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A CASE STUDY ON THE URBAN SKYLINES OF ISTANBUL: DIMENSIONS OF VISUAL COMPLEXITY WITH FRACTAL ANALYSIS (1)

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INTRODUCTION

Cities, like any globalized phenomenon, undergo continuous transformation to accommodate evolving human needs. Each city possesses a distinct geographical appearance by its unique morphological structure. This complex structure mirrors the interaction among its constituent elements, a manifestation influenced by numerous socio-economic processes, both natural and man-made, which are limited and shaped (Attoe, 1981; Kostof, 1991; Lynch, 1990). Consequently, the resultant outcome becomes integral to the morphological evolution of the city landscape. Such settlements exhibit regular and irregular morphological configuration, constantly evolving within their spatial confines. As part of this evolutionary trajectory, cities may alter their boundaries over time and space, leaving imprints on their morphological structures (Ford, 1994). Structural change mainly manifest along two axes: vertical and horizontal. Vertically, there is a trend towards towering structures ascending skywards, while horizontally, urban sprawl defines the extent of spatial occupation.

An effective approach to interpreting the geography of cities and understanding the ramification of these dual processes lies in analyzing their appearance (Van Cleef, 1932). In other words, examining city silhouettes offers a straightforward method of identification (Heath et al., 2000). The skyline, punctuated by towering skyscrapers, minarets, spires, and other structures attest to the artificial elements that shape the appearance of cities (Booth, 2012). In addition to man-made elements, natural elements interact with the cityscape, reflecting the characteristics of the geographic environment in which a city resides. Present-day cities, unlike in the past, marked by technological enrichment, organizational structure, and architectural diversity, notably embodied by the construction of skyscrapers, have contributed to the emergence of different urban appearances and complexities that cities exemplify (Abu-Ghazalah, 2007; Çobanli and Ceylan, 2023; Gottmann, 1966). The more complex cities are in spatial terms, the more complex their skyline profiles are (Akdağ Girginkaya and Bostancı, 2013).

Yet, there is no consensus on the factors (for example, shapes, geometries, patterns, and structures) defining the complex appearance of cities, leaving to diverse studies of cities at different scales and with varied definitions and approaches. One point of divergence is city skyline profiles, or urban cardiograms, which are integral to urban morphology, reflecting cities' dynamics and constantly evolving structure (Bostancı, 2021; Gassner, 2009). The evolving manifestations of urban areas, contribute to this divergence. Despite numerous urban/city studies, few have underscored visual assessment, cityscape character, and structure. Since visual narratives such as panoramic views and city skylines shape contemporary city definitions, the components of urban landscapes are also studied within the framework of visual landscape assessment (Perihan and Aşur, 2020). In planning and design studies, "visual quality" significantly defines landscape components or their structure (Asur and Alphan, 2018). It encompasses various factors such as attractiveness, readability, comprehensibility, harmony, naturalness, complexity, and aesthetics (Ateş and Kiper, 2023; Bulut and Acar, 2017; Kiper et al., 2017; Daniel, 2001; Nadal et al., 2010; Nasar and Terzano, 2010; Ode et al., 2010; Forsythe, 2009; Tveit et al., 2006; Ulrich, 1986).

Complexity, as a vital component of visual quality, influences visual assessment since it entails the amount, diversity, configuration, and interrelationship of various elements, in a landscape (Kalın, 2004). One of the most debated aspects of urban appearance is visual complexity. While the complex structures and appearances of cities are sometimes considered problematic, there is no consensus on when cities attain complexity (Oku, 1990). It is within this discourse that fractal geometry emerges, exploring the complexity of natural and everyday objects for decades. The emergence of fractal geometry represents a significant shift in understanding the complex structures of cities (Batty and Longley, 1994). This geometry not only introduces cities to a mathematical dimension but also provides a viable framework for measuring spatial elements. It aids in understanding order and regularity within seemingly irregular or disordered parts. With a structure that allows us to explore the functions and processes shaping natural and man-made structures, fractal geometry refines our understanding reality more precisely.

Studies on the fractal geometry of skyline profiles has addressed several key areas. Firstly, it has focused on developing new methods for deriving horizon profiles for fractal analysis (Ayadi et al., 2016; Chalup et al., 2009; Chiu et al., 2016; Cooper, 2003; Hagerhall et al., 2004; Keller et al., 1987; Martinez-Sanchez et al., 2022; Stamps, 2002; Wang, 2016; Yang et al., 2024). Secondly, it involves evaluating the complexity and aesthetics of skyline profiles from a human perception standpoint (Oku, 1990). Thirdly, it includes interdisciplinary studies connecting skyline profile to other city components (Akbarishahabi, 2021; Cooper and Oskrochi, 2008; Cooper, 2005). The main challenge with these visual morphology studies lies in the lack of specific standardization. There is no consensus acquiring skyline profiles, considerations during their derivation, and the perspective and distance for observing profile that influences their shape and context. This complexity arises from cities being visual representation of numerous urban components that reflect their complex nature.

Like many other cities worldwide, Istanbul has evolved uniquely on account of its geographical structure. Particularly in the last two decades, it has undergone significant changes, influenced by neoliberal policies and globalization dynamics. This transformation process has altered and introduced new form on the city in addition to its historical appearance, significantly altering its skyline. The changes in urban space during the transformation process have produced new spatial contexts in the city (Görgülü and Kaymaz Koca, 2009). In particular, the increasing number of high-rise buildings has been a major factor in this transformation, rapidly changing Istanbul's geographical appearance profile within its fast-growing urban ecosystem. Over time, the architectural enrichment of the city has also changed its appearance. The skyline of Istanbul is now characterized by towers, mosques, historic buildings, modern structures, skyscrapers, and natural features. In this regard, the research aims to assess the extent to which these elements contribute to the complexity of Istanbul's skyline. Therefore, this study evaluate the visual morphological complexity of sky-level horizon lines that reduce the urban appearance to a single line in the case of Istanbul and to identify the structural elements shaping the city's appearance. Thus, the study contributes to the growing research on fractal analysis of urban skyline profiles and adopts a new approach. Istanbul serves as a case study, offering insight into the complex and dynamic nature of skyline profiles. Using skyline drawings from panoramic views taken from Beyazıt Tower were divided into equal cells for analysis. The analysis process compares the values of fractal dimensions to focus on the complexity levels of the structural elements that affect cell appearance, objectively demonstrating their impact on the urban skyline.

METHOD AND MATERIAL

In this study, current photographs of Istanbul, captured from the Beyazıt Fire Tower, were used to measure the fractal dimension of its urban skyline (**Figure 1**). Photographs, widely utilized in skyline and visual landscape studies, serve as the primary data source (Polat, 2022). The utilization of these data sources typically centers around two focal points: street-level imagery and sky-level imagery. This dichotomy emerges from the different perspectives through which the visual landscape can be perceived or modeled: the human (place) perspective, reflecting how people typically experience their surroundings (walking, standing, etc.), and the aerial perspective, projecting the landscape vertically from above (Misthos et al., 2023). Factors such as the size, depth, and clarity of the visible area informed the choice of the focal point. The Beyazıt Fire Tower was selected as a reference point in the study because of its unobstructed view of the relevant urban center of Istanbul and its elevated position, which makes it easy to have a comprehensive perspective of the cityscape.

The skyline drawings used in the study represent the outlines of the points where all natural and man-made elements in the urban space meet the sky (Hagerhall et al., 2004). All components, such as electricity poles, trees, antennas, flags, minarets, chimneys, and tower cranes, identified in the landscape as seen in the photograph are included in the skyline. Seven separate photographs, each with a resolution of 6000x4000 pixels, were used for generating horizon line drawings in the study (**Figure 1)**. These silhouette drawings were created using Adobe Illustrator, a vector graphics editing software (**Figure 2**). The obtained photographs were processed in ImageJ software to prepare them for analysis, ascertaining

Figure 1. Sources of data used in the study

data readiness (**Figure 3**). Within the scope of the study, 29 different horizon line drawings were created by segmenting the drawn horizon line profiles into uniform parts based on pixel values. To calculate the fractal dimension of the horizon line, ImageJ digital imaging software and the FracLac fractal analysis plugin were utilized to analyze the skyline profiles (Karperien, 2015; Schneider et al., 2012). Unlike other programs,

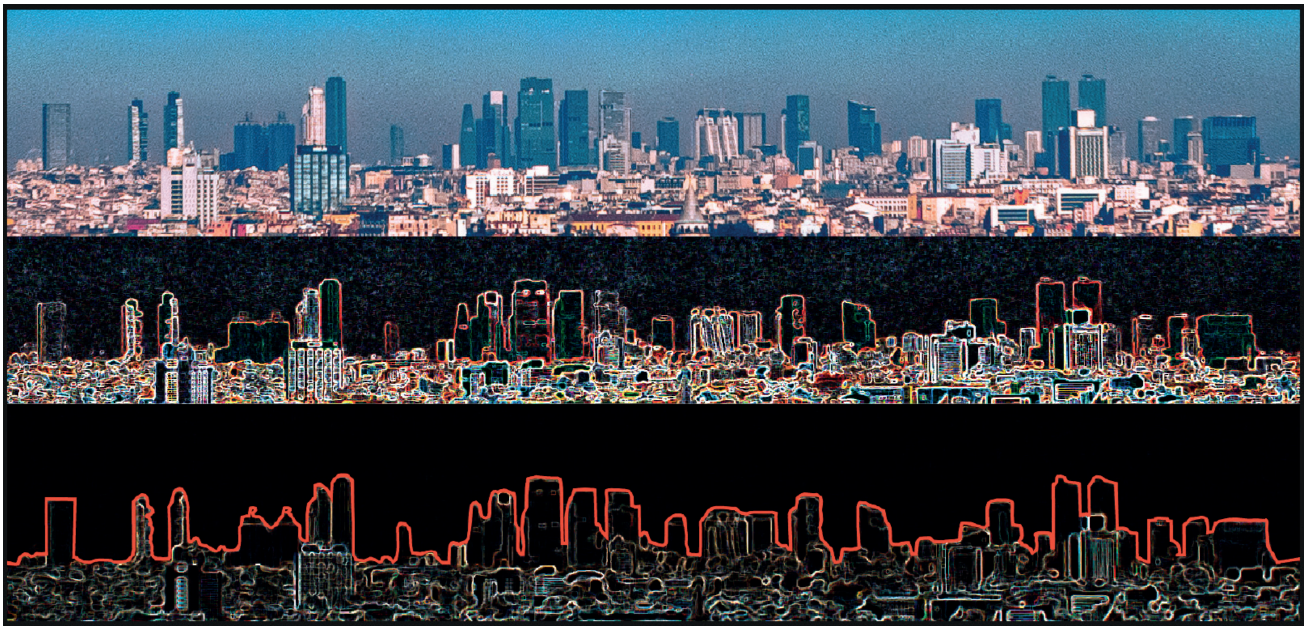

Figure 2. Process of creating city skyline profiles

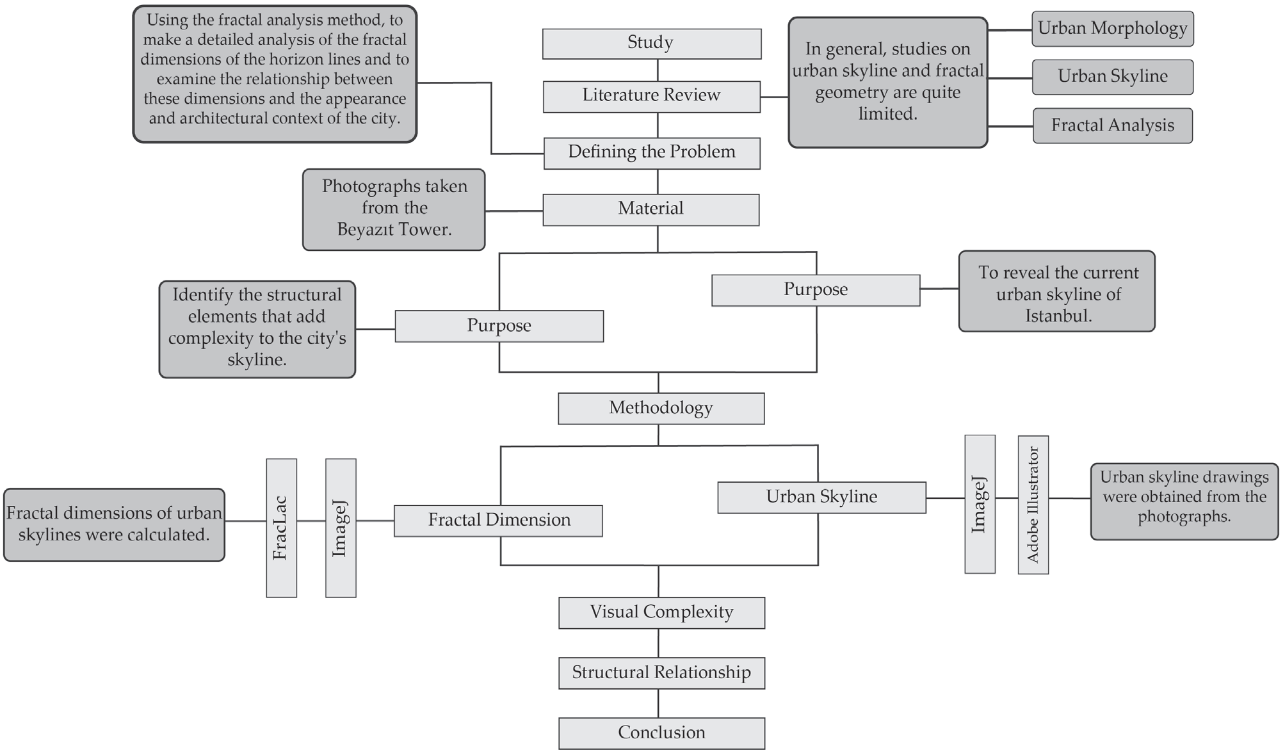

Figure 3. Study workflow

ImageJ offers several advantages for fractal analysis, featuring a user-friendly interface that accelerates the analysis process. Functions such as photo conversion to black and white (binary) format, background definition, and designing properties associated with the analysis process, are facilitated. Fractal analysis was performed using the box-counting method, well-suited for analyzing complex textures with varying degrees of self-similarity in studies of silhouette profiles across different scales (Oku, 1990). This mathematical technique is commonly used to measure the fractal dimension of horizon profiles (Chalup et al., 2009; Stamps, 2002; Cooper, 2003). Several factors including the black and white area, image position, line thickness, and image quality may affect the calculation process in the box-counting method. To rectify these, the available data were standardized before analysis (Ostwald and Vaughan, 2013).

The FracLac plugin utilizes the box-counting method, with the grid scale set as the default sample size and the maximum box size limited to 40% of the horizontal profiles. To increase the results reliability, calculations were conducted at 10 different grid positions. The fractal dimension of horizon profiles was obtained by averaging measurements taken with different box sizes and grid positions. Essentially, the fractal dimension concept involves dividing the horizon into smaller grid boxes and counting the number of boxes intersected by the lines. The fractal dimension is then calculated based on the ratio between the number and the size of the obtained fields. The skyline's fractal dimension is calculated using the formula $DB=(logN2-logN1)/(logS2-logS1)$, where DB represents fractal dimension, N signifies the number of boxes intersected by the skyline, and S denotes the box size. This fractal dimension serves as a metric for the complexity of the skyline; with higher values indicating greater complexity and lower values suggesting less complexity.

THE ESSENCE OF FRACTAL GEOMETRY AND URBAN HORIZON LINES

The fundamental understanding of fractal geometry, dating back to Mandelbrot, is based on the idea that while the physical surface of the world seems chaotic, discontinuous, and irregular, underneath lies an organized and infinitely complex order (Mandelbrot, 1989). The term “fractal,” from the Latin verb “frangere,” means broken and irregular (Mandelbrot, 1983). Fractals that closely follow the self-similarity rule at various scales are often observed in natural objects. The fractal dimension (D) allows the degree of irregularity of a shape or entity to be measured and represented, with values ranging between the Euclidean dimensions of one, two, and three. Unlike regular Euclidean shapes like squares and circles with integer dimensions, the non-integer nature of fractal dimension fascinates many mathematicians. The dimension, represented by D, is a fractional number that indicates how much a structure exceeds its base dimension to occupy the next dimension (Hagerhall et al., 2004). In essence, fractal dimension measure how effective an object fills the scape it occupies (Cooper, 2003). Accordingly, the fractal dimension of a line ranges from above one to two, while that of a surface extend from two to three. Mandelbrot stated that fractal geometry closely relates to geography, as it involves the mathematical representation of natural features such as coastlines and mountain ranges (Mandelbrot, 1989). Subsequent studies have extended fractal geometry’s application, especially in urban geography since the 1990s (Batty and Longley, 1994). Fractal analysis serves as a mathematical technique that allows for the study of complex systems in urban and natural environments using quantitative measures. At its core, fractal geometry depends on self-similarity, wherein a shape or pattern appears similar across different scales. This concept is often used in urban studies, especially for analyzing systems that shows repetition and self-similarity, like branching patterns in trees or street networks in cities. The application of fractal analysis cuts across various urban research areas, including spatial distribution analysis, comparative studies of urban systems, assessment of urban density and complexity, and evaluation of aesthetic potential.

Fractal geometry finds several applications in urban geography, one of which is the measurement of fractal dimensions of skyline profiles, the focus of this study. While this approach offers a new method for measuring the appearance of cities, it also presents some implementation shortcomings. Regardless of its importance as a tool for assessing the visual complexity of urban landscapes, there is no common theoretical framework across studies. In essence, the development of urban skyline profiles reflects a significant component of both planned and unplanned urban growth, intertwined within spatial and temporal contexts, and visually represented through skyline profiles. The complex nature of skyline structures has made it difficult to understand their shapes, processes, scales, and forms. Fractal geometry offers a solution to this complexity by measuring the fractal dimension of the linear structures that form skyline profiles, taking into account their irregularity and diversity. Unlike traditional geometric approaches that assume regularity and simplicity, fractal geometry provides a better understanding of the complexity and irregularity of urban phenomena. In short, the fractal dimension assessed in this study is a quantitative expression of the irregularity or complexity of urban phenomena.

The horizon line of a city holds significant symbolic meaning, unfolding across generations. The morphological features of the city and the resulting horizon line are tangible reflection of the degree of urbanization. In other words, a city's appearance, observed in its horizontal line, reflects its organization at a particular time and place, shaped by cultural processes, including social, economic, and political institutions, societal structures, technologies, and the values it holds. These lines, which represent cities, lend themselves to fractal analysis because of their structural characteristics. Fractal dimension serves as a useful tool for illustrating the complexity or roughness of horizon lines. Cities, with their different structures are unique, manifesting self-similar spatial organization. This common feature emerges between horizon lines and fractal geometry, both capturing the complexity and uniqueness of a city. While horizon lines serve as a visual representation of a city's built environment, fractal dimension presents a mathematical measure of irregularity, roughness, and complexity. This measure allows for the evaluation of various cities and their horizon lines across temporal and spatial scales, enabling the assessment of cities with diverse spatial structures collectively. The relationship between horizon lines and fractal dimension demonstrates the role of mathematics in understanding the complex patterns of urban structures and highlights the importance of interdisciplinary approaches in the study of cities.

The box-counting method utilized in this study produces a fractal value ranging between one and two, indicating the fractal dimension. As this number approaches 1, it indicates the absence of fractal geometry, instead exhibiting simplicity, plainness, and similarity to Euclidean geometry, with low visual complexity. In contrast, as the value approaches 2, the depth and complexity of the features increase. In terms of richness of detail, a final value close to 2 indicates a texture with a highly and complex structure. However, a value close to 1 shows a simpler structure with low complexity (Turan, 2022; Aydın, 2016). In essence, as illustrated in **Figure 4**, the object becomes more complex and detailed as the fractal dimension increases linearly from 1 to 2 (**Figure 4**).

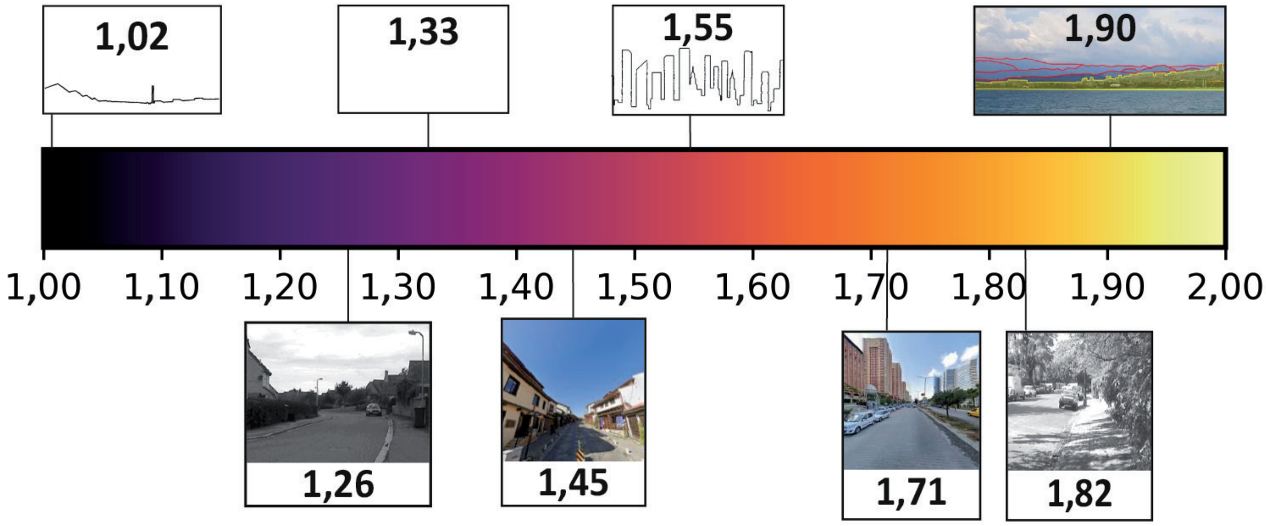

Figure 4. Relationship between skyline and fractal dimension according to different studies (Cooper, 2003; Güzel et al., 2021; Yılmaz et al., 2022)

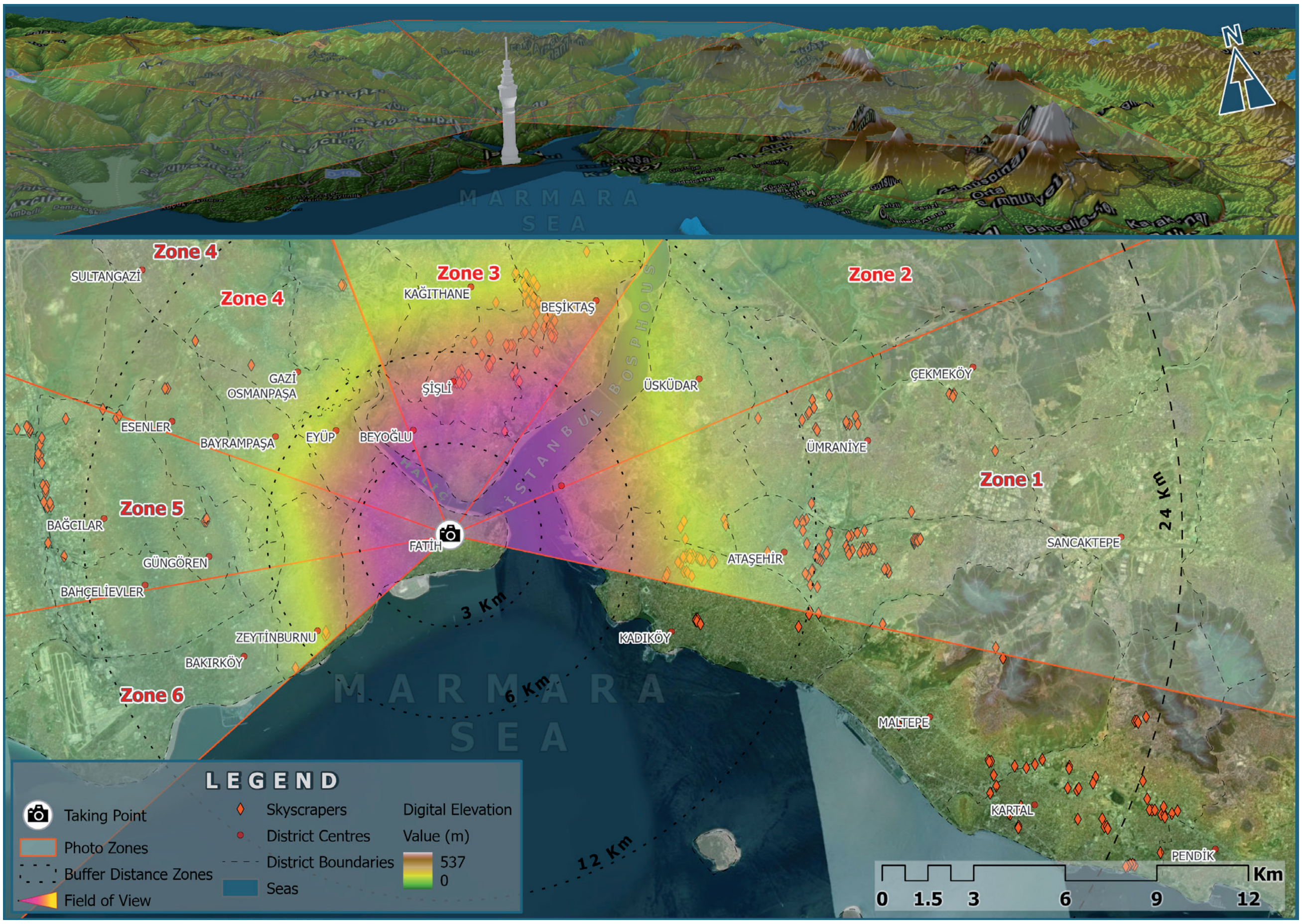

Figure 5. Location of the study area and photo zones

FRACTAL DIMENSIONS OF ISTANBUL'S URBAN HORIZON LINES

The exploration of fractal dimensions in urban horizon lines is still relatively limited but offers fascinating possibilities. In this regard, Istanbul, with its rich urban fabric and unique geography, presents a special urban setting for assessing these dimensions. This section focuses on the fractal dimensions of Istanbul's urban horizon lines, identified from the reference point of Beyazıt Fire Tower (**Figure 5**). The analysis of the urban horizon lines utilized box-counting method.

Table 1 presents the fractal dimensions of Istanbul's horizon lines and the corresponding photozones, where the horizontal lines were identified using the box-counting method. The fractal analysis performed revealed different fractal dimensions, ranging from 1.0731 to 1.2171 (**Table 1**). This information suggests that fractal dimensions and associated structural elements can be used to characterize the complexity and features of different city views in Istanbul, especially concerning architectural and natural features (**Figure 6**).

To assess the values of the obtained fractal dimensions according to their regions;

Horizon Line Zone 1

This zone encompasses both natural and human-made elements, resulting in a horizon line characterized by diverse elements. The fractal dimensions within this zone range from 1.0731 to 1.2171. The horizon lines here are

Main Horizon Line Zone	Lower Horizon Line Zone	Fractal Dimension (Fd)
1	1.1	1,1222
	1.2	1,1756
	1.3	1,1467
	1.4	1,0731
	1.5	1,1288
	1.6	1,108
	1.7	1,2171
2	2.1	1,1645
	2.2	1,1147
	2.3	1,1702
	2.4	1,1552
3	3.1	1,1767
	3.2	1,1609
	3.3	1,192
	3.4	1,1607
4	4.1	1,1521
	4.2	1,1555
	4.3	1,1755
	4.4	1,1303
	4.5	1,1614
5	5.1	1,0977
	5.2	1,1233
	5.3	1,135
	5.4	1,1303
	5.5	1,1181
6	6.1	1,0988
	6.2	1,1044
	6.3	1,1377
	6.4	1,1481

Table 1. Values of the fractal analysis for the zones of the horizon line

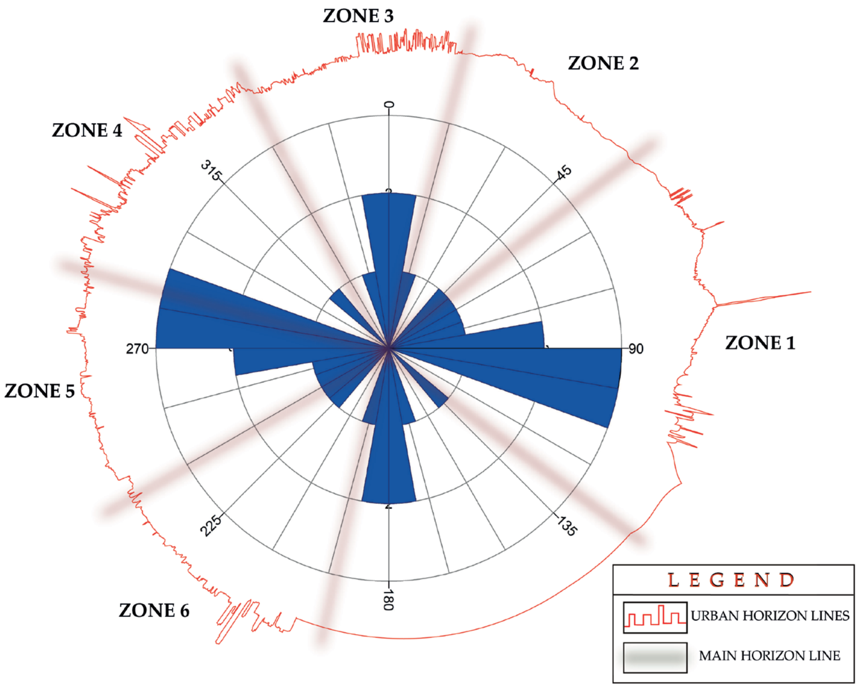

Figure 6. Urban horizon lines of istanbul

shaped by various natural and human-made structural elements such as Çamlıca Tower, Çamlıca Mosque, skyscrapers in Ümraniye, Ataşehir, and Üsküdar, as well as natural geographical features like Kayışdağı and Aydos Mountains. The highest fractal dimension value recorded in the study is found in sub-zone 1.7, corresponding to the horizon line created by Çamlıca Mosque. The higher fractal dimension of the horizon line in the sub-zone 1.7 can be attributed to its architectural features characterized by sharper lines, its organic structure, and its location, all contributing to its dynamic appearance. Following closely are the horizon lines created by skyscrapers in Ataşehir, Ümraniye, and Üsküdar with the second highest (1.1756) and third highest (1.1467) fractal dimension values, respectively. These horizon lines follow the natural texture found in Çamlıca Hill. The fractal values within this zone are 1.1288, 1.1222, 1.108, and 1.0731. Natural lines in this zone represent areas with the least complexity in visual appearance, while the horizon line created by Çamlıca Mosque and vertical structures stands out as the most complex elements. Thus, contributing significantly to the dynamic visual appearance. This zone represents both the highest and lowest levels of complexity.

Horizon Line Zone 2

The fractal dimension values in Horizon Line Zone 2 range from 1.1147 to 1.1702 in this region, which is dominated by the natural environment. Most of the skyline lines in this zone are shaped by the slopes situated in Beykoz. The upward structures in Beykoz, explicitly the high rises, disturb the normal skyline line (2.1). Situated in a sloping region within the normal surface, these designs serve as the main human-made components that disturb the regular organization of the skyline line. Sub-zone 2.2, presents a level and smooth appearance formed by the geography, lessening intricacy. However, the variations in topography, including slopes and the inclusion of the Bosphorus Bridge on the horizon line, contributes to the complexity in sub-zones 2.3 and 2.4.

Horizon Line Zone 3

The fractal dimensions in this area are 1.1767, 1.1609, 1.192, and 1.1607. Skyscrapers constitutes the majority of the associated structural elements, with the vertical structures located in the middle section of the horizon line havingfractal dimensions of 1.192 and 1.1609. Skyscrapers in Şişli, Kağıthane, Beşiktaş, and Sarıyer contribute to the visual complexity in this area, making it the second-highest visual complexity area after Zone 1 in the study. Despite interrupted vertical development towards the northwest in the visual composition, the city structures in this area, shaped by topography, create a more irregular appearance. Furthermore, the inclusion of natural landscapes in the northeast prevents an onward increase in visual complexity in this area.

Horizon Line Zone 4

The fractal dimensions in this area range from 1.1521 to 1.1755. Mosques located in the Historical Peninsula and the structures in Zeytinburnu, Esenler, and Bağcılar in the northwest contribute to shaping the horizon line. Particularly in the central section that forms the horizon line, the complex appearance created by structures with different heights is notable. In Zone 4.3, where the highest fractal dimension is observed, the flag in Edirnekapı, the minarets of Fatih Mosque, and the Tekstilkent (Koza) Plaza in Esenler contribute to the complexity of the horizon line. Sub-zones 4.1 and 4.2 exhibits a complex visual composition created by structures of varying heights along the Basın Ekspres Avenue. In Zone 4.4, the decrease in complexity indicates a more stable horizon line, but in Zone 4.5, the presence of another vertical structure (Viaport Venezia) leads to an increase in the complexity of the horizon line.

Horizon Line Zone 5

The fractal dimensions in this area range from 1.0977 to 1.1303. Shaped by the structures in the Historical Peninsula and other districts in the northwest, this zone exhibits a dynamic horizon line. In Zone 5.1, the regular mass housing structure reduces complexity. On the other hand, in Zone 5.2, where a linear horizon line continues, the presence of minaret increases complexity. Zones 5.3 and 5.4 display a mixed appearance with a combination of mass housing and skyscrapers outside the city walls. In Zone 5.5, the minimal height differences between the structures along the horizon line result in a fractal dimension of 1.1181.

Horizon Line Zone 6

The fractal dimensions in this area range from 1.0988 to 1.1481. This zone, shaped by structures with varying heights throughout the city, experience a gradual increase in complexity from the southwest coastline to the inland. The lowest complexity (6.1) is observed in the appearance created by mass housing along the coastline. In Zone 6.2, the introduction of 16/9 skyscrapers alters the horizon. Zones 6.3 and 6.4 exhibit a dynamic horizon line formed by mass housing and other urban structures located outside the city walls.

DISCUSSION AND CONCLUSION

In the past century, humanity has experienced significant urbanization, with cities now hosting more than half of the world's population. This urbanization, has significantly changed, the appearance of cities, with acceleration in vertical construction due to increasing population. Skyscrapers, as seen in Chicago and New York in the past, and currently prominent in Dubai, serves as concrete manifestations of urban vertical growth in Istanbul. Despite the growing importance of tall buildings in both local and national economies, there remains a deficit of understanding regarding how vertical development affects the visual appearance and horizon lines of cities. It is within this context that this study focused on the horizon lines of Istanbul and their level of complexity.

As cities experience growth and transformation, their horizon lines also evolve. This study illustrates, using fractal geometry and the example of Istanbul, that the horizon line is an effective tool for comprehending the intricate visual morphology of cities. Horizon lines also serve as representation of city's natural and human-made structures. The texture of these lines, which can range from simple geometric patterns to complex ones, reflects the complexity resulting from urban growth. The fractal dimension serves as a parameter for grasping this complexity and obtaining quantitative results. Using this approach, alterations in fractal values in Istanbul's horizon line have been associated with structural components in urban space.

One architectural elements that complicates Istanbul's horizon line is the Camlica Mosque, situated on Camlica Hill in the northern part of the city. Additionally, the highest (Zone 1.7) and lowest (Zone 1.4) fractal values were obtained in the first urban horizon line zone. This zone encompasses both natural and urban landscapes, including the highest morphological units of Istanbul, such as Kayışdağı and Aydos mountains. In this section where natural elements form the horizon line, complexity is at its lowest. The zones with highest fractal values are located in the north (Zone 3.3) and east (Zone 1.2) directions, containing the horizon lines formed by skyscrapers. Skyscrapers, being the highest products of vertical construction, serve as secondary structural elements that accentuates the complexity to the horizon line.

Understanding and evaluating the fractal dimensions of urban skylines in terms of structural components, as shown in this study, helps in perceiving the subtleties of visual morphological complexity of the city. This understanding is crucial because it allows us to comprehend the patterns and complexities that shape the built environment, thereby determining decisions concerning basic features such as building heights and spatial arrangement that affect the overall visual morphology of cities. This study evaluates the elements that complicate the urban appearance in Istanbul, aiming to enhance our understanding visual quality as a significant component. By distinguishing vertical spatial organization patterns and identifying the basic features and components influencing urban appearance, this evaluation contributes to urban architectural design and spatial planning processes. This is important for urban planners, architects, and urban geographers as it provides insight into the spatial organization and visual quality of urban environments.

The study has demonstrated, through a unique approach that fractal analysis effective serves as an analytical tool for understanding urban skyline patterns. The results of this method not only provide an analysis of the current state but also has the potential for comparing urban appearances and creating effective horizon lines or silhouette plans.

In urban planning and design, utilizing the nuances of the skyline can help create less complex urban vistas. Designers can consciously alter building heights, densities, and spatial configurations by understanding the fractal dimensions of silhouettes and the structural components of the city. This understanding can foster visual harmony and consistency. For instance, within the study's scope, could a design be developed for skyscrapers, such as the tallest examples of vertical architecture that blends seemingly with the existing skyline without adding further complexity to the city or region's skyline? Similarly, could an architecturally compatible design be created by considering the natural morphological features of the area, taking into account the skyline shaped by prominent landmarks such as the Çamlıca Mosque highlighted in the study? In line with these examples, an application-oriented approach could contribute to the development of less complex and sustainable urban landscapes by characterizing the morphological complexity of the urban skyline.

Among the study's limitations are issues pertaining data resolution, variations in urban shapes across different geographic zones, and the dynamic nature of urban landscapes. These factors make it challenging to accurately measure and interpret fractal dimensions over time. To overcome these constraints and challenges, drones can be utilized to capture primary source imagery. The precise control and flexible maneuverability offered by drones will enable comprehensive photography of urban areas at various scales.

For future research endeavors aimed at better understanding how horizon line analysis influence urban planning objectives, enhancing measurement resolutions, evaluating horizontal and vertical morphological development concurrently at street and sky scales, and incorporating additional variables such as socioeconomic factors could prove beneficial. Furthermore, integrating perspectives on issues such as sunlight exposure and access to clean air, arising from distorted urban development, could be incorporated into the study from various angles.

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REFERENCES

ABU-GHAZALAH, S. (2007) Skyscrapers as Tools of Economic Reform and Elements of Urban Skyline: Case of the Abdalı Development Project at Amman, *METU Journal of the Faculty of Architecture*, *24*(1) 49-70.

AKBARİSHAHABİ, L. (2021) Examining the Relationship Between Enclosure Ratio of Street and Skyline's Complexity, *ICONARP International Journal of Architecture and Planning*, 9(2) 851-73.

AKDAĞ GİRGİNKAYA, S., BOSTANCI, S. H. (2013) The Impacts of Prestige Projects on the Skyline of Istanbul, *ArchNet-IJAR: International Journal of Architectural Research*, 7(2) 269-81.

AŞUR, F., ALPHAN, H. (2018) Görsel Peyzaj Kalite Değerlendirmesi ve Alan Kullanım Planlamasına Olan Etkileri, *YYU Tarım Bilimleri Dergisi*, *28*(1) 117-125.

ATEŞ, M. M., KIPER, T. (2023) İstanbul İli Karaköy Bölgesi'nin Görsel Peyzaj Değerlendirmesi, *Akademia Doğa ve İnsan Bilimleri Dergisi*, *8*(1) 15-39.

ATTOE, W. (1981) *Skylines: Understanding and Molding Urban Silhouettes*, Wiley, Chichester.

AYADI, M., SUTA, L., SCUTURICI, M., MIGUET, S., BEN AMAR, C. (2016) A Parametric Algorithm for Skyline Extraction, J. Blanc-Talon, C. Distante, W. Philips, D. Popescu, P. Scheunders (Eds.), *Advanced Concepts for Intelligent Vision Systems*, Springer, 10016; 604–15.

AYDIN, N. (2016) *Kentsel Saçaklanmanın Kent Örüntüsü Üzerindeki Etkisinin Fraktal Geometri ile Tespiti; Isparta Örneği*, Yayınlanmamış Yüksek Lisans Tezi, Fen Bilimleri Enstitüsü, Şehir Bölge Planlama Anabilim Dalı, Süleyman Demirel Üniversitesi, Isparta.

BATTY, M., LONGLEY, P. A. (1994) *Fractal Cities: A Geometry of Form and Function*, Acad. Press.

BOOTH, C. (2012) Revisiting the Image of the City: Exploring the Importance of City Skylines, Unpublished Master Thesis, University of Waterloo, Canada.

BOSTANCI, S. H. (2021) Researching for Methods in Visual Analyses of Urban Skylines, *International Journal of Architecture and Design*, *7*(2) 161-73.

BULUT, Z., ACAR, C. (2017) Peyzajda Neden Görsel Kalite Analizi Yaparız ?, *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi*, 10(2) 19-29.

CHALUP, S. K., HENDERSON, N., OSTWALD, M. J., WİKLENDT, L. (2009) A Computational Approach to Fractal Analysis of a Cityscape's Skyline, *Architectural Science Review*, 52(2) 126-34.

CHİU, C.-C., LİU, Y.-J., CHİU, S.-Y., CHANG, H.-C., HSU, C.-L. (2016) A Skyline Detection Algorithm for Use in Different Weather and Environmental Conditions, *2016 IEEE International Conference on Electro Information Technology (EIT)*, 680-85.

ÇOBANLI, F.T. (2023) İstanbul'un Şehirsel Ufuk Çizgilerinin Fraktal Boyutları: Gökdelenler ve Diğerleri, *3. İstanbul Uluslararası Coğrafya Kongresi, 21-23 Haziran 2023, Özetler Kitabı*, eds. Ertek, T.A. Kahraman, M. Bayrak, M. Zayım, İstanbul; 347-49.

ÇOBANLI, F. T., CEYLAN, M. A. (2023) Şehrin Ufuk Çizgisine Etkileri Bakımından İstanbul'da Gökdelenler, *Doğu Coğrafya Dergisi*, *28*(50) 25-38.

COOPER, J. (2003) Fractal Assessment of Street-level Skylines: A Possible Means of Assessing and Comparing Character, *Urban Morphology*, 7(2) 73-82.

COOPER, J. (2005) Assessing Urban Character: The Use of Fractal Analysis of Street Edges. *Urban Morphology*, 9(2) 95-107.

COOPER, J., OSKROCHI, R. (2008) Fractal Analysis of Street Vistas: A Potential Tool for Assessing Levels of Visual Variety in Everyday Street Scenes, *Environment and Planning B: Planning & Design* (35)349-63.

DANIEL, T. C. (2001) Whither Scenic Beauty? Visual Landscape Quality Assessment in the 21st Century, *Landscape and Urban Planning*, *54*(1–4), 267–281.

FORD, L. R. (1994) *Cities and Buildings: Skyscrapers, Skid Rows, and Suburbs*, Johns Hopkins University Press.

FORSYTHE, A. (2009) Visual Complexity: Is That All There Is?, *Engineering Psychology and Cognitive Ergonomics,* ed. D. Harris, EPCE 2009 Lecture Notes in Computer Science, Berlin; 159,66.

GASSNER, G. (2009) Elevations, Icons and Lines: The City Abstracted Through Its Skylines, *Researching the spatial and social life of the city,* eds. Davis, C., Dean, G. Gassner, S. Hall, J. Keddie, citiesLAB London School of Economics and Political Science, London; 68-86.

GOTTMANN, J. (1966) Why the Skyscraper ?,*Geographical Review*, 56(2)190-212.

GÖRGÜLÜ, T., KAYMAZ KOCA, S. (2009) Küresel Akışlar, İstanbul ve İstanbul'da Küresel Mimarlık, *Megaron Journal*, 4(2), 101-9.

GÜZEL, M., GÜZEL, E. G., ATABEYOĞLU, Ö. (2021) Ordu Kent Merkezi Kentsel Alan Değişimlerinin Yeniden Fotoğraflama ve Fraktal Analiz Yöntemi ile Değerlendirilmesi, *Düzce Üniversitesi Bilim ve Teknoloji Dergisi*, 10(2), 1006-23.

HAGERHALL, C. M., PURCELL, T., TAYLOR, R. (2004) Fractal dimension of landscape silhouette outlines as a predictor of landscape preference, *Journal of Environmental Psychology*, 24(2) 247-55.

HEATH, T., SMİTH, S. G., LİM, B. (2000) Tall Buildings and the Urban Skyline: The Effect of Visual Complexity on Preferences, *Environment and Behavior*, 32(4) 541-56.

KALIN, A. (2004) *Çevre Tercih ve Değerlendirmesinde Görsel Kalitenin Belirlenmesi ve Geliştirilmesi: Trabzon Sahil Bandı Örneği*, Yayınlanmamış Doktora Tezi, Fen Bilimleri Enstitüsü, Peyzaj Mimarlığı Anabilim Dalı,Karadeniz Teknik Üniversitesi, Trabzon.

KARPERIEN, A. (2015) FracLac for ImageJ.

KELLER, J. M., CROWNOVER, R. M., CHEN, R. Y. (1987) Characteristics of natural scenes related to the fractal dimension, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *9*(5), 621-27.

KİPER, T., KORKUT, A., TOPAL, T. Ü. (2017) Görsel Peyzaj Kalite Değerlendirmesi: Kıyıköy Örneği, *KSÜ Doğa Bilimleri Dergisi*, *20*(3) 258-69.

KOSTOF, S. (1991) *The City Shaped: Urban Patterns and Meanings Through History*, Thames and Hudson.

LYNCH, K. (1990) *The image of the city* (20 st ed), Cambridge (Mass.) London: M.I.T Press.

MANDELBROT, B. B. (1983) *The Fractal Geometry of Nature*, W.H. Freeman.

MANDELBROT, B. B. (1989) Fractal Geometry: What Is It, and What Does It Do?, *Proceedings of the Royal Society of London. A. Mathematical and Physical Sciences*, *423*(1864) 3-16.

MARTİNEZ-SANCHEZ, L., BORİO, D., D'ANDRİMONT, R., VAN DER VELDE, M. (2022) Skyline Variations Allow Estimating Distance to

Trees on Landscape Photos Using Semantic Segmentation, *Ecological Informatics* (70) 101757.

MISTHOS, L.-M., KRASSANAKIS, V., MERLEMIS, N., KESIDIS, A. L. (2023) Modeling the Visual Landscape: A Review on Approaches, Methods and Techniques, *Sensors*, *23*(19) 8135.

NADAL, M., MUNAR, E., MARTY, G., CELA-CONDE, C. (2010) Visual Complexity and Beauty Appreciation: Explaining the Divergence of Results, *Empirical Studies of the Arts* (*28)* 173-91.

NASAR, J. L., TERZANO, K. (2010) The Desirability of Views of City Skylines After Dark, *Journal of Environmental Psychology*, *30*(2) 215-25.

ODE, Å., HAGERHALL, C. M., SANG, N. (2010) Analysing Visual Landscape Complexity: Theory and Application, *Landscape Research*, *35*(1) 111-31.

OKU, T. (1990). On Visual Complexity on the Urban Skyline, 日本建築学会計画系論文報告集 (412) 61-71.

OSTWALD, M., VAUGHAN, J. (2013) Representing Architecture for Fractal Analysis A Framework for Identifying Significant Lines, *Architectural Science Review* (56) 242-51.

PERİHAN, M., AŞUR, F. (2020) Tarihi Kentsel Peyzaj ve Kent Kimliği İlişkisi, *Kent Akademisi*, *13*(1), 163-75.

SCHNEİDER, C. A., RASBAND, W. S., ELİCEİRİ, K. W. (2012) NIH Image to ImageJ: 25 years of image analysis, *Nature Methods*, 9(7) 671-75.

STAMPS, A. (2002) Fractals, Skylines, Nature and Beauty, *Landscape and Urban Planning*, 60, 163-84.

TURAN, S. (2022) *Mimaride Görsel Karmaşıklığın Analizi: Fraktal Analiz*, Yayınlanmamış Yüksek Lisans Tezi, Lisansüstü Eğitim Enstitüsü, Mimarlık Anabilim Dalı, Konya Teknik Üniversitesi, Konya.

TVEIT, M., ODE, Å., FRY, G. (2006) Key Concepts in A Framework for Analysing Visual Landscape Character, *Landscape Research*, *31*(3) 229–55.

ULRICH, R. S. (1986) Human Responses to Vegetation and Landscapes, *Landscape and Urban Planning* (*13)* 29-44.

VAN CLEEF, E. (1932) The Urban Profile, *Annals of the Association of American Geographers*, 22(4) 237-41.

WANG, J. (2016) Fractal Dimension-A New Tool for Quantitative Analysis of Urban Skyline, *Civil Engineering and Urban Planning IV*, ed. Y. M. Liu, D. Fu, Z. X. Tong, Z. Q. Bao, B. Tang, CRC Press-Taylor & Francis Group, Boca Raton; 107–10.

YANG, L., YANG, X., LI, Y., LI, S. (2024) A New Quantitative Evaluation Method of Urban Skyline Based on Object-Based Analysis and Constitution Theory, *Environment and Planning B: Urban Analytics and City Science*, *51*(1) 259–74.

YILMAZ, D., ÖZTÜRK, S., IŞINKARALAR, Ö. (2022) Kent İmgesinin Yapıtaşı Olarak Sokaklarda Mekânsal Zenginliğin Fraktal Geometri İle Analizi, *Kent Akademisi*, *15*(3) 1341-58.

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FRAKTAL ANALIZ ILE GÖRSEL KARMAŞIKLIĞIN BOYUTLARI: İSTANBUL'UN ŞEHIRSEL UFUK ÇIZGILERI ÜZERINE BIR VAKA ÇALIŞMASI

Kentsel ufuk çizgileri zaman ve mekân ölçeğinde değişen koşulları yansıttıkları için dinamik yapıya sahiptirler. Bu dinamik yapı aynı zamanda kentlerin görsel niteliklerini ve karmaşıklığını değerlendirebilmek için bir kentsel bilgi aracı olma potansiyeli taşımaktadır. Bu makale, fraktal analiz yoluyla gerçekleştirilen kentsel ufuk çizgileri çalışmalarına İstanbul üzerinden yeni bir metodolojik bakış açısı sunar. Son 30 yılda kentlerin morfolojik özelliklerini ölçmek için bir dizi hesaplama teknikleri geliştirilmiştir. Bunlardan en bilineni ve en yaygını olarak fraktal analiz, görsel veriler vasıtasıyla elde edilen kentsel ufuk çizgilerinin karmaşık yapısını analiz etmek için çalışma kapsamında kullanılmıştır. Çalışma, ilk olarak, İstanbul'un güncel kentsel ufuk çizgisini ortaya koymak ikinci olarak ise bu ufuk çizgisini şekillendiren unsurların görünüme olan etkilerini fraktal geometri yoluyla ölçmeyi amaçlamaktadır. Bu amaç kapsamında kullanılan kutu sayımı ile ölçülen fraktal boyut, kentsel ufuk çizgilerinin karmaşıklığını açıklamak için kullanılan bir metriktir. Beyazıt Yangın Kulesi'nin referans noktası kabul edildiği bu çalışmada, kent panoramalarından elde edilen ufuk çizgilerinin fraktal boyutları ImageJ Programı ve FracLac eklentisi kullanılarak hesaplandı. Çalışma kapsamında gerçekleştirilen ufuk çizgilerinin fraktal analizi sonucunda 1,0731-1,2171 aralığında fraktal boyutlar elde edildi. Ufuk çizgileri ile eğilimleri gül diyagramı aracılığıyla sunulmakta ve fraktal analiz sonucunda şehrin görünümünü en fazla karmaşıklaştıran iki ana unsurun olduğunu göstermektedir: biri cami, diğeri ise gökdelenler.

A CASE STUDY ON THE URBAN SKYLINES OF ISTANBUL: DIMENSIONS OF VISUAL COMPLEXITY WITH FRACTAL ANALYSIS

Urban skylines have a dynamic structure because they reflect changing conditions in time and space. This dynamic structure also has the potential to be an urban information tool for evaluating the visual qualities and complexities of cities. This article presents a new methodological perspective on urban skyline studies through fractal analysis in Istanbul. In the last 30 years, several computational techniques have been developed to measure the morphological characteristics of cities. Fractal analysis, the most well-known and widespread of these, is used in this study to analyze the complex structure of urban skylines obtained through visual data. The study aims to first expose the existing urban skyline of Istanbul and then assess the influence of the factors influencing this skyline on its appearance by using fractal geometry. The fractal dimension, measured by the box count is used for this purpose and that is a metric used to describe the complexity of urban skylines. In this study, in which Beyazıt Fire Tower is accepted as the reference point, the fractal dimensions of the skyline obtained from urban panoramas are calculated using the ImageJ Program and FracLac plugin. As a result of the fractal analysis of the skyline, fractal dimensions in the range of 1,0731-1,2171 were obtained. The skylines and their trends are presented through the rose diagram, and fractal analysis shows that two main elements complicate the appearance of the city the most which are: mosque and skyscrapers.

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