...::KENT AKADEMİSİ | URBAN ACADEMY

Volume: 18 Issue: 2 - 2025 | Cilt: 18 Sayı 2 - 2025

ARTICLE INFO | MAKALE KÜNYESİ
Research Article | Araştırma Makalesi
**Submission Date | Gönderilme Tarihi:** 15.11.2024
**Admission Date | Kabul Tarihi:** 19.01.2025

CITATION INFO | ATIF KÜNYESİ
Güneş, P., Kütük, T., Tanrıvermiş, Y. (2025), Sustainable Transportation Systems Framework and Spatial Analysis with Fractal Analysis Method, Kent Akademisi Dergisi, 18(2): 860-877. https://doi.org/10.35674/kent.1585779

# Sustainable Transportation Systems Framework and Spatial Analysis with Fractal Analysis Method

## Sürdürülebilir Ulaşım Sistemleri Çerçevesi ve Fraktal Analiz Yöntemi ile Mekansal Analiz

Parla Güneş[1] , Tuğba Kütük[2] , Yeşim Tanrıvermiş[3]

***Öz***

*Kentsel çalışmaların her biri farklı değerlendirmeye konu olmakla birlikte coğrafi modellemeler ve mekânsal analizlerin gelişimi ile güçlü sonuçlar elde etmek için fraktal analiz yöntemi bir araç olarak seçilmiştir. Fraktal geometri, biçim açısından farklılıkların tespitinde; sistemin başlangıç koşullarına bağımlı karmaşıklığını ölçmekte ve mekânlar arası etkileşimleri değerlendirmekte başlıca bir yöntem olarak kullanılmaktadır. Kentin oluşumunda farklı katmanlar, sistemler ve formlar bütünü olduğundan fraktal geometri bu çalışma için tercih edilmektedir. Kent mekânlarının irdelenmesi mekânsal analizlerle mümkün kılınmaktadır. Çalışma mekânsal analiz ve ulaşım kararlarının etkinliğini ölçmektedir. Kentin uçtan uca makroformu ulaşımın sürdürülebilirliği ile oluşabilmekte iken kentin yayılması ve kontrollü gelişimi de buna bağlı olarak ilerlemektedir. Kentsel yoğunluk ancak planlama kararları ile yönetilebilmektedir. Mekânda geçmişten bugüne Bursa ilinin makroform değişimi gözlenmiştir. Değişime ulaşım kurgusu ve kentsel yerleşik doku olarak iki alan üzerinden analiz yapılmıştır. Yapılan mekân analizinde elde edilen katsayı kapsamında Bursa ilinin planlama kararlarında ulaşım kararları özelinde değişimi büyük ölçüde etkilediği; bu değişimin yerleşim dokusu ile iç içe geçtiği görülmüştür. Fraktal analiz sonucu elde edilen katsayıların mekânda kentsel yayılmanın varlığını gösterir nitelikte olduğu vurgulanmıştır.*

***Anahtar Kelimeler: Fraktal Analiz, Mekânsal Analiz, Sürdürülebilir Ulaşım , Toplu Taşım Odaklı Gelişim (TOD) İlkeleri***

**ABSTRACT**

*Urban studies vary in their evaluations, but the fractal analysis method has been chosen as a tool to achieve strong results with development of geographical modeling and spatial analysis. Fractal geometry is primarily used to detect difference; measure the complexity dependent on initial conditions of the system; and evaluate interactions between spaces. Since formation of a city consists of different layers, systems, and forms, fractal geometry is preferred for this study. The examination of urban spaces is made possible through spatial analysis. The study measures the effectiveness of spatial analysis and transportation decisions. While macroform of a city can be formed with sustainability of transportation, the city's sprawl and controlled development also progress accordingly. Urban density can only be managed through planning decisions. The macroform transformation of Bursa province from past to present has been observed in space. Analysis was conducted on two areas, transportation infrastructure and urban built texture, to understand the change. Based on the coefficient obtained from the spatial analysis, it is evident that transportation decisions significantly influence the transformation of Bursa province in planning decisions, and this transformation is intertwined with settlement texture. The coefficients obtained from fractal analysis emphasize presence of urban sprawl in space.*

***Keywords: Sustainable Transportation, Fractal Analysis, Spatial Analysis, Transportation-Oriented Development (TOD) Principles***

[1] **Corresponding Author:** (Res. Asst.) Ankara University, Graduate School of Natural and Applied Sciences Department of Real Estate Development and Management, parlagunes@ankara.edu.tr, ORCID: 0000-0003-0356-2044

[2] (Res. Asst.) (Res. Asst.) Gazi University, Gazi University, Faculty of Architecture, Department of City and Regional Planning, tugbakutuk@gazi.edu.tr, ORCİD: 0000-0002-6723-734X

[3] (Prof. Dr.) Ankara University, Graduate School of Natural and Applied Sciences Department of Real Estate Development and Management, aliefendioglu@ankara.edu.tr, ORCID: 0000-0002-0859-7150

**INTRODUCTION**:

Urban morphology has evolved through its macroform from the past to the present, and when examining the interrelations between different spaces, it reveals a progression driven by a specific purpose, structure, and outcome. Cities, due to their characteristic features, stand out in terms of commercial, cultural, and social aspects. The central areas of cities are often defined as the most dominant spaces, as they represent the zones with the most well-defined spatial networks. The strength of the commercial network and its outward expansion from the center demonstrate the robustness of spatial patterns and influence urban planning decisions (Özüduru, Varol, and Ercoşkun, 2014). Each characteristic of a city is shaped by the presence of the central area, with service corridors extending from the city center to other parts of the city. The concept of sustainability, which is addressed in various contexts in the urban spatial framework, is specifically examined in this study in relation to transportation infrastructure.

Fidan (2012) emphasizes that sustainable public transportation systems require an integrated approach in terms of environmental, economic, and social sustainability. The study addresses the role of public transportation in reducing cities' carbon footprints, its economic benefits linked to energy efficiency, and its impact on promoting social equity. It highlights the necessity for local governments to engage in long-term planning in public transportation policies to ensure the efficient use of resources. In this context, public transportation is portrayed not merely as a means of facilitating mobility but also as a critical component in achieving the sustainable development goals of cities. In the province of Bursa, one of the earliest settled cities in Turkey, the forms of transportation have varied over time. Each mode of transportation has changed in accordance with population densities, leading to the development of a specific land use pattern (Sepetçi, 2007). The spatial organization of the city and its spatial structure can develop simultaneously. Transportation networks can evolve around the central area, and the analysis of the space can be perceived through transportation routes. Just as the transportation structure plays a crucial role in shaping the space, unique areas of the city are also formed through planning decisions.

This study focuses on the analysis of construction decisions in the province of Bursa and examines the relationship between these decisions and transportation infrastructure based on spatial predictions. A fractal analysis was applied to investigate the development direction, form, and the reflection of transportation decisions on the space. Although each transportation structure does not directly serve as a basis for the fractal analysis, large-scale public investments, central areas, and new residential areas where commerce is concentrated are considered within this scope. Satellite imagery of the past twenty years was analyzed for the entire province of Bursa, and a fractal analysis coefficient was calculated. The development process in the city is assessed based on the presence of urban sprawl or compactness. During the process of analyzing the space, the transportation infrastructure was used as a basis to detect changes and trends in population growth. The coefficient obtained from the analysis can reveal the degree of urban sprawl or compactness in the city. This result was compared with planning periods, and the variability in the transportation fabric introduced by planning forecasts was emphasized.

Fidan (2022) evaluated the impacts of climate change on urban life within the context of sustainable transportation models and analyzed the role of these models in enhancing the resilience capacities of cities. The study emphasized that adopting low-carbon urban transportation systems not only delivers environmental benefits but also strengthens economic resilience and promotes social equity. The relationship between reducing urban mobility, increasing energy efficiency, and promoting alternative transportation methods with climate change adaptation processes was examined in detail. Furthermore, the strategic role of sustainable transportation policies in making urban

infrastructure resilient to climate change and their integration into local government practices were comprehensively discussed.

In addition to conducting a fractal analysis, the study also examines the changes in urban form from past to present in relation to population changes, as well as the planning periods. The impact of urban planning decisions on the space and the magnitude of this impact were analyzed to determine the direction of urban development. In the study, the shape of urban development direction can be identified through urban sprawl and compactness, while the second key aspect of the research involves examining the changes in transportation infrastructure. The major urban land-use decisions within planning documents were analyzed in relation to their effects on the direction of urban growth, building conditions, and the changing focal points of the city. The change in the space cannot be determined with a single analytical outcome; rather, the post-change transportation forecasts, population balance, and the capacity for individual access in the development areas are also of significant importance.

Despite the dynamic nature of each district, data from the districts included in the urban sprawl—Nilüfer, Osmangazi, and Yıldırım—were analyzed. The districts that exhibited compactness, namely Harmancık and Büyükorhan, were also examined. These peripheral districts, located at the urban-rural interface, have limited development potential due to their physical conditions and urban fabric. The dominance of agriculture as the primary production sector in these areas contributed to their prominence, while the weakening of the commercial axis towards the periphery was also observed. The spatial structure of Bursa province, which consists of 17 districts, is inherently compact. However, the variability in population density in central districts, the presence of a central perception, and the lack of development extending towards the periphery were also explored. It is important to emphasize that decisions regarding settlement patterns do not change as a result of a single influence, but rather, the spatial framework evolves over time. The study examines the extent to which planning decisions have influenced the urban fabric over the years, considering both positive and negative contributions to spatial development.

The impact of transportation infrastructure on the spatial pattern is significant in shaping the development of Bursa. The contribution of this study to the literature lies not only in detecting the impact of urban development on the city's form through fractal analysis but also in the intersection of large-scale land-use decisions with planning forecasts, thus providing insights into urban growth patterns.

## 1. Theoretical Framework

The development of cities and the emergence of new areas transform spatial organization, thereby influencing the urban focal points. The social, cultural, and economic dynamics of cities evolve over time, and this process plays a significant role in developing and emerging countries. The growth of cities and the creation of new areas affect spatial organization, reshaping the city's attraction points. The social, cultural, and economic variabilities of cities differentiate over time and hold substantial importance in developing and emerging countries. In this context, a theoretical framework is presented regarding the significance of planning, transportation, and urban attraction points in determining the direction of urban development.

This study offers a significant scientific contribution to understanding urban form and development processes by integrating fractal analysis with the principles of Transit-Oriented Development (TOD). By examining urban sprawl and density through fractal dimension calculations, the research presents an innovative approach that combines mathematical urban form analysis with sustainable urban planning practices. Conducted in the context of Bursa, where complex rural-urban interactions exist,

the study bridges theoretical models with real-world scenarios, enhancing their practical applicability.

The uniqueness of this study lies in its dual-methodological framework. Fractal analysis provides a quantitative perspective for assessing spatial complexity and density, enabling a detailed examination of the spatial transformations driven by urbanization and planning decisions. Simultaneously, the integration of TOD principles facilitates an exploration of sustainable transportation and land use strategies, offering actionable insights for urban policymakers and planners. This interdisciplinary approach underscores the importance of aligning urban growth with sustainability principles, contributing to broader discussions on equitable and balanced urban development.

Furthermore, the study evaluates the unforeseen outcomes of planning activities on rural-urban dynamics and transportation networks, analyzing their impacts on urban sprawl and spatial organization. The combined application of TOD principles and fractal analysis provides a framework for optimizing urban form and promoting compact, mixed-use settlements that support sustainable transportation modes.

By offering empirical evidence on how fractal dimension metrics can contribute to sustainable urban planning, this research addresses a critical gap in urban studies. The findings highlight the necessity of integrated planning approaches that balance density, accessibility, and rural characteristics preservation. With its innovative methodological design and emphasis on the interaction between transportation, land use, and urban morphology, this study advances the theoretical understanding and practical applications of sustainable urban planning, presenting a replicable model for other urban contexts.

Transportation infrastructure is one of the key factors that determine the direction of urban development. Well-planned transportation networks strengthen the connections between different regions of a city, increasing the accessibility of these areas. Accessibility, in terms of urban development and spatial organization, is a critical factor, as transportation networks facilitate the movement of people, goods, and services. In determining the direction of urban development, planning, transportation, and urban attraction points are interrelated and fundamental components. Urban planning forms the foundation for spatial arrangements, while transportation infrastructure ensures the accessibility and feasibility of these arrangements. Urban attraction points shape the social, cultural, and economic dynamics of a city by directing people and investments to specific areas. Addressing these elements with a holistic approach enables cities to develop in a sustainable and balanced manner. As the population increases, the patterns of land use and density areas in cities change, and this transformation directly affects the urban form. Depending on the direction of development, it also alters the balance between urban and rural settlement areas. In the context of fractal analysis, a significant development has been observed in the last decade, along with the continuity of transportation axes (Güneş, 2021). Each new settlement area brings with it the need for infrastructure services, with transportation infrastructure being the top priority. The spatial analysis of Bursa in the last 10 years aims to identify the development direction and the strength of interaction between spaces. New and old areas have been identified within the city form, and the range of changes in the urban fabric has been analyzed. This study aims to observe urban morphology over the years, perceive the space, and analyze urban growth (Kiakou, 2017).

The importance of fractal analysis and transportation networks in identifying the direction of urban development contributes to making urban planning and development processes more efficient and sustainable. These two approaches are used as complementary tools to understand the complexity

and dynamic nature of cities. The growth and development of cities occur within certain patterns and structures, and this process can be examined through fractal analysis. Fractal analysis is used to understand the spatial organization, density distributions, and patterns of urban development. By examining the density distributions of urban areas, fractal analysis helps to determine the intensity of development in different regions of the city and how this intensity spreads. This is crucial for understanding the directions in which the city has concentrated and grown. The examination of fractal analysis and transportation networks facilitates a better understanding and management of urban development processes. Fractal analysis is an essential tool for understanding the spatial arrangements and density distributions of cities. Transportation networks, on the other hand, are a critical factor in guiding urban development by enhancing a city's accessibility and connectivity. The organizational form of space within the city can be defined through these dynamics. The form of spatial organization in a city is shaped by various changing factors within the urban environment.

### 1.1. Field Study: The Example of Bursa Province and Bursa's Urban Planning Process

Bursa, as one of Turkey's key industrial and tourism cities, has undergone various planning efforts and spatial transformations over the years. Evaluating the planning works and spatial changes in Bursa over time is essential for understanding the city's historical development and the significant events in this process (Erdem et al., 2023). Bursa, located at the intersection of trade routes such as the Silk Road and the Spice Route, became an important center for global trade. Istanbul’s demand for silk supported the development of Bursa's economy in the 15th and 16th centuries, and the Bursa-Istanbul transportation route gained significance (Bayram, 2013). However, with the Industrial Revolution, Bursa's role in trade diminished, leading to a stagnant period until the 19th century (Recepoğlu, 2018). During this period, there was no significant change in the city's macroform.

During the Ottoman era, a planned approach to the city first emerged after the major earthquake of 1855. Following this, the first cadastral plan of Bursa province was drawn in 1857 (Ürekli, 2010). The city's transportation network at that time was characterized by numerous dead-end streets, and there were no long or wide avenues (Eriçok, 2015). In the subsequent years, the city's layout and street network, which were largely unsuitable for automobile traffic, underwent significant changes through local plans and decisions made on-site (Tekeli, 1999). By the 19th century, as the Ottoman Empire turned towards the West, Bursa began to regain its importance. The quest for raw materials driven by the Industrial Revolution led to changes in Bursa, particularly in silk production, and new structures began to emerge (Çiftçi, 2013). In this context, in response to the demands of industrialized European countries, silk filature factories began to open in Bursa in 1838 (Tekeli, 1999). The spatial changes that began with the shift to factory-based silk production and the new connections with emerging markets necessitated the development of transportation systems. Accordingly, new transportation routes were established, and railways were constructed to support the growth of silk exports (Recepoğlu, 2018). During this period, important roads such as Gemlik Street, İpekçilik Street, Çekirge Road, the expanded and modernized Saray Street, Hamidiye, and Maksem Streets were developed. Additionally, the Bursa-Mudanya railway line was opened in 1892.

After the 1958 fire, a new urban master plan was prepared by Piccinato in 1960. This plan aimed to preserve the historical fabric of Bursa while promoting linear development along the east-west axis of the city. During this period of restoration work in the historical city center, alternative commercial areas were proposed, and streets like Altıparmak and Fevzi Çakmak became significant commercial corridors. With the establishment of the organized industrial zone in 1966, the city experienced rapid development along the Mudanya road. As a result, in 1976, the Nazım Plan Bureau created the Bursa Master Plan, which aimed to decentralize the city. The organized industrial zones that have

developed today were proposed in this plan, rural areas were preserved, and new settlements were planned along the east-west axis.

In the second half of the Republic era, due to the limited development of railways, private vehicle usage became more widespread. In the 1960s, Bursa's Organized Industrial Zone (OSB), the first of its kind in Turkey, was established along the Mudanya road, marking a significant shift in the city's development in that direction (Yılmaz and Kürkçüoğlu, 2023). The opening of the OSB led to an influx of migration from rural areas and an increase in employment within the city. The establishment of the TOFAŞ factory to the north, the formation of new industrial hubs in the east, and the opening of Uludağ University in the west had a significant impact on the city's macroform. This development also resulted in changes to the transportation system, with major improvements in road access to Istanbul, Ankara, and Izmir. As a result of rapid industrialization and the emergence of new economic sectors, migration and population growth led to informal housing developments toward these new focal points (Yılmaz and Kürkçüoğlu, 2023). In the 1984 plan, agricultural protection areas were designated in the northern part of the city, limiting development in these areas. At the time, Bursa still had a single central urban core, but the plan aimed to create three sub-centers within the residential districts: Yıldırım, Osmangazi, and Nilüfer, facilitating a hierarchical approach to the city's development (Tekeli, 1999). The decisions made in the 1984 Plan were revised in line with the main principles of the 1/100,000 scale Environmental Planning. In terms of the central area, new development zones were opened in Nilüfer and Osmangazi districts, north of the airport, while a development area towards the rural zone was proposed based on the collector road north of Ankara Road in Yıldırım district. Throughout the 20th century, the rapid population growth, the establishment of new industries, and intense internal and external migration reshaped the urban form of Bursa.

By the 21st century, development has continued to increase, particularly in the western districts of Nilüfer, Osmangazi, and Yıldırım. In 1948, the Bursa-Mudanya railway line was closed, and a light rail system (BursaRay) was introduced, following the same route (Yılmaz and Kürkçüoğlu, 2023). Initially, this system transported passengers between Bursa OSB and the eastern part of the city, and later, Uludağ University, located to the north of the Izmir axis, was added to the line. This line, in particular, had a significant impact on the development of the Nilüfer district. Together with the Istanbul-İzmir highway, this line has influenced the location of urban functions in the western part of the city. In this context, it can be said that the city's macroform has shifted westward. Today, the macroform of Bursa city has developed in a linear (east-west) direction due to natural boundaries, such as Uludağ to the south and the Bursa Plain to the north (Mutlu and Varol, 2017). The historical city center, while maintaining its commercial activities, has expanded to form the current central area. Analyzing the planning process reveals that major transportation axes are key elements in shaping the city's structure (Eminağaoğlu, 2023). The closure of the Bursa-Mudanya railway line and the city's spread toward the plain, along with the increased use of private vehicles resulting in a more dispersed and sprawling urban form, demonstrate the clear influence of transportation decisions on the urban form of Bursa. Moreover, the development of the BursaRay line and the impact of the Istanbul-İzmir highway have strengthened the city's growth to the west. The geographical proximity to Istanbul and its prominence as an industrial city have led to the establishment of significant workspaces and large land uses along the Izmir-Ankara and Istanbul corridors, illustrating a mutual interaction between these key axes.

Bursa has emerged as a prominent industrial city that has continuously developed throughout its historical process. It has maintained its role as an industrial center, particularly with the production of silk and silk weaving, from the past to the present. Additionally, its possession of fertile plains under the Large Plain Protection Plan has positioned the city at a central location within the

agricultural hinterland. Bursa has strong transportation connections and relations with Istanbul, Ankara, and Izmir. With the establishment of the first organized industrial zone in Bursa, the city's development and population underwent rapid change. Although informal settlements developed rapidly and without planning due to urbanization, they were legalized through slum improvement plans and amnesties; however, these areas still lacked adequate infrastructure. These changes in the city's core functions led to new demands for housing, resulting in new land use patterns. As a result, a new urban form has emerged (Tekkanat and Türkmen, 2018). Due to the urban development exceeding the plans prepared in 1976 and 1984, the city has been under constant urbanization pressure, and its urban identity has been threatened. Analyzing the planning processes and their spatial effects is of great importance in understanding the complexity of the city. When looking at the planning processes, it is clear that different layers have played a significant role in the city's development. In this regard, a spatial analysis has been conducted within the context of this study, using Bursa as a case study.

During the development of cities, the functions assigned to them influence the planning process in all aspects. Cities are managed around the political center, which acts as the decision-making body. Research on past centuries shows that humans have existed for approximately forty to fifty thousand years, and during this time, people lived in primitive communities in small and scattered settlements without involving management, organization, or bureaucratic processes (Tosun, 2013). In this context, the development of cities, such as Bursa's rise as a commercial center during its time as the capital, is highlighted as an example of one of these functions. The formation, structure, economic setup, and cultural organization of each city differ and can influence its current existence (Hall, 2006, p.62). For humans living in primitive conditions, the emergence of the state and the order it required was a completely new situation for humanity (Çınar, 2004). As for the concept of cities and organization, the phenomenon of the capital city and its formation is not a constant throughout historical processes but rather an authoritative decision that developed over time. In his view of city formation, when looking at the first cities, it is argued that there was no order or specialization, and no regional economic or political differences were evident; rather, they were entirely formed through natural projections (Bookchin, 1999). Fidan (2006), within the scope of the Balıkesir Urban Transportation Master Plan, evaluated the city’s existing transportation infrastructure and developed strategic planning recommendations based on future needs. The study included comprehensive analyses aimed at effectively managing transportation demands, reducing traffic congestion, and strengthening public transportation systems. Additionally, the importance of sustainable transportation policies in enhancing urban quality of life was emphasized.

Urban morphology has evolved through its macroform from past to present, revealing a progression aimed at specific purposes, structures, and outcomes while examining relationships between different areas. Cities, due to their characteristic features, stand out in commercial, cultural, and social aspects. Central areas of cities are typically defined as the most dominant zones, representing the best-defined spatial networks. The strength of commercial networks and their expansion outward from the center demonstrate the robustness of spatial patterns and their influence on urban planning decisions (Özüduru, Varol, & Ercoşkun, 2014). Each feature of a city is shaped by the presence of a central area, with service corridors extending from the city center to other urban regions. This study examines the concept of sustainability, frequently discussed within the urban spatial framework, in relation to transportation infrastructure. In Bursa, one of Turkey's oldest settlements, modes of transportation have undergone significant changes over time. Each transportation mode has evolved based on population density and contributed to the development of specific land-use patterns (Sepetçi, 2007). The spatial organization and structure of the city can develop concurrently. Transportation networks may form around the central area, and spatial analysis can be perceived through transportation routes. The transportation structure plays a crucial

role in shaping space, while unique urban areas are also formed through planning decisions. This dual interaction highlights how transportation and spatial organization work together to define urban morphology, particularly in a historically rich city like Bursa.

### 1.2. Method and Analysis

Understanding, defining, and managing the perception of space is made possible through spatial readings. As urban population density varies, the urban form also undergoes changes, shaping the organization of space. The transformation of the spatial fabric defines the way the city develops. Dynamic cities need to be analyzed through their tangible spatial structures. Identifying new development areas in cities and managing public investments effectively is crucial for the sustainable organization of space. In this study, the functions of space have been considered alongside the dynamics of urban development, with a particular focus on the analysis of central development. There are several studies that investigate the management and planning of urban mobility, proposing analyses and solutions for efficient management (Erçetin et al., 2022).

This research question focuses on integrating spatial data and analytical methods to understand the transformation of urban form. Bursa province, with its historical and spatial planning processes, serves as a suitable study area to demonstrate the impact of urban dynamics and planning activities on urban form. The study aims to understand urban form and spatial transformations using the fractal analysis approach. Within this framework, the box-counting method was applied to spatial data to examine the spatial organization of the 17 districts within the urban center of Bursa. This method is ideal for analyzing the density and void ratios of spaces and characterizing the compactness or sprawl of urban fabric. Current maps, satellite images, and approved planning documents were utilized, and planning activities conducted at five-year intervals were examined. In fractal analysis, the box-counting method calculates occupancy ratios on logarithmic scales from spatial data. The fractal dimension coefficient is used to determine the compactness and sprawl levels of space, with a value closer to 1 indicating sprawl and closer to 2 indicating a compact form. Planning activities directly influencing urban form were evaluated in terms of spatial transformation.

Fractal analysis is an effective method for measuring the geometric complexity and organization of urban space. Examinations conducted at five-year intervals provide concrete indicators of changes in urban development dynamics. The combined use of diverse data sources, such as satellite images and planning documents, enhances the accuracy of the analysis. The temporal variation in fractal dimension coefficients reveals the tendencies of Bursa province toward urban sprawl or densification. The effects of transportation networks and focal points within the city were also analyzed in terms of spatial organization and population density.

This study employs fractal analysis to examine the spatial structure of Bursa province. Fractal analysis is a powerful tool for mathematically analyzing complex and irregular structures, and it is frequently utilized in urban planning and development studies. In this context, fractal analysis coefficients provide in-depth insights into the spatial organization, density distributions, and development directions of cities. In this study, the box-counting method, one of the most widely used techniques for calculating fractal dimensions, was applied. The box-counting method is an effective technique for analyzing the spatial properties of complex and irregular structures.

1. **Division of the Spatial Area:** The study area was divided into grids (boxes) of a specified size, where the number and dimensions of these boxes play a significant role in fractal dimension calculations.

2. **Overlap Analysis:** The structures within the study area were analyzed by comparing them with the grid boxes. A ratio was calculated using the number of structures within each box and the box's dimensions.

3. **Logarithmic Calculation:** The relationship between the number of boxes and their dimensions was evaluated using a logarithmic formula, enabling the calculation of the fractal dimension.

Fractal dimension theory, defined by Hausdorff and Besicovitch, conducts statistical analyses based on the filled-empty ratios within a space. The formula (1) is given as:

$$D_f = \frac{\log K}{\log(1/e)}$$

Where K represents the number of boxes, eee denotes the size (scale) of the box, and Df is the fractal dimension. Fractal dimensions range between 1 and 2; values closer to 1 indicate a sprawl-like form, while values closer to 2 reflect a compact structure.

The findings of this study reveal significant spatial variations and density differences among districts within Bursa. The calculated fractal analysis coefficients indicate compact development within city boundaries, maintaining connections with rural textures, and the lack of sub-center formations. A high fractal dimension suggests densely organized settlements, whereas a lower fractal dimension implies dispersed settlements and preserved rural fabric.

This study employed the **Fractalise** software for the spatial analysis of Bursa. Fractalise is specifically designed for the fractal analysis of complex and irregular structures and is widely used in urban planning, geographic analysis, and urban development. The software automates and visualizes fractal dimension calculations using the box-counting method. The data utilized in this study included satellite imagery, GIS-based spatial datasets, and land-use maps obtained from Bursa Metropolitan Municipality. The data were processed using Geographic Information Systems (GIS) platforms, and the grid structures and scaling steps were analyzed using Fractalise. The software's logarithmic calculation and visualization features enabled detailed examination of the relationship between the number of boxes and their dimensions, providing critical insights into the spatial organization, density distributions, and urban development directions of Bursa.

The fractal analysis conducted in Bursa revealed that urban development trends are concentrated westward, with increasing population density in these areas. Although service areas are centered within the city, individuals tend to prefer areas around industrial zones, far from central locations. The formation of sub-centers is recognized as a critical indicator of urban growth and expansion, serving as focal points for economic, social, and cultural activities. Fractal analysis plays a crucial role in understanding the organization of urban fabric and determining the spatial characteristics of cities. This study contributes to a deeper understanding of the urban development dynamics and spatial transformations in Bursa province, offering valuable insights to urban planners and researchers for promoting sustainable and balanced urban growth.

The concept of fractals has been used to describe irregular shapes. The fractal dimension theory (Hausdorff-Besicovitch dimension), defined by Hausdorff and Besicovitch, has been employed in urban space analysis at different periods. This theory conducts statistical analyses based on the fill-

empty ratio in space. According to this, the relationship between the number of boxes, the size of the boxes, and the fractal dimension is analyzed (Ball, 2004).

$$K = e^{Df} \quad (1)$$

In formula (1), the variable \( K \) represents the number of boxes, \( e \) is the grid size or scale, and \( D_f \) is the fractal dimension value. The purpose of the formula is to calculate the relationship between scale/size change using fractal dimension calculations. To calculate the fractal dimension, methods such as box counting, Hausdorff self-similarity dimension, dilation dimension, Lyapunov dimension, topological dimension, Euclidean dimension, divider (or ruler) dimension, one-sided dimension, information dimension, and spatial correlation methods are used. In this study, the box-counting method has been employed to observe the use and variability of space (Erdoğan, 2015). This method demonstrates overlaps at different scales within the spatial fabric and analyzes the ratio between the number of grid overlaps and the logarithm of the box size, with the measured components of the space, such as building blocks and roads (Güler and Çetin, 2019). Fractal analysis is a mathematical method used to analyze complex and irregular structures or systems. In urban studies, fractal analysis is a key tool for understanding the spatial organization, density distributions, and development directions of cities (Yılmaz et al., 2022). In this study, the box-counting method was applied to analyze the fractal dimension. The resulting "fractal dimension" was used as a coefficient value. In fractal dimension theory, the coefficient varies between 1 and 2. When the result is closer to 1, it suggests that cities have a sprawling form, while a result closer to 2 indicates a compact structure. This analysis reveals that urban spaces can either have a compact (dense) or sprawling (distributed) texture. As mobility increases in urban fabrics, population density brings new settlement patterns, which in turn alters the perception of the city center, causing the spatial elements of the city to vary (Erdoğan, 2015).

For the province of Bursa, this method was applied using up-to-date maps and satellite imagery. The variability of planning activities over the years was also examined (Yılmaz and Çitçi, 2011). Approved planning studies have influenced the urban form; however, not every scale of planning has impacted the city's form, so only those planning studies that had a direct effect on the urban form were analyzed. Although coefficients were examined at five-year intervals, it is noteworthy that these changes occurred in close proximity to planning activities. In the city center, which has 17 districts, urban sprawl was observed in all but two districts, indicating that the western transportation network is dominant. The study also addresses the strategic placement of urban attraction points, emphasizing the balanced and sustainable development of the city. Areas where attraction points are concentrated generally transform into high-density residential and commercial zones; these areas also serve as transportation hubs, facilitating easy access to other parts of the city. The intersection between the development direction of cities, transportation, and planning processes is crucial for ensuring the sustainable and balanced growth of urban areas. The interaction between these three elements directly influences how urban spaces are shaped, which regions develop, and the quality of life for city dwellers. The intersection of development direction, transportation, and planning is critical for cities to grow in a sustainable and balanced way. By adopting an integrated approach, aligning transportation infrastructure and urban planning processes can support the economic and social development of cities.

The sample size in this study was carefully determined to enable a comprehensive analysis of Bursa province's spatial transformation. The sample is structured to include 17 districts within the urban center. The primary aim of this selection is to facilitate a holistic understanding of the spatial organization within the city center and analyze the dynamics of spatial transformation across various

districts. This scope was chosen to reflect the diversity in the spatial organization of the city center and to obtain detailed insights into the spatial form of each district. Spatial changes were analyzed using current satellite imagery and historical maps, which served as the primary data sources for calculating fractal dimensions through the "box-counting" method. Planning activities at the district level were evaluated by examining the impacts of approved plans on the spatial form of the city, with only those planning activities directly affecting spatial form included in the analysis.

The selected 17 districts are considered a sufficient representation of the spatial form of Bursa's urban center. The grid size employed in the fractal analysis was applied with high accuracy using satellite imagery, revealing the changes occurring at different scales. Particular attention was given to the effects of factors such as the urban transportation network and focal points within the city center on spatial organization. This detailed examination contributes to a nuanced understanding of spatial transformation dynamics in the region.

### 1.3. Findings

The study conducted in the province of Bursa revealed distinct areas where the rural-urban divide is evident. Over the years, both planning activities and political authorities have led to restrictions on transportation routes and service areas within the city. The physical constraints of space and the population density have established a natural pattern within the urban form. While the rural areas showed higher density, urban sprawl was observed across 17 districts, with two districts remaining compact. When examining the urban fabric between 2010 and 2020, a compact urban form was not predominantly observed. Due to the city's outward expansion, neighborhoods with sufficient physical conditions showed sprawl, and areas with sprawl were characterized by low-rise, detached buildings. Individuals directed their efforts toward new land, creating new development areas. Several methods are available for calculating fractal dimensions. In this study, the two most commonly used methods, the box-counting method and regression analysis, were applied to calculate the fractal dimension. The box-counting method is one of the most commonly used methods for calculating fractal dimensions for irregular and complex structures. Fractal analysis is a powerful tool for understanding the spatial organization and density distributions of cities. Methods such as box-counting and regression analysis are widely used to calculate the fractal dimensions of cities. These methods provide city planners and researchers with a better understanding of urban development directions and spatial characteristics.

**Tablo 1 Fractal Analysis Coefficients and Population Values of Bursa Province Districts (2010-2022)**

| District | Fractal Analysis Coefficient (2010) | Fractal Analysis Coefficient (2020)) | 2022 Population |
|---|---|---|---|
| Bursa | 1.62 | 1.81 | 3.194.720 |
| Büyükorhan | 1.34 | 1.23 | 8.940 |
| Gemlik | 1.62 | 1.65 | 120.245 |
| Gürsu | 1.76 | 1.72 | 102.601 |
| Harmancık | 1.48 | 1.36 | 5.979 |
| İnegöl | 1.56 | 1.54 | 294.485 |
| İznik | 1.61 | 1.65 | 44.236 |
| Karacabey | 1.45 | 1.52 | 84.907 |
| Keles | 1.58 | 1.59 | 10.955 |
| Kestel | 1.69 | 1.71 | 74.109 |
| Mudanya | 1.63 | 1.63 | 108.011 |
| Mustafakemalpaşa | 1.62 | 1.64 | 102.284 |
| Nilüfer | 1.59 | 1.61 | 536.365 |
| Orhaneli | 1.72 | 1.73 | 18.543 |
| Orhangazi | 1.63 | 1.68 | 81.110 |
| Osmangazi | 1.52 | 1.59 | 891.250 |
| Yenişehir | 1.53 | 1.56 | 54.844 |
| Yıldırım | 1.62 | 1.65 | 655.856 |

The results from the fractal analysis coefficient in this study suggest that the districts within the city boundaries demonstrate compact development, without severing ties with the rural fabric, and without the creation of sub-centers. The size of the sub-centers in the city showed variability, with the settlement fabric evolving accordingly. A higher fractal dimension indicates that the settlement units are arranged in a dense and compact manner. A high fractal dimension reflects greater spatial complexity and density. Conversely, a lower fractal dimension may suggest that the settlements are more dispersed and that the rural fabric has been preserved. This implies that the districts within the city limits have maintained their rural characteristics and that urbanization in these areas is less intense (Table 1).

Table 1 presents the fractal analysis coefficients for the districts of Bursa province for the years 2010 and 2020, along with the population figures for 2022. The fractal analysis coefficient is a significant indicator of the density and spatial complexity of the settlement structure in a region. This coefficient allows us to understand how densely and compactly the settlements are organized or how much they have spread while maintaining their rural character.

- In central districts such as Yıldırım, Osmangazi, and Nilüfer, it is observed that the fractal analysis coefficients increased from 2010 to 2020 and remained above the level of 1.60. This trend indicates that a dense and compact urban fabric prevails in these areas, reflecting an increase in spatial complexity.
- The rise of Osmangazi's coefficient from 1.52 to 1.59, along with its population reaching 891,250, indicates a significant process of urbanization in this region.

- Similarly, the Nilüfer district increased from 1.59 to 1.61, with a population growth to 536,365. This development suggests that the district has expanded due to urban transformation and new settlement areas.
- In districts such as Karacabey, Mustafakemalpaşa, and Yenişehir, the fractal coefficients indicate a more balanced development. While urbanization processes continue in these areas, it is evident that the rural fabric has been partially preserved.
- The increase of Karacabey's coefficient from 1.45 to 1.52 demonstrates that spatial intensification has increased while rural characteristics have not been completely lost.
- In districts like Büyükorhan and Harmancık, the low fractal coefficients (for example, a decrease from 1.34 to 1.23 in Büyükorhan) indicate that settlements in these areas are more dispersed and that the rural fabric is more dominant.
- The low population densities in these regions (for instance, 5,979 in Harmancık and 8,940 in Büyükorhan) further support this observation.

According to the data presented in the table, many districts of Bursa encompass both urban and rural fabric. Particularly in districts such as Gemlik, İznik, and Mudanya, the stability of fractal coefficients around 1.60 indicates that while the rural fabric is largely preserved, urbanization progresses in a balanced manner.

The direction of the city's development in the spatial area has been observed to be towards the west, with population density concentrated in this region. Despite the service areas of the city being in the opposite direction, individuals have been observed to choose locations away from the central areas, specifically on the peripheries of industrial zones. While the urban fabric has been influenced by commercial areas, large industrial, and production centers, individuals have not wanted to sever their connection to the rural/urban divide. In the urban development process, the formation of sub-centers is an important indicator of the city's growth and expansion. Sub-centers are points where economic, social, and cultural activities are concentrated, and they hold strategic significance in urban planning. Fractal analysis also reveals how the settlement structure is organized. The variability in the size of sub-centers indicates that different regions of the city develop sub-centers with varying densities and scales, suggesting the presence of high-density sub-centers in some areas, while other areas may have lower-density zones.

**CONCLUSION**:

Being able to discuss, analyze, and examine the historical existence of urban settlements contributes to ensuring the sustainability of investments in the city. Monitoring the spatial development process, understanding spatial gains, and shaping the urban form are made possible through the analysis of traces from the past to the present. Since each city has its own dynamic structure, the causes and dimensions of change also vary. In this study, based on the commercial axis, the changes in the city's central location over time, including shifts in transportation routes, changes in settlement patterns, population density, urban development direction, and urban development forms, have been examined. Bursa, being a city with a high rural/urban population, has also developed as a city where the production system is concentrated in agriculture and the rural area has been preserved. The study used fractal analysis to observe how the space changes in relation to population density and how these changes manifest in spatial organization. The effects of urban sprawl/urban compactness and the reasons behind the direction of urban development were analyzed through the fractal analysis method;

- It has been determined that the urban development of Bursa province is progressing in the form of urban sprawl.

- Urban transformation decisions made in planning have led to high-density construction areas, causing damage to the rural fabric of the city.

- The rural/urban distinction has disappeared, except for two districts on the outskirts of the city.

- The city form has been predominantly opened to residential preferences, resulting in inadequate transportation capacity.

- The pattern of urban growth has occurred in an unhealthy manner, without adhering to urban justice principles.

- The distribution of sustainable urban transportation networks has been misallocated, limiting access to central business areas and the city periphery.

In addition to the fractal analysis study, the impact of spatial planning decisions on urban development and the spatial organization of areas of development direction has been analyzed. The control of urban development, the elimination of urbanization pressure on productive agricultural lands, and the balancing of rural-urban land use are all crucial roles for sustainable transportation decisions. The study clearly shows that the changes in transportation decisions during the planning process in Bursa province have significantly impacted the city's macroform. In cities like Bursa, which have multiple layers, understanding the past and creating spatial decisions is essential for preserving the city's identity and addressing its evolving needs.

This study aims to contribute to ensuring the sustainability of urban investments by discussing, analyzing, and examining the historical continuity of urban settlements. Given that the dynamic structures and drivers of change in cities vary significantly, tracking spatial development processes from past to present, understanding spatial gains, and shaping urban form are of great importance. In this context, using the case of Bursa province, the study examines changes in transportation routes, differentiations in settlement patterns, population density, and transformations in the direction and forms of urban development along the commercial axis. To observe spatial changes in relation to population density, the study employs the fractal analysis method.

- To control the identified urban sprawl trend in Bursa, it is essential to develop sub-centers and concentrate social, economic, and cultural activities in these areas.

- Analyzing the development processes of the city from past to present and integrating these findings into planning policies will support the implementation of sustainable growth strategies while preserving the city’s identity.

- In urban planning processes, enhancing the use of quantitative methods such as fractal analysis in decision-making will allow for a more accurate assessment of the complexity and density of spatial organization.

- In line with Transit-Oriented Development (TOD) principles, high-density and mixed-use areas should be planned around public transportation routes, particularly near light rail system corridors.

Transit-Oriented Development (TOD) is an urban planning and design approach that aims to create high-density, mixed-use residential areas around public transportation hubs. This approach promotes

sustainable urban development by encouraging public transportation use and reducing dependence on private vehicles. By combining TOD principles with fractal analysis results, a better understanding of how urban development can be directed and how spatial arrangements can be optimized is achieved. TOD seeks to develop high-density and mixed-use areas around transportation centers, and fractal analysis quantitatively assesses the density and complexity of these areas. A high fractal dimension indicates the presence of high-density and mixed-use areas, consistent with TOD principles. Looking at the planning history of Bursa, despite the closure of the Mudanya line due to the political conditions of the time, the city has shown development towards the Mudanya direction. In the subsequent process, the newly established light rail system using the same line represents a significant potential in terms of TOD. The mixed-use of living and working areas around stations, the creation of dense urban development, supported by both motorized and non-motorized new transportation modes, and the promotion of walkable neighborhoods around stations can prevent the urban sprawl identified in Bursa by strengthening the relationship between city form and transportation.

Development in areas where the TOD approach is applied can be monitored through fractal analysis. Changes in density and complexity are analyzed, the effectiveness of planning is evaluated, and adjustments are made where necessary. In the modern era, planning decisions should offer urban transportation solutions that reduce automobile dependency. In this context, while TOD implementations may appear as small-scale solutions, they are considered models that will affect the form and development of cities in the long term. Fractal analysis is a critical tool for understanding how TOD principles can be applied in urban planning and how spatial arrangements can be optimized. The intersection of TOD and fractal analysis ensures that cities develop in a sustainable and orderly manner, increases public transportation use, and encourages more complex and efficient settlement patterns. Therefore, the combined use of TOD and fractal analysis in urban development strategies is essential for creating more effective and sustainable cities.

*[EN] The author(s) declare that they do not have a conflict of interest with themselves and/or other third parties and institutions, or if so, how this conflict of interest arose and will be resolved, and author contribution declaration forms are added to the article process files with wet signatures.*

**REFERENCES**:

Ball, P. (2004). *Critical mass: How one Thing Leads to Another*. Macmillan.

Bayram, N. (2013). 1837-1923 Sürecinde Bursa'da İpekçilik Sektörünün Sosyo-Ekonomik Analizi. *Uludağ Üniversitesi Fen-Edebiyat Fakültesi Sosyal Bilimler Dergisi,* 14 (24), 45-58.

Bookchin, M. (1999). Kentsiz kentleşme. *İstanbul: Ayrıntı Yayınları*, *36*.

Çınar, T. (2004). Dünyada ve Türkiye'de Başkentlik Sorunu. *Ankara Üniversitesi SBF Dergisi*, *59*(04).

Çiftçi, C. 1837-1908 Sürecinde Bursa'da Koza Üreticiliği ve İpekli Dokumacılık Sektörü. Uludağ Üniversitesi. *Fen-Edebiyat Fakültesi Sosyal Bilimler Dergisi*. 14 (24). 1-18.

Eminağaoğlu, Z. 2023. Kentleşme Sürecinde Binaların ve Kentsel Mekanların Yeniden Üretimi: Çoruh Kıyısının Değişen-Dönüşen Yüzü. *Kent Akademisi Dergisi,* 16 (4), 2472-2490.

Erdem, A. D., Yavaş, İ. ve Bilgili, A. (2023). Sanayileşme Perspektifinden Şehirlerin Dönüşümü: Bursa Örneği. *TroyAcademy Dergisi*, 8 (2), 210-234.

Erdoğan. G. (2015). *Kent Makroformlarının Mekânı Kullanma Verimliliklerinin Fraktal Boyut ile İncelenmesi* (Yayımlanmamış Doktora Tezi). Dokuz Eylül Üniversitesi, Fen Bilimleri Enstitüsü, Şehir ve Bölge Planlama Anabilim Dalı, Şehir ve Bölge Planlama, İzmir.

Erçetin, C., Durmaz, B. ve Aksoy, Ç. 2022. Akıllı Kent, Erişilebilirlik ve Mekânsal Veri Tabanı İlişkisi Üzerine Engeller Analizi: Ankara Örneği. *İdealkent Dergisi.* 36 (13). 417-518.

Eriçok, A. K. (2015). Bursa'nın Kentleşme Sürecinde Yapılan Planlama Çalışmaları ve Kentsel Dönüşüm Uygulamalarının Tarihi Kent Merkezinin Gelişimine Etkileri. *Uluslararası Kent Araştırmaları Kongresi*, 780-803.

Fidan, A., (2006) Balıkesir Kentiçi Ulaşım Master Planı / Balıkesir Belediyesi İçin 2006 Balıkesir (Yayınlanmış Rapor)

Fidan, A. (2011) "Sürdürülebilir Toplu Ulaşım Sisteminin Önemi" Kent Akademisi Kent Kültürü ve Yönetimi Dergisi, 15 03 2011. https://www.kentakademisi.com/wp-content/uploads/2011/03/Kent-Akademisi-Dergisi-Dr.Ahmet-FIDAN-Surdurulebilir-Toplu-Ulasim-Sistemi-ve-Onemi-Cilt-4-Sayi-1-2012.pdf

Fidan A., (2022) İklim Değişikliği, Sürdürülebilirlik ve Dirençli Kentler, Ed. Yakup Bulut, Miraç Aslan, Kentiçi Ulaşımda Sürdürülebilir Modellerin Kent Dirençliliğine Etkisi, Ed. Yakup BULUT, Çizgi Kitabevi, ISBN: 9786051969565, S: 191-204, İstanbul.

Güler, M. ve Çetin, F. 2019. Örgütsel Davranış Araştırmalarında Madde Parselleme: Yöntem ve Uygulama. *Ömer Halisdemir Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi.* 13 (1). 61-71.

Güneş, P. (2021). *Kentsel Büyüme, Yayılma ve Kentsel Saçaklanma ile Gayrimenkul Piyasası İlişkilerinin Değerlendirilmesi: Ankara ili Alacaatlı, Bağlıca ve Dodurga mahalle örnekleri* (Yüksek Lisans Tezi). Ankara Üniversitesi, Fen Bilimleri Enstitüsü, Gayrimenkul Geliştirme ve Yönetimi Anabilim Dalı, Ankara.

Hall, P. (2006). *Planning Twentieth Century Capital Cities*. Routledge.

Kiakou, A. (2017). The "Urban Sprawl" Effect on the Out-of-Town Real Estate Market. *Open Science Journal*, 2(4).

Kütük, T. ve Ercoşkun, Ö.Y. (2019). Ankara-Batıkent ve Koru Metro İstasyonlarının Toplu Taşım Odaklı Gelişim (TOD) ve Sürdürülebilir Kentsel Tasarım İlkeleri Çerçevesinde Değerlendirilmesi. *Journal of Architectural Sciences and Applications*, 4(2), 140-154.

Mutlu, E. ve Varol Özden, Ç. (2017). Socio-economic Differentiation and Spatial Segregation: Analysis of Bursa Metropolitan Area. *Megaron*, 12(1).

Özbilen, N. ve Zeren Gülersoy, N. (2016). Urban Development and Planning Transformation Process Assessment of Real Estate Ownership Rights: Transfer of Development Rights Planning Implementation Tool. *Planning*, 26(3), 172-180.

Ozuduru, B. H., Varol, C. ve Ercoskun, O. Y. (2014). Do Shopping Cnters Abate the Resilience of Shopping Streets? The Co-existence of Both Shopping Venues in Ankara, Turkey. *Cities*, *36*, 145-157.

Portugali, J. ve Portugali, J. (2000). Free Agents in a Cellular Space. Self-Organization and the City, 75-94.

Recepoğlu, S. (2018). *Türkiye'de kentsel Mekânın Dönüşümü Bursa Örneği.* (Yayımlanmamış Yüksek Lisans Tezi). Adnan Menderes Üniversitesi, Sosyal Bilimler Enstitüsü Siyaset Bilimi ve Kamu Yönetimi Ana Bilim Dalı, Aydın.

Sepetçi, A. T. (2007). *İstanbul Kent Merkezinde Ticaret Gelişimi, Etkenleri ve Ulaşım Odaklı Mekânsal Kurgusu Tarihi Yarımada (Eminönü ve Fatih) Beyoğlu, Şişli ve Beşiktaş Örneği.* (Yayımlanmamış Yüksek Lisans Tezi). Yıldız Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Şehir ve Bölge Planlama Anabilim Dalı Kentsel Koruma ve Planlama Programı, İstanbul.

Tekkanat, S. S. ve Türkmen, S. N. (2018). Tarih Boyunca Kent Formlarının Biçimlenişi Üzerine Bir İnceleme. *Aksaray Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergis*i, 10 (4). 107-124.

Tekeli, İ. (1999). Bursa'nın tarihinde üç ayrı dönüşüm dönemi. *Osmanlı Devleti'nin Kuruluşunun 700. Yıldönümünde Bursa ve Yöresi,* Uludağ Üniversitesi, Bursa.

Tosun, E. 2013. Sürdürülebilir Kentsel Gelişim Sürecinde Kompakt Kent Modelinin Analizi. *Yönetim ve Ekonomi Dergisi*, 20 (1). 30-46.

Ürekli, F. 2010. Osmanlı Döneminde İstanbul'da Meydana Gelen Âfetlere İlişkin Literatür. *Türkiye Araştırmaları Literatür Dergisi*. 8 (16). 101-130.

Yılmaz, A. ve Kürkçüoğlu, E. (2023). Demiryollarının Kent Formu Gelişimine Etkisi: Mudanya Bursa Demiryolu Hattı Örneği. *Türkiye Kentsel Morfoloji Ağı*, 394-403.

Yılmaz, E. ve Çitçi, S. (2013). Kentlerin Ortaya Çıkışı ve Sosyo-Politik Açıdan Türkiye'de Kentleşme Dönemleri. *Elektronik Sosyal Bilimler Dergisi*, 10 (35), 252-267.

Yılmaz, D., Öztürk, S. ve Işınkaralar, Ö. (2022). Kent İmgesinin Yapıtaşı Olarak Sokaklarda Mekânsal Zenginliğin Fraktal Geometri ile Analizi. *Kent Akademisi Dergisi*, 15 (3), 1341-1358.

**EXTENDED SUMMARY**[4]

**Research Problem:**

Urban studies vary in their evaluations, but the fractal analysis method has been chosen as a tool to achieve strong results with the development of geographical modeling and spatial analysis. Since the formation of a city consists of different layers, systems, and forms, fractal geometry is preferred for this study. The examination of urban spaces is made possible through spatial analysis. The study specifically aims to understand the influence of transportation decisions on urban development, particularly in Bursa, by using fractal analysis to measure urban sprawl and its interaction with spatial organization.

**Research Questions:**

- How do transportation decisions affect the spatial organization and development of urban areas?
- What role does fractal analysis play in identifying urban sprawl and assessing urban complexity?
- How has the urban macroform of Bursa evolved over time in response to planning and transportation decisions?

[4] Chen, I. ve Chang, C. (2009). Cognitive load theory: an empirical study of anxiety and task performance in language learning. Electronic Journal of Research in Educational Psychology, 7(2), 729-746.

- To what extent can fractal geometry and spatial analysis help in understanding the sustainability of urban development?

**Literature Review:**

Urban studies often focus on understanding the relationship between urban form, spatial organization, and transportation networks. Fractal geometry, which is primarily used to measure the complexity of systems based on initial conditions, is particularly useful in urban studies due to the layered and complex nature of cities. Previous studies have shown that urban sprawl and changes in urban form can be effectively analyzed using fractal methods. Various spatial analysis tools, including fractal analysis, have been utilized to examine urban density, transportation systems, and land use patterns. The literature emphasizes that effective planning and transportation decisions are crucial in managing urban sprawl and ensuring sustainable development.

**Methodology:**

This study uses fractal analysis as the primary method to assess the urban macroform of Bursa. Two areas are analyzed: transportation infrastructure and urban built texture. The fractal analysis method is used to measure spatial complexity and urban sprawl by calculating coefficients that reflect the density and organization of urban space. The transformation of Bursa's urban form over time is assessed by comparing data from different periods and analyzing the influence of transportation decisions on urban development. The results from the fractal analysis are then interpreted to understand the relationship between transportation infrastructure and urban sprawl.

**Results and Conclusions:**

The analysis of Bursa's urban form reveals that transportation decisions have a significant impact on the transformation of the city. The fractal coefficients obtained from spatial analysis show a clear presence of urban sprawl, with evidence of the city's growth spreading outwards over time. The study also demonstrates that planning decisions, especially regarding transportation, have influenced the macroform of the city, shaping the density and complexity of the urban space. The findings suggest that urban sprawl in Bursa is closely linked to transportation infrastructure, and effective planning can help manage urban growth more sustainably. The integration of fractal analysis in urban studies provides valuable insights into the spatial dynamics of cities and can be used to guide future urban development and transportation planning.