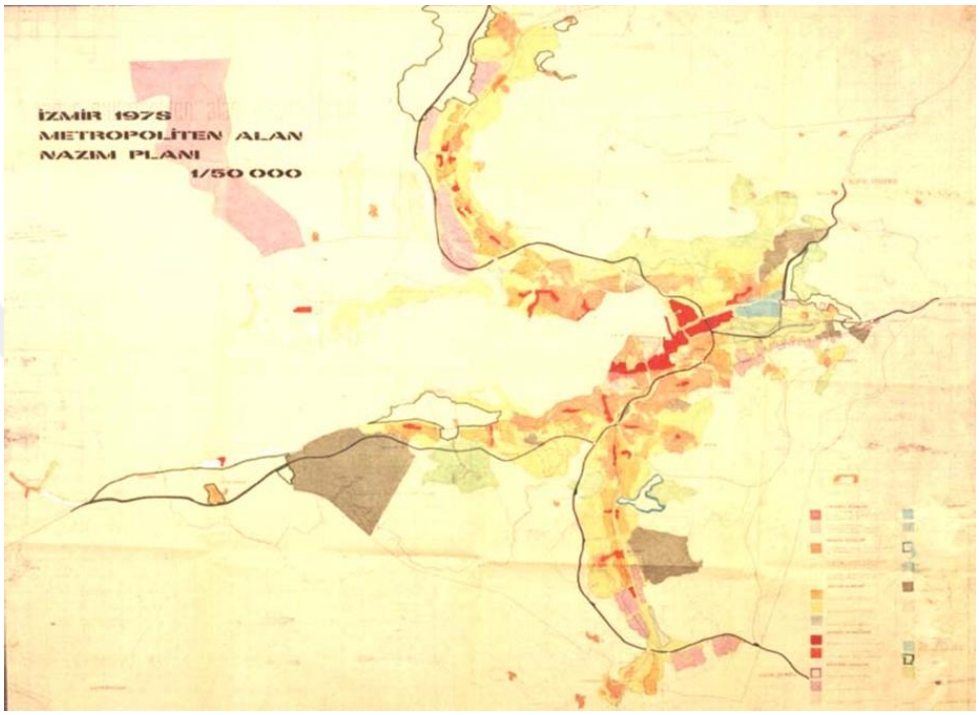


Figure 4.43 Metropolitan Planning Office Plan, 1978 (by Semahat Özdemir)

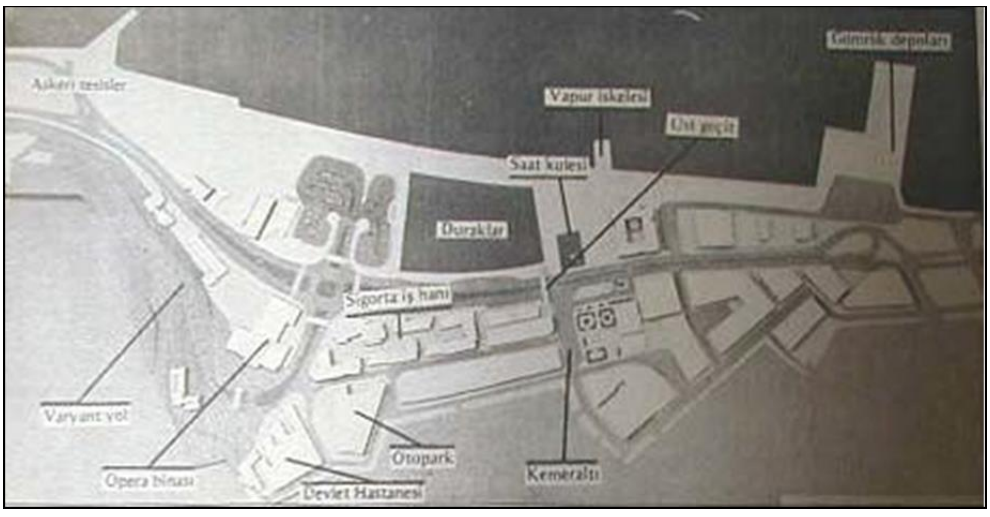


Figure 4.44 1976 Action Area Plan for Konak Square and Environment (YA, 24.04.1976)



Figure 4.45 Action Area Plan for 1st Kordon Street, 1973 (YA, 28.08.1973)

Theoretical Fundamentals and Implementation

İzmir's fifth planning initiative involved the participation of professional urban planners who were educated in a systematic and comprehensive planning approach. The adoption of this approach was supported by the Planning Act of 1957, which aligned Turkey's planning process with Western paradigms. The planning activities in İzmir followed a comprehensive rational methodology, aiming to generate precise estimates and identify future demands and trends. However, challenges arose during the planning process, such as the lengthy analysis and synthesis phase and the need for a robust control system.

The plan was not intended to be all-encompassing and was subject to adjustments. Community input was considered, although the perspectives of a small group held more weight. Discussions were held with local and ministry officials and industry representatives to inform the plan's development and implementation, especially regarding industrial growth.

The plan developed by the Metropolitan Planning Office included several ambitious projects funded by various government and private organizations. While specific measures were taken regarding manufacturing and housing, the envisioned transportation systems, which were considered crucial for achieving the desired

urban form, could only partially be realized. Despite recognizing most plan recommendations by the collaboration council, implementation delays occurred due to financial and administrative constraints. Projects such as the advancement of the rail network and the Bay rehabilitation project were only realized towards the late 1990s. In addition to financial and bureaucratic challenges, the concept of linear city expansion proved unrealistic for a city that had primarily grown around the bay and along five major highways (İstanbul, Ankara, Aydın, Çeşme, Çanakkale). Another notable shortcoming of the plan was the lack of effective measures to prevent the emergence of slums and the occupation of inactive green spaces by slum dwellers, despite providing new housing areas for low-income groups.

Nevertheless, certain aspects of the plan were successfully implemented, particularly in residential, manufacturing, and recreational zones, primarily along the north and west directions. The establishment of the Aliağa Processing plant in 1969 attracted the chemical industry to the northern region, leading to the initiation of regulated manufacturing zones in the late 1970s through the Ministry of Development and Settlement intervention programs. Significant efforts were also made, with the Ministry of Development and Settlement and the Bank of Estate and Credits's involvement to construct large-scale residential complexes along this direction, which remained in use until the late 1980s.

Furthermore, the expansion of the Alsancak seaport in the late 1970s facilitated the relocation of cargo port operations from the Gümrük area to the Alsancak seaport. In the western direction, the construction of low-density housing was successfully accomplished. The bay's coastline was also developed with land reclamation, and new recreational spaces were created. While the realization of the Çiğli exhibition and recreational park was not achieved, the concept for the İnciraltı recreational zone was substantially implemented and has become one of the most popular leisure areas in the city.

4.2.3 İzmir Metropolitan Municipality Plan, 1989

The 1973 plan underwent revisions in 1978 to address its shortcomings and incorporate additional partial planning determinations. Despite the efforts of local authorities to meet the growing demands during this revision, the actual urban development diverged from the original 1973 plan and its 1978 amendment. This divergence was primarily due to changes in government investment priorities and the proliferation of unauthorized housing and manufacturing projects. The sixth planning initiative in İzmir can be considered a revision plan undertaken by the municipality in response to a crucial turning point in Turkish history and guided by new planning legislation.

Turkey's Political and Socioeconomic Structure in the 1980s

In 1980, Turkey entered a new phase marked by a military coup and constitutional amendments, leading to significant changes in monetary policy and administrative structure. During Prime Minister Özal's term, the country implemented new liberal economic regulations aimed at integrating with the global community. These measures included the liberalization of international trade, privatization of state assets, and the introduction of new fiscal policies. In order to revive the economy, there was a particular emphasis on promoting the tourism and construction industries.

To achieve these economic goals, various development projects were initiated, including the construction of large-scale housing areas, high-rise towers, universities located outside the city, international trade hubs, new airports, and infrastructure investments. However, these endeavors were carried out without a comprehensive master plan. Instead, urban expansion occurred through piecemeal projects driven by the government's funding and placement decisions, which often took precedence over the principles outlined in master and implementation plans.

Among the new legislation and plan variations introduced during this time period were:

- ***1981 Mass Housing Act***: Government property might be used for massive dwelling.
- ***1982 Tourism Act (No. 2634):*** State property may be designated for touristic purposes, and the Ministry of Tourism could create tourism plans.
- ***1982 Amnesty Act (No. 2805):*** Unauthorized structures may be authorized, and slum areas may be established through redevelopment plans.
- ***1983 Conservation Act (No. 2863):*** The Ministry of Culture could draft preservation plans.
- ***1983 Environment Act (No. 2872)***
- ***1983 National Parks Act:*** The Ministry of Agriculture and Forestry could draft national park growth plans.
- The Ministry of Development and Settlement was merged with the Ministry of Reconstruction in 1983, giving rise to the Ministry of Reconstruction and Settlement.
- ***1984 Greater City Municipality Act (No. 3030):*** Metropolitan municipalities might create master plans for cities.
- ***1985 Planning Act (No. 3194):*** This legislation included provincial plans provided by the State Planning Department, master plans at 1/25.000 scale made by the Ministry of Reconstruction and Settlement, master plans at 1/5000 scale and execution plans at 1/1000 scale produced by municipal governments, modification plans, and incomplete plans. Prior to the introduction of the law, each municipal government may draft its own building rule; however, with this act, a standard regulation was brought for all municipalities, with the exception of the municipal governments covered by the Greater City Municipality Act. The law's theoretical foundation was comprehensive land use planning.
- ***1990 Coastal Act (No. 3621):*** The Ministry of Reconstruction and Settlement would develop coastal development strategies.

İzmir's Spatial Structure in the 1980s

During this period, the city of İzmir experienced horizontal and vertical expansion. While some of the land use decisions proposed in the previous metropolitan master plan were implemented, the overall shape of the city expanded in all directions rather than following a linear north-south axis. In addition to the expansion towards the north and south, the city also grew in the east and west directions. Over the past two decades, neighboring municipalities have also undertaken their urban development initiatives, including establishing municipal structures and creating master plans.

The master plans of Gaziemir, Narlıdere, Balçova, and Çamdibi municipalities was approved and implemented in 1981. The master plans of Buca and Bornova municipalities were authorized at different stages, with the master plan of Buca implemented in 1983 and Bornova in 1985.

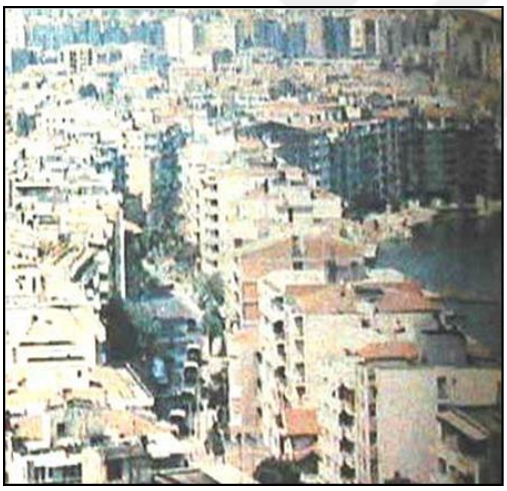


Figure 4.47 1980s Karataş and Güzelyalı Districts (YA, 27.09.1980)



Figure 4.46 1980s Konak Square Environs (YA, 27.09.1980)

Most of the central areas in the city of İzmir were developed based on the 1955 master plan and subsequent revisions, which aimed to increase urban density. However, many crucial infrastructure decisions and community projects proposed in previous plans remained incomplete. While one of the main roads recommended in the 1955 plan, Altınyol, was constructed, another important route, the Konak-

İnciraltı coastline route, was still being built. Despite completing the perimeter road, it did not effectively address traffic congestion and transportation issues.

The city faced significant challenges, including traffic congestion, air and water pollution, and inadequate green and open spaces. Recreational areas proposed in earlier plans were yet to be developed. The bay filling for road construction, recreational spaces along the coastline, and even residential neighborhoods exacerbated these issues.

While amnesty legislation legalized existing slums, new ones emerged outside the jurisdiction of municipal governments and planned districts within the neighboring territories of the metropolitan municipality. During this period, a notable effort was made to construct large residential buildings on government-owned land to address the housing crisis.



Figure 4.48 Trying to fill operations on the shores of İzmir Bay in the areas of Konak-İnciraltı and Bostanlı, 1980s (YA, 05.05.1980)

Planning Process

As a result of governmental reform in 1980 and subsequent changes, the planning department in İzmir was disbanded. In 1985, a new planning process was initiated, leading to a reassessment of the judgments made by the Metropolitan Planning Office. Starting in 1978, extensive studies were conducted to prepare master plans

at a 1/5000 scale and execution plans at a 1/1000 scale, which was finalized in 1987. Building upon these investigations, the Metropolitan Municipality administration decided to rewrite the existing master plan and incorporate new enhancements.

The Department of Planning, Programming, Coordination, and Project prepared the revised plan 1987. The proposal was adopted by the Reconstruction Commission in 1988 and authorized by the municipal council the following year under the leadership of Mayor Burhan Özfatura. In 1989, after being discussed in local authority sessions and receiving minor changes, the committee and the Ministry of Reconstruction and Settlement reapproved the plan in response to general complaints. Rather than a revision plan conducted through a comprehensive assessment of the urban fabric and future needs, the plan was developed by merging operational plans and providing recommendations for underdeveloped areas. The resulting plan consisted of 15 sheets and encompassed a total area of 87,000 hectares.

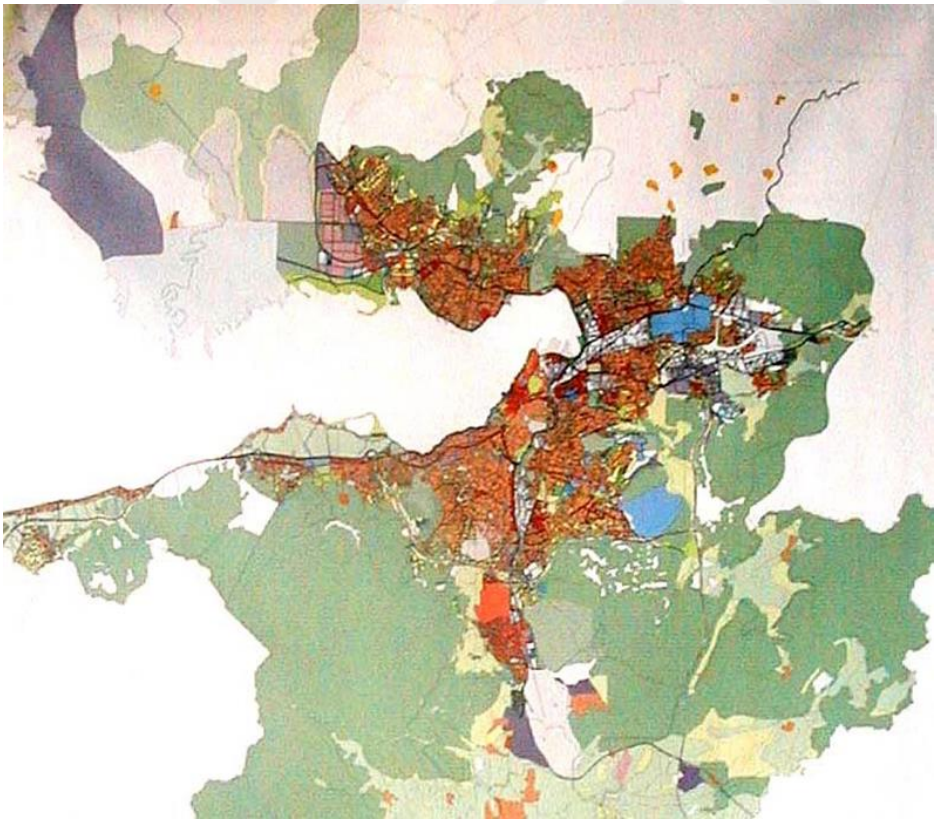


Figure 4.49 Combining of Implementation Plans from 1978 to 1987 (Metropolitan Municipality Archives)

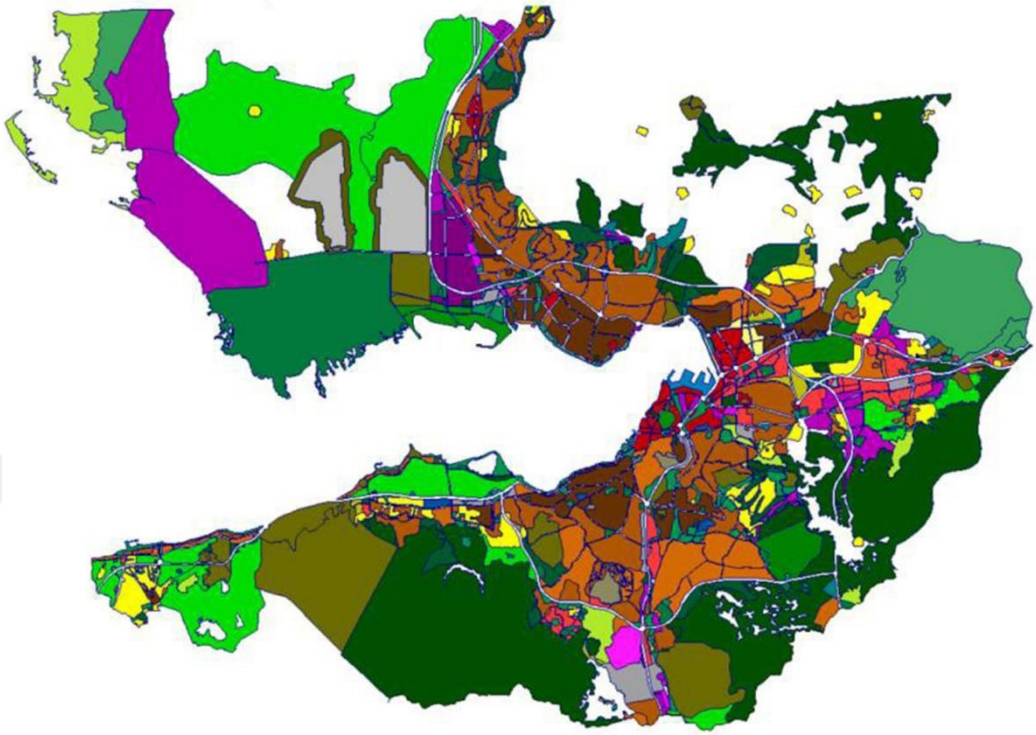


Figure 4.50 1989 Metropolitan Municipality Master Plan (Metropolitan Municipality Archives)

The plan's major objectives were:

- The populace was estimated to be 4.200.000 in 2005.
- The projected periphery route and highway routes in the 1978 plan were altered.
- The airfield in Çiğli remains an armed forces and civil airfield, with terminals at Gaziemir and Cumaovası.
- Aliağa's unrestricted area was shifted to Gaziemir.
- When considering the Tahtalı barrage area, expansions on the south direction are confined to Gaziemir and Cumaovası.
- With the unrestricted area and airfield in consideration, a 50-hectare business zone was established in Gaziemir.

- Dokuz Eylül University, that was founded in 1982, was given a campus location in Buca.
- The prior plan's fair and entertainment zone in Bostanlı-Çiğli was converted into housing uses and a purification facility.
- As depicted in the 1973 proposal, Bird Paradise would be designated as a national park, and the Tuzla area would be protected.
- The housing zones envisioned in the 1978 plan to the west of Çanakkale Highway were abandoned.
- Extant housing and manufacturing sectors on the east direction have been approved, and certain alterations have been made to the manufacturing, farming, and commercial sectors of Işıkkent and Pınarbaşı.
- A 30-hectare plot of land to the south and southeast of Balçova has been designated for housing development.
- A 160-hectare plot of land west of Güzelbahçe has been designated for housing development.
- Extant green spaces have been conserved.
- Changes have been made to approve constructed zones and enhance building storeys through exclusions of unlawful structures, incomplete plans, restoration plans, and so on (Metropolitan Municipality Archives).

The 1989 master plan for İzmir is currently being implemented within the boundaries of the Metropolitan Municipality. However, several subsequent planning efforts have taken place since 1996. These include the development of an environmental management plan for the Tahtalı barrage delta in 1996, the establishment of the Çiğli leisure area in 1997, and a global competition held in 2001 for the design of a new center for İzmir, encompassing the vicinity of the Alsancak port. In the 2002s, the Metropolitan Municipality formed a council of various organizations' representatives. The purpose of this council was to make strategic decisions for the city at different levels.

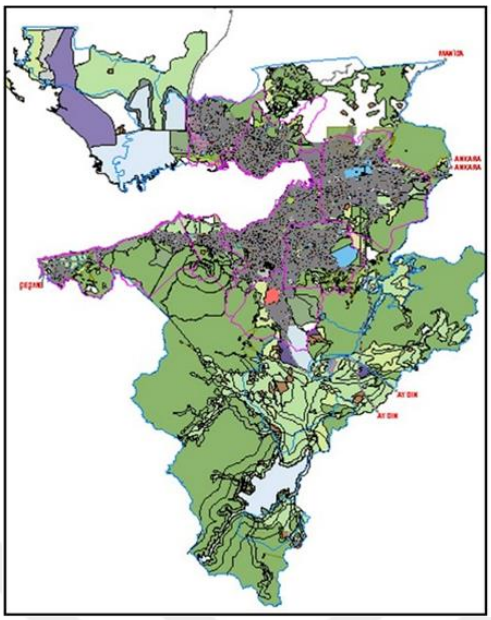


Figure 4.51 Extant Land Use Map from the 1990s (Metropolitan Municipality Archives)

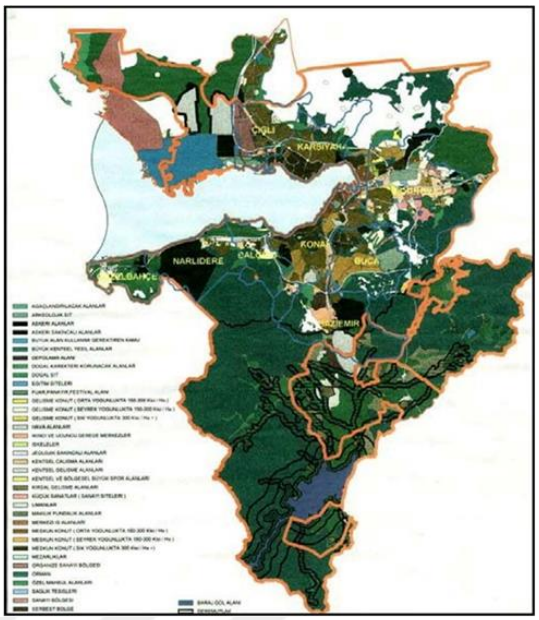


Figure 4.52 Metropolitan Municipality Plan, 1996, containing the Tahtalı Barrage Plan (Metropolitan Municipality Archives)

Theoretical Fundamentals and Implementation

Although based on the 1973 and 1978 plans of the Metropolitan Planning Office, the Metropolitan Municipality Plan cannot be considered a proper modification plan that complies with the legislative requirements. The suggestion differs from the guidelines outlined in the Planning Act 3194.

The main criticism of the plan was its failure to conduct a comprehensive evaluation of urban development. Instead, it focused on merging the area plans from 1978 with some subsequent adjustments and introducing changes and refinements in planning determinations, particularly concerning the government's major financial decisions. However, the plan needed a solid organizational foundation and began with a methodological framework based on a hypothesis. The planners may have recognized the limitations of previous planning attempts, which aimed to exert complete control over the urban framework but ultimately saw incremental changes

driven by public funding and private interventions. As a result, the planners may have prioritized incorporating emerging developments into the plan rather than ensuring the implementation of plan determinations.

The urban design and layout of the city remained unchanged as most development projects and government or private initiatives were approved and implemented in line with the plan. One of the main objectives of the plan was to improve the transportation system, which included the construction of external and main roads, a shoreline road, the introduction of a light rail system, and the enhancement of ferryboat harbors to alleviate traffic congestion, a significant concern for the city in the 1970s and 1980s.

Various critical adaptations of the plan were realized, such as the establishment of an airport and a public area in Gaziemir, a university campus in Buca, housing zones and a purification facility in Çiğli, a leisure zone in İnciraltı (excluding the relocation of the fair), a manufacturing area in Pınarbaşı, the development of the Işıklar district, the creation of a national park in Tuzla, and residential developments in Güzelbahçe.



Figure 4.53 Construction of a coastal highway (Metropolitan Municipality Archieves)

4.2.4 İzmir Metropolitan Municipality's Environmental Plan, 2012

The primary objectives of the Izmir Metropolitan Entire Environmental Plan are to address the challenges caused by rapid and uncontrolled urbanization and fragmented and sectoral planning and to ensure balanced industrialization and urban development. The plan aims to promote self-sustaining developments, prevent potential adverse effects on the ecological balance, and protect cultural and natural values until 2030.

To achieve these goals, a holistic approach is proposed, considering the city and its surroundings in the urbanization process. The aim is to move away from plans lacking implementation tools that cannot be effectively executed. Instead, the plan seeks to make rational decisions, respect environmental and cultural values, promote employment opportunities, and meet the region's settlement, socio-cultural, and urban needs.

Within the boundaries of the Izmir Metropolitan area, which offers diverse opportunities to its residents due to its abundant potential, it is crucial to identify strategies that enable society to achieve modern living conditions through healthy, safe, and well-organized urbanization.

Problem Definition and General Approach of the Plan

The 1/25000 Scale İzmir Metropolitan Whole Environmental Plan is an upper-scale plan produced for the borders of the metropolitan municipality and includes macro decisions. Izmir Metropolitan Municipality is the third largest metropolis of the country with 21 districts, 167 rural settlements and a population of 3,948,848 people as of 2010.

The plan emphasized that the main problem of İzmir Urban Region; It was not a matter of how much and how urban settlements, especially İzmir Central City, would grow. The problem has been identified as how to realize the principles of

sustainability, livability and fairness in the areas described by the current approved plans and how to create a healthier, safer and better-performing urban area with high quality of life and standards. Solving the identified problems would be possible by the sound determination of social, economic and spatial goals and program areas.

For the City of Izmir; The basic principle and strategy of the plan was to foresee a sustainable future by protecting vital areas (water basins, agricultural and forest areas) and ecosystems, biological diversity, underground and surface natural resources, water, soil and air quality.

The absence of a valid upper-scale plan in the planning region and the fact that the development is determined by daily, local and disconnected decisions are among the problems identified in terms of planning within the planning region. The absence of a valid holistic plan at this stage also prevented a holistic plan evaluation. Along with the Environmental Plan, an upper-scale plan including macro decisions for the entire planning area has been put forward.

It has been determined that the implementations are carried out in accordance with the environmental plan and the approved sub-scale plans contrary to these plans, especially in the settlements located in the coastal area within the planning boundaries. In other settlements, since there is no upper scale plan such as an environmental plan in terms of planning, planning decisions should be prepared together with other relevant stakeholders and put into effect in accordance with the legislation.

As a result of the researches on the existing plans approved by the pre-law administration no. 5216 in the planning region; It has been determined that the settlements planned a much wider area than the area they will need in the future when they were authorized. This situation, on the one hand, causes the deterioration and destruction of limited agricultural lands. On the other hand, it increases the infrastructure burden of local governments. For this reason, the natural structure and development of the city has been re-evaluated in terms of directing the natural

structure and development of the city, where necessary, as a result of the threshold synthesis, in the development areas opened as surplus to the need.

Another problem; The lack of upper-scale plan decisions due to different administrative boundaries within the planning area and the spatial fragmentation caused by this deficiency. While this situation led to fragmentary and sectoral planning, it also led to the emergence of settlements with insufficient infrastructure.

With this plan, it is aimed to eliminate this negativity in urban settlements and the surrounding areas, to prevent the opening of more areas for construction by planning the area needed for the target year, to develop planning decisions that ensure the protection of limited-sized fertile agricultural lands and maintain the development by considering the protection-utilization balance.

The problems determined as a result of the determinations made in terms of the general problems of the city can be listed as follows:

- The main problem here is not that the center has been the subject of serious public and private sector investments from past to present to attract a significant amount of population, but that its performance has declined to such an extent that it cannot meet the sustainability, livability and equity principles expected from a settlement system. Thus, making the stacked center meet the performance criteria is the first component of the problem that the plan must solve.
- The second component of the problem is the fringe issue, which can be dealt with in relation to the periphery of the centre. Peripheral sprawl, which is an important problem not only in Turkish cities but also in most developed countries' metropolises, points to the out-of-control land transfer and construction processes of regions outside the city but adjacent to the city, and which do not have rural characteristics at the same time. The periphery of the center of Izmir, unfortunately, is experiencing a process of fringing, which is the subject of housing, industry, storage and tourism purposes. For example, the fringes of the periphery between Güzelbahçe and Seferihisar with partial

residential developments, industrial and residential sprawls around the Seyrek settlement, and the fringes of the periphery area between Gaziemir and Torbalı for housing, industry and storage purposes adequately explain the magnitude of the problem.

- The third component of the problem is the issue of independent plans and projects produced by independent authorities within the city that derive their power from different legal regulations. As a matter of fact, the zoning plans that were built and approved by the settlements that were outside the borders of the former Izmir Metropolitan Municipality, but turned into districts and their subordinate neighborhoods with the law numbered 5216, constitute the most striking examples of this development.

Therefore, the main problem of the plan is not the question of how much and in what direction the other settlements, especially the center of İzmir, would grow, but how to realize the principles of sustainability, livability and equity in the areas defined by the current approved plans, to create a healthier, safer, higher-standard, and better-performing environment. It was a question of how the urban zone could be created. This plan has been handled according to the evaluations made as a result of all these approaches.

Spatial Structure of İzmir in 2000s

Residential Areas: There is approximately 11.109,2 ha residential area in the settled area of Izmir city. 4,310 ha of this area had been developed according to the results of slums and zoning amnesties. These residential areas were constituting 39% of the existing residential areas in the central city. According to the data of the State Institute of Statistics (1994), 42% of the Izmir Central City population (approximately 1.074.664 people) live in slum areas. Considering the number of independent units in areas requiring rehabilitation and renovation, when the number of slum-like buildings is accepted as approximately 86,219; When the number of buildings within the borders of İzmir Metropolitan Municipality was taken as

564.416 in line with the GIS 2007 data, it could be said that the rate of illegal and unhealthy construction is 15.3%. As a result of the population movements that have caused the continuous growth and spread of the city in the city of Izmir in recent years, the existence of an important housing problem in terms of quality is observed as the main problem in the field of housing. While the number of residences per thousand inhabitants in 9 districts was 347 in 2000 (the average for Turkey in the same year was 239), it increased to 459 in 2007. Similarly, considering that the household average in the city is 3.4 (for 2009) and the number of houses was 1.409.168 (for 2007), these houses (which can accommodate a population of approximately 4.791.171 people) are much higher than the population in 2007 (3.256.536). It iwas possible to say that families own more than one residence.

Although the number of high-rise buildings in İzmir (32 units) in 2009 was quite low compared to other metropolitan cities of Turkey (202 units in İstanbul, 87 units in Ankara), it was observed that the tendency towards mixed-use high-rise buildings had increased recently.

High-rise buildings differ from other structures in terms of their features; They affect the near and far surroundings in terms of physical environment, urban fabric and all kinds of urban infrastructure.

There were ongoing urban transformation projects in the city such as Kadifekale and Bayraklı Urban Renewal Project (Liquidation of Disaster-Exposed Areas), Cennetçeşme Urban Transformation/Renewal Project, Umurbey-Ege and Hilal Neighborhoods Urban Transformation Project. Efforts were underway to bring these areas in the city center to the city through projects that would be produced by considering the physical and social structure as a whole.

Industrial Areas: Considering the distribution of manufacturing industry within the borders of Izmir Metropolitan Municipality, it had been seen that Aliağa district had the most industrial area size, followed by Bornova, Torbalı, Gaziemir and Çiğli districts, respectively. Their area size was 2765.9 ha in the center, 530 ha on the

south direction, 22.4 ha on the west direction, 137 ha on the east axis, and 861.2 ha on the north direction.

- Ataturk Organized Industrial Zone: It was established on an area of 700 hectares in Çiğli district. Atatürk OSB, which was put into service in 1990, has had a capacity of 490 workplaces and 310 workplaces have been still in operation. When all companies have become operational, employment will be provided to 40,000 people. Projects were being developed for the solid waste and wastewater of the OIZ.
- Menemen Organized Leather Industry Zone: Located on the road to Maltepe Village of Menemen, ODSB was established in 1988 on an area of 200 hectares. There have been still 85 factories operating in the region, where space is reserved for 137 industrial facilities. In addition to all kinds of leather products, there were also establishments producing leather machinery and industrial establishments producing auxiliary materials, tools and equipment used in the leather industry. There were chemical and biological treatment facilities in the industrial zone, which has modern treatment facilities.
- Kemalpaşa Organized Industrial Zone (KOSBİ): In the district of Kemalpasa, 20 km distance from Izmir, on both sides of the Izmir-Ankara Highway, in the region where many industrial facilities develop irregularly, an area of 1300 hectares was allocated as an organized industrial zone in 1992. Currently, 116 industrial facilities have been operating. Construction of infrastructure and central treatment plant and expropriation works have been included in the program. The determination of the development area is carried out by the Ministry of Industry.
- Aliağa Organized Industrial Zone (ALOSBİ): İzmir Aliağa Organized Industrial Zone, which is currently in service, was established to increase competitiveness for industrialists, to open business areas by increasing investments, and to contribute to the country's economy. Petkim Organized Industrial Zone would be a region where factories processing Petkim products would be located. The region where the site selection was made, has

been included in the 1998 Investment Program. The ratio of those working in the industrial sector was 31.95%. Aliağa Small industrial site has consisted of 254 workplaces. Due to the lack of human capital that could carry out trade in Aliağa District, trade had not developed. There were many important industrial facilities such as ship dismantling facilities, paper mills, fertilizer industry, iron and steel factories, rolling mills, especially PETKİM and TÜPRAŞ.

Transportation: Urban transportation in İzmir is done by land, sea and metro. An average of 1.400.000 passengers are transported daily.

Transportation by metro has been on the route between Hatay-Üçyol and Bornova-Aegean University, and Üçyol-Üçkuyular route. In addition, there has been an 80 km long suburban line consisting of two main sections as Aliağa-Alsancak-Halkapınar (north) and Halkapınar-Alsancak-Cumaovası (south) direction. The operation of this line, which has carried out jointly by İzmir Metropolitan Municipality and TCDD, has operated by İZBAN. On the line, TCDD passenger and freight trains and suburban trains belonging to İZBAN has operated together.

In the suburban system, which passes through the most important transportation direction of Izmir from north to south, the daily passenger number of İZBAN was around 150.000.

Aliağa-Alsancak- Halkapınar route, known as the northern line, is 57 kilometers long and has had 19 stations on it. In the Cumaovası-Alsancak-Halkapinar section, which has been the southern line, the distance is 23 kilometers and there have been 12 stations on it.

Seaway is also important in urban transportation in İzmir. There have been 8 piers in İzmir, Bostanlı, Karşıyaka, Bayraklı, Alsancak, Passport, Konak, Göztepe and Üçkuyular, where passenger ferries depart. There have been mutual ferry services on Passport-Arşıyaka, Passport-Bostanlı, Passport-Alsancak, Alsancak-Karşıyaka, Alsancak-Bostanlı, Konak-Alsancak, Bostanlı-Konak, Karşıyaka-Konak, Bostanlı-

Pasport lines. In addition, transportation is provided in 25 minutes without entering the city traffic with the car ferry that makes regular trips between Üçkuyular and Bostanlı piers.

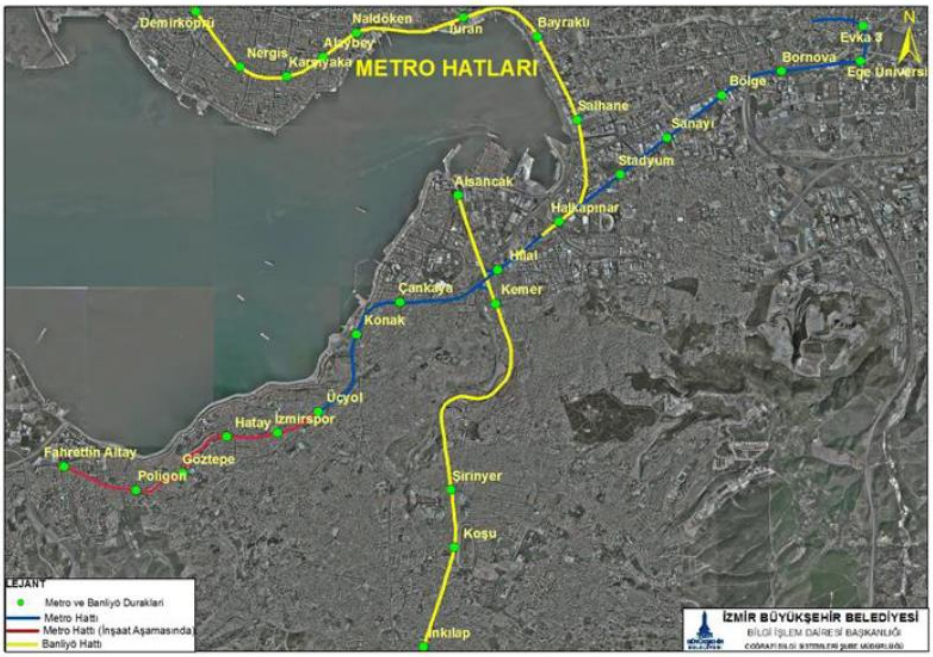


Figure 4.54 Metro Lines of Metropolitan Municipality in 2000s (IMM, 2012)

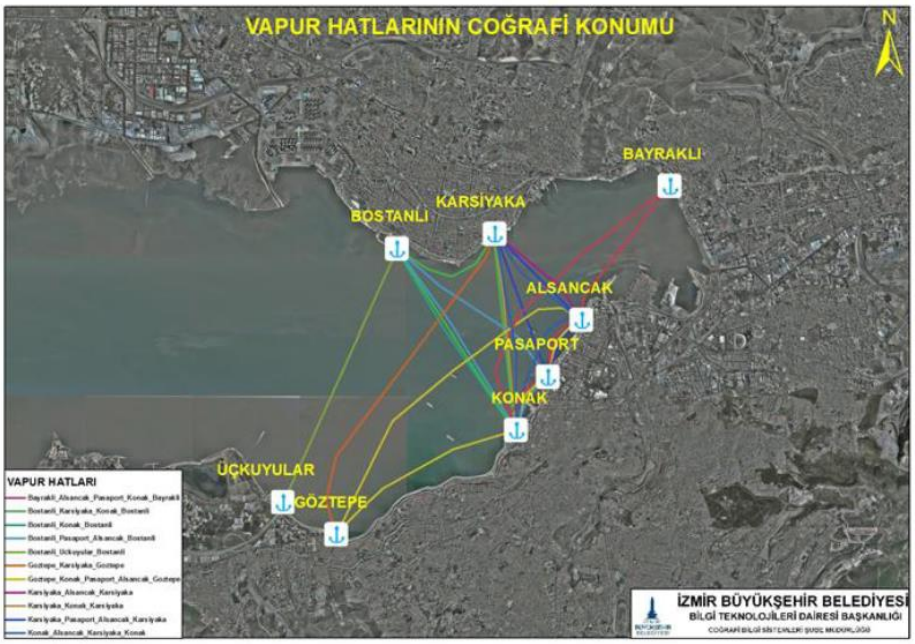


Figure 4.55 Ferry Lines of Metropolitan Municipality in 2000s (IMM, 2012)

Strategies of the IMM's Environmental Plan, 2012

City Centre: The city center, which has undergone socio-economic change with an increasing momentum since the 1950s, entered a rapid urbanization process and in this process, it has largely completed its construction and is based on natural and physical thresholds such as forest areas, protected areas, fertile agricultural lands. General plannnig strategies of İzmir Metropolitan City Center are as follows;

- To increase the social welfare and quality of life in the City Center.
- To develop urban technical and social infrastructure and social reinforcement areas and to raise standards.
- To provide the most suitable densities for social-cultural living standards.
- To ensure the stratification of the central trade areas and sub-centers (second-degree centers).
- To decentralize agglomeration in the central city by limiting development as approved plans allow.
- To encourage high technology in the industry, as well as to give particular weight to the tourism and trade sectors.
- To ensure the long-term decentralization of pollutants and large industries.
- To maintain the feature of being a port city, mainly as a passenger port.
- To improve public transport by providing quality, speed, accessibility and inter-species integration.
- To create a green belt from the ecological and culturally important areas surrounding the urban area in order to limit the crowding in the central city and to ensure that these areas are carefully protected.

Northern Direction: There are three main centers in the mentioned region, namely Menemen, Aliağa and Foça districts. Aliağa District is an important industrial center for the Aegean Region with its large-scale industrial establishments such as TÜPRAŞ and PETKİM, Aliağa Organized Industrial Zone and Iron and Steel Industrial Facilities. General plannnig strategies of İzmir Metropolitan City on northern direction are as follows;

- Taking necessary plan decisions for urban, social and technical infrastructure in order to ensure long-term urban development and to achieve high living standards in urban and rural settlements.
- Protection of the high agricultural potential of the Gediz Basin.
- Considering the future vision, taking into account the current land use situation, it is thought that industrialization will develop, and thus, ensuring a planned industrial development where the historical and natural values are preserved.
- Creating large urban green spaces to meet the needs of urban settlements.
- Protecting ecological and historical values and ensuring their transfer to future generations.
- The regions in the south and west of Aliağa District are generally considered as the regions where industry and storage areas are located, and it is predicted that there will be more urban settlement areas and service areas to be developed in the north and center of the district.
- Provided that the sectors for industrial production, energy and maritime transport, which have developed with the current situation and sub-scale zoning plans, are renewed in line with technological developments and continue their development, plan decisions for these sectors have been continued.
- In the section to the east of the Urban Settlement Area and in the 1/5000 scaled Master Plan, the area located in the high-density housing area was arranged as the Education Facility Area and the Health Facility Area, taking into account the public needs.
- A University Campus Area has been determined in Çaltidere Village, located in the north of Aliağa District, with the foresight to evaluate it scientifically, taking into account the rich sectoral diversity in Aliağa District and its immediate surroundings.

Western Direction: The Urla-Guzelbahçe-Seferihisar-Menderes-Selçuk section, which was determined as the West Axis; It has different natural thresholds with its

topography, agricultural areas, underground and surface water resources, geological-geomorphological structure and natural beauties.

The land structure of the area is rugged and dense forest texture is observed in the places where the elevation increases. In line with these topographic data, the settlements are located along the coastal road in the north and south of the peninsula, along the road parallel to the coast, and on the Seferihisar-İzmir axis along a line bordered by forest areas along the road. The area is bordered by the Tahtalı Basin in the east and southeast. General planning decisions and strategies on western direction are as follows;

- Creating sustainable, healthy, economic performance and therefore high self-sufficiency sub-regions in the areas defined by plans approved by independent authorities.
- The realization of green belts around the sub-region contributes to the prevention of further fraying of the center itself.
- Establishing the process relationship of the planning actors, using the plan in a hierarchical manner in a way that will direct the state investments and thus bring the plan into action quickly.
- Creating a real tourism activity and therefore an economic input by integrating this existing potential (culture-belief-history) of the West Axis, which is the most important region of Turkey.
- Accelerating the construction process of the infrastructure (yacht port, marina, boat repair, accommodation-background facilities-fisherman's shelters) required by the use of the coast for tourism purposes.
- Developing plan notes to create more space for tourism activities that have a limited development opportunity on the coast for various reasons, taking into account that the West Axis is a tourism sub-region.
- In some areas, developing eco-tourism activities in order to both increase the protection of special agricultural lands and contribute to tourism.

- Ensuring the protection of dams and water protection basins within the boundaries of the region from constructions.
- Developing it as a low-density living center due to its direct relationship with the West Urban Development Sub-region and the City Center. In this context, supporting developments on the basis of agricultural improvement, irrigation, boarding, hobby gardening, agriculture-health tourism, sports camping.
- Suggesting HRS connection between F. Altay- İ.Y.T.E area due to the location of the region, the functions it currently hosts and its intense relationship with the city center.

Southern Direction: It is forested in the north-facing areas of the area, and olive groves and agricultural areas in other places. While some of the settlements in the district are on the south-facing slopes of the mountains, most of them have moved to the plain in the south in 2010s. Due to the fact that Torbalı is located on the İzmir-Aydın highway, a double-track railway passes through the region, and it easily cooperates with the Aegean Free Zone, it is at a point that facilitates the supply and marketing of industrial and agricultural products with the necessary raw materials, with the transportation opportunities brought by its advantageous geographical location.

On this axis, there is an agricultural sector originating from the Küçük Menderes Basin and an agricultural industry structured in this direction. However, when we look into the industrial areas, it is observed that there are many different types of production due to the proximity to the airport, the southern provinces and the surface characteristics of the basin. Therefore, in this context, general planning decisions and strategies on southern direction are as follows;

- Providing infrastructure, transportation, social and cultural facilities, quality of life and settlement order on a regional and local scale.
- Ensuring planned development in residential and industrial areas.

- The protection of the agricultural basin and the allocation of high potential agricultural areas to agricultural activities, the development potential should be "agriculture" since there are many small settlements in terms of agriculture. In order to protect the agricultural basin, urban development should be concentrated in settlements. To strengthen and organize the agricultural potential by avoiding industrial and storage investments in rural areas.
- Preservation of ecological and historical values, evaluation with tourism and research.
- Improvement of central and secondary transport links in the context of regional service and economic cycle.
- Planning and making investments for the use of natural gas and geothermal resources to meet the energy needs of housing, industry and OIZs, and putting geothermal resources into operation for heating greenhouses.
- Directing the industries with unplanned and scattered development to the existing organized industrial zones, not allowing additional and new areas in the established and approved OIZs in the short term until full capacity is achieved, considering that planned industry sales are made but no industrial facilities are built into them, investments are more planned over time. Ensuring its spread.

Eastern Direction: The Eastern Axis is similar to the Mediterranean climate type in terms of macro climate types. This creates a favorable environment for the production of agricultural products. In addition, the lower region, which includes the Nif Basin, one of the branches of Gediz, is a region with high agricultural potential, surrounded by forests.

Nif Stream, which is the largest stream in the region, is fed by Uluçay and Kızılçay streams, and the livelihood of the local people is the sand quarries around the stream. In addition, Çiçek and Yiğitler streams cross the plain and reach the Gediz River. Of

the total agricultural land of 23418 ha, 54%, 12738 ha, is irrigated, while the remaining 10680 ha, 46%, is not irrigated.

One of the reasons why industrial establishments choose a location in this region is that it has a positive location in terms of transportation. Land and railway transportation connects the inner regions to İzmir and plays an important role due to this transportation structure. Products transported to İzmir by both land and railway transportation are opened to the outside world through İzmir Port. So, general planning decisions and strategies on eastern direction are as follows;

- Protection of the basin, which has a strong agricultural potential.
- Ensuring the most rational use of the potentials for history, tourism and agriculture in the region.
- Distributing the functions among the sectors in a balanced way and creating different sectors in the region to ensure hierarchical stratification between them.
- To determine the sectoral development targets and planning principles of the Eastern Axis and to ensure healthy development and growth in this direction.
- Providing planned industrial development by directing the partial and local industrial demands in the area to Kemalpaşa Organized Industrial Zone.
- Within the scope of ensuring sectoral diversity; highlighting the tourism investments by considering the natural and physical potential of the infrastructure as well as the industrial and agricultural identity.
- With the green belt created around the Nif basin, preventing the settlements in the basin from flowing to the south, thus protecting the agricultural potential in the green belts.
- Establishment of the Çiçek and Yiğitler Dam in order to prevent the water problem that may be caused by a large number of industrial facilities that use water intensively in the near future.

- In case the OIZ reaches full capacity, the development areas that would be required for the possible population to live in the region should be considered as a whole within the Kemalpaşa and Ulucak settlements.
- In terms of economies of scale, the separation of "Small Industrial Area" supporting the Organized Industrial Zone on the Ankara Road, provided that the conditions of accessibility and spatial suitability are sought in the area.
- To provide a solution to the energy problem of the industry and to ensure the efficient use of wind energy, which is one of the renewable energy sources, to deliver natural gas to the region within the scope of sustainability of agricultural basins.

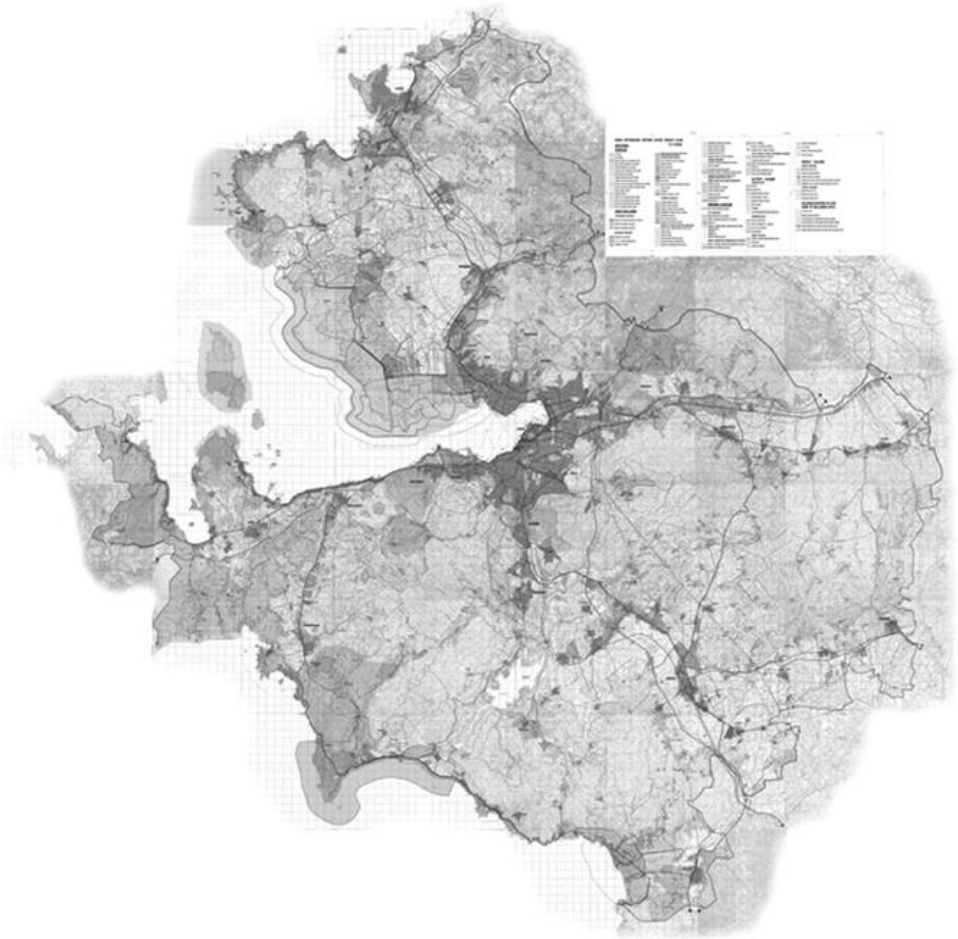


Figure 4.56 The Environmental Plan of İzmir Metropolitan Municipality, 2012

Transportation Master Plan of the IMM, 2009

The "İzmir Transportation Master Plan Report" has been concluded within the scope of the process of obtaining the Izmir Transportation Master Plan, which was initiated within the institutional structure of the Izmir Metropolitan Municipality. In the conclusion part of the report, a general description of the works that will need to be carried out from now on is also given.

Projected in the Izmir Transportation Master Plan and report; The transportation solutions and determinations, which are aimed to be developed for the City of Izmir until 2030 and can also be accepted as data for our 1/25.000 scale Izmir Metropolitan Environmental Plan, are generally as follows:

- The Tramway project, which will be a new alternative for the public transportation of the city of Izmir, has been foreseen and the lines of this project have been determined. For example, it is seen that the tram project, which is planned to be built in Göztepe and Kordon regions, will carry more than 100,000 passengers per day. It is understood that especially the section between Gündoğdu and Alsancak, which is connected to the suburb in Alsancak, will be quite effective.
- Starting from 2025, it is planned to establish a sea transportation line parallel to the coast, as envisaged on the Mithat Paşa coast.
- It is aimed to complete the suburban transportation system. In this system, Aliağa station, which is the northern line, Cumaovası station, which is the southern line, has been completed, and the Torbalı-Selçuk route is in the project phase. Considering Karşıyaka, Çiğli and the regions in the north, it is understood that the northern axis of the İzmir ring road, which is expected to be extended to Atatürk Organized today, with the suburban system that will serve this region, will significantly reduce the traffic load of Anadolu Caddesi, which carries the majority of the traffic load. However, in 2030, the road transportation network will need to be improved to a certain extent, and capacity should be increased especially in Koyundere and Asarlık sections of

Anadolu Caddesi; It is thought that it is vital to increase their efficiency by taking measures such as reconsidering the geometric arrangements on the main arterial and collector roads connected to Anadolu Caddesi and the ring road, eliminating roadside parking completely and controlling the intermediate public transportation systems in a healthy way.

- It is of great importance in terms of relieving the urban traffic that a main train station is established at suitable points selected in Bornova and Aliağa in order to save the freight and passenger demand from outside İzmir from the dependency of the highway, and that these train stations are connected to each other, at least by suburban and metro systems. Meeting the intense passenger demand between Manisa and İzmir with solutions for the road-based rail system will ensure that the interaction between the two important centers increases and resolves not only in the short term but also in the long term.
- It is predicted that the double track route of the tram, which is planned to be built in Buca, can serve an average of 60.000 passengers / day. It is thought that the private vehicle traffic on the double-track route will not show a high increase compared to the journey created, but some congestion may be seen in the first place due to the application of lane reduction.
- With the completion of the metro line, it could be said that the capacity of road transportation, especially on İnönü Street, would increase. Accordingly, it could be thought that as a result of the decrease in capacity due to the tram to be built on the Mustafa Kemal coastal boulevard, some of the private vehicle owners who normally use this line will shift to İnönü Street and as a result, the traffic load on the Mustafa Kemal coastal boulevard would decrease.
- It is understood that in the northern part of Anadolu Avenue and the section up to Menemen (including Menemen), road public transportation is effective to a certain extent, but once the suburban system is activated, the demand for

road public transportation will decrease, but demand can reach high values as of 2025.

- In Foça and Aliağa regions, it is seen that the demand for highway public transportation on the İzmir-Çanakkale state road is very low, whereas the demand for the side connection roads that reach the suburbs is high. This shows that the suburban system will be used effectively, as in Menemen, that the suburban transfer points are chosen correctly, and that the mass transportation demand between İzmir and the northern parts can be met mostly by the suburban system in the medium and long term.
- When the connections with the regions to the east of İzmir are examined, it can be said that the main arteries connecting to Kemalpaşa will serve with high occupancy rates in the future as they do today. In this section, it is seen that the main arterial and collector roads connecting the inner parts with the main road will carry high volumes of traffic load. It is predicted that the extension of the rail systems to Torbalı will be effective, and approximately 60,000 daily passengers from Bayındır and approximately 50,000 daily passengers from Selçuk will use the suburban system. When the highways parallel to the suburban system are examined, it can be said that intra-regional public transportation is effective especially in Torbalı. It is seen that the demand for highway private automobiles is also high.
- It is thought that the extension of the rail system in the west to İzmir Institute of Technology will meet the high travel demand, especially during the education period. However, when the whole year is taken into account, it is understood that the number of passengers to be carried by the part of the rail system up to Urla will be high when the whole year is considered. The line between Urla and İzmir Institute of Technology was thought to be used mostly by students and university staff. As a result of the calculations, it is seen that the existing highway system between İzmir and Urla can be operated at an acceptable service level even in 2030. It has been understood

that the demand for public transportation between İzmir and Urla will mostly be made by rail systems and this line can be considered effective.

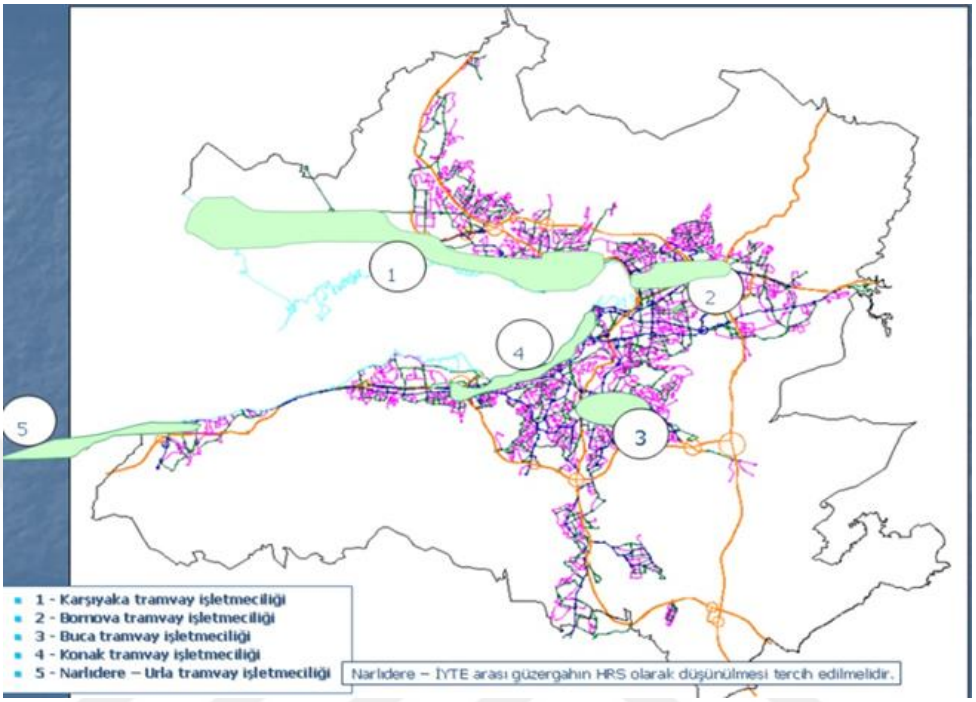


Figure 4.57 The Rail System

- The demand for existing lines, especially those connected to Karşıyaka pier, will continue to increase. Among the new lines, Eski Foça-Konak, Güzelbahçe-Mavişehir, Güzelyalı-Mavişehir, Konak-Mavişehir, Üçkuyular-Karşıyaka lines stand out as lines that will provide effective service. Increasing the capacity of these lines as of 2020 will be beneficial for the healthy operation of the system.
- It has been observed that the proposed connections of the pier planned to be built in İnciraltı will not attract enough trips to confirm the existence of the pier. A similar interpretation can be made for Bayraklı pier.
- It is seen that the metro system envisaged by the municipality will serve very effectively especially in the city center and will attract high transportation demand. If the metro (or rail system) is extended to İzmir Institute of Technology, it is thought that it will be used by students who go to university

more than those living in this region. It is understood that the rail system will serve the intense transportation demand up to Güzelbahçe. It is thought that the suburban system will be used very effectively like the subway. It is understood that a certain part of the journeys on the Aliağa, Menemen, Çiğli line in the north are related to Karşıyaka centre, the demand at the stations in Karşıyaka center decreased slightly, the second decrease in demand occurred in Bayraklı region, and the next highest demand was from Karabağlar and Gaziemir regions.

Spatial Purposes and Implementation

The city corresponds to a region defined as subject to the border established in accordance with the Metropolitan Municipality Law No. 5216. Due to the purpose of the law, a homogeneous region cannot be expected. Moreover, the city does not correspond to a plan region defined by close economic relations or geographical thresholds. However, it is inevitable that the spatial targets to be set by the plan include references outside these borders. For this reason, it would be beneficial to understand the spatial objectives of the plan from a much broader perspective, extending beyond the boundaries of the plan.

In this context, the center city will be confined within the so-called in-pot area in the directions allowed by the approved plans, provided that they are arranged from inside to outside. This is the first of the plan's spatial objectives.

The second is to establish a green belt immediately beyond this, merging with the basins of Gediz, Emiralem, Nif, and Tahtalı that make up the Küçük Menderes basin, which runs from west to east.

The third is establishing a peripheral settlement belt, beginning in the north at Aliağa and extending to Urla via Kemalpaşa and Torbalı.

The establishment of a second green belt, which connects the Büyük Menderes basin in the south of Selçuk with the Bakrçay basin in the north of Aliağa, is the fourth.

Thus, the growth of both the central city and the peripheral settlements will be constrained among the great green belts. The success in achieving these goals will largely depend on the settlement agreement and the growth management program to be prepared in line with this agreement. In addition to these general goals, another important spatial goal of the plan is to connect the Çeşme, Karaburun, Foça tourism corridor with a historical corridor connecting the high points of historical references consisting of Bergama, Sardes and Ephesus. The point to be noted here is that sea transportation will be used for the coastal tourism corridor and rail transportation will be used for the history corridor. It is inevitable that both corridors will be connected to the points of the central city with high historical and touristic values and that a manageable program of this system should be prepared.

4.3 A Discussion on the Development of Izmir Metropolitan Area

There is a debate in the political, academic, and planning circles in Izmir about whether the city's economic growth is slowing down. In order to make such a judgment, when discussing the city of Izmir, it is important to define terms precisely. The continuous redefinition of municipal boundaries in recent years has created significant problems. It could be said that in the last regulation, the widening of the metropolitan borders and their identification with the provincial borders eliminated some of the difficulties in this regard (Tekeli, 2017). Enlarging the definition of the area called İzmir will reduce the judicial errors that may arise from expanding İzmir beyond the municipality/province border. *However, the fact that the shape of the city of İzmir is not convex causes the continuation of the judicial mistakes made in this regard.*

Manisa is located in the *concavity* of the shape of İzmir in the northeast. It can be said that the problem created by this geometry started to be noticed when the Manisa Organized Industrial Zone was established as the second organized industrial zone in Turkey (Tekeli, 2017). With the start of land allocations to industries in 1970, the growth of an İzmir-based economy began to be influential in determining spatial

distribution. The distance from the organized industrial zone to İzmir is 31 km, and the distance to Manisa is 5,5 km. It is 29,9 km away from Kemalpaşa, 32 km from Menemen, 33 km from Menderes, and 104,2 km from Bergama. Considering that the city's borders are not convex, it becomes easy to comprehend what kind of distortions the city's growth creates in its results in terms of spatial differentiation.

This short discussion; shows that the boundaries of the Izmir urban region, which has economic integrity, should be determined to judge the amount of Izmir's growth in a certain period compared to Turkey's growth. At the center of this region is the Izmir CBD. Economic growth in this region varies over time because the growth of a place is a socio-spatial process. Therefore, the extent of an urban area defined according to the integrity of the functioning of the socio-spatial process is determined not by administrative decisions but by economic relations. Therefore, in order to develop a judgment on the economic growth of Izmir, it is necessary to first define the Izmir-centered urban region, then calculate the economic development indicators of this region, and then reach a judgment (Tekeli, 2017).

How the growth of Izmir's urban area differs has been revealed in the research of *Ayda Eraydın and Güldem Özatağan.* The authors of the study reveal the spatial differentiation of economic/demographic growth as a socio-spatial process around İzmir CBD in three rings.

- ***The Rings***

  The first ring is formed by the inner core surrounding the İzmir inner gulf. This ring has lost its growth dynamic, has become stagnant in population and employment growth, and even shrinks.

  First Ring: Konak

  The second ring is formed by rapid growth zones surrounding the nucleus. Today, when it is talked about the growth of İzmir in terms of population and employment, the developments in this second ring are meant. If this population extends beyond the borders of İzmir province, judgments about the growth of

İzmir based on calculations based on İzmir provincial borders will also be misleading. For this reason, Manisa must entered the concavity of İzmir province.

*Second Ring**:** Karşıyaka, Bornova, Güzelbahçe, Narlıdere, Güzelbahçe, Narlıdere, Balçova, Çiğli, Buca, Bayraklı, Karabağlar, Gaziemir*.

The third ring is the outermost ring of the Izmir urban area. It does not show rapid growth yet. However, as the development stagnates in the second ring and as the country-wide infrastructure projects passing through this zone change the accessibility of different points, the developments will also spread to this ring.

The radius of the sum of these ***three rings*** that make up the urban area is approximately 50-60 km. The influence of Izmir as the economic center of the Aegean Region is not limited to this distance, beyond that, it has an impact on the settlements of the Aegean Region. The growth of these settlements also differs depending on their history, size and level of global articulation.

Third Ring: Menemen, Aliağa, Kınık, Bergama, Dikili, Kemalpaşa, Menderes, Seferihisar, Urla, Karaburun, Torbalı, Selçuk, Tire, Bayındır, Ödemiş, Kiraz, Beydağ, Foça

In the work of *Ayda Eraydın and Güldem Özatağan*, the spatial differentiation of growth according to the rings around the city center is examined in detail based on employment and population data. For our discussion here, it will suffice to dwell on the spatial differentiation of population increases. Researchers, in the Izmir city region; defined İzmir as an area consisting of the provinces of Manisa and the districts of Aydın province adjacent to the İzmir border. By calculating the population growth "quotients" of the districts in this region between two censuses, they determined which districts grew relatively faster and marked them on the map (Tekeli, 2017).

Other Peripheral Settlements: Saruhanlı, Gölmarmara, Akhisar, Manisa Center, Kuşadası, Söke, Germencik, İncirliova, Köşk, Yenipazar, Sultanhisar, Turgutlu, Ahmetli, Salihli, Ayvalık, Gömeç, Çeşme, Aydın Center.

- ***The Maps***

Map 1

It gives the spatial differentiation of population growth in the Izmir City Region between 1990 and 2000. The places marked in dark gray on the map show the districts with population growth rates above 1. On the other hand, light gray shows the districts with population growth rates less than the average and population growth rates less than 1.

Map 1 also allows the three rings of the spatial differentiation of growth to be clearly observed in the Izmir City Region. Konak, Gaziemir, Buca, Balçova, and Narlıdere districts are located in the first ring. The districts in the second and third rings can be read from the map (Tekeli, 2017).

Map 2

It shows the spatial differentiation of the population growth rate between 2000-2008 in the Izmir city region. Three rings in which the growth differs are clearly observed in this map. However, there are some changes in the scope of the rings over time. For example, Bayraklı, Bornova, and Güzelbahçe were added to the inner core compared to the previous period. Defining this differentiation through population growth causes some growth facts to be ignored. For example, the observations about the growth of places, such as the district of Çeşme, whose economic activities are revived in certain seasons, are not reflected in the population numbers determined according to their permanent residence.

In the definition of the rings, the definitions of local governments were taken as the basis. Konak district is located in the first ring or core. The first and second rings together cover the metropolitan area boundaries determined in 1981. When the third ring is added to the first two rings, the city population of Izmir (metropolitan

population) is obtained (Tekeli, 2017). This is an administrative border. With the addition of other peripheral settlements to these first three rings, the Izmir City region is defined, which is not an administrative but a border created by Izmir's influence area.

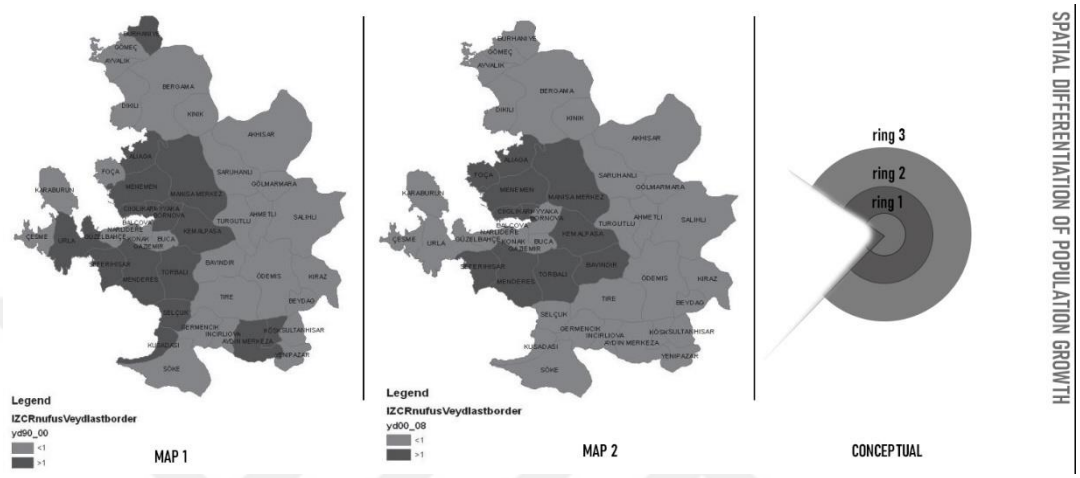


Figure 4.58 Spatial Differentiation of Population Growth, (Tekeli, 2017)

However, since the concavity of the shape of the borders of İzmir province is not taken into account in the definition of these rings, the growth in the third ring remains small. Suppose Manisa Center, which is among the other periphery districts due to the border concavity, is taken to the third ring, and some districts on the outer edge of the third ring are transferred to the fourth ring. In that case, the numbers regarding the rapid growth ring will become more apparent (Tekeli, 2017).

After determining the spatial differentiation of growth in rings, it is necessary to dwell on the reasons for this differentiation. In the period after 1950, when the population of İzmir increased rapidly, in the 1960s and even in the 1970s, the city's growth was largely in the first ring. On the one hand, slum developments were taking place in the city's immediate vicinity. On the other hand, builders were carrying out demolition and build processes, and multi-storey apartments were taking the place of two-storey residences on the shores of Izmir. In this period, the city's development was guided by the tendencies that emerged in the market mechanism and the demolition projects of the politicians, starting with the demolition of the *Sarı Kışla* in

Konak Square in 1953. At the same time, the law of the floor has solved the legal problems of this process. It can be said that during these years, İzmir got to know the destructive face of modernity closely.

It is understood that this process reached its limits in the 1980s. There are multiple reasons for this.

- ***The Reasons***

The first of these is against the destructiveness of modernity, the destruction of the historical memory of the society, the destruction of the cultural heritage; The reason for this is the realization of the institutionalization that limits destructiveness, with the awareness created by the opposition of professional chambers, professional circles and non-governmental organizations, and the declaration of the city's natural and historically valuable areas as sites. In short, society has developed resistance mechanisms against the destruction and transformation of the city.

The second reason is that the state has developed or contributed to its development; The fact that university campuses, organized industrial zones, free zones, and similar infrastructures were built on the treasury lands in the second ring contributed significantly to the formation of the second ring. In this context, the construction of the Buca Campus of Dokuz Eylül University, the Adnan Menderes civil airport, the establishment of 17 organized industrial zones and two free zones (Menemen leather products and Gaziemir advanced technology products free zones) in the Izmir city region can be counted. In terms of the contribution of state policies to the growth of the second circle, the effects of infrastructures such as İzmir Çeşme Highway, İzmir Aydın Highway, Aliağa-Torbalı İZBAN railway should not be forgotten (Tekeli, 2017).

The growth concentration in the second ring has also realized the transition of İzmir from the single dominant centered metropolitan structure to the polycentric urban region structure. A differentiation of specialization has also

emerged among the new foci formed in this transition. In this respect, it is necessary to refer to the determinations made by the researchers in question based on the changes in employment. Considering the changes in the sectoral distribution of employment, it is seen that the losses in the inner circle are not only in those working in the agriculture and manufacturing industry but also in wholesale and retail trade and social and personal services (Tekeli, 2017). The population and industrial employment shifts to the second ring and create new foci here, attracting services to new foci to a large extent. Finance, insurance, and real estate services focus on the first ring. In this ring, it is seen that the newly growing foci of the region have a particular specialization among themselves. In this ring, Aliağa, Manisa industrial center, Menemen, Kemalpaşa, Turgutlu, Torbalı, Menderes, Aydın agriculture-industry centers, Çeşme and Seferihisar are specialized as tourism and summer resort centers (Tekeli, 2017).

The third reason is that cities in Turkey started to grow not with the addition of individual buildings, as before the 1980s, but with the construction of mass housing areas organized differently. Because İzmir started to grow with the addition of urban parts, on the one hand, it became difficult to find such extensive land in the inner ring of the city. On the other hand, due to the externalities provided by the urban parts, it made it easier to break away from the city center. Hence, the concentration of development in the second ring emerged (Tekeli, 2017).

- ***A Review of the discussion for the study***

A discussion being mentioned in this section aims to explore and comprehend the various processes that are taking place in the city of Izmir. In this study, the objective is to utilize new theories and concepts that have been developed within the field of urban planning to analyze these processes. The study is significant because it endeavors to examine the impacts of the planning decisions made during these processes on the city's complexity. This research aims to evaluate the extent to which

these land use decisions have influenced the city's overall complexity using computational methods.

Urban planning is a crucial discipline that focuses on the planning, design, and development of cities, towns, and transition areas. Complexity theory is a relevant framework for analyzing urban planning processes because it seeks to understand the interplay between various elements and systems within a city. This theory recognizes that cities are complex systems that are made up of numerous interrelated components, and it provides a useful framework for analyzing the relationships between these components. When applied to the context of urban planning, complexity theory can help us understand how the various planning decisions taken in the city of Izmir have influenced its overall complexity. By using computational methods, this study aims to provide a quantitative analysis of the effects of these land use decisions on the city's complexity, further enhancing our understanding of urban planning processes and their impact on cities.

4.4 Chapter Summary

Urban planning is a complex process that requires balancing social, economic, and environmental factors to achieve desired outcomes. In rapidly growing and changing urban environments, such as İzmir, Turkey, urban planners must navigate a complex web of factors that can impact the success of their plans. Understanding the relationship between complexity and urban planning is crucial for developing effective and efficient approaches to urban planning.

The first section of this chapter, which looks at unimplemented plans for İzmir, provides valuable insights into why some urban plans may not come to fruition. This section highlights the challenges urban planners may face when implementing plans in a complex urban environment. Some critical factors that may impact the implementation of plans include resistance from local communities, limited resources, and shifting political priorities.

The second section of the chapter, which examines implemented plans in İzmir, provides a contrasting view of the urban planning process and highlights the challenges and successes associated with bringing plans to life. This section provides valuable insights into how urban planners can navigate the complexities of the urban environment to achieve their desired outcomes.

The third section of the chapter, which discusses the city's development, provides an opportunity to reflect on the study's findings and offer recommendations for the future development of İzmir. This section considers the implications of the findings for urban planning practice and identifies areas for future research.

The study's approach to urban planning considers the multifaceted and dynamic nature of the urban environment. The complexity of the urban environment is acknowledged as a critical factor that must be considered when developing and implementing urban plans. Examining both unimplemented and implemented plans in İzmir provides a comprehensive overview of the challenges urban planners face in a complex urban environment and highlights the importance of considering the complexity in the planning process.

Overall, this study provides a valuable examination of the relationship between complexity and urban planning in the context of İzmir, Turkey. The study's focus on the complexities of the urban environment and its examination of both unimplemented and implemented plans provide valuable insights into the challenges faced by urban planners and highlight the importance of considering complexity in the urban planning process. The study's findings contribute to developing more effective and efficient urban planning approaches that consider the complexities of the urban environment.

CHAPTER 5

THE METHOD OF THE STUDY

In this chapter, the technique that was used in the research is explained in more detail. In the beginning, the purpose of the study and the research questions are presented. After that, the case study area is discussed. The chapter covers data preparation and calculation of fractal dimensions using various methods, including box-counting analysis, local connected fractal dimension analysis, and sub-fractal analysis. The results will be evaluated through difference analysis and cluster analysis using Moran's I spatial autocorrelation technique with hotspot analysis. The findings will provide valuable insights for informed decision-making by city planners and for future planning endeavors to ensure the city's complexity and resilience.

5.1 Aim of the Study and Research Questions

In the previous chapters of this study, the literature related to the transition from conventional theories in urban planning to new approaches is explored. Conventional theories in urban planning have focused on rational, top-down approaches to the design and management of urban areas. However, in recent years, there has been a shift towards more bottom-up, participatory approaches that aim to increase the complexity and resilience of urban areas. This literature examines these new approaches' fundamental principles and methods and explores how they differ from conventional theories.

In the later parts, this study looks into the literature related to fractal analysis and its applications in urban planning. Fractal analysis is a mathematical technique that can be used to measure the complexity of a dynamical system and has been applied in various fields, including urban planning. The literature review investigates how fractal analysis has been used to measure the complexity of urban areas and explores

the potential of this technique as a tool for urban planning and design. This literature review also helps to provide a solid foundation for the research. It informs the study's analytical framework and ensures its findings are well-grounded in the existing literature. It contributes to the advancement of knowledge in the field of urban planning.

In light of this context, this study aims to thoroughly examine the effects of master plan decisions on the level of complexity in the city of İzmir. It specifically focuses on identifying the critical land use decisions that significantly impact the complexity and determining how these decisions affect it. Additionally, the study investigates which Master Plan of İzmir has had the most significant impact on the level of complexity and will explore how plans have addressed emerging issues related to complexity over time. The study delves into the relationship between different parts of the city's system and the overall level of complexity, looking at how they interact and affect one another.

Furthermore, the study evaluates whether urban macro-form can be used as an initial condition for bifurcation by sub-fractal analysis, a method to study the complexity of the urban structure. The study also investigates if development corridors or belts can be determined by changes in complexity level, which could provide valuable insights for future planning decisions. Moreover, another purpose of the study is to determine the range of adaptive capacity of the entire system, meaning how well the system can adapt to changing conditions, and explore the use of complexity level as a monitoring criterion for master planning. So, it could help in evaluating the effectiveness of the master plans in addressing the complexity level in the city.

Overall, the study aims to provide a comprehensive understanding of the relationship between master plan decisions and complexity in İzmir and identify potential improvement areas in future planning decisions.

The following research questions are formed in order to arrive at a definitive framework, and their formulation is based on the stated objectives:

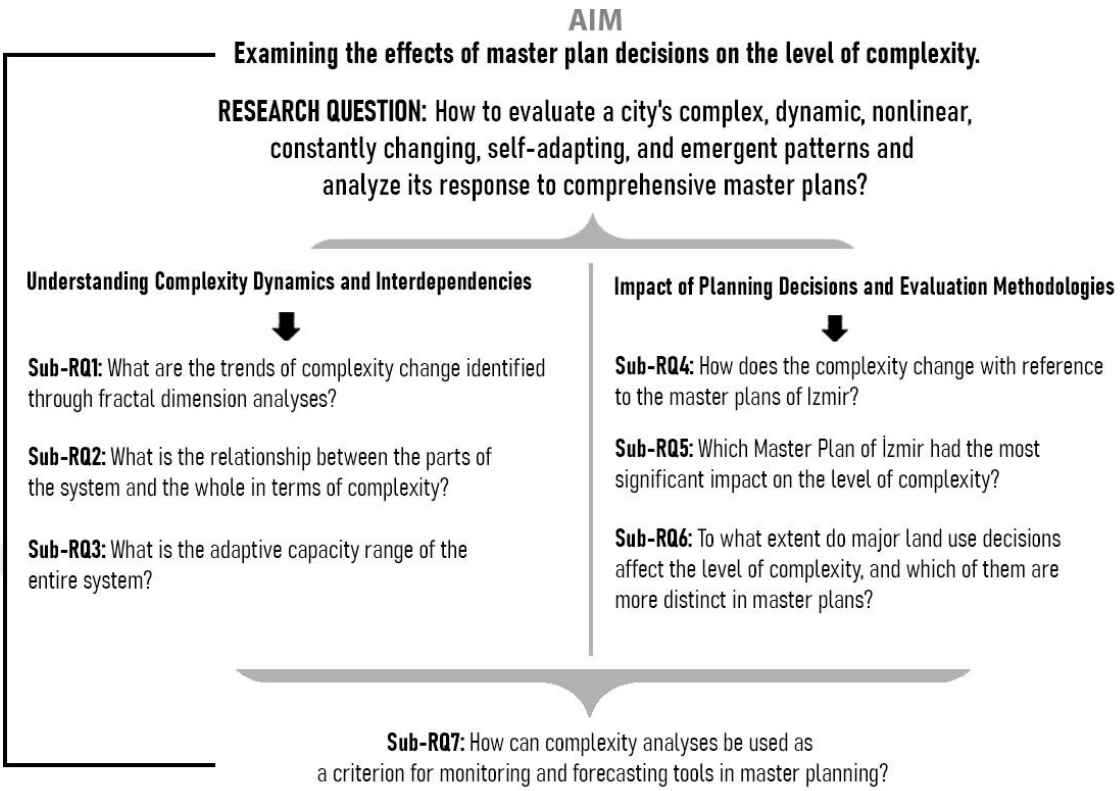


Figure 5.1 Flow Chart for Research Questions

Research Question: How to evaluate a city's complex, dynamic, nonlinear, constantly changing, self-adapting, and emergent patterns and analyze its response to comprehensive master plans?

- **Sub-RQ1:** What are the trends of complexity change identified through fractal dimension analyses?
- **Sub-RQ2:** What is the relationship between the parts of the system and the whole in terms of complexity?
- **Sub-RQ3:** What is the adaptive capacity range of the entire system?
- **Sub-RQ4:** How does the complexity change with reference to the master plans of Izmir?
- **Sub-RQ5:** Which Master Plan of İzmir had the most significant impact on the level of complexity?
- **Sub-RQ6:** To what extent do major land use decisions affect the level of complexity, and which of them are more distinct in master plans?

- **Sub-RQ7**: How can complexity analyses be used as a criterion for monitoring and forecasting tools in master planning?

5.2 The General Development of the Izmir Metropolitan Region and the Appropriateness for the Research Area

Izmir, a city in western Turkey, has undergone significant changes in its urban development throughout history. The city's first known master plan was developed in 1834, which primarily focused on expanding the city's port and constructing new public spaces. This plan reflected the modernization ideologies of the time, prioritizing economic development and infrastructure expansion to facilitate trade and commerce.

In the early 20th century, a new master plan was developed to modernize the city and improve its infrastructure. This plan, known as the "Greater Izmir Plan," included the construction of new roads, parks, and public buildings. However, it also led to the destruction of many historic neighborhoods and the displacement of residents. This approach to urban planning is known as the "Eradication of the Slums" approach, which sought to improve the living conditions of residents by demolishing overcrowded and unsanitary areas. However, it negatively impacted the city's historic fabric and the community's social cohesion.

In the 1960s and 1970s, a new approach to urban planning emerged in Izmir, which emphasized preserving the city's historic fabric and involving residents in the planning process. This approach, known as the "Conservation-Restoration" approach, aimed to balance the need for urban development with preserving the city's cultural heritage. This led to the creation of several conservation areas, such as the Kemeralti bazaar district, and the development of new residential areas with a mix of low-rise buildings, parks, and community facilities.

More recently, there has been a shift towards more sustainable and livable urban development in Izmir. This approach, known as the "Sustainable City" approach,

aims to reduce the city's ecological footprint and improve the quality of life for residents. This has included the promotion of public transportation, the development of green spaces, and the creation of walkable neighborhoods. This approach is based on creating a more livable and sustainable urban environment where the city's resources are used efficiently and the well-being of residents is prioritized.

- ***A Discussion for Appropriateness***

  It is important that cities exhibit chaotic behavior in the long run, with a mix of steady states and slow processes, represented by macro-decisions such as master plans for cities, as well as fast processes and turbulences, represented by emergent activities in the city's independent from master plans, in the short run. The idea is that these macro-decisions, such as master plans for cities, are made by the authorities and intended to guide the city's development. However, the actual development of the city is not always aligned with these plans. Emergent activities often influence the city, such as the spontaneous formation of neighborhoods, businesses, and cultural venues.

  The interplay between these two types of processes, the macro-decisions, and the emergent activities, leads to a highly nonlinear and unpredictable system characterized by high sensitivity to initial conditions and small changes in input. This chaotic behavior can manifest as sudden changes in the housing market, shifts in political power, or other unexpected events.

  To capture the city's chaotic motion, this study aims to examine the change of a region for as much time as possible concerning data availability. The availability of data is an important limitation in this endeavor. However, by examining the change of a region over time, researchers can gain insights into the underlying patterns and mechanisms that drive the behavior of the city and better understand the relationship between macro-decisions and emergent activities.

Overall, this study aims to understand how different processes interact and shape the city's development, how master plans and emergent activities interplay, how the city is affected by these interactions, and how we can predict and adapt to them.

In conclusion, the historical development of Izmir city, through master plans, reflects the changing perspective in urban planning, from the modernization and expansion of the city in the past to the more complex and new approaches that focus on livability, sustainability, and preservation of historic fabric. The evolution of these approaches in urban planning can be seen as a response to the changing needs and priorities of the city and its residents, as well as the advancement of knowledge and understanding of urban development.

Finally; as it can be understood from the previous parts of this study related to the Izmir plans and this summary, the city of Izmir attaches importance to planned development with the plans that have been implemented and not implemented since the beginning of the republic. The reflection of the implemented plan decisions on the space can be observed well. This also enables the observation of emergent urban activities outside the plan decisions. In addition, the trending theories in the planning discipline were also reflected in the preparation stages of the plans. The cities that have grown over time with Turkey's planned development culture are Ankara and Izmir. If enough long-term periodic data access can be provided, a similar research study can be carried out for the city of Ankara. In this situation, long term data could be achieved for Izmir, thus the Metropolitan Izmir has ben selected as the case study area.

5.3 Observing the Effects of Planning Decisions with the Boundaries

A detailed literature review is presented in the previous sections to examine the impact of master plan decisions on complexity. In the first part of this study, the transition process from classical urban theories to new approaches in planning and

the effects of developments in natural sciences on social sciences are explained. Then, complexity theories are explained in terms of data availability and background context, in order to decide which complexity theory approach will be the most appropriate for analysis studies. As a result of the literature review, it is understood that determining the urban border is primarily deterministic and uncertain.

In other words, since relationships emerge through networks and nodes, where the city begins and where it ends cannot be represented by regional differentiation. As can be understood from the literature, cities are now conceptualized as living organisms. The traditional understanding of the city is changing and the city is no longer determined by borders, but by internal and external relations.

Another finding obtained from complexity approaches is that while some decisions made while preparing master plans change the complexity level of cities to a large extent, some decisions do not have the same effect. However, some occurrences may occur without a plan decision. In this study, in order to capture the chaotic movement and observe the effects of planning decisions on complexity, the data of the city were collected periodically and care was taken to ensure that these periods are long enough for the planning decisions to be implemented.

First of all, all the master plans made in the city of Izmir from the first years of the republic until now were examined. Since the aim of the study is to examine the effect of plan decisions on the complexity of the city, the planning area boundary is the determining factor for each plan's own period. Since the master plans are prepared by determining a plan boundary while composing them, it is necessary to evaluate the planning decisions and the activities independent of the plan decisions within this limit.

Eight master plans have been prepared by different institutions and professionals for the city of Izmir since the republican period, but four of these plans have been implemented.

The implemented plans are listed below;

- Aru, Özdeş, and Canpolat developed a competition proposal in 1952, which was refined by the planning department of the Municipal government of İzmir with Aru's help and authorized in 1955
- Metropolitan Planning Office's Plan, finished in 1972, Authorized in 1973, and amended in 1978.
- In 1989, the Metropolitan Municipality authorized a plan, 1/50.000 Scale.
- The Plan of the Metropolitan Municipality of İzmir in 2012, 1/25.000 Scale.

Since the aim of this study is to periodically investigate the effect of the decisions taken within the implementation boundiries of the plans on the complexity level of the city, the main determining factor is the plan borders.

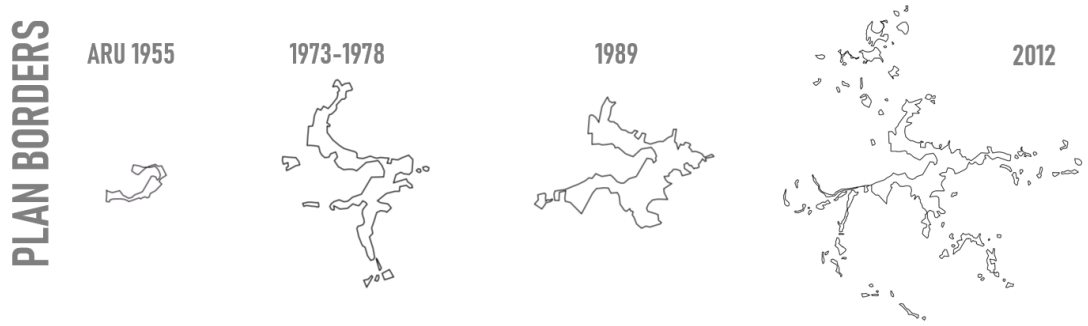


Figure 5.2 Conceptual Boundiries of the Master Plans

Please note that: *In the analysis studies, the plan borders were processed on the raw data in a coordinated manner, and the area outside the plan borders was cleaned and used. These conceptualized boundaries are used here for illustrative purposes.*

5.4 The Reason of Using Urban Road Network Data for Fractal Analysis

It was noted in the earlier sections of the research that three different data samples at the urban planning scale might be employed in fractal analysis investigations (Part 3.5). This section discusses the reasons why alternative urban data formats are not utilized. And, the reasons why the urban road network system was chosen as data are stated.

- ***Why not urban macro-form stain:***

Using the macro-form data of cities that change over time requires drawing a definite border.

According to a survey of the literature on emerging urban planning techniques based on complexity concerns, the distinction between non-urban and urban regions has been blurred. Consequently, determining the urban border is both deterministic and indeterminate. In other words, since relationships arise via networks and nodes, the geographical difference cannot indicate where the city starts and ends. Second, urbanization has been conceived of as a metabolic process. Non-urban places, including internal and external linkages, modify and develop traditional understandings of the urban. A broader or regional context is intended to understand urban, non-urban, or partly urban locations across those results. Another result of complexity methods is that cities exhibit chaotic behavior in the long run, with stable states or slow processes being followed by rapid processes and turbulences in the short run. In order to capture chaotic mobility, the goal of this research is to evaluate the transformation of a metropolitan area as much as possible in terms of data availability.

Finally, this data type focuses on measuring how compact or sprawl a city is over time in terms of usage. However, urban macro-form data is insufficient for this purpose, as this study aims to observe the effect of plan decisions on the level of complexity over time.

- ***Why not the Built Environment of the City Structure:***

This study aims to determine how the main development trends change within the framework of planning decisions. Therefore, it is examined how master plan decisions at the master plan level and up to 1/25,000 scale change the complex and dynamic system of the city. Secondly, this study was not carried out on the lacunarity analysis, as there are limits to reaching long-term built environment data. However, if other studies want to examine the change in smaller-scale areas and if enough long-

term data can be accessed, lacunarity analysis can be performed over the built environment.

- ***Why Urban Road Network of the City:***

Urban road networks are used for fractal analysis because they are a good representation of the complex, interconnected structure of cities and can provide valuable information for examining the impact of planning decisions on the level of complexity in a city.

The fractal analysis provides a way to quantitatively describe and understand the complexity of urban dynamic system and how they are organized in space. The fractal dimension of an urban road network is a measure of its degree of self-similarity and roughness and can be used to quantify the complexity of the network. A road network with a high fractal dimension is considered more complex and branching than a road network with a low fractal dimension.

By examining the fractal dimension of an urban road network, planners can gain insight into the level of complexity of the network and how it has been shaped by various factors, such as the planning decisions that have been made or emengent urban activities independent from planning decisions. This information can be used to inform future planning decisions and to understand better the functioning of cities and how they can be improved.

Overall, fractal analysis of urban road networks provides a valuable tool for examining the planning decisions that have been made in a city and how they have affected the level of complexity of the urban system.

5.5 Data Preperation

Recent technological developments, such as satellite imaging and data obtained via remote sensing, make it possible to get geographical information for use in studies of short-term complexity. Before the turn of the millennium, it was not possible to

get aerial images covering greater regions. Therefore, periodic maps should be used to study more extended time periods while conducting a complexity analysis. Because the primary objective of this research is to determine the emergent urban activities that develop in spite of the plan decisions, examine the reflections of the plan decisions on the space, and observe the relative changes of the same spatial context over time, the language of the maps, the level of detail, the symbols, and the signs should be consistent. Because of these factors, it is vital to make use of standardized maps created by public entities while doing research on an area over an extended period of time.

Two independent organizations in the Republic of Turkey are responsible for producing regular and standardized maps for various uses. The General Directorate of Highways is the first organization, and it has been responsible for producing road maps for several decades. These road maps provide an investigation of the road network. Second, starting at the turn of the 20th century, the General Directorate of Maps has been responsible for producing various military maps. These maps are made in various scales, each with its own distinct level of detail. Maps with a scale of 1/25.000 include the most important information and detail. These maps show boundaries, transportation systems, macro-forms of significant settlements, groves, wetlands, and crucial point notations. The locations of the villages are identified using a consistent presentation that does not vary regardless of the location at where the map was created, or the period being shown on it.

In light of this knowledge, preparing the data may be divided into two distinct steps, these are:

- The construction of the city's road network is the initial step in the process.
- The next step is determining the planned area boundaries of the implemented plans and where those boundaries overlap with this road network map.

5.5.1 Data Collection: The Raw Data

The maps of *"the General Directorate of Maps"*, prepared on a scale of 1/25.000, are used for the Izmir Metropolitan Area examination. The legends on the maps are standardized and will not evolve over time. As a consequence of this, it is permissible to utilize them for comparative analysis. These raster maps include a wealth of information, including terrain, vegetation, railways, and other infrastructure components, as well as a hierarchy of roadways ranging from walkways to freeways. With the assistance of NetCAD software, every map has been synchronized. Each of the 123 sheets that make up the province of Izmir has a scale of 1/25.000, and all of the sheets were created in a different year. Nevertheless, the following constitutes each of the four time periods:

- First Period – (1958-1964)
- Second Period – (1974-1980)
- Third Period – (1996-2000)
- Fourth Period – (2012-2020)

Then, for each of the four time periods, six degrees of roadways, ranging from path to highway, are drawn. Fourth-period thickness degrees of roads were acquired in a manner that preserves the hierarchy, and the repositioning of the created roadmap with satellite pictures and open-source roadmaps was assured. Because older eras of maps use the same standard legend, it is possible to achieve consistency in the thickness of various roads over the first three time periods.

The process described in the original statement involves multiple steps for analyzing and manipulating maps using various software tools. The first step is to export the completed map in a PDF file format and import it into Photoshop. This allows for further editing and manipulation of the map within the Photoshop software.

Once the map has been imported into Photoshop, threshold images are acquired. These threshold images segment the map into different regions and highlight specific features or areas of interest.

The maps and their corresponding threshold images are then imported into the Fractalyse software. This software includes a counting model which allows the user to pick a "free box" algorithm, which is a method for selecting regions of the map to analyze. Additionally, the software has the capability to perform automated iterations of the analysis, which can save time and effort.

Using the *Fractalyse* software, the correlation coefficient is determined as 0.999 for uni-fractal analysis. The correlation coefficient is a statistical measure that reflects the strength of the relationship between two variables. In this case, it indicates a high correlation between the map and the uni-fractal analysis. This suggests that the map and the uni-fractal analysis are highly consistent and that the analysis results are reliable. And, the road network maps prepared periodically are as follows:

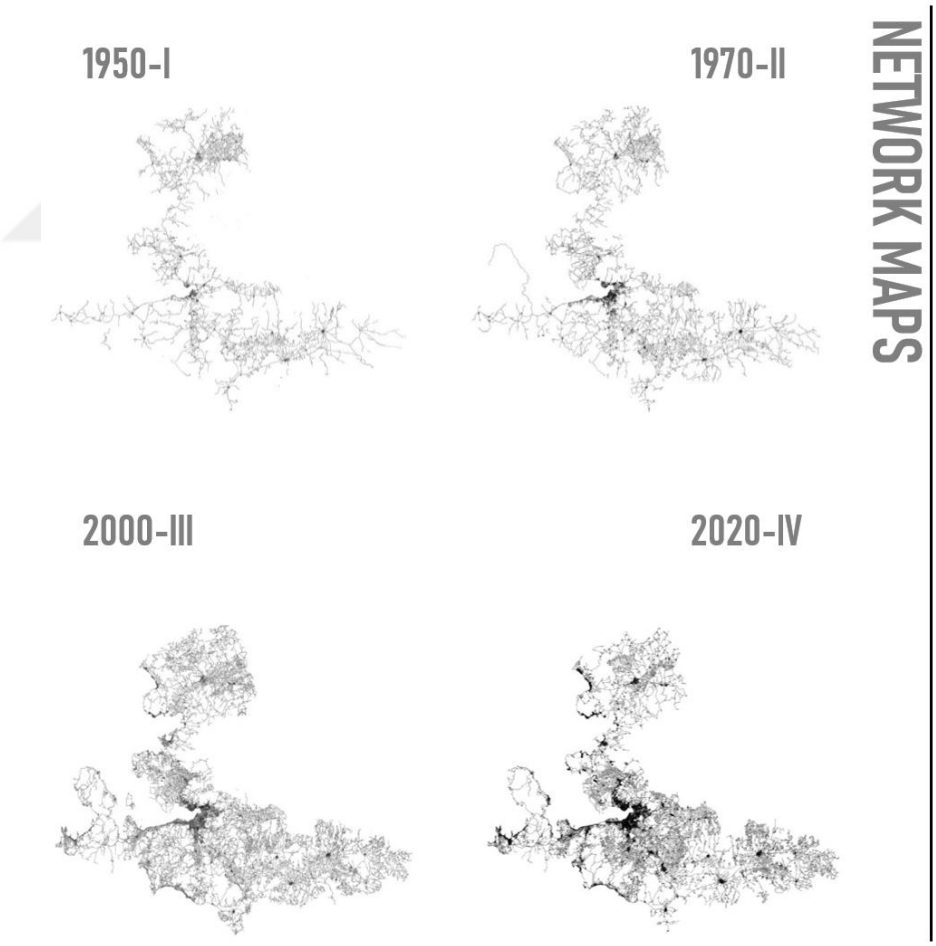


Figure 5.3 Network Maps with their Periods

5.5.2 Overlapping the Raw Data with the Plan Boundries

For seventy years, the boundaries of the districts have been changed, some villages and towns have turned into districts, and some districts have been separated or merged. The municipal boundaries of İzmir were changed in specific periods, and legal regulations continued as the city developed. Therefore, it is not correct to accept the municipal boundaries as the defining element to analyze the plan decisions' effect comparatively. Therefore, using municipal boundaries as a determining factor for evaluating the impact of plan decisions reveals *inconsistencies*.

The study conducts an examination of all master plans created for the city of Izmir from the early years of the republic until present day, with the goal of evaluating the impact of planning decisions on the complexity of the city. In order to accomplish this, the planning area boundary is used as a determinant for each plan's respective period, allowing for an analysis of the planning decisions and activities within the boundary of each master plan, and independent of any other plan decisions.

In other words, the study is focused on evaluating the effect of planning decisions on the complexity of the city of Izmir by analyzing all the master plans made in the city since the republic's early days. To achieve this, the study defines the planning area boundary as the determinant for each plan's own period. This is important as it allows the study to evaluate the planning decisions and the activities independently of the plan decisions within this boundary, which will help to isolate the effects of specific planning decisions on the complexity of the city, and, thus more accurately assess their impact.

As the last part of the data preparation section, the plan boundaries and raw road network map data discussed in the previous sections were overlapped in a coordinated manner, and the area outside the plan boundaries was cleared.

Since there are current state road network maps representing four different time zones and four master plans prepared at certain time intervals, a total of 16 maps in which the area outside the plan's boundaries was cleared were produced.

And, the maps in which the area outside the planning area is cleared are as follows;

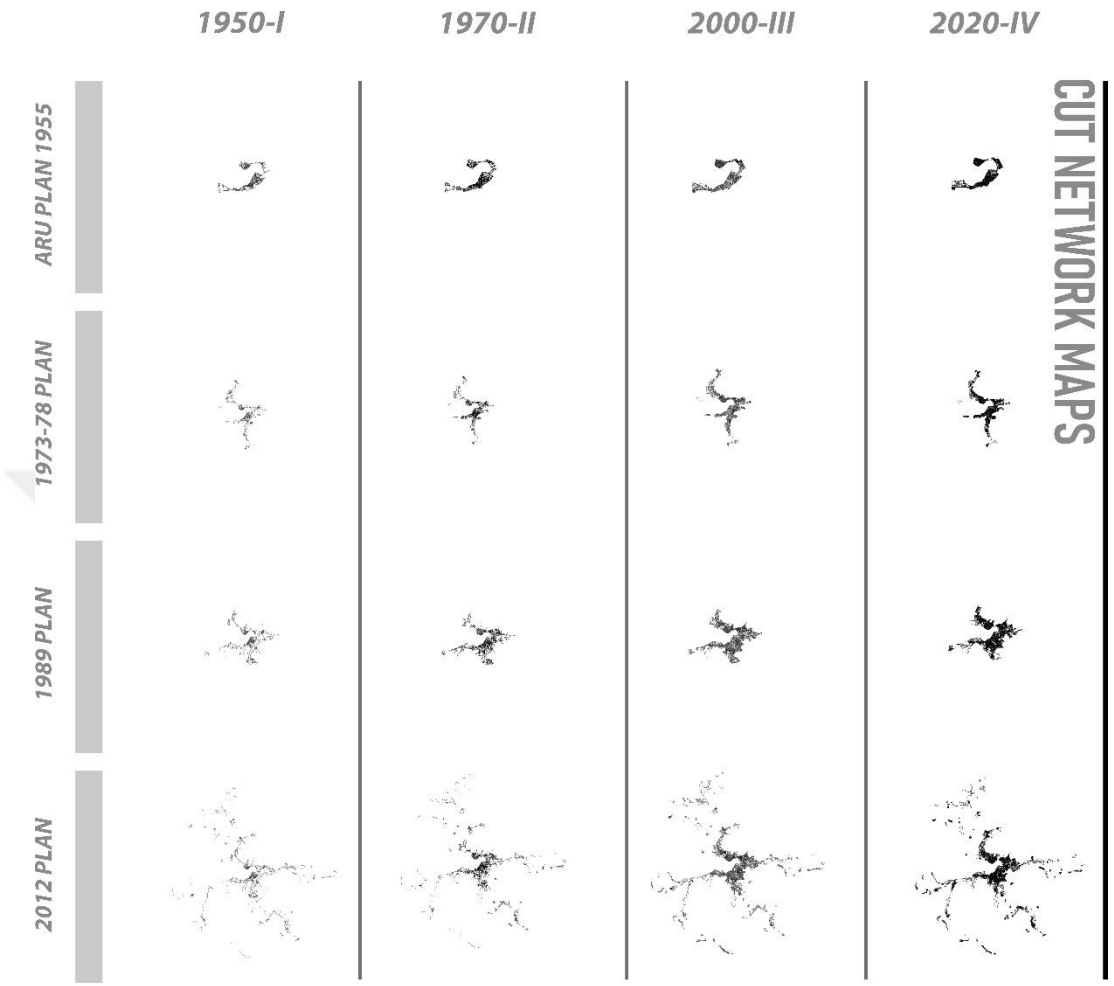


Figure 5.4 The maps in which the area outside the planning area

5.6 Tool for Fractal Calculation: *ImageJ with FracLac*

ImageJ-Fraclac is a plugin for the open-source image processing software ImageJ that allows for calculating fractal dimensions in images. It provides several methods for calculating fractal dimensions, including box counting, information dimension, and correlation dimension. The plugin was developed by researchers at the Technical University of Catalonia in Spain and is freely available for download and use. Fractal dimension is a mathematical concept that can be used to quantify the complexity and

self-similarity of structures in images. The ImageJ-Fraclac plugin can be used in various fields, such as:

Urban structure analysis: In urban structure analysis, fractal dimension can be used to quantify the complexity of various features of a city, such as the street network, building shapes, or land use patterns. A city's street network can be represented as a graph, where the nodes are intersections, and the edges are the streets. The fractal dimension of the street network can be used to quantify the degree of self-similarity, which can be related to the degree of clustering of the streets, the degree of hierarchy, and the degree of regularity. The fractal dimension of building shapes can be used to quantify the degree of self-similarity of the shapes, which can be related to the degree of regularity and the degree of complexity of the shapes. The fractal dimension of land use patterns can be used to quantify the degree of self-similarity of the patterns, which can be related to the degree of clustering of the land use types, the degree of hierarchy, and the degree of regularity.

Medical imaging: In medical imaging, fractal dimension can be used to quantify the complexity of structures in medical images, such as blood vessels, tumors, or cells. Material science: In material science, fractal dimension can be used to quantify the complexity of structures in materials, such as the microstructure of metals or the pore structure of soils.

Ecology: In ecology, the fractal dimension can be used to quantify the complexity of structures in ecosystems, such as the patterns of plant distribution or the architecture of river networks.

Geology: In geology, fractal dimension can be used to quantify the complexity of structures in geological images, such as rock textures or soil patterns.

The ImageJ-Fraclac plugin can be used to calculate the fractal dimension of these features in the above fields, providing a quantitative measure of the complexity of the images. With this, researchers and practitioners in these fields can gain insights

into the underlying patterns and mechanisms that shape the structure and use this information to understand better and make more informed decisions.

In this study, this software was chosen for similar purposes and used as the main computational tool for the analyzes described in the next section.

5.7 Methods Used for the Analysis

For analysis, fractal calculations will be used as the primary analysis method. The previous sections of the study explain how to use this method for road and city systems. This section will discuss different display methods of fractal analysis calculations. These representations of the fractal analysis method were needed to understand better the relationship between urban systems, planning decisions, and complexity. These are *the Box-counting Analysis, the DLC Analysis and Sub-fractal Analysis for Urban Network Systems.*

Note that; In this study, these three methods were used together because the results obtained with the application of these methods have different ways of presenting the urban space. Thus, it was ensured that the changes in the urban system over time could be observed better. The application of fractal analysis in three different ways is necessary to detect inconsistencies in the city system and the general development process of the city. In this way, the reliability of the results is to be obtained to determine the urban structure that develops with the plan decisions or the emergent urban activities that take place outside the plan decisions.

5.7.1 Fractal Dimension Analysis

The fractal dimension is a mathematical concept that can be used to describe the complexity of a road network system. There are different methods to calculate the fractal dimension of road networks, including:

- *The Box-counting analysis:* This method involves dividing the network into a series of boxes of different sizes and counting the number of boxes that contain a part of the network. The fractal dimension is calculated from the relationship between the number of boxes and the size of the boxes.
- *The Local connected fractal analysis:* This method calculates the fractal dimension based on the connectivity of the network rather than its geometric structure. It involves dividing the network into smaller segments and counting the number of segments that are connected to each other.
- *Sub-fractal analysis:* This method focuses on the fractal dimension of sub-components of the road network, such as individual roads or groups of roads. The sub-fractal analysis can provide insights into the fractal properties of different parts of the road network and help identify areas that may be particularly complex or important.

Each method has its own advantages and disadvantages, and the choice of method will depend on the specific characteristics of the road network being analyzed and the goals of the analysis. In general, the fractal dimension provides a way to quantitatively describe the complex structure of urban road networks. It can be a valuable tool for understanding the patterns and processes that shape these systems.

- ***Basic Claculation for Fractal Analysis with the Box-counting Approach:*** *The box-counting approach* is used to compute fractal scale in this study. More than one mesh with various matrix sizes is overlaid with the urban layout in the box counting approach. The following is the link between the grid, box size, and fractal aspect:

$$K=A.\varepsilon^{-D_f}$$

K stands for number of boxes, ε stands for grid dimensions, A stands for constant coefficient, and D_f stands for fractal aspect.

The position of the grid, including the size and quantity of boxes, are all factors that make the box-counting approach vulnerable. Because the urban fabric is

heterogeneous, all of the above characteristics might influence the outcome. The application *ImageJ-FracLac* was being used to tackle this challenge by computing fractal dimensions for various grid layouts and grid positions. The maximum rate has been considered as the fractal dimension among sequential computations. The fractal dimension is generated by the logarithmic ratio between altering grid sizes and the quantity of grid cells covered by entities in this manner (Mandelbrot, 1983), (Peitgen et al., 2004), (Kaya & Bölen, 2017). The following is a description of the formula:

$$D_B = (\log K_{S1} - \log K_{S2}) / (\log(1/S_2) - (\log 1/S_1))$$

D_B: box counting dimension, K: the number of boxes (cells), S: for the box side length.

5.7.1.1 The Box-Counting Analysis

The box-counting method is a mathematical method for calculating the fractal dimension of a complex system, including an urban road network. The basic idea is to divide the network into a series of boxes of different sizes and count the number of boxes that contain a part of the network. The fractal dimension is calculated from the relationship between the number of boxes and the size of the boxes (Qi & Zhang, 2017).

In the context of urban road network analysis, the box-counting method can provide insights into the complexity and organization of the network, including patterns of connectivity and the distribution of roads and intersections. By calculating the fractal dimension of the network, it is possible to quantify the degree of self-similarity, or repetition of patterns, in the network, which can provide valuable information for understanding the underlying processes that shape the network and inform planning and decision-making (Wang & Li, 2017).

For example, the box-counting method can be used to identify areas of the network that are particularly complex or have unique connectivity patterns, which may need

special attention or resources. Additionally, by comparing the fractal dimensions of different road networks, it is possible to make comparisons and gain insights into the relative complexity and organization of different urban areas.

Overall, the box-counting method is a powerful tool for understanding the complex structure of urban road networks and can provide valuable insights for urban planning and decision-making.

- ***Basic Calculation for the Box-counting Analysis:*** *The formula for calculating* the fractal dimension using the box-counting method is based on the relationship between the number of boxes N that contain a part of the network and the size of the boxes L:

$$D = log(N) / log(1/L)$$

Where D is the fractal dimension, N is the number of boxes, and L is the size of the boxes.

The network is first divided into a series of boxes of different sizes to apply the formula. The number of boxes that contain a part of the network is then counted for each size of the box. The fractal dimension is calculated by plotting the logarithm of the number of boxes N against the logarithm of the inverse of the size of the boxes 1/L and fitting a linear regression line to the data (Liu & Chen. 2017). The slope of the regression line is equal to the fractal dimension. *the process of calculating D_f of a system can be made more efficient through the use of fractal dimension tools. This involves determining the highest R^2 value, representing the correlation between the observed and predicted values in a regression analysis. The process is considered complete once the R^2 value surpasses 0.999, indicating a robust correlation between the observed and predicted values (Thomas & Frankhauser, 2012).*

It is worth noting that the formula for the fractal dimension is an approximation, and there may be different ways to apply the box-counting method and calculate the fractal dimension in practice, depending on the specific characteristics of the road network and the goals of the analysis. However, the basic idea of the box-counting

method is to use the relationship between the number of boxes and the size of the boxes to calculate the fractal dimension and gain insights into the complexity and organization of the network (Liu, Li, & Chen, 2015).

- ***Sliding Types of Box-Counting Analysis:*** The scanning box-counting method is another variant of the box-counting method, in which the boxes are scanned over the network in a controlled way to determine the number of boxes that contain a part of the network. There are several common types of scanning box-counting methods, including:
    - Fixed grid: In this method, a grid of boxes of fixed size is placed over the network, and the number of boxes that contain a part of the network is counted.
    - Sliding box: In this method, a single box of varying size is moved over the network, and the number of boxes that contain a part of the network is counted at each size of the box.
    - Concentric boxes: In this method, a series of concentric boxes are placed over the network, and the number of boxes that contain a part of the network is counted at each size of the box.

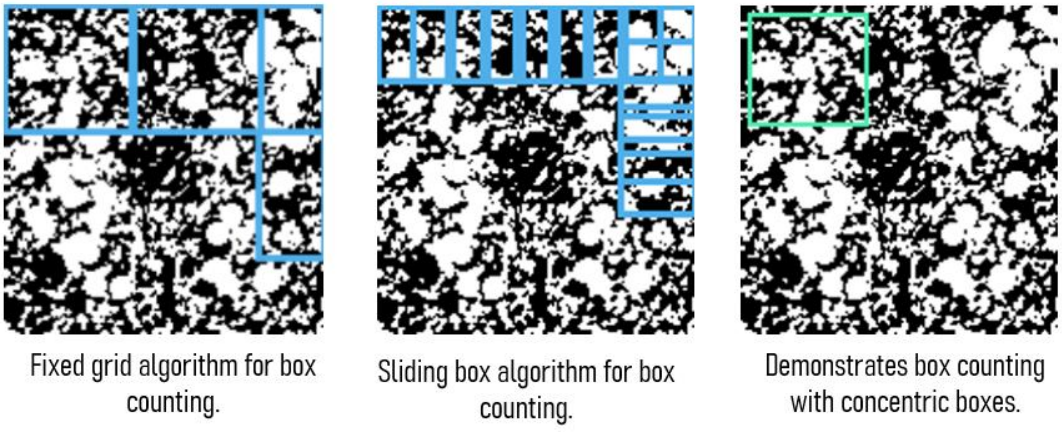


Figure 5.5 The box-counting analysis scanning types (cited from *wiki.com/boxcounting)*

The choice of scanning method will depend on the road network's specific characteristics and the analysis's goals. For example, a fixed grid may be preferred

when the goal is to capture the fractal dimension at a specific set of scales, while a sliding box or concentric boxes may be preferred when the goal is to capture the fractal dimension over a broader range of scale. In this study, all scanning types of box-counting are used for fractal calculation (Liu, Li, & Chen, 2015).

In this study, box-counting analysis was applied to 16 maps cut according to the plan boundaries mentioned in the previous sections. It is aimed to observe the holistic change of fractal values in 4 time periods according to each plan boundary and to question the consistency of these values. The Fraclac plugin of the *Image_J* program is used to do the sub-fractal examination.

5.7.1.2 The Local Connected Fractal Dimension (the DLC) Analysis

Local Connected Fractal Dimension (LCFD) analysis is a mathematical method used to quantify the complexity of spatial patterns in remote sensing images or geographical information systems. It is based on the concept of fractal geometry, which deals with self-similar patterns that can be found at different scales. LCFD analysis is used to measure the fractal dimension of an object, which provides a measure of its "fractalness" or degree of self-similarity (Fan, Chen, & Du, 2018).

LCFD analysis extracts information from satellite images or aerial photographs in remote sensing. It provides a way to quantitatively describe urban areas' spatial structure and identify different urban morphologies, such as the distribution of land uses, the arrangement of buildings, and the topology of street networks (Niedertscheider & Schrenk, 2015).

In urban planning and urban morphology, LCFD analysis is used to study the form and structure of urban areas. It can help urban planners and researchers to understand the organization and development of urban landscapes, including the distribution of land uses, the arrangement of buildings, and the morphology of street networks. The results of LCFD analysis can provide valuable information for decision-making in

urban planning, such as the allocation of land uses, the design of urban layouts, and the assessment of urban sprawl (Li & Weng, 2012).

The formula for calculating LCFD is based on the number of pixels that are connected to a target pixel within a given radius (r). The LCFD value is calculated as follows:

$$N_r = r^{-D_S} \qquad D_s = \frac{\log N_r}{\log r^{-1}}$$

Where "N_r" is the number of connected pixels and "r" is the scale of analysis. The LCFD ($D_{s)}$ value measures the degree of self-similarity and the complexity of the spatial patterns of the object at different scales (Fan, Chen, & Du, 2018). The scale with the highest LCFD value is considered to be the most representative of the fractal dimension of the object. *The process of calculating* LCFD (D_s) *of a system can be made more efficient through the use of fractal dimension tools. This involves determining the highest* R^2 *value, representing the correlation between the observed and predicted values in a regression analysis. The process is considered complete once the* R^2 *value surpasses 0.999, indicating a robust correlation between the observed and predicted values (Thomas & Frankhauser, 2012).*

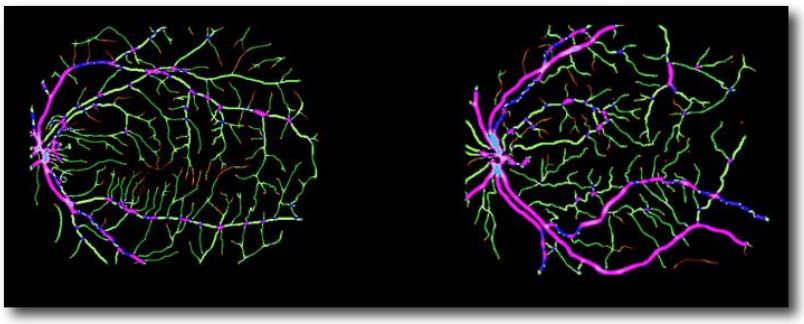


Figure 5.6 An example from other research fields (cited from *imagej.nih.gov*)

Here are a few examples of how Local Connected Fractal Dimension (LCFD) analysis can be applied:

Urban form analysis: LCFD can be used to quantify the complexity of urban form and to identify different urban morphologies, such as the distribution of land uses, the arrangement of buildings, and the topology of street networks (Fan, Chen, & Du, 2018).

Land use classification: LCFD can be used to classify different land uses based on their fractal characteristics, such as agricultural land, residential areas, and commercial areas (Li & Weng, 2010).

Urban sprawl analysis: LCFD can be used to analyze the degree of urban sprawl and to support decision-making in urban planning, such as the allocation of land uses, the design of urban layouts, and the assessment of urban sprawl.

Building extraction: LCFD can be used to extract building footprints from satellite images or aerial photographs and identify buildings' arrangement and distribution.

In conclusion, LCFD analysis is a powerful tool for characterizing urban areas' spatial patterns and providing valuable information for urban planning and urban morphology. It can provide a better understanding of the form and structure of urban areas and support decision-making in urban planning (Li, X., & Weng, Q. 2012).

In this study, the primary purpose of LCFD analysis is to observe the connectivity of the urban system and to question the relationship between increases or decreases in fractal values. It has also been applied to the 16 cut maps mentioned in the previous sections. The Fraclac plugin of the *Image_J* program is used to do the sub-fractal examination.

5.7.1.3 Sub-Fractal Analysis

The sub-fractal analysis provides a more detailed understanding of the structure of urban road networks by examining their complexity at finer scales. This is important because road networks are complex systems that can exhibit self-similar patterns and structures at different scales. By analyzing these patterns and structures, urban

planners can understand the underlying factors that shape the city's organism and affect its growth and development (Chen & Huang, 2018).

One of the critical benefits of sub-fractal analysis is that it provides a quantitative measure of the level of complexity of urban road networks. This can be useful for comparing different cities and tracking changes over time. For example, sub-fractal analysis can be used to compare the complexity of road networks in different cities and see how they have evolved over time (Wang & Shi, 2017).

Another benefit of sub-fractal analysis is that it can help to identify the factors that influence the complexity of road networks. For example, it can be used to examine the impact of urban planning decisions, such as the creation of new roads or the introduction of transportation infrastructure, on the complexity of a city's road network (Fan & Ouyang, 2019). This information can then be used to make more informed decisions about optimizing the road network for improved functionality and sustainability.

Overall, the sub-fractal analysis provides valuable insights into the complexity and structure of urban road networks that can inform urban planning decisions and help improve cities' functionality and sustainability.

Identifying the complexity of the city-inherent region and determining how to express it are two of the study's main objectives. In addition to figuring out the fractal nature of the entire framework, the fractal nature of the individual components could also be assessed using a mesh that offers the fewest non-overlapping boxes N_s with size S. On a log-to-log graph, the mesh size (S) and box count (N_s) are shown, and the regression technique is used to calculate the Fractal Dimension (D) for the following pairings of N_s and S:

$$\ln N_S = A + D ln\left(\frac{1}{S}\right) + E_S$$

$$D = \lim_{\Delta_S \to 0} \left(-\frac{\ln N_S}{\ln S}\right)$$

in which A represents the interception and E_s represents the standard error (Li & Wang, 2016). According to Thomas et al (2011) and Thomas & Frankhauser (2012), *the process of calculating the fractal dimension of an object can be made more efficient through the use of fractal dimension tools. This involves determining the highest R^2 value, representing the correlation between the observed and predicted values in a regression analysis. The process is considered complete once the R^2 value surpasses 0.999, indicating a robust correlation between the observed and predicted values.*

The possible minimum mesh density for every era is determined by a 1 percent pixel proportion of the core region's network representation. Because the grid automation position varies each era, the horizontal grid position is maintained to retain comparable findings among eras. The *Fraclac* plugin of the *Image_J* program is used to do the sub-fractal examination.

Minimum Sample Size

While performing sub-fractal analysis, it is necessary to define the box size in which detail the sub-region fractal value is to be calculated. However, the software used in this study was asked to calculate the smallest possible box size. The reason for this is to observe the effects of planning decisions on the city system in as much detail as possible.

The canvas size of the area to be analyzed must be the same because the same boxes must show the same areas to ensure the analysis's consistency so that the changes in these areas can be obtained clearly over time. Due to this critical requirement, the map with the largest area size cut according to the plan boundary naturally determined the canvas size.

As a result of these mentioned, the software has determined *the minimum sample size as 800 m x 800 m by taking 1% minimum pixel ratio.* This may be a study limitation but not an obstacle to performing the analyses.

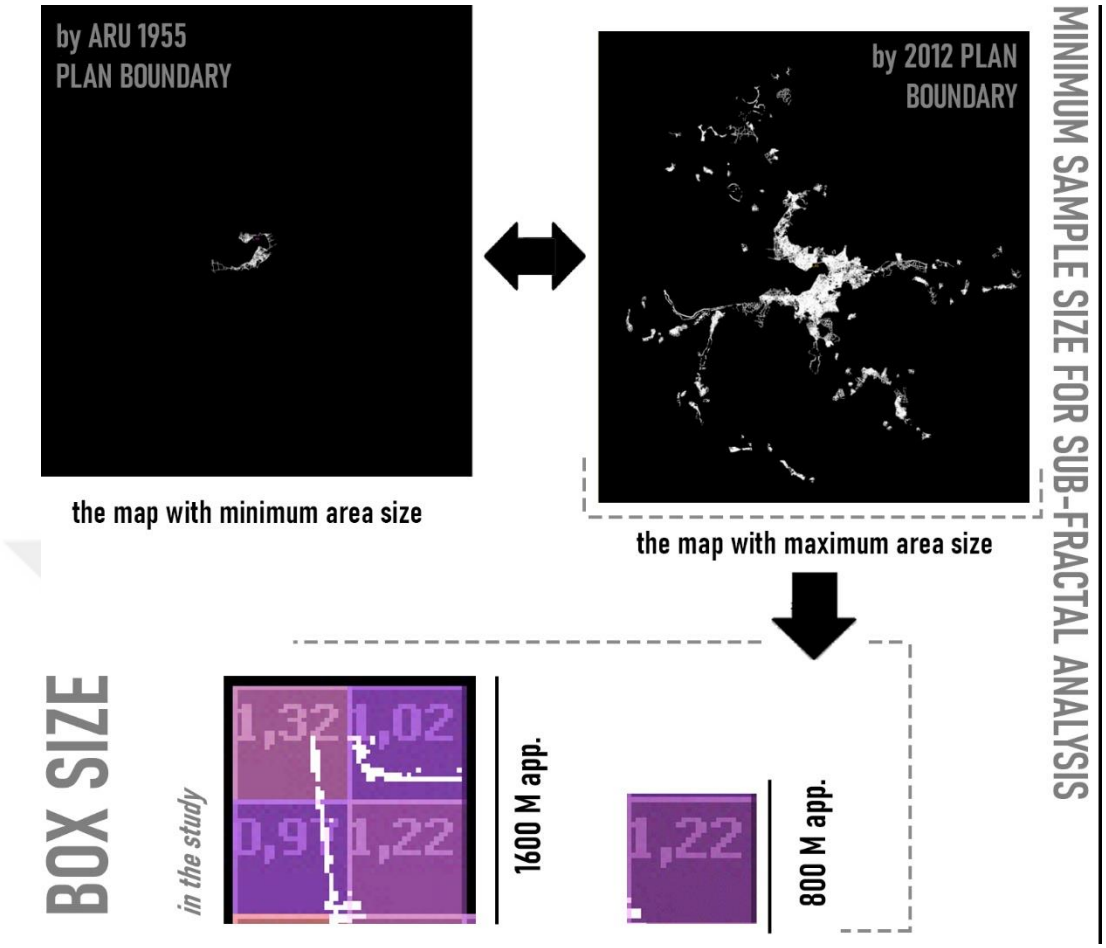


Figure 5.7 Box Size Determination Chart for Sub-Fractal Analysis

- ***Sub-Fractal Analysis by text:*** It is the case of overwriting the box values of sub-fractal analysis. Because the software does not present the numbers and fractal values of the boxes to the user in a different file format, these values are needed in difference analysis calculations.

- ***Sub-Fractal Analysis by color:*** It is the case of performing sub-fractal analysis with color codes. It provides a better understanding of perceptually the fractal change values in the sub-regions. Since these two variants of sub-fractal analysis could not be performed together, they were performed separately.

5.8 Methods Used for Evaluating the Analysis

All the analyzes in this section were made for each of the 16 maps, and these results were overlapped and it was aimed to see the results of 3 different analyzes together and to prepare them for the evaluation process together with the plan decisions.

It is aimed to determine the initial condition and post-plan status of the relevant plan by observing whether there is consistency among the calculated fractal values by periods and also considering the year in which the relevant plan was made. After the initial condition and the post-plan situation are determined, the result of the other two periods can be eliminated.

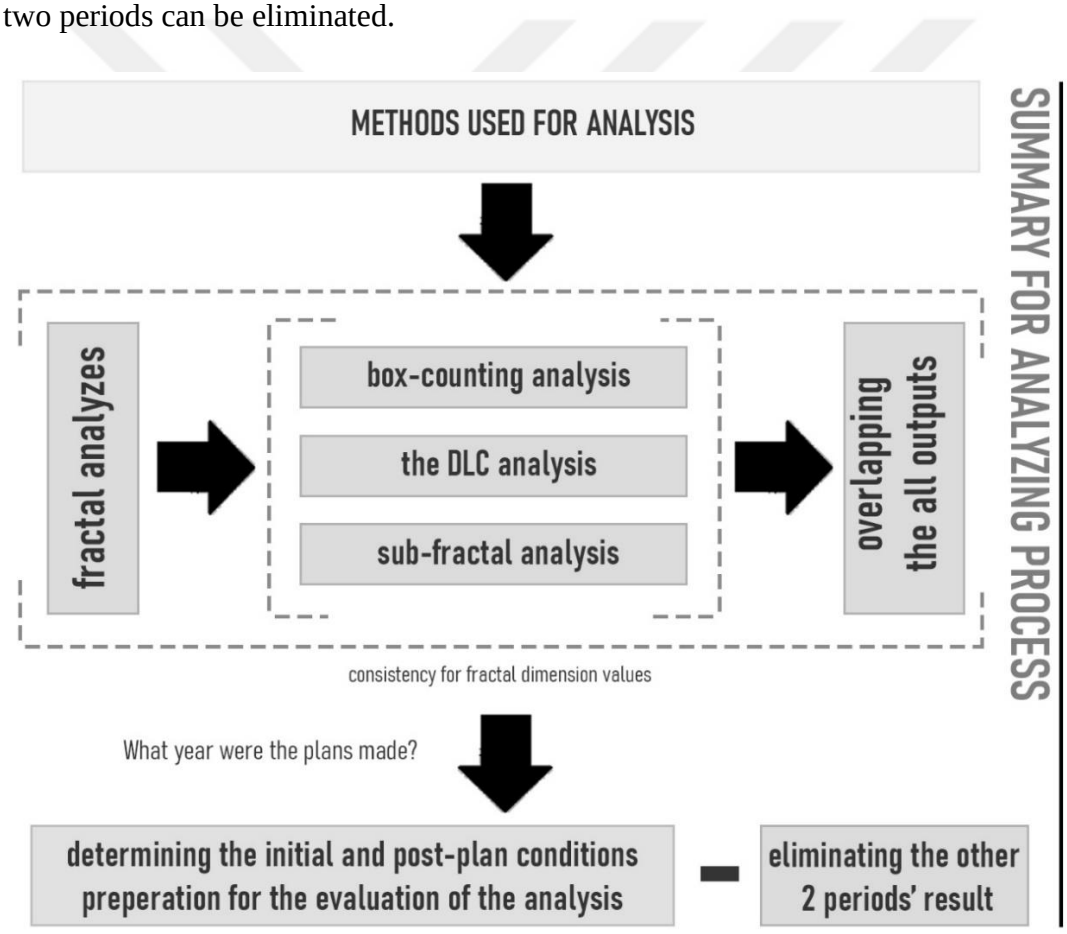


Figure 5.8 An Algorithm for Analyzing Process

This section's analyses are mostly performed to interpret fractal analysis results better. Two analysis studies are carried out to observe the developing-changing urban structure better and facilitate better prediction of future trends, with and outside the effects of plan decisions.

- The first of these is the *difference analysis* to identify the areas of differentiation.
- The second is *cluster analysis*, which is realized to observe and interpret the relations of the differentiating areas with each other.

5.8.1 Difference Analysis

This study aims to examine in depth the impact that planning decisions have on the complexity of a city. In order to achieve this, the researchers plan to undertake a series of evaluations and assessments, which will enable them to reinterpret the city and its interventions in a new light, taking into account both the principles of the planning discipline and the complexities involved.

In the evaluation phase, the research will make periodic comparisons of the initial and post-plan conditions. The goal of these comparisons is to determine the change in complexity value, which is a critical aspect of understanding the master plan and how it is influenced the city's dynamic structure. This will involve calculating the difference in complexity between the initial and post-plan conditions so that a comprehensive understanding of the relationship between planning decisions and the complexity of a city can be achieved.

The sub-fractal value of each box formed in the post-plan state is subtracted from the sub-fractal value of the boxes in the initial state, and new values are calculated.

In order to do this, the boxes must represent the same region in both cases. The stages are:

- For both cases, an "excel" file is created by naming the boxes and their fractal values.

- The box fractal dimension values of the initial conditions are subtracted from the box fractal dimension values of the post-plan state.

- As an essential point, these numerical values are not calculated as absolute values, so negative and positive values may be obtained due to the calculation. The result is not calculated as an absolute value because the negative or positive number values determine the direction of the change in complexity.

- It is necessary to establish a number range system for the values reached. For this study, it is necessary to establish meaningful intervals. *The optimal range was determined based on the range in which the difference values accumulated (the adaptive capacity range is explained in the evaluation chapter).* Therefore, the interval was calculated as 0.25.

- It means that the change in the sub-fractal value of a box ***is determined by the range 0-0.25, whether it is high or low***. Because the normal range of variation in the complexity level of this dynamic city system (this means the Izmir city) is 0-0.25. This situation can be compared *to the basal metabolic rate* in living organisms.

- A new map is prepared using color codes at 0.25 intervals. Color codes; Negative values are created by grading cool colors, and positive values are created by grading warm colors. The amount of change determines these degrees.

- This map shows the direction and amount of change in complexity, indicating the ranges of change.

- The purpose of this new map is to test the impact of planning decisions regionally. Thanks to this map, whether the boxes with highly varying sub-fractal values change by plan decision or emergent can be observed well.

- With this map, by comparing the master plans and the satellite image or land use map of the period, it can be understood why the change in complexity level arises and what level of change has occurred.

- The difference analysis conducted as part of this study will provide an approximation of the areas that have undergone the largest or smallest changes as a

result of planning decisions. This will give an overall understanding of these decisions' impact on the city's complexity. However, a further analysis study utilizing the spatial autocorrelation technique is necessary to determine if these changes are clustered together or spread out evenly. This will give a more detailed insight into the pattern of changes and how they are distributed across the city. The outcome of this analysis will be critical in determining the effectiveness of the planning decisions and their impact on the complexity of the city.

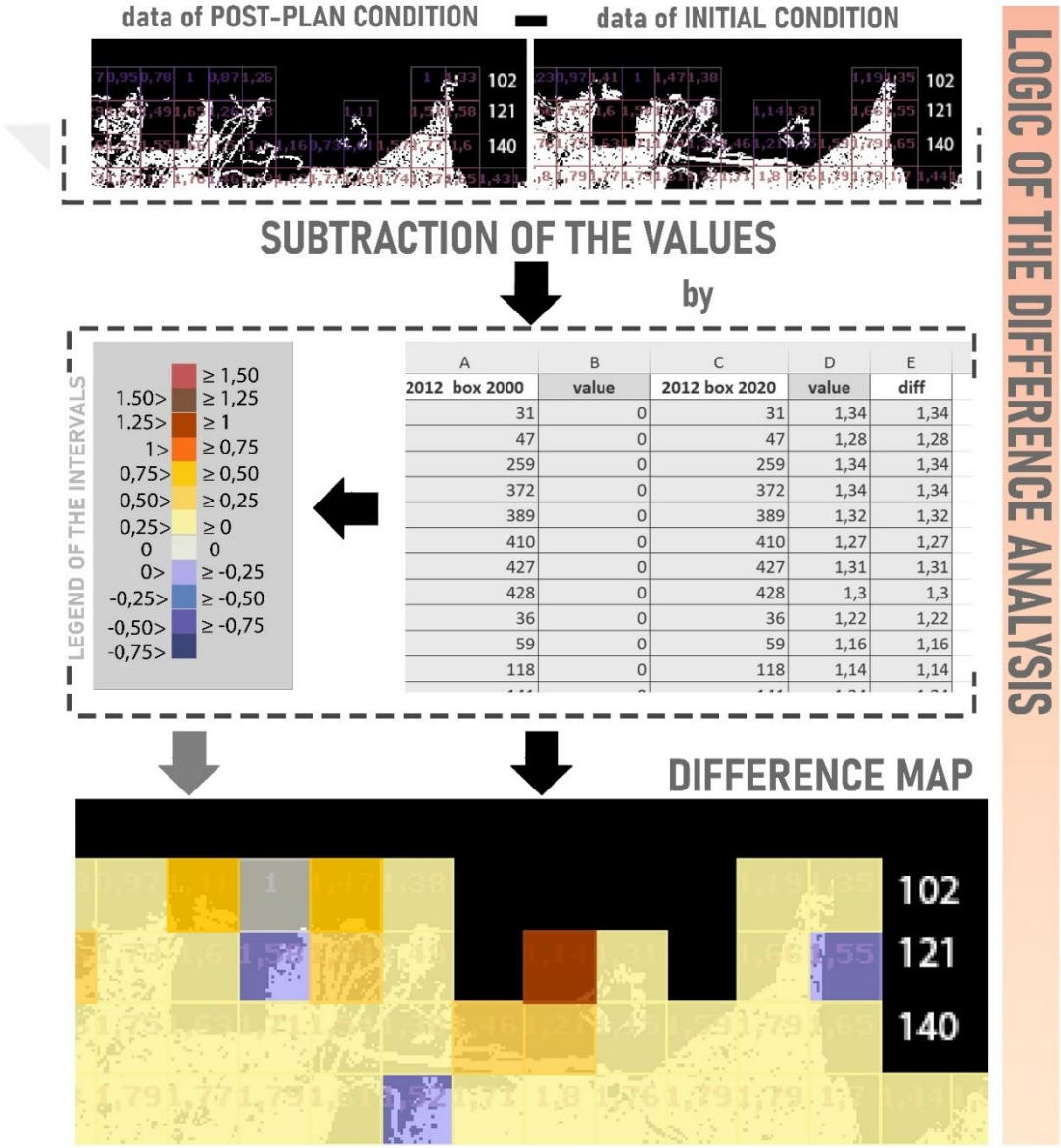


Figure 5.9 Flow Chart for Difference Analysis

5.8.2 Cluster Analysis: *Moran's I (A Spatial Autocorrelation Tool)*

In GIS, spatial autocorrelation reveals one feature's similarity to others in the area. Moran's, I quantify spatial autocorrelation. The first rule of geography was formulated by the late great geographer Waldo R. Tobler:

> *"Everything is interconnected, yet nearby items are more interconnected than distant ones."*

Moran's I is a commonly used statistical tool in spatial autocorrelation analysis, which is used to examine the pattern of similarity or dissimilarity between the values of a set of variables in a spatial context. It measures the degree of spatial association, which is the extent to which similar values tend to be located close to each other, or dissimilar values tend to be located far from each other (Haining, 2003). This information can be used to understand how various urban planning variables, such as population density, land use, and transportation, influence each other and contribute to the complexity of a city (Rey & Anselin, 2010).

- ***Calculations***

  Global Moran's I is a measurement of how the geographic data are generally clustered. Its definition is;

$$I = \frac{N}{W} \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{N} (x_i - \bar{x})^2}$$

- N is the number of spatial units indexed by i and j,
- x variable of interes,
- $\bar{x}$ is the mean of x,
- w_{ij} is a matrix of spatial weights with zeroes on the diagonal (i.e., $w_{ij} = 0$),

  and W *is* the sum of all w_{ij}; (i.e. $W = \sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}$)

The calculation of Moran's I involves several steps (Anselin, 1995):

- The values of the variable being studied are assigned to each observation in the spatial context.
- A spatial weighting matrix is constructed, which reflects the spatial relationships between each pair of observations. The weighting matrix can take into account various types of spatial relationships, such as distance, adjacency, or a combination of both. The next step is to calculate the mean value of the variable, which is then used to compute the sum of squared deviations from the mean (Rey & Anselin, 2010).
- The Moran's I statistic is calculated by dividing the sum of the products of the spatial weighting matrix and the deviations from the mean by the sum of the weights and the sum of squared deviations.

The interpretation of Moran's I values is based on the scale of the statistic, which ranges from -1 to 1. A value close to 1 indicates strong positive spatial autocorrelation, meaning that similar values tend to be clustered together (Anselin, L. 1995). A value close to -1 indicates strong negative spatial autocorrelation, meaning that dissimilar values tend to be separated. A value close to 0 indicates weak or no spatial autocorrelation (Haining, 2003).

In the context of urban planning and complexity, Moran's I can be a valuable tool for understanding the spatial distribution of urban variables and how they relate to each other. By analyzing the results of a Moran’s, I calculation, urban planners can make informed decisions about urban planning and development that consider the city's complexity and its variables. The information provided by Moran's I can be used to identify areas with similar or dissimilar characteristics, which can help urban planners allocate resources and make decisions that address the unique needs of different parts of the city (Anselin, 1995).

Spatial autocorrelation is multidirectional and multidimensional, which makes it useful for discovering patterns in complex data sets (Rey & Anselin, 2010). Comparable to correlation coefficients, it ranges from -1 to 1. However, while other

correlation coefficients compare perfect correlation to no correlation, Moran's coefficient measures the opposite (owing to the spatial computations' complexity):

In conclusion, Moran's I is a powerful tool in urban planning and complexity analysis that provides insight into the spatial patterns of urban variables and how they relate to each other. By using Moran's, I, urban planners can make informed decisions that consider the city's complexity and its variables, which can lead to more effective and sustainable urban planning and development (Anselin, 1995).

Sub-fractal values are obtained at the end of the difference analysis in this study; Cluster analysis is needed to question whether clusters are formed in the urban structure and to identify these boxes. As a result of the analyzes made, four difference maps were produced. These maps are made to question the effects of the implemented decisions of the four master plans and to define the places of emergent urban activities that occur outside these decisions.

- ***Hot Spot Analysis (Spatial Cluster Analysis)***

Hot spot analysis is a spatial statistical technique used to identify clusters of high or low values in a dataset. It can be used in various fields, including urban planning, to analyze the spatial distribution of various phenomena, such as crime rates, land use patterns, and demographic characteristics. The analysis is based on the concept of spatial autocorrelation, which refers to the degree to which observations at nearby locations are similar to each other (Anselin, 1995).

In the context of sub-fractal analysis, hot spot analysis can be used to identify areas with high or low values of fractal dimensions. Fractal dimension measures the complexity of a pattern, and sub-fractal analysis involves calculating fractal dimensions at multiple scales. By performing hot spot analysis on the results of sub-fractal analysis, it is possible to identify areas with significant spatial clustering of high or low fractal dimensions. This information can be used to identify areas with different levels of complexity, which can have implications for urban planning and design (Wei, Ma & Qiao, 2018).

One benefit of hot spot analysis in urban planning is its ability to identify areas of high or low risk or opportunity. For example, in the context of crime prevention, hot spot analysis can be used to identify areas with high crime rates, which can guide the allocation of resources and interventions (Rodríguez, Wimberly & Navarro, 2019). In the context of land use planning, hot spot analysis can be used to identify areas with high or low levels of development or activity, which can inform decisions about zoning and infrastructure investments (Getis & Ord, 1992).

Forecasting is the process of using historical data and statistical techniques to make predictions about future trends and outcomes. In the context of urban planning, forecasting can be used to anticipate changes in population growth, economic activity, land use patterns, and other phenomena. By incorporating forecasting into hotspot analysis, planners can make more informed decisions about where to allocate resources, which interventions are likely to be most effective, and how to plan for future growth and development.

For example, hotspot analysis can be used to identify areas with high crime rates, but forecasting can be used to anticipate how crime rates may change over time due to changes in population, economic conditions, and other factors. This information can guide decisions about where to allocate resources for crime prevention, which interventions are most likely to be effective, and how to plan for long-term public safety (Rodríguez, Wimberly & Navarro, A. 2019). Similarly, hotspot analysis can be used to identify areas of high economic activity, but forecasting can be used to anticipate how this activity may change over time due to technological advancements, demographic shifts, and other factors. This information can guide decisions about planning for sustainable economic growth and development.

In addition to guiding decision-making, forecasting can help urban planners communicate with stakeholders and the public. By providing clear and accurate information about future trends and outcomes, planners can build trust and credibility with stakeholders and help to ensure that planning decisions are transparent and accountable.

Overall, hotspot analysis is a crucial tool in urban planning, but forecasting is essential for making informed decisions and planning for the future. By incorporating forecasting into hotspot analysis, planners can anticipate changes and make more effective and sustainable decisions about allocating resources, interventions, and infrastructure investments. This can ultimately lead to better community outcomes and help create more livable, sustainable, and equitable urban environments (Wong, 2019).

- ***Defining the Distance Type (for Hotspot Analysis)***

Hotspot analysis is a spatial analysis technique used to identify areas of statistically significant spatial clustering in a dataset. The choice between Manhattan distance and Euclidean distance as the distance metric in hotspot analysis depends on the data's nature and the analysis's specific objectives (Getis & Ord, 1992).

Manhattan distance, also known as a city block or taxicab distance, measures the distance between two points by summing the absolute differences between their coordinates along each dimension. It is suitable for analyzing spatial patterns in areas with a regular street grid or when movement is constrained to a grid-like pattern. Manhattan distance is often used in urban environments where movement primarily occurs along perpendicular axes, such as city streets (Anselin, 1995).

Euclidean distance measures the straight-line distance between two points in Euclidean space. It represents the shortest distance between two points and is commonly used when considering distances in continuous space without constraints on movement direction. Euclidean distance is suitable for analyzing spatial patterns in various contexts, including geography, ecology, and statistics (Anselin, 1995).

In hotspot analysis, ***Euclidean distance is chosen*** over Manhattan distance because the analysis for this study aims to capture spatial patterns in a continuous space, and movement is not constrained to a grid-like pattern. Euclidean distance provides a more accurate representation of the distances between points and allows for a broader exploration of spatial relationships.

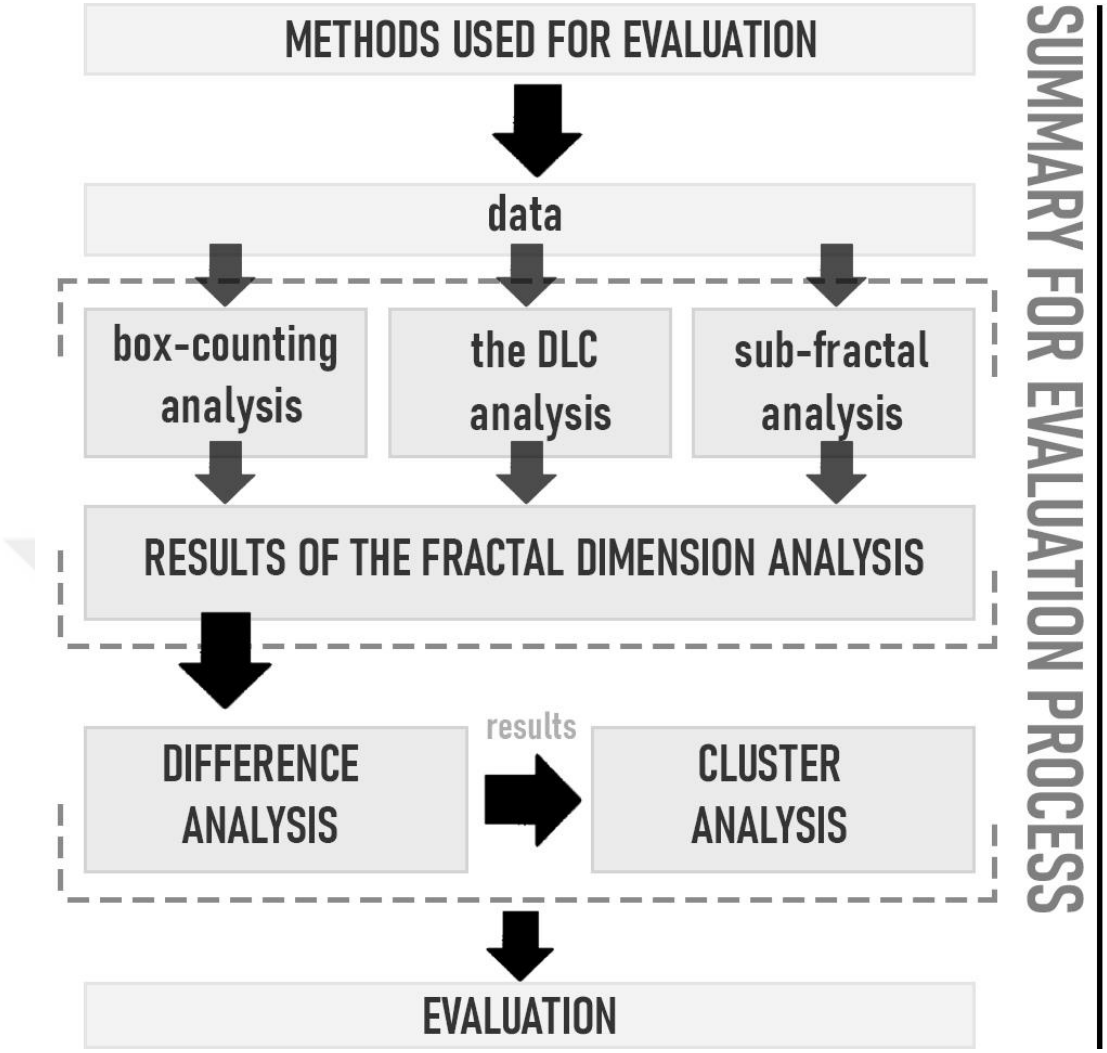


Figure 5.10 An Algorithm for Evaluation Process

5.9 Chapter Summary

The present study examines the impact of planning decisions on the complexity of the Izmir Metropolitan Region in Turkey. The study adopts a fractal analysis framework to examine changes in the region's complexity over time, utilizing urban road network data as the basis of the analysis.

The data collection and preparation process involved the collection of raw data and the overlay of the same with the boundaries of the plan to ensure a high degree of accuracy in depicting changes. In conjunction with the FracLac tool, the ImageJ

software was employed for calculating fractal dimensions. The study utilized three distinct fractal dimension analysis methods: the box-counting analysis, the local connected fractal dimension (DLC) analysis, and the sub-fractal analysis. The results obtained from each of these methods were then synthesized to yield a comprehensive overview of changes in the region's complexity.

In addition, the study employed two methods to evaluate the analysis results. The first was a difference analysis, which aimed to approximate the areas that underwent the most significant or minor changes due to planning decisions. The second method was a cluster analysis using Moran's I spatial autocorrelation technique, which aimed to provide a more nuanced understanding of the pattern of changes and their distribution across the city.

It is crucial to emphasize the significance of this study, as it offers a comprehensive evaluation of the impact of planning decisions on the complexity of the city. The study's results will be instrumental in informing city planners' decision-making process and providing valuable insights for future planning endeavors. By evaluating the effectiveness of planning decisions, the study seeks to ensure that the Izmir Metropolitan Region remains complex and resilient in facing future challenges.

CHAPTER 6

COMPLEXITY ANALYSIS OF THE METROPOLITAN IZMIR

The complexity analysis for the Izmir metropolitan area will be explained in detail in this study chapter. In explaining the results, the visuals and number values obtained from the analyses will be shared. In the first part, fractal dimension values were obtained in 3 different ways according to the plan boundaries. These are box-counting analysis, DLC analysis, and sub-analysis, which are calculated separately according to the limit of the four plans prepared for Izmir. They will also be calculated using map data of the four periods mentioned in the previous sections. In the second part, evaluation analyzes will be passed. These are difference analysis and cluster analysis. In the last part, evaluations and interpretations will be made in line with all the results.

6.1 Periodic Fractal Dimension Analysis with respect to Plan Boundaries of the Izmir Metropolitan Area

The analysis of the periodic fractal dimension concerning the plan boundaries of the Izmir Metropolitan Area is crucial in understanding the region's complex urban structures and patterns. By examining the periodic fractal dimension, it is possible to quantify the self-similarity and regularity of the plan boundaries in the metropolitan area, providing valuable information for urban planners and designers in optimizing the use of space and resources. This analysis can provide insights into the overall structure and organization of the Izmir Metropolitan Area and help inform future decisions regarding urban development and growth.

6.1.1 Periodic Box-Counting Analysis

The periodic box-counting analysis is a method for determining the periodic fractal dimension of a given object. It involves dividing the object into a series of increasingly smaller boxes and counting the number of boxes intersecting it. The resulting data can then be used to calculate the fractal dimension, which indicates the level of complexity in the object's structure. In the context of the Izmir Metropolitan Area, this method can be applied to the plan boundaries to understand the fractal dimension and how it changes over time and concerning different parts of the metropolitan area.

It is purposed in this part of the analysis that one value will be found for every period of each plan.

6.1.1.1 For the Izmir Plan of Aru 1955

The master plan for the city of Izmir, prepared by Kemal Aru in 1955, was a comprehensive plan for the development and growth of the city. It aimed to address the rapid population growth and urbanization that was taking place in the city at the time, and to provide a framework for the orderly development of the city in the future. The plan focused on improving the infrastructure and transportation networks, creating new residential areas, and preserving the historical and cultural heritage of the city.

One of the critical elements of the master plan was the creation of a green belt around the city to provide a buffer between the urban area and the surrounding rural areas. The plan also included provisions for the development of parks and open spaces, as well as the expansion of the city's industrial and commercial zones.

The master plan prepared by Kemal Aru had a significant impact on the development of Izmir and is considered one of the most important planning documents in the

history of the city. It provided a vision for the city's future and set the stage for its continued growth and development over the next several decades.

Here in this part, the values of box-counting analysis are calculated within the boundary of Kemal Aru Plan of Izmir by periods.

- ***Period I- 1950***

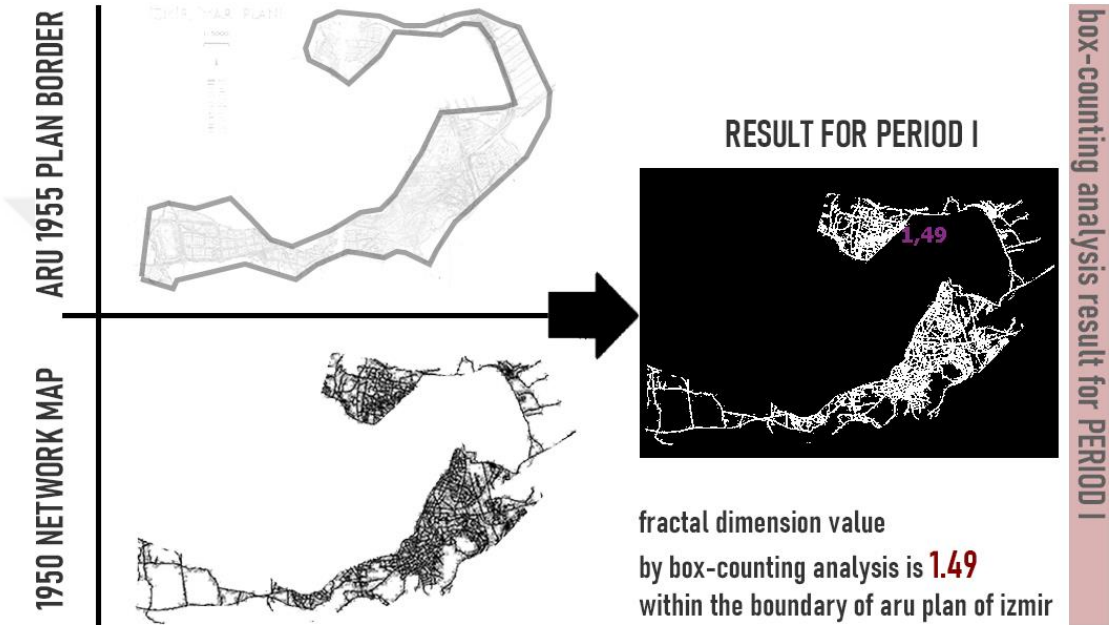


Figure 6.1 BC Analysis Result for Period I by Kemal Aru plan of Izmir, 1955

- ***Period II- 1970***

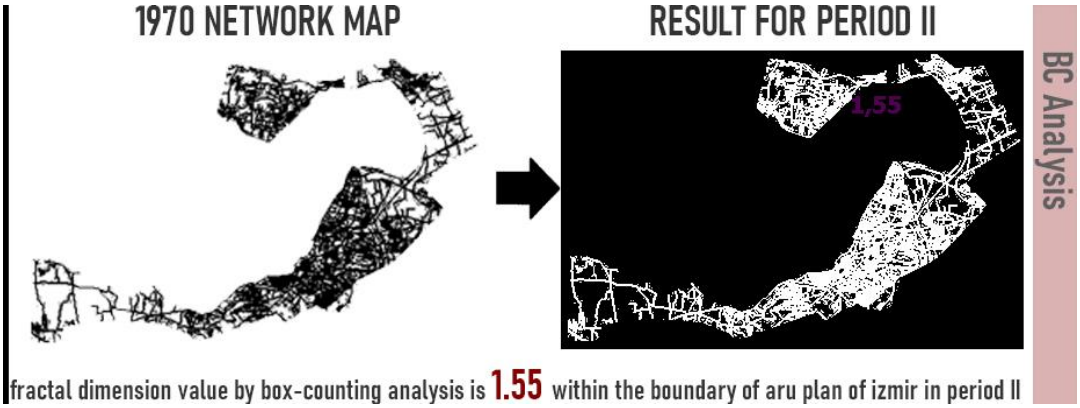


Figure 6.2 BC Analysis Result for Period II by Kemal Aru plan of Izmir, 1955

- ***Period III- 2000***

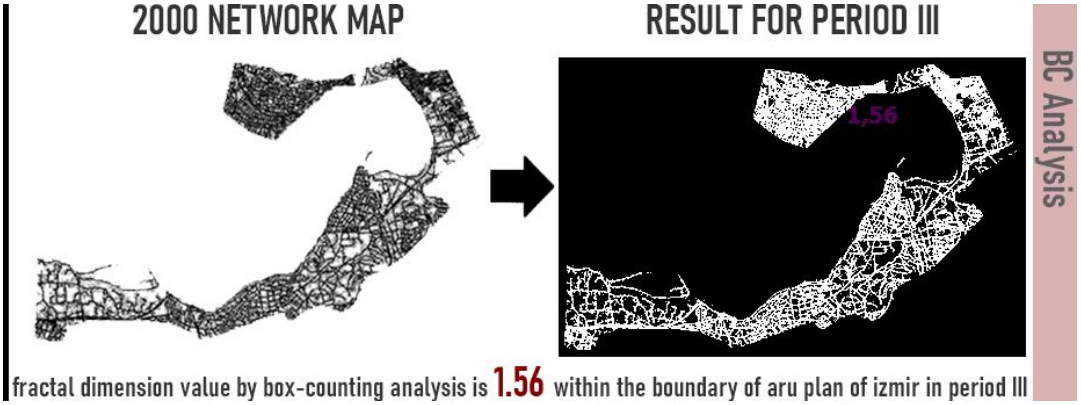


Figure 6.3 BC Analysis Result for Period III by Kemal Aru Plan of Izmir, 1955

- ***Period IV- 2020***

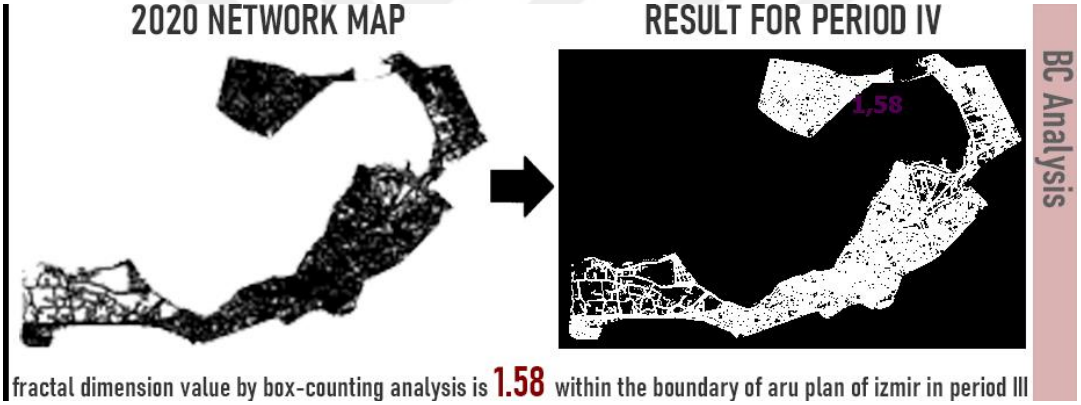


Figure 6.4 BC Analysis Result for Period IV by Kemal Aru Plan of Izmir, 1955

6.1.1.2 For the IMM Plan 1973-1978

During the 1950s and 1960s, İzmir experienced a rapid trend of urbanization. As a result, the city started to expand and merge with its surrounding areas, transforming into a metropolitan town. However, the prior planning attempts failed to address the city's growing challenges effectively. To address this, there was a need to develop a comprehensive plan that considered both the city and its surrounding areas and the administration's growth goals over the next five years. The fifth planning exercise in İzmir took place in a new economic and political environment involving multiple

institutions. This new approach aimed to provide a more effective solution to the city's problems and accommodate its growth.

In this section, the values of box-counting analysis are calculated within the boundary of Izmir Metropolitan Planning Office's Plan, 1973-1978 by periods.

- ***Period I- 1950***

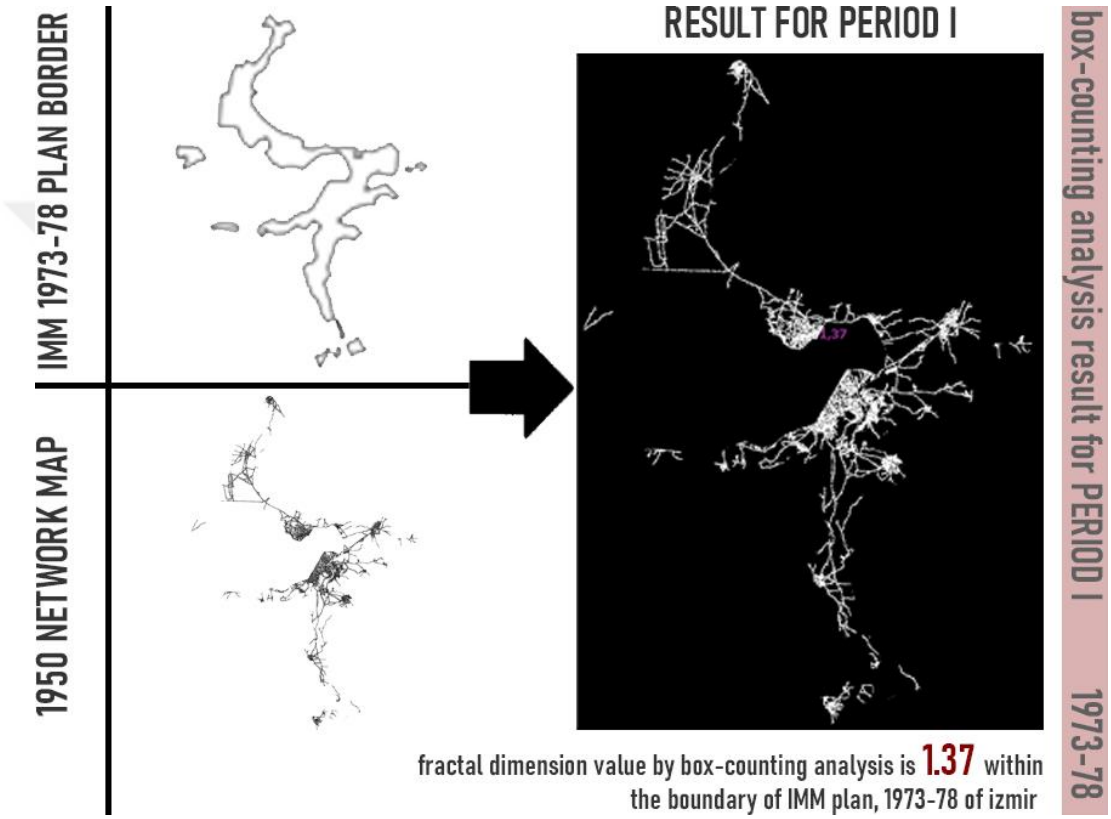


Figure 6.5 BC Analysis Result for Period I by IMM Plan of Izmir in 1973-78

Please note that; *The method described in the section on the analysis of the fractal dimension involves using a canvas larger than what is shown in the results presented in the sections. This larger canvas size is critical to ensure accurate results and provide a comprehensive view of the object being analyzed. For clarity and to improve the visual experience, the results have been presented in cut versions in these sections. However, it is essential to remember that the full, original canvas size must be used for the analysis to be reliable and produce accurate results.*

- ***Period II- 1970***

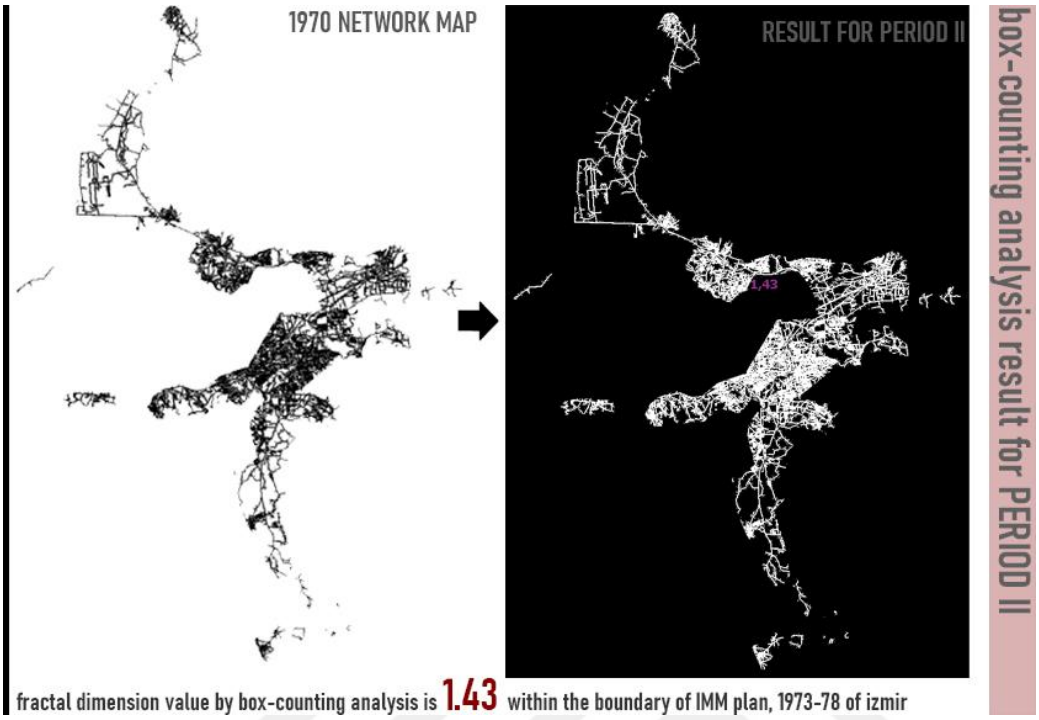


Figure 6.6 BC Analysis Result for Period II by IMM Plan of Izmir in 1973-78

- ***Period III- 2000***

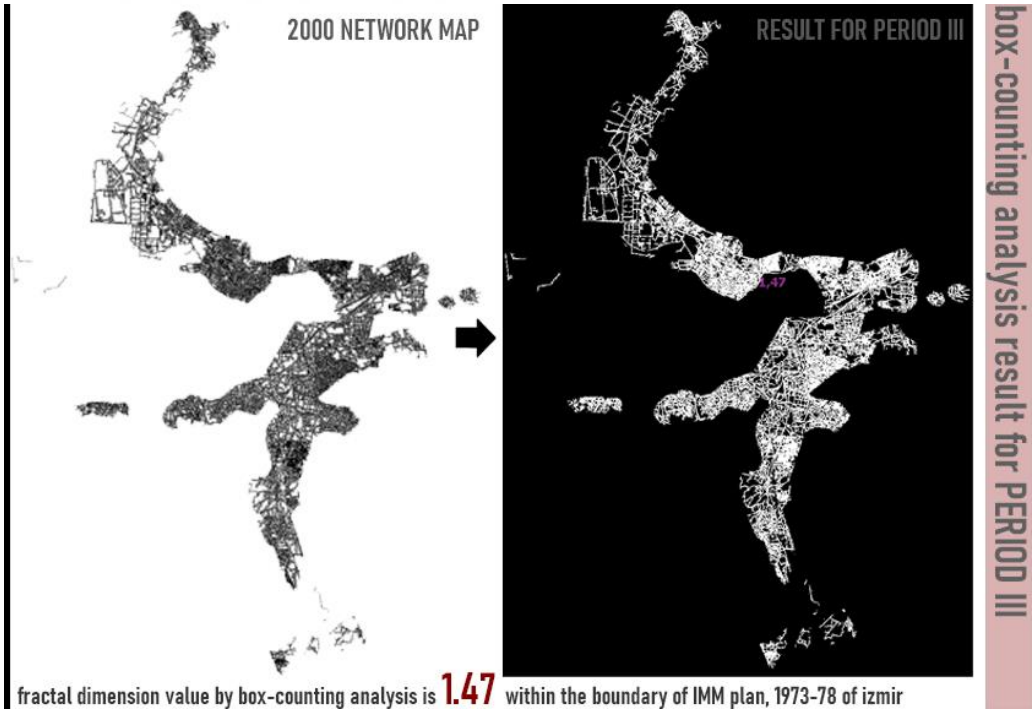


Figure 6.7 BC Analysis Result for Period III by IMM Plan of Izmir in 1973-78

- ***Period IV- 2020***

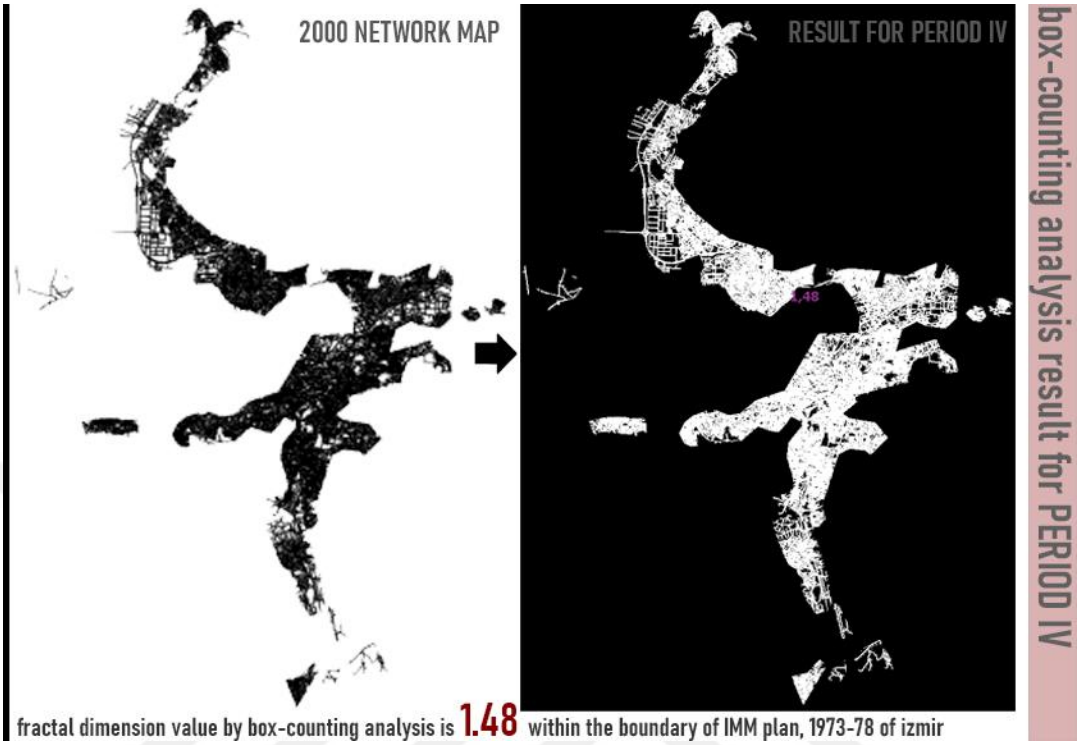


Figure 6.8 BC Analysis Result for Period IV by IMM Plan of Izmir in 1973-78

6.1.1.3 For the IMM Plan 1989

The 1973 plan was initially created to guide the growth and development of İzmir, but as the city continued to grow and change, it became apparent that the plan had limitations and needed to be revised. In 1978, the plan was amended to address these weaknesses and incorporate additional partial planning determinations. Despite the efforts of the governors to keep pace with the increasing needs of the city, the urban landscape continued to evolve differently from the original plan and its 1978 modification, largely due to changes in government investment decisions and the proliferation of illegal housing and industrial projects.

This revising plan was developed under the direction of new planning legislation following a critical turning point in Turkish history. As a municipal planning effort,

it aimed to address the challenges faced by İzmir and to provide a more comprehensive framework for its growth and development.

In conclusion, the 1973 plan for İzmir was amended in 1978 to address its limitations and provide more comprehensive guidance for the city's developmentDespite efforts to follow the original plan, the city's development deviated due to government investment changes and illegal housing and industrial projects.The sixth İzmir planning practice represented a significant turning point in the city's development, providing a more comprehensive framework for its growth and ensuring its sustainability.

In this section, the analysis is being performed within the boundaries of the 1989 Izmir Metropolitan Planning Office's Plan. The values of the box-counting analysis are calculated over a specified period of time, allowing for an examination of changes in the fractal dimension of the object over time.

- ***Period I- 1950***

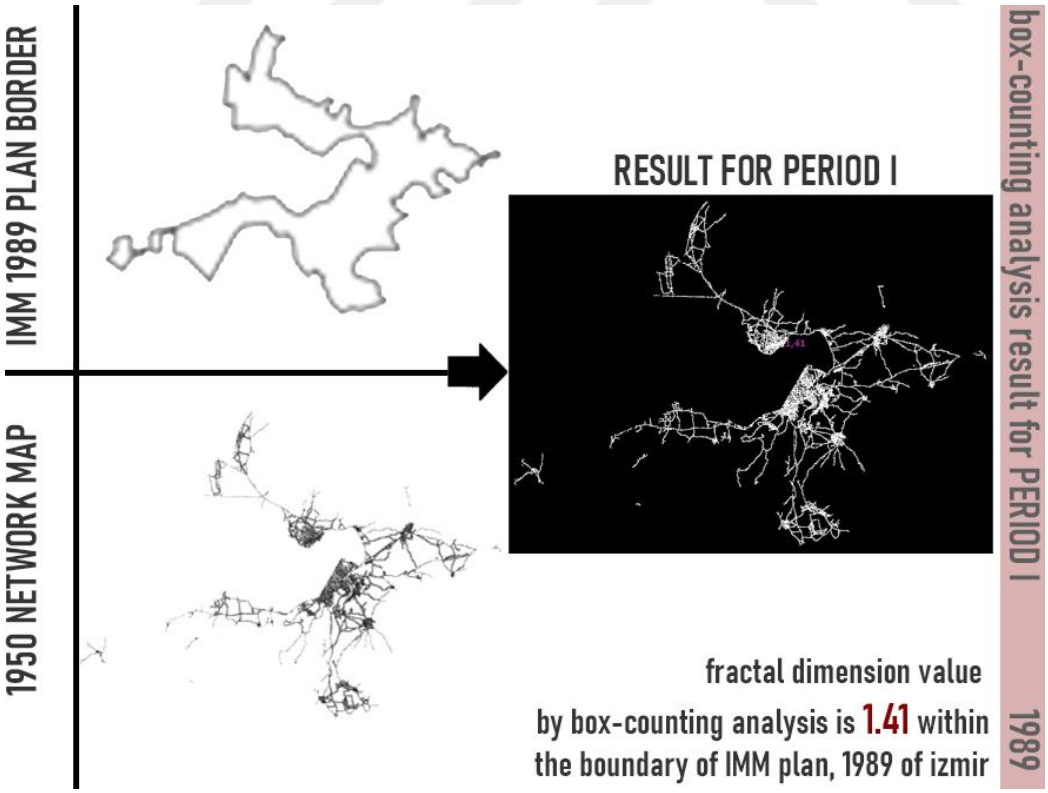


Figure 6.9 BC Analysis Result for Period I by IMM Plan of Izmir in 1989

- ***Period II- 1970***

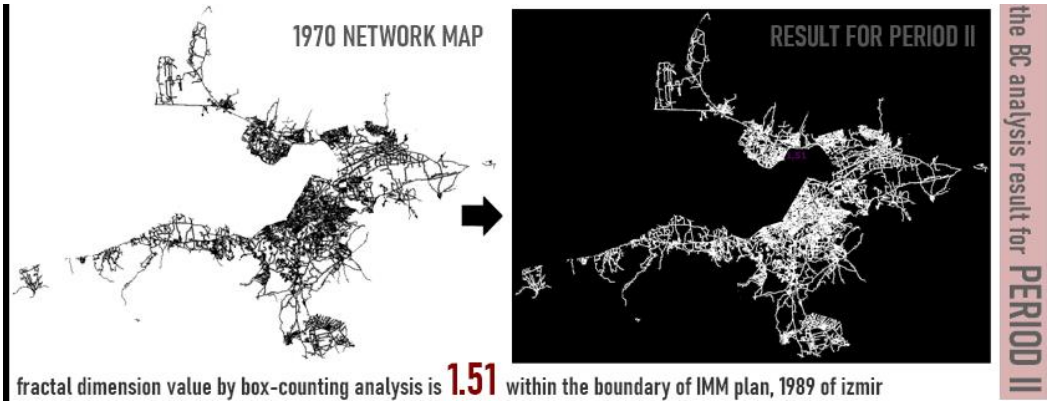


Figure 6.10 BC Analysis Result for Period II by IMM Plan of Izmir in 1989

- ***Period III- 2000***

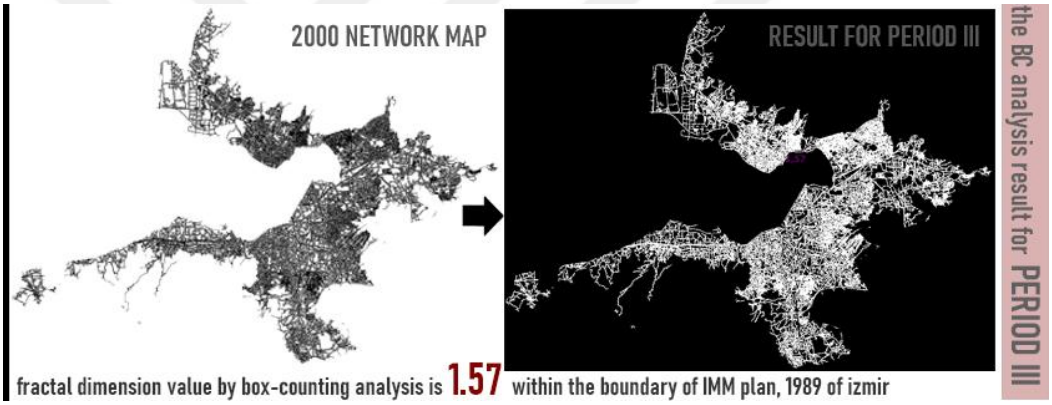


Figure 6.11 BC Analysis Result for Period III by IMM Plan of Izmir in 1989

- ***Period IV- 2020***

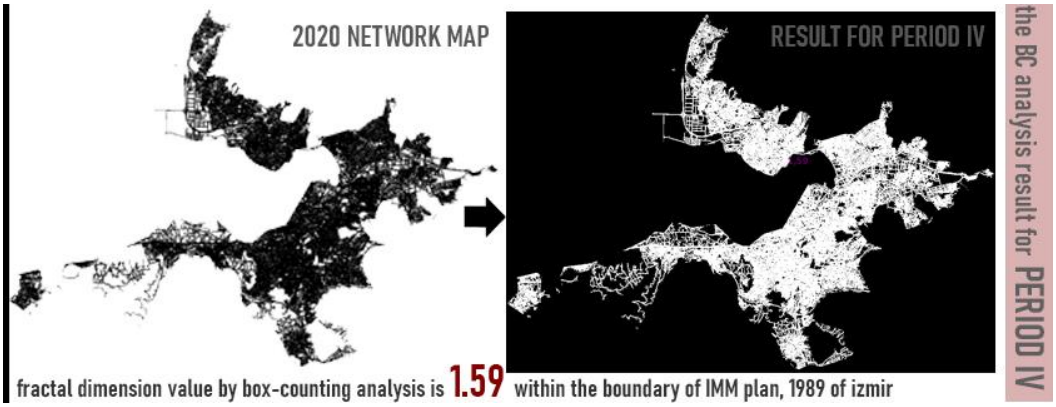


Figure 6.12 BC Analysis Result for Period IV by IMM Plan of Izmir in 1989

6.1.1.4 For the IMM Plan 2012

The İzmir Metropolitan Municipality's Environmental Plan aims to address the problems caused by rapid and uncontrolled urbanization, fragmented planning and the uncontrolled advancement of industrialization and urbanization. It seeks to promote sustainable development and protect cultural and natural values until 2030. The plan takes a holistic approach to urbanization by considering the city and its surroundings. The plan aims to promote healthy, safe, and orderly urbanization while taking advantage of the region's rich potential.

In this section, the values for the box-counting analysis are determined over time within limits set by the 2012 Environmental Plan of the Izmir Metropolitan Municipality.

- ***Period I- 1950***

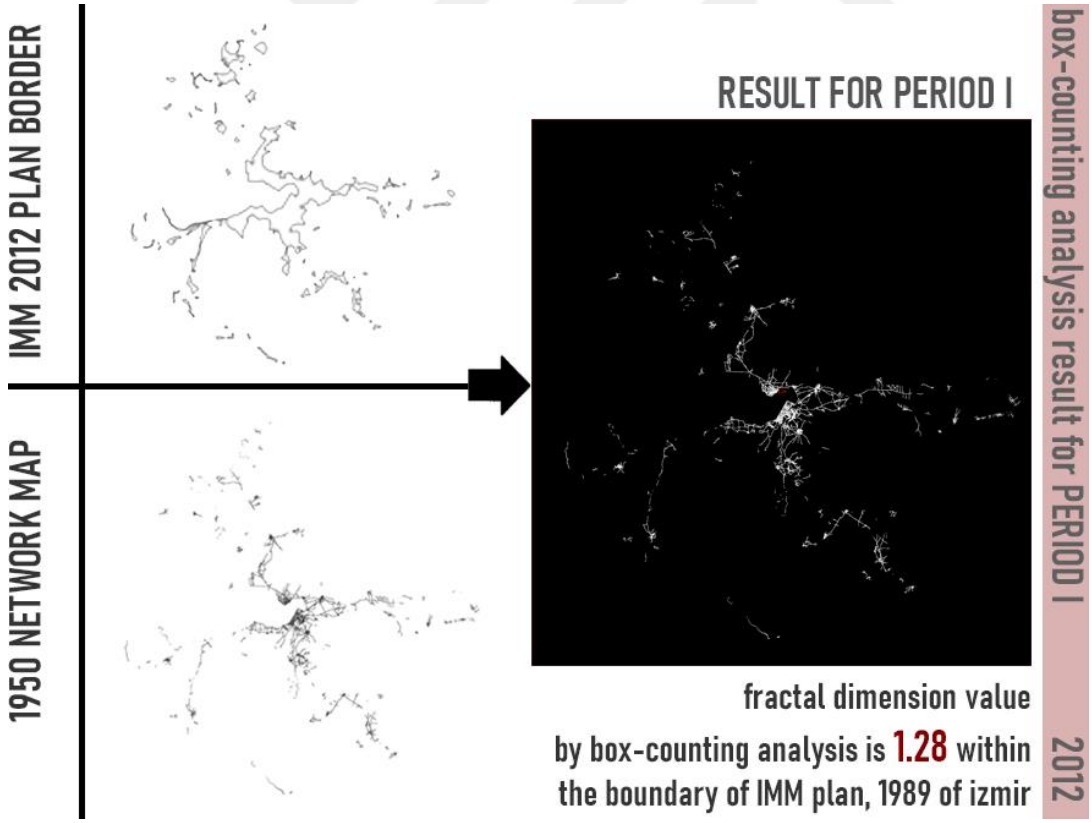


Figure 6.13 BC Analysis Result for Period I by IMM Plan of Izmir in 2012

- ***Period II- 1970***

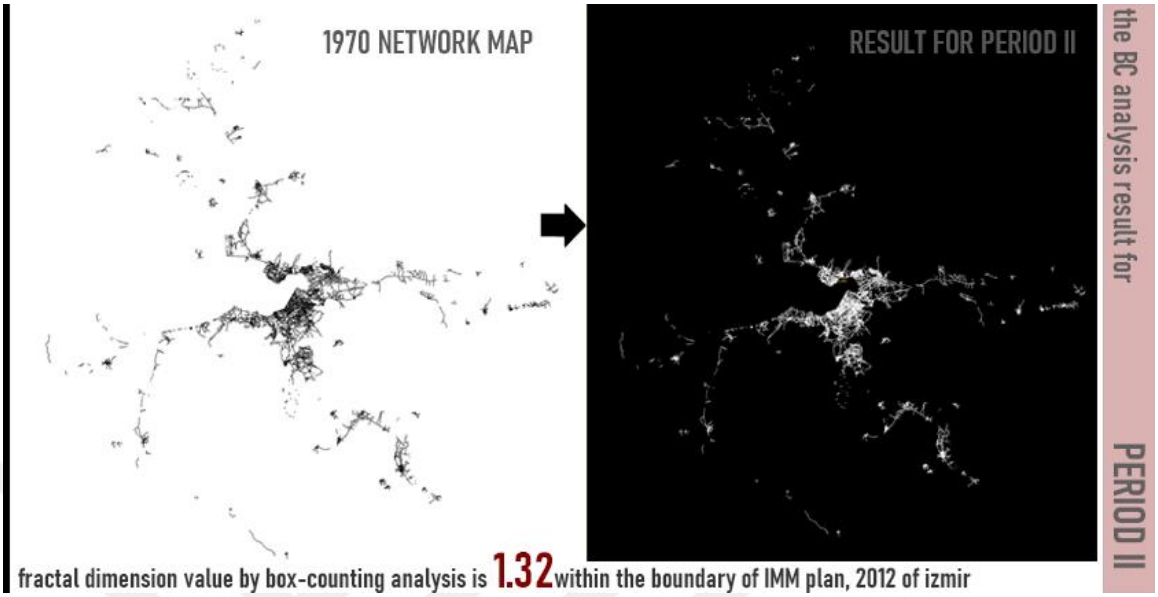


Figure 6.14 BC Analysis Result for Period II by IMM Plan of Izmir in 2012

- ***Period III- 2000***

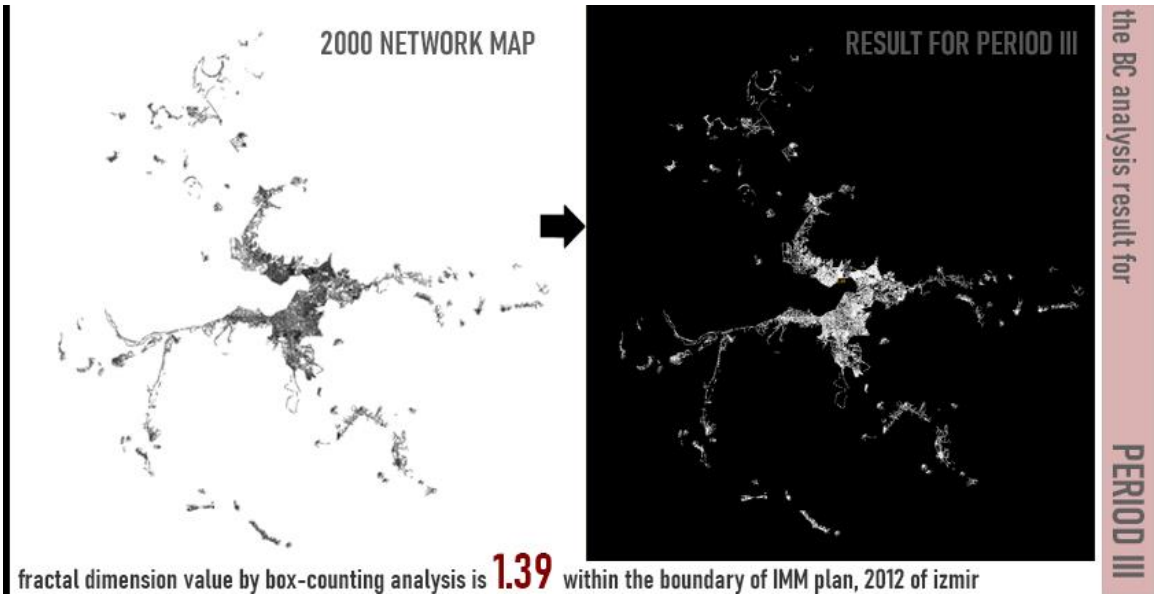


Figure 6.15 BC Analysis Result for Period III by IMM Plan of Izmir in 2012

- ***Period IV- 2020***

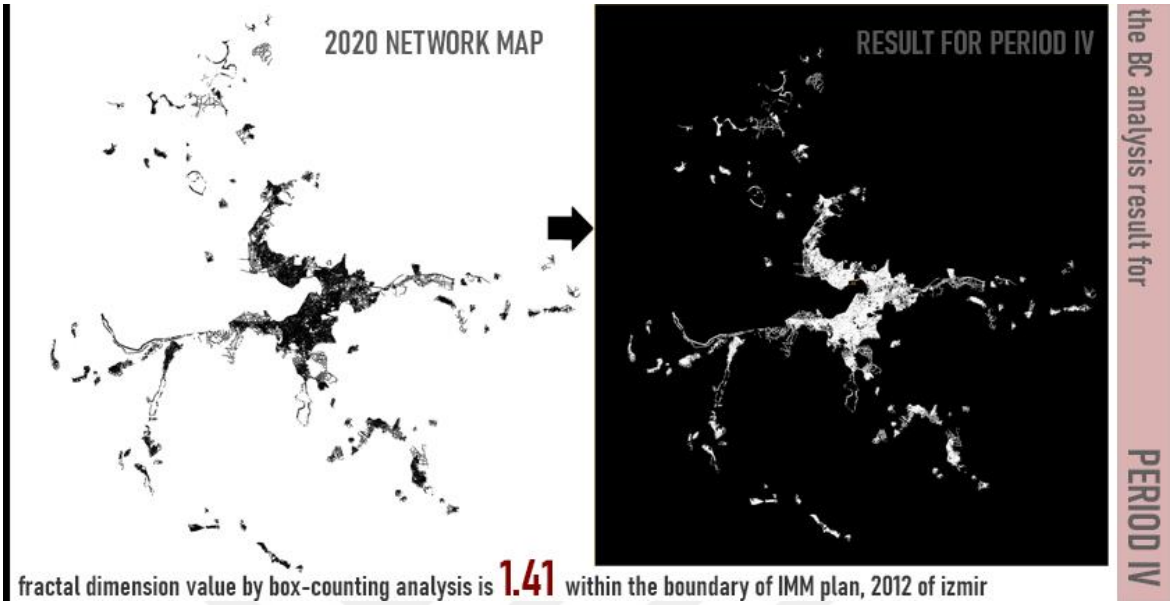


Figure 6.16 BC Analysis Result for Period IV by IMM Plan of Izmir in 2012

- ***A Summary for Box-Counting Analysis***

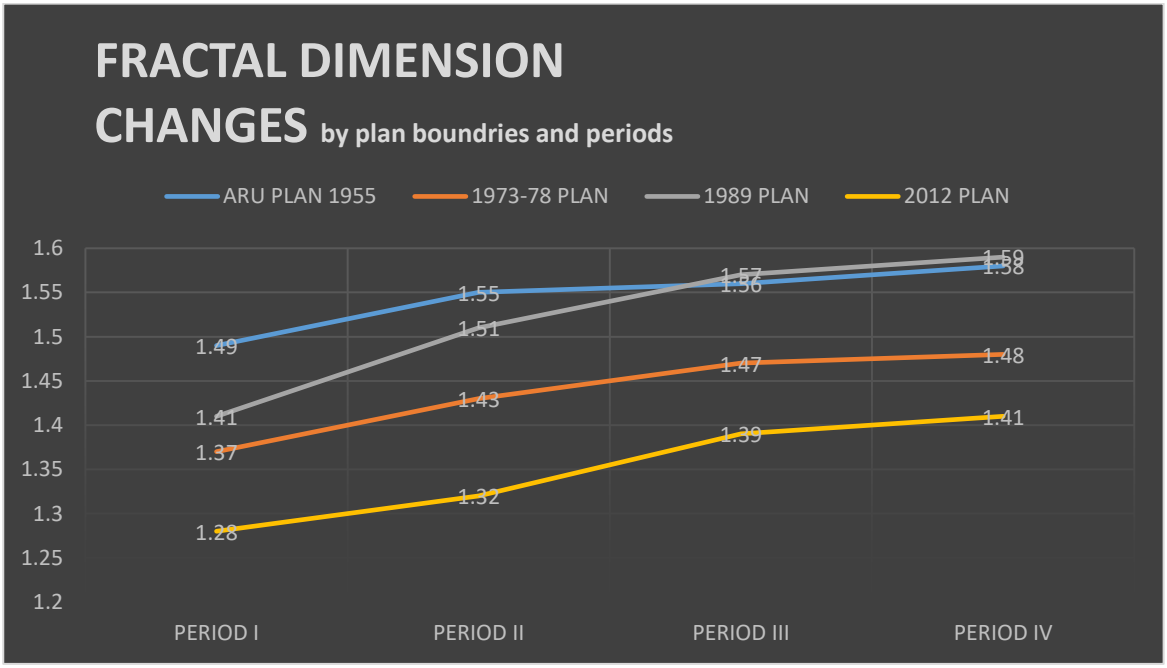


Figure 6.17 The Graph of Total Fractal Dimension Value Changes

- ***Kemal Aru Plan, 1955 and IMM 1973-78 Plan Periods***

In order to understand the fractal dimension results of the Kemal Aru plan and the IMM 1973-78 Plan, it is vital to consider the fractal dimension in urban planning. The fractal dimension is a measure of the complexity of an urban pattern, and it helps to understand the structure and organization of a city.

The periodic fractal dimension results offer a numerical representation of the complexity of the urban structures resulting from the four plans being compared. By analyzing these values, it is possible to gain insights into the nature of the urban structures and how they compare to one another.

Starting with the comparison between the Kemal Aru Plan and the IMM 1973-78 Plan, it is evident that it resulted in a more complex and diverse urban structure. The fractal dimension values for the Kemal Aru Plan range from 1.49 to 1.58, which are consistently higher than those for the IMM 1973-78 Plan, which range from 1.37 to 1.48.

This difference in fractal dimension values can be interpreted as a difference in the complexity and diversity of the urban structures resulting from the two plans. A higher fractal dimension value typically indicates a more complex and diverse urban structure characterized by a greater variety of land uses, building types, and street networks. On the other hand, a lower fractal dimension value suggests a simpler and more uniform urban structure with fewer land use types and a less intricate street network.

In terms of consistency, the results for the Kemal Aru Plan suggest a relatively stable and consistent implementation. The slight increase in fractal dimension values from period to period indicates a consistent and gradual increase in complexity and diversity over time, rather than significant fluctuations.

In contrast, the IMM 1973-78 Plan results show a slightly larger increase in fractal dimension values from period to period. This could suggest a less consistent

implementation of the plan or that the urban structure resulting from the plan was subject to greater fluctuations in terms of complexity and diversity over time.

In conclusion, the periodic fractal dimension results provide valuable information on the complexity of the urban structures resulting from the plans being compared. By comparing the results, it is possible to gain insights into the nature of the urban structures and how they compare to one another. However, these results should be considered in the context of other factors, such as the plans' goals, objectives, and constraints and the cultural, social, and economic context in which they were developed.

- ***IMM 1973-78 Plan and IMM 1989 Plan Periods***

In the realm of urban planning, the fractal dimension can serve as a measure of the complexity of a given urban plan. The fractal dimension results for the IMM 1973-78 plan and IMM 1989 plan, as expressed in the given data, allow for a comparison of the complexity of these two plans.

Starting with the IMM 1973-78 plan, the fractal dimension values for each period range from 1.37 to 1.48. The IMM 1989 plan, on the other hand, has fractal dimension values that range from 1.41 to 1.59. This indicates that the IMM 1989 plan has a higher degree of complexity compared to the IMM 1973-78 plan.

One possible explanation for this difference in complexity is the level of development that took place between these two plans. The IMM 1989 plan may represent a more advanced stage of urban development, with a more intricate and diverse range of urban structures and configurations, compared to the IMM 1973-78 plan.

Additionally, it is essential to consider the consistency of the fractal dimension values for each plan. The IMM 1989 plan shows relatively stable values for each period, ranging from 1.41 to 1.59, whereas the IMM 1973-78 plan shows slightly more fluctuation, ranging from 1.37 to 1.48. This suggests that the IMM 1989 plan

may be characterized by a more consistent level of complexity, reflecting a higher degree of planning and design coherence.

In conclusion, the comparison of the fractal dimension results for the IMM 1973-78 plan and the IMM 1989 plan provides insight into the complexity of these urban plans. The higher fractal dimension values and greater consistency of the IMM 1989 plan indicate a more advanced stage of urban development and a higher degree of planning and design coherence than the IMM 1973-78 plan.

- ***IMM 1989 Plan and IMM 2012 Plan Periods***

There are several key differences to note when comparing the IMM 1989 plan and the IMM 2012 plan. Firstly, the periodic fractal dimensions for the IMM 1989 plan are generally higher than those for the IMM 2012 plan, with values ranging from 1.41 to 1.59, compared to values ranging from 1.28 to 1.41 for the latter. This suggests that the IMM 1989 plan may have been more complex and consistent in its design compared to the IMM 2012 plan.

However, it is essential to note that the fractal dimension is a measure of the consistency and pattern of a system rather than its overall size or density. The lower values for the IMM 2012 plan may not necessarily indicate a lack of development but rather a more simplified and consistent approach to urban planning.

In urban development, consistency and simplicity can be seen as positive attributes, as it allows for a more straightforward and predictable implementation of plans, leading to more efficient use of resources. Additionally, a consistent and predictable urban environment can improve citizens' quality of life.

It is also worth considering the different historical and contextual factors that may have influenced the design of each plan. For example, the IMM 1989 plan was developed at a time of significant economic growth, which may have allowed for a more complex and ambitious approach to urban development. On the other hand, the IMM 2012 plan was developed during economic uncertainty, which may have influenced a more conservative and simplified approach.

In conclusion, while the lower values of the periodic fractal dimension for the IMM 2012 plan may indicate a less complex and consistent approach to urban development, they can also be seen as a positive attribute in terms of simplicity and consistency.

Here in Table 2, the relationship between the complexity level and fractal dimension values performed by the box-counting method is explained within the framework of the size of the planning area.

Table 2 Fractal Dimension Change by boudries and the Relation with the Complexity

FRACTAL DIMENSION CHANGE, AREA SIZE AND COMPLEXITY				
PLANNING AREA SIZE ➡	ARU PLAN 1955 <	IMM 1973-78 <	IMM 1989 <	IMM 2012
PERIOD I	1.49	1.37	1.41	1.28
PERIOD II	1.55	1.43	1.51	1.32
PERIOD III	1.56	1.47	1.57	1.39
PERIOD IV	1.58	1.48	1.59	1.41
COMPLEXITY BY BOUNDRIES ➡	IMM 2012 <	IMM 1973-78 <	IMM 1989 <	ARU PLAN 1955

6.1.2 Periodic Local Connected Fractal Dimenson (the DLC) Analysis

The Periodic Local Connected Fractal Dimension (DLC) Analysis is a mathematical tool used to determine the fractal dimension of a time series data set, providing insight into its complexity and self-similarity. When applied to road network data, DLC Analysis can provide valuable information about the network's structure and connectivity, which can inform urban planning and transportation engineering decisions. The DLC analysis is used to understand the relationship between the road network and regional economic and social activities. The fractal dimension of a road network can give insight into its connectivity and accessibility, which can affect economic and social activities in a region. A highly interconnected road network

with many accessible paths can facilitate commerce and transportation. In contrast, a poorly connected network with limited accessibility can limit economic and social activities in the region.

The purpose of DLC analysis in urban planning is to provide a quantitative measure of the road network's structure and connectivity, which can be used to optimize the network for various purposes.

For example, the analysis can inform decisions about developing and maintaining the network to support economic and social activities, improve accessibility, and enhance social well-being. DLC analysis provides a valuable tool for exploring the relationship between the structure and connectivity of road networks and regional economic and social activities. Researchers can use the analysis to examine this relationship in different regions and to understand the impact of changes in the road network on economic and social activities. Overall, DLC analysis is a valuable tool for urban planners, researchers, and policymakers interested in understanding the relationship between road networks and regional economic and social activities. By providing a quantitative measure of the structure and connectivity of road networks, DLC analysis can help inform urban planning decisions and support the development of road networks that are optimized for various purposes.

6.1.2.1 For the İzmir Plan of Aru 1955

The Kemal Aru Plan, which was put into practice in 1955, is a significant urban planning initiative that has had a major impact on the development and growth of the region. To understand the effects of the plan, it is essential to compare the results of the first two periods, Period I (1950) and Period II (1970). This comparison provides insights into the changes that have occurred in the region over time and helps to identify trends and patterns of development.

The results of Period I and Period II are essential in understanding the impact of the Kemal Aru Plan. By examining the data from these two periods, it is possible to see

the changes that have occurred in the region over time and evaluate the plan's effectiveness. This information can be used to make informed decisions about further developing and maintaining the region in a way that supports economic and social activities.

- ***Period I- 1950***

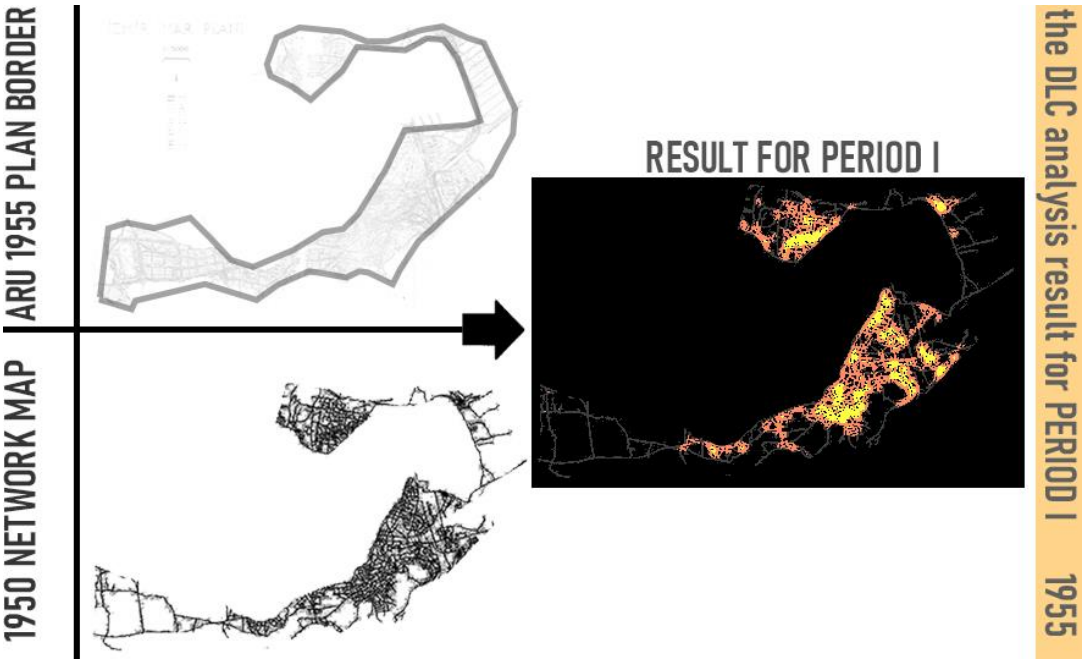


Figure 6.18 DLC Analysis Result for Period I by Aru plan of Izmir, 1955

- ***Period II- 1970***

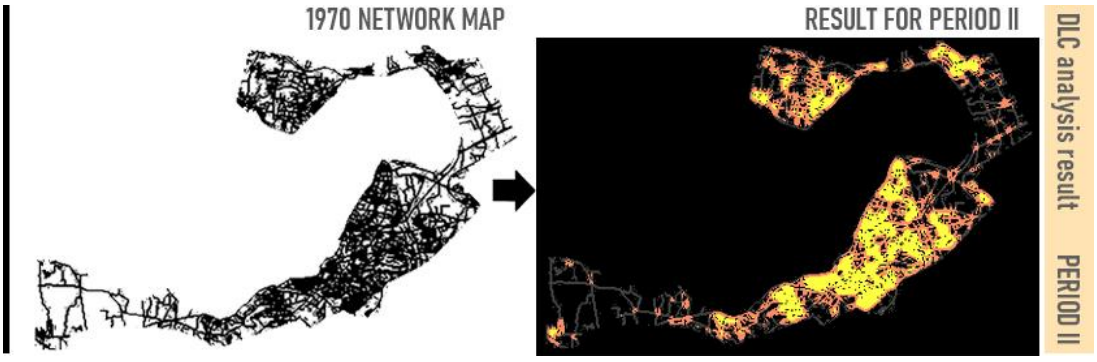


Figure 6.19 DLC Analysis Result for Period II by Aru plan of Izmir in 1955

- ***Periond III- 2000***

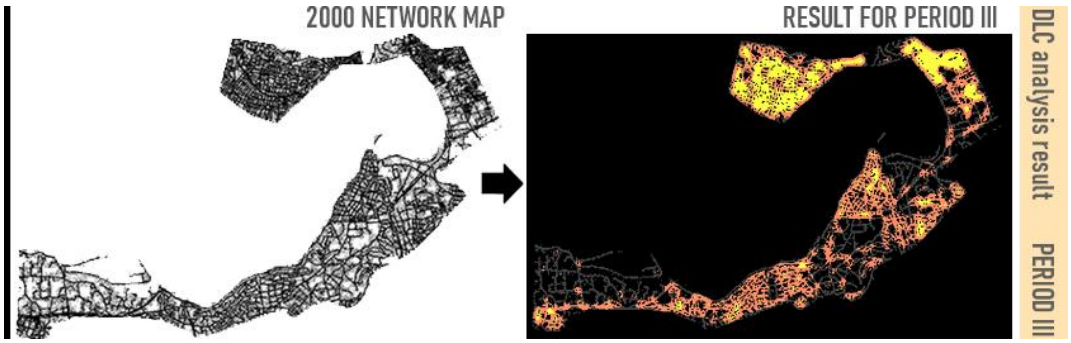


Figure 6.20 DLC Analysis Result for Period III by Aru plan of Izmir in 1955

- ***Period IV- 2020***

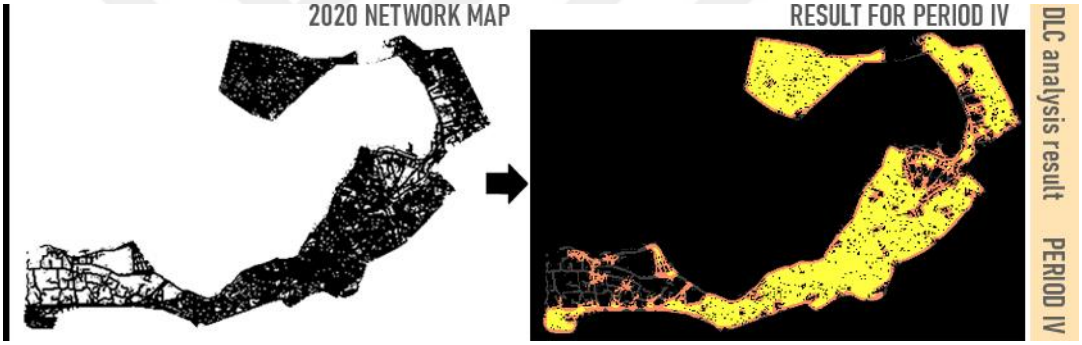


Figure 6.21 DLC Analysis Result for Period IV by Aru plan of Izmir in 1955

- ***Comparison of the Plan's Initial Condition and the Post-Plan Status***

The Kemal Aru plan of Izmir in 1955 was aimed at transforming the city's urban structure and providing a more organized, functional, and livable urban environment. The results of the Local Connected Fractal Dimension (DLC) Analysis show that the connectivity increased in all directions, not just along corridors, but from the center to the outskirts of the city.

In terms of connectivity, the plan positively affected the city as it improved the flow of people, goods, and services within the city, making it easier for residents to access essential amenities and services. The improved connectivity also helped to create a

more vibrant and dynamic urban environment, as it facilitated the development of new economic and social activities.

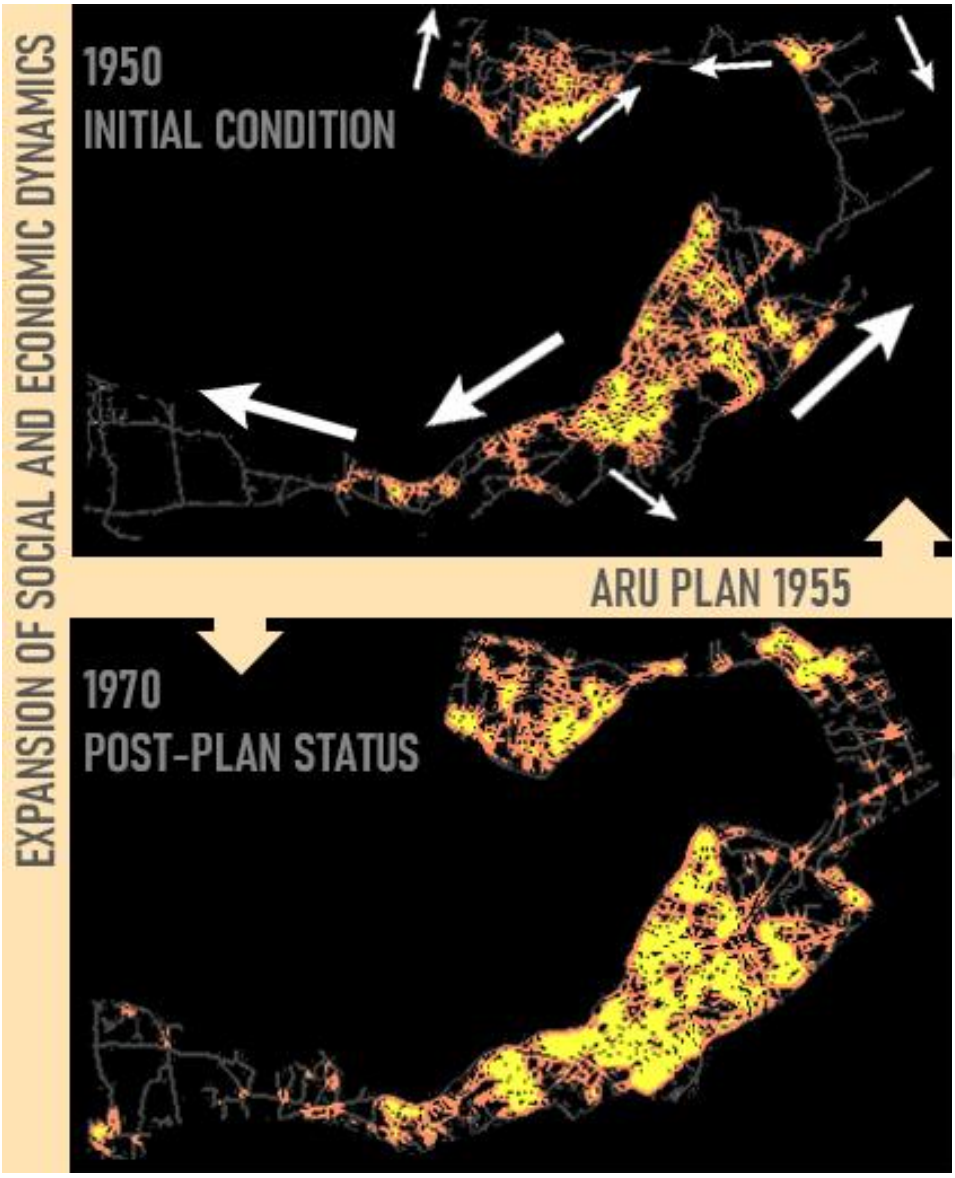


Figure 6.22 Comparison of Kemal Aru Plan's Initial Condition and Post-plan Status by DLC Analysis

The Kemal Aru plan of Izmir in 1955 was aimed at transforming the city's urban structure and providing a more organized, functional, and livable urban environment. The results of the Local Connected Fractal Dimension (DLC) Analysis show that the connectivity increased in all directions, not just along corridors, but from the center to the outskirts of the city.

In terms of connectivity, the plan positively affected the city as it improved the flow of people, goods, and services within the city, making it easier for residents to access essential amenities and services. The improved connectivity also helped to create a more vibrant and dynamic urban environment, as it facilitated the development of new economic and social activities.

In terms of compactness, the plan also had a positive impact. By promoting the city's growth in a more organized and controlled manner, the plan helped to reduce the spread of urban sprawl, leading to inefficient land use, increased transportation costs, and social and environmental problems. The compact city form that emerged as a result of the plan helped to create a more efficient and sustainable urban environment, as it allowed for the provision of services and infrastructure to be more concentrated and accessible to a larger number of people.

Overall, the Kemal Aru plan of Izmir in 1955 had a significant impact on the city's urban structure and had a positive effect on both connectivity and compactness.

6.1.2.2 For the IMM Plan 1973-1978

The IMM 1973-78 Plan, which was started to implement in 1978, was a crucial urban planning initiative that greatly influenced the growth and evolution of the region. To assess the impact of the plan, it is crucial to analyze the data from two different periods, Period II (1970) and Period III (2000). This comparison offers valuable insights into the transformations that have taken place in the region over time and reveal patterns and trends of development.

Analyzing the results from Periods II and III is critical for comprehending the effects of the IMM 1973-78 Plan. By examining the data from these two periods, it is possible to discern the changes in the region over time and assess the plan's efficacy. This information can then be utilized to make informed decisions regarding the future development and maintenance of the region to promote economic and social activities.

- ***Period I- 1950***

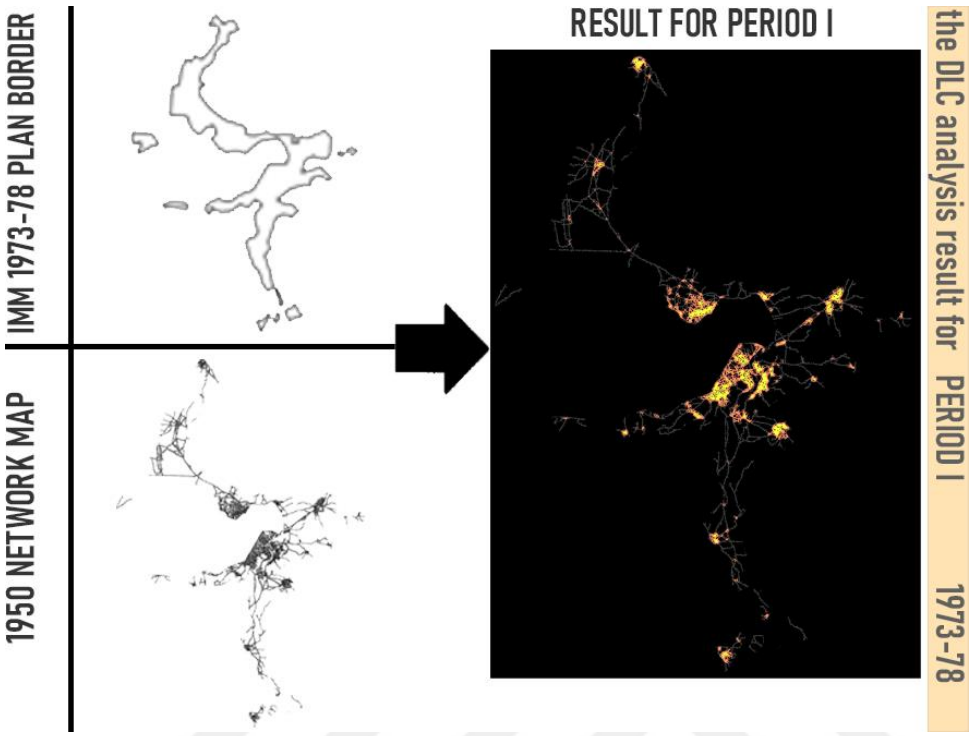


Figure 6.23 DLC Analysis Result for Period I by IMM Plan of Izmir, 1973-78

- ***Period II- 1970***

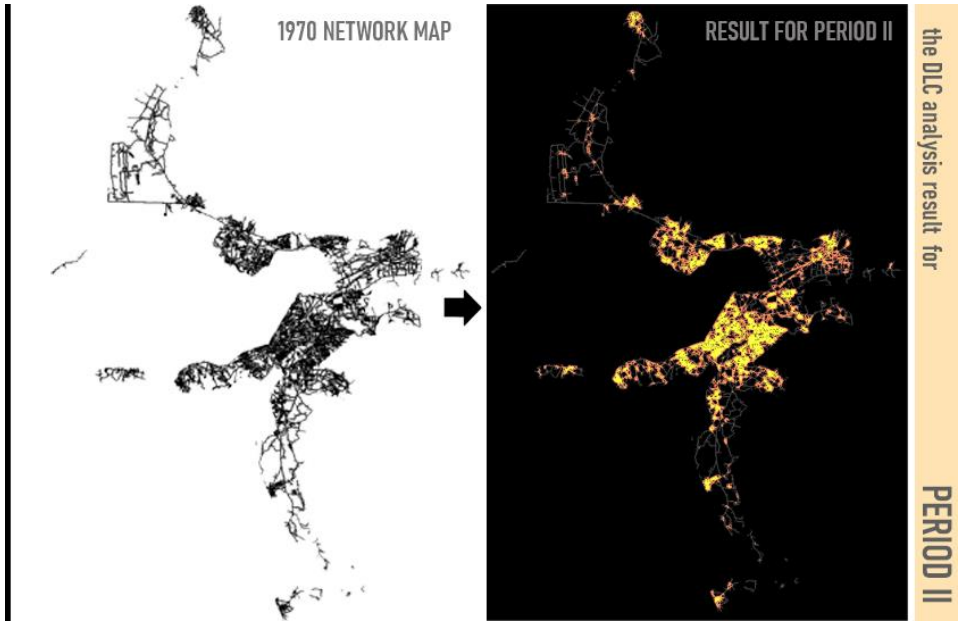


Figure 6.24 DLC Analysis Result for Period II by IMM Plan of Izmir, 1973-78

- ***Period III- 2000***

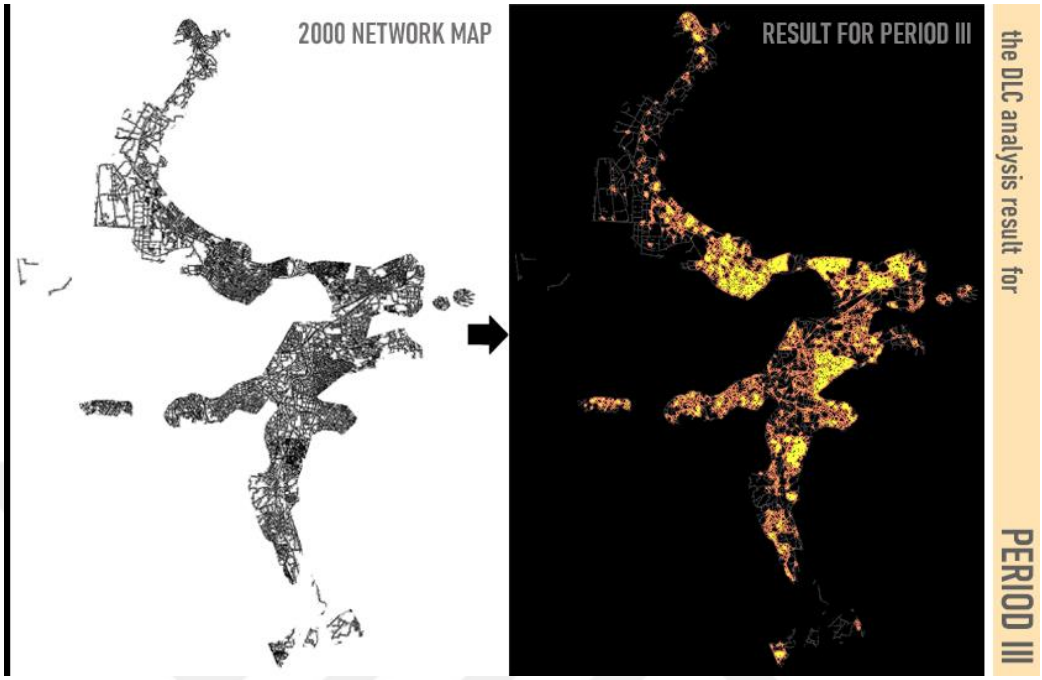


Figure 6.25 DLC Analysis Result for Period III by IMM Plan of Izmir, 1973-78

- ***Period IV- 2020***

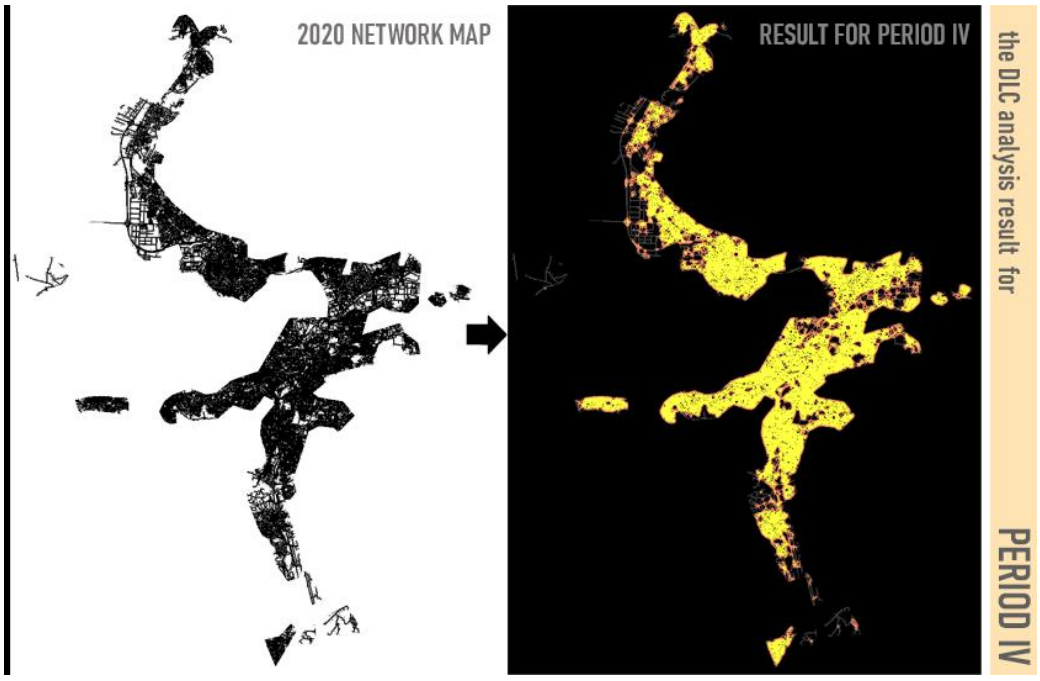


Figure 6.26 DLC Analysis Result for Period IV by IMM Plan of Izmir, 1973-78

- ***Comparison of the Plan's Initial Condition and the Post-Plan Status***

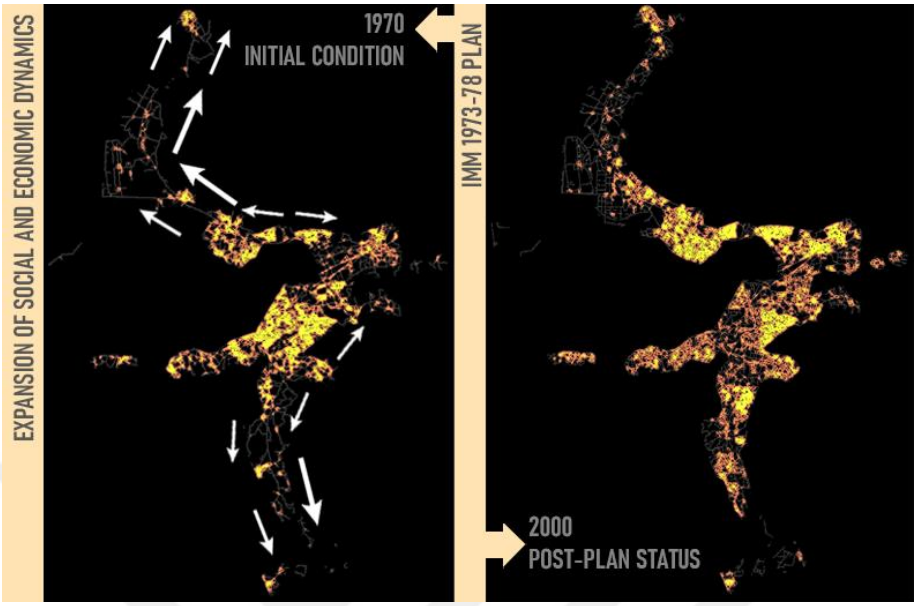


Figure 6.27 Comparison of the IMM 1973-78 Plan's Initial Condition and Post-plan Status by DLC Analysis

The results of the DLC analysis suggest that the IMM 1973-78 Plan of İzmir significantly impacted the connectivity of the city's network map. The analysis found that the connectivity increased in the direction of the south and north corridor, indicating that these areas were prioritized in the plan. This increase in connectivity is likely due to the construction of new infrastructure, such as roads and transportation systems, which made it easier for people and goods to move in these areas. However, the increased connectivity also decreased compactness, as the city's network map became less centralized and more spread out. This reduction in compactness is likely due to the city's expansion in these areas, which created more suburban-style developments and reduced the density of the central city. At the same time, the results of the DLC analysis also suggest that the city's network's complexity increased due to the plan mostly. This is likely due to the increased number of roads and transportation systems that were built, which created more interconnections and nodes in the city's network. This increased complexity made it more difficult for people and goods to move around the city, as there were more options to choose from and more congestion points.

In conclusion, the results of the DLC analysis indicate that the IMM 1973-78 Plan of İzmir significantly impacted the connectivity and complexity of the city's network map. While the plan increased connectivity in certain areas, it also led to a decrease in compactness and an increase in complexity. These changes had both positive and negative effects on the city, and further analysis is needed to understand the full impact of the plan on the city's growth and development.

6.1.2.3 For the IMM Plan 1989

It is crucial to evaluate the impact of the IMM 1989 Plan on the development and growth of the region by comparing the results of Period II (1970) and Period III (2000). This comparison provides valuable insights into the changes that have taken place in the region and allow for an assessment of the plan's effectiveness.

- ***Period I- 1950***

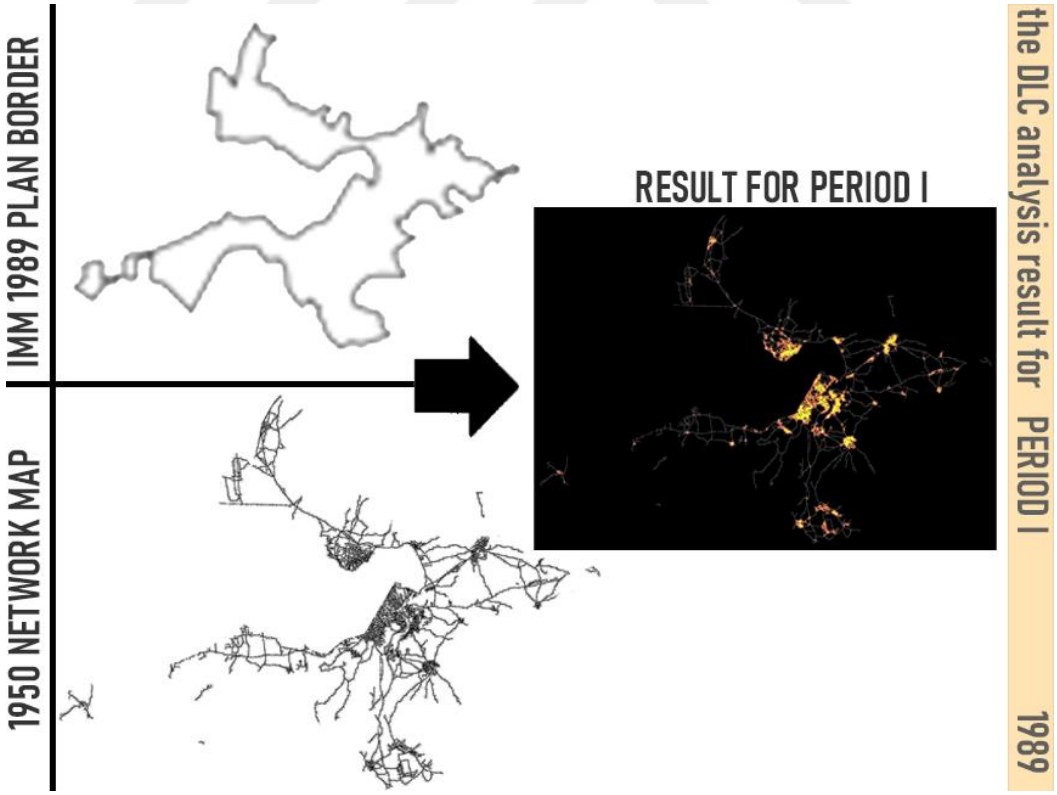


Figure 6.28 DLC Analysis Result for Period I by IMM Plan of Izmir, 1989

- ***Period II- 1970***

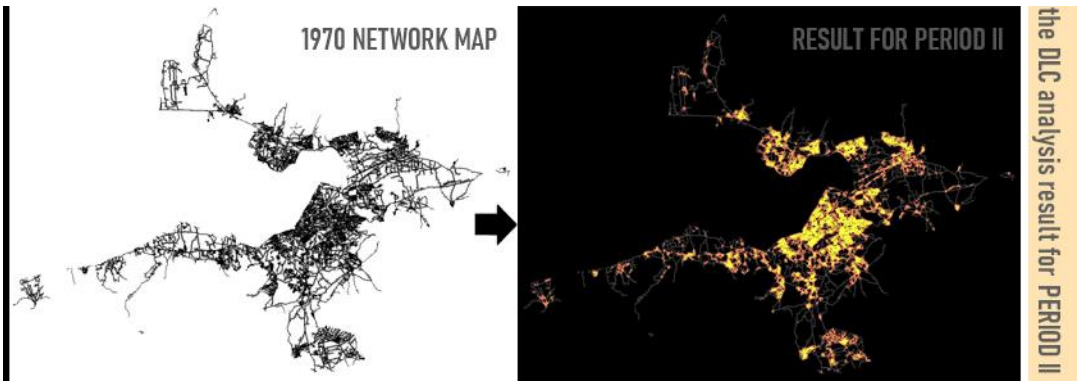


Figure 6.29 DLC Analysis Result for Period II by IMM Plan of Izmir, 1989

- ***Period III- 2000***

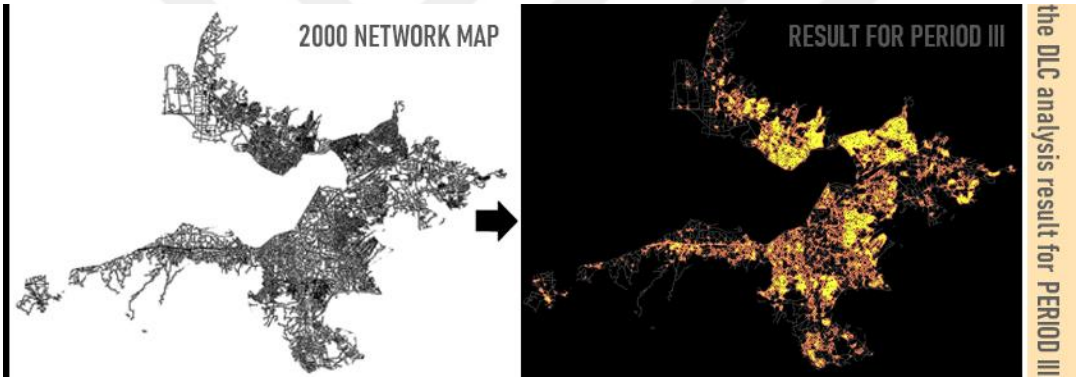


Figure 6.30 DLC Analysis Result for Period III by IMM Plan of Izmir, 1989

- ***Period IV- 2020***

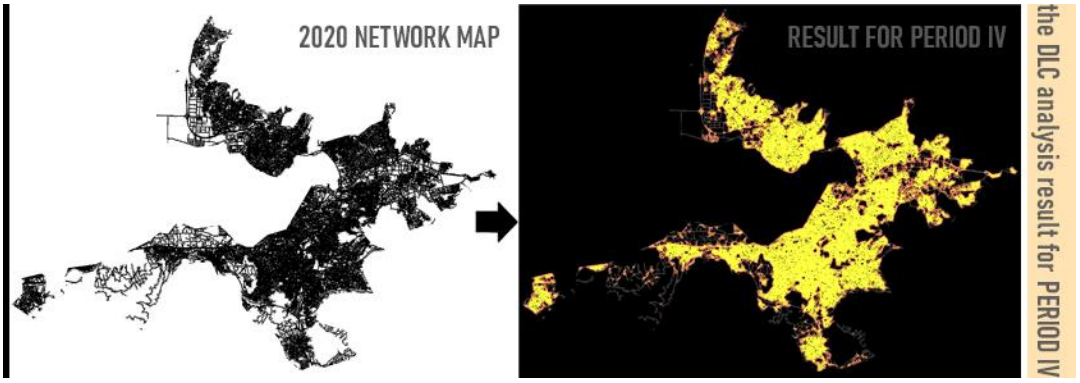


Figure 6.31 DLC Analysis Result for Period IV by IMM Plan of Izmir, 1989

- ***Comparison of the Plan's Initial Condition and the Post-Plan Status***

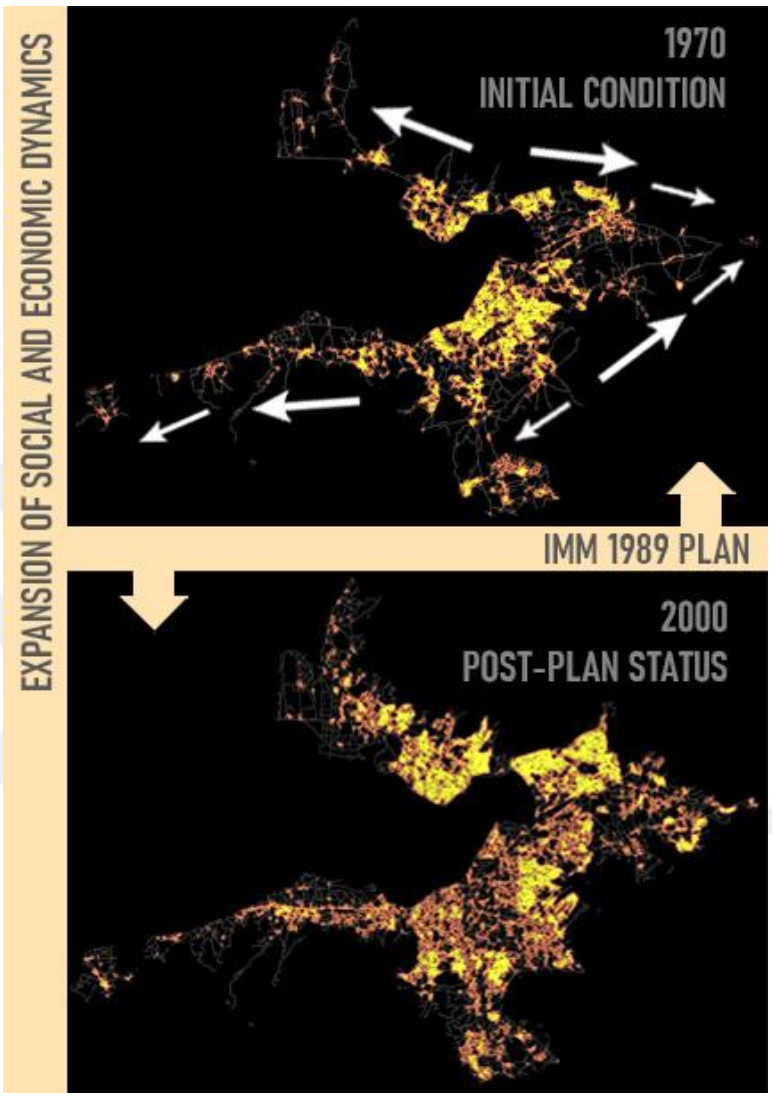


Figure 6.32 Comparison of the IMM 1989 Plan's Initial Condition and Post-plan Status by DLC Analysis

The results of the Local Connected Fractal Dimension (DLC) Analysis of İzmir, based on the IMM 1989 Plan, show an increase in connectivity in the direction of west-east corridor development. This highlights the success of the plan in enhancing the connectivity and accessibility of the region, which can support economic and social activities. An increase in connectivity can also foster a more livable environment by improving access to essential amenities and services.

However, the decrease in compactness observed in the DLC analysis suggests that the plan has contributed to inefficient land use. This can result in urban sprawl, which can lead to problems such as increased traffic congestion, air pollution, and strain on the environment. Additionally, a decrease in compactness can lead to greater distances between urban centers and their surrounding communities, creating challenges for residents who need to commute.

The highest complexity observed in the DLC analysis suggests that the region has become increasingly complex in terms of its physical and functional organization. This can result in a more challenging urban environment for residents, particularly in terms of navigation and access to essential amenities and services. In addition, increased complexity can lead to greater difficulties in managing the region, such as in the areas of traffic management and maintenance of public facilities.

In conclusion, the results of the DLC analysis of İzmir indicate that the IMM 1989 Plan has had both positive and negative impacts on the region. While the plan has succeeded in enhancing connectivity, it has also led to decreased compactness and increased complexity. To fully understand the effects of the plan, it is important to continue conducting further evaluations and assessments and to consider the results when making decisions about future development and maintenance in the region.

6.1.2.4 For the IMM Plan 2012

The IMM 2012 Plan, which was launched in 2012, had a substantial impact on the region's growth and evolution. To assess its effects, it is important to compare data from two different time periods, 2000 (Period III) and 2020 (Period IV). This comparison gives valuable insights into the transformations that have taken place in the region over time and reveal patterns and trends of development.

Examining the data from Periods III and IV is critical for comprehending the impact of the IMM 2012 Plan. By analyzing the changes in the region over time, it is possible to evaluate the effectiveness of the plan and make informed decisions about

the future development and maintenance of the region to support economic and social activities.

- ***Period I- 1950***

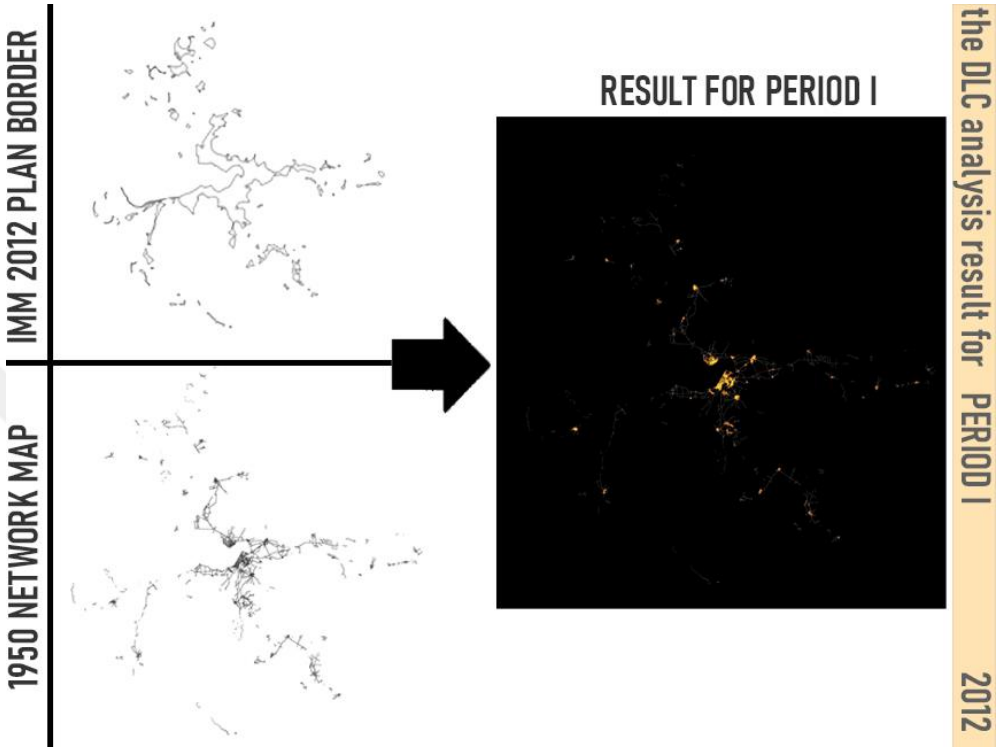


Figure 6.33 DLC Analysis Result for Period I by IMM Plan of Izmir, 2012

- ***Period II- 1970***

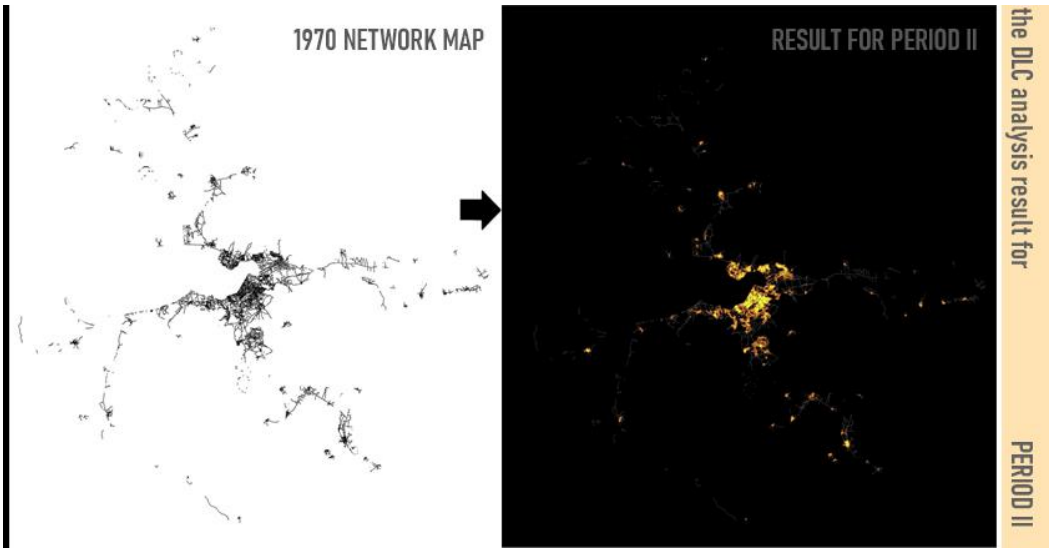


Figure 6.34 DLC Analysis Result for Period II by IMM Plan of Izmir, 2012

- ***Period III- 2000***

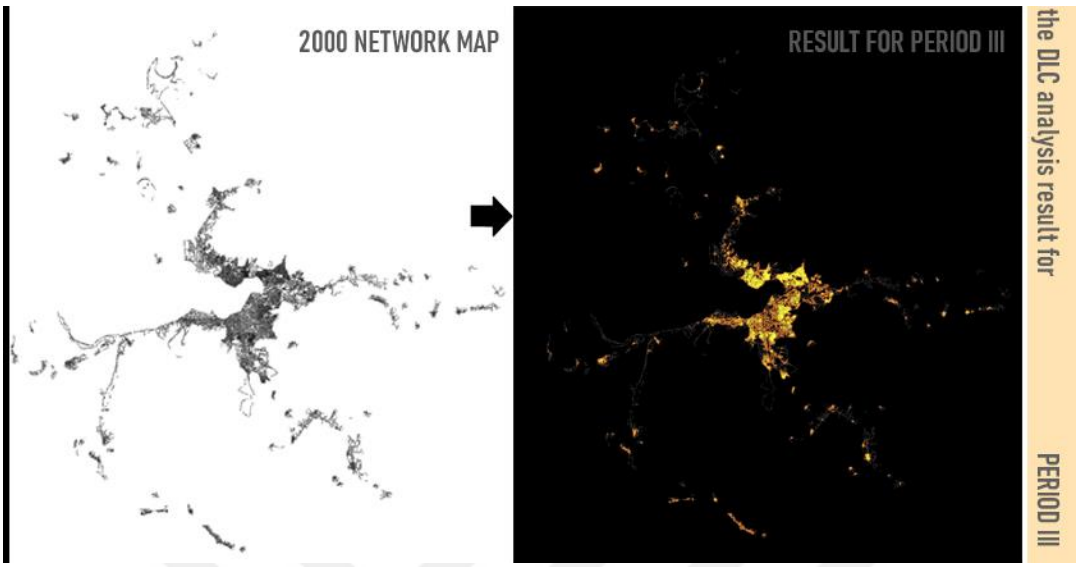


Figure 6.35 DLC Analysis Result for Period III by IMM Plan of Izmir, 2012

- ***Period IV- 2020***

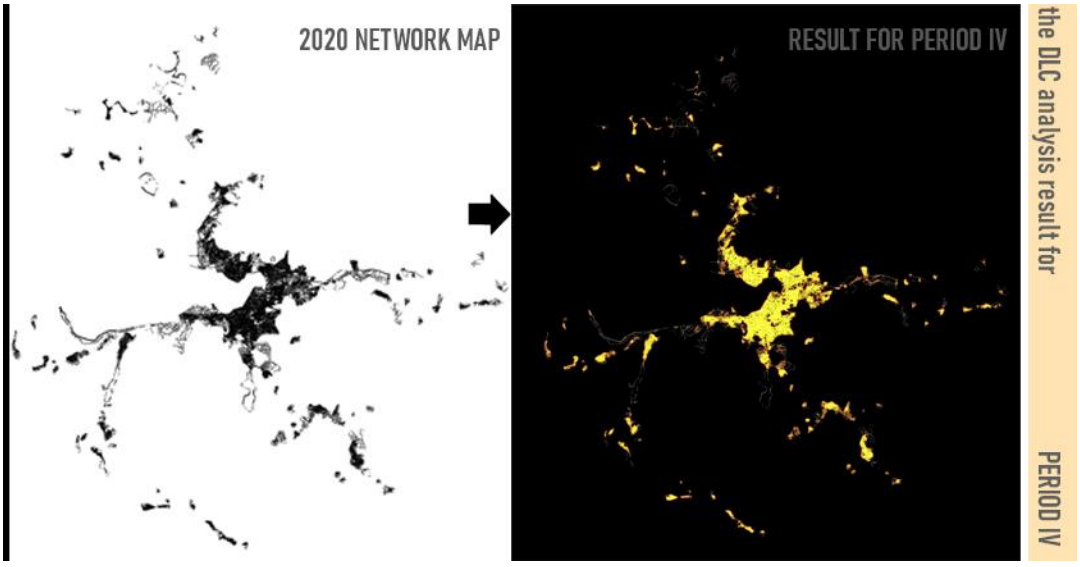


Figure 6.36 DLC Analysis Result for Period IV by IMM Plan of Izmir, 2012

- ***Comparison of the Plan's Initial Condition and the Post-Plan Status***

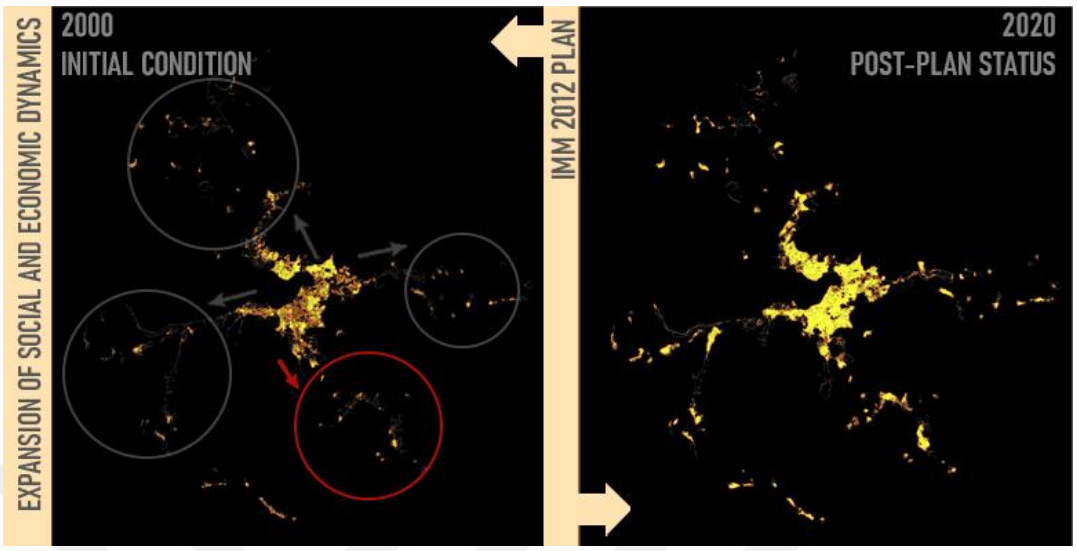


Figure 6.37 Comparison of the IMM 2012 Plan's Initial Condition and Post-plan Status by DLC Analysis

The results of the Local Connected Fractal Dimension (DLC) Analysis demonstrate a marked enhancement in the interconnectivity of the city of İzmir as compared to the initial conditions in the year 2000. The analysis reveals that this increase in connectivity has largely occurred along the southern corridor axis, with a lesser degree of expansion along the west-east axis.

The increase in connectivity is a reflection of the implementation of the IMM 2012 Plan, and its effects are complex and multifaceted. On the one hand, increased connectivity can bring about numerous benefits, such as greater access to essential services, more robust economic activity, and improved opportunities for social engagement. On the other hand, the increase in sprawl development, as indicated by the decrease in compactness, can lead to negative consequences, such as elevated traffic congestion, decreased air quality, and reduced open space.

Given these considerations, it is crucial to examine the effects of the IMM 2012 Plan in the context of connectivity, sprawl development, and compactness. The increasing complexity of the network, as revealed by the DLC analysis, must also be taken into account when evaluating the impact of the plan.

In summary, the IMM 2012 Plan has had a profound impact on the connectivity and development of İzmir, and it will be imperative to continue monitoring and assessing its effects to make informed decisions regarding the future of the city. The careful consideration of the interplay between connectivity, sprawl, and compactness will be essential in ensuring sustainable urban development for the city and its residents.

6.1.3 Periodic Sub-Fractal Analysis (*by text and color code*) with Overlapped Visuals of the Analyzes

Periodic Sub-Fractal Analysis (PSFA) is a mathematical and computational framework that provides insights into the complexity of cities. In this framework, cities are treated as complex networks of interrelated elements, such as transportation systems, land use patterns, and human activities. The goal of PSFA is to understand the periodic and fractal patterns that are present in the structure and dynamics of cities and how they interact with each other.

To perform a PSFA analysis, periodic network maps are used to capture the periodic patterns present in the city. These maps show the distribution of different elements in the city, such as transportation networks, land use patterns, or human activities, and provide a visual representation of the periodic patterns present in the city. By analyzing these periodic network maps, researchers can gain a deeper understanding of the complexity of a city and how different aspects of the city influence and interact with each other.

Using PSFA, researchers can evaluate the effects of urban plans on the city. For example, they can use PSFA to study how changes in land use patterns or transportation networks affect the overall complexity of the city. This information can then be used to guide urban planning decisions, helping to create more livable and sustainable cities.

In summary, Periodic Sub-Fractal Analysis using periodic network maps is a valuable tool for understanding the complexity of cities and the impact of urban plans

on their structure and dynamics. It provides a mathematical and computational framework for analyzing the periodic and fractal patterns present in cities and the interactions between different elements, such as transportation, land use, and human activities. By using PSFA, researchers can gain insights into the complexity of cities and help guide urban planning decisions toward creating more livable and sustainable cities.

After the DLC and BC analyzes were made and observed, a sub-fractal analysis study was needed to examine how the sub-parts of the city worked and how they changed over time. It has been clearly observed that the city works differently as a whole and sub-parts with this analysis method. The comparative interpretation of the analysis results in this section is left to the end of that section in order to be able to relate it to the planning decisions, as it will be clearer in the next difference analysis study. While performing the sub-fractal analysis study was done in two different ways. The first of these provides a holistic observation of high or low values with the color code. The second is done by printing the sub-fractal values on the region indicated. The software used (ImageJ-FracLac) does not output sub-fractal values as an "excel" or "spps" file. For this reason, the analysis was carried out in two different ways in order to convert all the results into an excel file.

At the same time, the analyzes made in this section were brought together by overlapping with other analyzes, and it was ensured that they could be observed together. No discrepancy or inconsistency was observed between the analyses. The basis for difference analysis is ready at this stage.

When showing sub-fractal analysis studies, the first period shows how all analyzes are combined, but this was not required in other periods. As in other analyzes, the initial condition and post-plan status were determined in this analysis study, and the sub-fractal analysis average was calculated for the relevant cases. The purpose of doing this is to calculate how much planning decisions change the urban structure and to observe which plan has the most impact.

6.1.3.1 For the İzmir Plan of Aru 1955

- ***Period I- 1950***

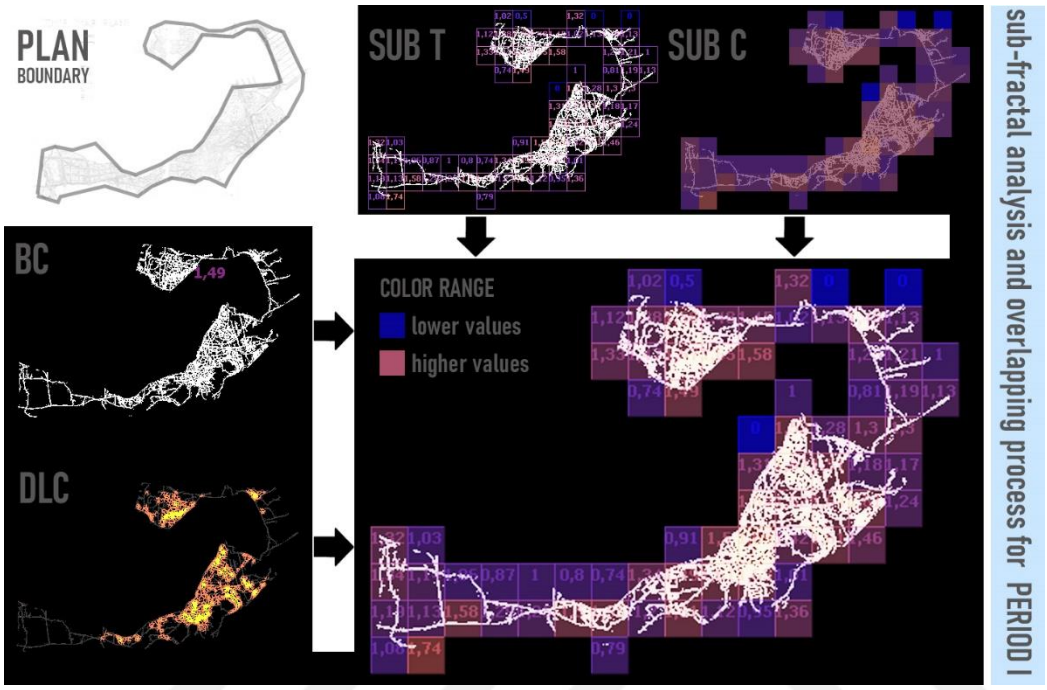


Figure 6.38 Sub-Fractal Analysis and Overlapping Process for Period I by Kemal Aru plan of Izmir in 1955

- ***Period II- 1970***

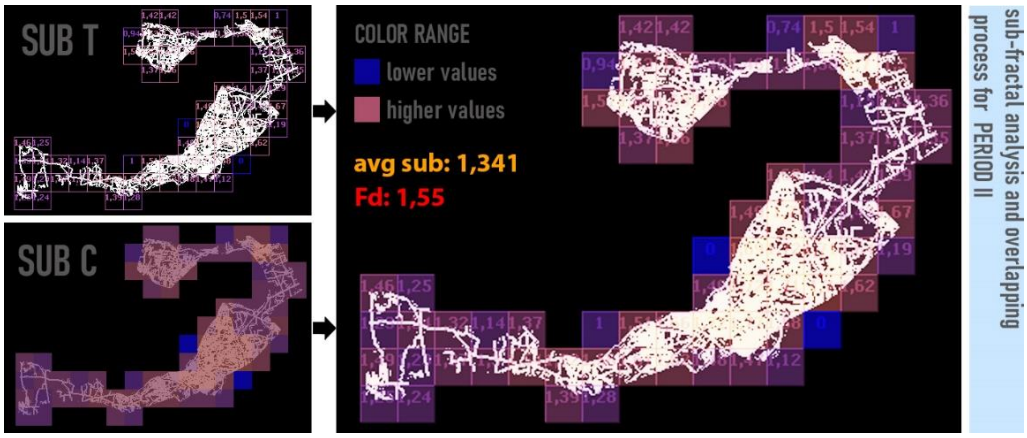


Figure 6.39 Sub-Fractal Analysis for Period II by Aru plan of Izmir, 1955

- ***Period III- 2000***

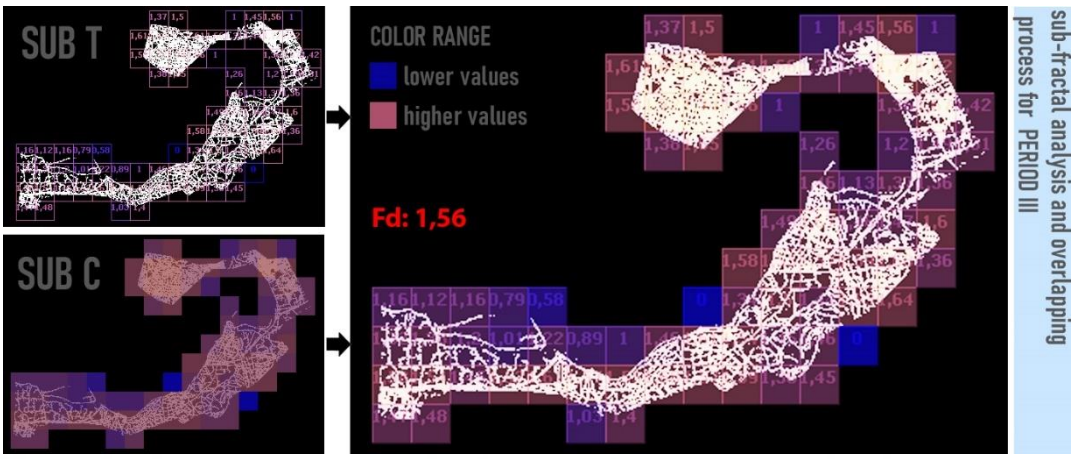


Figure 6.40 Sub-Fractal Analysis for Period III by Aru plan of Izmir, 1955

- ***Period IV- 2020***

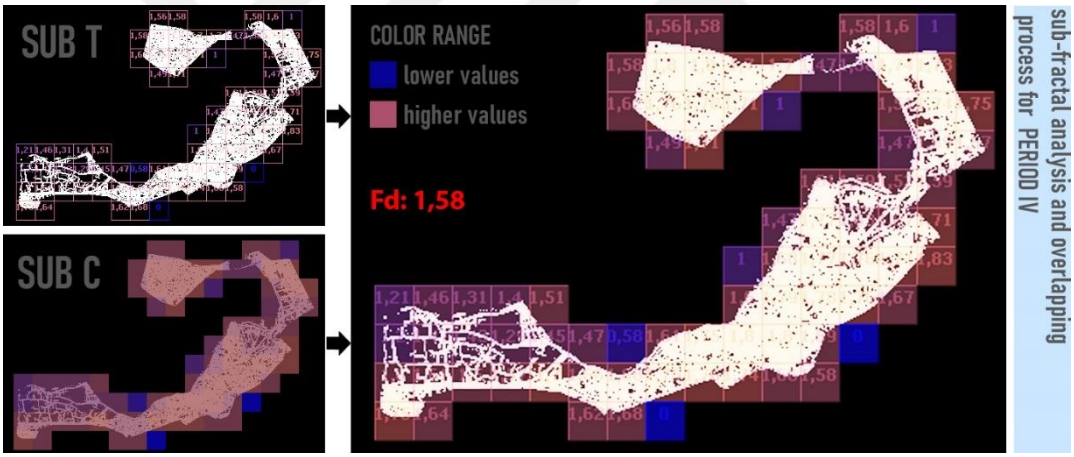


Figure 6.41 Sub-Fractal Analysis for Period IV by Aru plan of Izmir, 1955

Since the initial status of Kemal Aru 1955 Plan was 1950 road network map and post plan status were 1970 road network, sub-fractal averages were taken and processed on the image. The same method was followed for the other Plan boundaries. For this study, it is essential to observe and determine the changes in the city structure, taking into account the planning decisions. Therefore, the results obtained from other analyzes were also processed on these images, and a holistic understanding was developed for the analyzes.

6.1.3.2 For the IMM Plan 1973-1978

- ***Period I- 1950***

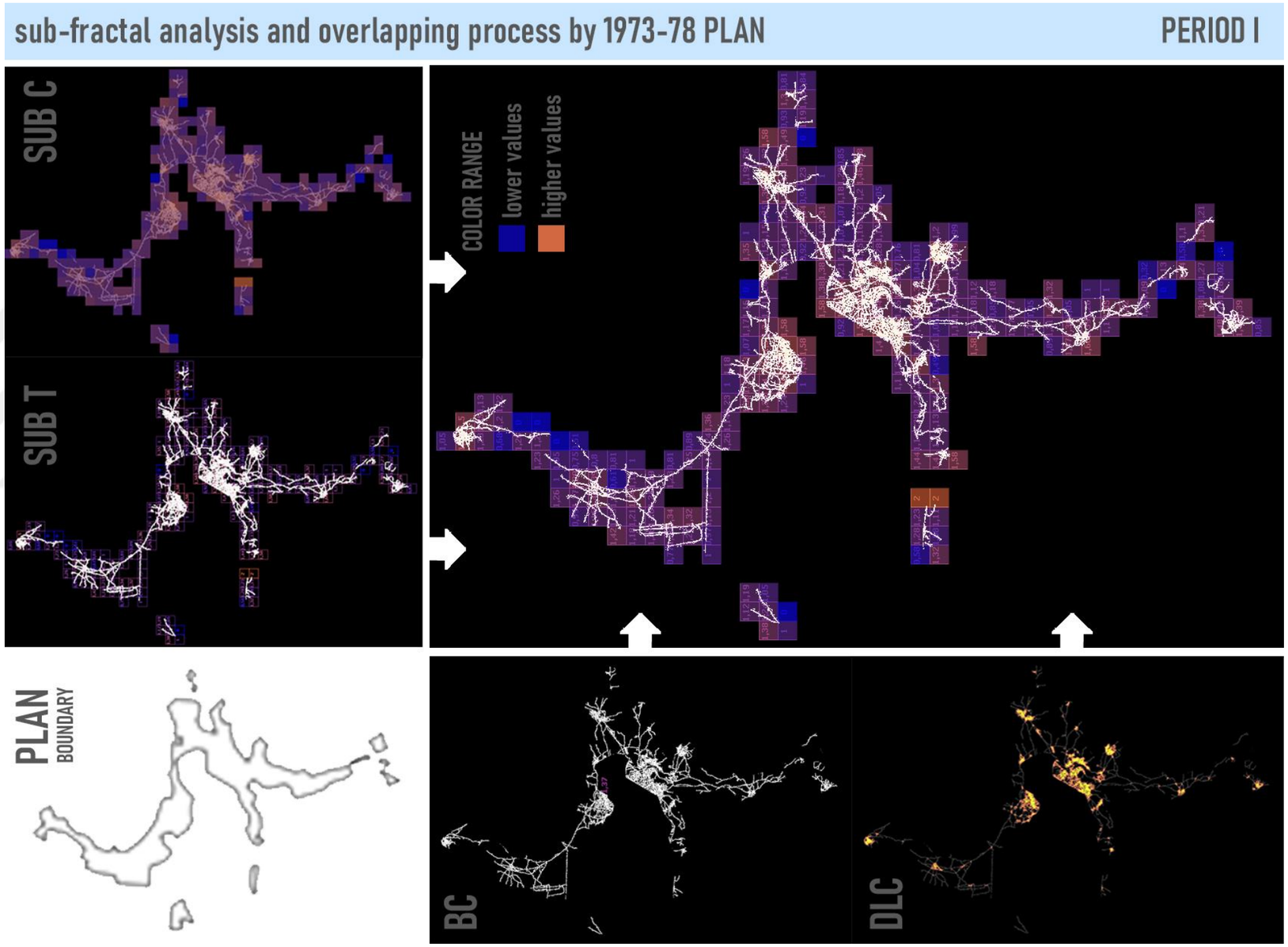


Figure 6.42 Sub-Fractal Analysis and Overlapping Process for Period I by IMM plan of Izmir, 1973-78

- ***Period II- 1970***

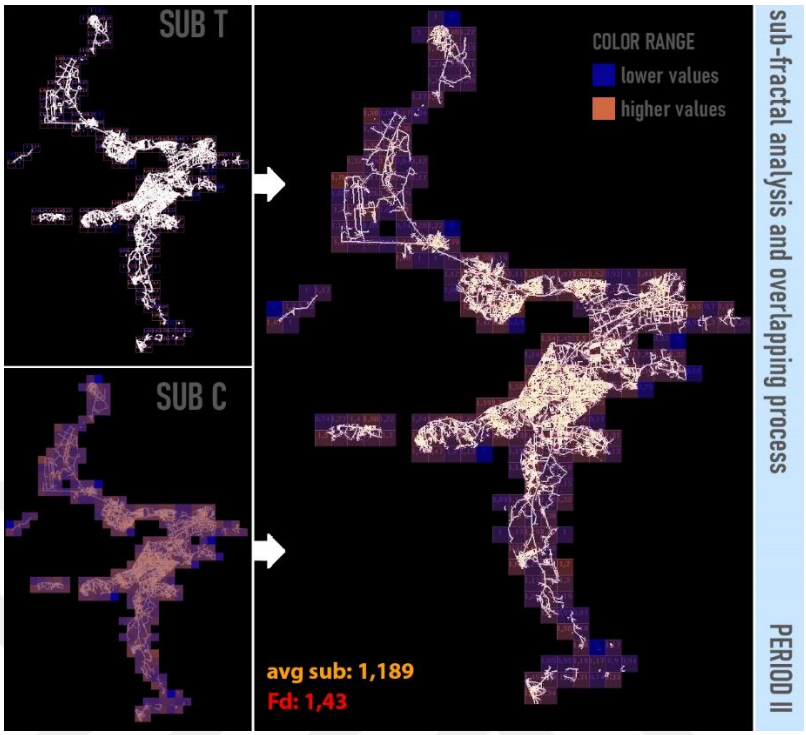


Figure 6.43 Sub-Fractal Analysis for Period II by IMM plan of Izmir, 1973-78

- ***Period III- 2000***

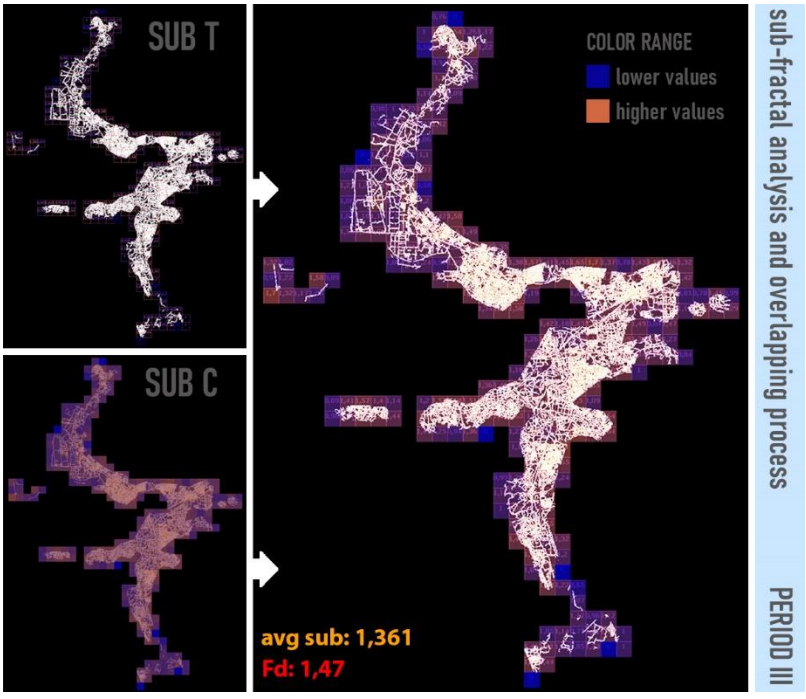


Figure 6.44 Sub-Fractal Analysis for Period III by IMM plan of Izmir, 1973-78

- ***Period IV- 2020***

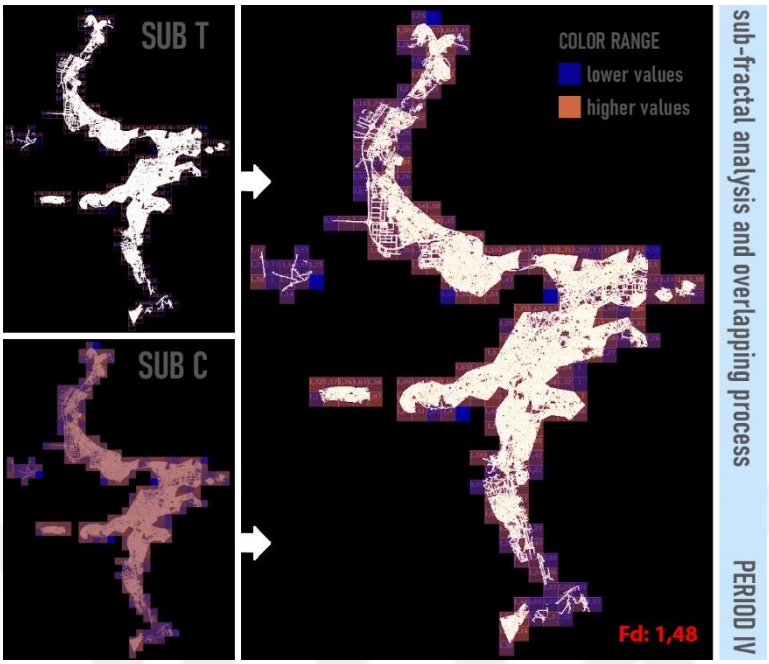


Figure 6.45 Sub-Fractal Analysis for Period IV by IMM plan of Izmir, 1973-78

6.1.3.3 For the IMM Plan 1989

- ***Period I- 1950***

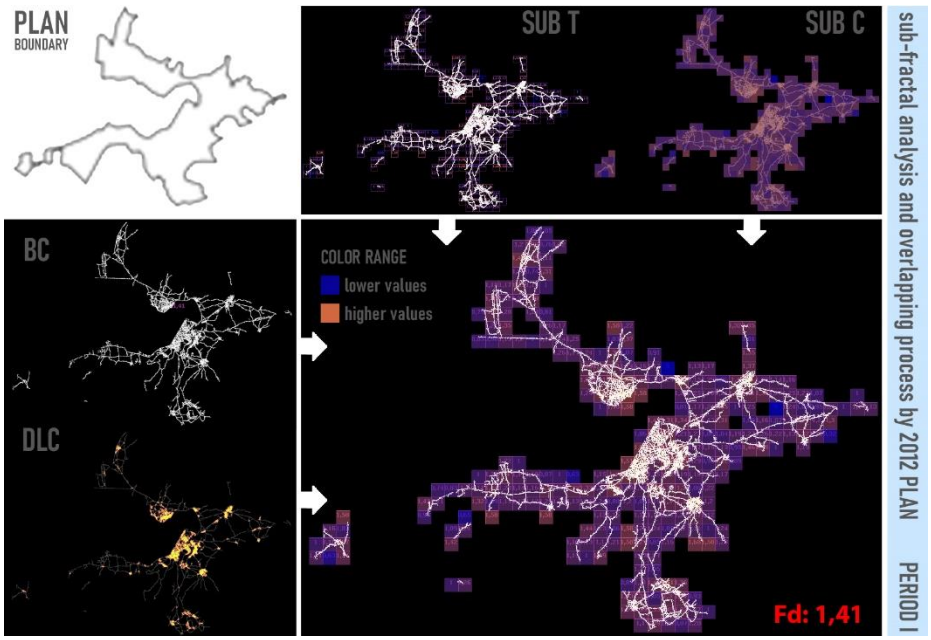


Figure 6.46 Sub-Fractal Analysis for Period I by IMM plan of Izmir, 1989

- ***Period II- 1970***

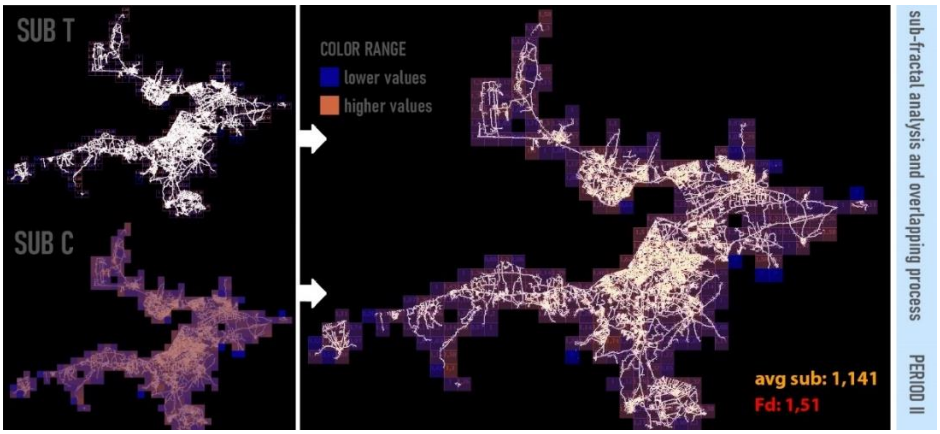


Figure 6.47 Sub-Fractal Analysis for Period II by IMM plan of Izmir, 1989

- ***Period III- 2000***

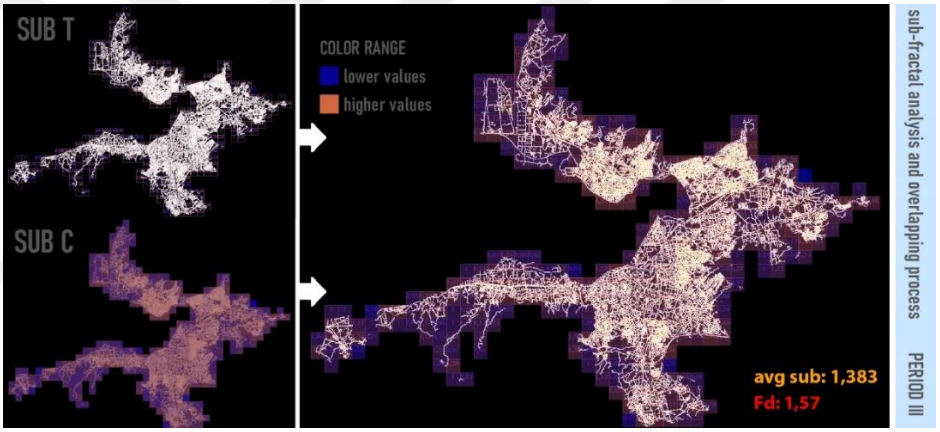


Figure 6.48 Sub-Fractal Analysis for Period III by IMM plan of Izmir, 1989

- ***Period IV- 2020***

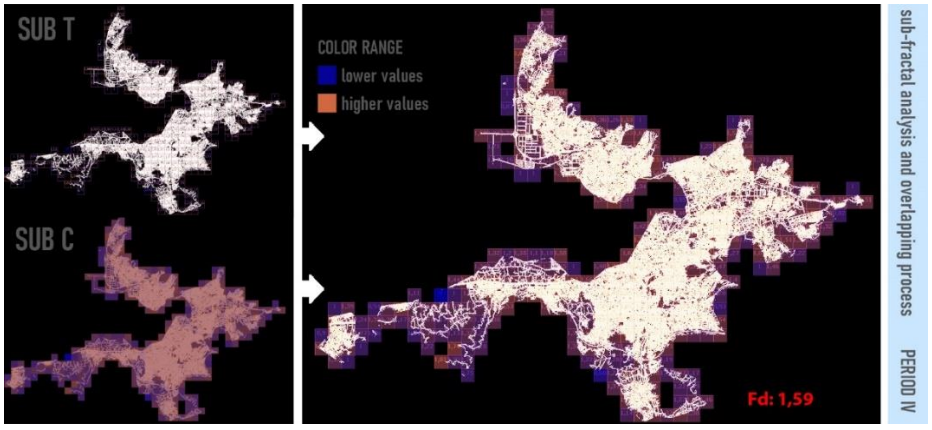


Figure 6.49 Sub-Fractal Analysis for Period IV by IMM plan of Izmir, 1989

6.1.3.4 For the IMM Plan 2012

The initial and post-plan status of the IMM 2012 plan is defined as 2000 and 2020 network maps due to the preparation date of the plan. Since the borders of this plan represent the largest area, it has been divided into regions in the analyzes following this section.

- ***Period I- 1950***

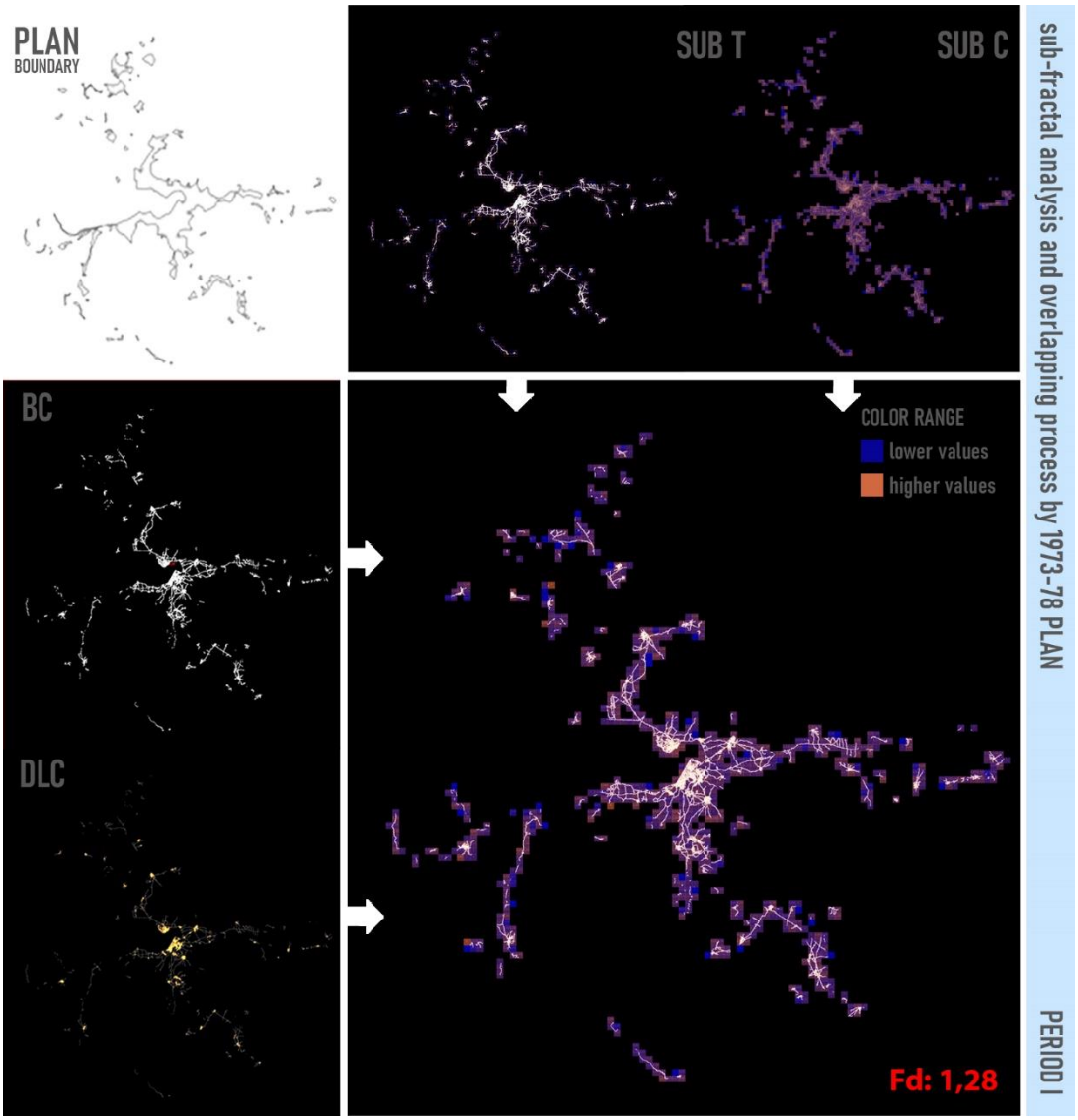


Figure 6.50 Sub-Fractal Analysis for Period I by IMM plan of Izmir, 2012

- ***Period II- 1970***

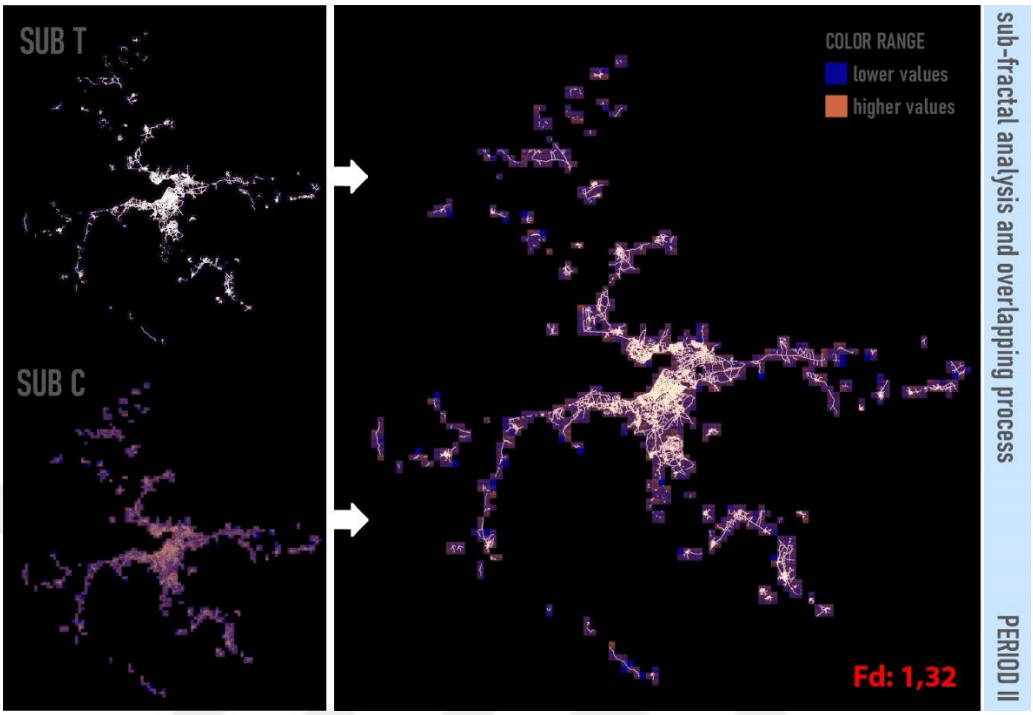


Figure 6.51 Sub-Fractal Analysis for Period II by IMM plan of Izmir, 2012

- ***Period III- 2000***

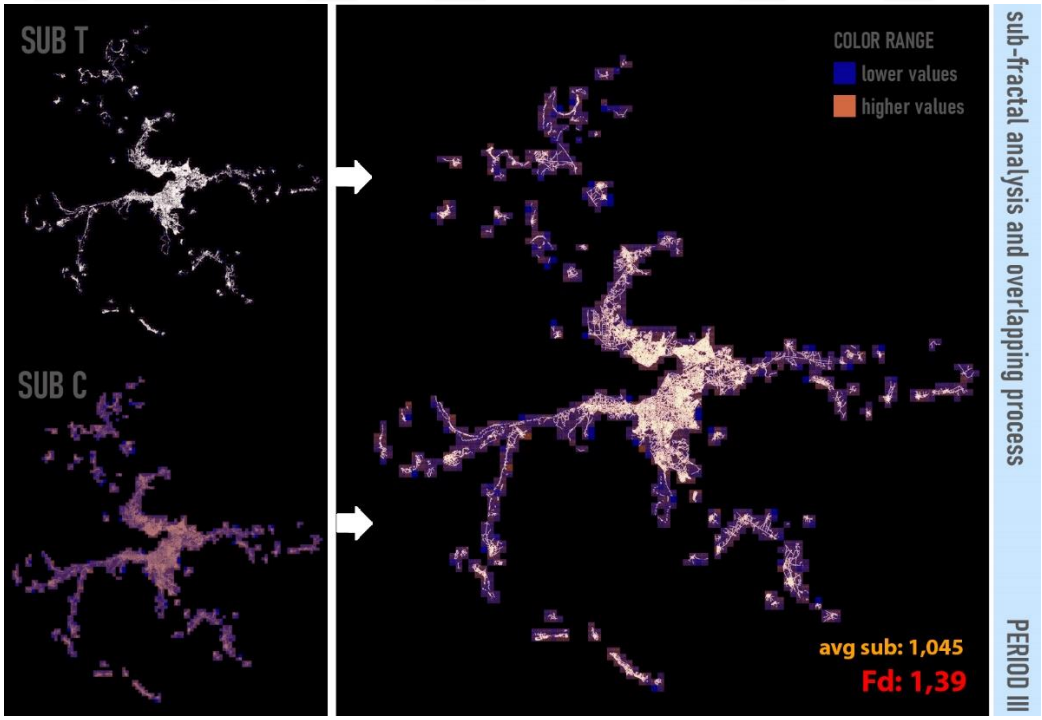


Figure 6.52 Sub-Fractal Analysis for Period III by IMM plan of Izmir in 2012

- ***Period IV- 2020***

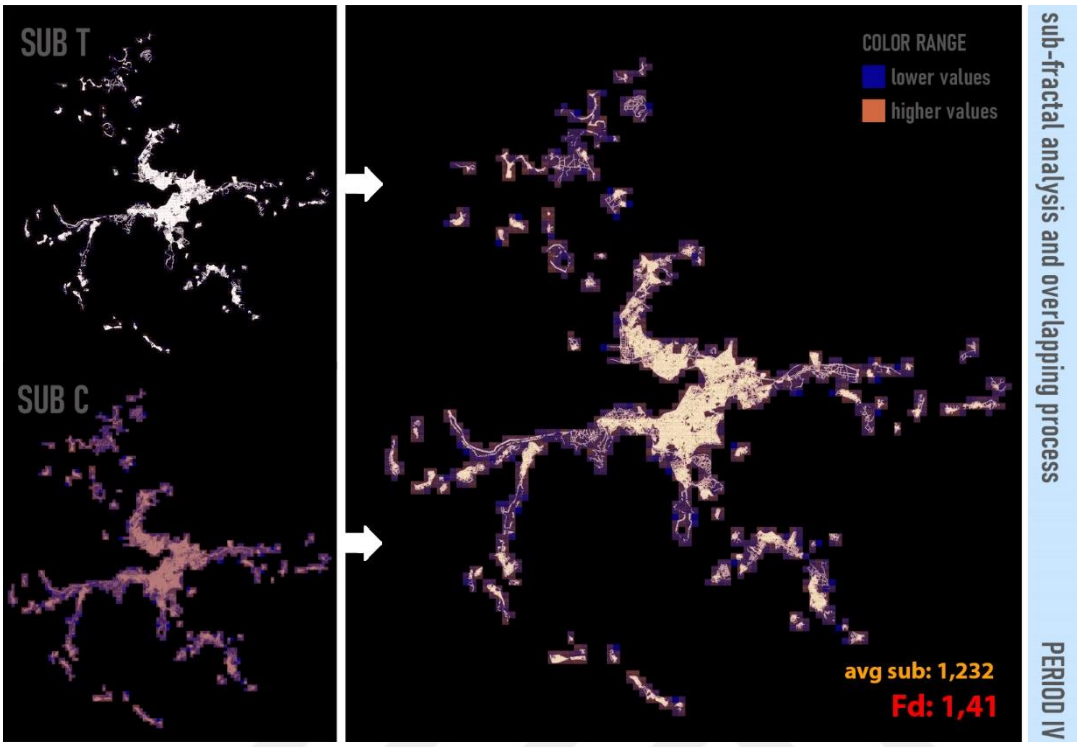


Figure 6.53 Sub-Fractal Analysis for Period IV by IMM plan of Izmir, 2012

- ***Comparison of the Plans' Initial Conditions and the Post-Plan Status***

Kemal Aru Plan, 1955 (between Period I and Period II)

The results of the study indicate that the sub-fractal dimensions of urban areas have varied over time, with different plans and areas exhibiting different levels of complexity. In particular, the comparison of Kemal Aru Plan period I and period II shows that there has been a significant increase in sub-fractal dimension, indicating a higher degree of complexity and development in the urban area. The average sub-fractal dimension for the period I of the Kemal Aru Plan was 1.188, while the average sub-fractal dimension for period II was 1.341.

The sub-fractal analysis is an important tool in urban planning and complexity frameworks, as it allows for the identification and measurement of patterns and structures within a city. By analyzing sub-parts of the city, planners can gain a deeper

understanding of the spatial and functional relationships between different areas and develop more effective strategies for managing and improving urban environments.

In the case of the Kemal Aru Plan, the increase in sub-fractal dimension between period I and period II suggest that there has been significant development and growth in the urban area. *This may be due to range of reasons including the top-down decisions like planning decisions or public investements and the emergence dynamics as bottom-up processes like micro-decisions of inhabitants, segregation and slum development.*

Overall, the results of the study highlight the importance of sub-fractal analysis in urban planning and complexity frameworks and demonstrate how this approach can be used to gain insights into the evolution and development of urban areas over time.

The IMM 1973-78 Plan (between Period II and Period II)

The study's sub-fractal dimension results reveal interesting findings about the development of urban areas over time. The IMM 1973-78 Plan's period II and III comparison shows a significant increase in sub-fractal dimension from an average of 1.189 to 1.361, indicating increased complexity and development in the urban area. The sub-fractal analysis is a valuable tool in urban planning and complexity frameworks because it allows for identifying and measuring patterns and structures within a city. The increase in sub-fractal dimension between periods II and III suggests significant growth and development, potentially due to factors such as population increase, land use changes, or new planning policies. This study emphasizes the importance of continued research and analysis in developing effective planning strategies for urban areas.

The IMM 1989 Plan (between Period II and Period III)

The sub-fractal dimension analysis is a valuable approach in studying the urban development process, as it offers insights into the micro-systems or fast systems of the city that cannot be observed in the macro-scale analysis. By comparing the sub-fractal dimension results for the IMM 1989 Plan period III (initial condition) and

period IV (post-plan status), we observe an increase in the average value from 1.141 to 1.383. This suggests a shift towards a more complex and diverse urban pattern, which indicates the success of the urban development strategy adopted in the plan.

The box-counting values for the same periods show a more significant increase from 1.51 to 1.57, which implies a substantial increase in the overall complexity and diversity of the urban system. The difference between the sub-fractal and box-counting values can be attributed to the fact that the box-counting method measures the slow or macro-scale systems, which are influenced by the interaction between different sub-parts and the overall context of the city.

The difference between the sub-fractal and box-counting values is related to the concept of turbulence in complexity theory. Turbulence refers to the dynamic and unpredictable behavior of complex systems. The sub-fractal analysis captures the local dynamics and fluctuations of the urban system, while the box-counting analysis reflects the overall coherence and organization of the system. By integrating this analysis with other methods, such as box-counting, planners and policymakers can gain a more comprehensive and nuanced understanding of the urban system and develop effective strategies to enhance its sustainability and livability.

The IMM 2012 Plan (between Period III and Period IV)

The sub-fractal dimension analysis provides valuable insights into the complex dynamics of urban development by examining the spatial patterns and distribution of sub-parts of the city. It helps to reveal the micro-systems or fast systems that are not observable in macro-scale analysis and to understand the relationship between the local and global properties of the urban system.

In the case of the IMM 2012 Plan, the comparison between the sub-fractal dimension results for period III (initial condition) and period IV (post-plan status) shows an increase in the average value from 1.045 to 1.232, which suggests a shift towards a more complex and diverse urban pattern. This indicates that the urban development

strategy adopted in the plan has been successful in promoting more diverse and interconnected sub-parts of the city.

However, the box-counting values for the same periods show a slight increase from 1.39 to 1.41, which implies an increase in the overall complexity and diversity of the urban system. This can be explained by the fact that the box-counting method measures the slow or macro-scale systems, which are influenced by the interaction between different sub-parts and the overall context of the city. Thus, the sub-fractal and box-counting analyses provide complementary perspectives on the urban development process and highlight the importance of considering both micro and macro-level factors in planning and managing the urban system.

The difference between the sub-fractal and box-counting values can be related to the concept of turbulence in complexity theory, which refers to complex systems' dynamic and unpredictable behavior. Turbulence can arise from the interaction between different scales of organization and the emergence of new patterns and structures that the properties of individual components cannot explain. Thus, the sub-fractal analysis captures the local dynamics and fluctuations of the urban system, while the box-counting analysis reflects the overall coherence and organization of the system.

In conclusion, the sub-fractal dimension analysis is a helpful tool for understanding urban development's complex and dynamic nature and identifying the city's sub-parts that require attention and intervention. By combining this analysis with other methods, such as box-counting, urban planners and policymakers can gain a more comprehensive and nuanced understanding of the urban system and develop effective strategies to improve its sustainability and livability.

- *The following four pages consist of summary algorithms showing the general logic of the analysis, the working process, and the results. It explains conceptually how the data is used and how the analysis results are reached. And additionally shows the summary algorithm of the difference analysis.*

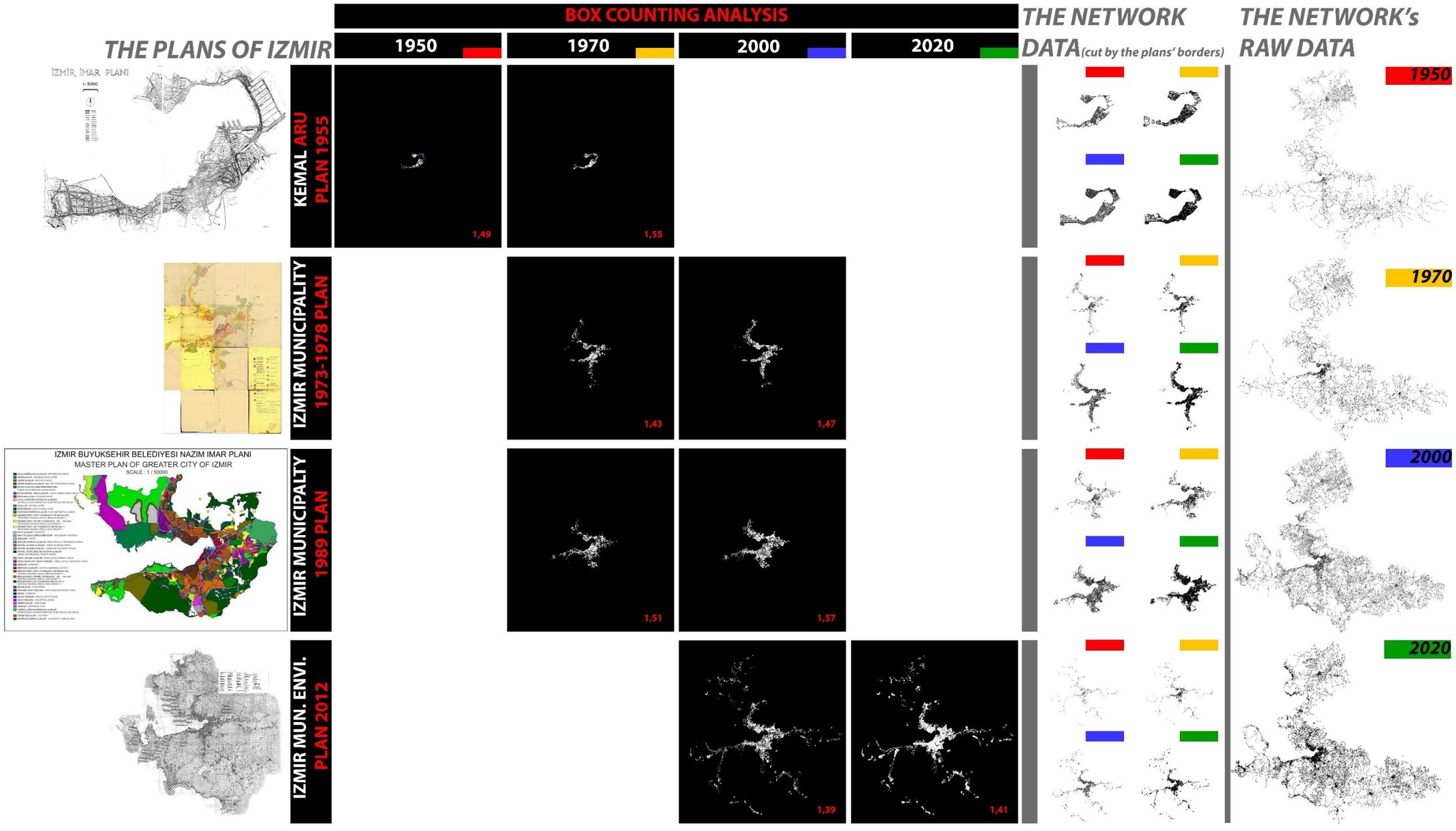


Figure 6.54 Matrix and Algorithm Showing Box-Counting Analysis Results and Analysis Logic

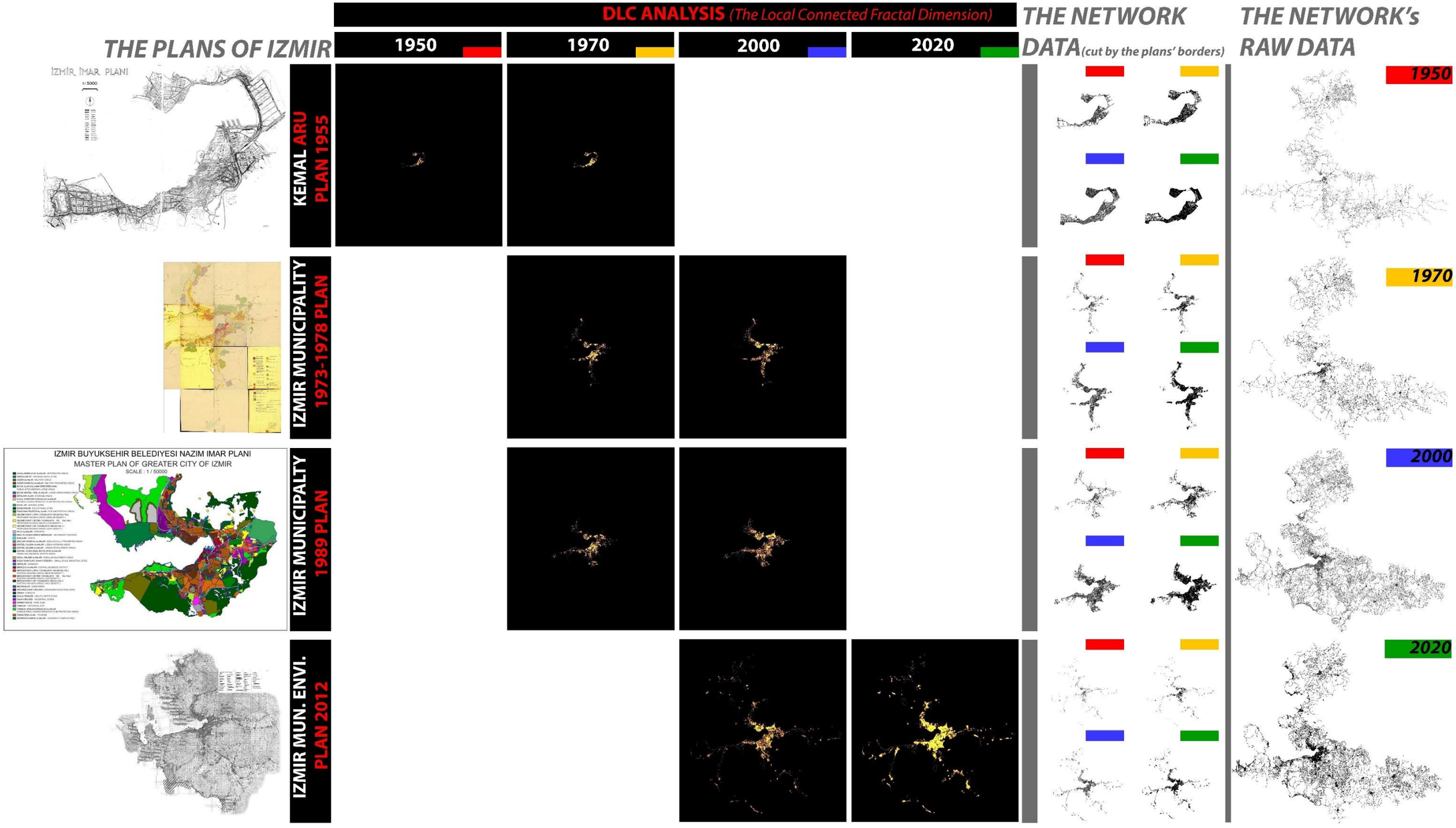


Figure 6.55 Matrix and Algorithm Showing the DLC Analysis Results and Analysis Logic

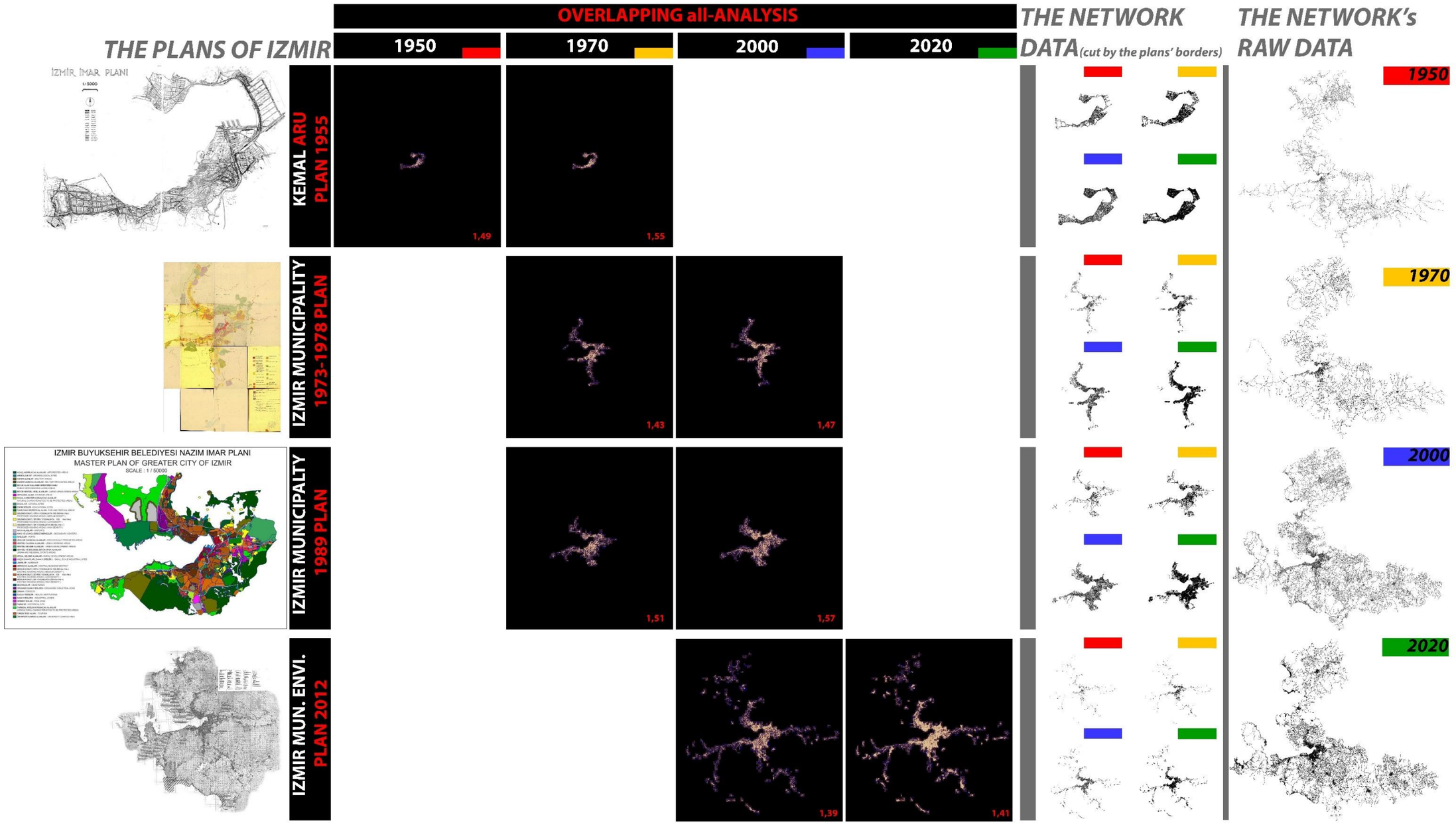


Figure 6.56 Matrix and Algorithm Showing Sub-Fractal Analysis Results and Overlapping All Results together, and Analysis Logic

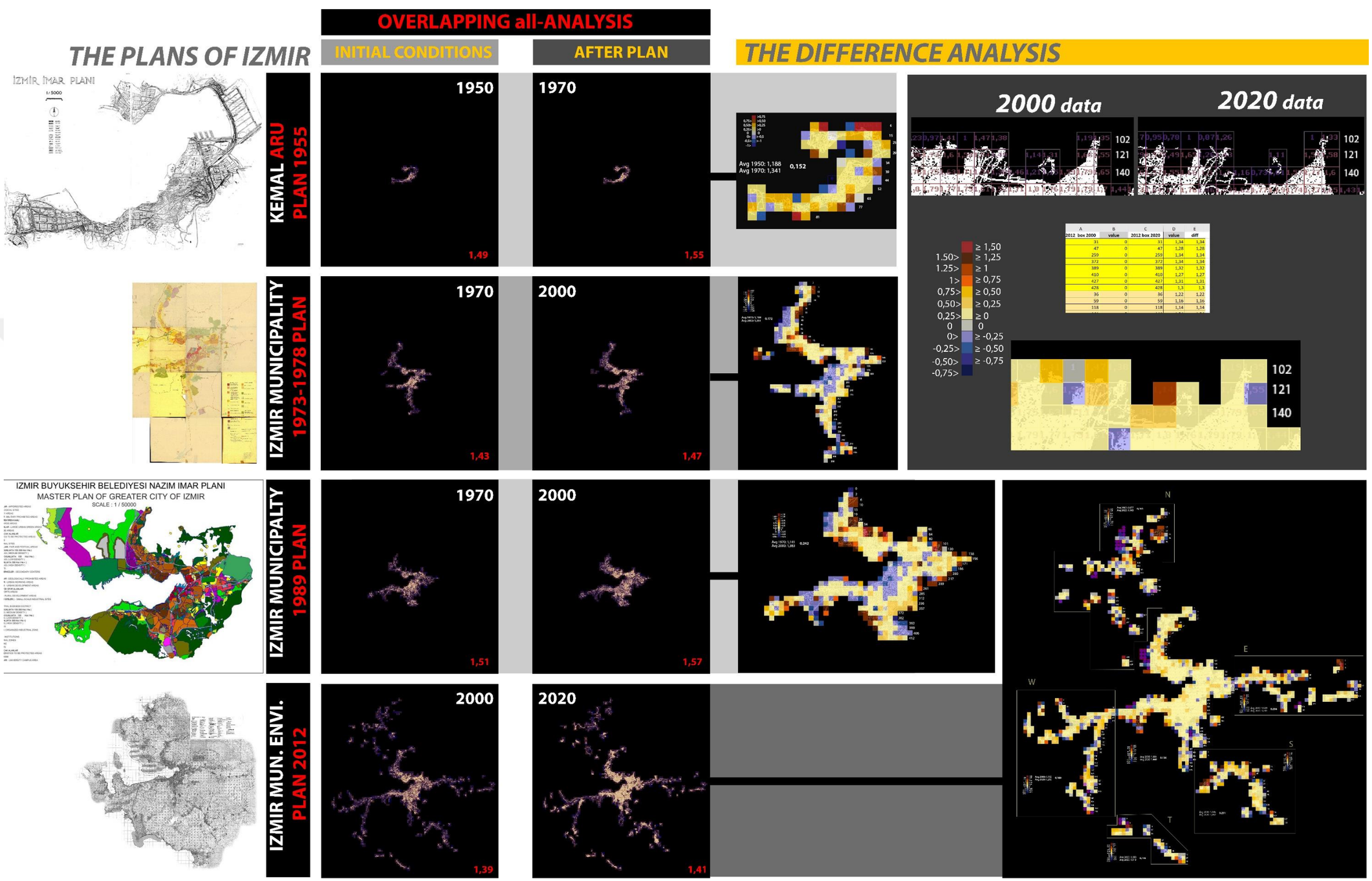


Figure 6.57 Matrix and Algorithm Showing Sub-Fractal Analysis Results and Overlapping All Results together, and Difference Analysis Logic

6.2 Difference Analysis for the Results of Sub-Fractal Analysis

The study of urban systems is a complex and multi-dimensional endeavor that involves the analysis of a wide range of factors, including historical, cultural, political, economic, and technological forces. To better understand the patterns and dynamics of urban systems, researchers and practitioners have turned to fractal analysis techniques, which can help identify spatial patterns and relationships within and between different parts of a city. One such technique is serial sub-fractal analysis, which involves partitioning a city or urban area into a series of boxes at different scales and calculating the fractal dimension for each box. The fractal dimension measures the complexity of the pattern within each box, with higher values indicating greater complexity.

The use of serial sub-fractal analysis in urban studies has enabled researchers to identify changes in the spatial complexity of urban systems over time. For example, by comparing the sub-fractal values of different time periods, it is possible to identify an increase in the heterogeneity of the urban structure, as reflected in the emergence of new patterns or features. However, interpreting the meaning of changes in sub-fractal values can be challenging without additional analysis. Difference analysis is one such technique that enables researchers to identify specific changes in the spatial patterns of urban systems associated with different urban plans or time periods.

Difference analysis involves subtracting the sub-fractal values of one period from another, resulting in positive or negative values that indicate an increase or decrease in the spatial complexity of the urban system over time. Positive values suggest the emergence of new patterns or features, while negative values suggest a trend toward homogeneity or simplification of the urban system. The goal of difference analysis is to provide insight into the impact of planning decisions and emergent urban activities on the spatial complexity of urban systems. By comparing the sub-fractal results of different urban plans or time periods, researchers can identify specific changes in the spatial patterns of urban systems associated with each plan.

In conclusion, using fractal analysis techniques, including serial sub-fractal analysis and difference analysis, has enabled researchers and practitioners better to understand the patterns and dynamics of urban systems. By identifying changes in the spatial complexity of urban systems associated with different urban plans or time periods, researchers can better inform future planning and design decisions and gain a deeper understanding of the relationship between urban form and function.

6.2.1 For the İzmir Plan of Kemal Aru 1955

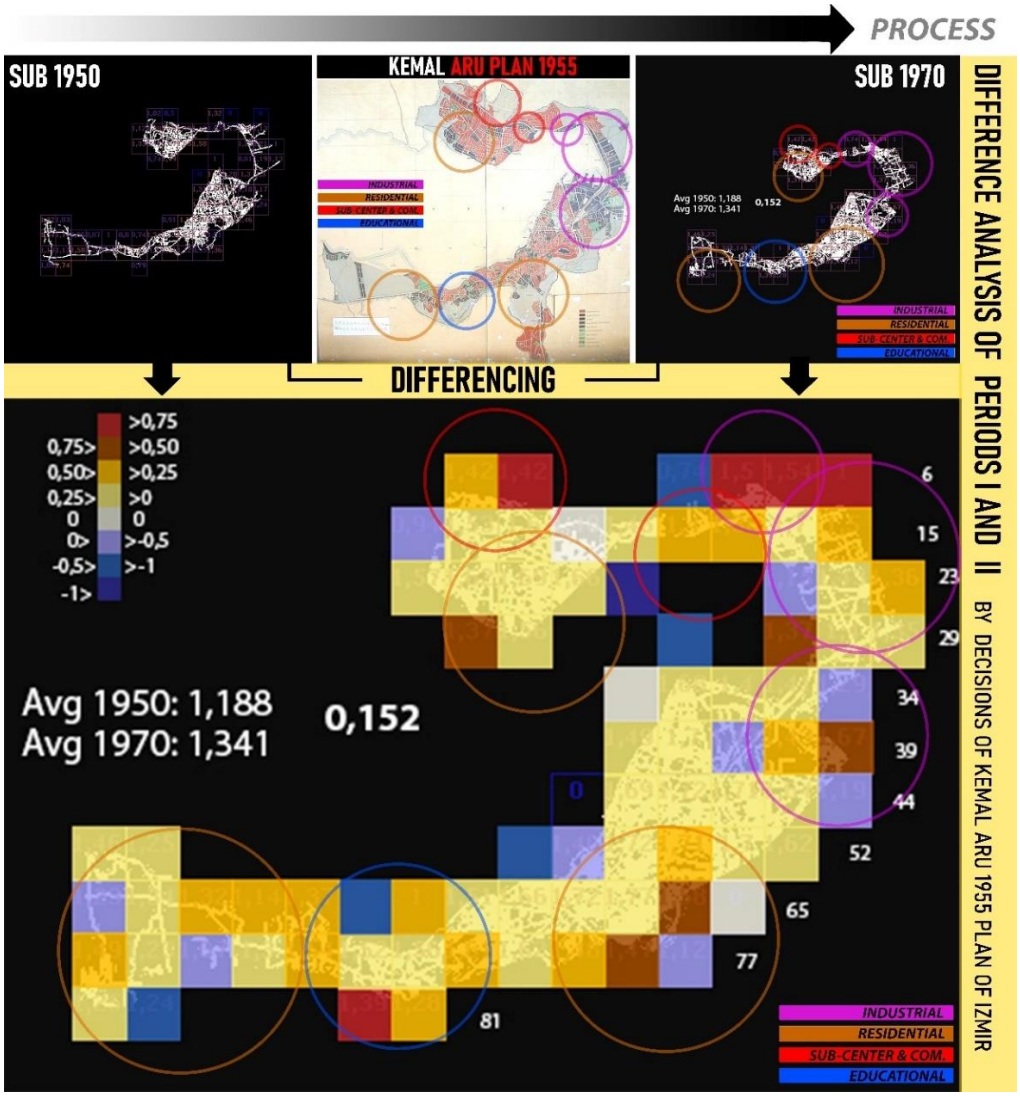


Figure 6.58 Difference Analysis of Periods I and II by decisions of Kemal Aru 1955 Plan of Izmir

As seen in the figure above, 1950 initial condition sub-fractal values and 1970 post-plan condition sub-fractal values, and Kemal Aru 1955 Plan of Izmir were given together. A new difference map created by the difference analysis method was created. *The major planning decisions for this analysis process are evaluated under four headings. These are industrial, residential, commercial, or sub-center, and broad-use education or health land-use decisions.*

In line with these major land-use decisions, the remarkable boxes with high variations in complexity values are zoned with the colors of the relevant plan decisions.

Adaptive Capacity Range: Identifying Negative or Positive Changes

> ***Adaptive capacity*** *in a complex system refers to the ability of that system to adjust and respond to changing conditions or disturbances. The system can reorganize, learn, and evolve in the face of unexpected changes or challenges.*
>
> *In complex systems, adaptive capacity is critical to maintaining system stability and resilience. It involves the ability of the system to absorb and adapt to changes without losing functionality or becoming destabilized.*
>
> *Adaptive capacity can be influenced by various factors, such as the diversity and redundancy of the system's components, the system's ability to learn and self-organize, and the availability of resources to support adaptation. A system with high adaptive capacity can withstand and recover from disruptions and maintain its essential functions. In contrast, a system with low adaptive capacity may be more vulnerable to collapse or failure (Berkes & Folke, 1998).*

The concept of the adaptive capacity range of an urban system has emerged as a crucial component of urban resilience theory. The adaptive capacity of a city refers to its ability to adapt to changes and disturbances while maintaining its functionality and resilience. The adaptive capacity range, in particular, is an essential aspect of the

urban system's adaptive capacity, as it identifies the range of values for which a city system is considered to be adaptive.

Sub-fractal analysis, as a method for analyzing the spatial patterns of urban systems, has proven to be a valuable tool for understanding the adaptive capacity range of cities. The analysis involves comparing the fractal dimensions of network maps of urban systems before and after planning decisions or interventions. By identifying changes in the fractal dimensions and box values, the sub-fractal analysis provides insights into the specific effects of planning decisions on the complexity and adaptability of urban systems.

> *After the Kemal Aru 1955 Plan, a total of 81 boxes were obtained in the difference analysis prepared by using sub-fractal analysis of 1950 and 1970 network maps, and the value of 37 of these boxes is calculated between 0.25 and 0.*

In the case of Izmir city, the adaptive capacity range has been found to be $0.25 < n < 0$, indicating that the city has a highly adaptive structure. This range is specific to Izmir and can vary among different urban systems. The analysis of the effects of the Kemal Aru Plan, a significant urban planning intervention in Izmir, on the adaptive capacity range of the city is particularly relevant in this context.

The Kemal Aru Plan, implemented in 1955, aimed to modernize and transform the city of Izmir. The plan involved the construction of new road networks, buildings, and public spaces, as well as the demolition of traditional buildings. The plan's implementation had significant impacts on the spatial patterns of the city, which can be analyzed using sub-fractal analysis to identify the specific effects of the plan on the city's adaptive capacity range.

The sub-fractal analysis of the Kemal Aru Plan reveals that the plan had a significant impact on the complexity and adaptability of the city. The construction of new road networks and public spaces, for example, may have increased the connectivity and accessibility of the city, contributing to a higher adaptive capacity range. On the other

hand, demolishing traditional buildings may have reduced the city's historical and cultural value, potentially negatively affecting its adaptive capacity range.

In conclusion, the concept of the adaptive capacity range of an urban system is a valuable tool for understanding the complexity and adaptability of cities. The sub-fractal analysis provides a means to analyze the effects of planning decisions and interventions on the adaptive capacity range of urban systems.

This range has also been accepted as the normal variation range for the city of Izmir. In other words, if the box values obtained as a result of the difference analysis are above this number range, it means that there has been a high increase in the complexity level. If it is below the range, there is a negative change, which means a decrease in the complexity level.

The Effects of the Major Landuse Decisions

The study aims to investigate how urban planning decisions affect the complexity level of a city. Specifically, the study categorizes major land use decisions into industrial, residential, commercial/sub-central, and wide-use educational/health areas. The study uses sub-fractal analysis to measure the complexity level of the city before and after the implementation of Kemal Aru Plan in 1955 in Izmir, Turkey. The results show that the complexity level of the city has changed significantly after the plan was implemented, with the degree of change varying depending on the type of land use decision made.

The analysis indicates that industrial area decisions had the most significant impact on the complexity level of the city, with box values showing a change of $C>0.75$. This suggests that the implementation of Kemal Aru Plan led to significant changes in the industrial area of the city, likely reflecting changes in the economic structure of the city and the shift towards industrialization.

The commercial/sub-central area decisions had a moderate impact on the complexity level of the city, with box values showing a change of $0.75>C>0.50$. This suggests

that the plan led to some changes in the central business district and other commercial areas, reflecting changes in the transportation system or zoning regulations.

The residential area decisions also had a moderate impact on the complexity level of the city, with box values showing a change of 0.50>C>0.25. This suggests that the plan led to changes in the city's residential areas, perhaps reflecting changes in population density or housing policies.

Finally, the wide-use educational/health area decisions also had a moderate impact on the complexity level of the city, with box values showing a change of 0.50>C>0.25. This suggests that the plan led to changes in the city's locations and distribution of educational and health facilities, reflecting changes in social and public services policies.

Overall, the study provides valuable insights into the relationship between urban planning decisions and the complexity level of a city. The results suggest that different types of land use decisions can have varying impacts on the complexity level of the city, with some decisions having a more significant impact than others.

Total Change of the City System

A total of 81 boxes were obtained in the results of the sub-fractal analysis prepared using the 1950 network map within the boundaries of the Kemal Aru 1955 Plan, and the average of these box values is approximately 1.188. Again, within the boundaries of the same plan, a total of 81 boxes were obtained in the results of the sub-fractal analysis prepared using the 1970 network map, and the average of these box values is approximately 1.341. The result obtained by subtracting the next and previous mean values from each other shows the change in the mean values. The difference between them is approximately 0.152. Therefore, the change in the mean box values between the sub-fractal analysis prepared using the 1950 network map and the 1970 network map within the boundaries of the Kemal Aru 1955 Plan is approximately 12.89%. Moreover, there has been a total change of 12.89% in the complexity level of the city system after this plan.

Development Direction

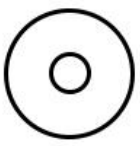
The study examined the changes in the city structure of İzmir before and after the implementation of the Kemal Aru 1955 Plan. The analysis was conducted using the 1950 and 1970 network maps, and the sub-fractal analysis was performed to determine the complexity level of the city. The box values obtained from the analysis were then compared, and the difference values were calculated to determine the changes in the city structure.

The results of the analysis showed that the city of İzmir experienced peripheral development during the specified period. The high fractal values observed in the city periphery suggest that new development areas were mainly located in this area. The change values of the boxes in the periphery were found to be high, indicating that the peripheral areas of the city underwent significant changes during the specified period. Overall, the results of this study provide insights into the changes in the city structure of İzmir and highlight the importance of considering the impact of urban planning on the development of peripheral areas.

Findings

Table 3 Findings of the Difference Analysis for Kemal Aru Plan 1955

SUMMARY OF DIFFERENCE ANALYSIS RESULTS FOR KEMAL ARU PLAN 1955

LAND-USE DECISION	CHANGE (C) by decision	TOTAL CHANGE of the system	ADAPTIVE CAPACITY RANGE (a)	DEVELOPMENT direction	
INDUSTRIAL	C > 0,75	%12,79 positive	0,25 > a > 0	 PERIPHERIAL	PERIODS I-II
RESIDENTIAL	0,50 > C > 0,25				
SUB-CENTRAL& COMMERCIAL	0,75 > C > 0,50				
EDUCATION & HEALTH	0,50 > C > 0,25				

6.2.2 For the IMM Plan 1973-1978

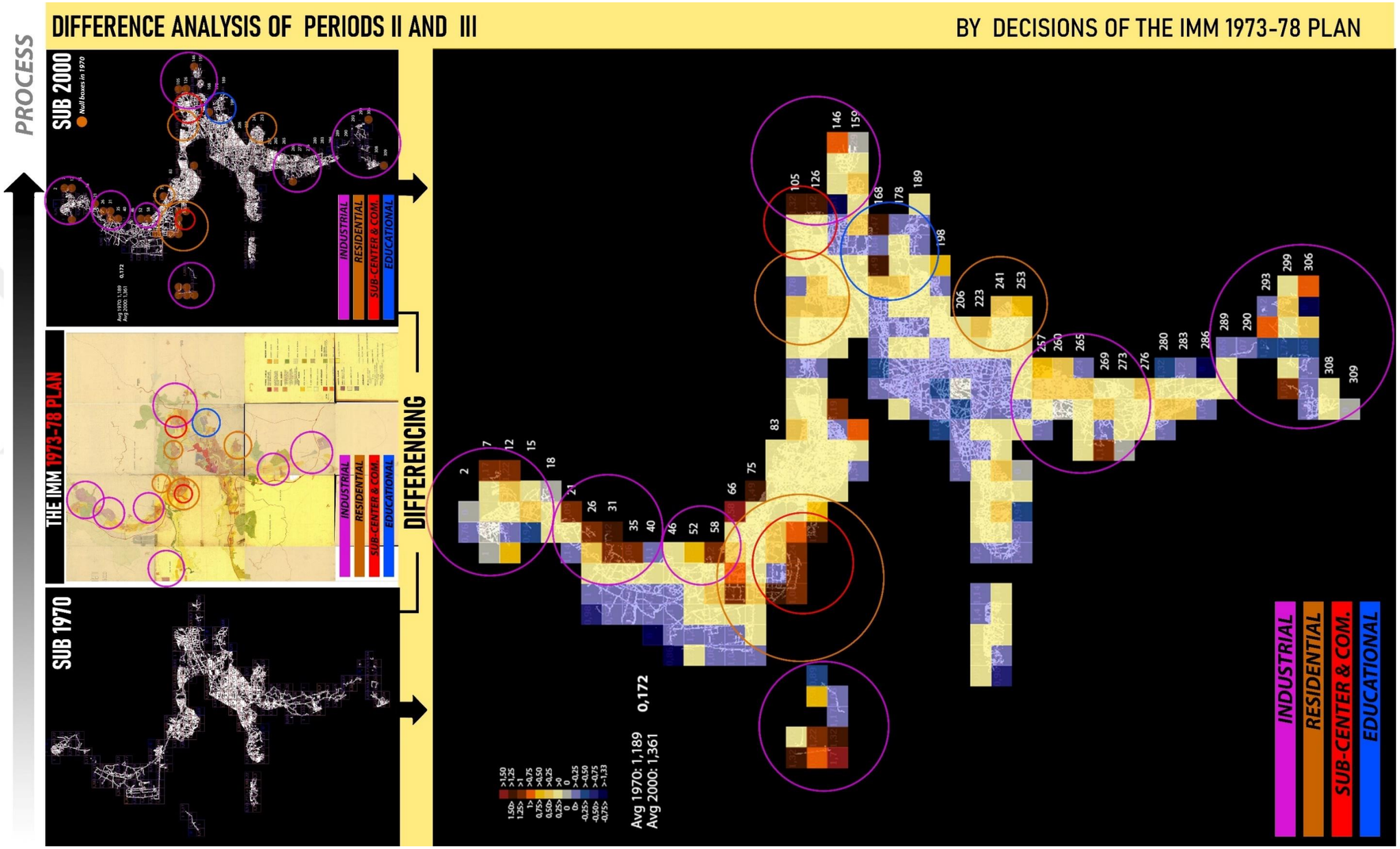


Figure 6.59 Difference Analysis of Periods II and III by decisions of the IMM 1973-78 Plan

Adaptive Capacity Range

The present study aimed to assess the impact of the Izmir Metropolitan Municipality's (IMM) 1973-78 Plan decisions on the complexity of the city of Izmir. To accomplish this, a difference analysis was performed by subtracting the box values of the sub-fractal analyses using 1970 and 2000 network maps. The resulting 309 box values were then used to evaluate city structure changes over time.

The study's findings revealed that 127 of the 309 boxes fell within the range of 0.25>C>0, commonly referred to as the adaptive capacity range. This range suggests that the city could adapt to the changes introduced by the IMM 1973-78 Plan decisions and maintain its level of complexity. The concept of adaptive capacity refers to the ability of a system to adjust and respond effectively to changes in its environment while maintaining its essential functions and structures.

The results of the study suggest that the city of Izmir was able to maintain its complexity and adaptability in response to the changes introduced by the IMM 1973-78 Plan decisions. The study's use of sub-fractal analysis and network maps allowed for a detailed assessment of the city's structure and changes over time.

The Effects of the Major Landuse Decisions

The research uses sub-fractal analysis to measure changes in complexity before and after the implementation of the IMM 1973-78 Plan, with the difference analysis resulting in values represented by "C" for each decision area.

The results show that the IMM 1973-78 Plan significantly impacted the city's complexity level. The industrial area decisions had the highest impact, with values of C>1, indicating that these decisions resulted in the most significant changes in complexity. This is likely due to the large-scale industrial developments during this time, resulting in new infrastructure and changes to the built environment.

The commercial or sub-central area decisions had values between 1.50>C>1, indicating a moderately high impact on complexity. This could be attributed to the development of new commercial centers, which would have introduced new

buildings and transportation infrastructure, changing the character of the surrounding areas.

The residential area decisions had values between 0.75>C>0.25, indicating a moderate impact on complexity. This may be due to changes in the density of residential areas or new housing development, leading to changes in the local urban fabric.

Finally, the wide-use educational or health area decisions had values between 1.25>C>0.75, indicating a moderately high impact on complexity. This could be attributed to the development of new institutions, such as hospitals or universities, which may have introduced new buildings and services, changing the character of the surrounding areas.

Total Change of the City System

In the sub-fractal analysis, results prepared using the 1970 network map within the boundaries of the IMM 1973-78 Plan, a total of 309 boxes were obtained, and the average of these box values is approximately 1,189. In the sub-fractal analysis results prepared by using 2000 network maps within the same plan boundaries, a total of 309 boxes were obtained, and the average of these box values is approximately 1.361. The result obtained by subtracting the next and previous mean values from each other shows the change in the mean values. The difference between them is approximately 0.172. Therefore, the change in the mean box values between the sub-fractal analysis prepared using the 1970 network map and the 2000 network map within the boundaries of the IMM 1973-78 Plan is approximately 14.46%. Therefore, there has been a total of 14.46% change in the complexity level of the city system after this plan.

Development Direction

The present study aims to evaluate the effects of the Izmir Metropolitan Municipality (IMM) 1973-78 Plan on the structure of the city of Izmir, before and after its implementation. Sub-fractal analysis was performed using the 1970 and 2000

network maps to accomplish this. The analysis involved obtaining box values from the maps, subtracting them from each other, and then calculating the difference values. The results showed a high fractal value in the north-south axis direction, indicating a corridor development trend in this direction during the period of interest. The analysis further revealed that new development areas were mainly foreseen on the north-south axis, and new box formations were observed in this region, with the change values of these boxes being relatively high. Specifically, the sub-fractal analysis using the 2000 network maps within the boundaries of the IMM 1973-78 Plan indicated the addition of 31 new boxes, with 26 of them being located on the north-south axis. This finding supports the view that the plan advocated for corridor development in the north-south direction and that the proposed development decisions within the framework of these analyzes were largely implemented. Overall, the study provides insights into the effects of urban planning and development policies on the spatial structure of cities, with implications for future planning and policy decisions.

Findings

Table 4 Findings of the Difference Analysis for the IMM 1973-78 Plan

SUMMARY OF DIFFERENCE ANALYSIS RESULTS FOR IMM 1973-78 PLAN

LAND-USE DECISION	CHANGE (C) by decision	TOTAL CHANGE of the system	ADAPTIVE CAPACITY RANGE (a)	DEVELOPMENT direction
INDUSTRIAL	C > 1	%14,46 positive	0,25 > a > 0	THE AXIS OF NORTH-SOUTH
RESIDENTIAL	0,75 > C > 0,25			
SUB-CENTRAL& COMMERCIAL	1,50 > C > 1			
EDUCATION & HEALTH	1,25 > C > 0,75			

PERIODS II-III

6.2.3 For the IMM Plan 1989

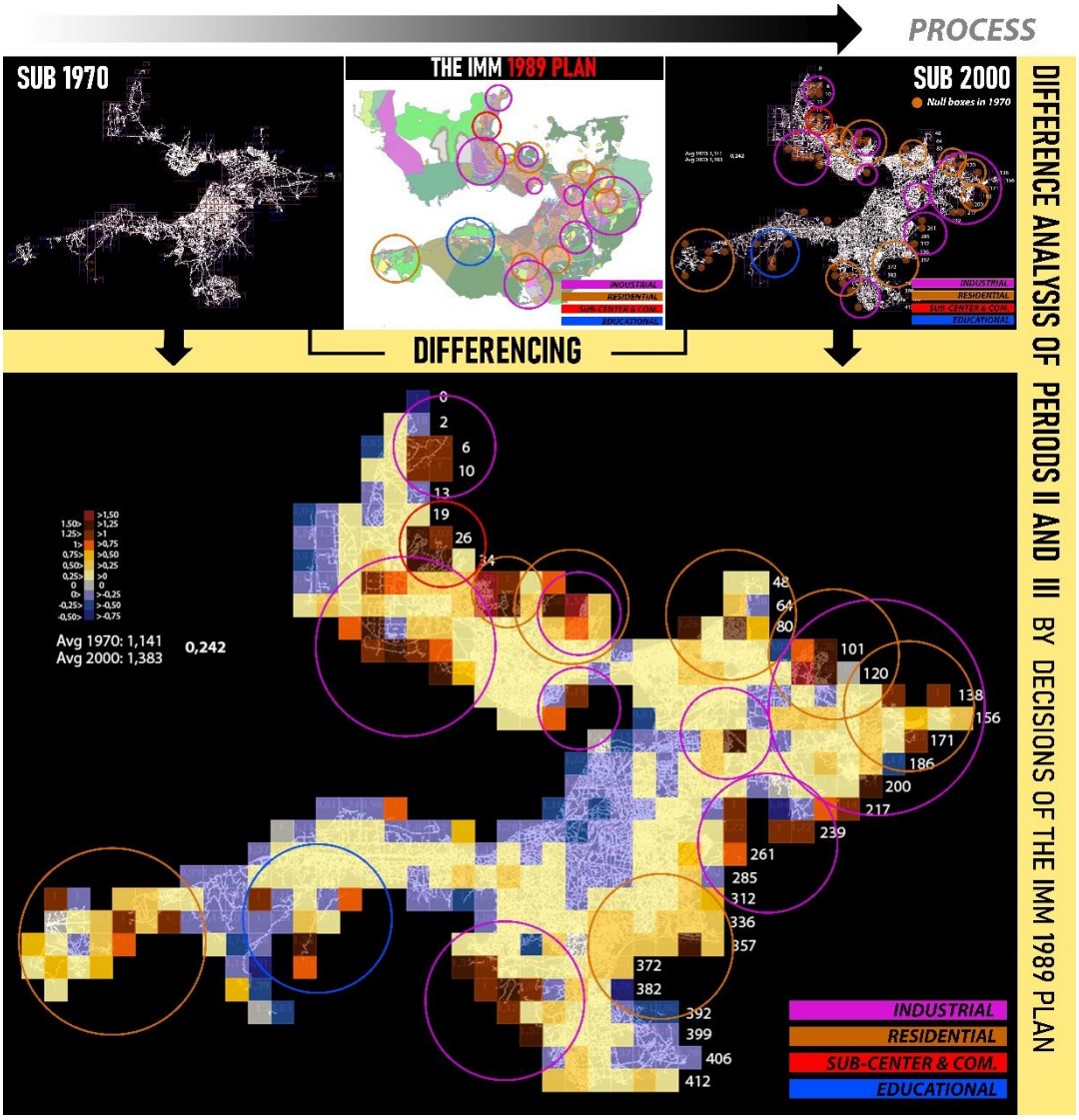


Figure 6.60 Difference Analysis of Periods II and III by Decisions of the IMM 1989 Plan

Adaptive Capacity Range

The difference analysis study, which aimed to observe the effect of the IMM 1989 Plan decisions on the complexity of the city, has resulted in a total of 413 box values. Among these, 166 boxes had values in the 0.25>C>0, which is the adaptive capacity range of the complex city structure of İzmir. This finding suggests that the city has a high level of adaptability and resilience to changes in its structure.

The adaptive capacity range is desirable for complex city structures, as it indicates that the city can effectively cope with changes and maintain its complexity. This result can be attributed to the decisions made under the IMM 1989 Plan, which may have contributed to the adaptability and resilience of İzmir's urban structure.

However, it is essential to note that further research is needed to fully understand the factors that contributed to this adaptive capacity range. The study could also benefit from analyzing other indicators of urban complexity, such as land use patterns, to provide a more comprehensive understanding of İzmir's urban structure.

The Effects of the Major Landuse Decisions

The study aimed to investigate how planning decisions under the IMM 1989 Plan affected the complexity level of İzmir city. The study categorized major land use decisions into four groups: industrial area decisions, residential area decisions, commercial or sub-central area decisions, and wide-use educational or health area decisions. The difference analysis of sub-fractal analysis was performed by comparing the initial condition (1970 network map) to the post-plan condition (2000 network map) to observe the changes in box values of each decision area, which is represented by "C" values.

The study found that the IMM 1989 Plan's planning decisions significantly impacted the complexity level of İzmir city. The box values related to industrial area decisions had the highest change rate, with C values greater than 1. This finding suggests that the decisions made regarding industrial areas considerably impacted the complexity level of İzmir's urban structure.

The commercial or sub-central area decisions had the second-highest change rate, with C values ranging between 1.50 and 1. This result implies that the planning decisions regarding commercial or sub-central areas also significantly influenced the complexity level of İzmir city.

The values related to residential area decisions had C values ranging from 1 to 0.50, which indicates a moderate impact on the complexity level of the city. Finally, the

wide-use educational or health area decisions had C values ranging from 1.25 to 0.75, suggesting that these planning decisions had a moderate impact on the complexity level of İzmir's urban structure.

In the context of urban planning and complexity, the study highlights the importance of considering the impact of planning decisions on the complexity level of a city. The results of this study demonstrate that land use decisions made under the IMM 1989 Plan significantly impacted the complexity level of İzmir city.

Total Change of the City System

The study conducted a sub-fractal analysis of the IMM 1989 Plan area using network maps from 1970 and 2000 to examine the changes in the complexity level of the city system. The analysis revealed a total of 413 boxes in both the 1970 and 2000 network maps. The average box value in the 1970 network map was around 1.141, while the average box value in the 2000 network map was approximately 1.383. By subtracting the mean value of the 1970 network map from the mean value of the 2000 network map, the change in the mean values was determined to be approximately 0.172. This indicates that the mean box values increased by about 21.19% between the two periods within the boundaries of the IMM 1989 Plan, implying a significant change in the complexity level of the city system. Overall, the study highlights the importance of evaluating the impact of planning decisions on the complexity level of a city system to ensure its sustainability and resilience.

Development Direction

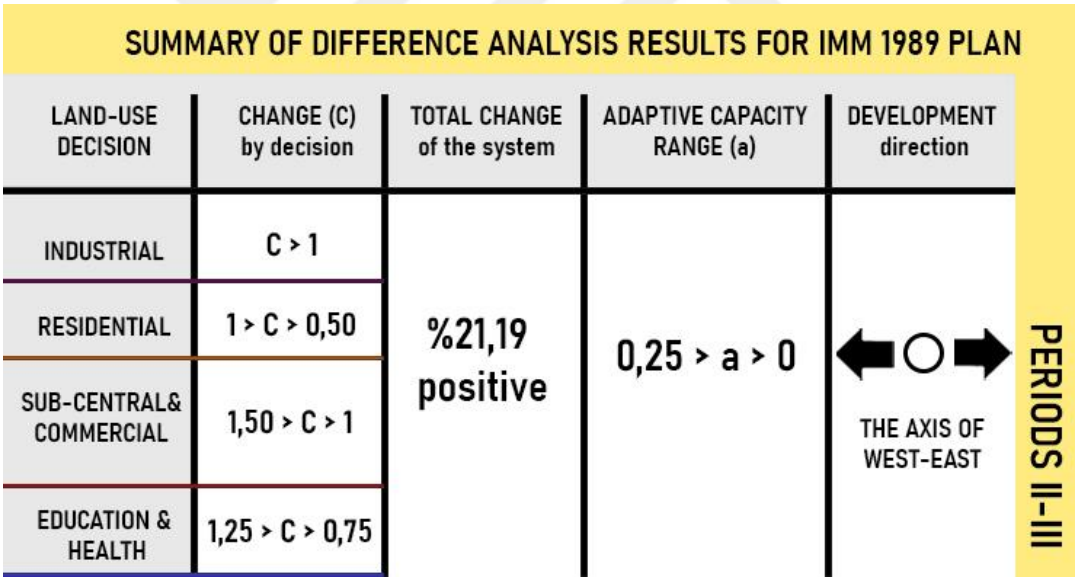
The state of a city's structure is often evaluated through sub-fractal analysis of its network maps. In the case of Izmir, this was done using the 1970 and 2000 network maps, both before and after the implementation of the Izmir Metropolitan Municipality (IMM) 1989 Plan. By subtracting the box values obtained from each other, the difference values were calculated, and it was determined that a high fractal value was generally observed in the east-west axis direction. This analysis revealed

that corridor development along this axis was observed in Izmir during the specified period, with new development areas mainly being foreseen in this direction.

The sub-fractal analysis conducted using the 2000 network map prepared within the boundaries of the IMM 1989 Plan revealed that 58 new boxes were added, with 35 of these located on the east-west axis. Consequently, this plan suggested a corridor development in the east-west direction, and it is observed that the proposed development decisions were realized within the framework of these analyses. Overall, the findings of the sub-fractal analysis serve as a valuable tool for policymakers in developing strategies to manage urban growth and improve the city's overall structure.

Findings

Table 5 Findings of the Difference Analysis for the IMM 1989 Plan



6.2.4 For the IMM Plan 2012

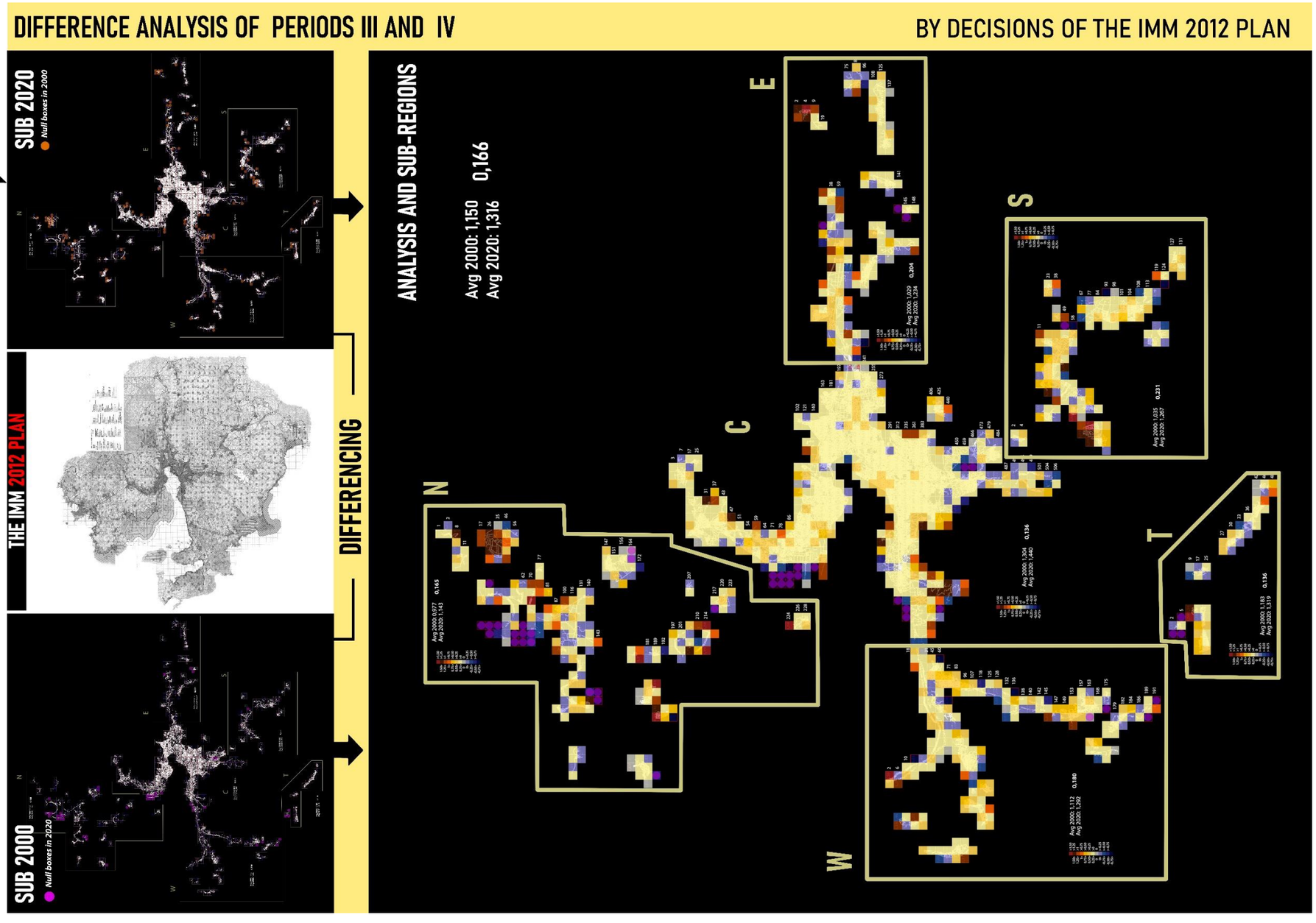


Figure 6.61 Difference Analysis of Periods III and IV by Decisions of the IMM 2012 Plan

Adaptive Capacity Range

This study aimed to evaluate the impact of the IMM 2012 Plan decisions on the complexity of the city of Izmir using a difference analysis approach. *The sub-fractal analyses of the 2000 and 2020 network maps were subtracted to obtain 1252 box values, with 603 of these falling within the adaptive capacity range (0<C<0.25) of the city's complex structure.*

The results indicate that the IMM 2012 Plan decisions have significantly influenced the complexity of the city of Izmir, as evidenced by its adaptive capacity range. The city has exhibited a high degree of resilience and adaptability in response to the changes brought about by the plan, contributing to the overall complexity of the city. These findings have important implications for urban planning and policy-making, emphasizing the need to consider the adaptive capacity of cities when designing and implementing urban plans and policies.

Further research is needed to investigate the underlying mechanisms of the observed changes in the complexity of the city, as well as the long-term effects of the IMM 2012 Plan decisions on the city's adaptive capacity and overall complexity. Nonetheless, this study provides valuable insights into the dynamic interplay between urban planning, complexity, and adaptive capacity in contemporary urban environments.

The Effects of the Major Landuse Decisions

The study aimed to investigate how planning decisions affect the complexity level of a city. Specifically, it focused on four major land-use decisions, including industrial, residential, commercial or sub-central, and wide-use educational or health area decisions. The study used sub-fractal analysis to compare the complexity level of the city before and after the implementation of the IMM 2012 Plan of İzmir, which is a comprehensive urban planning policy.

The study found that the IMM 2012 Plan significantly affected the complexity level of the city, and the impact varied across different land-use decisions. The industrial

area decisions showed the highest change, with an average change value (represented as "C") greater than 1.25, followed by the commercial or sub-central area decisions, with C values between 1.50 and 1. The residential area decisions showed the lowest change, with C values between 1.25 and 0.50, while the wide-use educational or health area decisions had C values between 1.25 and 0.75.

In the context of urban planning and complexity, the study's results suggest that land-use decisions can significantly affect the complexity level of a city. Industrial area decisions, which often involve large-scale infrastructure and transportation systems, significantly impact the complexity level. On the other hand, residential area decisions, which typically involve smaller-scale developments, have the least impact. Furthermore, the study's findings highlight the importance of considering the complexity level in urban planning decision-making processes.

Total Change of the City System

The sub-fractal analysis of the IMM 2012 Plan's boundaries was conducted using the 2000 and 2020 network maps. The results of the analysis yielded a total of 1252 boxes for both maps. The average box value for the 2000 network map was approximately 1.150, while the average box value for the 2020 network map was approximately 1.316. The next mean value was subtracted from the previous mean value to determine the change in the mean box values between the two network maps, yielding a difference of approximately 0.166. This indicates that the change in the mean box values between the sub-fractal analysis prepared using the 2000 network map and the 2020 network map within the boundaries of the IMM 2012 Plan is approximately 14.43%. Therefore, it can be concluded that the complexity level of the city system has undergone a total change of 14.43% after the implementation of the IMM 2012 Plan.

Development Direction

The results describe an analysis of the urban structure and sub-fractal features of the city of Izmir before and after implementing the IMM 2012 Plan. The analysis was

conducted using network maps from 2000 and 2020, and box-counting was used to obtain values for each analysis. By comparing the box-counting values for each analysis, it was possible to determine the extent of development and changes to the urban structure. The analysis revealed that areas with high fractal values were generally dispersed within newly developed regions. This suggests that the city's development was not centralized but rather spread out across different areas of the city. In addition, it was found that new development areas were not concentrated in a particular direction but instead dispersed in almost all directions within the planning boundary. The emergence of new box formations was observed to be irregular and scattered, with relatively high change values. This indicates that new development areas were not located in a regular or predictable pattern, but rather in a dispersed and haphazard manner. This was evidenced by the sub-fractal analysis, which revealed the addition of 93 new boxes to the 2000 network maps within the IMM 2012 Plan boundaries, with no discernible pattern for their location. Based on the analysis, it can be concluded that the city of Izmir underwent a sprawl development in the prescribed period. The plan suggested an overall tendency towards sprawl development, and it is evident that the proposed development decisions were realized in accordance with these analyses.

Findings

Table 6 Findings of the Difference Analysis for the IMM 2012 Plan

SUMMARY OF DIFFERENCE ANALYSIS RESULTS FOR IMM 2012 PLAN					
LAND-USE DECISION	CHANGE (C) by decision	TOTAL CHANGE of the system	ADAPTIVE CAPACITY RANGE (a)	DEVELOPMENT direction	
INDUSTRIAL	C > 1,25	%14,43 positive	0,25 > a > 0	 SPRAWL	PERIODS III-IV
RESIDENTIAL	1,25 > C > 0,50				
SUB-CENTRAL& COMMERCIAL	1,50 > C > 1				
EDUCATION & HEALTH	1,25 > C > 0,75				

- ***North Region "N"***

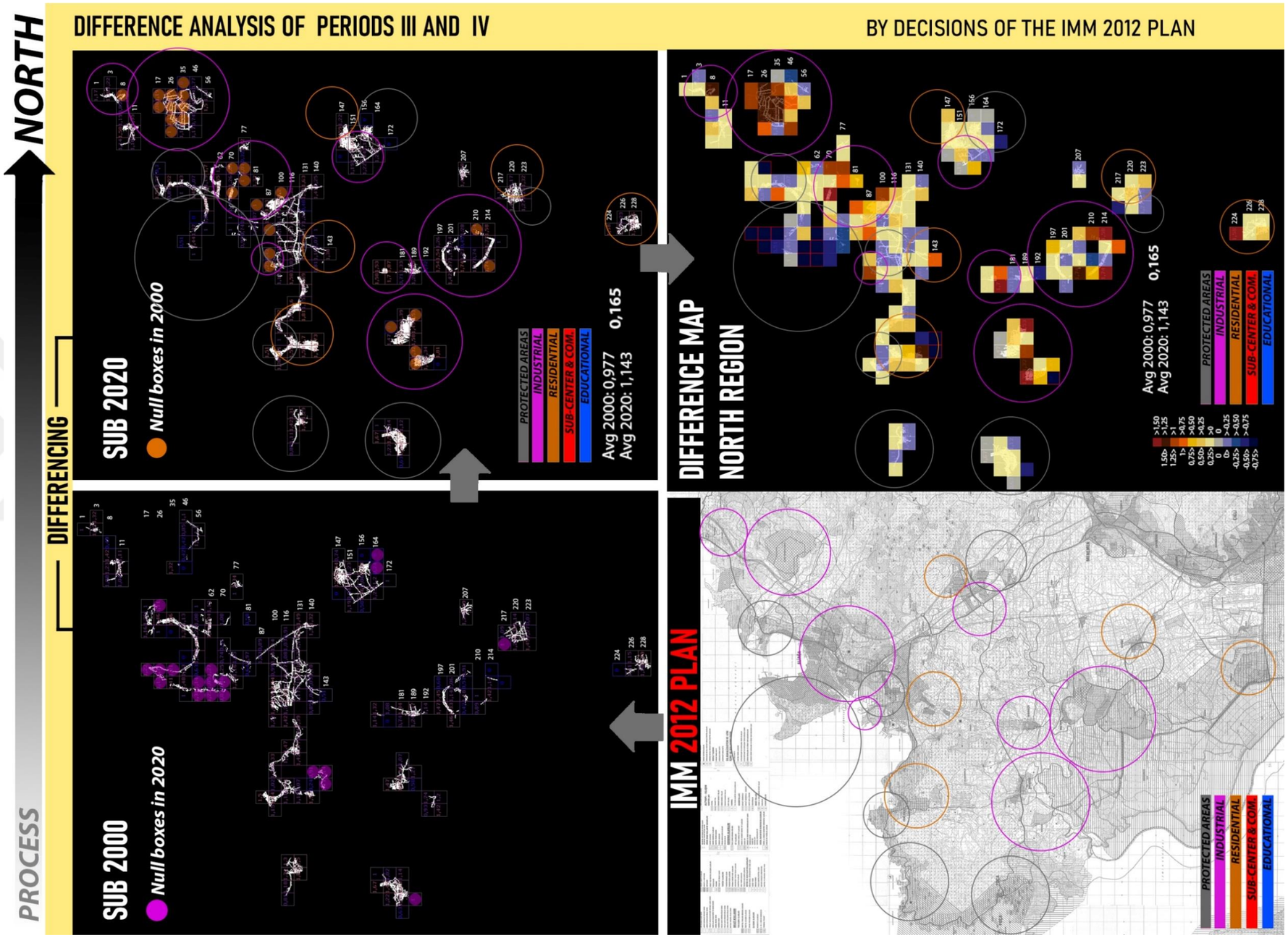


Figure 6.62 Difference Analysis of Periods III and IV by Decisions of the IMM 2012 Plan, North Region "N"

Adaptive Capacity Range

The study aimed to examine the impact of 2012 urban planning decisions on the complexity of the northern part of the city. The researchers conducted a difference analysis by comparing sub-fractal analyses of the 2000 and 2020 network maps, resulting in 228 box values. Of these values, 73 fell within the adaptive capacity range of the complex city structure, defined as the most common range where box values fall between $0.25>C>0$, where C represents the change in box values compared to the previous period.

Total Change of the Region

The sub-fractal analysis of the north region of Izmir city was conducted using the 2000 and 2020 network maps within the boundaries of the IMM 2012 Plan. In this analysis, 228 boxes were identified for each map. The average box value for the 2000 network map was found to be approximately 0.977, while the average box value for the 2020 network map was approximately 1.143. By subtracting the previous mean value from the next mean value, a difference of approximately 0.165 was obtained, which indicates a change in the mean box values between the two analyses. Thus, the complexity level of the north region of the city has changed by approximately 16.89% after the implementation of the IMM 2012 Plan.

The Effects of the Major Landuse Decisions

This part of the study also investigates how different planning decisions affect the complexity level of the North region of İzmir, Turkey. The major land-use decisions considered in this study are Industrial Area decisions, Residential Area decisions, and Protected Area decisions. To evaluate the impact of these decisions, the study uses sub-fractal analysis, which measures the complexity of a system by analyzing its spatial distribution.

The study further categorizes the observed changes by looking at the box values in the decision areas. The average change of the box values with the related area is represented by "C." The results show that the values of the boxes related to the

Industrial Area decisions are C>1, indicating a high level of complexity. The values related to the Residential Area decisions are between 1>C>0.25, indicating a moderate level of complexity. The values related to the Protected Area decisions are 0≥C, indicating a low level of complexity or negative effect on complexity.

Findings

Table 7 Findings of the Difference Analysis of the North Region for the IMM 2012 Plan

SUMMARY OF DIFFERENCE ANALYSIS RESULTS FOR IMM 2012 PLAN			NORTH REGION	PERIODS III-IV
LAND-USE DECISION	CHANGE (C) by decision	TOTAL CHANGE of the system	ADAPTIVE CAPACITY RANGE (a)	
INDUSTRIAL	C > 1	%16.89 positive	0,25 > a > 0	
RESIDENTIAL	1 > C > 0,25			
PROTECTED AREAS	0 ≥ C			

- ***South Region "S"***

Adaptive Capacity Range

This study aimed to investigate the effects of 2012 urban planning decisions on the complexity of the southern part of a city. The researchers performed a difference analysis by comparing sub-fractal analyses of the 2000 and 2020 network maps, resulting in 131 box values. Of these values, 48 fell within the adaptive capacity range, the most common range where box values fall between 0.25>C>0, where C represents the change in box values compared to the previous period.

Total Change of the Region

The sub-fractal analysis of the south region of Izmir city was conducted using the 2000 and 2020 network maps within the boundaries of the IMM 2012 Plan. In this

analysis, 131 boxes were identified for each map. The average box value for the 2000 network map was found to be approximately 1.035, while the average box value for the 2020 network map was approximately 1.267. By subtracting the previous mean value from the next mean value, a difference of approximately 0.231 was obtained, which indicates a change in the mean box values between the two analyses. Thus, the complexity level of the south region of the city has changed by approximately 22.32% after the implementation of the IMM 2012 Plan.

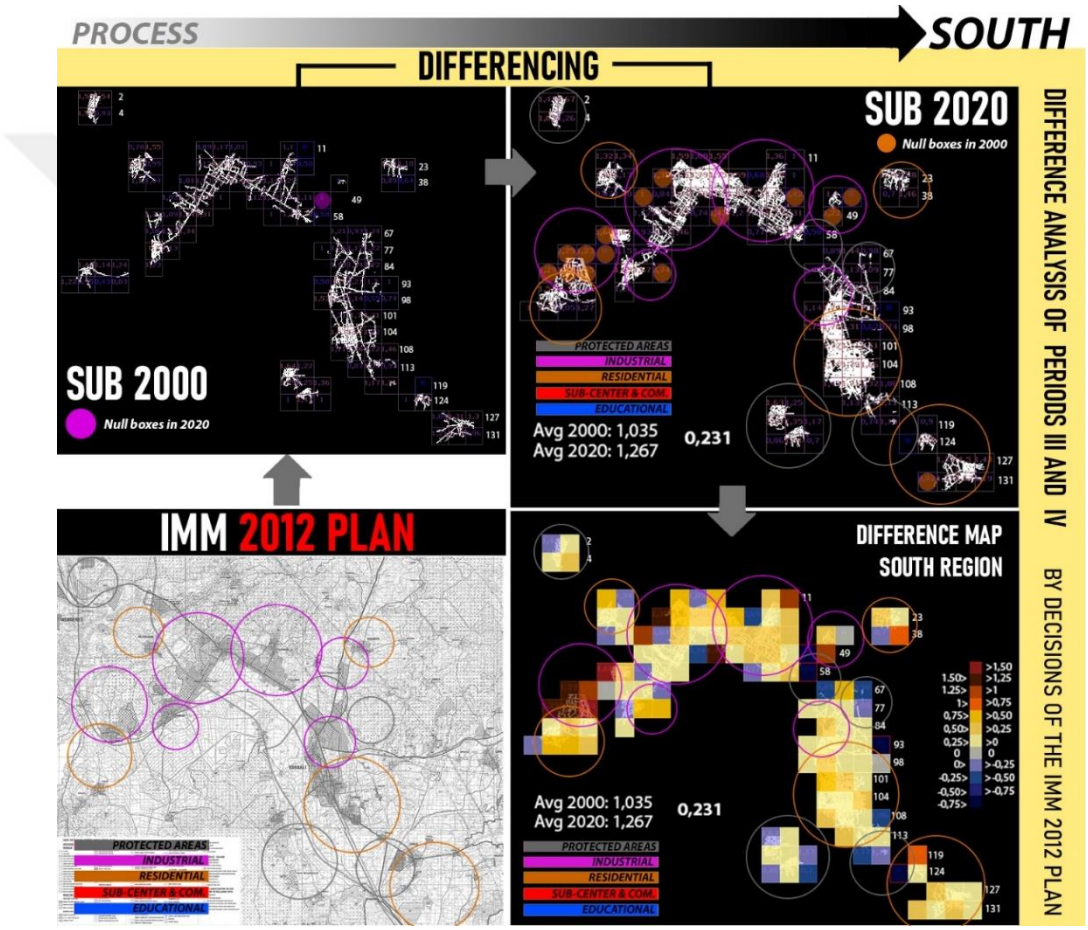


Figure 6.63 Difference Analysis of Periods III and IV by Decisions of the IMM 2012 Plan, South Region "S"

The Effects of the Major Landuse Decisions

The major land-use decisions considered are Industrial Area, Residential Area, and Protected Area decisions. The study uses sub-fractal analysis to evaluate these

decisions' impact on the region's complexity. The analysis compares the initial condition of the South region's network map before implementing the IMM 2012 Plan (in 2000) with the post-plan condition (in 2020). The results of the difference analysis indicate that the implementation of the IMM 2012 Plan has significantly affected the complexity level of the South region.

The study categorizes the observed changes by examining the box values in the decision areas. The average change of the box values with the related area is represented by "C." The results show that the Residential Area decisions have had the most significant impact on the complexity level of the region, with C values between 1.25 and 0.25. The Industrial Area decisions also substantially impacted the complexity level, with C values greater than or equal to 1.25. On the other hand, the Protected Area decisions had no impact or negative impact on the complexity level of the region, with C values less than or equal to 0. Overall, the findings indicate that the planning decisions made in the South region of Izmir have substantially impacted the complexity level of the area. The highest impact is observed in the Residential and Industrial Area decisions.

Findings

Table 8 Findings of the Difference Analysis of the South Region for the IMM 2012 Plan

SUMMARY OF DIFFERENCE ANALYSIS RESULTS FOR IMM 2012 PLAN			SOUTH REGION	PERIODS III-IV
LAND-USE DECISION	CHANGE (C) by decision	TOTAL CHANGE of the system	ADAPTIVE CAPACITY RANGE (a)	
INDUSTRIAL	C > 1,25	%22.32 positive	0,25 > a > 0	
RESIDENTIAL	1,25 > C > 0,25			
PROTECTED AREAS	0 ≥ C			

- ***West Reagion "W"***

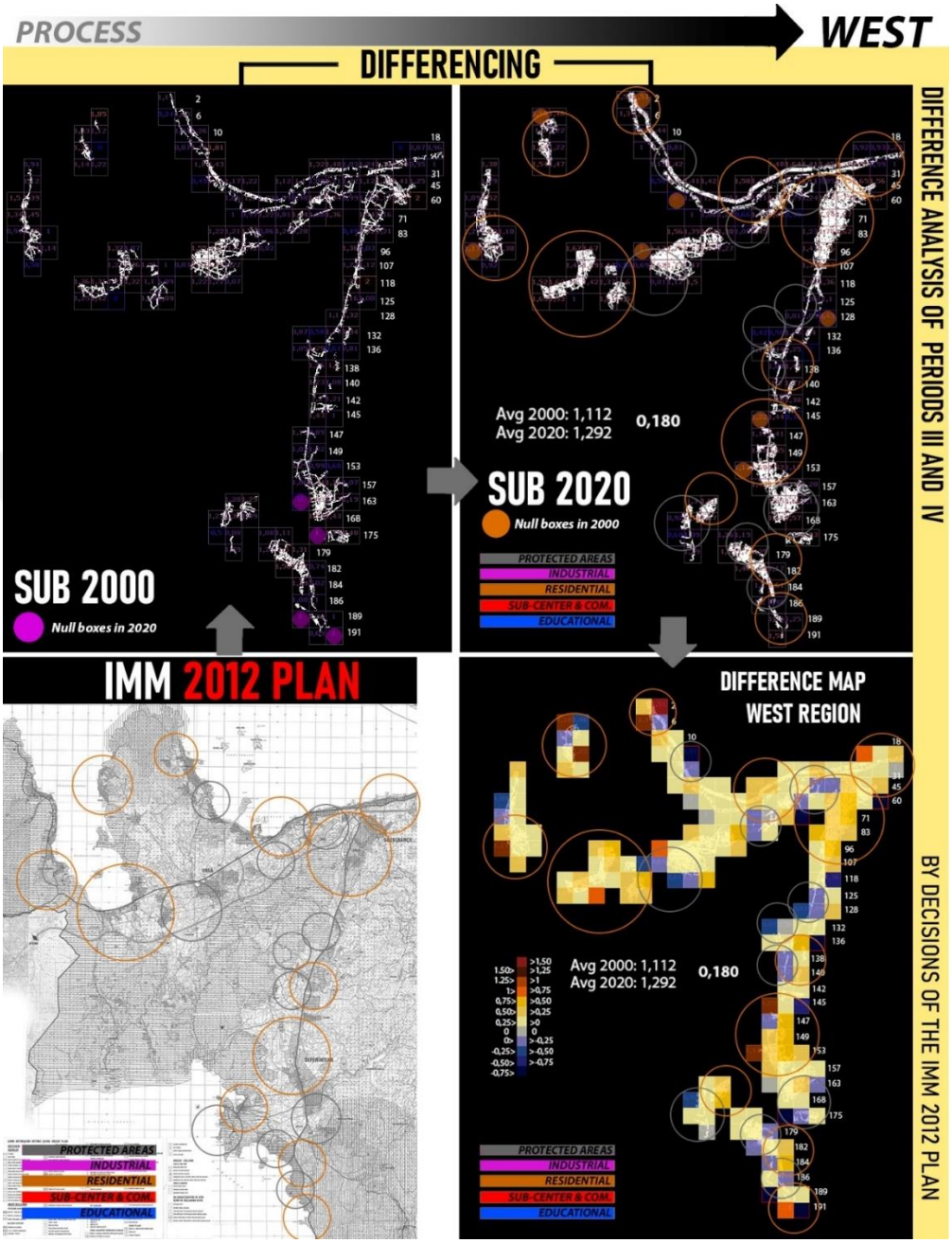


Figure 6.64 Difference Analysis of Periods III and IV by Decisions of the IMM 2012 Plan, West Region "W"

Adaptive Capacity Range

Based on the difference analysis between the 2000 and 2020 network maps, the study aimed to observe the effects of 2012 plan decisions on the complexity of the western

part of the city. A total of 191 box values were calculated in the analysis, and 82 of these boxes had values between 0.25>C>0, where C represents the change in box values compared to the previous period. This range of values is referred to as the adaptive capacity range of the complex city structure of the northern part of the city.

Total Change of the Region

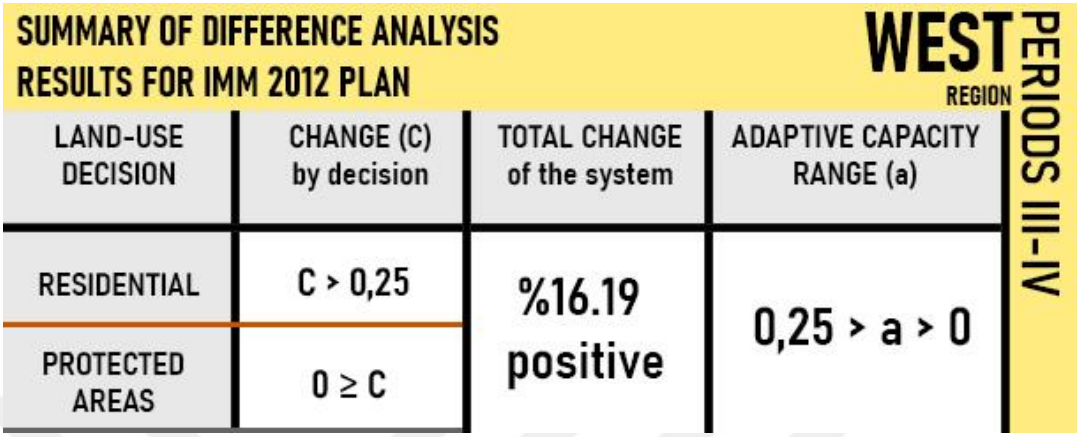
The sub-fractal analysis of the western region of Izmir city was conducted using the 2000 and 2020 network maps within the boundaries of the IMM 2012 Plan. In this analysis, 191 boxes were identified for each map. The average box value for the 2000 network map was found to be approximately 1.112, while the average box value for the 2020 network map was approximately 1.292. By subtracting the previous mean value from the next mean value, a difference of approximately 0.180 was obtained, which indicates a change in the mean box values between the two analyses. Thus, the complexity level of the west region of the city has changed by approximately 16.19% after the implementation of the IMM 2012 Plan.

The Effects of the Major Landuse Decisions

The study examines the impact of major land-use decisions, specifically Residential and Protected Area decisions, on the complexity level of the West region of İzmir. Using sub-fractal analysis, the study compares the network map before implementing the IMM 2012 Plan (in 2000) with the post-plan condition (in 2020) and finds significant changes in the complexity level of the region. The average change of the box values with the related area is represented by "C," and the values related to Residential Area decisions are C>0.25, indicating moderate complexity. The values related to Protected Area decisions are 0≥C, indicating no or negative impact on complexity. The IMM 2012 Plan's land-use decisions, specifically Residential and Protected Area decisions, have significantly impacted the complexity level of the West region of İzmir. The study finds that the Residential Area decisions have had the most significant impact, leading to the highest level of complexity. In contrast, the Protected Area decisions have had little to no impact or even a negative impact on complexity.

Findings

Table 9 Findings of the Difference Analysis of the West Region for the IMM 2012 Plan



SUMMARY OF DIFFERENCE ANALYSIS RESULTS FOR IMM 2012 PLAN			WEST REGION	PERIODS III-IV
LAND-USE DECISION	CHANGE (C) by decision	TOTAL CHANGE of the system	ADAPTIVE CAPACITY RANGE (a)	
RESIDENTIAL	C > 0,25	%16.19 positive	0,25 > a > 0	
PROTECTED AREAS	0 ≥ C			

- ***East Region "E"***

Adaptive Capacity Range

This study aimed to examine how the 2012 plan decisions affected the complexity of the eastern part of the city. The research methodology involved performing a difference analysis of the box values of sub-fractal analyses using 2000 and 2020 network maps. In total, the analysis generated 148 box values, and 66 of these values fell within the adaptive capacity range of the complex city structure, which is defined as having values between 0.25>C>0.

Total Change of the Region

The east region of Izmir city underwent a sub-fractal analysis within the boundaries of the IMM 2012 Plan using the 2000 and 2020 network maps. A total of 148 boxes were obtained from each map, with an average box value of approximately 1.029 and 1.234, respectively. The difference of approximately 0.204 between the next and previous mean values indicates a change in the mean box values between the two analyses. As a result, the complexity level of the east region of the city has increased by approximately 19.83% since the plan's implementation.

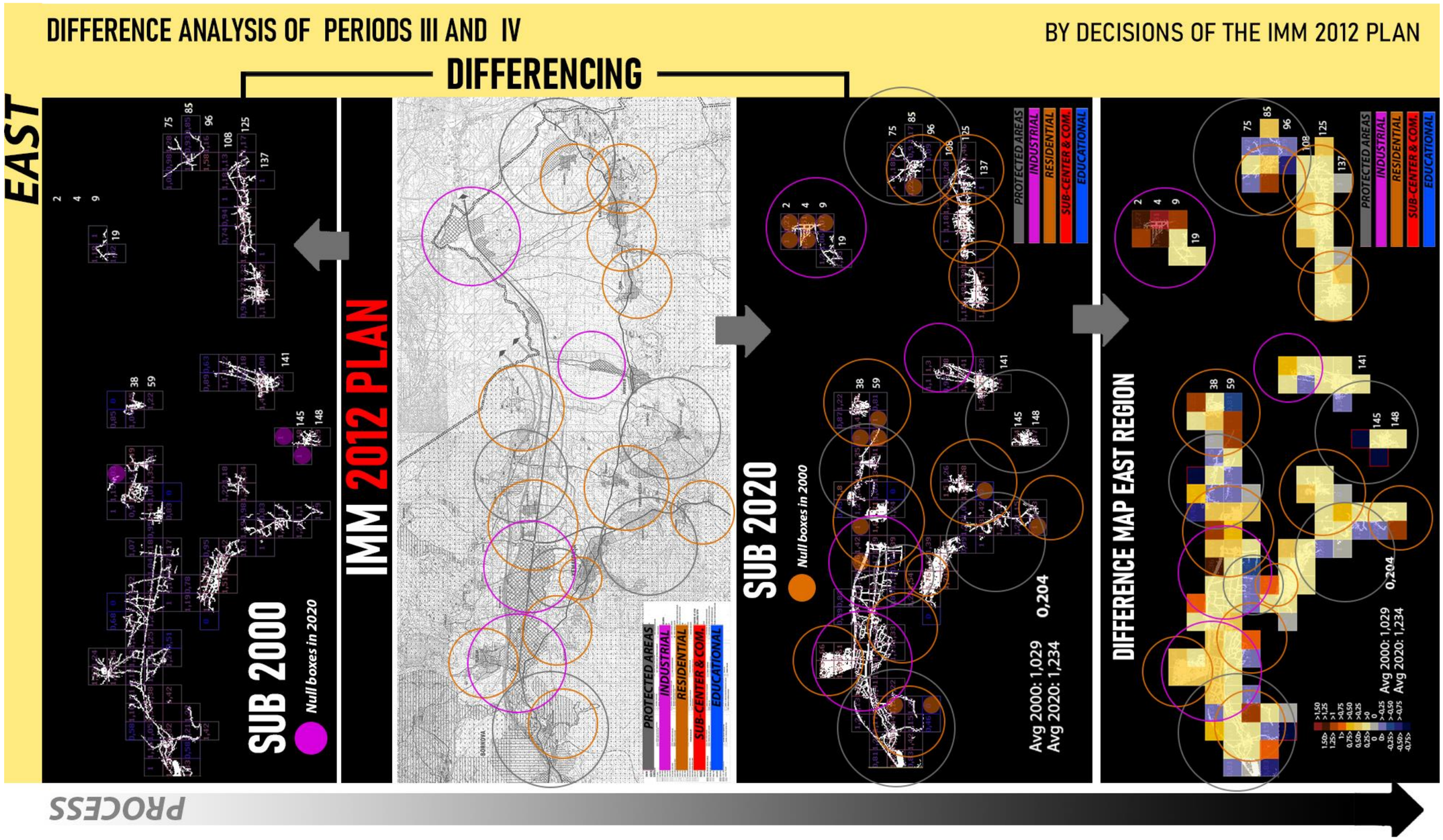


Figure 6.65 Difference Analysis of Periods III and IV by Decisions of the IMM 2012 Plan, East Region "E"

The Effects of the Major Landuse Decisions

The major land-use decisions considered are industrial area decisions, residential area decisions, and protected area decisions. The study aims to determine which decisions have the most significant impact on the region's complexity level.

The sub-fractal analysis is used to compare the initial condition (2000 network map) with the post-plan condition (2020 network map) after implementing the IMM 2012 Plan for the east region. The results show that the plan's implementation has significantly impacted the complexity level of the region.

The study categorizes the observed changes based on the box values in the decision areas. The average change of the box value with the related area is represented by "C." The results show that the values of the boxes related to the residential area decisions are between 1>C>0.25, indicating a high level of complexity. The values related to the protected area decisions are 0≥C, indicating no impact or negative impact on the complexity level of the region. The values related to the industrial area decisions are C≥1, indicating a high level of complexity.

Findings

Table 10 Findings of the Difference Analysis of the East Region for the IMM 2012 Plan

SUMMARY OF DIFFERENCE ANALYSIS RESULTS FOR IMM 2012 PLAN — **EAST REGION** — **PERIODS III-IV**

LAND-USE DECISION	CHANGE (C) by decision	TOTAL CHANGE of the system	ADAPTIVE CAPACITY RANGE (a)
INDUSTRIAL	C > 1	%19.83 positive	0,25 > a > 0
RESIDENTIAL	1 > C > 0,25		
PROTECTED AREAS	0 ≥ C		

- ***Tourism Region "T"***

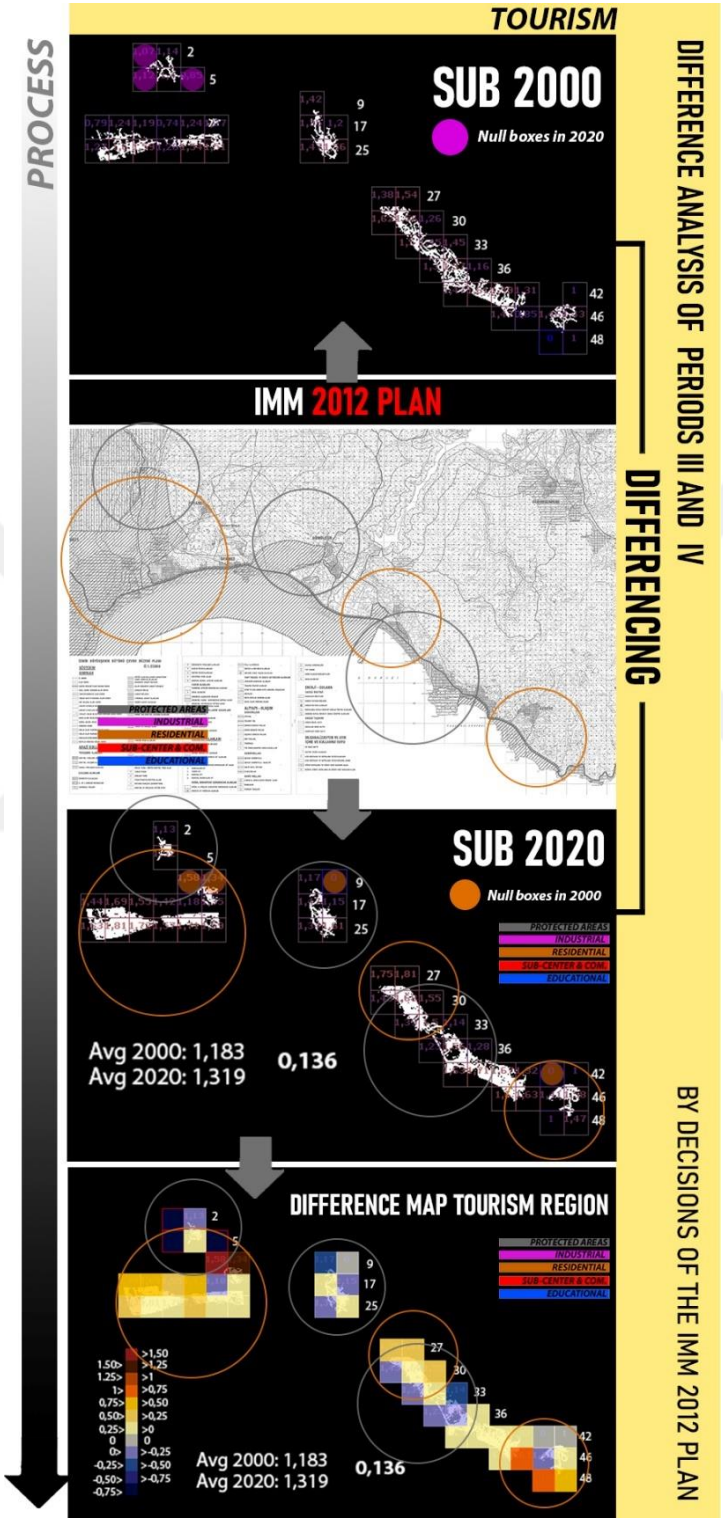


Figure 6.66 Difference Analysis of Periods III and IV by Decisions of the IMM 2012 Plan, Tourism Region "T"

Adaptive Capacity Range

This research aimed to examine how the 2012 plan decisions impacted the complexity of the city's tourism (Gümüldür Region) area. The methodology involved performing the difference analysis of the box values of sub-fractal analyses using 2000 and 2020 network maps. The analysis resulted in 48 box values, of which 17 were within the adaptive capacity range (0.25>C>0) of the complex city structure of the tourism part of the city.

Total Change of the Region

According to the results of the sub-fractal analysis of the tourism region in İzmir city using the 2000 and 2020 network maps within the boundaries of the IMM 2012 Plan, there were a total of 48 boxes in each analysis with an average box value of approximately 1.183 and 1.319, respectively. The difference between the mean box values of the two analyses is approximately 0.136, indicating an 11.50% change in the complexity level of the tourism region after the plan.

The Effects of the Major Landuse Decisions

The major land use decisions in the region are classified into two categories: residential area decisions and protected area decisions. The study finds that the average change of boxes related to the residential area decisions is C>0.25, while for the protected area decisions, it is 0≥C.

Findings

Table 11 Findings of the Difference Analysis of the Tourism Region for the IMM 2012 Plan

SUMMARY OF DIFFERENCE ANALYSIS RESULTS FOR IMM 2012 PLAN			TOURISM REGION	PERIODS III-IV
LAND-USE DECISION	CHANGE (C) by decision	TOTAL CHANGE of the system	ADAPTIVE CAPACITY RANGE (a)	
RESIDENTIAL	C > 0,25	%11.50 positive	0,25 > a > 0	
PROTECTED AREAS	0 ≥ C			

- *Central Area "C"*

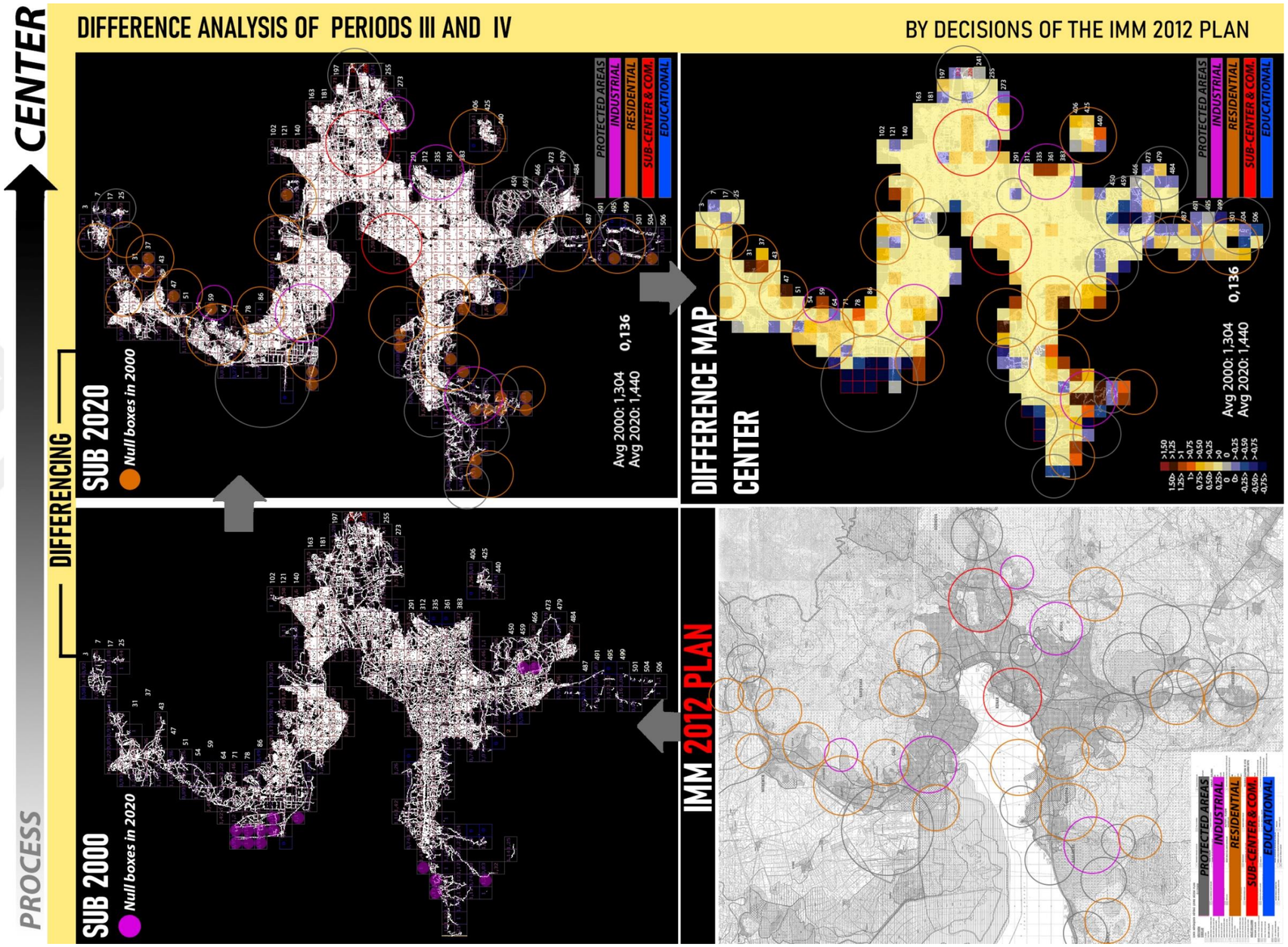


Figure 6.67 Difference Analysis of Periods III and IV by Decisions of the IMM 2012 Plan, Central Area "C"

Adaptive Capacity Range

The research objective was to assess how the decisions made in 2012 affected the complexity of the city's central area. To accomplish this goal, this study conducted a difference analysis by subtracting the box values obtained from sub-fractal analyses of the network maps from 2000 and 2020. They analyzed a total of 506 box values and found that 313 fell within the 0.25>C>0, where C represents the change in box values compared to the previous period. The researchers referred to this range as the adaptive capacity range of the complex city structure of the central part of the city. The study concluded that the central part of the city has demonstrated the ability to adapt to the changes made in 2012 based on the findings.

Total Change of the Region

The sub-fractal analysis of the central area of İzmir city was conducted using network maps from 2000 and 2020 within the boundaries of the IMM 2012 Plan. A total of 506 boxes were obtained from the analysis using the 2000 network map, with an average box value of around 1.304. Similarly, the analysis using the 2020 network map yielded 48 boxes, with an average box value of approximately 1.440. By subtracting the mean values of the two analyses, a difference of approximately 0.136 was obtained, indicating a change in the mean box values. This difference in mean box values between the sub-fractal analyses using the 2000 and 2020 network maps within the boundaries of the IMM 2012 Plan corresponds to a change of approximately 10.43% in the complexity level of the central area of İzmir city.

The Effects of the Major Landuse Decisions

The major land use decisions in the area are classified into four categories: industrial area decisions, residential area decisions, sub-central & commercial area decisions, and protected area decisions.

The study employs a sub-fractal analysis technique. The initial condition is represented by the network map from 2000 before implementing the IMM 2012 Plan for the Central Area. The network map from 2020, after the implementation of the

plan, represents the post-plan condition. The study obtains the difference analysis result by analyzing the difference between these two conditions.

The study observes the box values in the decision area after the plan's implementation, and the average change of the boxes value with the related area is represented by "C." The study finds that the average change of boxes related to the industrial area decisions is C>1, while for the residential area decisions, it is 1.25>C>0.50. For the sub-central & commercial decisions, the average change is 0.75>C>0.25, and for the protected decisions, it is 0≥C.

Findings

Table 12 Findings of the Difference Analysis of the Central Area for the IMM 2012 Plan

SUMMARY OF DIFFERENCE ANALYSIS RESULTS FOR IMM 2012 PLAN — **CENTRAL AREA** — **PERIODS III-IV**

LAND-USE DECISION	CHANGE (C) by decision	TOTAL CHANGE of the system	ADAPTIVE CAPACITY RANGE (a)
INDUSTRIAL	C > 1	%10.43 positive	0,25 > a > 0
RESIDENTIAL	1,25 > C > 0,50		
SUB-CENTRAL& COMMERCIAL	0,75 > C > 0,25		
PROTECTED AREAS	0 ≥ C		

6.3 Cluster Analysis for the Outputs of the Difference Analysis

Difference analysis is a valuable tool for understanding the impact of urban planning decisions on the spatial complexity of urban systems. The results of this analysis provide insight into the emergence or disappearance of specific spatial patterns or features in the urban system over time. However, it is often necessary to use

additional analytical techniques to gain a complete understanding of the spatial patterns of the urban system and the potential implications of these patterns for urban planning.

One such technique is cluster analysis, which is commonly used to identify spatial clusters of high or low values in datasets. Moran's I is a commonly used statistical technique in cluster analysis that measures the degree of spatial autocorrelation in a dataset. Spatial autocorrelation refers to the tendency of similar values to cluster together in space. In other words, if a particular value is high in one location, it is more likely to be high in neighboring locations as well.

In the context of urban planning, cluster analysis with Moran's I can be applied to the outputs of difference analysis to identify clusters of high or low values that correspond to specific planning decisions or urban activities. For example, if the difference analysis reveals a positive change in the sub-fractal values associated with the implementation of a particular urban plan, cluster analysis with Moran's I can be used to identify spatial clusters of high sub-fractal values that correspond to areas where the plan was implemented.

Identifying these spatial clusters can help urban planners and policymakers better understand the impact of their decisions on the spatial complexity of the urban system. By identifying areas of high or low spatial complexity, planners can adjust their strategies and interventions to ensure that the urban system develops in a sustainable and resilient manner. Overall, the combination of difference analysis and cluster analysis with Moran's I can provide a robust analytical framework for understanding the complex spatial dynamics of urban systems and guiding effective urban planning and management.

In this part of the study, the results obtained from the difference analysis; Moran's I Spatial Autocorrelation technique was combined with the Hotspot (Getis-Ord Gi*) mapping technique and applied on the dynamic city structure formed as a result of four plans prepared for İzmir. How these plans affect the complexity of the city and

what types of clusters they cause are explained in this section with Spatial and Statistical representations.

Technical Process: *The studies in this section started with the digitization of the box value results obtained in the difference analysis in ArcGIS software. First, the number value representing the sub-fractal change value of that box is defined as a point in the middle of each box. Secondly; As a result of the sub-fractal analysis created by the post-plan situation, the outermost boxes were accepted as the border and the lines forming this border were defined as polygons. Finally; Spatial Autocorrelation Tool was run and Spatial and Statistical results were obtained by iterating for each plan boundary.*

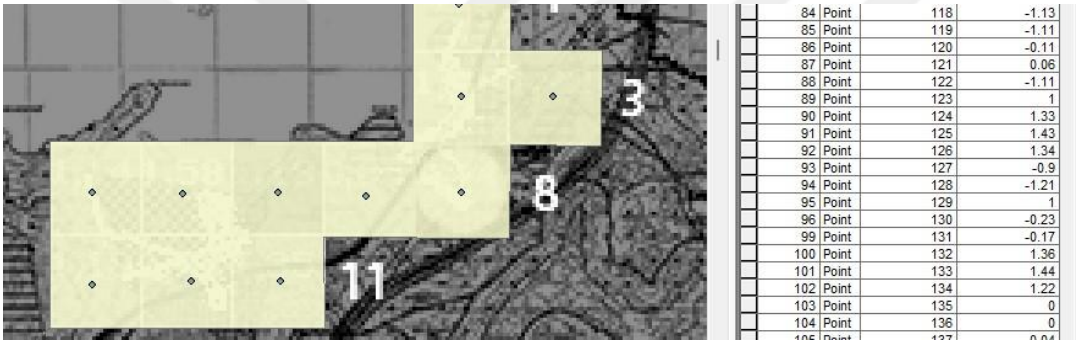


Figure 6.68 Technical Process for Cluster Analysis Digitization

6.3.1 For the İzmir Plan of Kemal Aru 1955

- ***Spatial Autocorrelation Report***

When the technical process was applied, the Spatial Autocorrelation Report of the dynamic urban structure assembled after the implementation of the Kemal Aru 1955 Plan (considering the change between the I. and II. Periods) is formed as follows;

The Spatial Autocorrelation Tool was used to analyze the change of the İzmir's sub-fractal values between the period I and II by the border of Kemal Aru Plan 1955 at different locations. The analysis showed that the results appear to be random based on Moran's Index value of 0.112293, the z-score of 1.380766, and the p-value of 0.167351. The critical value (z-score) falls between 1.96 and 2.58, which means that

the pattern is not significantly different than random based on the z-score of 1.380766.

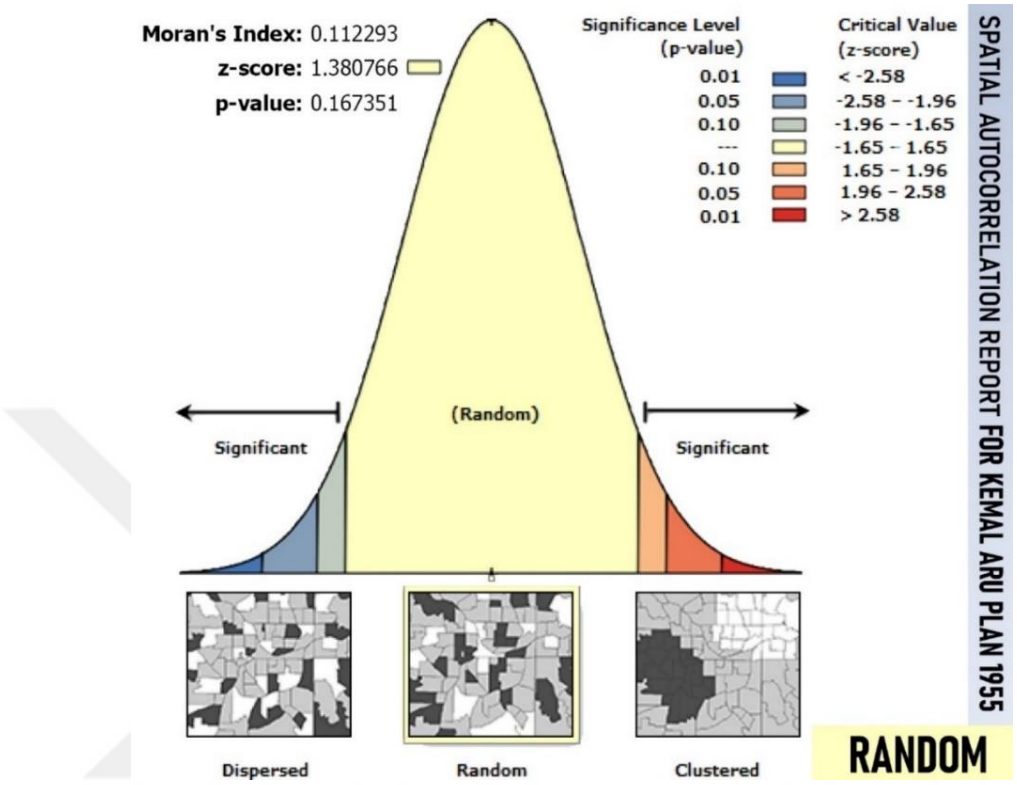


Figure 6.69 Spatial Autocorrelation Report for Kemal Aru 1955 Plan Boundary of İzmir

The reason why the analysis result is "random"

- ***Statistical Outliers:*** *A statistical outlier, also known as an "extreme value," is a data point that is significantly different from the other data points in a dataset. Outliers can occur due to data collection or measurement errors, natural variation, or extreme events. Identifying outliers is essential because they can significantly impact statistical analyses and modeling. Outliers can skew results, reduce the accuracy of predictions, and even invalidate statistical tests* (*Barnett & Lewis, 1994).*

In this area, the sub-fractal difference between the two periods was excessively above the average in a few boxes. For this reason, a "random" result was obtained from the cluster analysis, and these boxes were determined as "statistical outliers".

Important Notice; *In the Moran's I Spatial Autocorrelation report conducted within the boundaries of Kemal Aru 1955 Plan, it was stated that the box values did not create a significant statistical and spatial perfect clustering. In these cases, it is not correct to make interpretations on this result.*

6.3.2 For the IMM Plan 1973-1978

- ***Spatial Autocorrelation Report***

The Spatial Autocorrelation Report of the system assembled after the implementation of the IMM 1973-78 Plan (considering the change between the II. and III. Periods) is formed as follows;

The Spatial Autocorrelation Tool was used to analyze the change of İzmir's sub-fractal values during periods II and III around the IMM 1973-78 Plan boundary. The tool determined that the feature locations exhibited a clustered pattern, meaning that high or low values were more likely to be found near other high or low values rather than being randomly distributed.

Moran's Index, a measure of spatial autocorrelation, was calculated as 0.227685, which indicates a moderately strong positive correlation between neighboring feature locations. The z-score, which measures the deviation from the expected value, was found to be 5.017434, indicating a highly statistically significant result.

The p-value, which measures the probability of obtaining a result as extreme as the observed result, was determined to be 0.000001, which is less than the significance level of 0.01. This indicates that there is less than a 1-percent likelihood that the observed pattern is a result of random chance. Therefore, the clustered pattern of sub-fractal values around the IMM 1973-78 Plan boundary is considered a meaningful and statistically significant result.

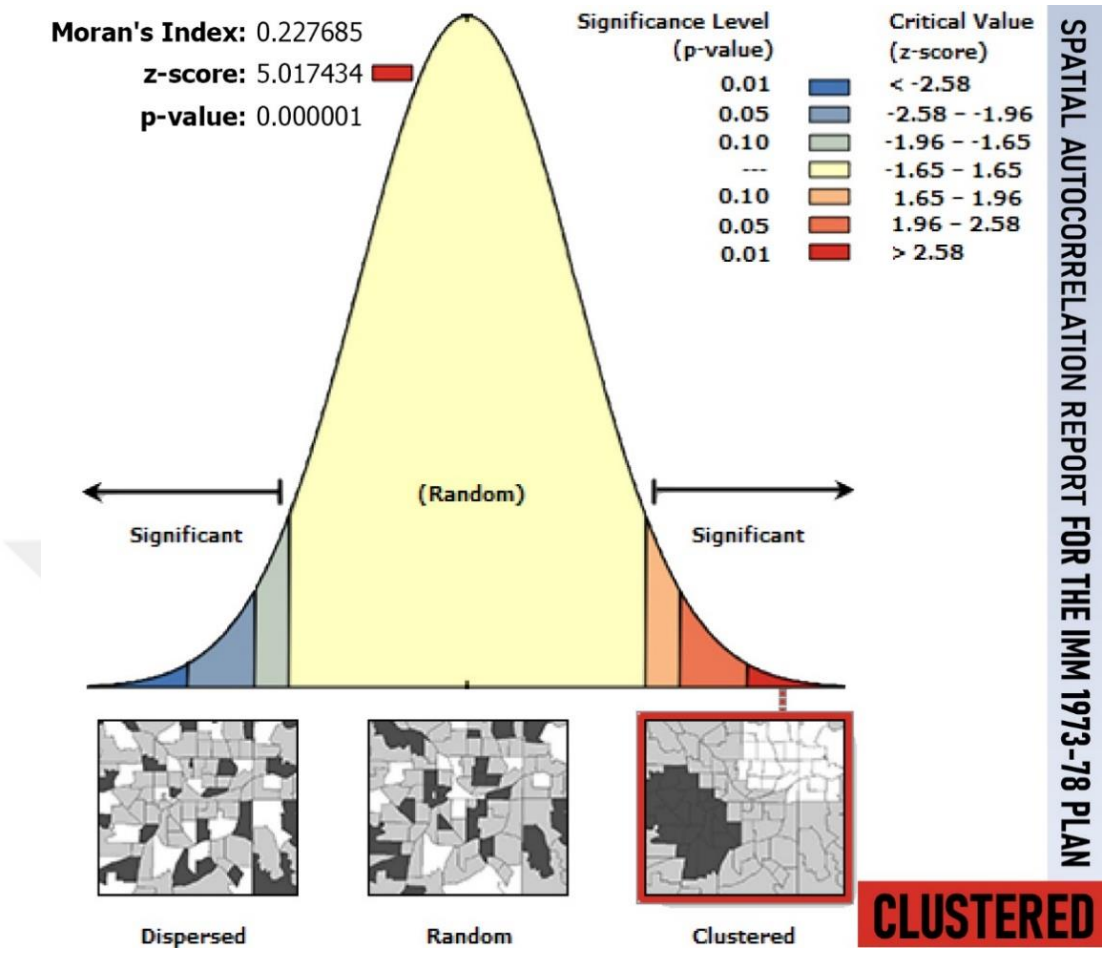


Figure 6.70 Spatial Autocorrelation Report for the IMM 1973-78 Plan Boundary of İzmir

- ***Mapping with Hot Spot Analysis (Spatial Cluster Analysis)***

Within the boundaries of IMM 1973-78 Plan, using the results of periods II-III sub-fractal difference analysis, hot spot analysis technique was applied and the map below was obtained.

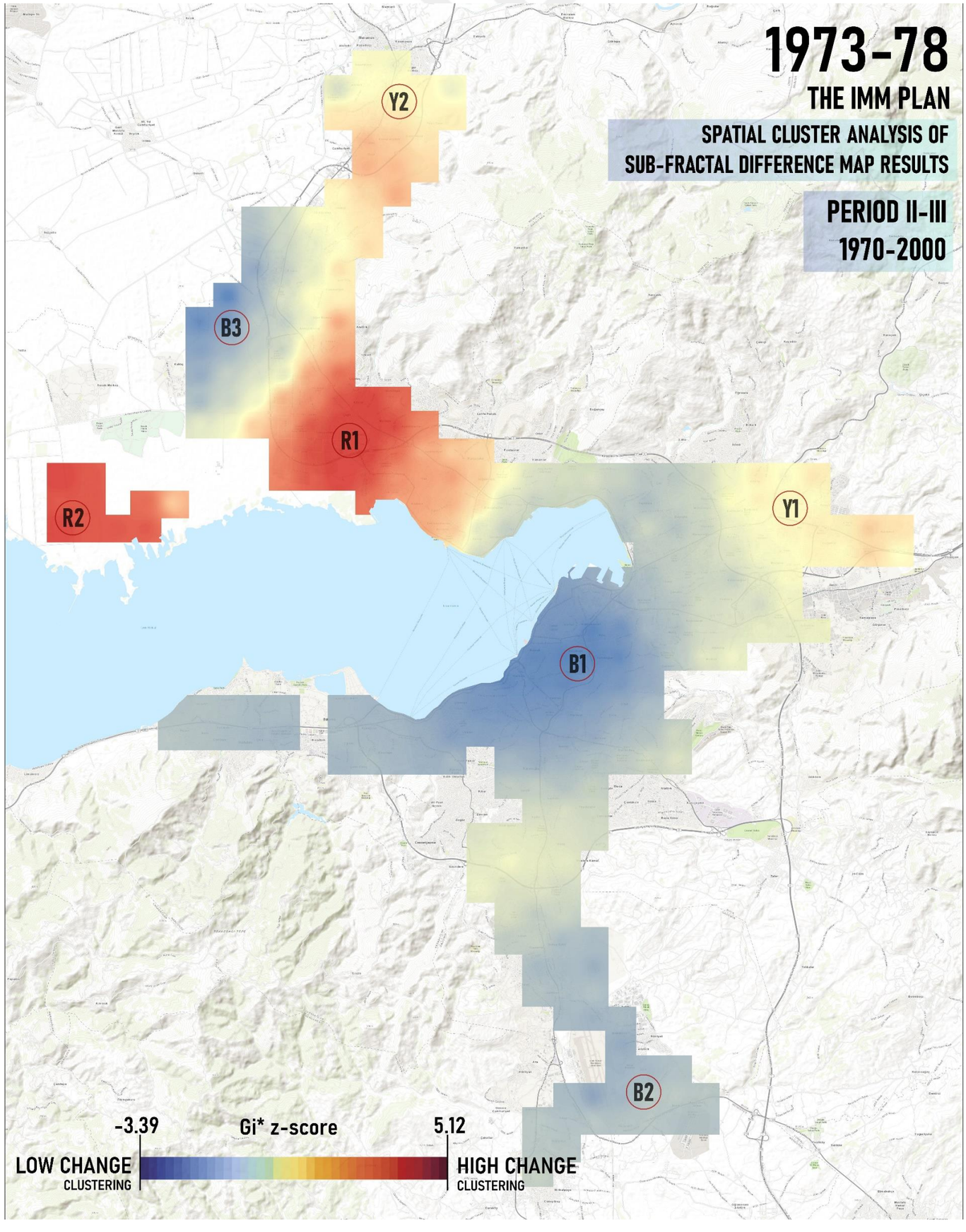


Figure 6.71 Spatial Cluster Analysis of the Sub-fractal Difference Map Results of the IMM 1973-78 Plan

- ***Interpretations of the Cluster Analysis***

Zone R1 1973-78:

The area marked on the map encompasses a wide region that extends towards the Karşıyaka region and includes the İzmir-Çiğli district and its surrounding areas. Analyses conducted within the Izmir Metropolitan Municipality (IMM) 1973-78 Plan boundaries reveal that the area experienced clustering due to high-level sub-fractal change between Period II and Period III. The plan initially incorporated the Çiğli district within the city limits, which included various production facilities located south of its center. These areas were included in the plan in their existing form, but the plan did not propose any new industrial development areas within the region. Instead, new industrial development areas were considered in the more northern parts of the city.

Although the 1973-78 Plan proposed significant housing development in the Çiğli district, the plan was unable to meet the area's housing needs, resulting in rapid squatting. The reasons for squatting included the continuation of industrialization in the south of Çiğli, the inability to produce houses to meet the workforce needs of the industrial zone, and the settlement of homeless citizens in the Güzeltepe and Şirintepe neighborhoods following the Varto earthquake in 1966. The latter reason also contributed to the migration trend from east to west in Turkey. The IMM 1973-78 Plan aimed to construct a fairground near the industrial area in the south of the Çiğli district, but the decision remained a rumor for an extended period, leading to an influx of investment and attraction in the district.

The military coup in 1980, right after the IMM 1973-78 Plan was approved, also caused the plan decisions to not be implemented due to economic reasons. The plan made few decisions concerning the Çiğli district. As a result, the region's development at both the country and local scale was inadequately predicted, leading to continued squatting. Emergent urban activities in the region have progressed far ahead of planned decisions.

The plan decisions regarding the area are as follows;

- *"...Farmlands would be kept. İnciraltı and the fair area in Çiğli would be reforested, and portions of the beachfront would be extended for community access by infill."*
- *"The location of Çiğli-Çamaltı Tuzla has been recommended as a venue for an international fair."*
- *"To tackle harbor contamination, a purification facility was suggested at Çiğli as part of the major canal construction (Master Plan Report, 1972, pp. 108-132)."*

Zone R2 1973-78:

The area indicated with this notation represents the İzmir-Çamaltı Saltpan and its surroundings. In the analyses prepared within the IMM 1973-78 Plan boundaries, clustering caused by high-level sub-fractal change is observed in the area from Period II to Period III.

In the area, there is Turkey's most giant sea salt pan with an area of 53 square kilometers and a history of 150 years until 1973. İzmir Bay and Sasalı Town in the south and west, Sasalı Organized Industrial Zone, Süzbeyli Village; In the north, there are İzmir-Menemen Organized Leather Industry Zone and İzmir Bird Sanctuary (Tarihçe Çamaltı Tuzlası, 2023). The following decisions regarding the area are included in the IMM 1973-78 Plan;

- *"The location of Çiğli-Çamaltı Tuzla has been recommended as a venue for an international fair."*
- *"Alsancak seaport would be extended, and a modern manufacturing port in the Çamaltı Tuzla zone suggested, with the bay in the Gümrük-Pasport area changed into a tourist port. Yacht amenities and cabins have been suggested in Bostanli, İnciraltı, and Güzelbahçe (Master Plan Report, 1972, 108-132)."*

However, these decisions were not implemented. With the expropriation and expansion works carried out since 1952, the production capacity of the Çamaltı

Saltworks area has been increased to 400,000 tons. The United Nations Industrial Development Organization (UNIDO) also contributed to these studies in 1973. The report prepared within this scope states that the lack of full use of the missing evaporation area, insufficient reserve water in these areas, and insufficient high-density water stock reduce production. For this reason, another 20 square kilometers of land was expropriated, and the salt mine operation area was increased to 73 square kilometers (Tarihçe Çamaltı Tuzlası, 2023).

In line with these developments, the increase in the number of facilities and roads in the area caused the change in the level of complexity to be high. In light of this information, it can be said that the structural change in the area occurred as emergent, beyond the control of the plan.

Zone B1 1973-78:

The area indicated with this notation represents the İzmir-Konak district and its surroundings. In the analyses prepared within the IMM 1973-78 Plan boundaries, clustering caused by a negative sub-fractal change (represented by blue-intensity colors as a cold spotted area) is observed. Konak district is also the old settlement of Izmir and is the historical center. Since this area has a very old history, the city structure contains different pattern types. The dominant one among these is the organic urban pattern from the Ottoman Empire. While the IMM 1973-78 Plan was being prepared, there was no initial decision about the area. However, the earthquake in Izmir in 1974 caused various damages to the historical pattern of the Konak district, and some plan decisions were added that included some renewals. The plan decision regarding the area is as follows;

- *"...Old neighborhoods like as Kemeraltı, Tilkilik, and Bayraklı would be conserved, as would newer areas such as Kordon, Cumhuriyet Square, Karşıyaka Yalı Street, Konak-Üçkuyular seashore, and Hatay Road. Additional zones would be restructured by altering the layout, intensity, and infrastructure to some extent. Slum settlements would be repaired and reconstructed (Master Plan Report, 1972, pp. 108-132) ..."*

This plan decision has been implemented. With this decision, the physical structure of the area began to change. Central İzmir, which had an organic urban texture before, with the decision taken, has evolved into a modern geometric urban texture consisting of rectangular building blocks. This situation directly changed the complexity level of Konak and its surroundings and brought it to a less complex level, and the difference in change between periods II and III resulted in a negative result. Therefore, the clustering in this area is also shown with blue colors (cold spotted area).

Zone B2 1973-78:

The area indicated with this notation represents the south of İzmir-Gaziemir district, Cumaovası locality, and the area between Menderes and Kısık Villages. In the analyzes prepared within the boundaries of the IMM 1973-78 Plan and showing the change between periods II and III, clustering caused by a negative sub-fractal change (represented by blue-intensity colors as a cold spotted area) is observed. In the IMM (Izmir Metropolitan Municipality) 1973-78 Plan, new medium and low-density residential development areas were proposed in the north-south direction of the Gaziemir district. However, although the change in the physical structure of the city was not very high, it generally took place around the intersection of İzmir Ring Road and Aydın-Denizli Road. The sub-fractal range of this region is observed to be in the range of $0<C<0.25$, and the changes in this region correspond to the range of ACR (Adaptive Capacity Range) discussed in the previous sections. It can be said that the foreseen planning decisions are partially realized.

Cumaovası Airport is located within the area specified with the notation, and it has been included in the Plan. A new airport proposal has not been made. This airport was used when Çiğli Airport was insufficient. Later, due to the technical inadequacies of this airport, a need for a new airport arose. In 1987, Adnan Menderes Airport was completed and opened for use. This need was not foreseen in the 1973-78 Plan.

While an organic physical pattern was dominant in the area before and during Period II, it was observed that the sub-fractal values were lower in Period III with the planned development afterward. Another important reason for this situation is that, together with the airport decision, which was not foreseen in the 1973-78 Plan, the region remained within the Airport Mania Plan and did not allow for intensive construction.

The IMM 1973-78 Plan generally proposed a North-South direction development and took planning decisions. One of them is the Menemen-Cumaovası railway. Although it played an essential role in developing the Menemen district and its surroundings, it could not be as effective in the north of the city due to airport-based measures in the Cumaovası region.

The relevant plan decisions are as follows;

- *"Menemen and Cumaovası would develop as polar subsidiary zones on the northern and southern axes, respectively, while Urla and Güzelbahçe would develop on the eastern and western axes."*
- *"The suburb railroad lines Aliağa-Menemen-Manisa and Aliağa-Menemen-İzmir-Cumaovası-Torbalı would be energized as a result of the improvements as mentioned earlier (Master Plan Report, 1972, pp. 108-132)."*

Zone B3 1973-78:

The area specified with this notation is located within the borders of the İzmir-Çiğli district. It represents the military areas and their surroundings located between the west of İzmir-Aliağa road and the town of Kaklıç. In the analyses prepared with Period II and III data within the IMM 1973-78 Plan boundaries, clustering caused by a negative sub-fractal change in the area (represented by blue-intensity colors as a cold spotted area) is observed. There is Çiğli Military Air Base in the specified area, so there is no planning decision for this area. It is home to the 2nd Main Jet Base Flight Training Central Command, affiliated with the Air Training Command of the Turkish Air Force. The runway was completed in 1980.

As it is a military area and there is a flight track in the area, it is not possible to intervene in the area with the planning decisions of the local administrations. Making adjustments in the area over time (such as road and building additions) and the regular geometric character of these arrangements, the disappearance of the pattern or the change in the detail of the area's processing on the maps may have caused the complexity of the area and its surroundings to appear to have decreased over time.

Zone Y1 1973-78:

The region denoted by this symbol corresponds to the district of Izmir-Bornova, encompassing the main campus of Ege University and its adjacent vicinities. This area is located on the western side of the junction of the Istanbul-Bursa and Ankara-Afyon roads, with Naldöken Village situated east. Analyses conducted within the 1973-78 Plan of the İzmir Metropolitan Municipality indicate that clustering occurred in this zone from Period II to Period III (represented by yellow-intensity colors), resulting from a sub-fractal change at a mid-level. The Gi* z score serves as an intermediate measure for these regions. The region has predominantly developed through planned means, and there is no evidence of squatting. Furthermore, this area has expanded according to the city's dynamic structure, as evidenced by the Adaptive Capacity Range headings in the preceding sections.

In 1955, Ege University was founded, and the plan included decisions regarding the development of university areas. Subsequently, in the 1973-78 plan, the district of Bornova and the village of Naldöken were incorporated within the boundaries of İzmir city and included in the investment program of the İzmir Metropolitan Municipality administration. The relevant plan decisions regarding this matter are outlined as follows.

- *"Major (Whole) City comprised the towns of core İzmir, Bornova..., and 31 surrounding villages: Kaynaklar, Çatalca, Gölcükler, Görece, Kısık, Uzundere... Naldöken and major investment programs were all examined (Master Plan Report, 1972, pp. 35-75)."*

- *"Main İzmir, Karşıyaka, Bornova, Karaburun, Çeşme, Urla, Seferihisar, Selçuk, Torbalı, Bayındır, Kemalpaşa, Menemen, Foça, Dikili, Bergama, Kuşadası, and pivotal Manisa sub-provinces were incorporated in the Metropolitan Zone. Physical environment, social, economic, and demographic elements are all examined at this scale (Master Plan Report, pp. 23-35, 1972).*

As a result of these decisions, recommendations for developing the university campus were proposed, including suggestions for medium and low-density residential areas. Additionally, the decision to establish a production facility in the western region of Naldöken led to the formation of an industrial corridor between the university area and the Naldöken district. Furthermore, when examining the designated area on the map, it is observed that the hotspot areas have increased towards Naldöken, a situation that was not anticipated in the 1973-78 plan. This can be regarded as an emergent urban activity that has arisen due to the plan itself.

Zone Y2 1973-78:

The area specified in this notation represents the İzmir-Menemen district and its surroundings. In the analyzes prepared within the boundaries of the IMM 1973-78 plan, clustering from Period II to Period III is caused by the mid-level sub-fractal change in the area (represented by yellow-density colors). Gi* z score is calculated as a medium level for these areas.

The area is generally developed with the plan, and no slums are found. At the same time, this area has developed in the dynamic structure of the city (see Adaptive Capacity Range titles in previous sections). It is seen that Hotspot areas are increasing to the south of central Menemen. In the IMM 1973-78 plan, the Menemen district has been included in the metropolitan area and has become open to the investments of the Metropolitan Municipality.

The plan proposed a large industrial area in the south of Menemen. It can be considered the main reason for the increase of hotspot areas towards the south in the

analysis. Middle and low -density housing areas were also proposed for the need to increase with industrial areas. Another crucial decision affecting sub-fractal change was the new railway lines. When these decisions are combined, it is observed that Menemen and İzmir evolved into a corridor development in the north-south direction. The relevant plan decisions are as follows.

- *"Main Izmir, Karşıyaka, Bornova, Karaburun, Çeşme, Urla, Seferihisar, Selçuk, Torbalı, Bayındır, Kemalpaşa, Menemen, Foça, Dikili, Bergama, Kuşadası, and pivotal Manisa sub-provinces were incorporated in the Metropolitan Zone ... "*
- *"Menemen and Cumaovası would develop as polar subsidiary zones on the northern and southern axes, respectively..."*
- *"The suburb railroad lines Aliağa-Menemen-Manisa and Aliağa-Menemen-İzmir-Cumaovası-Torbalı would Be Energized as a result of the Aforemented ImproVements (Master Plan Report, 1972, pp. 91-95)."*

It can be observed that industrial development positively changes the complexity level of the cities more than a housing development. This is clearly demonstrated when the decisions made in the same plan are compared within the same time period.

6.3.3 For the IMM Plan 1989

- ***Spatial Autocorrelation Report***

The Spatial Autocorrelation Report of the system assembled after the implementation of the IMM 1989 Plan (the change between the II. and III. Periods) is formed as follows;

The Spatial Autocorrelation Tool indicates a clustering pattern in the change of İzmir's sub-fractal values between periods II and III along the border of the 1989 Plan at each feature location. The analysis shows a Moran's Index value of 0.362549, a z-score of 9.409407, and a p-value of 0.000000. The critical value (z-score) falls between 1.96 and 2.58, suggesting a less than 1% likelihood that the

observed clustering pattern is due to random chance. Therefore, the results suggest that the clustering pattern is statistically significant and not a result of chance.

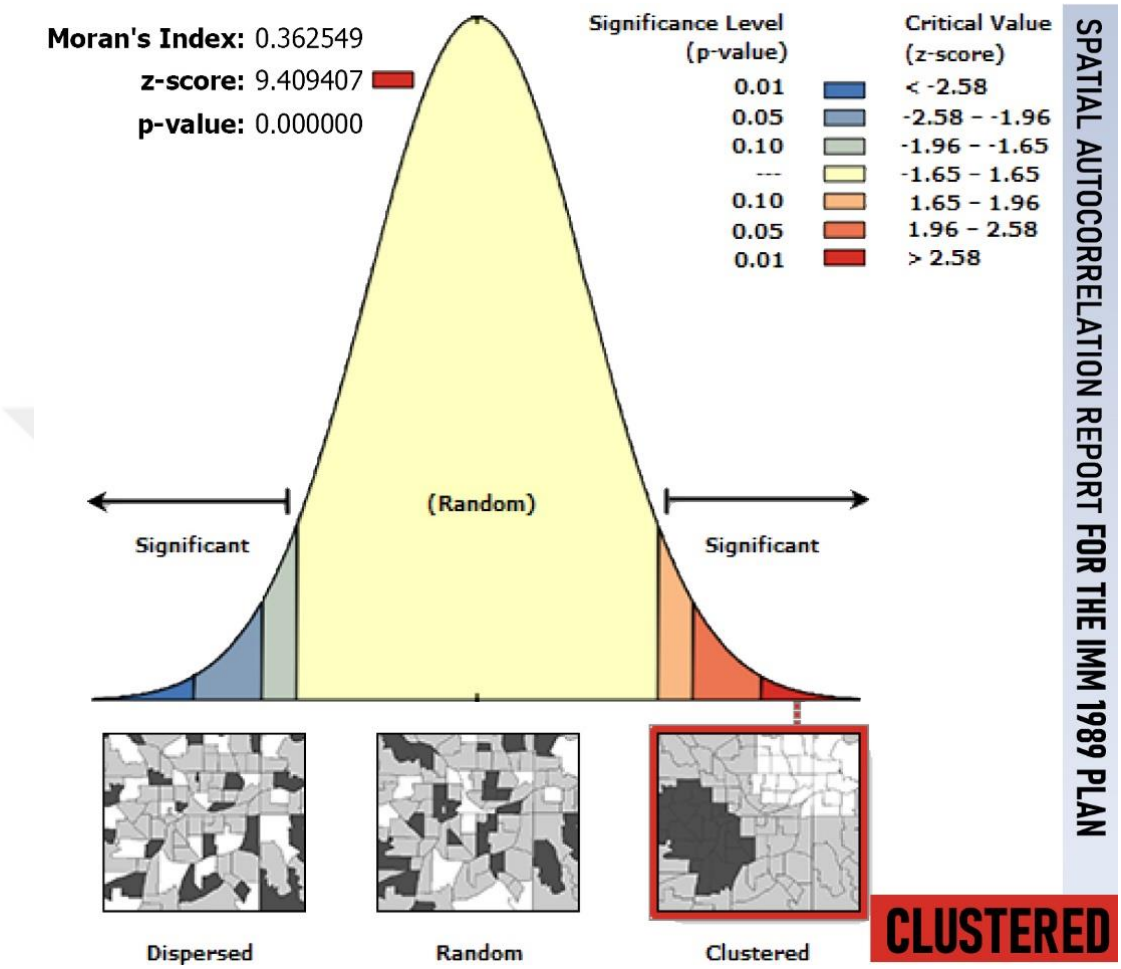


Figure 6.72 Spatial Autocorrelation Report for the IMM 1989 Plan Boundary of İzmir

- ***Mapping with Hot Spot Analysis (Spatial Cluster Analysis)***

Within the boundaries of IMM 1989 Plan, using the results of periods II-III sub-fractal difference analysis, hot spot analysis technique was applied and the map below was obtained.

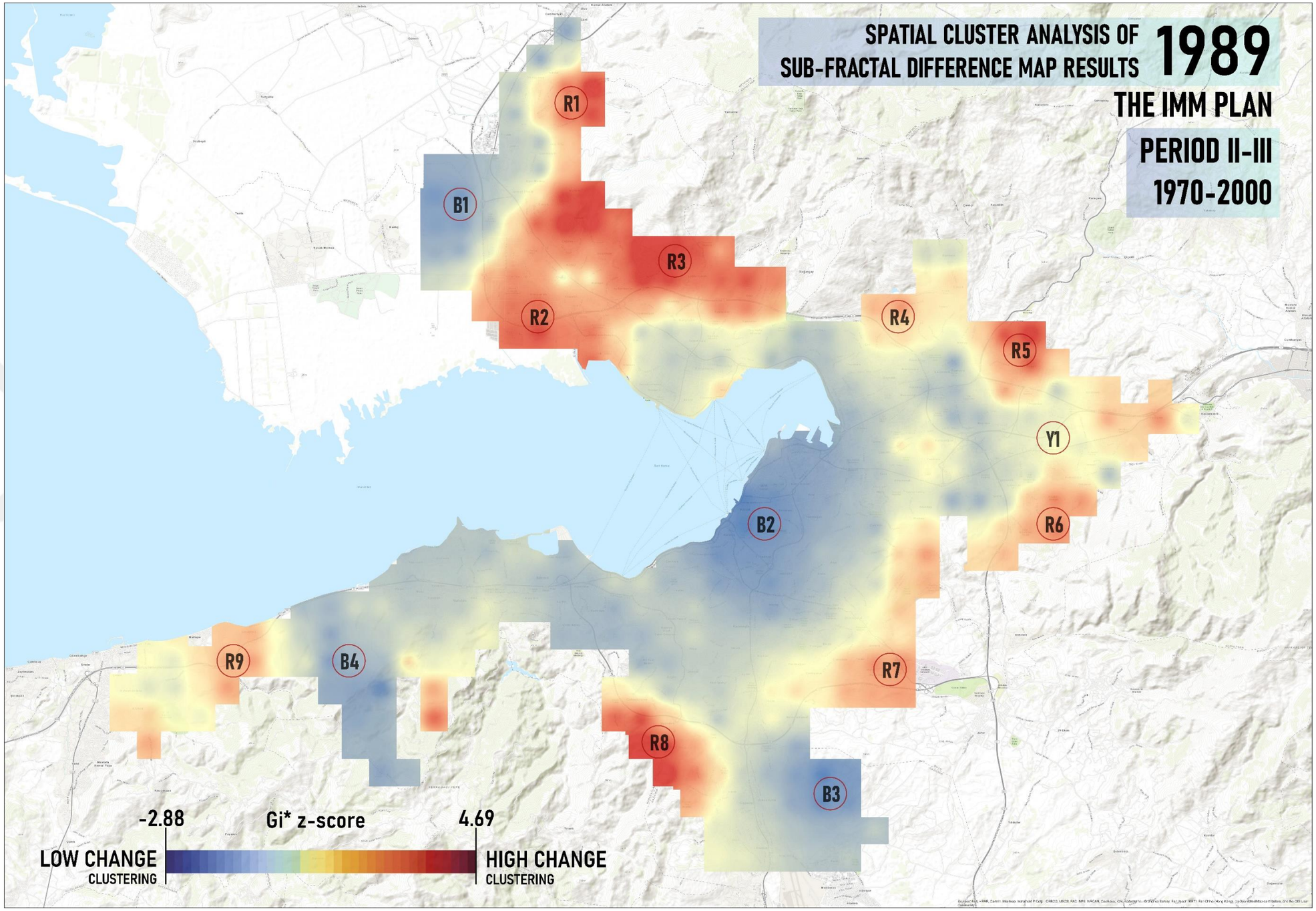


Figure 6.73 Spatial Cluster Analysis of the Sub-fractal Difference Map Results of the IMM 1989 Plan

- ***Interpretations of the Cluster Analysis***

Zone R1 1989:

The area indicated with this notation represents the region located in the exact border area of the south of İzmir-Menemen district and the north of İzmir-Çiğli District and its surroundings. In the analyzes prepared within the boundaries of the IMM 1989 Plan, clustering caused by high-level sub-fractal change is observed in the area from Period II to Period III.

The IMM 1973-78 Plan designated this region as an industrial area and proposed housing development areas that would support it. However, implementing this plan could have been more successful, and the proposed industrial investment remained a rumor in the city. Despite this, the rumor led to a rapid increase in housing development, driven by the belief that the region would attract industrial investment.

It is worth noting that in the IMM 1973-78 Plan, the decision regarding the industrial areas was given adjacent to the Çanakkale road, which could not be implemented due to several reasons, such as the irregularities in the economic and political structure of the country and the inability to analyze the dynamics in the city well. Nonetheless, the rumor of an industrial investment decision in the IMM 1973-78 plan intensified the population growth in the region and resulted in a drastic change in its physical pattern.

The clustering observed in the region from Period II to Period III was caused by the high-level sub-fractal change, as analyzed in the IMM 1989 Plan. The hot spots formed in the north of Çiğli Fevzi Çakmak Street also suggest the presence of this clustering phenomenon. The IMM 1989 Plan recognized the existing residential area in the region and did not propose any new development.

Overall, the region's developmental history is marked by a failed attempt to establish an industrial area, leading to the spread of a rumor that resulted in a rapid increase in housing development. The resulting physical pattern changes in the region, combined with high-level sub-fractal changes, contribute to the clustering

phenomenon observed in the area. The IMM 1989 Plan recognized these changes and incorporated them into the existing residential area without proposing any new development.

Zone R2 1989:

The subject area of this discussion is located in the south of the İzmir-Çiğli district, primarily encompassing the region between the İzmir Ring Road and Anadolu Avenue, as well as its surrounding areas. An analysis of this region, conducted during the preparation of the İzmir Metropolitan Municipality (IMM) 1989 Plan, revealed a clustering effect caused by a high-level sub-fractal change observed between Period II and Period III.

The IMM 1973-78 plan decided to expand the existing industrial areas to fill gaps in the region, and this decision was subsequently implemented. This development and expansion continued until the commencement of the IMM 1989 plan studies, where it was followed and processed as a "plan decision." Due to the high and positive sub-fractal change observed in the areas where the industrial area developed and expanded, it has caused a high level of clustering. In contrast, residential-commercial regions are increasing in the inner parts of the Çiğili district, and clustering in these regions appears to be relatively close to the middle level.

The plan decision of IMM 1989 Plan regarding the area is as follows;

- *"The prior plan's fair and entertainment zone in Bostanlı-Çiğli was converted into housing uses and a purification facility (Metropolitan Municipality Archives)."*

In the IMM 1973-78 plan, it was decided to build a fair and recreation area in the south of the region. However, this decision was not implemented, and the increasing industrial and residential areas have increased pressure on this area. As a result, it was decided in the IMM 1989 plan to construct a residential area and purification facility in the region where the fair and recreation area could not be built. Although the purification facility decision was implemented, the decision to build a residential

area was changed, and an industrial area decision was made instead. This change can be attributed to the area's proximity to the existing industrial area, which increases the rent pressure on the region.

Zone R3 1989:

The geographical location described by the given notation refers to a vast area that encompasses the northwestern region of İzmir's Bayraklı-Yamanlar district and the Cumhuriyet district of İzmir's Çiğli region, situated on the east side of Anadolu Avenue. The analyses carried out within the Izmir Metropolitan Municipality's (IMM) 1989 Plan boundaries reveal that this area experienced significant sub-fractal changes, resulting in clustering, particularly between Period II and Period III.

The IMM's 1973-79 plan proposed new residential development areas along Anadolu Caddesi, which extends towards the Çanakkale road. However, the 1989 Plan rescinded this decision, causing a halt to the proposed development.

The relevant plan decision is as follows;

- *"The housing zones envisioned in the 1978 plan to the west of Çanakkale Highway were abandoned (Metropolitan Municipality Archives)."*

Consequently, the city authorities failed to provide the necessary legal housing production to meet the demands of the industrial area situated south of Çiğli, leading to rampant squatting. Moreover, the economic and social reasons for migration from the east to the west of the country, especially during the latter part of the 1990s, further intensified this slum.

Incorporating the existing slum areas into the 1989 Plan as legal residential areas and proposing only a few new housing development zones was the solution suggested by the İzmir Metropolitan Municipality. This decision was also influenced by the fact that the central administration legalized these slum areas through various laws. However, despite these measures, the IMM 1989 Plan failed to suggest adequate new housing development areas, leading to the continued prevalence of squatting in the region.

Although this region had legal housing areas, the 1989 Plan could not prevent the emergence of enormous slum areas. The organic structural character of these areas also contributed to high sub-fractal changes, making the situation even more challenging. Regarding the geographical location indicated by the given notation, the IMM 1989 Plan acknowledged the slum areas that existed until its preparation year as residential areas. However, it failed to propose any future solutions to address the issue of squatting.

Zone R4 1989:

The region situated to the southeast of the Izmir-Bornova-Laka neighborhood and its surrounding area has been subject to analysis within the scope of the 1989 plan of the İzmir Metropolitan Municipality (IMM) from period II to period III. These analyses have revealed the existence of a cluster caused by a high level of sub-fractal change in the area.

Before the adoption of the 1989 plan, the IMM had yet to decide to designate this area as a housing zone, and it remained within the boundaries of the Metropolitan Municipality as a village. However, the area came under pressure for housing during the 1990s due to the city's slum movement and its proximity to the port of industrial areas. Due to the topographic structure of the area, it began to expand organically, and thus the cluster caused by the high-level sub-fractal change was observed. In the analyses conducted within the boundaries of period III and the IMM 1989 plan, the changes in the complexity level of the area were identified.

As the region was declared a housing area in the 1989 plan, urban transformation studies were carried out to address the housing problem. With the official declaration of a zoned housing development area, it can be said that the physical structure of this area has changed with the planned development. Evka-4 neighborhood was completed in this region in the 1990s, and it is considered to be one of the essential examples of preventing the formation of shanty areas. This example demonstrates that the development of a zoning housing development had a lower impact on sub-fractal change than that of industrial areas.

Overall, the study highlights the significant role that planned urban development can play in addressing housing problems in rapidly growing cities while demonstrating the importance of considering topographical factors in the planning process. The example of the Evka-4 neighborhood also highlights the positive impact of planned development in preventing the formation of informal settlements, underscoring the need for continued investment in urban development efforts.

Zone R5 1989:

The specified area in the İzmir-Bornova district consists of the Evka 3 neighborhood and Yenikent 1-2 sites, located between Istanbul and Ankara Avenues and north of the Ege University campus. The urban structure of this area underwent significant changes due to various factors, including the establishment of Ege University in 1955, the development of industrial zones, and the implementation of the İzmir Metropolitan Municipality 1989 Plan.

Before the 1960s, the area experienced a rapid formation of squatter settlements due to the influence of Ege University and industrial zones. As the industrial areas in the city expanded in the direction of Naldöken-Kemalpaşa, the need for housing increased, and the İzmir Metropolitan Municipality focused on developing the region as a rare new development area under the 1989 Plan.

Implementing both parcel and large-scale transformation projects in the 1990s significantly changed the existing urban pattern. The geometries used in the urban structure were close to organic geometry and were influenced by the topographic system of the area. This resulted in a high-level clustering of sub-fractal difference values, indicating the reproduction of a large part of the urban pattern in the relevant region with more complex geometries.

There were three main reasons for the high-level cluster of the field:

- The existence of squatter formations in the area contributed to the need for urban development.

- The İzmir Metropolitan Municipality's 1989 Plan identified the region as a housing development area and implemented this decision.
- The implementation of large-scale urban transformation projects and the use of complex geometries due to the topography also contributed to the high-level cluster in the area.

Overall, the changes in the urban structure of the İzmir-Bornova district were driven by various factors, including the establishment of Ege University, the development of industrial zones, and the implementation of the İzmir Metropolitan Municipality's 1989 Plan. These factors transformed the area's urban pattern, resulting in a high-level clustering of sub-fractal difference values.

Zone R6 1989:

The specified area in question is located in the Bornova district of İzmir, Turkey. The neighboring regions include the Işıkkent Shoemakers Site to the north, İzmir Ring Road to the west, and the Kemalpaşa and Gürpınar neighborhoods to the east.

According to the analyses conducted within the boundaries of the Izmir Metropolitan Municipality (IMM) 1989 plan, the area has undergone a significant cluster of sub-fractal changes, particularly between period II and period III. This can be attributed to the intense industrialization that took place in the Kemalpaşa road area during the 1970s.

The IMM 1973-78 plan proposed industrial and storage areas in the specified direction to adapt to these developments. However, it was soon recognized by the plan authorities that industrialization had exceeded the regions proposed until 1989, which prompted new suggestions for expanding industrial and storage areas.

- The IMM 1989 plan decision specified that *existing housing and manufacturing sectors in the east direction should undergo specific alterations. Furthermore, changes were proposed for the manufacturing, farming, and commercial sectors of Işıkkent and Pınarbaşı (Metropolitan Municipality Archives).*

In the early 2000s, the planning decisions of the IMM 1989 plan were implemented, resulting in a high level of sub-fractal changes, as observed in the analyses. The areas with high sub-fractal change values were identified as hotspots, indicating that the physical structure of the area had become more complex under the influence of the IMM 1989 plan.

In summary, the area in question has undergone significant changes in its physical structure due to the industrialization that took place in the 1970s, which prompted the authorities to propose new plans for expanding industrial and storage areas. Implementing these plans has led to further sub-fractal changes and the emergence of hotspots in the area.

Zone R7 1989:

The specified area with this notation can be found in the district of İzmir-Buca and Buca Koop, located between the intersection of İzmir Ring Road and Doğuş Street. It encompasses either all or a portion of the neighborhoods of Yıldız, Çamlıke, Atatürk, and Kuruçeşme, while Dokuz Eylül University Tınaztepe Campus is situated to the east of the area. The analysis conducted from period II to period III within the boundaries of the 1989 plan of the Izmir Metropolitan Municipality (IMM) revealed the high-level sub-fractal change in the region.

During two different periods between 1960-1975 and 1990-1995, the area underwent an intensive shanty process. In the 1973-78 plan of the IMM, new housing development areas were proposed around the center of Buca, yet this shanty process persisted due to the inability of both central and local administrations to produce affordable and rapid housing solutions to address the city's needs.

Consequently, the submission of Amnesty and Mass Housing laws by the central government in the 1980s legalized the illegal construction activities in the area, and the IMM 1989 plan declared it as a housing area. Urban transformation studies began upon the approval of the plan, and five large-scale projects, namely İzkonut, Buca Koop., Egekent 3, Evka 1, and İzkent 1, were executed in the region between 1990-

2000. The rugged terrain of the area resulted in a more complex network pattern of the transformation areas, which was reflected in the analysis studies that observed a cluster caused by high sub-fractal change between the specified periods.

It can be argued that the increase in the complexity level of the area during the 1980s was primarily influenced by planning decisions that incorporated legal arrangements on a country-wide scale into the preparation process of the IMM 1989 plan.

In summary, the notation describes a specific area located in the İzmir-Buca district and outlines the various changes that it has undergone, such as an intensive shanty process and subsequent urban transformation projects. It also highlights the impact of planning decisions on the complexity of the area, which is reflected in the high sub-fractal change observed in the analysis studies conducted between specific periods.

Zone R8 1989:

The specified area is situated in the Karabağlar district of Izmir and comprises the Aegean Free Zone along with the Uzundere, Cennetçeşme, and Yaşar Kemal neighborhoods, primarily located in the southern part of the Izmir Ring Road. This region is also referred to as the south region of the Karabağlar district. The analysis of this region, from period II to period III, prepared within the limits of the Izmir Metropolitan Municipality's 1989 Plan, reveals the clustering of high-level sub-fractal change.

The Uzundere neighborhood, which was initially a village, was included in the area while preparing the Izmir Metropolitan Municipality's 1973-78 Plan. This plan suggested a bipolar corridor development with the Menemen-Cumaovası (north-south) axis and organized industrial and residential areas accordingly. However, implementing this plan was not possible due to the national-level developments and the dynamics of the city of Izmir. Moreover, the lack of housing facilities suitable for the social structure led to squatting in this region.

In 1985, when the north of Gaziemir district was declared the Aegean Free Zone, there was a massive demand for labor, leading to intense illegal urbanization pressure in the area. Despite the Izmir Metropolitan Municipality's 1989 Plan's declaration of the site as an "Urban Working Area," the rapid industrialization of the Aegean Free Zone and the failure to fulfill the workforce's housing needs have resulted in the formation of slums. The area's proximity to the industrial area is another factor that contributed to squatting, which continued throughout the 1990s.

To address the problem of slums, local and central administrations produced urban transformation and mass housing projects in the area. Among these, the Uzundere and Cennetçeşme Urban Transformation Projects, implemented between 1990 and 2000, are the most significant. The site's sloping topography has resulted in the construction of new residential areas in place of slums, leading to the continuation of the complex network of the region.

The increase in sub-fractal change values of the area is mainly due to the inadequacy of housing facilities in response to industrial investments, squatting of public lands near industrial areas, and the opening of new roads between the relevant periods. Although slum areas are considered illegal housing areas, it is evident that industrial formations and industrial area decisions have a direct impact on their formation.

Furthermore, the development of the Aegean Free Zone and the demand for labor intensified illegal urbanization, leading to the formation of slums. The lack of affordable housing and the failure of the central and local governments to produce housing suitable for the social structure contributed to the squatter settlements' emergence. These squatter settlements in turn, had a detrimental impact on the urban environment, resulting in sub-fractal change values increase.

Urban transformation projects and mass housing initiatives were implemented to address the problem of squatter settlements and slums in the region. These initiatives led to the construction of new residential areas, resulting in a more complex network in the region. However, the topography of the area posed challenges in creating a uniform network pattern.

In conclusion, the clustering of high-level sub-fractal change in the area can be traced back to the failure of urban planning decisions and the lack of affordable housing facilities. The emergence of squatter settlements and slums in the region results from these challenges, with industrial formations and industrial area decisions playing a significant role. Urban transformation projects and mass housing initiatives were implemented to address the problem, forming a more complex network of new residential areas.

Zone R9 1989:

The area indicated with this notation is at the intersection of the İzmir-Güzelbahçe district, Maltepe neighborhood border and the İzmir-Narlıdere district Limanreis neighborhood border intersection, and at the same time, this area is on İzmir Çeşme Road. In the analyzes prepared within the boundaries of the IMM (Izmir Metropolitan Municipality) 1989 Plan from Period II to Period III, clustering caused by high-level sub-fractal change is observed in the area. This region is not within the boundaries of the IMM 1973-78 Plan. In the IMM 1989 Plan, this area is included in the plan borders, and its borders are specified as the Military Area. Almost all of the places where sub-fractal change is observed are within the boundaries of the military area. In line with the usage decisions of the Turkish Army, various physical changes have occurred in the area, and the pattern has changed from year to year.

Although it has been observed that the urban network structure formed around these areas, along with military and protection areas, has a less complex structure than in the previous period, this is not the case for the said area. Being on the İzmir-Çeşme road and being close to the İzmir Center may have led to more urban usage decisions and the complexity of the site may have increased. Finally, this area; is used as the National Defense University-Turkish Military Academy (Maltepe Campus).

Zone B1 1989:

The area located between the east of İzmir-Çiğli district Kalkıç town and İzmir-Aliağa road and its surrounding regions has been analyzed as part of the IMM (Izmir

Metropolitan Municipality) 1989 Plan from Period II to Period III. The analysis has revealed that a low-level sub-fractal change in the region causes a clustering pattern. However, this area, along with the areas west of Kalkıç town, was designated as Military Areas in the IMM 1989 plan, and no decision was made regarding their development.

High-ranking air officers identified the need for a new airport for civilian flights in the region in the 1970s. As a result, the central administration of the period responded positively to this demand and started construction work for the runway, which was completed by the end of the 1970s. However, the area was put into service for the Turkish Air Force following the 1980 military coup, and it could not be opened for civilian flights (Anadol, 2022).

In the present study, it has been observed that there is a more complex pattern in the analyzes made with 1970 network data than in the analyzes made with 2000 network data. This change in pattern can be attributed to the construction of the flight runway, which required the use of a geometric network character that involved the complete removal of some roads.

This removal resulted in a decrease in the complexity of the region. Moreover, the construction of the airport has made the area around it less sensitive to development due to its proximity to military sites. Consequently, the negative calculation of the sub-fractal difference values in the region has resulted in the observation of coldspot (negative) clustering in the last hotspot analysis.

Overall, the results of this study suggest that the airport's construction has significantly impacted the development and complexity of the region. The negative clustering observed in the area highlights the need for further studies to explore the effects of military sites on regional development and complexity. The findings of such studies can inform policymakers and urban planners in their decision-making processes.

Zone Y1 1989:

The given notation refers to a specific region situated within the confines of the İzmir-Bornova district, which encompasses a considerable area bordering the eastern side of Kemalpaşa Street and its surrounding environs extending towards the east of the Egemenlik Neighborhood.

The analysis conducted within site, based on the 1989 plan of the Izmir Metropolitan Municipality (IMM), reveals mid-level sub-fractal changes that occurred from period II to period III. A hotspot analysis conducted on the region highlights the clustering of yellow *(also Adaptive Capacity Range 0<C<0.25)* and blue densities.

In its 1973-78 plan, the IMM proposed that industrial and storage areas should remain confined to the inner sections of the city. However, this plan was only partially successful in its implementation. With the adoption of the IMM's 1989 plan, decisions were made to establish "Urban Working Areas" and "Industrial Areas" along the specified direction. Though attempts were made to implement these decisions, their development progressed slowly. This can be attributed to the economic shift towards the construction sector at both local and national levels, urban transformation, and appreciation for mass housing projects. The relevant plan decision taken in the IMM 1989 Plan is as follows;

- *"Extant housing and manufacturing sectors on the east direction have been approved, and certain alterations have been made to the manufacturing, farming, and commercial sectors of Işıkkent and Pınarbaşı (Metropolitan Municipality Archives)."*

In this site, without any planning decision, the spontaneous formation of industrial areas triggered various legal and illegal housing around the area. The main factor that triggers industrial formation can be considered as one of the leading transportation arteries of the site and its proximity to agricultural production areas. Later, this situation allowed the place to be maintained as an industrial zone. The rationale behind proposing industrial development in this region is due to the

development of residential areas in proximity that would cater to the need for labor. These residential areas include both squatter and zoning areas.

The clustering of yellow densities observed in the area is anticipated to evolve into a high-level sub-fractal change that would cause clustering in later periods. This could signify potential developments in the region, including the possibility of increased industrial activity and further urbanization.

To expand on this academic interpretation, it can be inferred that the urbanization process in the region is highly influenced by the economic growth of the construction sector, which has resulted in the slow development of the proposed industrial and urban working areas. The clustering of yellow densities observed in the site highlights the potential for future regional growth.

Zone B2 1989:

This notation refers to the entirety of the Konak district in İzmir and sections of other central districts surrounding it. An analysis conducted within the boundaries of the 1989 plan of the Izmir Metropolitan Municipality (IMM) shows a cluster of low-level sub-fractal changes between the II and III periods. The results of the Hotspot analysis indicate that blue-density colors represent this area. The decision made for the relevant field in the 1973-78 plan of the IMM continued to be applicable in the 1989 plan *(refer to Zone B1 1973-78).*

Zone B3 1989:

The area identified by a specific notation falls within the Dokuz Eylül Neighborhood of the İzmir-Gaziemir district. It encompasses the territory to the east of the İzmir-Aydın road and its surrounding regions. The analysis conducted within the precincts of the Izmir Metropolitan Municipality Plan between 1989, from period II to period III, reveals the clustering effect caused by low-level sub-fractal changes in the area. Hotspot analysis indicates that blue-intensity colors characterize this region.

The area under consideration is demarcated as a military zone in both the 1973-78 and 1989 plans of the Izmir Metropolitan Municipality. During the specified periods,

a general reduction in the complexity level is observed in the vicinity of such areas. The underlying reason for this phenomenon is attributed to either modifying the network pattern in the field with a less complex geometric pattern or eliminating part or all of the network structure. Military areas impose restrictions on surrounding regions' sudden and rapid development for security reasons, which could explain the blue color intensity of the hotspot analysis results.

Zone B4 1989:

The area indicated by this notation is situated within the confines of the Huzur Neighborhood in the Narlıdere district of Izmir and encompasses the region and its environs to the south of the Izmir-Urla Road. An examination of the data collected from the 1989 plan of Izmir Metropolitan Municipality (IMM) reveals that, during the period between phases II and III, there was a low-level sub-fractal change cluster in this area. Hotspot analysis has determined that blue-density colors characterize this area. The 1989 IMM plan designates this area as a military field used by the Aegean Army Rault Association. The basis for concluding that this area is a coldspotted zone is similar to the aforementioned *Zone B3 1989* notation.

6.3.4 For the IMM Plan 2012

- ***Spatial Autocorrelation Report***

The Spatial Autocorrelation Report of the system assembled after the implementation of the IMM 2012 Plan (the change between the III. and IV. Periods) is formed as follows;

Based on the results of the Spatial Autocorrelation Tool analysis, it has been found that there is a notable clustered change in the sub-fractal values of İzmir between period III and IV, specifically along the border of the IMM 2012 Plan at each feature location. Moran's Index, which quantifies the spatial autocorrelation of the data, was calculated to be 0.288264, indicating a moderate degree of clustering. The z-score value, which measures the deviation of the observed clustering pattern from

the expected random pattern, was found to be 12.604294, a significantly high value. Furthermore, the p-value was calculated to be 0.000000, indicating an extremely low likelihood that the clustered pattern was due to random chance. The critical value (z-score) was found to be greater than 1.96 but less than 2.58, indicating that the observed clustering is statistically significant with less than 1-percent probability that it is the result of random chance.

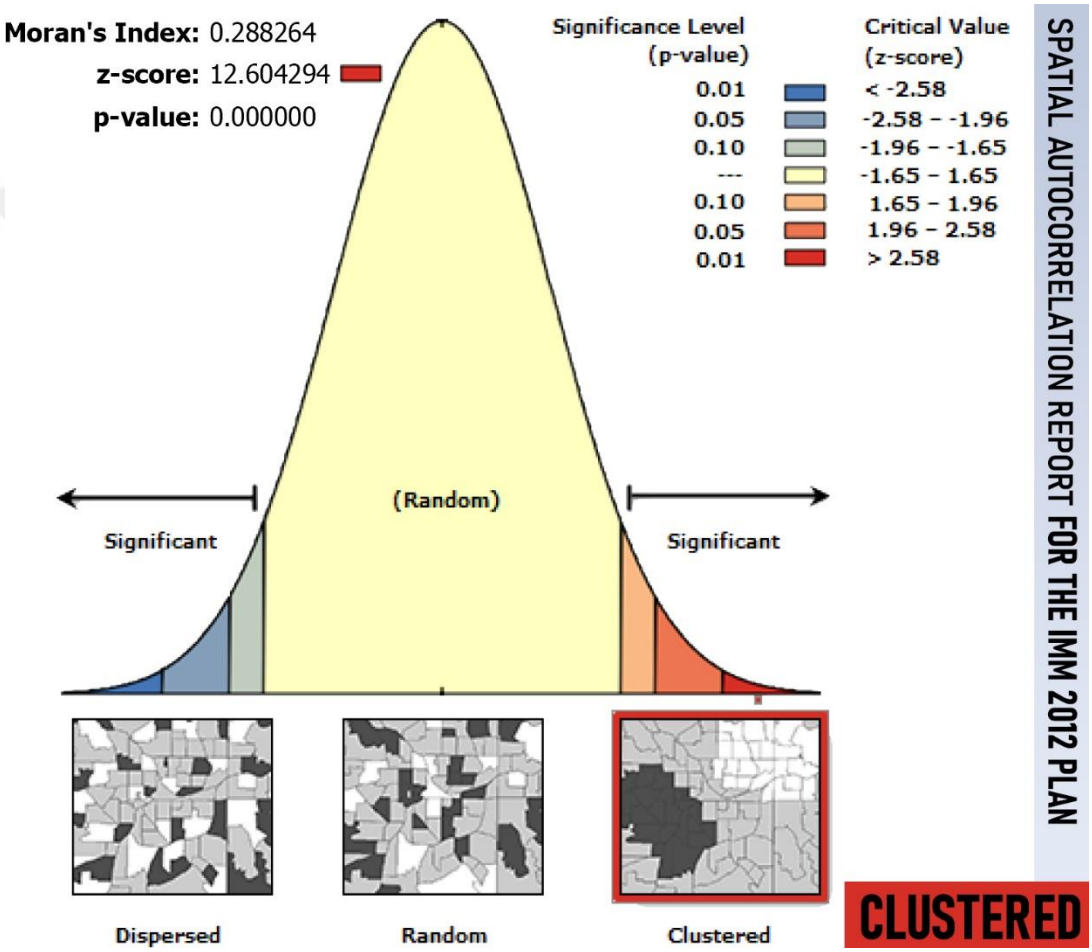


Figure 6.74 Spatial Autocorrelation Report for the IMM 2012 Plan Boundary of İzmir

- ***Mapping with Hot Spot Analysis (Spatial Cluster Analysis)***

The map below was created using the hot spot analysis technique within the IMM 2012 Environmental Plan framework, utilizing the results obtained from the sub-fractal difference analysis of periods II-III. Hot spot analysis refers to the process of

identifying areas that exhibit statistically significant clustering of a particular phenomenon or variable, in this case, environmental network data.

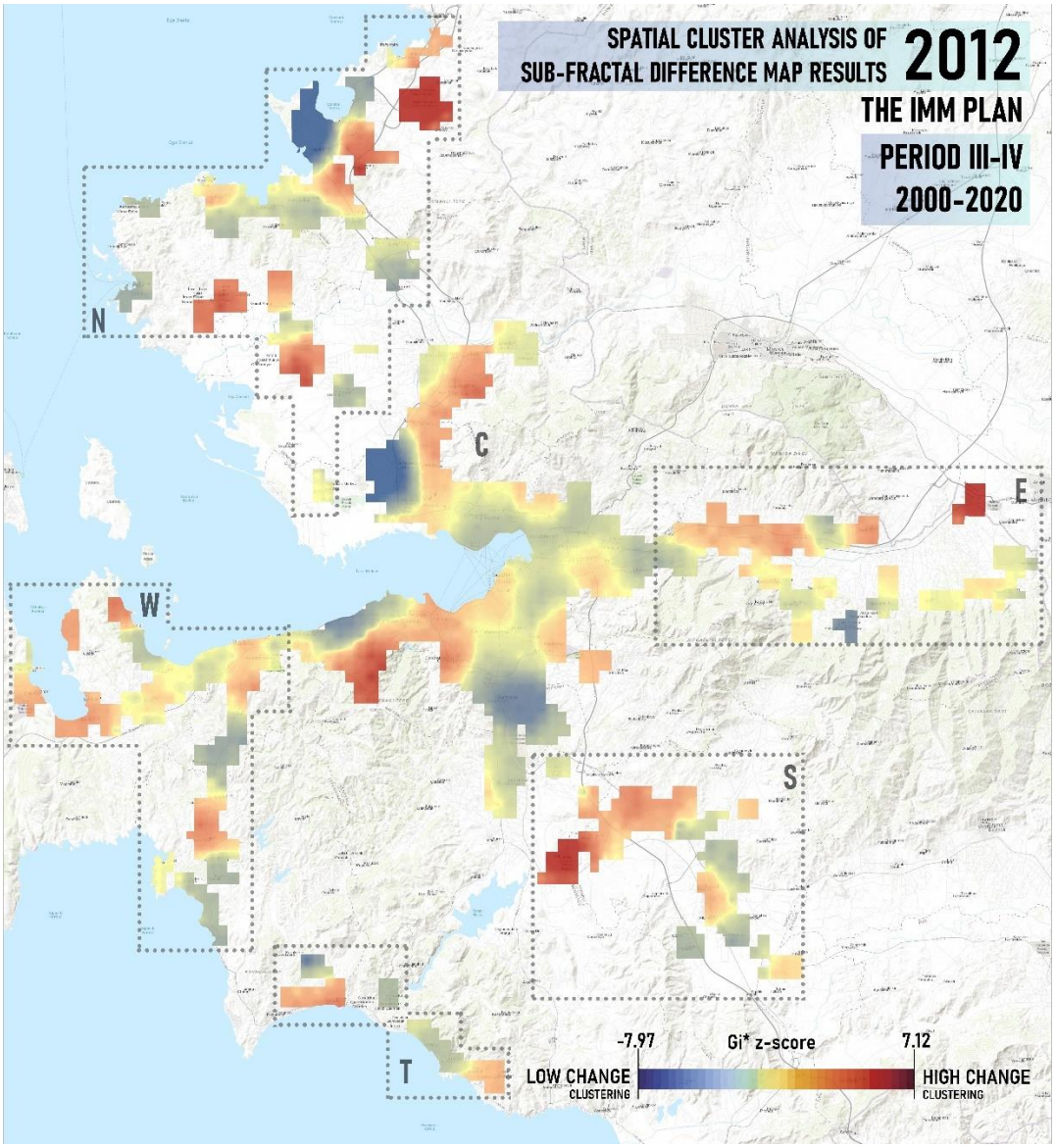


Figure 6.75 Spatial Cluster Analysis of the Sub-fractal Difference Map Results of the IMM 2012 Plan

- ***Interpretations of the Cluster Analysis***

Note that; *the study on spatial clustering analysis, which calculated the sub-fractal change between periods III and IV, has been completed based on the environmental plan of IMM 2012. However, to better understand the impact of the planning*

decisions on the complexity change of the city of Izmir and to enhance the visual experience, the IMM 2012 plan was divided into six regions, and comments were provided for each of these regions.

- ***North Region "N"***

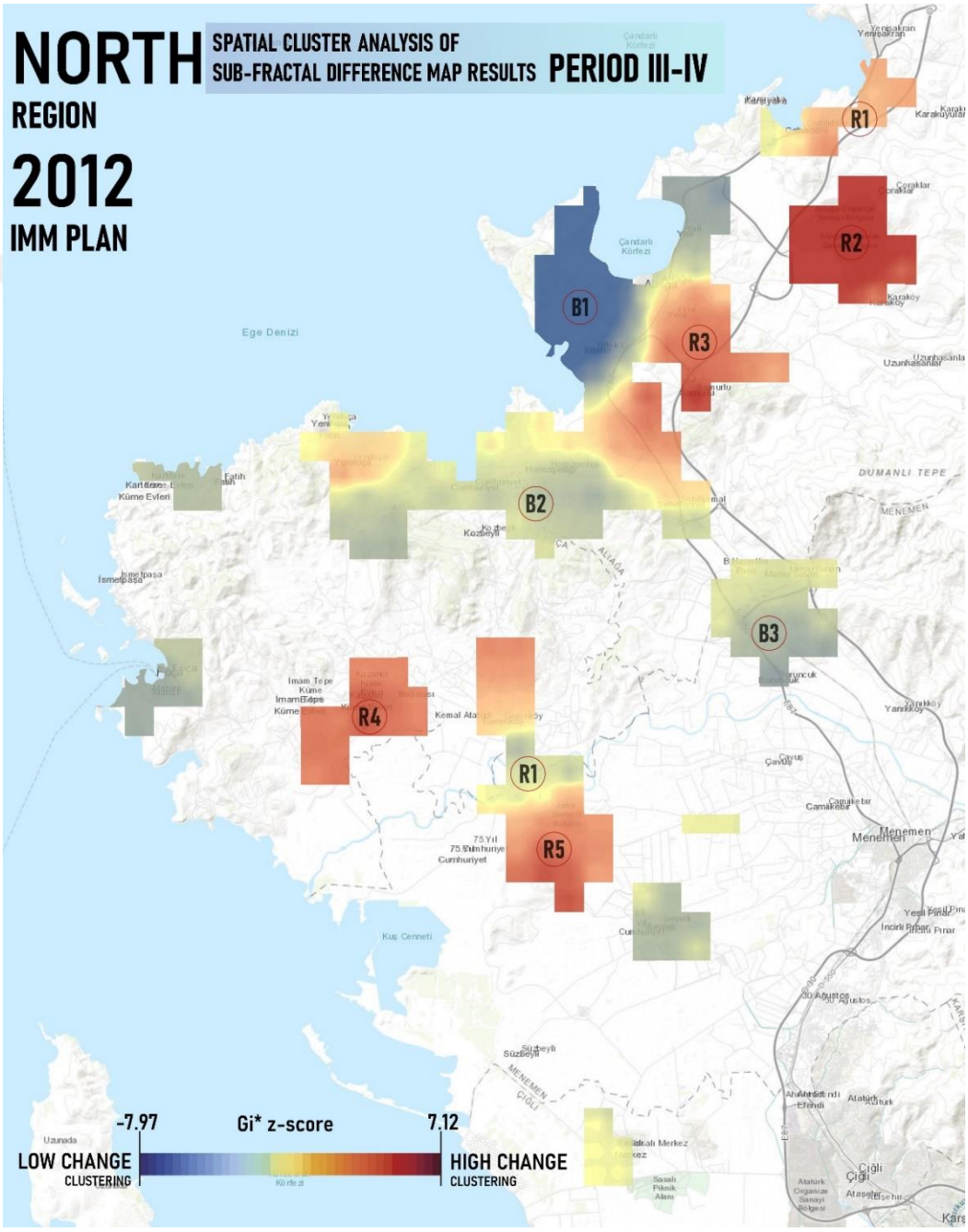


Figure 6.76 Spatial Cluster Analysis of the Sub-fractal Difference Map Results of the IMM 2012 Plan, the North Region

Zone R1 2012 North Region:

This notation refers to an area located in the Çaltılıdere, Kalabak, and Hacıömerli neighborhoods of the İzmir-Aliağa district, situated along the Çanakkale road, near the North Aegean Motorway. An analysis conducted within the boundaries of the IMM's 2012 Plan, from period III to period IV, shows that a high-level sub-fractal change resulted in a cluster. The Hotspot analysis indicates that this area has a high density, represented by the color red. The Yacht and Boat Manufacturing Center is the most critical location in the region. The IMM 2012 Plan proposed new residential development areas in these neighborhoods. The analysis studies reveal that there has been a positive sub-fractal change in this area, which is reflected in the result.

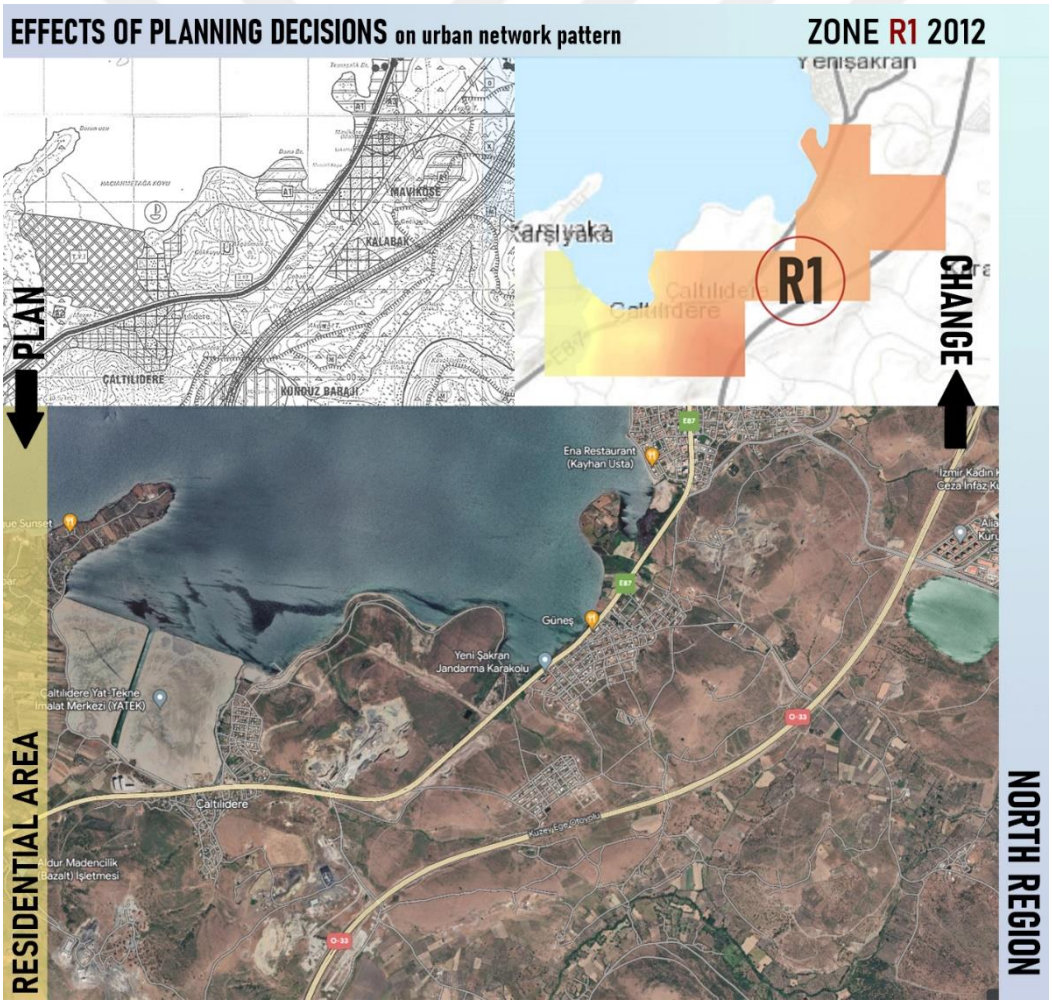


Figure 6.77 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the North Region, Zone R1 2012

Zone R2 2012 North Region:

The designated region specified in this notation is situated in the İzmir-Aliağa district, encompassing the area located between Koca Stream and Çoraklar Village to the east of the North Aegean Highway. According to the analyses conducted as part of the IMM 2012 Plan, which spans from Period III to Period IV, the area exhibits clustering resulting from a very high level of sub-fractal change. The hotspot analysis has revealed that this region is characterized by red-intensity colors, signifying a high degree of clustering.

The IMM 2012 Plan has declared this area as an Organized Industrial Zone, and this decision has been implemented. The rationale behind this decision was the proximity of the region to the TÜPRAŞ and PETKİM facilities located in Aliağa Bay and its location along the North Aegean Highway. The local and central administrations have played a supportive role in the development of this industrial zone, resulting in its rapid growth. As a result of this growth, the area's sub-fractal values have increased excessively compared to the previous period. The hotspot analysis has highlighted this area as one of the regions with the highest positive clustering value.

Additionally, the North Aegean Highway that runs through the area provides a vital link between the industrial facilities, making it an attractive location for businesses looking to establish a presence in the region. As a result, the area has seen significant development over the years, resulting in a marked increase in sub-fractal values, as highlighted by the hotspot analysis.

Moreover, the IMM's decision to designate the region as an Organized Industrial Zone is motivated by the goal of promoting economic development and job creation in the area. The implementation of this plan has resulted in the establishment of a diverse range of industrial facilities in the region, such as manufacturing plants, logistics centers, and warehouses, contributing to the growth of the local economy. The development of this industrial zone has also resulted in improved infrastructure, including road networks, utility services, and transportation facilities, which has facilitated the ease of conducting business operations.

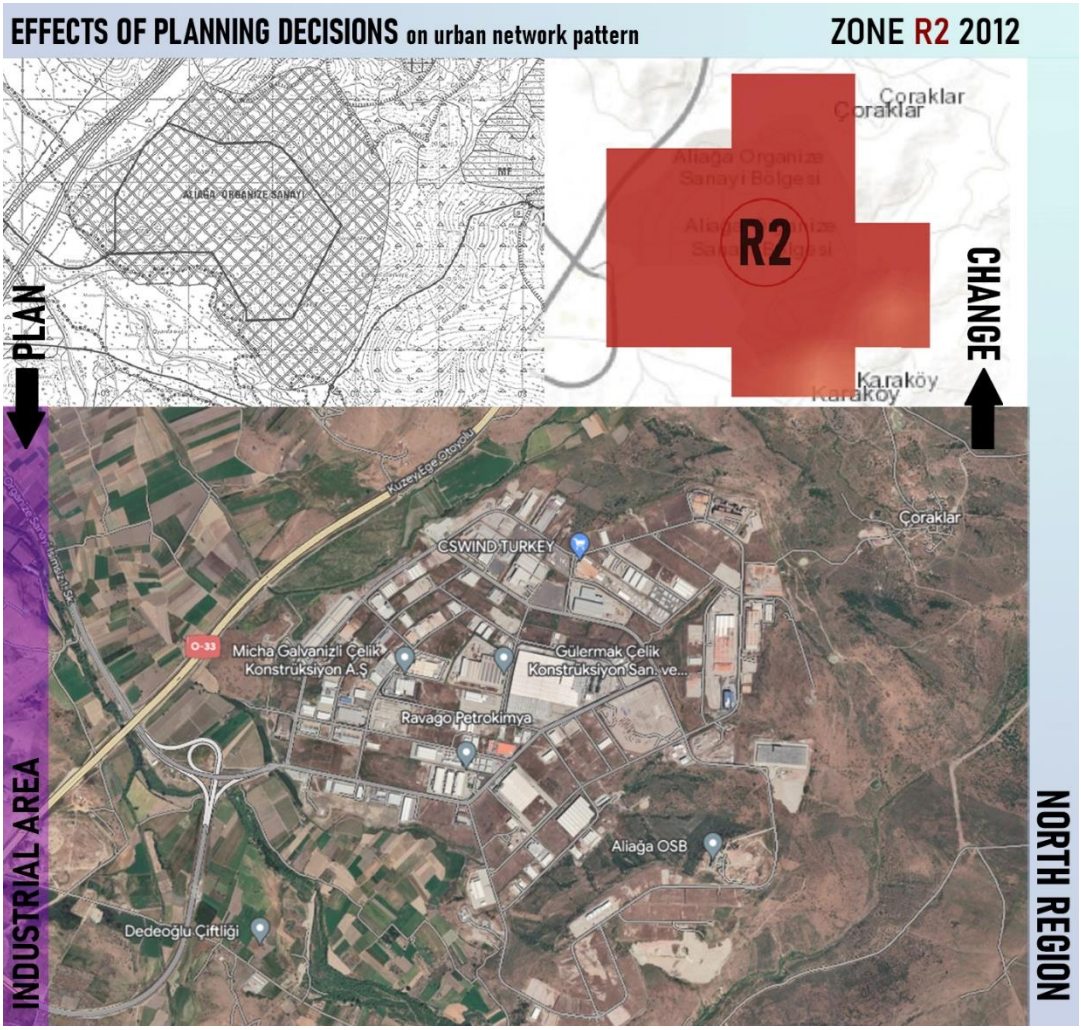


Figure 6.78 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the North Region, Zone R2 2012

Zone R3 2012 North Region:

The notation pertains to the Samurlu and Güzelhisar villages and surrounding areas, including the Yeni Neighborhood, located on the outskirts of the İzmir-Aliağa district center. The analyses were conducted using the III. and IV. period network data within the boundaries of the 2012 plan reveal a significant cluster resulting from high-level sub-fractal changes in the field. The area is identified as a hotspot, represented by red-density colors, which suggests a potential for further urbanization and development.

The developing industrial areas in the region are expected to generate demand for housing, leading to residential development in the IMM 2012 plan. Accordingly, plan proposals are being put forth in the Aliağa city center and nearby neighborhoods, as well as conservation areas that have been designated for preserving agricultural quality and forested regions. These regions are proposed as potential areas for housing development due to their strategic location along the North Aegean Motorway, which serves as the main transportation axis. Urban development along this axis is expected to alter the character of the urban network pattern.

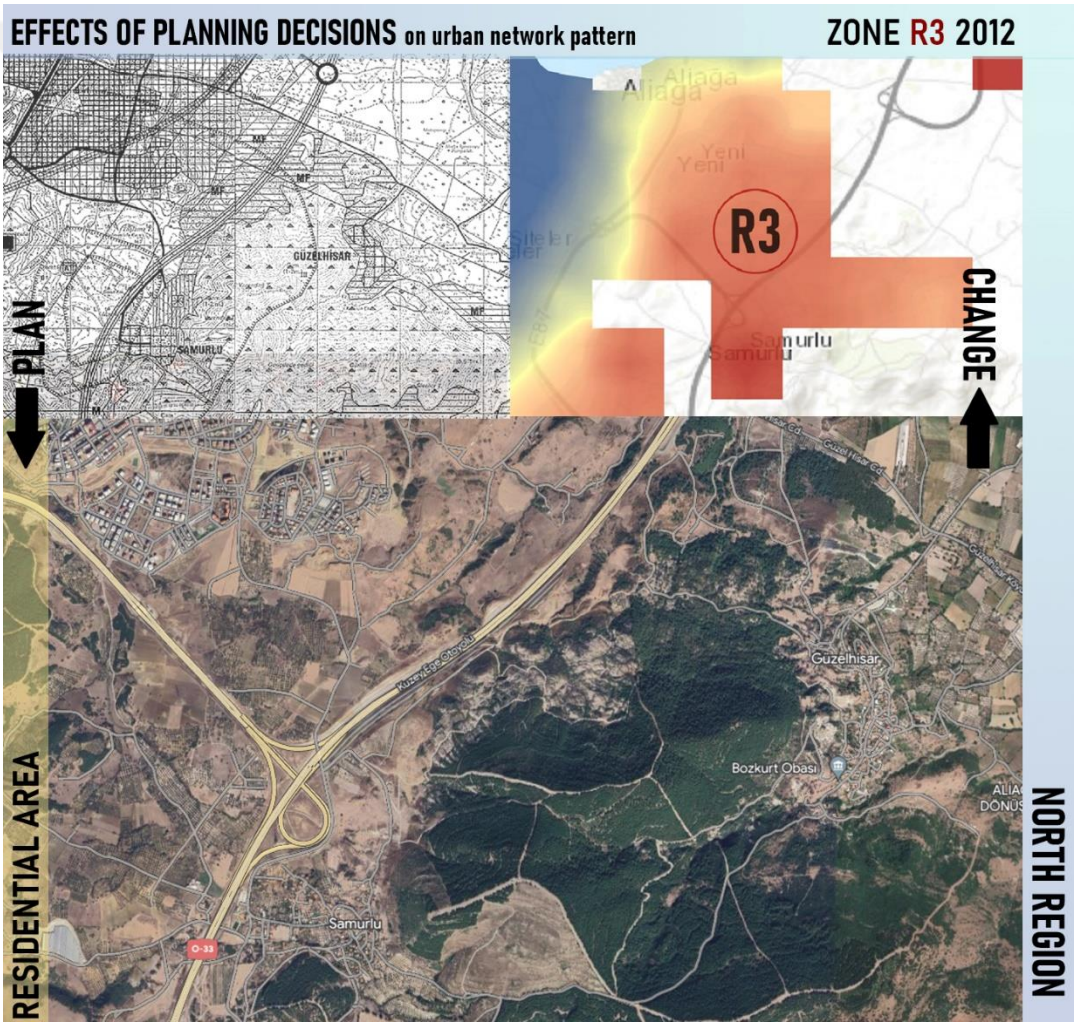


Figure 6.79 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the North Region, Zone R3 2012

Zone R4 2012 North Region:

The area indicated by this notation represents the centers of Bağarası, Yeni Bağarası, and Söğütçük neighborhoods of the Foça district in İzmir, as well as the surrounding areas. In the analyses prepared within the 2012 İzmir Metropolitan Municipality Plan using network data from periods III and IV, clustering was observed in the area due to a high-level sub-fractal change. As a result of hotspot analysis, this area is shown in red color indicating high density. These settlements have been observed to receive demand for seasonal use, and the planning authorities have recommended it as residential development areas. It is observed that the decision taken has been implemented.



Figure 6.80 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the North Region, Zone R4 2012

Zone R5 2012 North Region:

The area includes Maltepe and Villakent neighborhoods in the Menemen district of Izmir and the surrounding areas. Clustering was observed using network data from periods III and IV, caused by high-level sub-fractal changes within the boundaries of the 2012 Plan of Izmir Metropolitan Municipality. The Menemen Leather Free Zone, which was opened in 1998, was renamed Izmir Free Zone-IZBAS in 2011 (the decision numbered 2011/1649 was published in the Official Gazette on 28.04.2011 by the Council of Ministers). The 2012 plan proposed residential development around this industrial zone according to the needs and demands, which was implemented based on the conducted analyses.

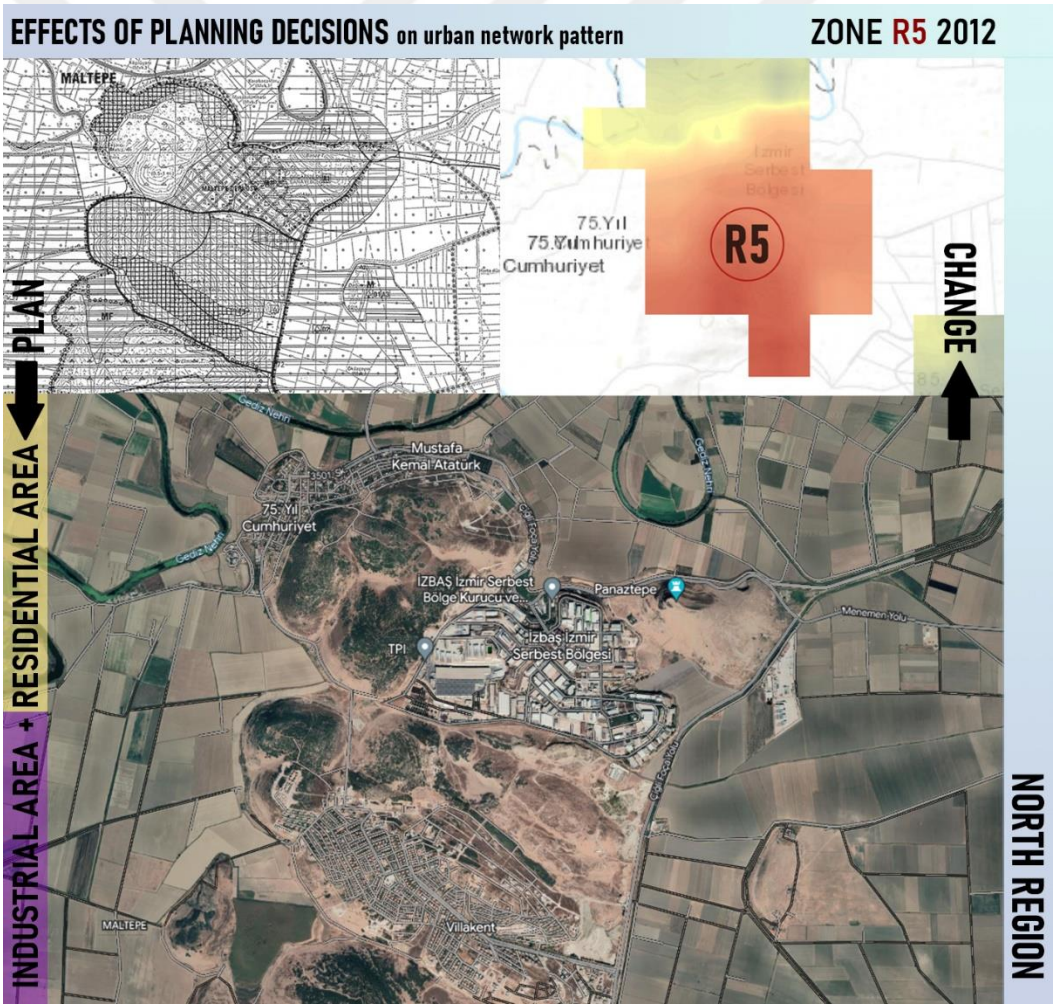


Figure 6.81 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the North Region, Zone R5 2012

Zone B1 2012 North Region:

The area represented by this notation is located in the Atatürk neighborhood of the Aliağa district of İzmir, and it includes the industrial facilities of TÜPRAŞ and PETKİM, located to the west of the Aliağa (Çandarlı) Gulf.

According to the analysis conducted using periods III and IV network data within the boundaries of the İzmir Metropolitan Municipality (IMM) 2012 Plan, clustering is observed in the area due to a very low-level sub-fractal change. The hotspot analysis shows this area with high density in blue.

PETKİM was established in this area in 1965, followed by TÜPRAŞ in 1972. Over time, the facilities have expanded and reached their current boundaries, which have been maintained in the relevant plans.

The clustering and hotspot analyses conducted in the area showed that industrial areas are generally expressed with positive clustering tendencies and red density representations. However, in this area, the opposite result was obtained. In other words, the area was expressed with a negative clustering tendency and a blue density representation.

There are two reasons for this situation;

- First, the area was designated as a "Special Project Area" by the Ministry of Environment and Urbanization with the Ministerial Approval no. 7792 dated 23.05.2013, in accordance with Article 2, paragraph (ğ) of the Law on the Organization and Duties of the Ministry of Environment and Urbanization, No. 644 (Çevre ve Şehircilik Bakanlığı, 2013).
- Second, the coasts of TÜPRAŞ were declared as "Special Security Zone." Due to these reasons, the network data for this area could not be processed on the Period IV network map.

Therefore, as there was a significant decrease in the pattern formation, the results of the clustering and hotspot analyses were reflected as negative clustering tendencies.

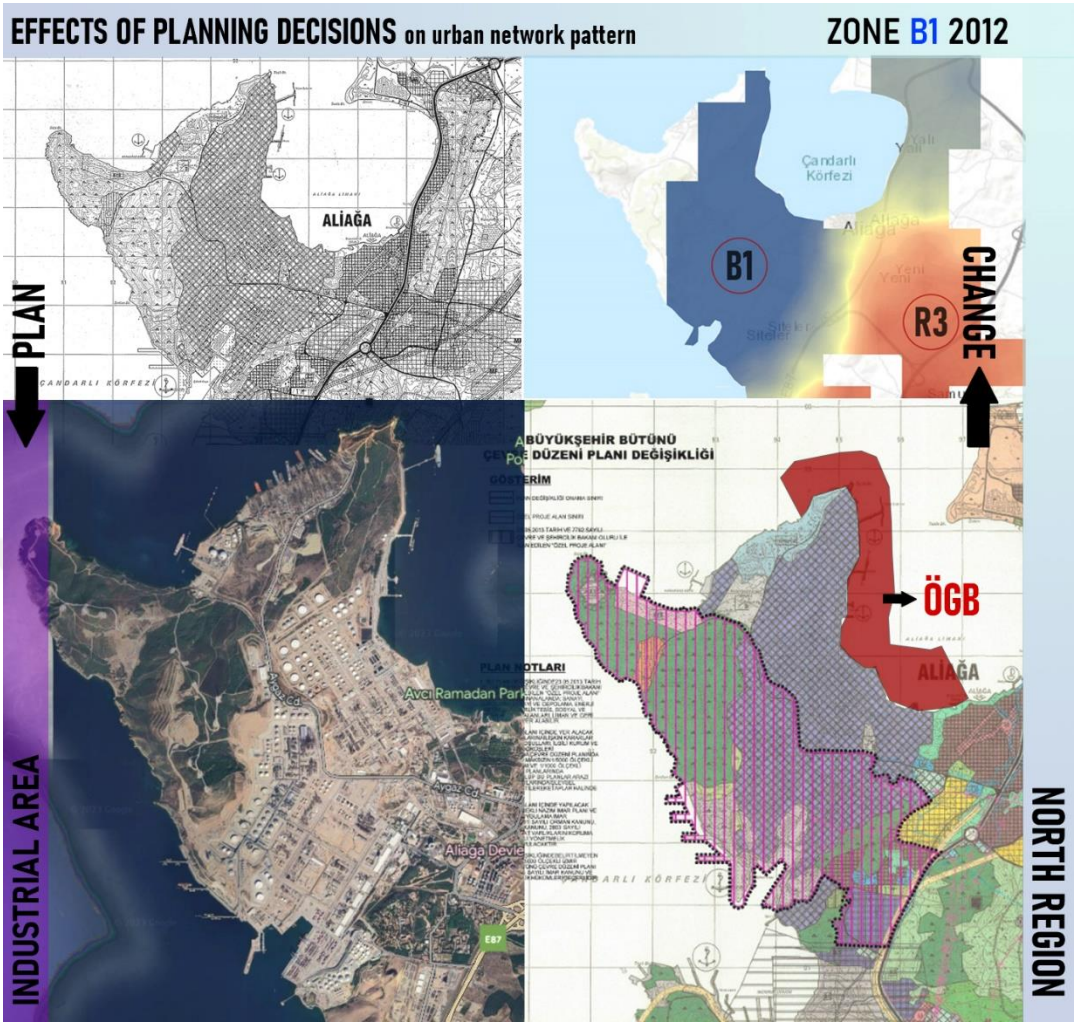


Figure 6.82 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the North Region, Zone B1 2012 (Çevre Şehircilik Bakanlığı, 2013)

Zone B2 2012 North Region:

The area represented by this notation is the forested and qualified agricultural areas located south of the Foça connection road within the boundaries of the Bozköy neighborhood of the İzmir-Aliağa district. In the analyses prepared using the period III and period IV network data within the scope of the IMM (Izmir Metropolitan Municipality) 2012 Plan, clustering caused by low-level sub-fractal change is observed in the area. As a result of the hotspot analysis, this area is shown in blue-density colors. In the IMM 2012 plan, this area is designated as a forest area, and no change has been observed in the network pattern from 2000 to 2020.

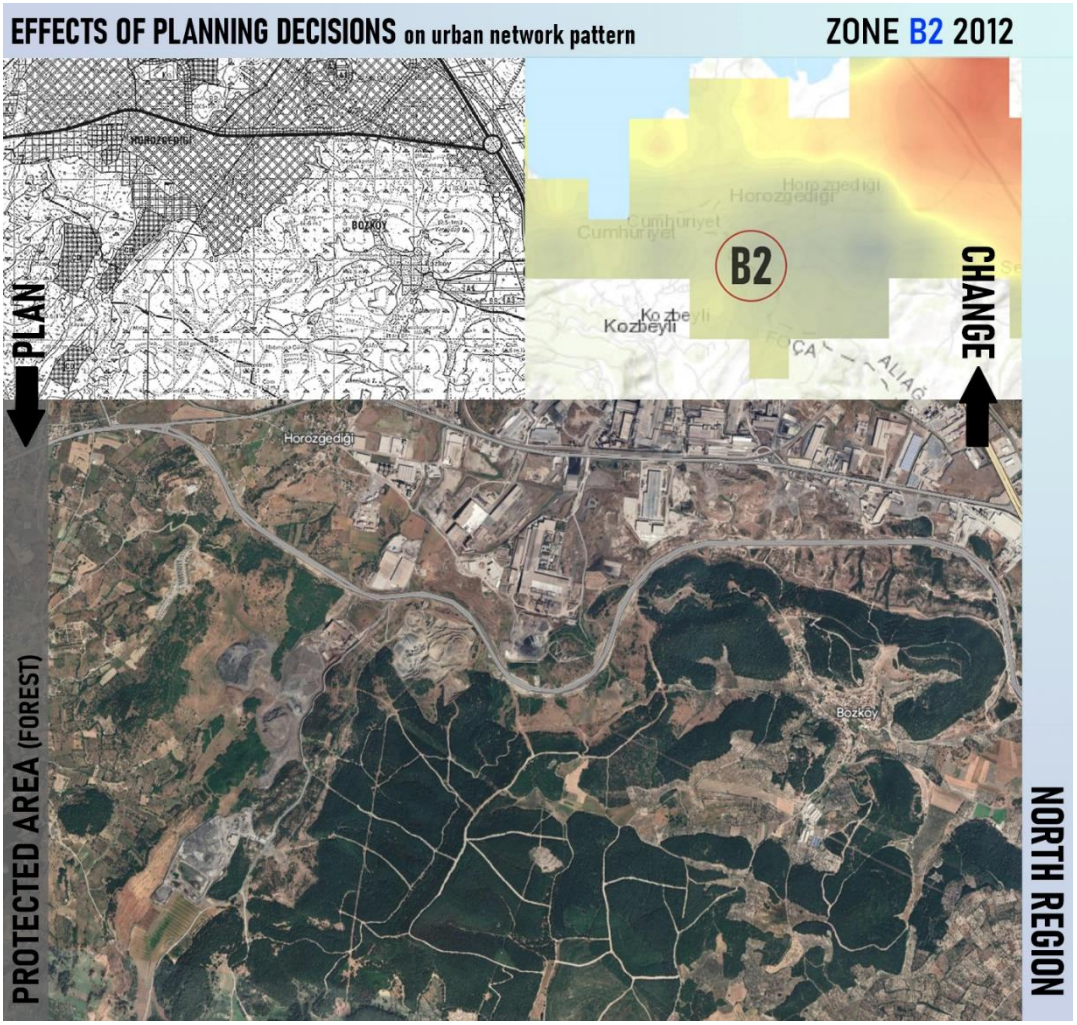


Figure 6.83 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the North Region, Zone B2 2012

Zone B3 2012 North Region:

The area indicated by this notation represents the Buruncuk neighborhood of the Menemen district of Izmir, located to the east of the Izmir-Canakkale Road and its surroundings. In the analyses prepared using period III and period IV network data within the boundaries of the Izmir Metropolitan Municipality's (IMM) 2012 Plan, clustering caused by low-level sub-fractal change is observed in the area. As a result of the hotspot analysis, this area is shown in blue-dense colors. In the IMM 2012 plan, this area is identified as an archaeological site with Roman-Byzantine ruins, and no change has been observed in the network pattern from 2000 to 2020.

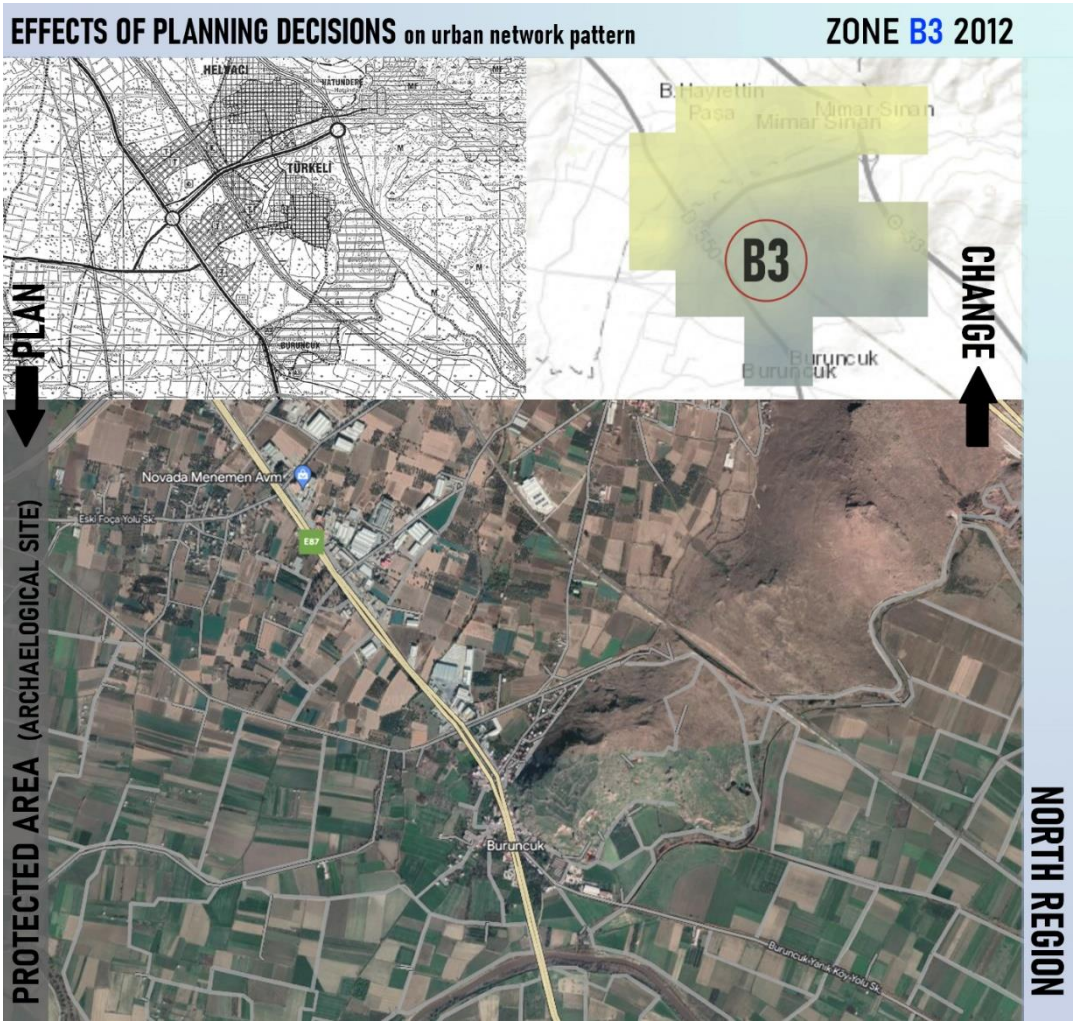


Figure 6.84 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the North Region, Zone B3 2012

- ***South Region "S"***

The southern region of the city of Izmir exhibits the highest sub-fractal variation in the previous sections of this study, with an observed change of 22.32%. When looking at the area as a whole, it can be said that the main reason for this change is the industrial area decisions made in the IMM 2012 plan. However, it is observed that these decisions were not aimed at establishing new industrial areas from scratch, but rather a legal regulation was implemented to facilitate the organized development of the industrial areas that were already emerging in the region. The reasons for the shift of industrial areas to this region can be attributed to; the completion of new fast

highways making the region more favorable for production, the limits of industrial areas in other regions reaching their thresholds, and a certain saturation level being reached in the network pattern of these areas.

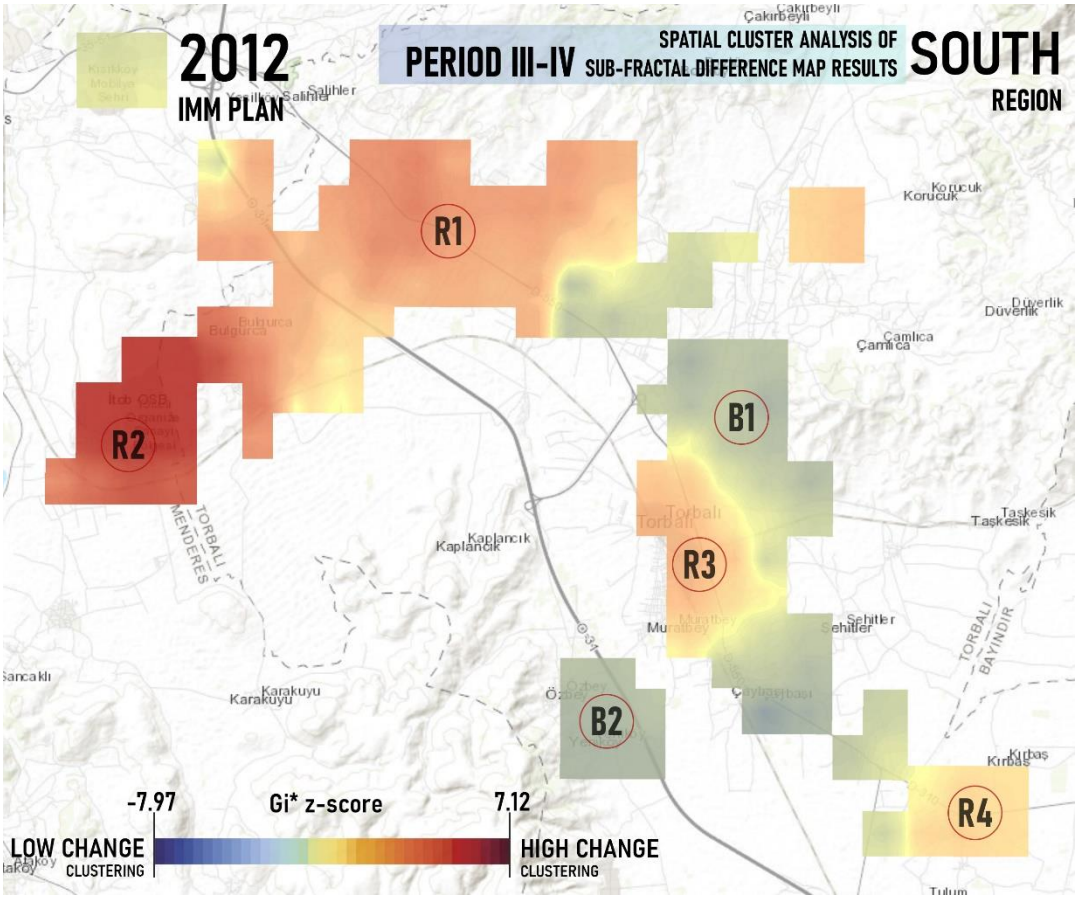


Figure 6.85 Spatial Cluster Analysis of the Sub-fractal Difference Map Results of the IMM 2012 Plan, the South Region

Zone R1 2012 South Region:

The area represented by this notation is generally located in the northern region of the İzmir-Torbalı district and corresponds to the industrial zones in the region. These areas are organized along the Old İzmir-Aydın Avenue and the New İzmir-Aydın Highway. The region covers a large area that includes Pancar, Torbalı OSB, Bahçelievler, Ayrancılar, and Yazıbaşı neighborhoods.

In analyses prepared using period III and period IV network data within the scope of the İzmir Metropolitan Municipality (IMM) 2012 Plan, clustering caused by a high-

level sub-fractal change was observed in the area. As a result of hotspot analysis, this area is shown in red high-density colors.

In the IMM 2012 Plan, new industrial areas were proposed for this area due to the effect of existing industrial areas and new highways. In addition, new residential development areas were proposed around neighborhood centers due to the expected population growth. It has been observed that these recommendations have been implemented or are in the process of being implemented and have caused positive changes in the network pattern of the area based on the analyses conducted.

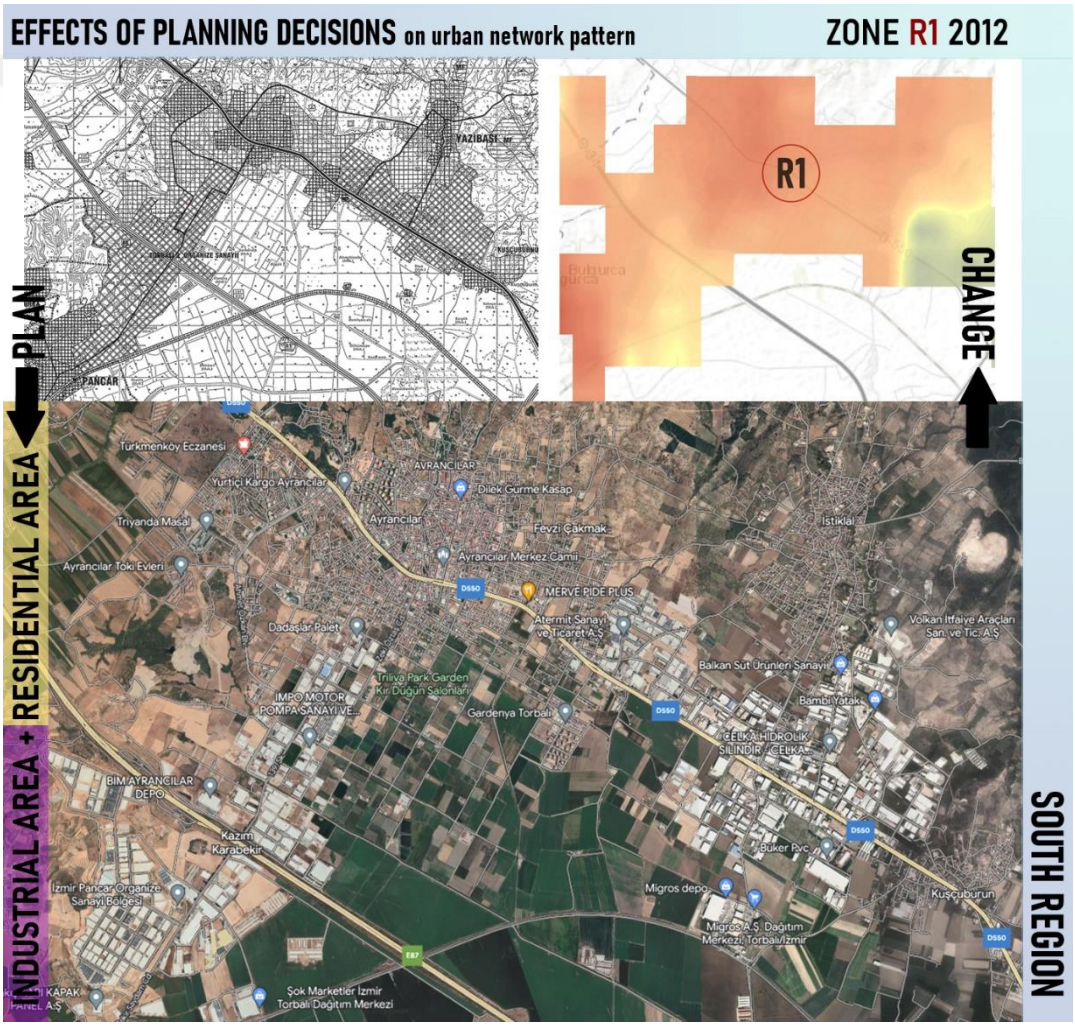


Figure 6.86 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the South Region, Zone R1 2012

Zone R2 2012 South Region:

The area indicated by this notation represents the Tekeli Atatürk, Tekeli Fevzi Çakmak, and İTOB OSB neighborhoods and their surroundings in the Menderes district of İzmir.

In analyses prepared using period III and period IV network data within the boundaries of the İzmir Metropolitan Municipality (IMM) 2012 Plan, clustering caused by a very high level of sub-fractal change is observed in the area. As a result of hotspot analysis, this area is shown in red density colors.

In 2002, the decision to establish an organized industrial zone belonging to the İzmir Chamber of Commerce was made in the region, and it was implemented. This area was identified as an industrial zone by the IMM 2012 plan authorities, and a small amount of residential development area was suggested in response to its potential for attracting the population.

As seen in this example, the industrial area was formed first and then included in the plan. The effect of industrial areas established after 2000 was reflected in the 2020 data, and it was observed that the complexity level of the network pattern of industrial areas had a very high impact.

This area is not suitable for development and expansion due to the thresholds around it. There are forest areas to the north of the area, qualified agricultural areas to the south, and one archaeological site.

It is observed that these handicaps were not considered when the industrial area was established, and it was seen that the planning principles were not reflected in space by the authorities during the formation of the industrial area.

Finally, according to the analyses conducted, it is observed that the said region is one of the areas where the network pattern undergoes the most change.

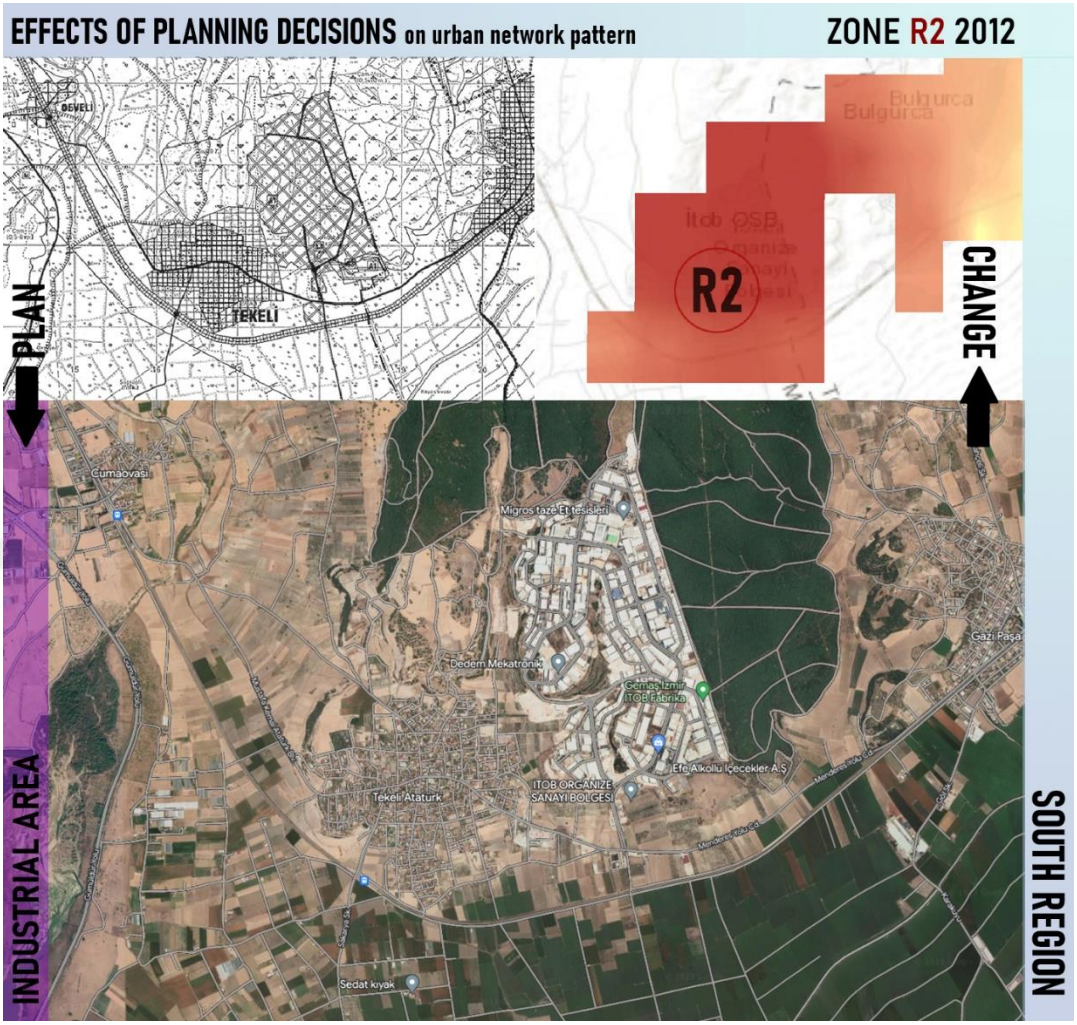


Figure 6.87 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the South Region, Zone R2 2012

Zone R3 2012 South Region:

This notation represents the center of the Torbalı district of Izmir and its surroundings. In the analyses prepared using period III and period IV network data within the boundaries of the 2012 Plan of Izmir Metropolitan Municipality (IMM), clustering caused by high-level sub-fractal changes were observed in the area. As a result of the hotspot analysis, this area is shown in red density colors.

Before 2000, an industrial area was established north of the Torbalı district. The site, which was proposed as a 260-hectare organized industrial zone by the Ministry of Industry and Trade and approved initially as approximately 665,000 m^2 (66.5

hectares), was mostly completed before the early 2000s. It was observed that the sub-fractal changes values of the parts that could not be completed and the areas where the residential development area proposals of the IMM 2012 plan were located, had high sub-fractal change values.

The previously realized industrial area was included in the plan, and the residential development area proposal associated with this industrial area was introduced with the IMM 2012 plan. In the analysis results, it was observed that the plan proposal was realized and changed the network pattern.

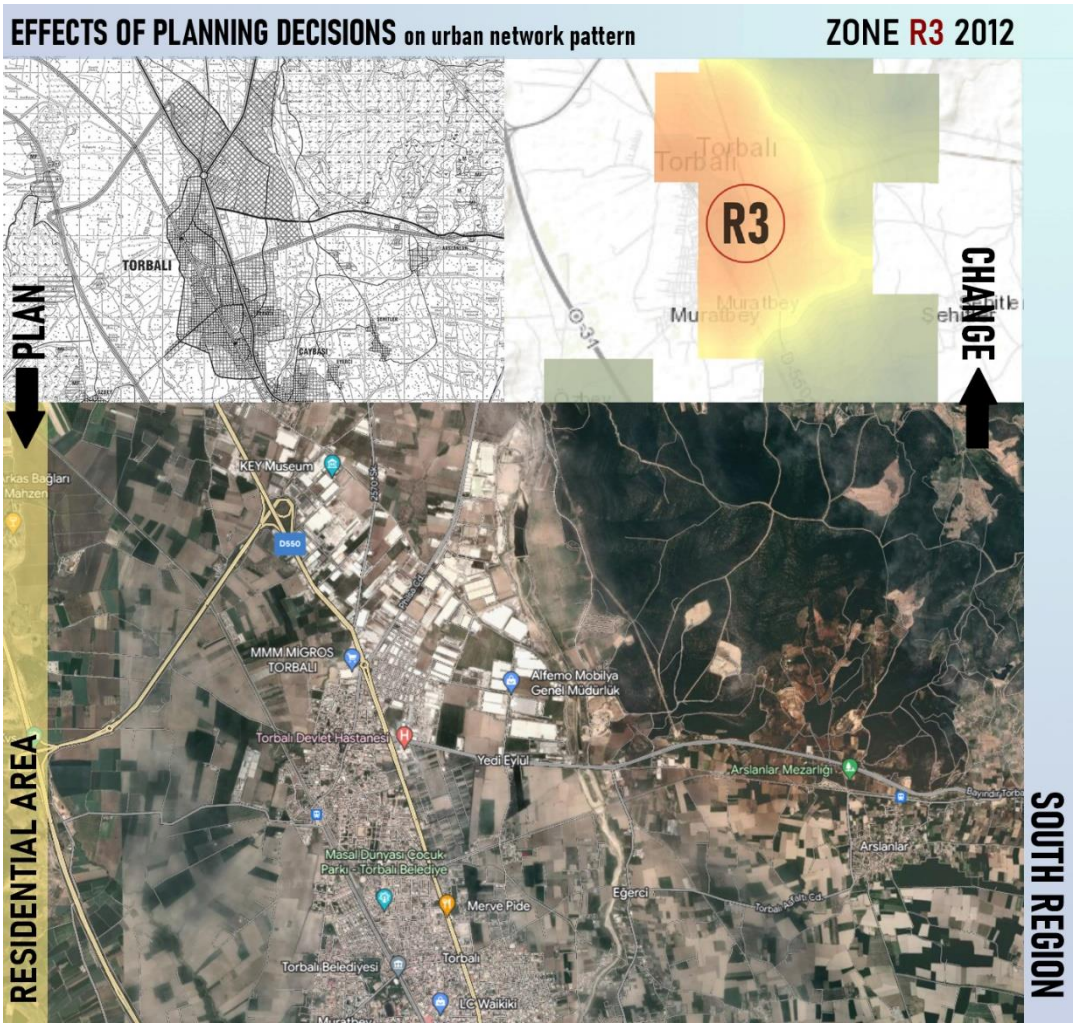


Figure 6.88 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the South Region, Zone R3 2012

Zone R4 2012 South Region:

The area represented by this notation corresponds to the center of Subaşı neighborhood in the district of Torbalı, İzmir. In the analyses conducted using the network data of periods III and IV within the boundaries of the IMM 2012 plan, a clustering phenomenon caused by a high-level sub-fractal change was observed in the area. As a result of the hotspot analysis, this area is indicated by a red color indicating high density. IMM 2012 Plan proposed a residential development area around the Subaşı neighborhood. The main reason for this proposal can be considered as the population increase caused by the industrial and storage areas that emerged to the west of the Subaşı neighborhood. Then, the IMM 2012 Plan proposed the expansion of the boundaries of the new residential areas that had already begun to emerge, designating them as residential development areas.

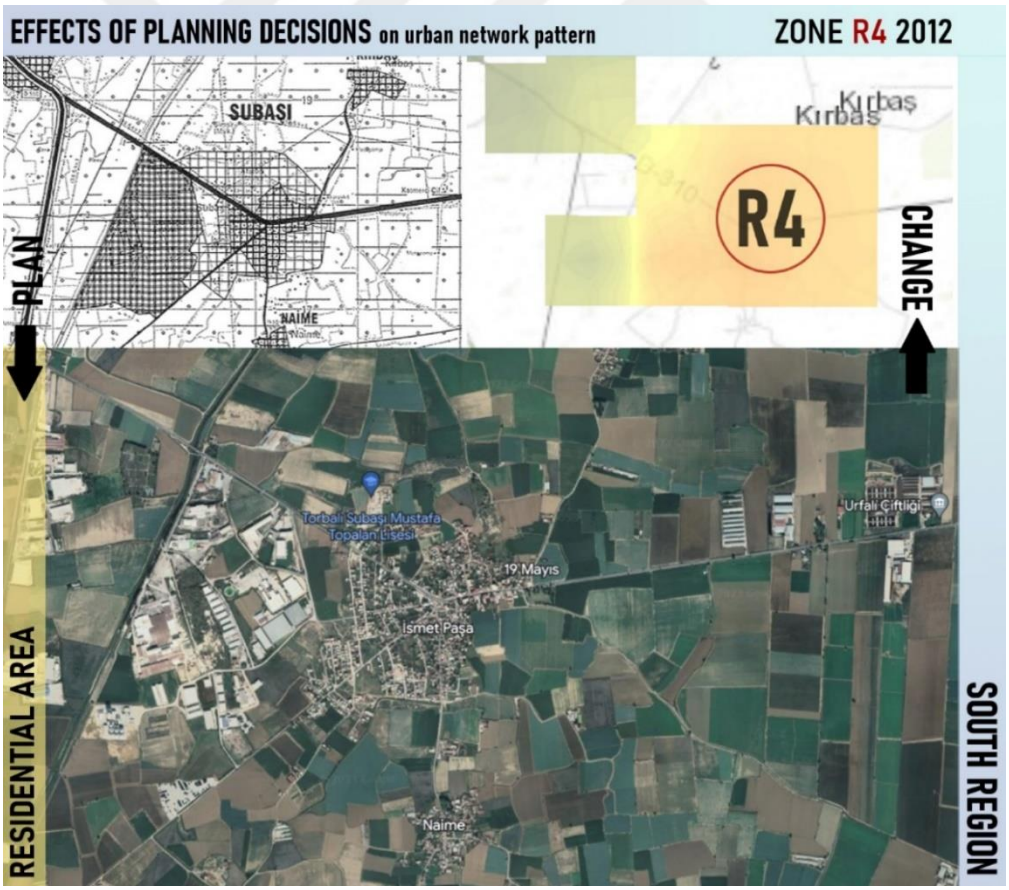


Figure 6.89 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the South Region, Zone R4 2012

Zone B1 2012 South Region:

The area represented by this notation encompasses the agricultural lands located north of the Torbalı Organized Industrial Zone and the forested areas to the east of the Torbalı district in İzmir. Analyses prepared using period III and IV network data within the scope of the İzmir Metropolitan Municipality (IMM) 2012 Plan reveal clustering caused by low-level sub-fractal variation in the area. As a result of the hotspot analysis, this area is depicted in blue-density colors. According to the IMM 2012 Plan, the areas in the north are designated as "agricultural areas" while the areas to the east are designated as "forest areas." Consequently, it was observed that there was no change in the network pattern as these areas were protected, and the results of the analysis were reflected accordingly.

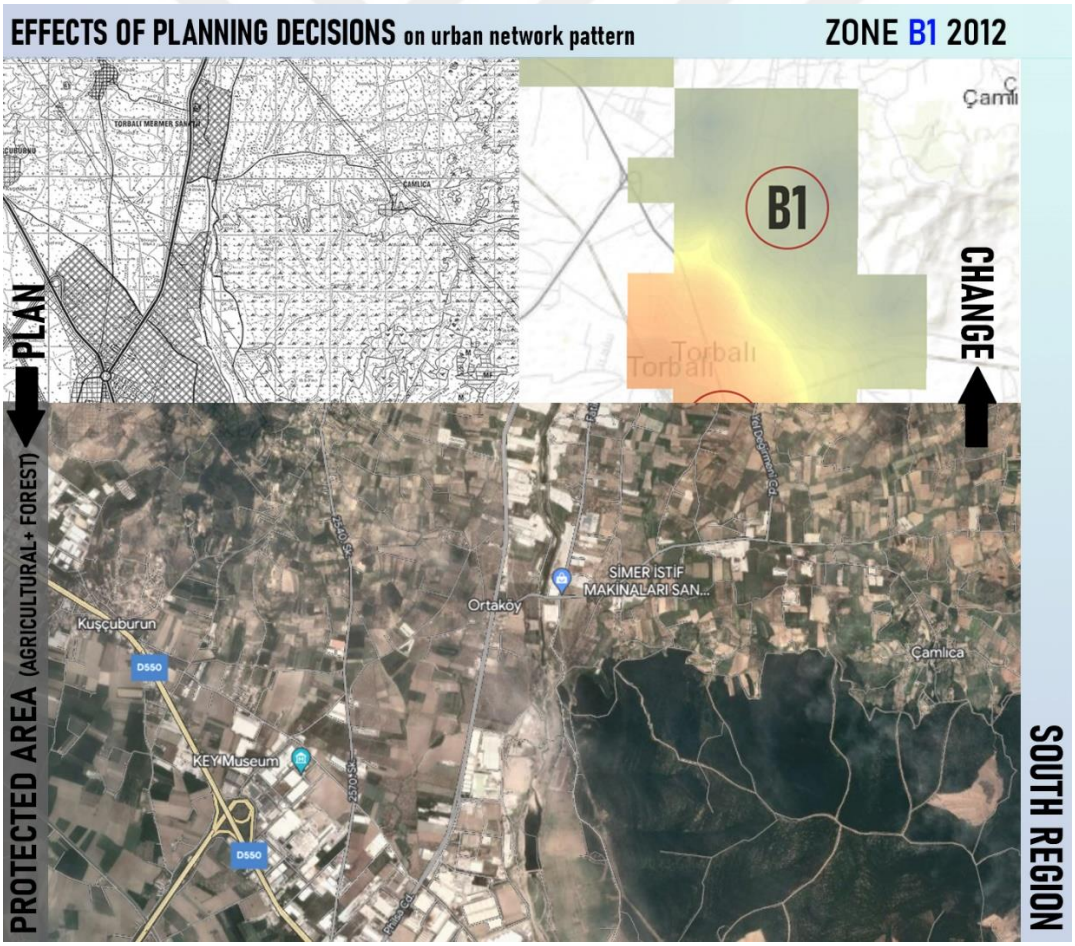


Figure 6.90 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the South Region, Zone B1 2012

Zone B2 2012 South Region:

The area indicated by this notation represents the neighborhoods of Özbey and Yeniköy in the Torbalı district of Izmir, along with the surrounding areas. According to the analyses conducted using the network data of periods III and IV within the boundaries of the IMM's 2012 Plan, clustering has been observed in the area due to low-level sub-fractal changes. As a result of the hotspot analysis, this area is shown in blue-density colors. In the 2012 plan of the IMM, the area between the neighborhoods of Özbey and Yeniköy is defined as a first-degree archaeological site. The east of the neighborhoods consists of qualified agricultural areas, while the west is composed of shrubland and forest areas. Based on these definitions, no change has been observed in the network pattern, which is reflected in the analysis results.

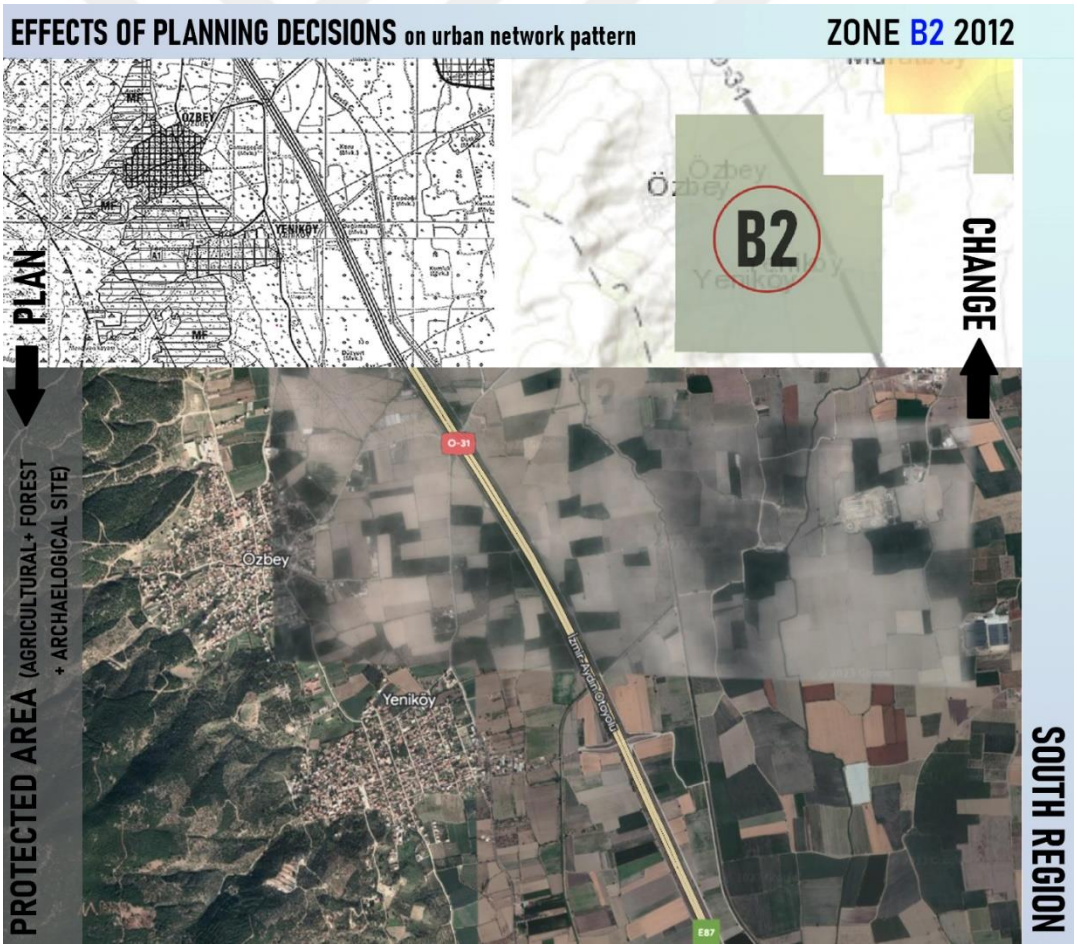


Figure 6.91 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the South Region, Zone B2 2012

- ***West Region "W"***

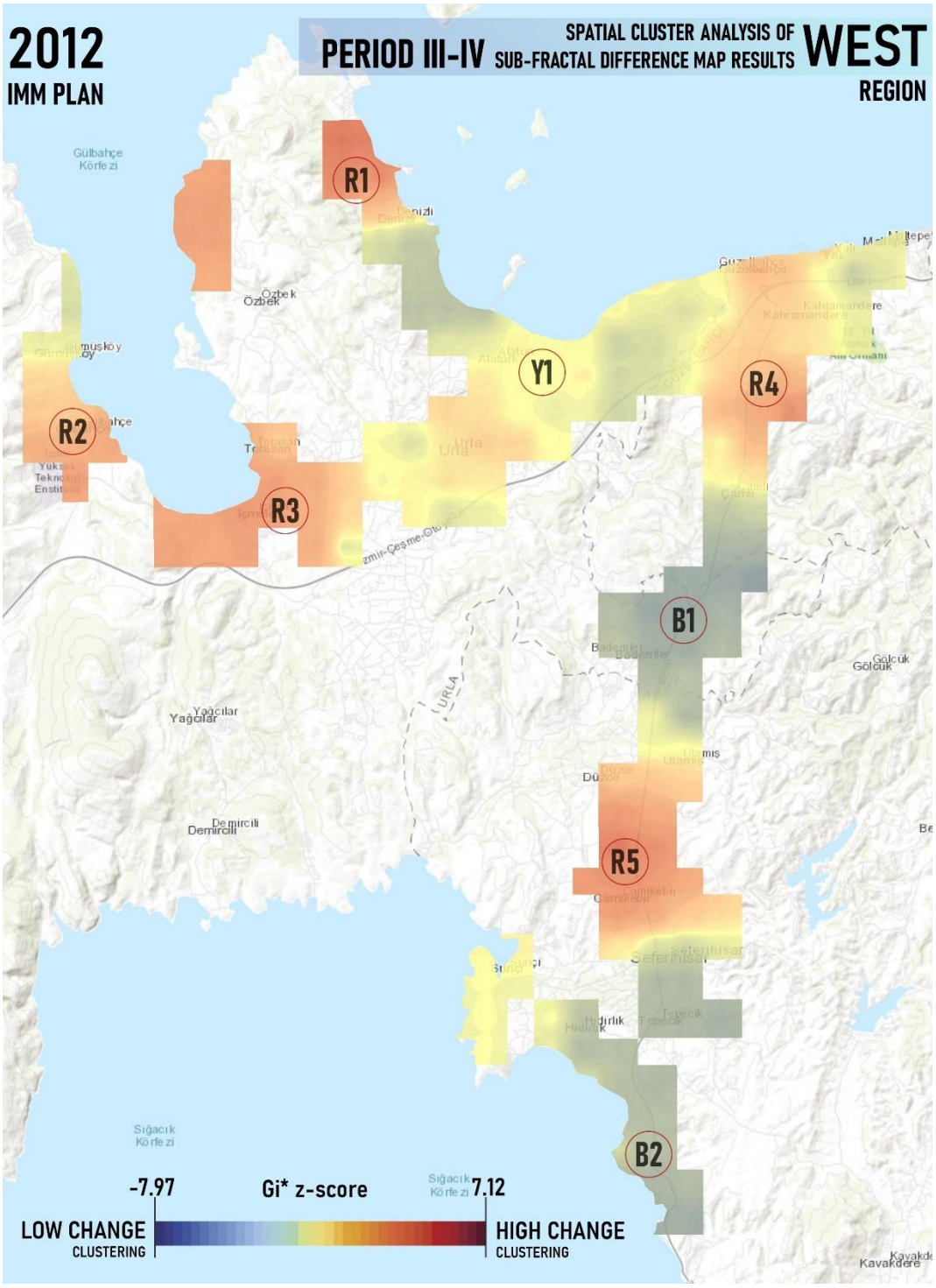


Figure 6.92 Spatial Cluster Analysis of the Sub-fractal Difference Map Results of the IMM 2012 Plan, the West Region

Zone R1 2012 West Region:

The area represented by this notation encompasses the Çeşmealtı, Güvendik, and Denizli neighborhoods of the Urla district in İzmir, as well as the surrounding areas. Analyses conducted using network data from periods III and IV within the boundaries of the IMM 2012 Plan have revealed clustering in the area due to high-level sub-fractal changes. As a result of hotspot analysis, this area is represented by red intensity colors. In the IMM 2012 Plan, the area south of the region, which contains an archaeological site, was proposed as a new residential development area between the archaeological site and urban settlements that had already begun forming. The north of the area was designated as a preferred usage area for the IMM 2012 Plan (suitable for all types of commercial use). As evidenced by the analysis results, these developments have positively influenced the network pattern.

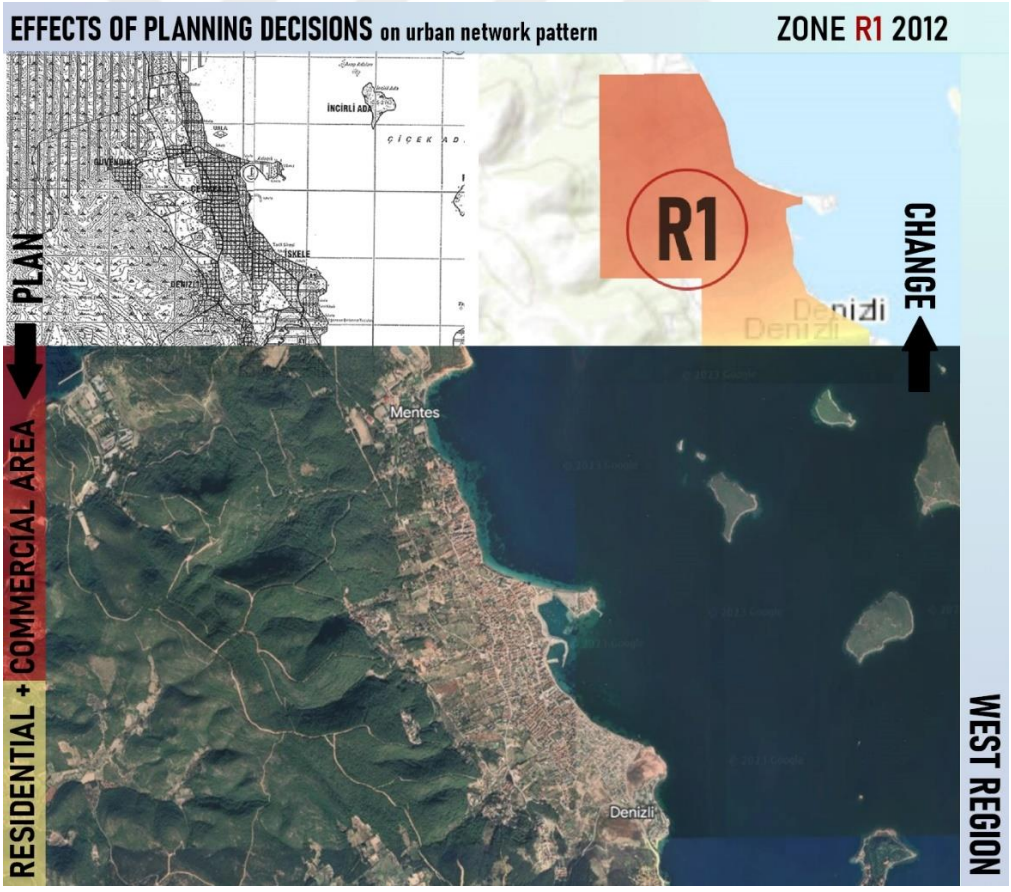


Figure 6.93 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the West Region, Zone R1 2012

Zone R2 2012 West Region:

The area indicated by this notation represents the Gülbahçe neighborhood of the Urla district in İzmir, as well as the surrounding area of the İYTE Gülbahçe Campus. In the analyses prepared using period III and period IV network data within the boundaries of the IMM 2012 Plan, clustering caused by high-level sub-fractal changes in the area was observed. As a result of hotspot analysis, this area is shown in red high-density colors. The İYTE Gülbahçe Campus was opened in 1999, which led to population growth pressure in the area. The IMM 2012 Plan proposed new residential development areas in response to the need for local residential areas. Since the opening of the Teknopark area within the campus and the expansion of the campus after 2000, it has been observed that the network pattern of the region has changed positively.

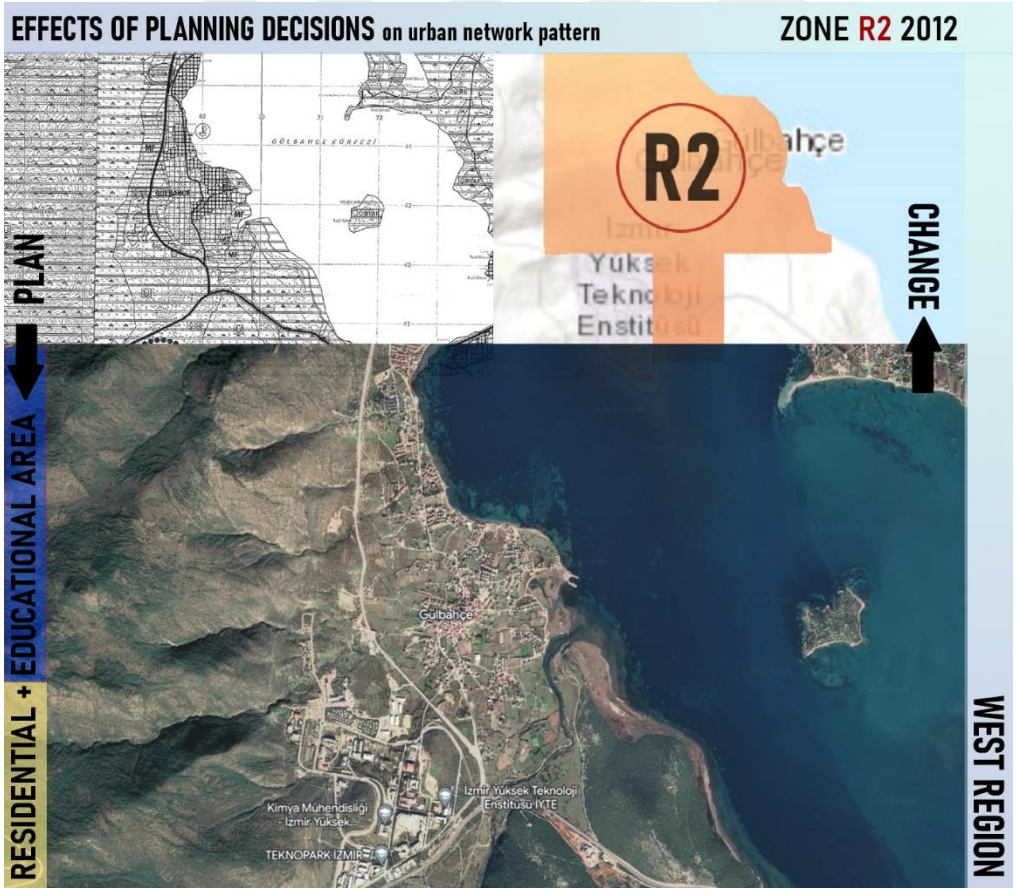


Figure 6.94 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the West Region, Zone R2 2012

Zone R3 2012 West Region:

The area indicated by this notation represents the surroundings of the İçmeler and Torasan neighborhoods of the Urla district in İzmir, Turkey. In analyses conducted using network data from phases III and IV, within the boundaries of the 2012 Plan of the IMM, clustering was observed in the area due to high-level sub-fractal change. As a result of the hotspot analysis, this area is shown in red-colored densities. Local movements have occurred in the area due to its tourist attraction. The IMM 2012 Plan, therefore, proposed the coastal areas of İçmeler and the western region of the İçmeler neighborhood as a "tourism facility area." At the same time, residential development areas were proposed due to the natural increase in the area's population, and it was observed that these proposals changed the network pattern.

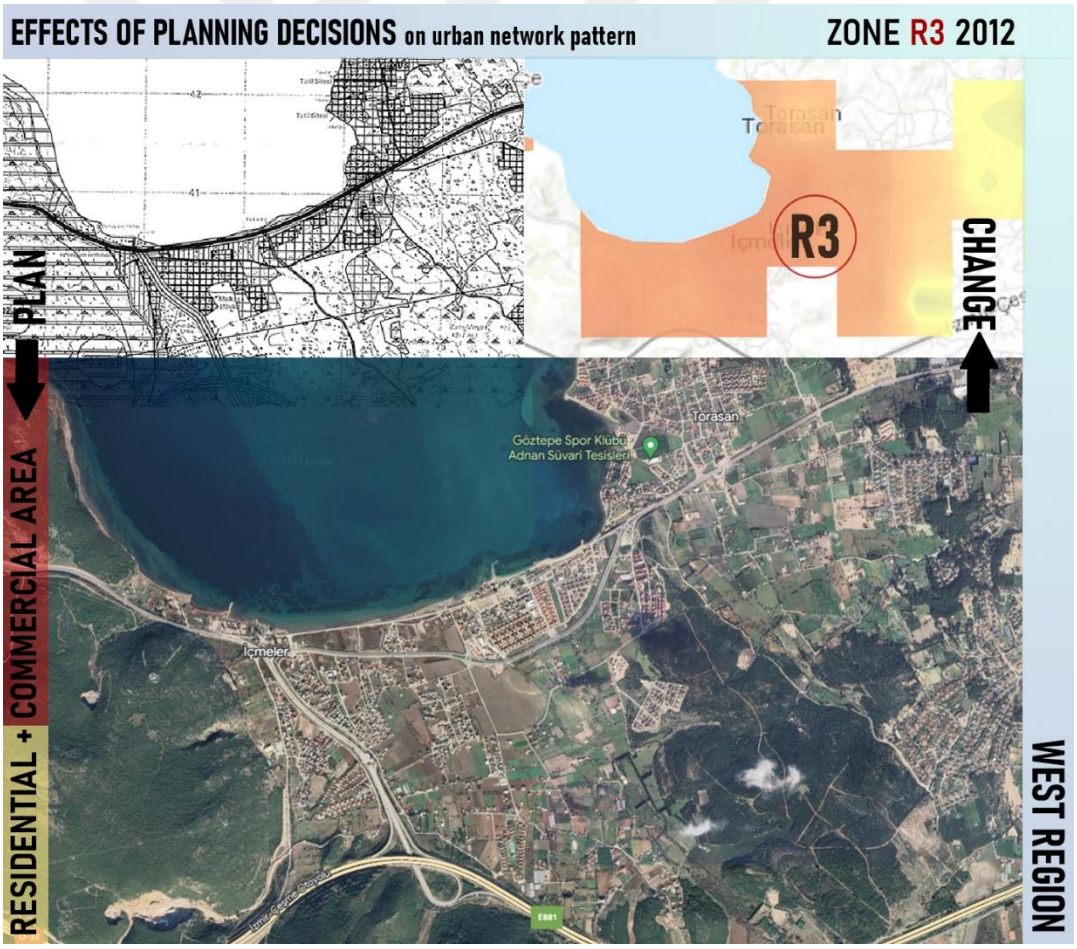


Figure 6.95 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the West Region, Zone R3 2012

Zone R4 2012 West Region:

The area indicated by this notation represents the southern parts of the Güzelbahçe district of Izmir and its surroundings. Within the boundaries of the 2012 Izmir Metropolitan Municipality (IMM) Plan, using period III and IV network data, analyses were conducted, which revealed clustering due to high-level sub-fractal variation in this area. As a result of hotspot analysis, this area is shown in red, indicating high density. Local mobility has been observed in the area due to its tourist attraction. The 2012 IMM Plan proposed residential development areas in response to the demand of summer residents, and it has been observed that these proposals have changed the network pattern.

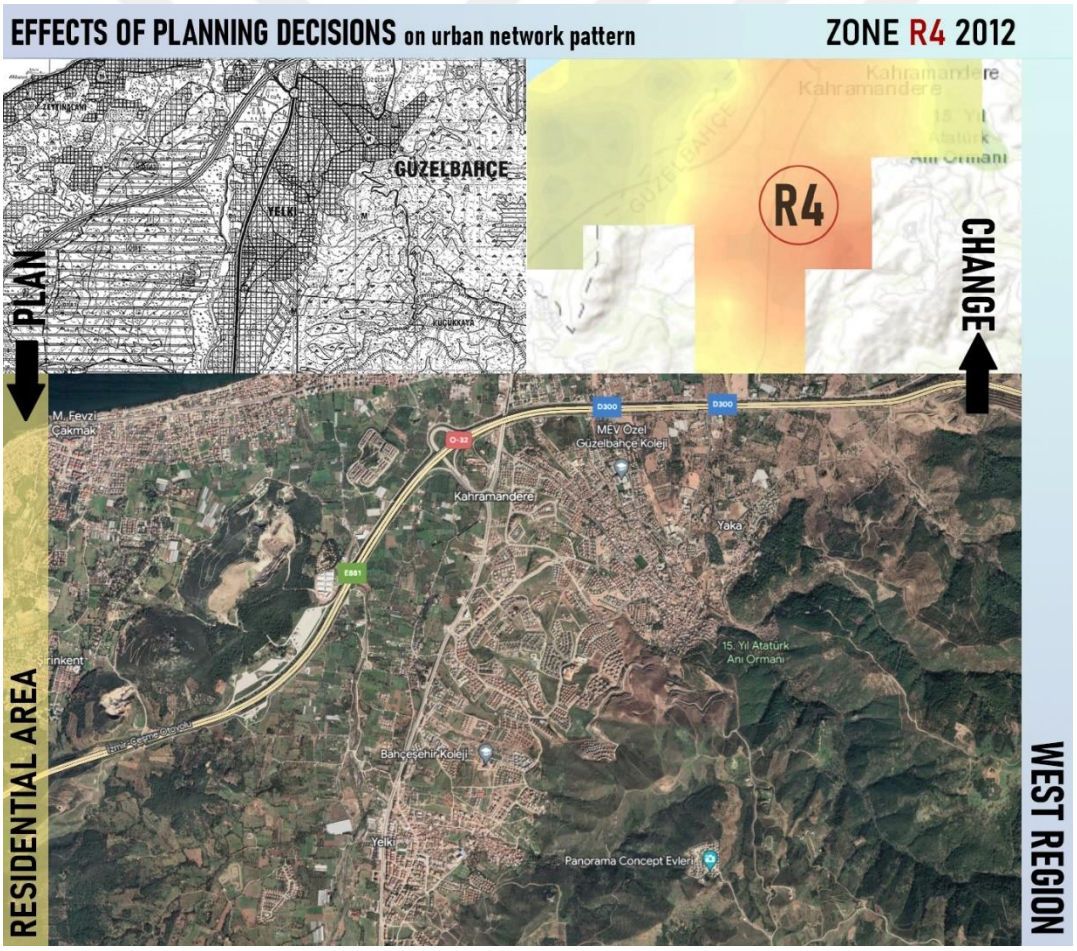


Figure 6.96 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the West Region, Zone R4 2012

Zone R5 2012 West Region:

The area indicated by this notation represents the northern parts of the Seferihisar district of İzmir, namely the Düzce neighborhood and its surroundings. In the analyses prepared using the period III and period IV network data within the scope of the 2012 Plan of İzmir Metropolitan Municipality (IMM), clustering caused by high-level sub-fractal changes is observed in the area. As a result of the hotspot analysis, this area is shown with red intensity colors. Local mobility has occurred in the area due to its tourist attraction. The IMM 2012 Plan suggests residential development areas and a tourism facility area in the westernmost part of the region due to the demand from summer residents. These suggestions have been observed to have changed the network pattern.

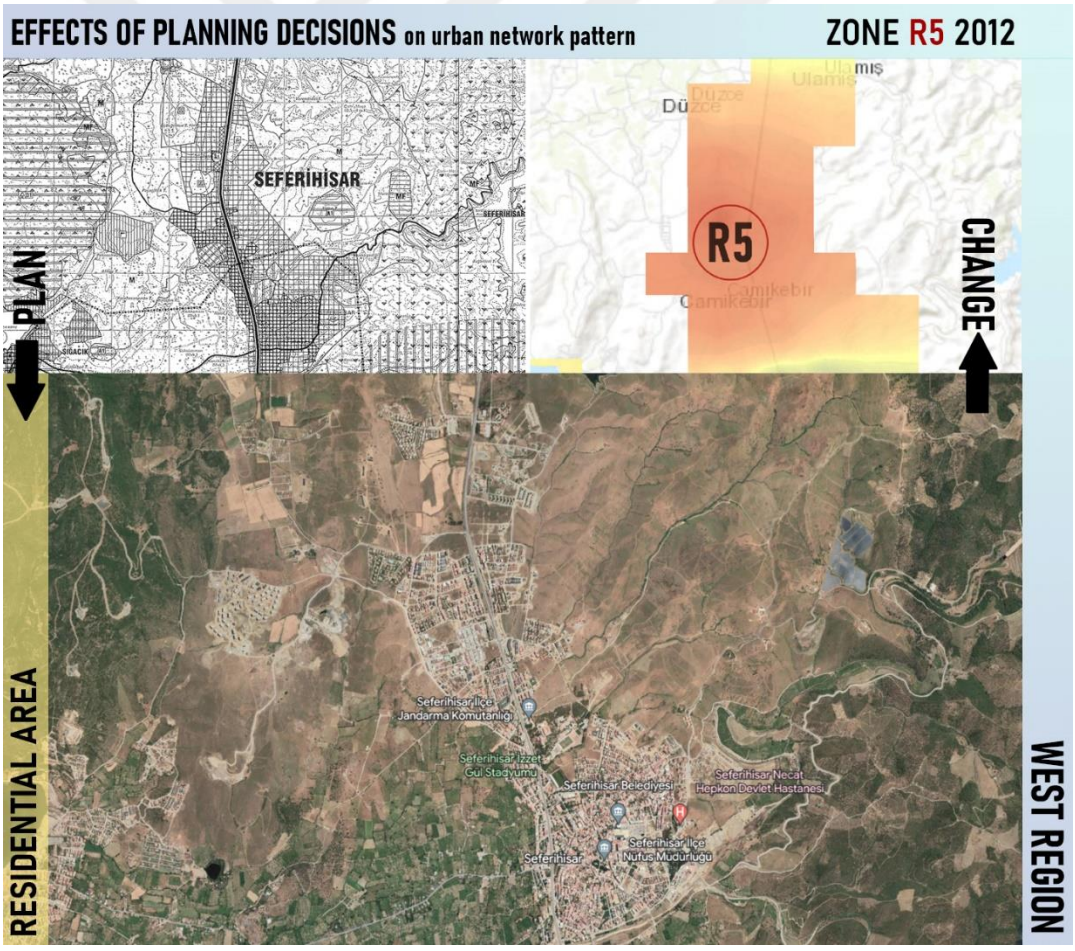


Figure 6.97 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the West Region, Zone R5 2012

Zone Y1 2012 West Region:

The area indicated by this notation represents the coastal neighborhood of Atatürk and its surroundings, located to the north of the İzmir-Urla district. In the analyses prepared using the network data of period III and period IV within the scope of the 2012 Plan of İzmir Metropolitan Municipality (IMM), it is observed that medium-level sub-fractal changes in the area cause clustering. As a result of the hotspot analysis, this area is shown with yellow high-density colors. Since the mentioned area has a tourist attraction, there have been local movements in the region. In the IMM 2012 Plan, residential development areas were proposed due to the region's demand for summer residents. The development pattern was calculated to result in regular geometric forms and medium-level complexity changes.

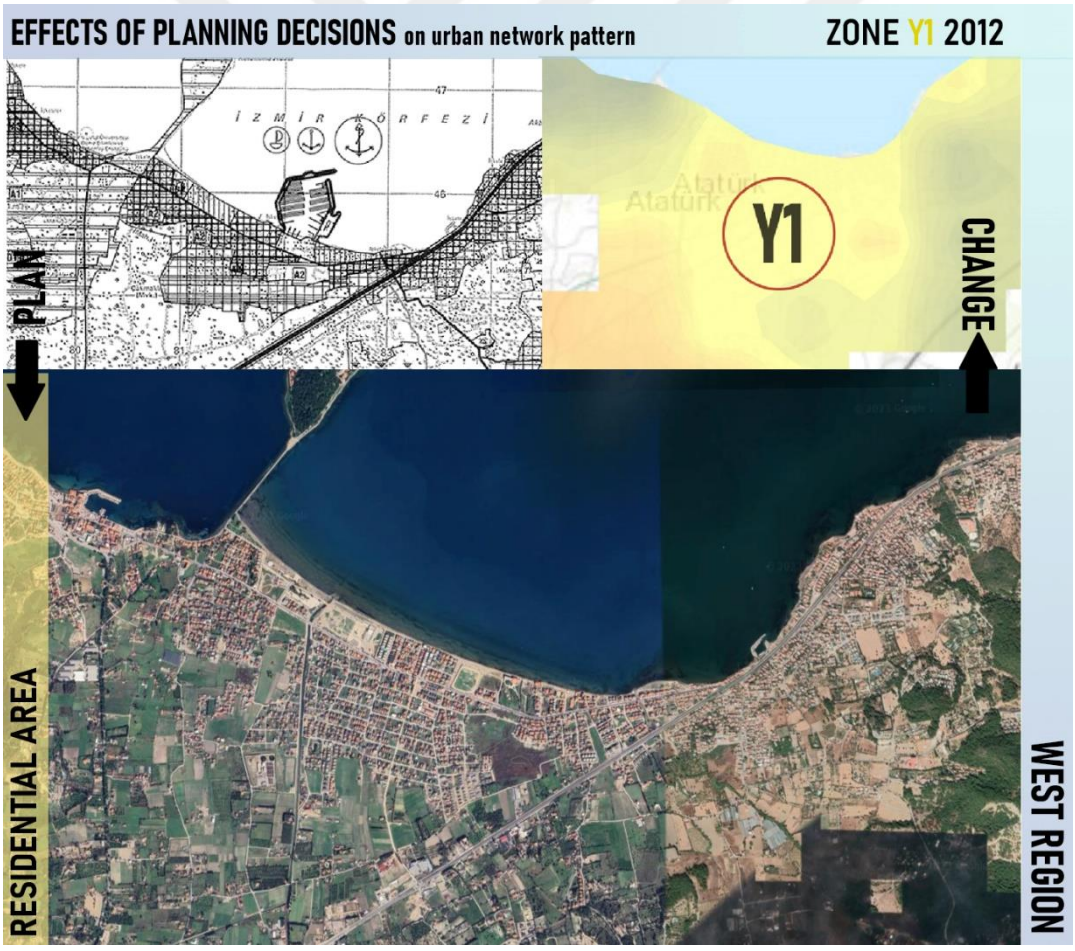


Figure 6.98 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the West Region, Zone Y1 2012

Zone B1 2012 West Region:

The area indicated by this notation represents the region located between the Bademler and Çamlı neighborhoods of the Urla district in İzmir, Turkey, along with its surroundings. In the analyses prepared using the period III and period IV network data within the scope of the 2012 Plan of İzmir Metropolitan Municipality (IMM), clustering caused by low-level sub-fractal changes was observed in the area. As a result of the hotspot analysis, this area is shown in blue-density colors. The area in question became planned with the IMM 2012 Plan, and it was previously used before the year 2000. The protected areas (scrubland-woodland areas, forest areas, etc.) and preferred usage areas in the area are notable. It was observed that the preferred usage areas in this area were not evaluated in a way that would change the network pattern.

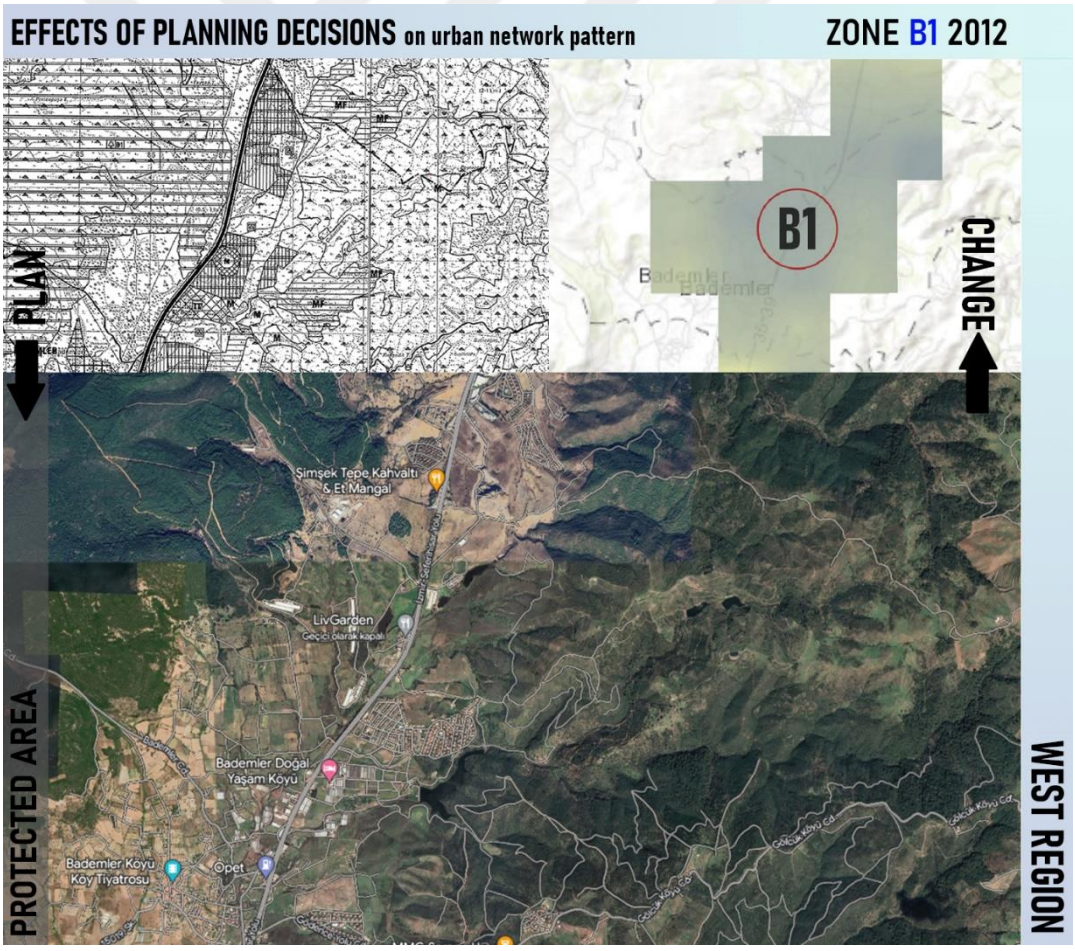


Figure 6.99 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the West Region, Zone B1 2012

Zone B2 2012 West Region:

The area indicated by this notation represents the coastal stretches of Hıdırlık and Tepecik neighborhoods, located in the Seferihisar district of Izmir. According to the analyses prepared using the network data of periods III and IV within the boundaries of the IMM 2012 Plan, clustering caused by low-level sub-fractal changes has been observed in this area. As a result of the hotspot analysis, this area is represented by blue-colored density. This area has been declared as a "preferred use area" with the IMM 2012 Plan. The eastern part of the region consists of areas with military restrictions and is not suitable for development due to natural thresholds. Similarly, a section to the east of the area has been declared as a tourism facility area, but no physical use has been reflected in the area. The preferred use areas and other uses in this area have not been evaluated in a way that would change the network pattern.

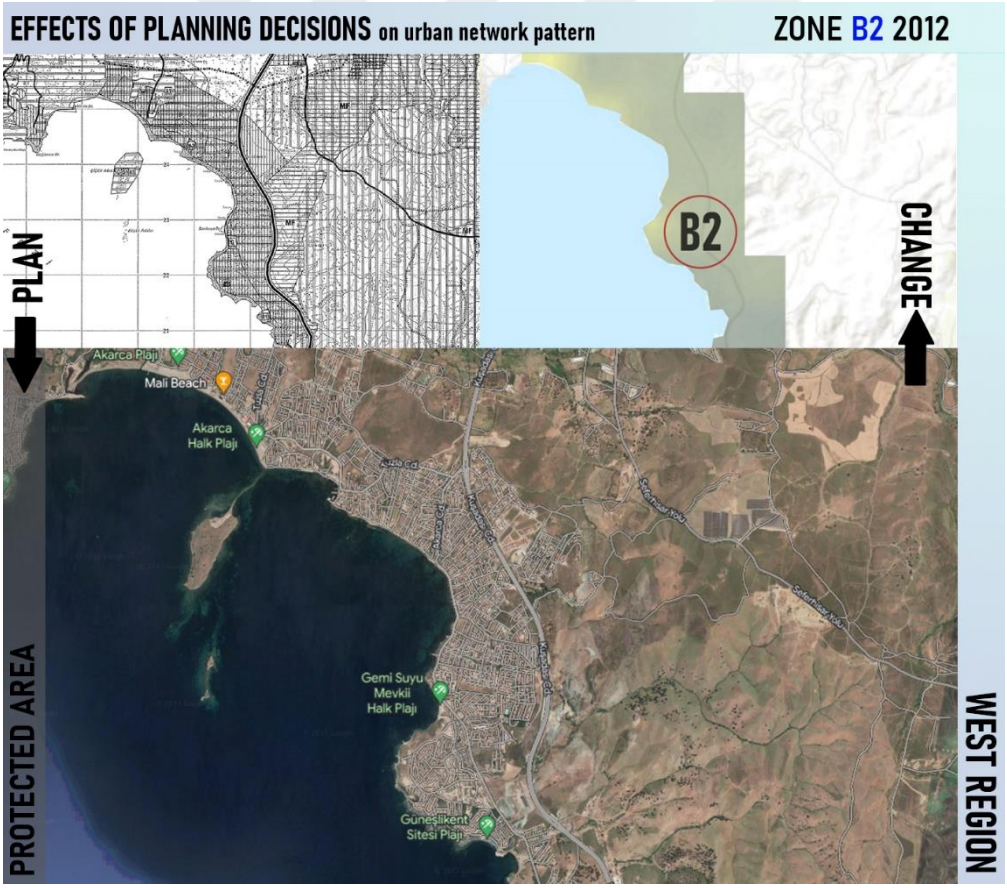


Figure 6.100 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the West Region, Zone B2 2012

- ***East Region "E"***

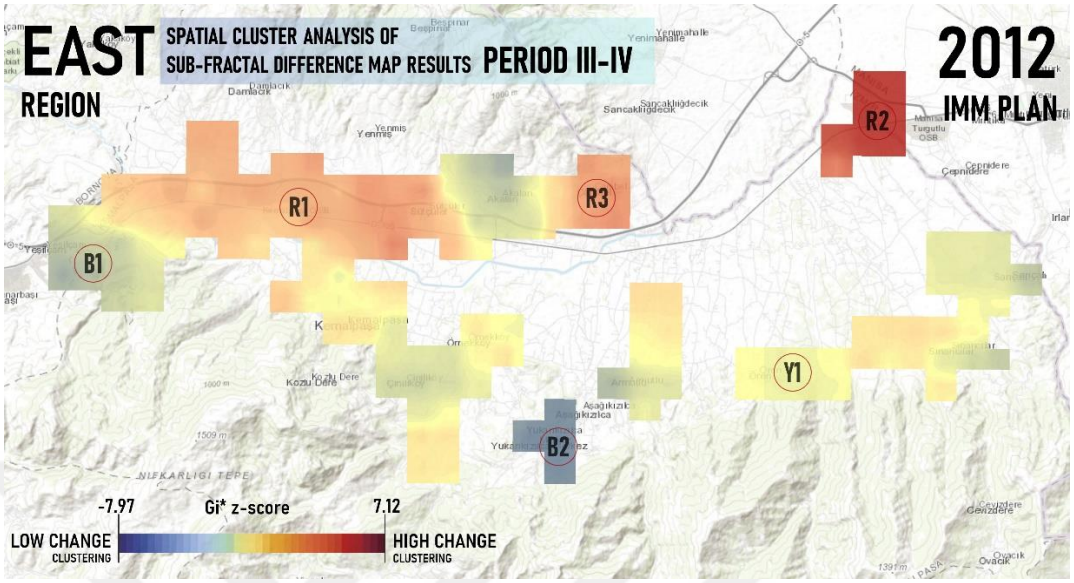


Figure 6.101 Spatial Cluster Analysis of the Sub-fractal Difference Map Results of the IMM 2012 Plan, the East Region

Zone R1 2012 East Region:

The area indicated by this notation is within the boundaries of the Kemalpaşa district of Izmir. It represents the Kemalpaşa OSB neighborhood along Ankara Street, which is the extension of Kemalpaşa Street and the surrounding area. In the analyses prepared using period III and period IV network data within the scope of the IMM 2012 Plan, it is observed that clustering is caused by a high-level sub-fractal change in the area. As a result of the hotspot analysis, this area is shown in red high-density colors. The analysis studies conducted using period II and period III network data for the IMM 1989 Plan showed that hot spotted areas formed around the parts of Kemalpaşa Street located in the Bornova district due to industrialization. The region's location on the Ankara-Izmir Road and university investments in the mid-1980s increased industrial investments and rapidly changed the network pattern. The area mentioned above is a continuation of this industrial line. The IMM 2012 Plan declared the area on the Kemalpaşa side of the Ankara-Izmir Road as an "industrial area" by considering the developments when it was prepared. However, it did not suggest sufficient space for new industrial areas. It has been observed that new

industrial areas have emerged outside the industrial zones specified in the plan. The IMM 2012 Plan also proposed new residential areas around the Kemalpaşa center, taking into account industrial developments, and completed analyses showed that the new residential areas also positively changed the network pattern.

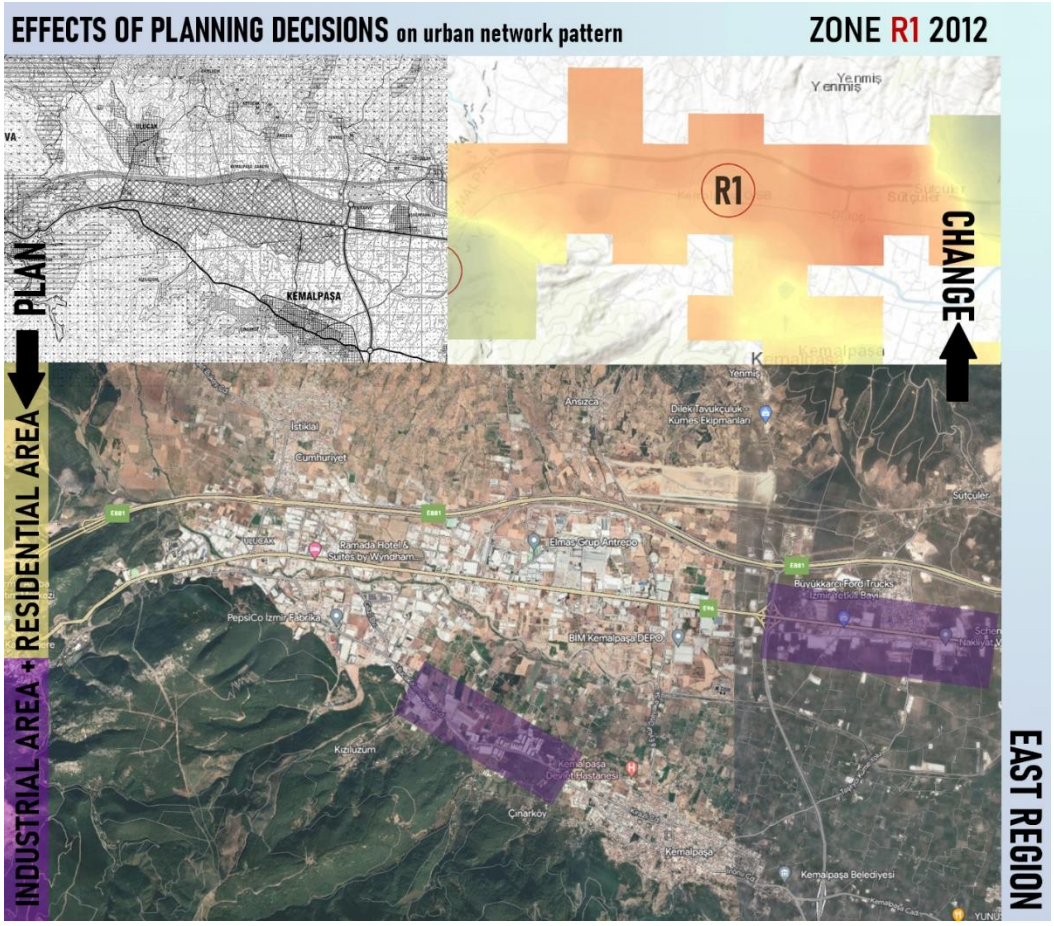


Figure 6.102 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone R1 2012

Zone R2 2012 East Region:

The area indicated by this notation represents the area and its surroundings located on the Izmir-Ankara highway, in the border region between Izmir and Manisa, west of the Turgutlu Organized Industrial Zone. In the analyses prepared using the period III and period IV network data within the scope of the IMM 2012 plan, a clustering caused by a very high-level sub-fractal change is observed in the area. As a result of the hotspot analysis, this area is shown with red high-density colors. For the

mentioned area, the IMM 2012 Plan suggests an organized industrial zone for the northern part and a small industrial area with an industrial site for the southern region. The plan also proposes storage areas, as shown in the figure. The suggestions have been partially implemented and are still ongoing. Therefore, the network pattern has changed positively, and the complexity level of the area has increased.

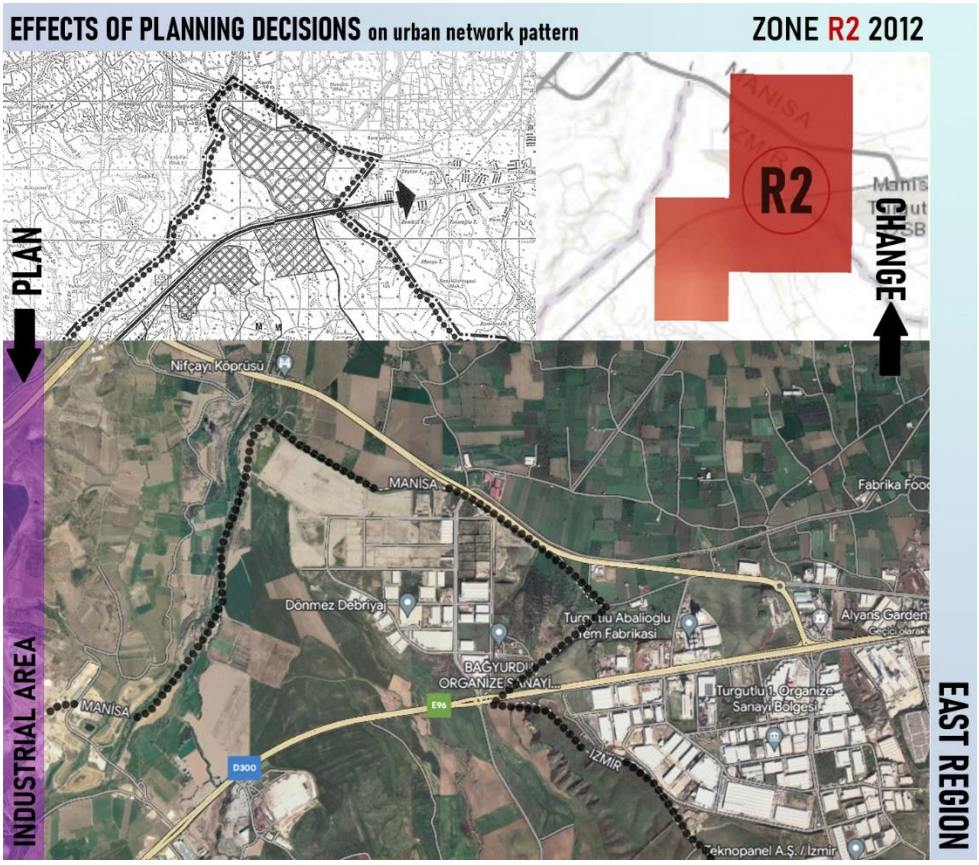


Figure 6.103 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone R2 2012

Zone R3 2012 East Region:

The area indicated by this notation represents the Çambel neighborhood and its surroundings within the boundaries of Kemalpaşa district in Izmir, located north of the Izmir-Ankara Highway. In the analyses prepared using period III and period IV network data within the Izmir Metropolitan Municipality's 2012 Plan boundaries, clustering caused by a high-level sub-fractal change has been observed in this area. As a result of hotspot analysis, this area is shown in red density colors.

Within the scope of the Izmir Metropolitan Municipality's 2012 Plan, new residential development areas have been proposed around the Çambel neighborhood center, considering the proximity to industrial areas. At the same time, a residential development area has also been offered and realized to the west of the neighborhood center. The striking feature of this area is that it differs from the unique organic network pattern of the neighborhood center. Although the surface area of the western area is larger, the regular geometry of the network pattern has caused the complexity level of this area to be lower. The example area indicated by this notation can be considered an indicator of how vital the complexity of the geometries used in the network pattern is. Planning decisions have been applied for both areas, and a positive change in the network pattern has been observed.

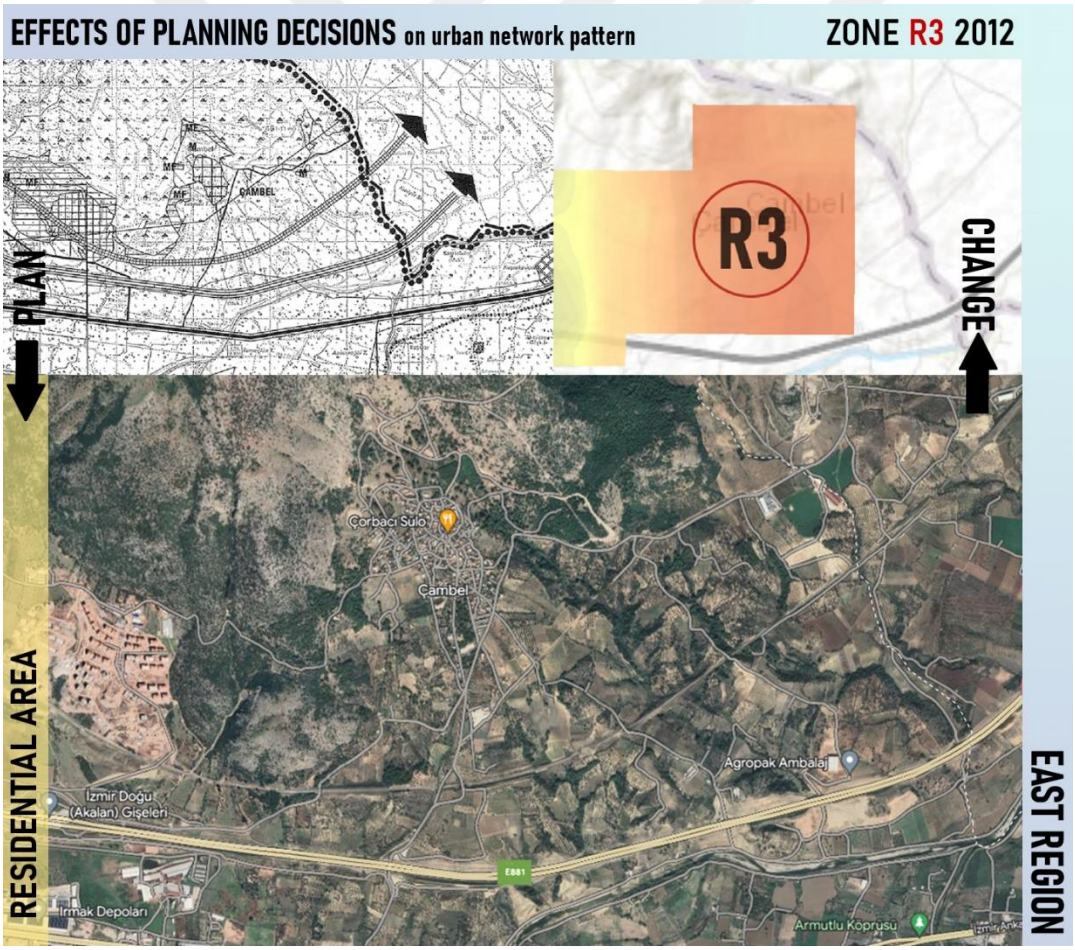


Figure 6.104 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone R3 2012

Zone Y1 2012 East Region:

The area designated by this notation represents the centers of the former Ören, Yiğitler, and Bağyurdu villages, located within the boundaries of the Kemalpaşa district of İzmir. It also encompasses the surrounding areas of these villages. In the analyses prepared using the period III and period IV network data within the scope of the IMM 2012 Plan, it has been observed that clustering occurs in the area due to medium-level sub-fractal changes. As a result of the hotspot analysis, this area is shown with yellow high-density colors. The IMM 2012 Plan proposed residential development areas for the area, and the network pattern of this region has positively changed at a relatively slow pace. Another reason for the observed medium-level changes in the area is the use of regular geometries in the network pattern.

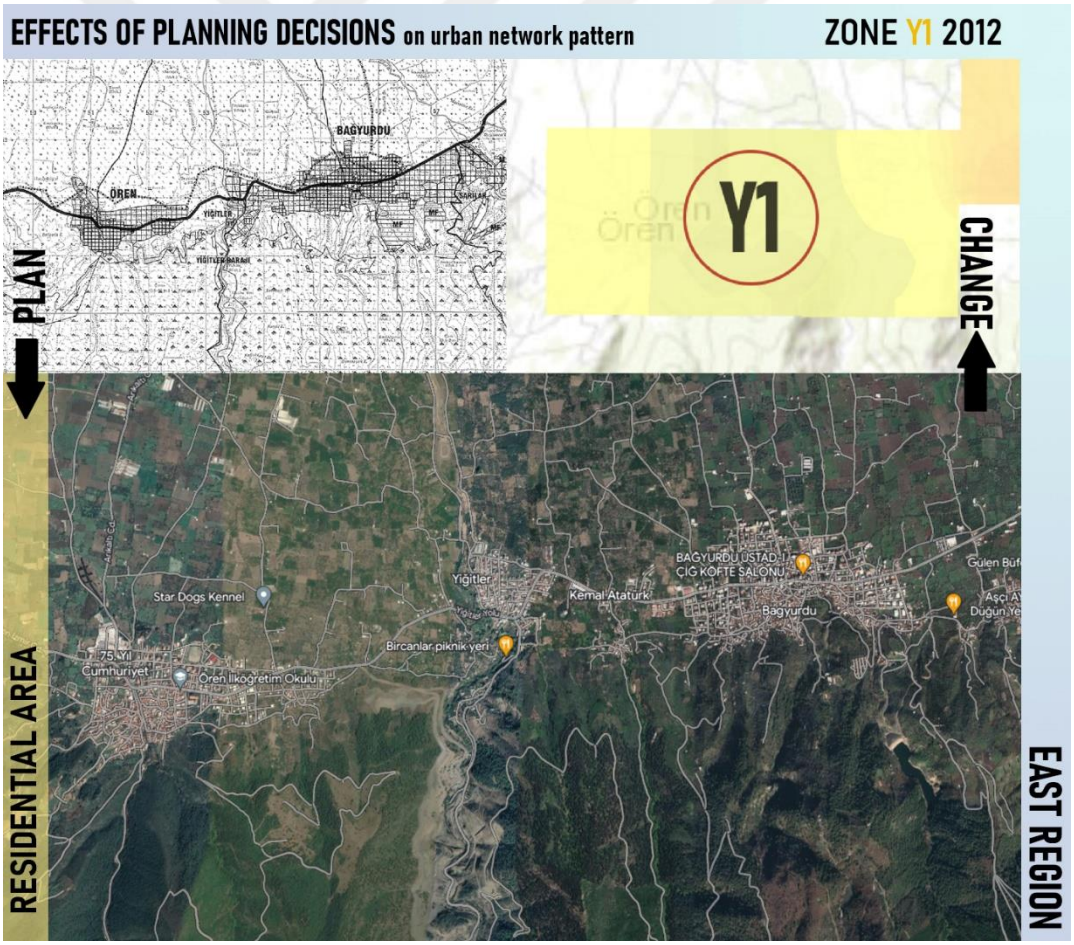


Figure 6.105 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone Y1 2012

Zone B1 2012 East Region:

The area indicated by this notation represents the Kavaklıdere neighborhood and its surroundings located within the boundaries of the Bornova district of İzmir. It is included in the 2012 Plan of İzmir Metropolitan Municipality (IMM), and analyses prepared using the period III and period IV network data have shown clustering caused by low-level sub-fractal changes in the area. As a result of hotspot analysis, this area is shown in blue-density colors. The IMM 2012 Plan indicates forest areas, first-degree conservation areas, high-quality agricultural areas, and military areas in the designated area. Since there are such areas that need to be protected in the region, no significant changes have been observed in the network pattern between 2000 and 2020.

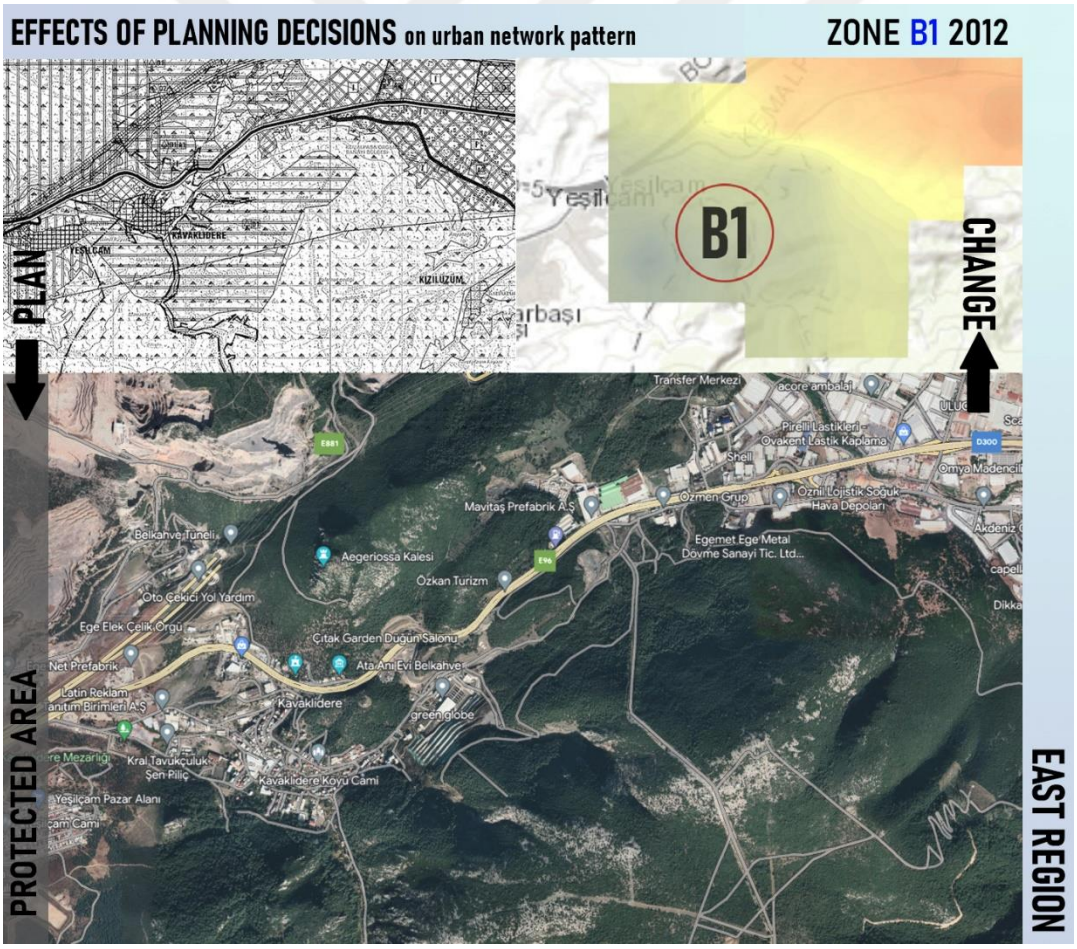


Figure 6.106 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone B1 2012

Zone B2 2012 East Region:

The area indicated by this notation represents the Yukarıkızılca neighborhood and its surroundings located within the Kemalpaşa district of İzmir. Based on the analysis prepared using the period III and period IV network data within the scope of the 2012 Plan of IMM, it has been observed that clustering is caused by a very low level of sub-fractal variation in the area. As a result of the hotspot analysis, this area is shown with blue high-density colors. The 2012 Plan of IMM indicated forest areas and qualified agricultural lands in the mentioned area.

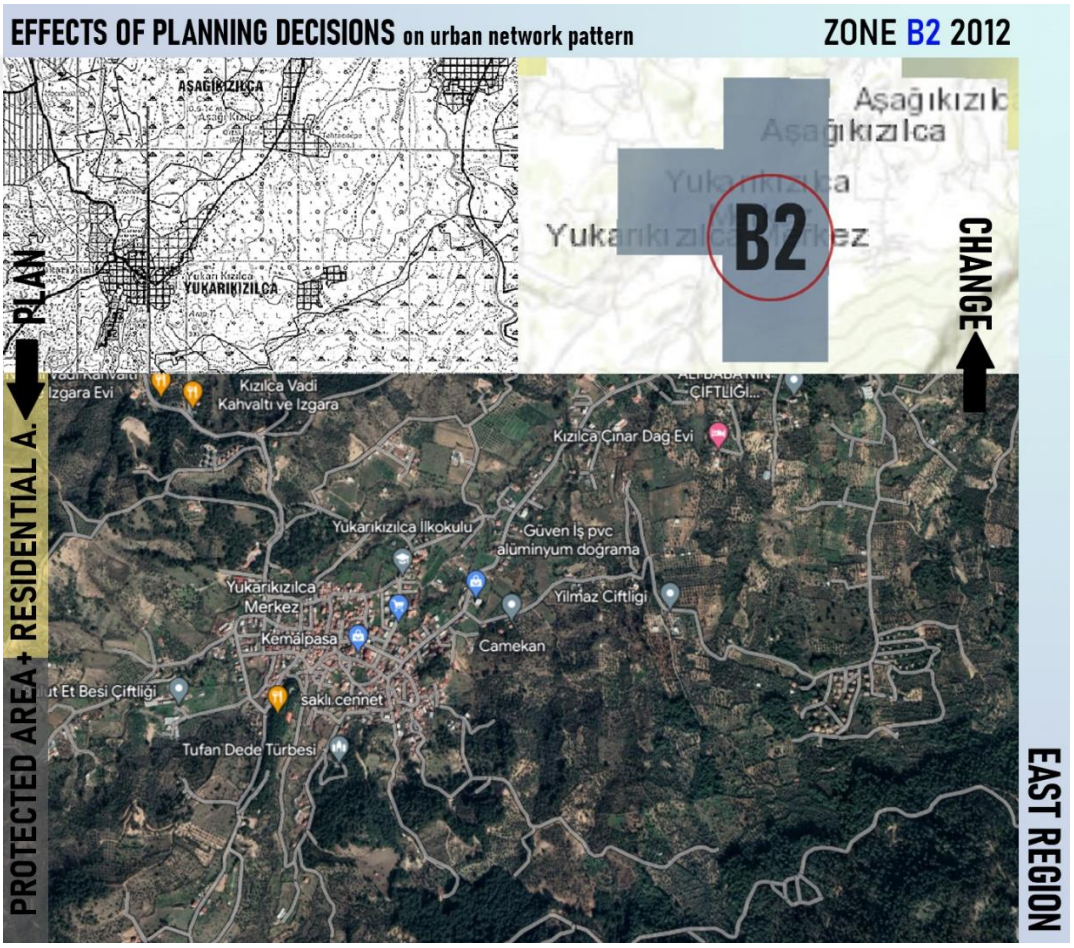


Figure 6.107 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone B2 2012

In addition, the amount of network patterns around the neighborhood center has increased with the natural population growth, and the site has been proposed as a

residential development area. Typically, a high sub-fractal variation trend is expected in the area. *However, in the sub-fractal analysis conducted for the year 2000, 4 boxes were calculated for the region, while 2 boxes were calculated in the 2020 analysis.* This has caused the sub-fractal variation average to fall into negative results and therefore led to negative clustering.

- ***Tourism Region "T"***

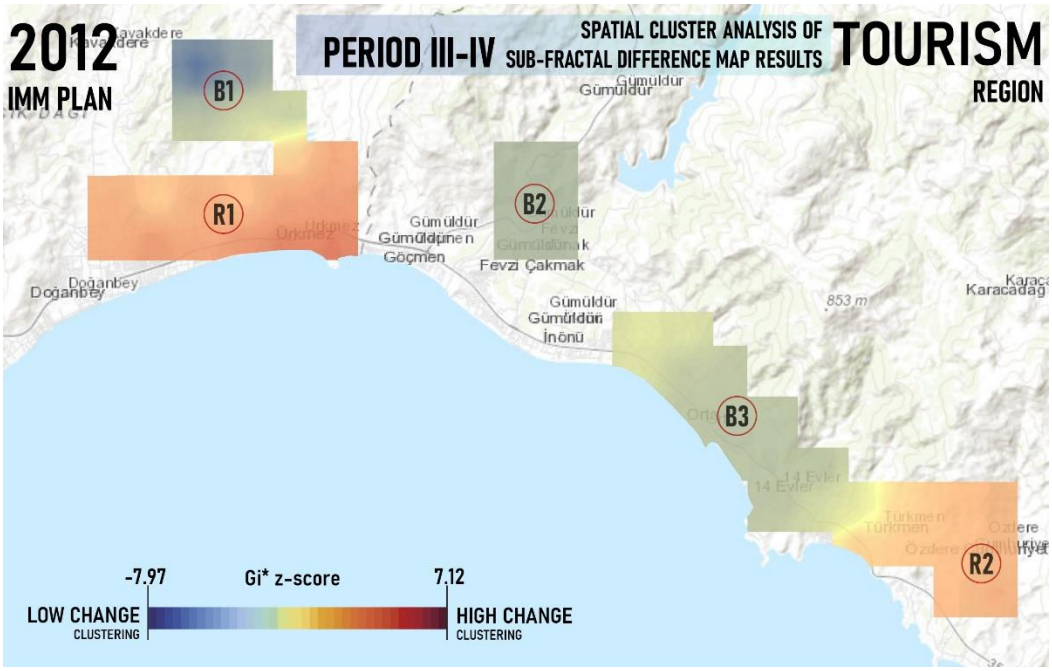


Figure 6.108 Spatial Cluster Analysis of the Sub-fractal Difference Map Results of the IMM 2012 Plan, the Tourism Region

Zone R1 2012 Tourism Region:

The area described by this notation represents the coastal neighborhoods (Atatürk, Cumhuriyet, Ürkmez, and Payamlı) located within the boundaries of the Seferihisar district of İzmir, as well as the area extending along the Kuşadası-Seferihisar road and its surroundings. Analyses prepared using the period III and IV network data in the 2012 Plan of the İzmir Metropolitan Municipality (IMM) indicate that clustering is observed in the area due to a high-level sub-fractal change. As a result of hotspot analysis, this area is shown in red density colors.

With the IMM 2012 Plan, a part of the area and its surroundings were declared as a tourism center. The plan suggested a residential development area for the western part of the Atatürk neighborhood, but it was not realized. On the other hand, although the northern parts of the Kuşadası road were designated as a qualified agricultural area in the Plan, no proposal was made for them, and they were opened up for construction. This has resulted in a significant positive change in the network pattern.



Figure 6.109 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone R1 2012

Zone R2 2012 Tourism Region:

This notation represents an area located within the boundaries of the district of İzmir-Menderes, including the Özdere and Çukuraltı neighborhoods and its surroundings. In the analyses prepared using period III and period IV network data within the scope

of the İzmir Metropolitan Municipality (IMM) 2012 Plan, it has been observed that clustering occurs in the area due to high-level sub-fractal changes. As a result of hotspot analysis, this area is shown in red high-density colors.

The IMM 2012 Plan has declared the coastal areas of this area as a tourism center. However, the settlements in the area are surrounded by protected areas such as forests. The IMM 2012 Plan has shown these areas and has yet to propose residential development areas considering them. Nevertheless, it has been observed that the number of residential sites has increased in the area, the network pattern has changed positively, and sub-fractal values have increased, indicating that the complexity level of the area has increased.

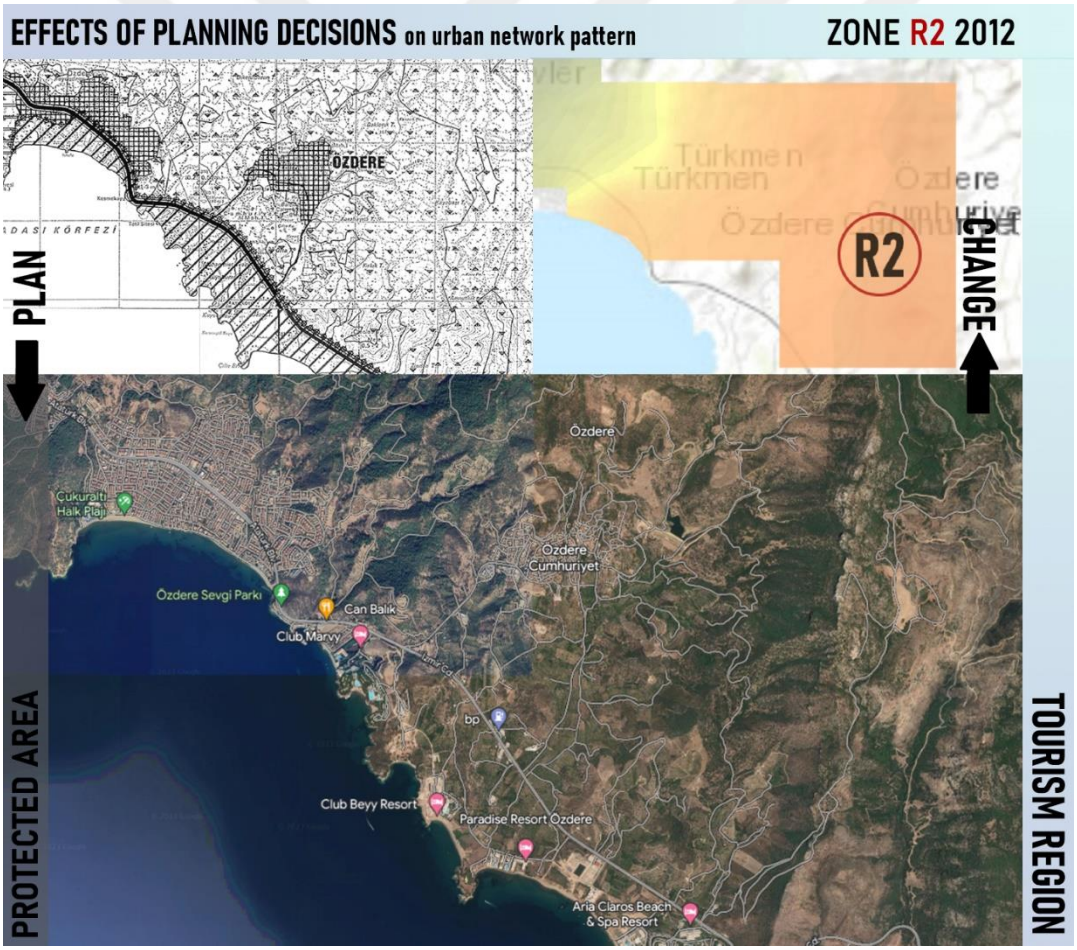


Figure 6.110 Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone R2 2012

Zone B1 2012 Tourism Region:

The area indicated by this notation represents the forested areas northwest of the Payamlı neighborhood within the boundaries of the Seferihisar district of Izmir. In the analyses prepared using the period III and period IV network data within the scope of the İzmir Metropolitan Municipality's 2012 Plan, clustering caused by low-level sub-fractal variation is observed in the area. As a result of the hotspot analysis, this area is shown in blue-dense colors.

In the IMM 2012 Plan, forested areas, military areas, and forested areas within the tourism center declared location are shown in this region. As a result of the analyses, no network pattern change has been observed in this area.

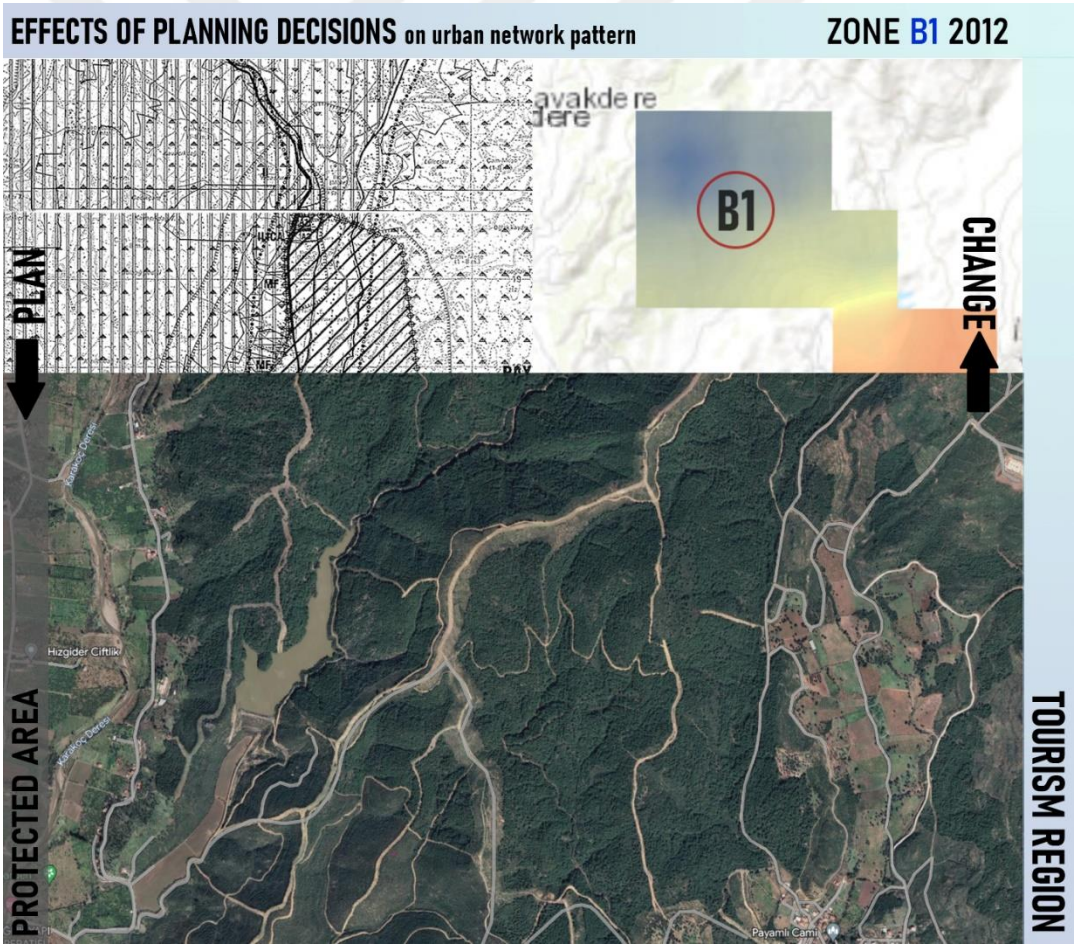


Figure 6.111 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone B1 2012

Zone B2 2012 Tourism Region:

The area specified by this notation represents the Fevzi Çakmak neighborhood and its surroundings within the boundaries of the Menderes district in İzmir. In the analyses prepared using the period III and period IV network data within the scope of the IMM 2012 Plan, clustering caused by low-level sub-fractal changes was observed in the area. As a result of the hotspot analysis, this area is shown in blue high-density colors. The IMM 2012 Plan added the residential development that occurred until 2000 in the established area to the plan. No new residential settlement was proposed outside these areas. It can be considered that the protected areas around the area (such as forest areas, etc.) were effective in making this decision. Therefore, no pattern change was observed in the area in question as a result of the analyses.

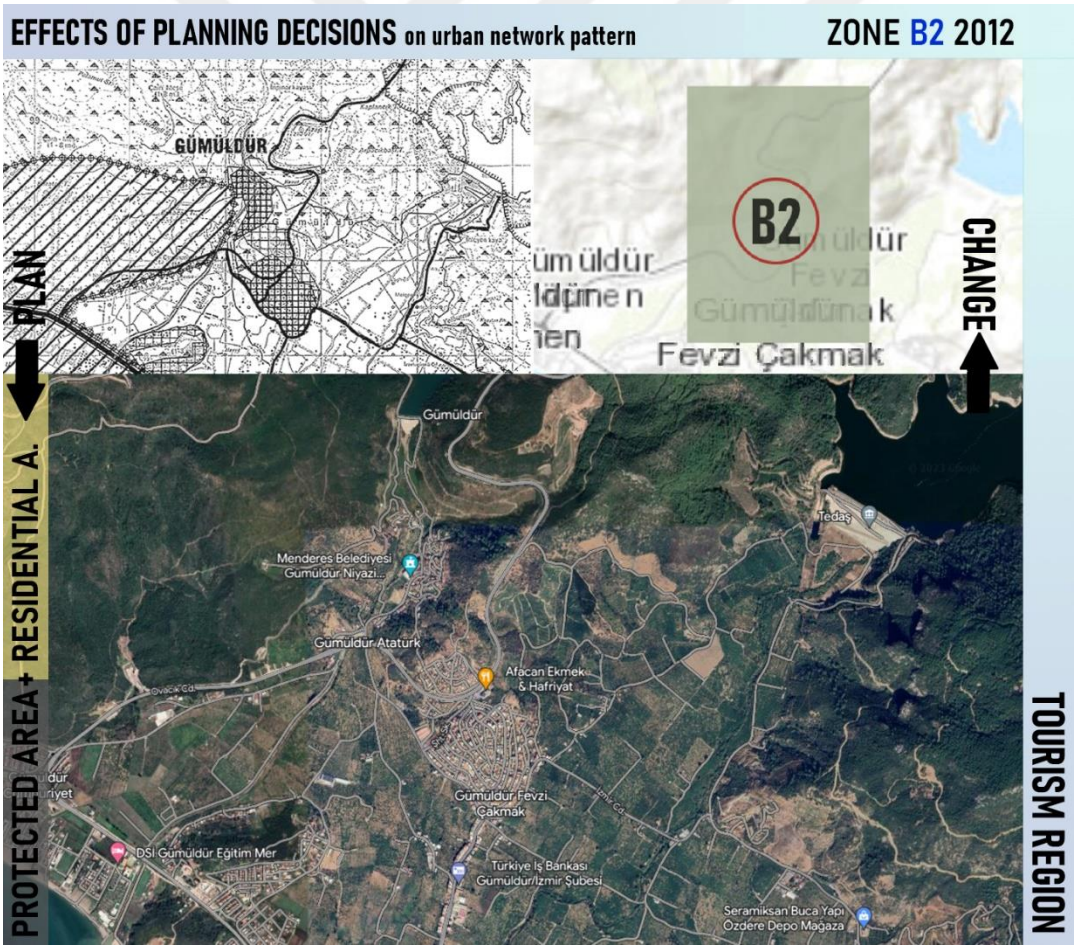


Figure 6.112 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone B2 2012

Zone B2 2012 Tourism Region:

The area indicated by this notation represents mainly the coastal areas and surroundings of Atatürk and Fevzi Çakmak neighborhoods within the borders of the district of İzmir-Menderes. In the analyses prepared using period III and period IV network data within the boundaries of the 2012 Plan of IMM, clustering caused by low-level sub-fractal changes is observed in the area. As a result of the hotspot analysis, this area is shown with blue-density colors. In the 2012 Plan of IMM, the coastal areas of the mentioned region are shown as preferred usage areas, military areas, and first-degree conservation areas, while the northern parts are shown as qualified agricultural areas and forest areas. The network pattern of the site has remained the same between the indicated years. Therefore, a negatively oriented sub-fractal change has been observed as a result of the analyses.

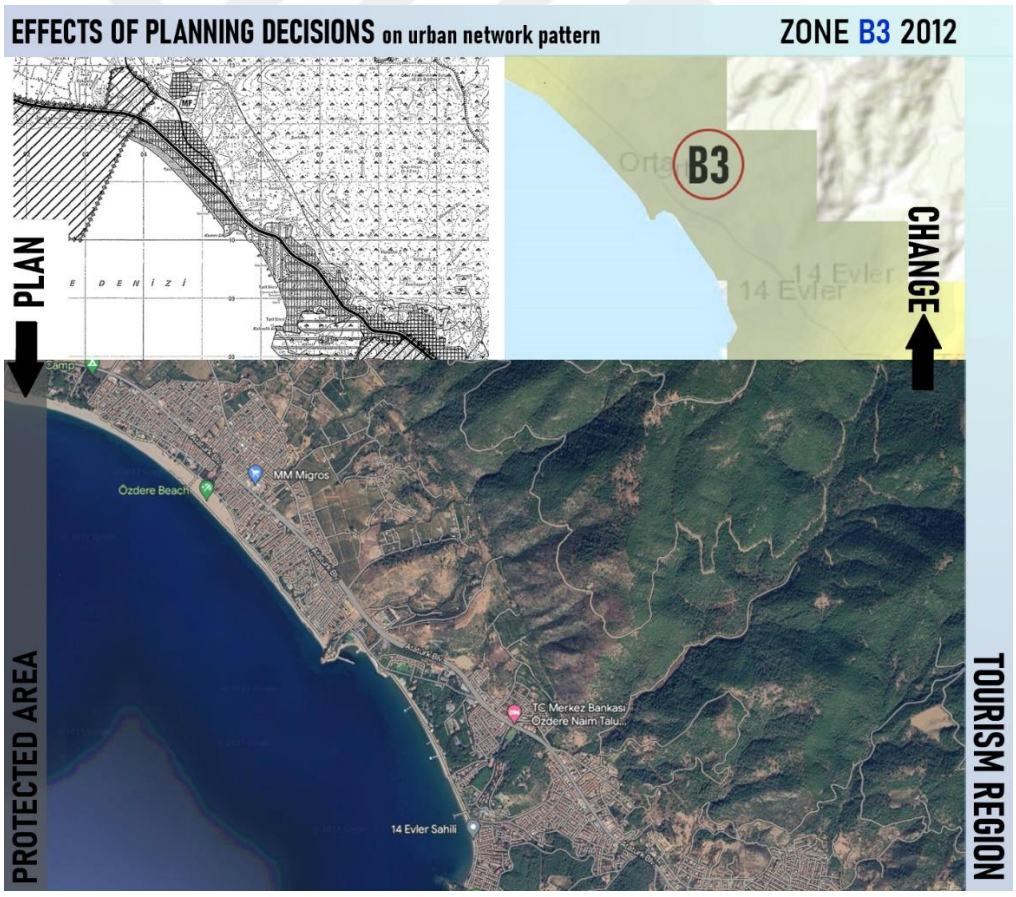


Figure 6.113 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the East Region, Zone B3 2012

- ***Central Area "C"***

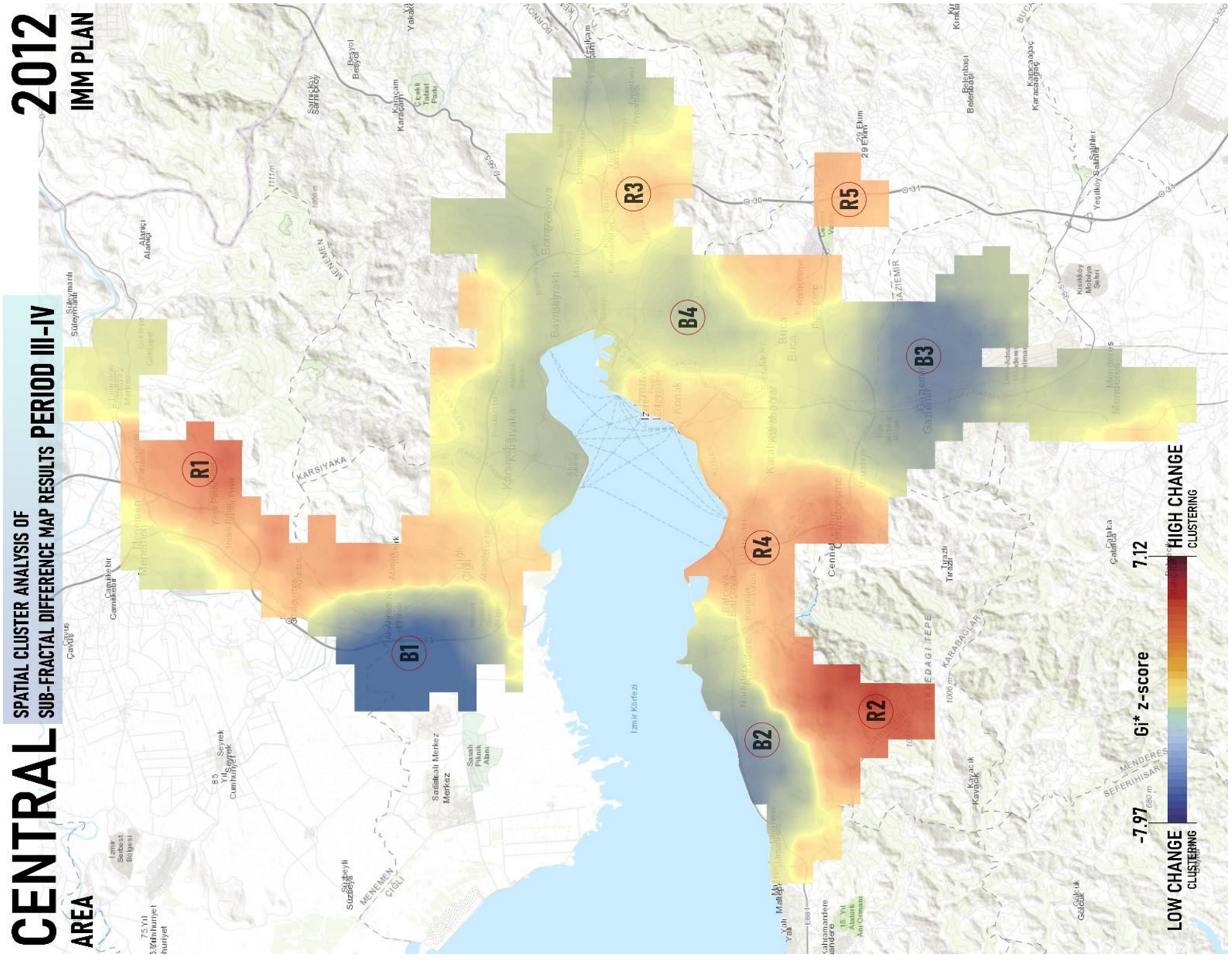


Figure 6.114 Spatial Cluster Analysis of the Sub-fractal Difference Map Results of the IMM 2012 Plan, the Central Area

Zone R1 2012 Central Area:

The area indicated by this notation represents the neighborhoods (Gazi, Kemal Atatürk, Zeytinlik, Gölcük, Irmak, İsmet İnönü, Yeşilpınar Uğur Mumcu, and Yahşelli) located south and southeast of the Menemen district of İzmir. In the analyses prepared using the period III and period IV network data within the boundaries of the IMM 2012 Plan, clustering caused by a high-level sub-fractal change was observed in the area. As a result of the hotspot analysis, this area is shown in red density colors. The IMM 2012 Plan proposed residential development areas within the city, taking into account the industrial areas developing in the designated areas and generally towards the south.

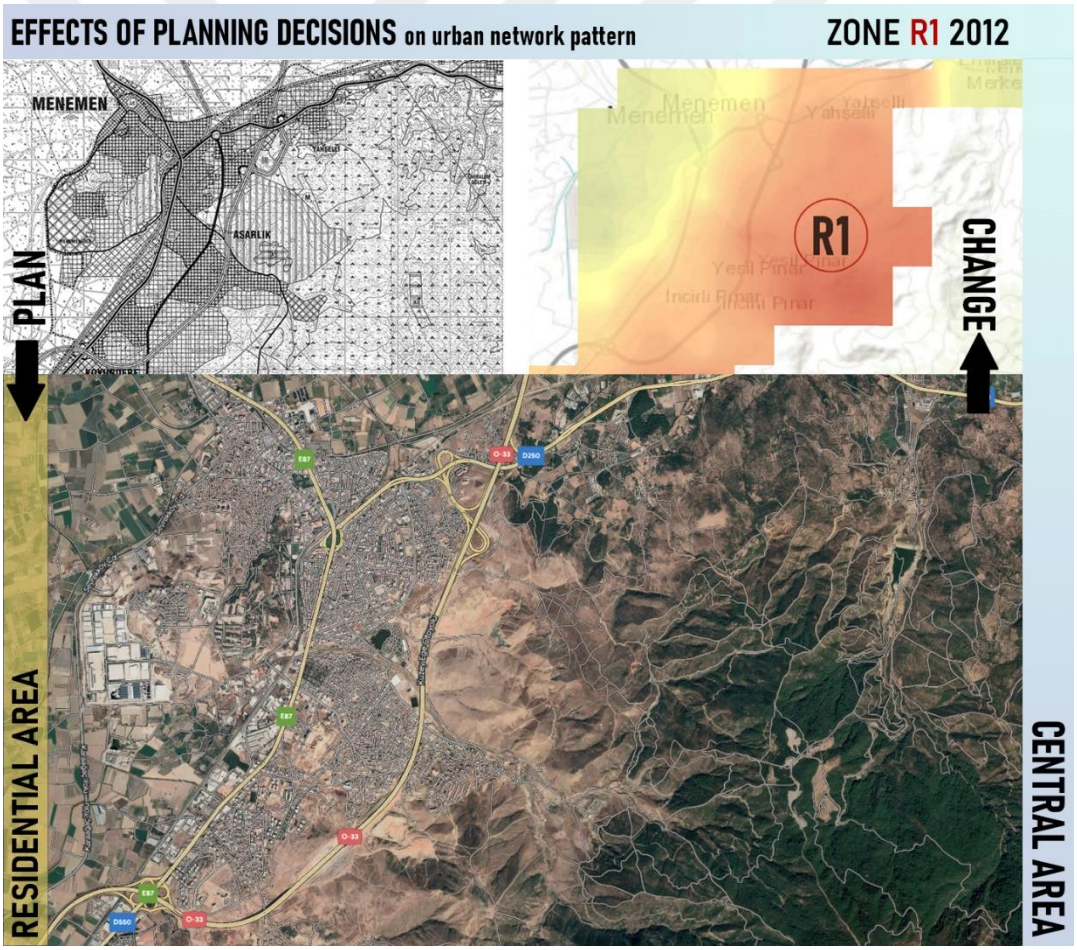


Figure 6.115 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the Central Area, Zone R1 2012

In addition, the housing development around the Yahşelli neighborhood to the east of the Menemen settlement has also been included in the planning study as residential development areas. As a result, an increase in residential areas in the region was observed. The network pattern has changed positively, with sub-fractal values increasing, indicating an increase in the area's complexity level.

Zone R2 2012 Central Area:

This notation refers to the region that is comprised of the forested regions and the lands immediately around them that can be found to the north of the Narlıdere district of Izmir and included entirely inside the Huzur neighborhood.

Clustering that was brought on by high-level sub-fractal alterations was spotted in the region during the studies that were carried out in the context of the Izmir Metropolitan Municipality's (IMM) 2012 Plan. These analyses were carried out utilizing the period III and period IV network data. Because of the findings of the hotspot research, the density colors in this region are indicated to be red.

The areas in question were given the designation of "forested areas" and "military restricted areas" under the IMM 2012 Plan. After 2000, in line with the choices made by the military efforts in the province of Izmir, new roads were opened up inside the wooded area. This was the primary cause of the shift in the network design that existed in the region. The second and primary cause was the choice made prior to the IMM 2012 Plan to build a drinking water dam in the area. This decision was ultimately included in the IMM 2012 Plan. Because of the completion of the dam project in 2016, significant changes were brought about in the network layout of the region as a result of the opening of new forest roads during fieldwork. Despite the dam's construction not yet being finished, needless roadways have been opened up inside the wooded region as part of the operation.

As a consequence of this, the network pattern evolved favorably as a consequence of the reasons that were given. As a consequence of this, it was seen that the sub-fractal values grew, as well as the complexity level of the region.

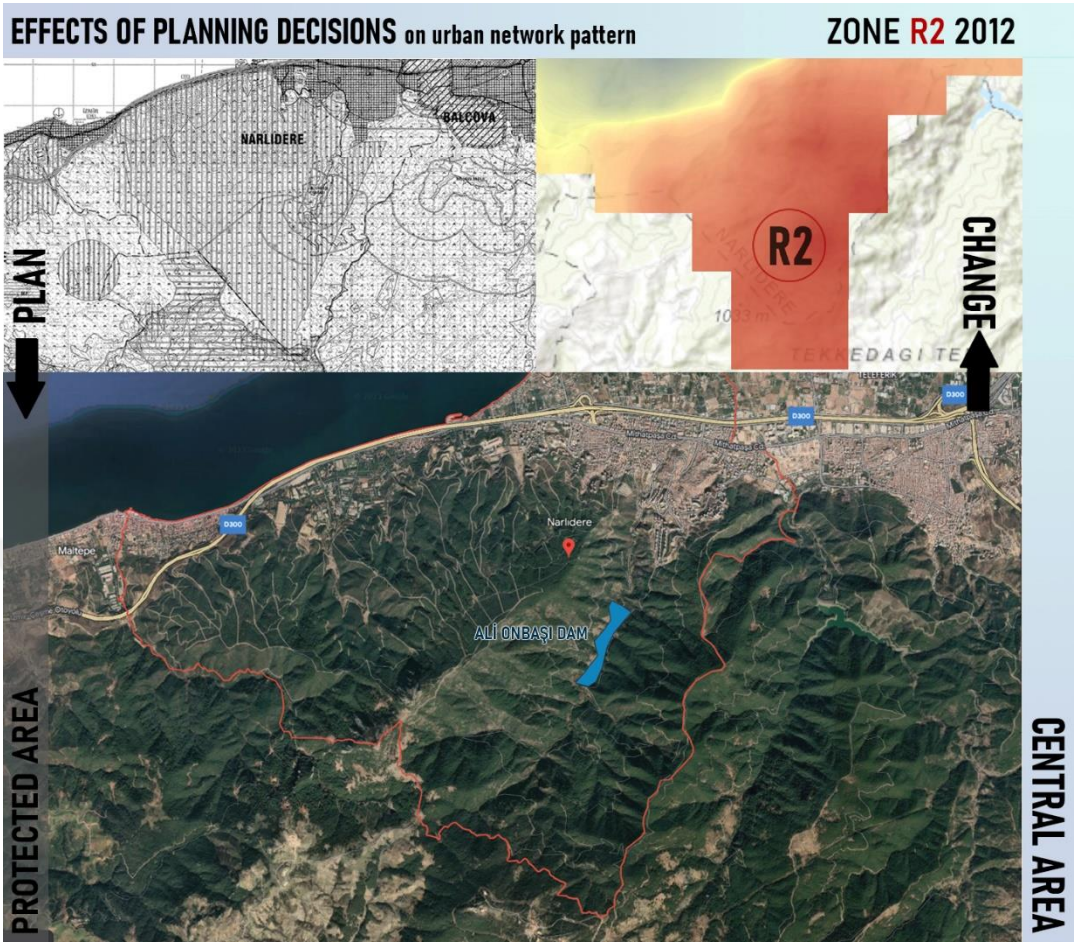


Figure 6.116 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the Central Area, Zone R2 2012

Zone R3 2012 Central Area:

The area indicated by this notation represents the region of Egemenlik, Işıkkent, and Karacaoğlan neighborhoods, located within the boundaries of the Bornova district of Izmir, and its surroundings, where the Izmir ring road and Kemalpaşa avenue intersect.

In the analyses prepared using the period III and period IV network data within the scope of the 2012 Plan of theI IMM, high-level clustering caused by sub-fractal changes have been observed in the area. As a result of the hotspot analysis, this area is shown in red density colors. The area specified in the IMM 2012 Plan has been designated as an industrial area and a secondary center, considering the

developments after 2000. However, no new proposed usage areas that are processed into the plan according to the current usage of the areas have been suggested. On the other hand, the industrial areas have continued to develop, and it has been observed that the areas designated as qualified agricultural areas in the IMM 2012 plan have also been included in the industrial areas. As a result, the network pattern has changed positively, and sub-fractal values have increased, indicating an increase in the complexity level of the area.

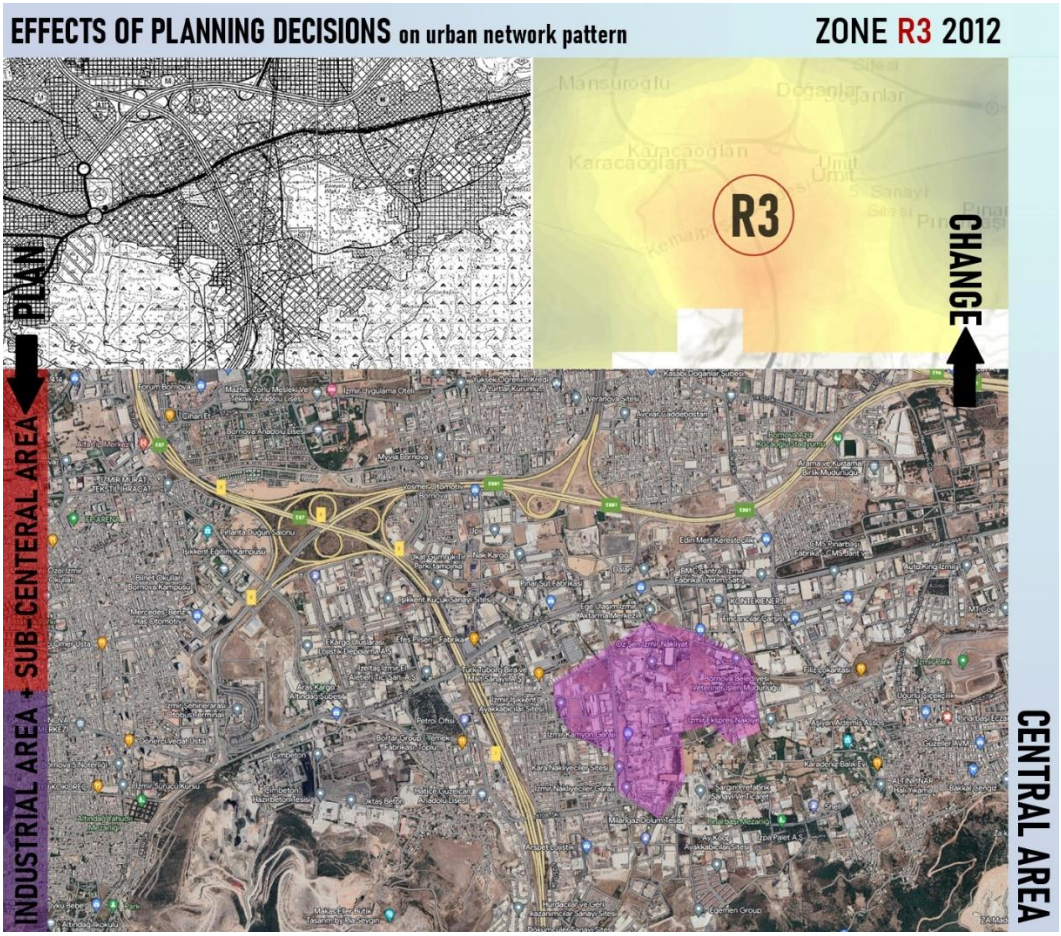


Figure 6.117 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the Central Area, Zone R3 2012

Zone R4 2012 Central Area:

The area specified by this notation represents the areas that start from the border region between the Konak district of Izmir and Balçova district and extend along the Konak coast, south of the Mustafa Kemal Beach Boulevard, and its surroundings.

In the analyses prepared using the period III and period IV network data within the scope of the 2012 Plan of İzmir Metropolitan Municipality (IMM), clustering caused by high-level sub-fractal changes is observed in the area. As a result of the hotspot analysis, this area is shown in red colors indicating high density.

In the areas on the Balçova side of the area specified in the IMM 2012 Plan, new residential areas formed after 2000 are shown as residential development areas. However, the main factor that caused a positive change in the network pattern is the addition of new road network patterns due to transportation decisions to make urban transportation more efficient.

In addition, the new metro lines added to this region have an important effect on the positive change of the upper network pattern. The relevant plan decisions are as follows:

- *"The demand for existing lines, especially those connected to the Karşıyaka pier, will continue to increase. Among the new lines, Eski Foça-Konak, Güzelbahçe-Mavişehir, Güzelyalı-Mavişehir, Konak-Mavişehir, Üçkuyular-Karşıyaka lines stand out as lines that will provide adequate service. Increasing the capacity of these lines as of 2020 will be beneficial for the healthy operation of the system (IMM Plan Report, 2012)."*
- *"Transportation by metro has been on the route between Hatay-Üçyol and Bornova-Aegean University, and Üçyol-Üçkuyular route. In addition, there has been an 80 km long suburban line consisting of two main sections as Aliağa-Alsancak-Halkapınar (north) and Halkapınar-Alsancak-Cumaovası (south) direction (IMM Plan Report, 2012) …"*

As a result, it has been observed that the network pattern has changed positively, and the sub-fractal values have increased, indicating an increase in the area's complexity level due to the abovementioned reasons.

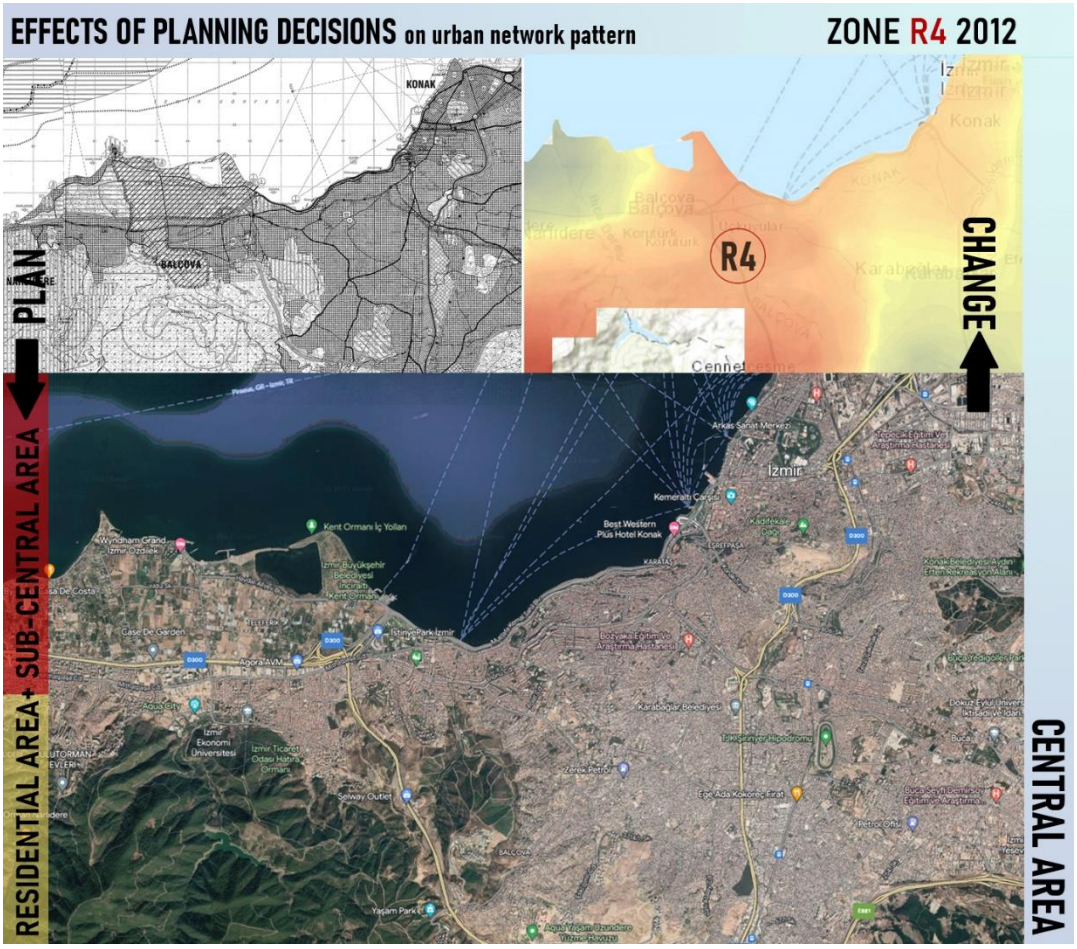


Figure 6.118 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the Central Area, Zone R4 2012

Zone R5 2012 Central Area:

The area indicated by this notation is located within the boundaries of the Buca district of Izmir. It represents the region and its surroundings at Ataturk Avenue and Izmir Ring Road intersection in the Zafer and 29 Ekim neighborhoods.

In the analyses prepared using the period III and period IV network data within the scope of the 2012 Plan of the Izmir Metropolitan Municipality, a clustering phenomenon caused by a high-level sub-fractal change was observed in the area. As a result of the hotspot analysis, this area is shown in red density colors.

The 2012 Plan of the Izmir Metropolitan Municipality proposed a small industrial area in the mentioned area. However, it is observed that some areas that are currently

used for residential purposes have also been converted into industrial zones. Therefore, the network pattern has changed positively, and sub-fractal values have increased, indicating an increase in the complexity level of the site.

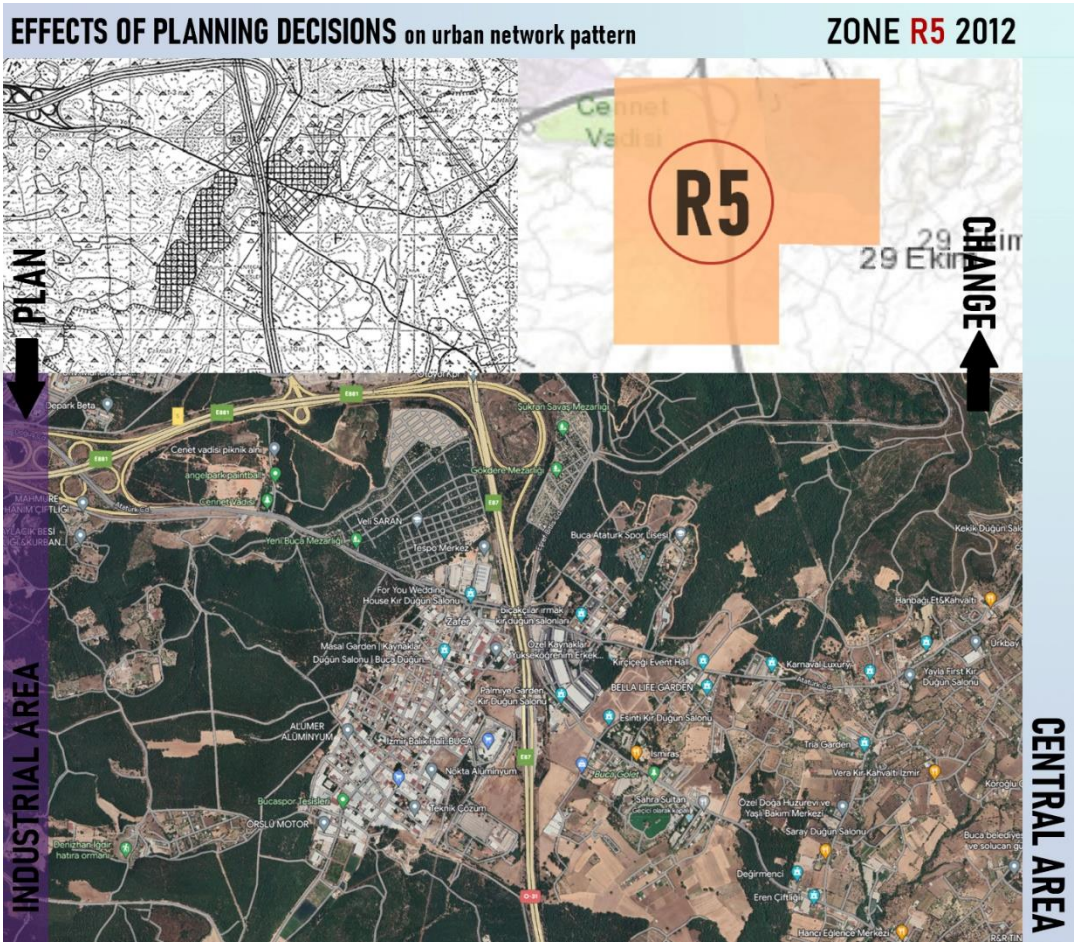


Figure 6.119 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the Central Area, Zone R5 2012

Zone B1 2012 Central Area:

This notation indicates the area in the Çiğli district of İzmir. It represents the eastern part of the Kaklıç neighborhood, mostly west of the İzmir Ring Road, and its surroundings.

The analyses prepared using the network data of period III and period IV in the 2012 Plan of İzmir Metropolitan Municipality (IMM) show that clustering is caused by a

very low-level sub-fractal change in the area. As a result of hotspot analysis, this area is shown in shades of blue.

In the IMM 2012 Plan, the majority of this region is occupied by a military airfield. In the analyses conducted compared to the previous period (see Zone B1 1989), network data was shared by the authorities, and it was observed that there was no change in the pattern or it shifted to less complex patterns.

When the 2020 network data was obtained, the relevant institutions did not share data about this area. Therefore, the site appears entirely negative.

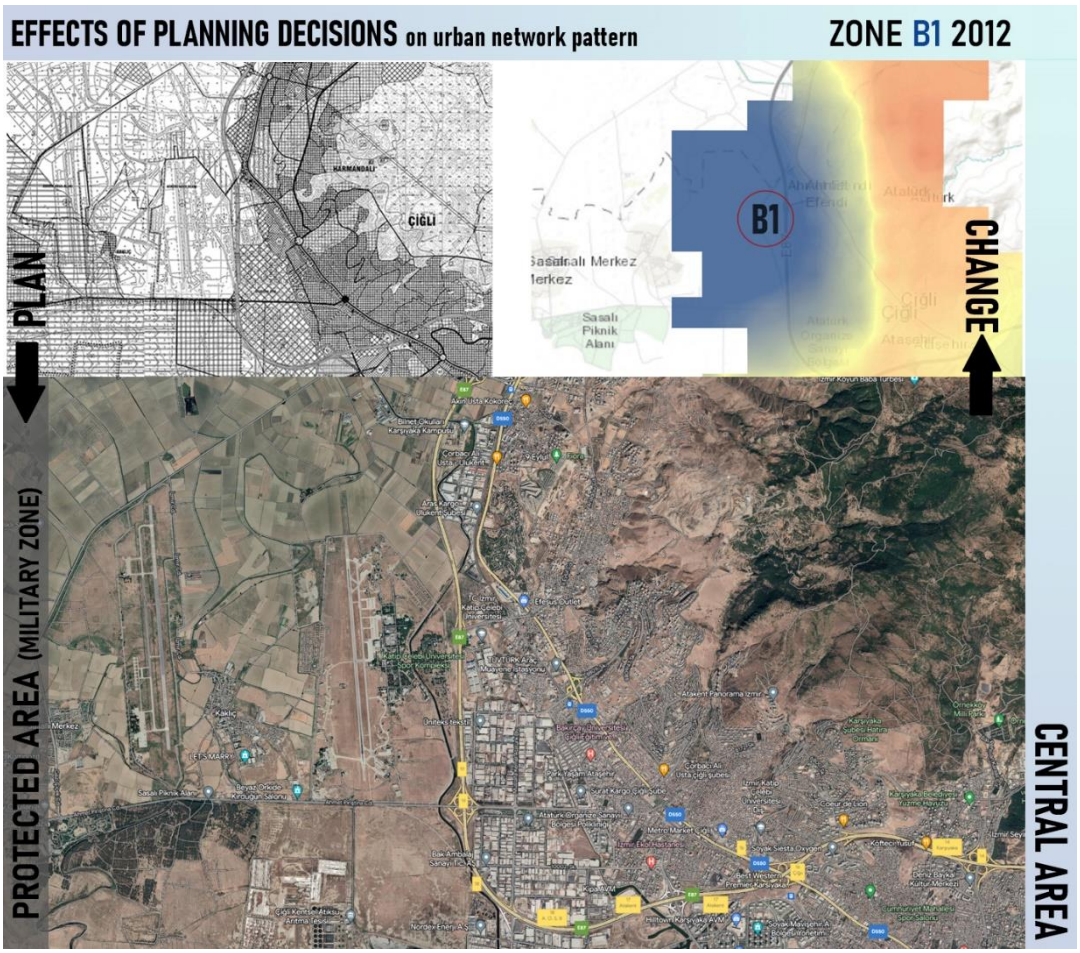


Figure 6.120 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the Central Area, Zone B1 2012

However, when verified with satellite photos, it can be observed that there is no positive change in the network pattern of the area. The fact that the majority of the

site consists of military and conservation areas can also be considered another factor. In the overall evaluation, it was observed that the network pattern had negatively changed, and the sub-fractal values had decreased, indicating a decrease in the complexity level of the area.

Zone B2 2012 Central Area:

The area indicated by this notation represents a line that extends along the Mustafa Kemal Coastal Road, covering the coastal neighborhoods of Narlıdere and Balçova in İzmir, including Limanreis, Altınevler, Sahilevleri, and İnciraltı, up to the boundaries of Konak district, and its surroundings.

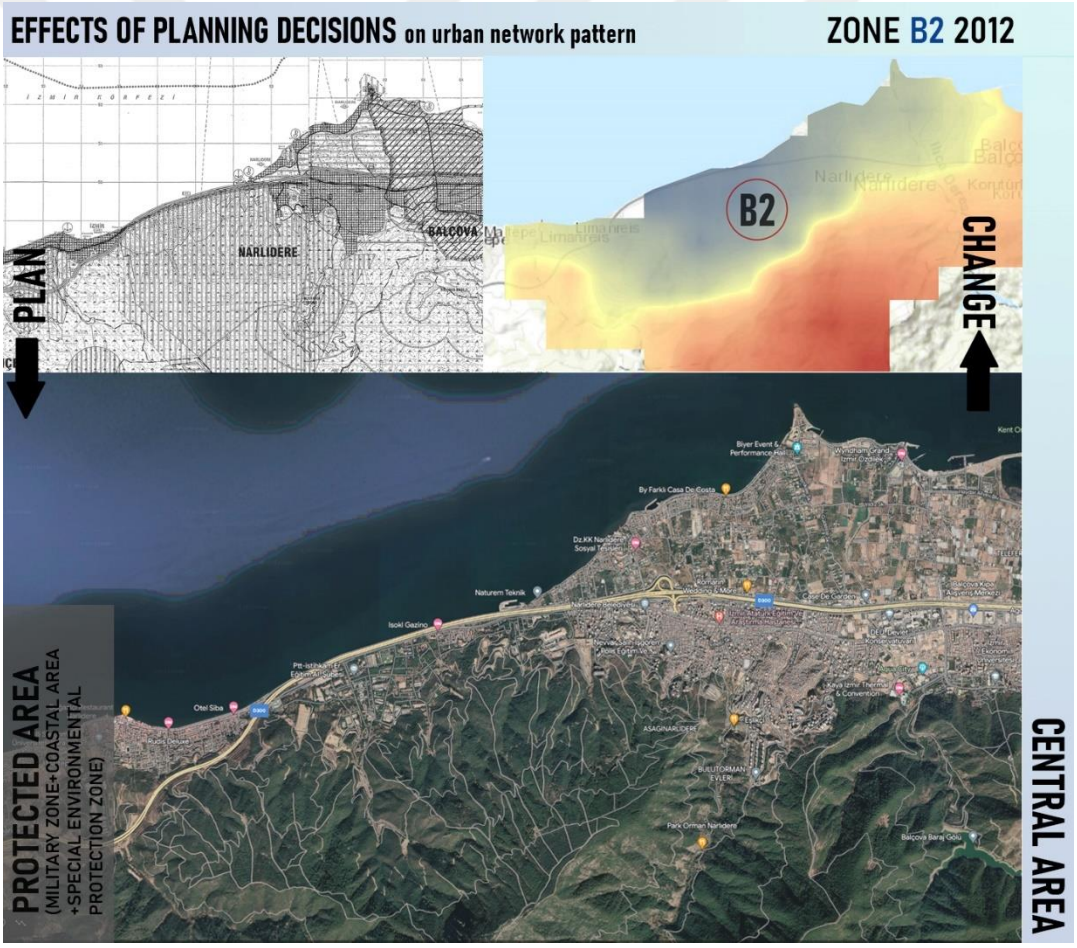


Figure 6.121 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the Central Area, Zone B2 2012

In the analyses prepared using the network data of periods III and IV within the scope of the 2012 Plan of IMM, clustering was observed in the area due to low-level sub-fractal changes. As a result of the hotspot analysis, this area is shown with blue density colors.

In the 2012 Plan of IMM, this area consists of special environmental protection areas consisting of agricultural lands, military areas, and forested areas, and no new development area is proposed.

In the general evaluation, no change has been observed in the network pattern, and a negative trend has been observed. Sub-fractal values have decreased less or remained unchanged, and it has been seen that the complexity level of the area tends to decrease.

Zone B3 2012 Central Area:

The area indicated by this notation represents a wide area surrounding the Dokuz Eylül neighborhood, which predominantly comprises the eastern region of the Gaziemir district in İzmir.

Analysis conducted using period III and period IV network data within the scope of the 2012 İzmir Metropolitan Municipality (IMM) plan revealed clustering caused by low-level sub-fractal variation in this area. As a result of hotspot analysis, this area is represented by shades of blue.

In the 2012 IMM plan, this area was designated as a residential area along with military areas and forests. The current uses of the area were incorporated into the plan, but no new uses were proposed. The Military School of Non-commissioned Officers and facilities for military use are located within the military area.

While the network pattern of the military area in this region was shared in the 2000 network data, it was not shared in the 2020 data. A general evaluation reveals a decreasing trend in the network pattern. Therefore, sub-fractal values have decreased, and a tendency toward a decrease in the complexity level of the area was observed.

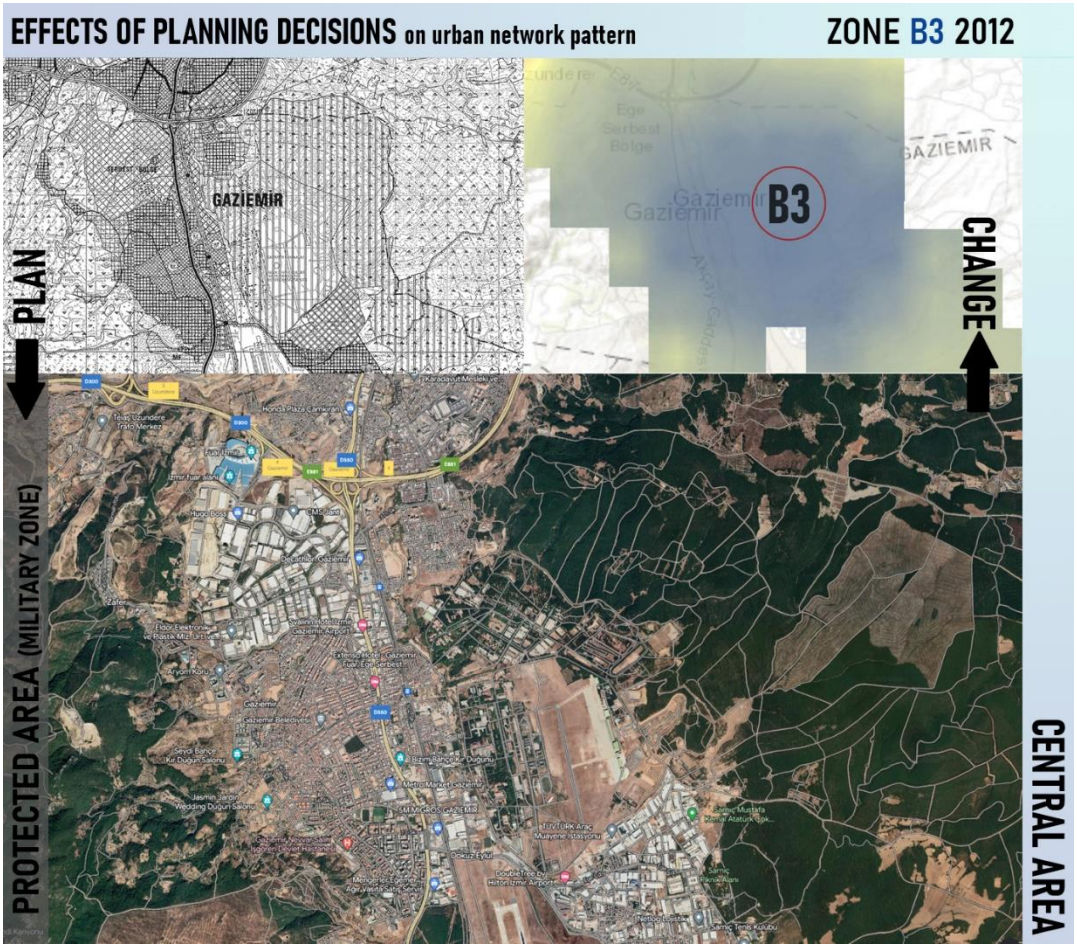


Figure 6.122 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the Central Area, Zone B3 2012

Zone B4 2012 Central Area:

The area specified by this notation is located on the border of the Konak and Bornova districts in İzmir, encompassing a wide area that includes the southern part of the İzmir Atatürk Stadium, Şehitler Avenue, and the high neighborhoods of the Konak district.

In the analyses prepared using the period III and period IV network data within the scope of the İzmir Metropolitan Municipality (IMM) 2012 Plan, clustering has been observed in the area due to low-level sub-fractal changes. As a result of the hotspot analysis, this area is shown in blue-dense colors.

In the IMM 2012 Plan, existing uses in this area have been marked the plan, and no new use has been proposed. Since the area is located in the central district of İzmir, which is the center of urban life, it maintains its urban center position, and it has been observed that it has reached pattern saturation physically.

For this reason, there has been no significant pattern change in the area, which is also reflected in the analysis results. Sub-fractal values have decreased less or remained the same, and it has been observed that the complexity level of the area is decreasing.

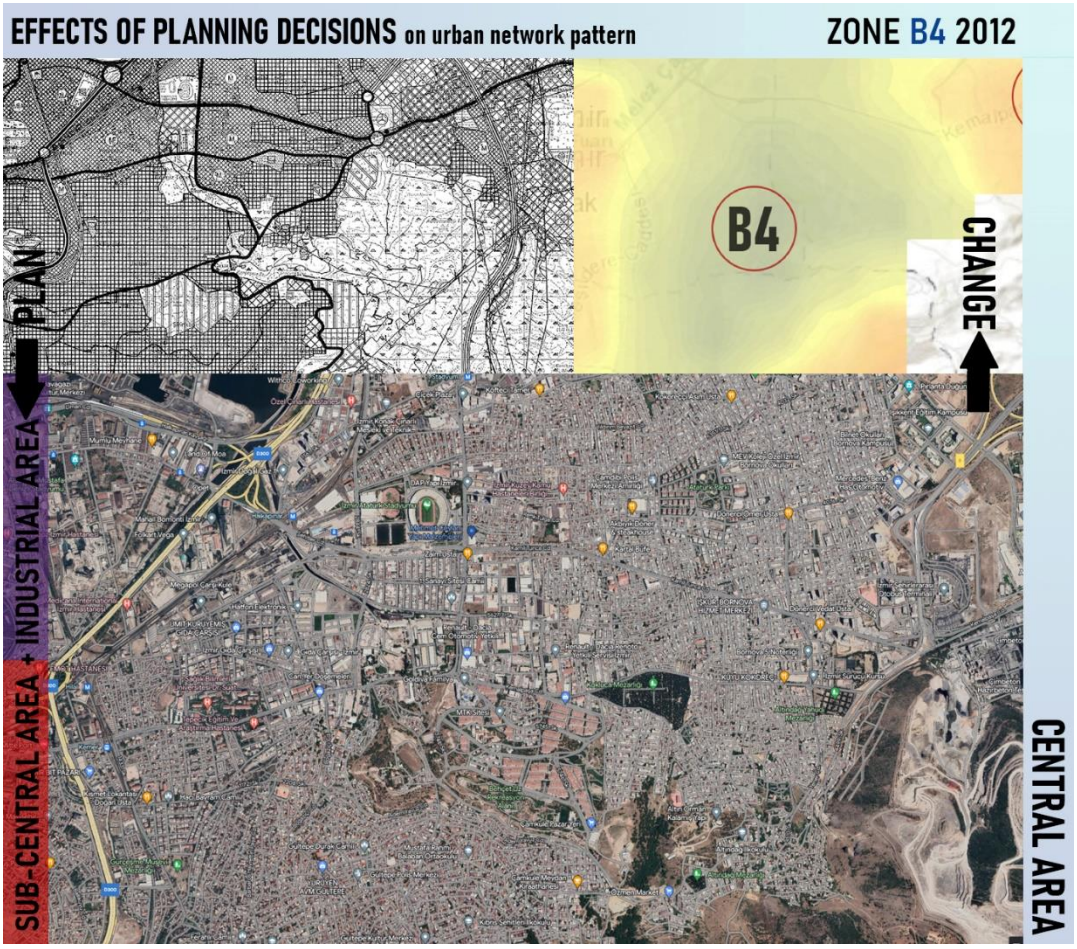


Figure 6.123 The Effects of the Planning Decisions on the Urban Network Pattern of İzmir, the Central Area, Zone B4 2012

6.3.5 Resources Used in the Evaluation of Cluster Analysis Results

From the beginning of the 1950s until the year 2000, intense informal settlement (squatters) formation was observed in various parts of the city of Izmir. As a result of analyses, changes in the sub-fractal values of these areas, mainly through their transformation, were observed. These resources were crucial in order to document which squatter areas formed before which plans and which mass housing and urban transformation projects were implemented in their place.

The first map, taken from a study prepared using the archival data of the Izmir Metropolitan Municipality in 2000 by Karadağ, shows where and when the squatter areas were formed and where the mass housing projects were implemented.

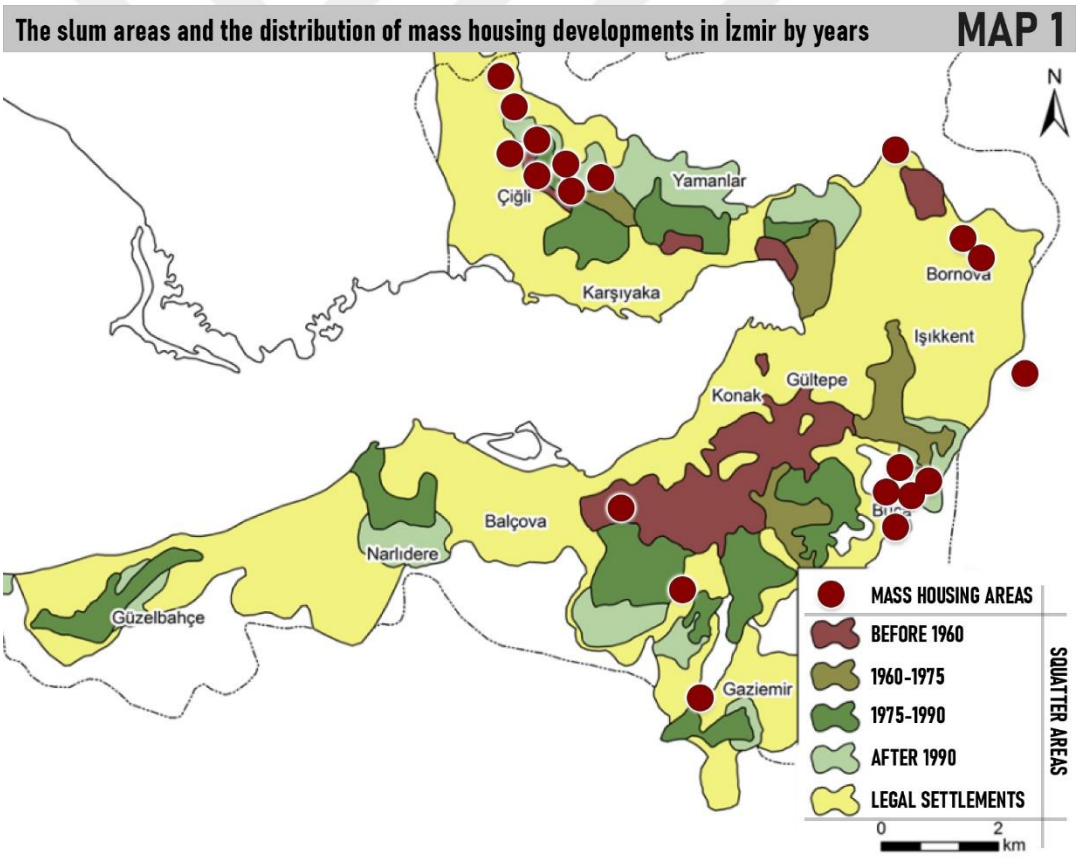


Figure 6.124 The Slum Areas by years and Mass Housing Developments in İzmir (Karadağ, 2000)

The second map, prepared by Mutluer in 2000 using the same archival data of the municipality, shows the distribution of the formation of mass housing areas by year. Cluster analysis results were evaluated using these resources, and the changes in the city's complexity level were observed.

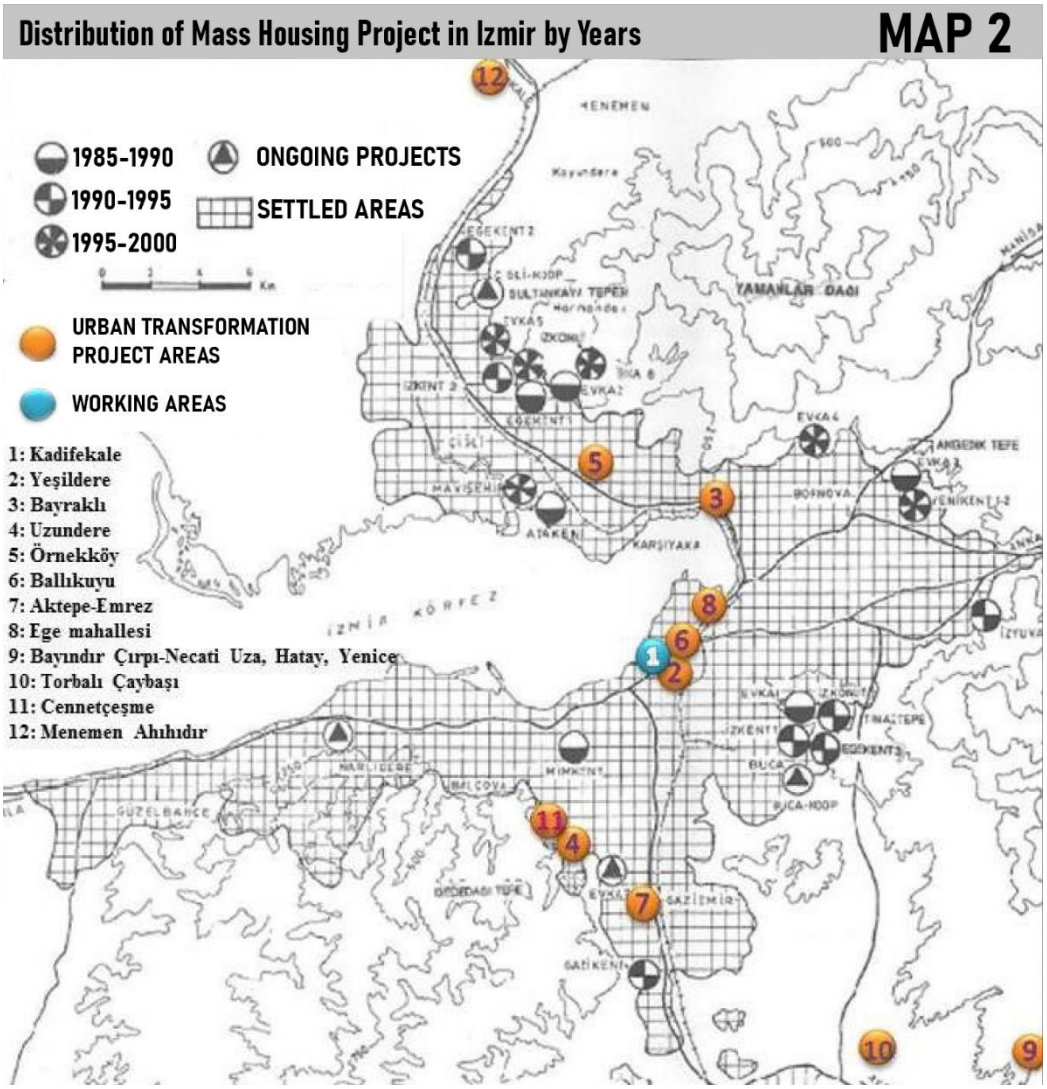


Figure 6.125 Distribution of Mass Housing Project in İzmir by years (Mutluer, 2000)

6.4 Chapter Summary

This chapter provides an in-depth analysis of the complexity of the Izmir Metropolitan Area using fractal dimension analysis methods. It is divided into three

main sections, each contributing to a deeper understanding of the region's complexity.

The first section examines periodic fractal dimension analysis techniques, such as periodic box-counting analysis, periodic local connected fractal dimension (DLC) analysis, and periodic sub-fractal analysis. These methods are used to analyze the fractal dimensions of different plans within the Izmir Metropolitan Area and compare their complexity.

The second section compares the fractal dimensions obtained from four specific plans of the Izmir Metropolitan Area. The chapter performs a difference analysis to reveal variations in fractal dimensions across plans and identify those with higher or lower complexity levels.

The final section explores the spatial autocorrelation of fractal dimensions using cluster analysis with Moran's I. This analysis identifies clustering patterns and areas with different complexity levels. The chapter also provides external spatial resources used to evaluate cluster analysis results.

Overall, this chapter comprehensively analyzes the Izmir Metropolitan Area's complexity using fractal dimension analysis. It emphasizes the importance of considering different plans when assessing complexity and demonstrates how fractal dimension analysis can evaluate and compare them. The chapter also offers insights into clustering patterns and identifies areas with similar complexity levels.

CHAPTER 7

CONCLUSION

The present study comprises six chapters concentrating on different aspects of fractal analysis and urban planning in the Izmir metropolitan area. Next, the study examines the historical development of urban planning and the concept of complex-cities. It explores the evolution of urban planning theories and contemporary approaches to urban planning while introducing complexity theories and their application in understanding complex urban systems. Additionally, it explores several models related to complex-cities, including dissipative cities, cellular automata cities, sandpile cities, FACS and IRN cities, and fractal cities.

Then, the study explains the contextual frameworks for fractal analysis by defining the concept of fractals and discussing different subjects of fractal analysis, such as multi-scale fractal structures, self-affine fractal structures, time series with fractal characteristics, and multi-fractal structures. The chapter also discusses various applications of fractal geometry in urban planning, including urban morphology and urban geography. It provides an overview of research on the applications of fractals and examines different data types for fractal analysis of cities, including calculating fractals in road and city systems.

Continuing with the study, the focus shifts to the planning processes of Izmir city. It discusses both unimplemented plans, such as Rene and Raymond Danger's and Henri Prost's Plan, 1925, Le Corbusier's Plan, 1949, and Albert Bodmer's 1960 Plan, and implemented plans, such as the proposal of Kemal Ahmet Aru, Gunduz Ozdes and Emin Canpolat, 1955, the Izmir Metropolitan Planning Office's Plan, 1973-1978, the Izmir Metropolitan Municipality Plan, 1989, and the Izmir Metropolitan Municipality’s Environmental Plan, 2012. The chapter also delves into the development of the Izmir metropolitan area.

Next, the study discusses the method employed, including the aim of the study and research questions, the general development of the Izmir metropolitan region, and the appropriateness of the research area. It also examines the effects of planning decisions within the plan's boundaries and justifies using urban road network data for fractal analysis. The chapter details data preparation, the tool for fractal calculation, and the analysis methods employed, such as fractal dimension analysis and overlapping all outputs. Evaluation methods are also discussed, such as difference analysis and cluster analysis with Moran's I.

The study then proceeds to examine the Izmir metropolitan area through complexity analysis techniques. Specifically, it focuses on periodic fractal dimension analysis related to plan boundaries, involving periodic box-counting analysis, periodic local connected fractal dimension analysis (DLC), and periodic sub-fractal analysis using overlapped visuals. The chapter also discusses the difference analysis of the results obtained from the fractal dimension analysis and cluster analysis using Moran's I to analyze the outputs of the difference analysis.

In summary, *this study aims to investigate the impact of urban planning decisions on the complexity level of the urban system in the Izmir metropolitan area.* It examines the evolution of urban planning theories and contemporary approaches to urban planning, and explores various theories on complex-cities. The study also provides an overview of the different applications of fractal geometry in urban planning and discusses the planning processes of Izmir city. Employing the fractal analysis method, it analyzes the complexity level of the Izmir metropolitan area using techniques such as periodic fractal dimension analysis, cluster analysis, and difference analysis. Overall, the study offers a detailed description of the fractal analysis method used and the results of complexity analysis, providing valuable insights into the complex systems of urban structure.

Finally, in this chapter, the study's contribution to the planning and fractal analysis literature is discussed, along with a general evaluation of the findings. The technical and theoretical challenges related to complexity theories are also addressed, and potential avenues for future studies are explored.

7.1 Evaluation of the Research Findings

Alternative planning approaches, such as Habermas' planning based on communicative action (1984), have emerged as a response to criticisms of rational planning. These approaches accept uncertainty in spatial design and emphasize dialogue with local stakeholders to transform uncertainties into collective certainties (De Roo & Rauws, 2012). Contemporary planning theories navigate between technical and communicative rationality, known as the "two cultures of planning" (Portugali, 2012). They have evolved towards more flexible approaches prioritizing communication and interaction (de Roo, 2010). Complexity theory recognizes cities as dynamic and complex systems operating in a fuzzy environment between technical and communicative rationality (De Roo, 2010).

As Hillier (2010) described, strategic spatial planning involves pragmatic and adaptive navigation beyond knowledge and control. It encompasses two planes: the transformative and creative plane of immanence and the structured plane of an organization (Hillier, 2011).

To navigate these planes effectively, planners utilize fractal analysis, spatial statistics, and GIS. The fractal analysis quantifies the complexity and irregularity of spatial phenomena, aiding in understanding spatial dynamics (Hillier, 2011). When combined with spatial statistics and GIS, it helps assess spatial distributions, identify patterns, and make informed decisions in strategic planning (Hillier, 2011). Fractal analysis, supported by spatial statistics and GIS, enables planners to evaluate spatial consequences, anticipate developments, and optimize resource allocation (Hillier, 2011). This holistic approach fosters adaptive strategies to respond to emerging challenges and avoid unintended consequences.

7.1.1 Findings and Discussion

In this study, the main research question focused on investigating the effects of planning decisions on the level of complexity. To address this central question: *"How*

to evaluate a city's complex, dynamic, nonlinear, constantly changing, self-adapting, and emergent patterns and analyze its response to comprehensive master plans?" several sub-research questions were formulated and grouped into two categories.

The first group of sub-research questions aimed to understand complexity dynamics and interdependencies. Throughout the study, three specific research questions were posed and answered in their respective sections, providing insights into complex systems' intricate dynamics and interrelationships.

The second group of research questions explored the impacts of planning decisions and evaluation methodologies. This part of the study aimed to initiate a discussion regarding the approach taken to answer these questions and the findings that emerged from the analysis.

By structuring the research questions into these two distinct groups, the study could comprehensively examine the complex nature of planning decisions and their implications. The findings from addressing these research questions contribute to a deeper understanding of the relationships between planning decisions and complexity, informing future planning practices and evaluation methodologies.

Understanding Complexity Dynamics and Interdependencies

- **Sub-RQ1:** *What are the trends of complexity change identified through fractal dimension analyses?*

This question has been answered through box-counting and DLC analysis. These analyses aimed to observe how the complexity tendencies of the entire city changed during specific periods and to understand the development directions of the city. They helped identify periods of fluctuations in complexity levels.

According to the findings obtained in the conducted studies, the analyses for all periods revealed that the highest fractal dimension values were observed in the I and II periods within the boundaries of the Aru Plan in 1955. In the III and IV periods, it

was observed that the IMM 1989 plan had the highest fractal dimension values. In the case of Izmir, the main reason for these remarkable values can be attributed to the intensification of slums due to industrial development during these periods and the failure of the planning decisions to adapt to these changes. In other words, the presence of numerous emergent urban activities during these periods resulted in significant increases in the level of complexity.

Through DLC analysis, the development directions suggested by the plans and the development trends resulting from the functioning of the city's internal dynamics were observed, and compatible and incompatible situations were identified. The relevant sections of the study present and discuss the development trends of all periods.

Additionally, it is essential to highlight a significant capability of DLC analysis. DLC analysis enables leveling of connectivity in terms of fractal dimension values. For this specific study, the two highest levels of fractal values were calculated as significant, and the city's development trend was determined based on these levels. However, planning professionals may only sometimes focus on high fractal values; there may be instances where medium and low values hold significance, and the reasons for this may be specific research topics. Therefore, DLC analysis is an essential tool for professionals to observe different levels of urban complexity and their causes easily.

- ***Sub-RQ2:*** *What is the relationship between the parts of the system and the whole in terms of complexity?*

The question explores the relationship between different components in urban systems and overall complexity. Understanding how changes in specific elements influence the entire system's complexity helps identify critical urban complexity factors. To determine these changes, the sub-fractal analysis method was utilized. This analysis method revealed that the system's sub-parts fractal values differ from those observed in previous analyses. Additionally, it was observed that the average sub-fractal values do not match the overall fractal values of the system. It also

indicates that changes observed in the system's components have varying effects on the entire system.

The sub-fractal analysis serves as a data source for difference analysis. By using these two analyses together, local changes can be observed based on box size, and whether planning decisions directly affect specific areas can be determined. In the case of Izmir, this study identified which decisions were effective in which areas and at what levels of change. The relevant sections of the study include the necessary calculations to illustrate these findings. The fundamental idea here is to understand the sensitivities of the city when making spatial planning strategies and to determine in advance how this complex system will respond to interventions.

The sub-fractal analysis method, when used in conjunction with difference analysis, allows planning professionals to make more informed planning interventions. It is essential to highlight the high technical capacity of this method. In the scope of the study, the relevant methods were applied within the temporal boundaries of the city's plans. *However, optimizing box sizes makes it possible to calculate changes from neighborhood scale to regional scale, and even interregional changes, and determine sensitivities at the respective scales.* Planning professionals should pay attention to this scalability or capacity, and with accurate data, it should become a commonly used tool in analyzing urban systems' complexity.

- ***Sub-RQ3:*** *What is the adaptive capacity range of the entire system?*

The primary objective of this sub-question is to ascertain the adaptive capacity range of the urban system, focusing specifically on the city of Izmir. Adaptive capacity refers to the inherent capability of a system to adjust and respond to internal and external changes while preserving its essential functions and structures. By evaluating the system's adaptability to various planning decisions, researchers can discern the limits and potentials of urban resilience. This knowledge is imperative for sustainable land-use planning, ensuring the system can withstand and adapt to future challenges.

Through a comprehensive difference analysis encompassing all planning boundaries and periods in Izmir, the research findings reveal that the Adaptive Capacity Range (ACR) falls within the range of $0<a<0.25$. This determined value assumes significant importance as it delineates the system's high and low change levels. The ACR should be actively employed during spatial planning decisions to ensure that the introduced magnitude of change maintains the system's continuity, minimizes functional losses within the area, and fosters harmonious integration between the intervened zone and its surrounding context.

Nevertheless, it is vital to acknowledge that the calculated ACR value is specific to the context of Izmir and may not be universally applicable to all cities. This realization underscores the notion that planning decisions cannot be readily generalized, and identical interventions or strategies may not yield optimal outcomes across diverse urban settings. Consequently, specific analyses and calculations must be conducted concerning the particular city under investigation, thereby enabling the development of spatial strategies characterized by the requisite flexibility tailored to the unique sensitivities and dynamics of that specific urban context.

For instance, while decisions about industrial areas result in substantial high-level complexity changes within Izmir's urban system, another city may experience comparable high-level complexity changes from decisions concerning tourism areas or large-scale educational facilities. Such observations underscore the site-specific nature of adaptive capacity and the necessity for localized analyses and tailored planning approaches.

The ACR data thus assumes a critical role as an indispensable criterion for urban planners and decision-makers in formulating robust spatial policies, delineating appropriate intervention levels, and determining the spatiotemporal distribution of these intervention levels over time. By incorporating the insights gleaned from the ACR analysis, planning professionals can make informed decisions and devise contextually sensitive strategies that enhance the adaptive capacity of the urban

system, thereby fostering sustainable development and resilience in the face of future uncertainties.

The Impact of Planning Decisions and Evaluation Methodologies

- ***Sub-RQ4:*** *How does the complexity change with reference to the master plans of Izmir?*

The primary objective of this inquiry is to evaluate the influence of master plans on the complexity of Izmir, a specific city. Master plans, which serve as comprehensive urban planning documents, offer a long-term vision and strategies for diverse aspects of urban development. By scrutinizing the variations in complexity associated with different master plans, researchers can effectively assess the efficacy of specific planning interventions in managing and shaping urban complexity. To achieve this, the Spatial Cluster analysis method was employed.

This analysis indicates that the initial two plans, namely the Aru 1955 Plan and the IMM 1973-78 Plan, prominently embody the top-down approach characteristic of the Comprehensive Planning concept. Evidently, the decisions formulated within these plans and the following activities within the city system exhibit a noticeable degree of inconsistency. Despite the intentions behind these master plans, namely to exert control over the city and foster a healthier urban environment, their top-down deterministic approach proved inadequate in managing the city's complexity, resulting in emergent urban activities.

Conversely, the following two plans, the IMM 1989 and IMM 2012 plans, extensively incorporated existing urban developments into the planning process while legitimizing ongoing urban activities. Notably, the inclusion of informal settlements as designated residential development areas and the integration of existing residential areas within the decisions of the IMM 1989 Plan serve as exemplars of this inclusive approach. These inclusions occurred concomitantly with the emergence of squatter settlements and the enactment of planning laws in the

1980s. These plans prioritize establishing legal frameworks to accommodate the ongoing urban activities rather than solely focusing on devising spatial policies that foster improved health and sustainability. Various legal requirements predominantly drive such an approach.

The pertinent sections of this research extensively deliberate on the various factors that influenced planning decisions and led to changes in complexity. In light of the observed inconsistencies, this study strongly implies the necessity of transitioning Turkey's urban planning paradigm away from a top-down deterministic approach. The findings from this specific study conducted in Izmir accentuate the urgency of adopting a more flexible and adaptive approach to urban planning that can effectively respond to the complexity inherent in urban systems.

- ***Sub-RQ5:*** *Which Master Plan of İzmir had the most significant impact on the level of complexity?*

This inquiry aims to identify the master plan that exerted the most substantial influence on the complexity level of Izmir. By comparing different master plans, researchers can ascertain practical planning approaches and strategies for addressing the dynamics of urban complexity. This understanding will inform future planning endeavors and enable decision-makers to prioritize interventions that have a pronounced impact on managing urban complexity. Accordingly, the average calculations of sub-fractal change values were performed for Izmir, allowing the identification of the plan period during which urban complexity underwent the most significant alteration. Moreover, the spatial cluster analysis method was employed to determine whether these changes exhibited a negative or positive trend and to investigate their association with planning decisions.

The results based on the average sub-fractal change values reveal that the IMM 1989 Plan period witnessed the most substantial increase in the complexity level of Izmir, amounting to 21.19%. While it may initially appear that the planning decisions implemented under the IMM 1989 Plan exerted a remarkable influence on augmenting urban complexity, it is crucial to recognize that this escalation primarily

stems from the intensified industrial investments at both the national and local levels, which correspondingly heightened labor demand and accelerated the proliferation of squatter settlements. As previously alluded to, the complexity analyses conducted in this study suggest that the IMM 1989 Plan functions more as a plan aimed at legitimizing the existing urban context rather than a spatial vision plan. Consequently, it can be inferred that, in the context of Izmir, emergent urban activities arising from non-linear relationships play a more pivotal role in driving the elevation of complexity levels than the planning decisions themselves.

Conversely, a similar scenario unfolds in the southern region during the IMM 2012 plan period. This area experienced the most pronounced upsurge in complexity level, registering a value of 22.32% under the IMM 2012 Plan. Although the plan primarily designated industrial areas for this region, empirical observations indicate that the pace of industrialization exceeded the spatial boundaries initially prescribed. Given that the IMM 2012 Plan was formulated as a spatial vision plan targeting the year 2030, the emergence of novel areas surpassing the initially demarcated industrial zones in the early 2020s underscores the need to critically evaluate the prevailing approaches employed in Turkey's planning realm.

To summarize, while spatial planning decisions may act as triggers for urban complexity, this investigation reveals that the emergent urban activities engendered by non-linear relationships constitute the decisive factors driving the augmentation of complexity levels in the case of Izmir.

- ***Sub-RQ6:*** *To what extent do major land use decisions affect the level of complexity, and which of them are more distinct in master plans?*

This question investigates the impact of major land use decisions on urban complexity, particularly in the city of Izmir. Land use decisions, encompassing zoning regulations and the allocation of space for different purposes, are recognized as fundamental factors shaping urban areas' physical and functional attributes. The primary objective of this inquiry is to identify which specific land use choices exert

a more pronounced influence on urban complexity patterns, thereby offering valuable insights for effective urban planning strategies.

To address this objective, the analysis employs a difference-based approach. Sub-fractal change calculations are conducted, enabling the examination of the relationships between land use decisions and changes in complexity. Specifically, spatial planning decisions are evaluated by intersecting sub-fractal change grids, allowing for a thorough investigation of their associations with complexity dynamics. The findings provide a nuanced understanding of the differential impacts of various land use decisions on urban complexity levels.

The results obtained from the study indicate that certain land use decisions have a more significant positive impact on urban complexity in Izmir. Decisions related to industrial areas, sub-centers, major commercial areas, and large-scale educational and healthcare facilities exhibit a more substantial positive influence on complexity levels compared to decisions pertaining to residential areas. *The analysis reveals that non-residential land use decisions are pivotal in driving significant positive changes in complexity, followed by subsequent residential land use decisions.*

In contrast, the study finds that protected areas, owing to their inherent characteristics, do not contribute substantially to the positive evolution of complexity levels. In fact, in some cases, areas designated as protected exhibit a negative trend in complexity, which can be attributed to modifications made to the road network geometry, often involving the removal of existing roads to preserve the area's natural integrity.

These research findings contribute to the scholarly discourse on the relationship between land use decisions and urban complexity. Identifying meaningful land use choices informs urban planners and decision-makers in Izmir and other similar contexts about the specific land use strategies that have a tremendous potential to shape urban complexity. This knowledge enhances the capacity to develop more informed and effective urban planning interventions, ultimately facilitating sustainable urban development and the management of urban complexity.

A Question for Planning Practice

- ***Sub-RQ7:*** *How can complexity analyses be used as a criterion for monitoring and forecasting tools in master planning?*

Complexity analyses can serve as valuable criteria for monitoring and forecasting tools in master planning. By incorporating complexity metrics and methodologies into the planning process, urban planners and decision-makers can gain deeper insights into the dynamics of urban systems and make informed decisions regarding future development trajectories. The utilization of complexity analyses as a criterion for monitoring and forecasting tools in master planning can be approached in the following ways:

- ***Monitoring Urban Complexity:*** Complexity analyses can provide a systematic framework for monitoring the evolution of urban complexity over time. By regularly assessing and analyzing complexity metrics such as fractal dimension values, spatial patterns, and connectivity indices, planners can track changes in the urban system and identify emerging trends. This monitoring process enables planners to understand the current state of the city and its underlying dynamics, facilitating evidence-based decision-making.
- ***Identifying Critical Points of Intervention:*** Complexity analyses can help identify critical intervention points within the urban system. By examining the relationships between land use decisions, infrastructure development, and complexity patterns, planners can pinpoint areas where specific interventions are likely to impact urban complexity significantly. This information can guide the prioritization of resources and efforts, ensuring that planning interventions are targeted and effective.
- ***Scenario Analysis and Forecasting:*** Complexity analyses can be used to simulate and forecast the potential outcomes of different planning scenarios. By applying complexity models and simulation techniques, planners can explore the effects of various development options on urban complexity. These scenario analyses provide valuable insights into the potential future trajectories of the urban system,

enabling planners to anticipate the consequences of different decisions and make proactive adjustments to achieve desired outcomes.

- ***Assessing Resilience and Vulnerability:*** Complexity analyses can help assess the resilience and vulnerability of urban systems. By quantifying and analyzing complexity patterns, planners can identify areas more susceptible to disruptions or exhibit lower resilience levels. This information enables the development of targeted strategies to enhance the system's resilience, such as improving connectivity, diversifying land use patterns, or strengthening infrastructure networks.
- ***Stakeholder Engagement and Communication:*** Complexity analyses can facilitate stakeholder engagement and communication in the master planning process. By visualizing complexity patterns and their implications, planners can effectively communicate the challenges and opportunities of different planning options. This engagement promotes a shared understanding among stakeholders and fosters collaborative decision-making, leading to more inclusive and effective master plans.

It is important to note that other planning methodologies and tools should complement complexity analyses to ensure a comprehensive and integrated approach to master planning. Additionally, the application of complexity analyses should consider the specific characteristics and context of the city under study, as urban systems vary in their dynamics and complexities. Therefore, integrating complexity analyses as a criterion for monitoring and forecasting tools in master planning requires careful adaptation and customization to suit each urban context's unique needs and challenges.

Implications and Summary of the Findings

In the light of aforementioned explanations, the conclusions that can be drawn at the end of the study are as follows;

- As a result of fractal analysis studies, necessary calculations were made on the "effects of planning decisions on the level of complexity," and pure technical findings were obtained and shared in the relevant sections of the study. It has been possible to make the following technical inferences, considering the relevant periods in the plans prepared and implemented for Izmir.
- Settlements create open, dynamic, and processual patterns. Settlement patterns, which intertwine numerous spatial and temporal scales, undergo transformations influenced by countless variables.
- However, these complex systems emerge and self-organize through ***macro-micro*** relationships. They arise from interactions at the micro level, determined by simple rules such as household location decisions, traveler behaviors, or entrepreneurial preferences. Once they emerge, these formations sustain themselves at the macro level, despite micro-level changes, by self-organizing their existence.
- Although settlement patterns at the macro level are composed of interconnected natural, artificial, and social subsystems, they also possess their macro-level characteristics that cannot be reduced to the belongings of their constituent parts. Variables such as population size, density, road networks, morphological structure, and land use distribution enable us to track changes in settlement patterns. This is because settlements transform by exhibiting observable regularities and patterns.
- In the 1960s, the Izmir urban region and its metropolitan area were characterized by a pattern defined by the central Izmir. By the 1980s, it transformed into a single-focused structure centered around Izmir. In the 2000s, it expanded with corridor developments along the north, south, and peninsula directions, resulting in a sprawl-like formation. Today, we can speak of a metropolitan area formation with the Gulf periphery surrounding the inner bay. In the outer ring, a city region has emerged, encompassing Manisa and Aydin.
- Regions are not merely territorial entities defined by administrative boundaries but spatial and social units shaped by socio-spatial processes. Legal and

governance arrangements, power relations, discourses, local-specific relationships, cultural symbols, official or unofficial means, plans, strategies, and projects, legitimize and institutionalize the jurisdictions of regions.

- The Izmir Metropolitan Municipality has governed Izmir based on the networked regional characteristics, learning to cope with economic challenges and setting the path for growth through specific strategies. However, there is a need for more flexible governance structure that allows for new socio-spatial transformations and emergences, enabling an 'open' and/or 'fluid' region.
- Instead of forcing settlements to conform to a specific form or shape through legal and administrative regulations or central planning, strategies, policies, and projects should be developed to enhance places' reflexivity forms and self-governing capacity.
- In today's context, where the spatial planning practice has become a tool for political and urban rent-seeking, there is necessary to move beyond traditional approaches in the solutions that are attempted to be produced through decision-makers, planners, or administrators within the legal and administrative framework. This requires the capacity to establish networks and relationships among scales and actors in spatial planning practice.
- It is certain that planning, considered as a final product, along with the generated legal documents, as well as the envisioned urban development and designed physical environment, will bring along potential triggers for the surrounding area within or in interaction with the project and planning area.
- In line with this understanding, intervention in the complex system created by the urban structure, as evident in the findings of the current research project, demonstrates the harmony between spatial decision-making and its internal dynamics, as well as the representations and capacities generated at different scales and among actors, rather than being limited to the dilemma of outcome and result.
- Plan decisions produced as interventions in urban space, along with their various implementation tools and the roles of actors who are actively involved in the

process, should not only be considered as triggers for change but also possess the necessary flexibility to adapt to the physical, social, and spatial changes that occur within the process.

In this new era where local conditions and context gain importance, understanding the complexity of the urban structure and effectively managing urban development requires a new planning approach that focuses on the process rather than the outcome. This approach should evaluate this focus across different scales and periods and be flexible to adapt to potential outcomes. However, another crucial aspect that emerges here is the role of planners and what role they should assume.

The planning literature highlights the role of planners as mediators in transitioning to communication-based approaches, utilizing their common sense to cope with the whims of political will (Hillier, 2002, p. 3) and acting as crucial problem solvers and facilitators of democratic citizen participation (Tewdwr-Jones, 2002). However, it should not be forgotten that the successful realization of the role attributed to planners as professionals is also proportional to their accumulated experience within the historical trajectory, the strengthening or weakening their authority and capacity.

GENERAL EVALUATION & RESEARCH FINDINGS

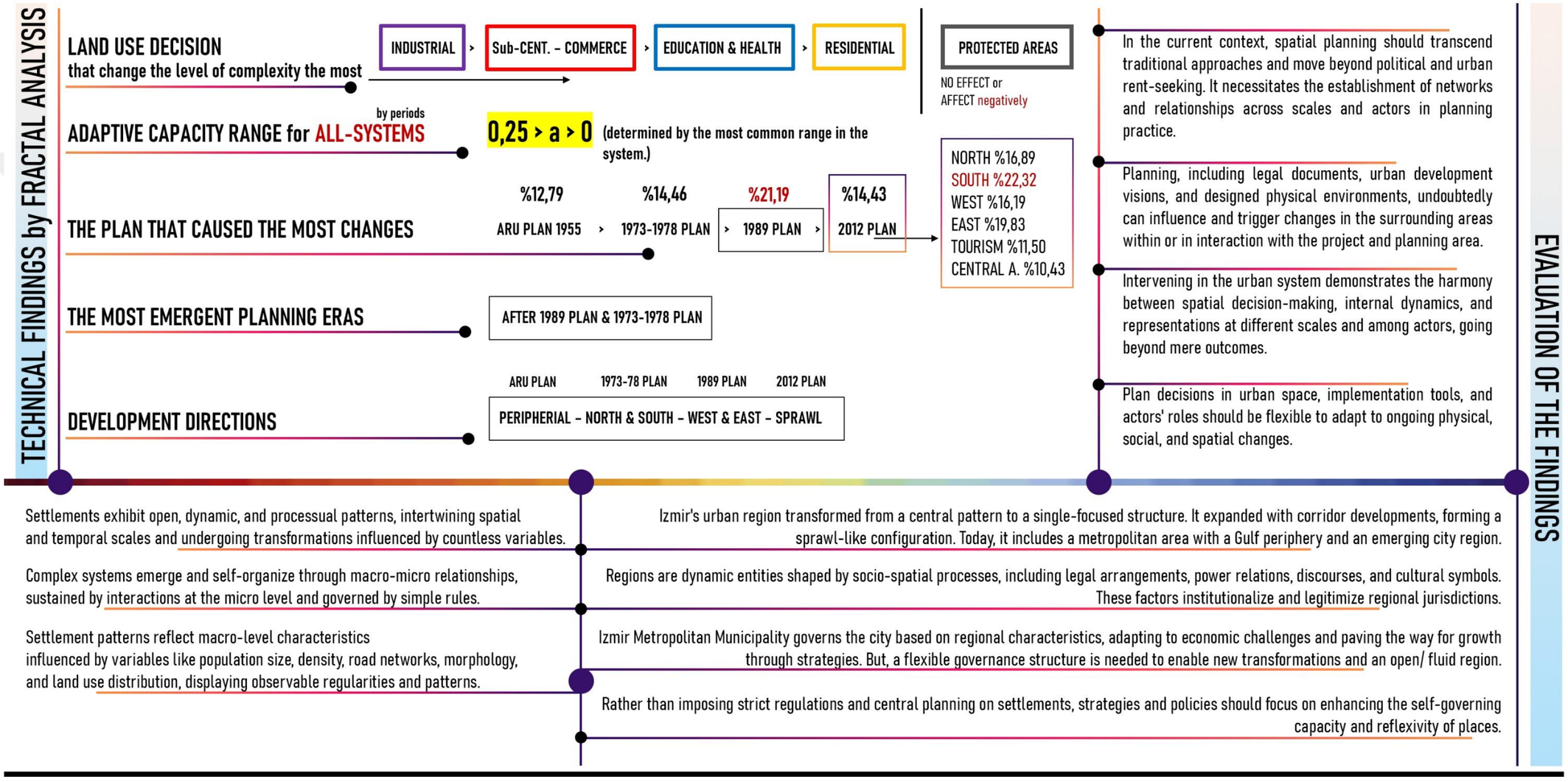


Figure 7.1 Technical Findings by Fractal Analysis and the Evaluation

7.2 Limitations and Prospects of Models on *Complex-Cities*

Urban modeling has a history of creating numerical models to depict urban development's complex and dynamic nature. However, despite the progress made, several challenges need to be addressed theoretically and practically to develop effective models. These include accurately representing urban development's spatial and temporal dimensions, modeling interactions between various urban subsystems and processes, dealing with complex feedback loops, and accounting for non-linear dynamics inherent to urban systems.

It is also critical to produce models that capture the unique characteristics of different urban areas, such as small towns, suburban areas, and large cities. Nevertheless, there is an increasing recognition of the significance of urban modeling in informing urban policy and planning, and efforts are being made to improve the accuracy and effectiveness of urban models.

7.2.1 Limitations in *Complex-City* Modeling Approaches

Theoretical approaches to urban modeling, such as the urban ecological, social physics, and neoclassical approaches, are limited in describing urban development (Sui, 1998; Batty, 1981; Echenique, 1975; Lee, 1973). Each approach focuses on specific aspects of urban development while neglecting others. The systems approach provides insights into the complex relationships within urban systems but needs to explain the organization and evolution of these systems. Conventional modeling practices have emphasized technical aspects rather than developing new theories, limiting their ability to generate new insights (Sui, 1998).

Based on fractals and chaos theory, cellular automata modeling has shown potential for generating new theoretical insights in urban modeling (Batty, 2000; Couclelis, 1997, 1989, 1985; Toffoli & Margolus, 1987). It has been widely used in various scientific disciplines (Clarke et al., 1995; Mainster, 1992; Doolen & Montgomery,

1987; Guan, 1987; Sander, 1986; Vincent, 1986; Burks & Farmer, 1984; Hillis, 1984; Vichniac, 1984). However, this approach needs further development and testing (Sui, 1998).

Validating and testing the behavior and sensitivity of urban models are crucial theoretical concerns. Verification and validation of models are necessary to ensure their accuracy in representing real-world systems (Echenique, 1975). Many traditional urban models need more verification and validation tests, limiting their utility in testing urban policies or comparing growth scenarios (Echenique, 1975).

There is a need for models that can capture urban development patterns in less-developed countries and those with communist governments (Echenique, 1975). The urban ecological approach based on Western societies cannot adequately explain urbanization in communist countries. Efforts in developing models for urban development in less-developed countries have been limited compared to those in more developed countries. The theoretical foundation of urban modeling is considered weak, and validation of the models is often insufficient (Echenique, 1975).

7.2.2 Limitations of the Modelling Technics

Urban modelling faces technical challenges related to data availability and handling and the application of GIS in implementing and visualizing urban models.

- In the past, researchers collected data for urban modeling through specific research projects. With the advancement of GIS and remote sensing technology, more data is available from commercial data providers, government agencies, and professional institutions. However, challenges exist regarding the compatibility and accuracy of the data and the way they are handled. These challenges relate to differences in the spatial unit used for different purposes, the level of spatial data aggregation, and the methods used to acquire spatial data. Various factors influence data accuracy, including the data source, storage, and presentation. Unfortunately,

there is a lack of high-quality data for specific research purposes, making it challenging to obtain good data for urban modeling. This highlights the need for better data management and acquisition practices to improve data quality used in modeling efforts.

- Integrating GIS and urban modeling has provided new data management and visualization opportunities. However, this integration has yet to address fundamental issues in urban modeling or GIS, as it remains primarily technical (Nyerges, 1995; Sui, 1998). The difference in spatial data representation between urban modeling and GIS is due to the development of GIS-based on a limited map analogy. In GIS, geographic features are represented as fixed points, lines, polygons, or raster cells within map layers. This is in contrast to the representation of urban systems in modeling, which involves dynamic and interdependent variables (Abel, Kilby, and Davis, 1994; Burrough & Frank, 1995; Harris & Batty, 1993; Peuquet, 1988; Raper & Livingstone, 1995; Gazelton, Leahy, and Williamson, 1992). The way spatial data is represented in GIS, with a limited map analogy, is unsuitable for the relative/social and dynamic conceptualization of space in urban modeling. Therefore, integrating GIS with urban modeling requires research at a higher level of conceptualizing space, leading to new geographic information sciences. This integration currently needs to be more adequate and requires further research. (Sui, 1998; Goodchild, 1992; NCGIA, 1995)

7.2.3 Future Prospects

The development of self-organizing systems and complexity theories has provided new ways of understanding urban development patterns and processes. This theoretical framework has been applied and tested under various conditions and in different regions, resulting in a large body of literature on building urban models under the enhanced self-organizing paradigm. Through these efforts, the theoretical foundations of urban development can be better understood through locally defined

urban transitions. With this awareness, improvements can be made in urban modelling practice.

In urban modeling, theoretical development can improve data collection and handling. As March (1974) suggests, data is collected with a specific purpose and informed by underlying theoretical frameworks. By developing more comprehensive and accurate theoretical models of urban development, researchers can better collect and analyze data relevant to understanding the complex processes at play in cities.

Researchers require specific data types to develop urban models, and integrating urban modelling with GIS demands that only the necessary data be sought after (Echenique, 1975). Sui (1998) suggests that the problems associated with integrating urban modelling and GIS cannot be resolved by treating it merely as a technical issue. Sui (1998) proposed a new framework for urban modeling based on the emerging field of geographic information science. He argued that the issues in integrating urban modeling with GIS could not be solved if treated only as a technical problem. Models developed under this framework should allow researchers to describe the emerging urban structure more comprehensively, explain the underlying processes contributing to the emergence of new structures, and suggest effective urban policies to steer the underlying processes toward promoting the best urban structures.

7.3 The importance of Fractal Analysis for Urban Planning and Planning Professionals

Fractal analysis is an essential tool for urban planners because it allows them to study and understand cities' complex and dynamic nature. One of the main advantages of fractal analysis is its ability to predict future trends in urban development and identify areas that need improvement. For example, fractal analysis can be used to evaluate the efficiency of transportation networks, predict the potential for future urban expansion, and identify areas with high potential for development. Additionally, fractal analysis can be used to identify areas with high levels of social and economic inequality and inform policies to address these inequalities.

Regarding understanding the city, fractal analysis can provide insights into the underlying patterns and structures that shape urban growth and development. It can also be used to study the self-similarity of urban patterns, meaning the repetition of similar patterns on different scales. This can help to understand the underlying mechanisms that drive urban growth and development.

Fractal analysis is also closely related to the concept of self-organization, which is the process by which a system organizes itself without the need for external control or guidance. In the context of urban planning, self-organization refers to how cities naturally evolve and adapt over time. Fractal analysis can be used to study the self-organizing properties of urban systems, such as how transportation networks, land use patterns, and social and economic systems interact to shape the city.

In conclusion, fractal analysis can provide valuable insights into the structure and functioning of urban systems, which can inform the planning and design of more sustainable and livable cities. It can be used to predict future trends, understand the underlying mechanisms that drive urban growth and development, and study the self-organizing properties of urban systems, providing a holistic view of the city.

7.4 Fractal Analysis Methods in Parametric Urban Design Studies: Contributions to the Urban Design Era

Fractal analysis and sub-fractal analysis methods offer valuable tools for parametric urban design studies, providing insights into the complexity and self-similarity of urban forms. These methods contribute to urban design by enhancing the understanding of spatial patterns, connectivity, and scale in the built environment. This section will explain and discuss the academic perspectives on how fractal analysis and sub-fractal analysis methods can be applied in parametric urban design studies.

Fractal analysis involves quantifying the irregular and self-repeating patterns in urban structures using mathematical algorithms. It measures the fractal dimension,

which characterizes the degree of complexity and intricacy in urban forms. By examining the fractal properties of urban elements such as road networks, building footprints, or green spaces, designers can gain insights into the spatial organization and hierarchical structure of cities.

Sub-fractal analysis is an extension of fractal analysis that explores patterns within patterns, enabling a deeper understanding of spatial complexity. It focuses on analyzing specific elements or components within a fractal system, revealing the nested relationships and variations in form and scale. This approach can be used to examine the distribution of building heights, the arrangement of open spaces, or the connectivity of transportation networks at different levels of detail.

Applying fractal and sub-fractal analysis in parametric urban design studies offers several benefits. Firstly, it provides designers with quantitative metrics to evaluate and compare alternative design scenarios. Fractal dimensions and other fractal-based metrics can serve as objective measures to assess the degree of complexity, coherence, and diversity in urban layouts. This aids in the generation of more informed and responsive design solutions.

Secondly, these methods enable designers to generate urban forms that exhibit desired fractal characteristics. By manipulating the parameters and rules within parametric design frameworks, designers can generate fractal patterns that align with specific urban design objectives. This opens up opportunities to create visually pleasing, environmentally sustainable, and socially cohesive urban environments.

Moreover, fractal and sub-fractal analysis can facilitate the integration of local context and global design principles. They allow designers to consider both the local-scale details and the overall coherence of urban forms. This integration helps in achieving a balance between human-scale experiences and larger urban patterns, fostering a sense of place while promoting connectivity and efficiency.

Several studies have highlighted the potential of fractal analysis and sub-fractal analysis in parametric urban design. For example, Batty and Longley (1994) applied

fractal analysis to understand the morphological characteristics of street networks in different cities. Jiang and Claramunt (2004) explored sub-fractal analysis to examine the hierarchical structure of land use patterns in urban areas. These studies demonstrate the applicability and value of these methods in urban design research.

In conclusion, fractal analysis and sub-fractal analysis methods offer valuable tools for parametric urban design studies. They contribute to the urban design era by providing quantitative measures, guiding the generation of complex and coherent urban forms, and integrating local context with global design principles. By incorporating these methods into the design process, designers can enhance their understanding of spatial complexity and create more responsive and sustainable urban environments.

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CURRICULUM VITAE

Surname, Name: Şahin, Mustafa Raşit

EDUCATION

Degree	Institution	Year of Graduation
MS	METU Urban Design	2014
BS	METU City and Regional Planning	2010
High School	Çorum Science High School, Çorum	2005

FOREIGN LANGUAGES

Advanced English

PUBLICATIONS

No publications.