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Object-Based Spatial Analysis of Airbnb Homes in Istanbul

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Abstract: This study investigates the sociocultural and functional organization of residential interiors in Istanbul through an object-based spatial analysis. Utilizing a dataset of over 46,780 photographs from 1,968 Airbnb listings in Istanbul, the research employs computational methods, specifically web scraping with Python for data acquisition, and advanced computer vision and artificial intelligence models (MiniCPM-V:8B and LLaVA-Llama3:8B) for identifying objects and mapping their spatial relationships. The study aims to reveal how the interconnections between objects within distinct room types–dining room, kitchen, living room, bathroom, and bedroom–shape spatial integration and influence daily life activities. Key findings demonstrate the central role of the dining table in dining rooms through strong connections with chairs, the critical function of the sink in kitchens linked to preparation areas and appliances, the dominant relationship between the coffee table and sofa in living rooms reflecting comfort and social interaction, and the distinct functional priorities of hygiene in bathrooms and comfort in bedrooms. The analysis reveals that the spatial structure of domestic environments in Istanbul is increasingly characterized by object clusters and user-object interactions, moving beyond traditional physical boundaries. These findings underscore the significant influence of cultural values, hospitality practices, and social interaction patterns on the spatial configuration and integration of contemporary homes, offering insights into the evolving nature of domestic space in an urban context.

Keywords: artificial intelligence, object-based analysis, computer vision, Airbnb, data analysis

1. Introduction

As a living space, the interior design of houses is a multidimensional reflection of an individual's socioeconomic position, past experiences, developed identity, and psychological orientation beyond its material function [1]. Home interiors shape and functionalize daily human activities such as shelter, food preparation, consumption, rest, and storage [2]. Homes function as a spatial entity where social relations are structured, as well as individual and family relations. Applications for the home, which are a reflection of aesthetic and moral values, have a temporal and spatial framework [3]. Cultural applications create the interaction of individuals and objects in the home [4]. In addition to the fact that home interior design does not mediate the emergence of the lived experience, it is also effective in structuring the experience [5]. The dynamic interaction that occurs with home interior design reveals the existing connection between the individual and society and provides information about the existing adaptation to the environment and the socioeconomic structure [6]. Interior designs also emerge from a holistic acceptance of common values. Although interior design professionals apply stylistic and functional frameworks, residents continue to negotiate on aesthetics in arranging household items [7]. In this way, different interior environments can be created that inherit functional and new norms but blend them with tradition and local customs [8].

The house, which is considered both a living and design space, provides a study area where theoretical and experimental evaluations can be made for spatial applications [9]. The arrangement and usage methods of household items provide valuable insights in examining the mutual relationship between the residents living in the house and the design of the space [10].

In this study, a research methodology is proposed that covers the understanding of the behavioral field and the mapping of household objects as a whole, not individually, with other items they are together with. This study focuses on ordinary spatial urban apartment spaces. The focus of this study is a critical research in order to understand the broad urban phenomena of interior spaces [11, 12].

Computer vision, especially object recognition applications, plays an effective role in examining interior spaces. Data obtained with computer vision provides insights into understanding domestic symbolism. The decline of symbolic visual environments in home interiors has become increasingly evident since the industrialization and urbanization processes of the 19th century. This change provides reflections on the formal, individual, and social identity structuring and transformation of domestic life on a social basis [13]. With the reach of industrialization to the most remote areas, changes have occurred in the interior spatial, formal, and functional meanings even in traditionally accepted homes. The emotional and cultural semantic bond that individuals form with space has been reshaped. The development of computer vision has paved the way for in-depth analysis of the transformation process. In particular, developments in the fields of deep learning and artificial intelligence have enabled object recognition and image processing algorithms to obtain more valuable results [14]. The analysis of visual data with the use of these technologies allows monitoring the location, function, and transformation of certain symbols and design elements in domestic spaces over time. In addition, it is effective in revealing the psychological effects of space on individuals [15].

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The visual imagery of furniture and decoration elements used in interior spaces reflects symbolic elements in a cultural context. These symbols are often associated with social status, family dynamics, and power relations. Since the 19th century, interior spaces have become relatively standard due to mass production. As a result, symbolic meanings have diminished and become unclear [16, 17]. On the other hand, new cultural meanings imposed by digital and social media platforms that can reach wide areas with the opportunities provided by developing technology have begun to gain strength. In the design of a home interior in today's world, new social norms created through social media, as well as individual preferences, are aesthetically effective. In this context, it makes it possible to analyze the symbolic meaning of home interiors from a cultural and social perspective through computer vision technologies [18, 19].

This study aims to investigate how the sociocultural and functional organization of residential interiors in Istanbul can be grasped through object-based spatial analysis. In particular, it examines how the connections between objects in different room types shape spatial integration and how these structures affect daily life practices. The study aims to understand the evolutionary nature of domestic space in the urban context by going beyond traditional physical boundaries. In this context, the main research questions conceptually reveal how the connections between objects in different spaces, such as the dining room, kitchen, living room, bathroom, and bedroom in Airbnb residences in Istanbul, determine spatial integration and its effects on daily life activities.

The main hypotheses addressed in the study are as follows:

1) The spatial organization of residential interiors in Istanbul is determined not only by traditional physical boundaries but also by the relationships between objects in different room types.
2) Cultural values, hospitality practices and forms of social interaction significantly shape the spatial configuration and integration of contemporary residences in Istanbul.
3) Certain objects are positioned as spatial centers or functional anchors in various rooms, and the relationships these objects establish with other elements reflect both functional and aesthetic priorities.

In addition, it is argued that objects found in domestic spaces form functional clusters that determine room-specific activities, not just areas defined by physical boundaries. For example, objects related to cooking in the kitchen or objects related to hygiene in the bathroom are examples of such clusters.

The spatial arrangement of objects in Airbnb residences in Istanbul reflects cultural values, hospitality practices, and social interaction patterns, leading to the formation of unique integration models between different districts or room types.

In this context, the main hypothesis of the study is that contemporary residential interiors in Istanbul are organized through object clusters and user interactions, rather than rigid architectural divisions; thus, "invisible" boundaries that adapt to urban lifestyles are formed.

The object layouts of urban interiors of Airbnb residences located in New York and Boston were analyzed. In the study, object-based graphic methods were introduced to develop predictions for future interior designs, and household behavior patterns were revealed through this method [20]. In addition, analyses were performed using graphic convolutional networks to understand the spatial structuring rules of floor plans, which are one of the main factors affecting interior organization [21]. A total of 3,960 interior photos of properties listed on Airbnb for touristic purposes in Siena, Italy, were examined, and it was determined that snapshots emphasizing local identity were prominent [22]. In another study conducted on a global scale, interior photos of Airbnb residences located in 10 major cities around the world were analyzed in terms of decoration, color use, and style features; it was determined that color preferences were similar due to the effect of globalization, but there were differences in the level of ostentation of decoration depending on different locations within the same city [23–25].

Studies conducted in Switzerland and Mexico aimed to develop insights into the ambient qualities of residences. In this direction, a variance explanation rate of up to 42% was achieved with the model created [26]. On the other hand, Airbnb has established certain standards and taken various remedial measures in order to increase the quality of photographs of the places to be listed on the platform. However, as a result of the evaluations, it was revealed that only a small part of the interior photographs met these criteria [27, 28]. Studies on Airbnb residences were not limited to interior arrangements. Profile photographs of the people responsible for renting the houses were also analyzed extensively, and as a result of these analyses, important insights were obtained regarding the perception of reliability [14, 15, 29–31]. In addition, various empirical studies have been conducted on the factors affecting the rentability and rental values of houses [32, 33].

2. Method and Data

2.1. Data set

Airbnb was founded in 2008 and is an influential and leading multinational company in the sector, with the slogan "live like a local." The Airbnb platform allows people to discover and book listings of accommodations [34]. It is a platform that contains valuable data used in many areas such as tourism, sharing economy, and behavioral psychology. The study uses interior images of houses listed on Airbnb. As a policy, Airbnb aims for interiors to have as much interaction between hosts and guests as possible, while expecting local cultural influences. It is especially recommended that they reflect touristic elements in the surroundings [35]. As a home-sharing platform, Airbnb provides the necessary data for visual-based analysis of home spaces. The data obtained facilitates the contextualization of sociocultural frameworks belonging to the relevant geography through interior spaces [36, 37].

The level of personalization of the space is one of the main differences between Airbnb houses and permanent residences [38]. In the houses where individuals live for a long time, there are physical elements that reflect their identities, habits, and values. On the other hand, Airbnb residences have a more neutral and universal aesthetic approach. Property owners tend to prefer functional and standard spatial decoration in order to be noticed by a wider audience [39, 40]. This situation causes the anonymity of the spaces and plays an effective role in the spread of accepted norms in terms of accommodation trends. Although these properties strive to be standard and lack personal belongings, they contain clues in terms of basic elements. This study uses a dataset consisting of more than 46,780 photographs of the interior spaces, such as living rooms, dining rooms, kitchens, bathrooms, and bedrooms of a total of 1,968 randomly selected Airbnb properties in Istanbul, which is visited by many tourists with its unique historical and cultural heritage. The number of photographs of living rooms, bedrooms, bathrooms, kitchens, and dining rooms is 14,503, 13,555, 8,627, 6,614, and 3,481, respectively. The dataset was obtained by web scraping using the Python programming language within the scope of this study.

In this study, the web scraping method was applied using the Python programming language in the dataset creation process. In open-source data collection processes, two basic methods generally stand out: Direct use of datasets previously prepared and shared by third parties and provision of necessary data through Application Programming Interfaces provided by data providers. However, in cases where the data source does not provide appropriate access to these methods, the web

scraping method is used as an effective alternative. In the literature, web scraping is defined as the process of systematically collecting content and data on a website through specially developed scripts [41].

Although web scraping operations can be performed using different programming languages, Python was preferred in this study due to its simple syntax, ease of use, and wide library ecosystem. BeautifulSoup library in the Python ecosystem plays an important role in parsing HTML content, requests library in managing HTTP requests, and Selenium in interacting with dynamic web content. These libraries help to increase both the accuracy and efficiency of data scraping processes, helping to execute the process in a systematic and reliable manner. Additionally, Python's large user and developer community provides comprehensive documentation and educational resources, making the language accessible to beginners as well as a solid foundation for advanced and complex scraping projects.

2.2. Image preprocessing and graphics generation

Large language models (LLMs) are models that are created to understand a given instruction and produce meaningful responses in return. As a result of the emerging needs, models that enable visual data to be understood and processed have emerged. By combining text-based artificial intelligence systems with computer vision capabilities, it is possible to both analyze images and produce text-based responses about images. Models that provide text-based inferences from images are called LLM vision models [42]. These models generally work by integrating image processing models, such as Vision Transformer or ResNet, with LLMs such as GPT. In the context of image processing, MiniCPM-V:8B and LLaVA-Llama3:8B models are open-source advanced artificial intelligence models that stand out in text and visual processing [43]. These models have the ability to analyze, interpret, and produce text-based responses about images. MiniCPM-V:8B is a model with 8 billion (8B) parameters and exhibits significant performance in understanding visual data [44]. It has surpassed models such as GPT-4V, especially in single-image, multiple-image, and video understanding. LLaVA-Llama3:8B is a model that can process visual and text data together, based on the Llama 3 model. It is integrated with CLIP's visual backbone, which allows it to perform more comprehensive analyses by processing text and visual inputs together.

In the training, development, and use of artificial intelligence models, the capacity of the hardware infrastructure on which they are run stands out as one of the determining factors. An artificial intelligence model, after being trained, shows performance in the computing infrastructure where it is run, especially depending on the RAM and graphics card (GPU) capacity, in order to be used. Recently, LLMs that have achieved high success in various fields have been developed. Although the success of these models depends on many factors, their effective use by the end user necessitates the need for advanced hardware infrastructures.

One of the important factors affecting the performance level of an LLM model is the number of parameters the model has. The increase in the number of parameters increases the accuracy and comprehensiveness of the output produced; however, this situation causes the scale of the required hardware resources to grow in parallel. In this study, 32 GB RAM and an 8 GB NVIDIA GPU were used for data processing and model running processes. Within the specified hardware configuration, it was determined that the number of parameters of the LLM models that can be run should be approximately 8B. The file sizes of models of this size generally vary between 4.5 GB and 6 GB. As a result of the literature review, it was determined that the highest performing models with 8B parameter size were MiniCPM-V: 8B and LLaVA-Llama3: 8B. In line with these reasons, it was decided to use these two models [45, 46].

This study focuses on the systematic analysis of images within the scope of the given guideline with the LLM vision models MiniCPM-V:8B and LLaVA-Llama3:8B. The models used are powerful and effective tools in the definition and analysis of residential interiors and objects. It provides the creation of an object-based spatial graph by revealing the relationships based on room classification, object detection, and the coexistence of objects detected in the same image. The graph-based methodology created within the scope of the study provides a structured framework for examining the spatial relationships of objects. Modeling the configuration of domestic spaces investigates the abstract behavioral network in which objects are organized into an implicit home logic. As can be seen in Figure 1(a), the analytical approach presented allows for an in-depth quantitative assessment of domestic object presence. The study, in which each room type is identified (Figure 1(b)) and evaluated separately, shifts the focus from individual rooms to the interaction of objects in the home environment (Figure 1(c)). In this context, the study provides an alternative perspective on the spatial organization of daily life. In addition, the dataset can be enriched with attributes such as property prices, location, and housing type, depending on existing open data sources. The presented methodology can be applied to a range of design analysis scales from a single room to an entire house or multiple rooms in Airbnb listings.

It is important to provide the correct instructions in order to obtain the correct results for LLMs. The correct acquisition of the requested information and the production of the output in the specified order depend on the quality of the instructions during the data acquisition process of the study. Figure 2 shows the instructions given before the photographs related to the space are given to the LLM vision model.

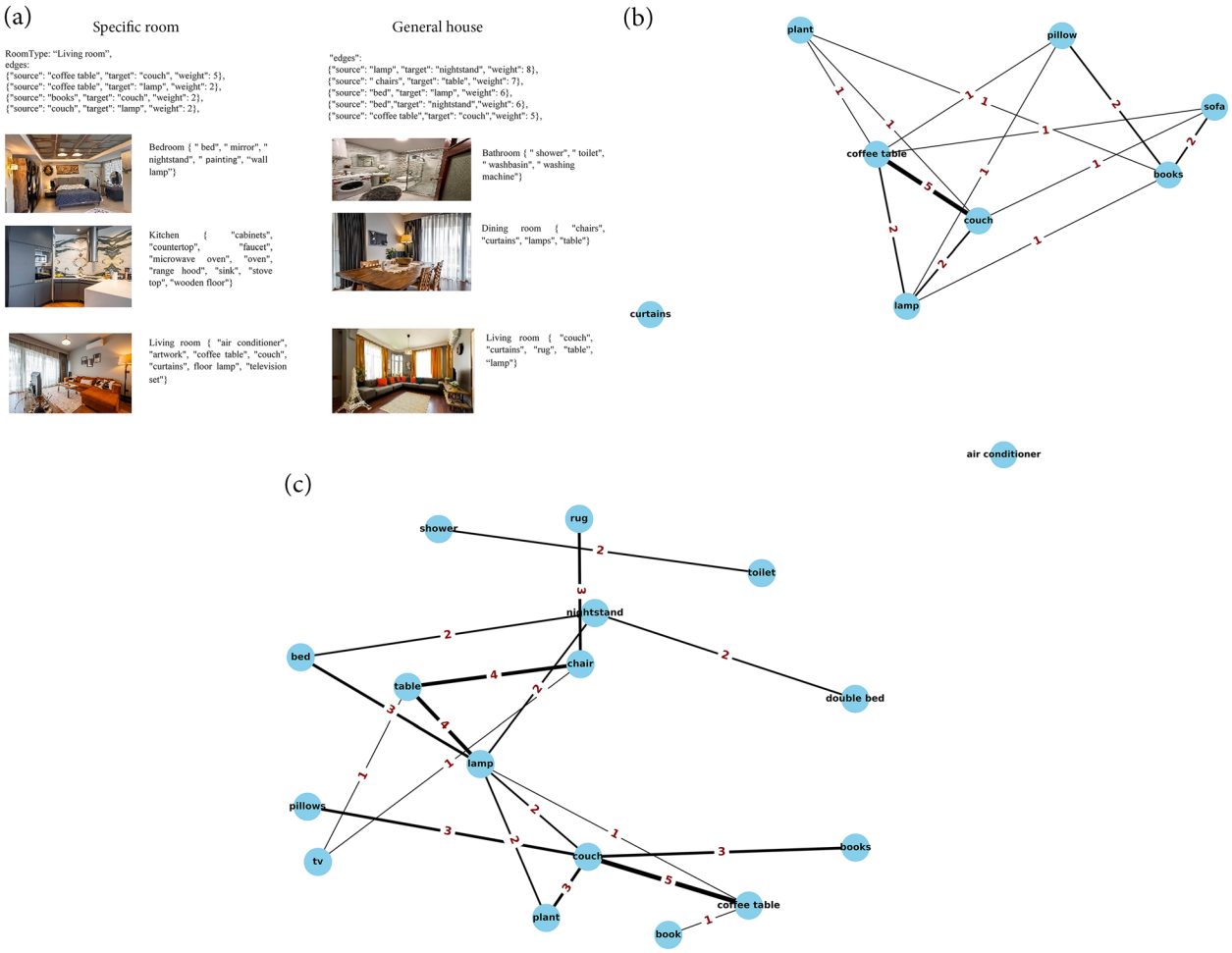
In the preliminary instruction sent to the model, information is given about the task it will perform, the order in which it will output, and the sample order. It has been stated that because LLM models tend to create as many explanatory answers as possible while generating answers, the answer in the generated JSON format should not contain single words or additional explanations. In addition, the hallucinatory features of LLM models can still reduce the quality of the data. For this reason, it is emphasized in the instruction that it should definitely stick to the objects that exist in the given scene. The sample answer obtained as a result of the instruction is given in Figure 3.

2.3. Object-based graph and centrality measurement

This study presents a methodological framework covering the analysis of the distribution and association of objects in domestic spaces using graph theory. The proposed approach involves the formation of a graph in which nodes in domestic spaces represent individual objects such as furniture and decor, while edge connections represent entities or relational adjacencies in the space. This spatial network emphasizes the object-object interaction of basic components, extending one level beyond the traditional room-based analyses. The weight formed in each edge connection reflects the frequency or importance formed by the association with the objects to which it is connected. As a result of the analysis, the order and behavioral tendencies in domestic spaces are perceived in detail.

This research exhibits a significant departure from traditional assessment methods by aiming to quantify domestic activities through object relations. Although traditional approaches generally focus on physical properties such as size, connection, and home layout, this study offers a more comprehensive perspective by analyzing the relationships between objects. From a methodological perspective, it allows the identification of unique object pairs in order to minimize redundancy within a single graphical representation, while edge weights are used to record the frequency of co-occurrence of these object pairs. This analytical approach allows high-frequency object pairs to significantly affect centrality measures within the overall structure of the spatial network. Thus, it contributes to a more in-depth and dynamic understanding of domestic activities.

Figure 1
Two approaches to converting images into an object-based graphic



The node set V, consisting of objects, and the edge set E representing object pairs, are defined by the graph G = (V, E). The degree centrality (DC) of each node is a metric that allows determining its importance within the graph. This value is calculated based on the existing connections of the node with other nodes. In graph theory, the concept of centrality reveals the relative importance of a node within the network, as it is a criterion evaluated through its connections with other nodes. In addition, since the importance of a node can be evaluated from different perspectives, it also causes the emergence of various centrality measures. Within the scope of the study, an analysis was created based on the DC and intermediate centrality measures in particular. These metrics play a key role in revealing the structure of the relationships between objects and the interaction factors.

In network theory, DC is one of the basic metrics used to determine the importance of a particular node within the network. In the graph, DC for node *i* is expressed by Equation 1. In this context, Md represents the DC of a particular node in a graph. The neighborhood matrix A, which determines the structure of the graph, is defined as Aij. The defined matrix represents the edge weight between nodes *i* and *j*. If there is no direct connection between two nodes, in other words, if there is no edge detected between them, then $A_{ij} = 0$.

The DC of a node is obtained by calculating the total weight of the edges connected to that node. This process is shown by the expression $\sum A_{ij}$. It is obtained by summing over all neighboring nodes (*j*). In this expression, n represents the total number of nodes, while the value n-1 is the normalized maximum number of connections that a node can reach. In this way, the DC value becomes comparable between networks of different sizes.

$$M_d = \frac{\sum_{j}^{n=1} A_{ij}}{\mathrm{n}-1} \tag{1}$$

In the context of in-home spatial analysis, DC quantifies the extent to which an object is directly connected to other objects and provides insights into its functional importance within the home. Objects with a high degree of centrality exhibit strong spatial relationships with other objects and serve as central elements in household activities. This reveals how directly a particular object is connected to other objects, indicating its overall importance or frequency of use within the household. The DC metric helps understand the spatial organization of objects and the relationship of the occupants to this organization.

In short-term rentals such as Airbnb, this organization may be due to the owner's previous life experiences or assumptions about the needs of potential tenants. When applied to a real home environment, this analysis can reveal cultural and behavioral trends in the daily activities of family members.

An object or group of objects with a higher DC value has a strong spatial connection to other objects within the home and may form a central or core element of an object-focused behavioral network. Such a network helps understand the role that objects play in daily life and the dynamics within the home.

Figure 2
Pre-prompt

```
# Send request to Ollama
try:
    response = ollama.chat(
        model="minicpm-v:8b",
        messages=[
            {
                "role": "user",
                "content": '''
                    Extract a structured list of objects in JSON format and identify the room type.
                    Follow the exact JSON format below, without extra descriptions:

                    {
                      "roomType": "<room_type>",
                      "objects": ["<object1>", "<object2>", "<object3>"]
                    }

                    Ensure:
                    - The "roomType" is a single word category like "bedroom" or "kitchen."
                    - The "objects" list includes only recognized objects in the scene.
                    - No additional explanations or descriptions are included in the JSON response.
                    ''',
                "images": [encoded_image]
            }
        ]
    )
```

Figure 3
LLM model respond output


```
[
  {
    "roomType": "living room",
    "objects": [
      "couch",
      "curtains",
      "rug",
      "table lamp"
    ],
    "file_name": "abnb_1000514436739051915_image_1.jpg",
    "directory": "abnb_1000514436739051915"
  },
  {
    "roomType": "kitchen",
    "objects": [
      "dishwasher",
      "washing machine",
      "refrigerator",
      "microwave oven",
      "coffee maker",
      "stove",
      "cup",
      "plant pot"
    ],
    "file_name": "abnb_1000514436739051915_image_10.jpg",
    "directory": "abnb_1000514436739051915"
  }
]
```


In graph theory, the broker centrality (BC) of a node expresses the degree to which a given node plays a broker role in a network and is defined in Equation 2. In the context of this study, the expression C_b denotes the BC value of a given node v. The formula is calculated by summing over all node pairs in the node set V. Here, σst is the total number of shortest paths between nodes s and t, and $\sigma st(v)$ is the number of paths passing through node v.

$$C_b = \sum_{s,t \in V} \frac{\sigma\, st(v)}{\sigma\, st} \tag{2}$$

BC is a metric that measures how often a node acts as a bridge along the shortest paths between two other nodes. BC determines the impact of a node on the overall system by controlling the flow of information or movement within network structures. In this context, it can also be used to analyze the spatial and behavioral importance of objects within the home.

BC plays a critical role in determining objects that act as axial connection points or intermediaries between different areas or functional zones within the home. Unlike traditional room or function-based analysis approaches, this study emphasizes the importance of an object-centered analysis. The spatial importance of objects is not only related to their physical existence or functionality, but also to how they affect and structure behavioral systems within the home.

When the BC values of objects are examined, it can be understood how physical arrangements and individuals' lived experiences shape spatial interactions. Objects with high BC values not only connect different object clusters within the home but also play critical roles in the organization of domestic activities and the formation of "behavioral areas." This phenomenon reveals a more fluid and dynamic spatial order understanding compared to the traditional approach, where physical walls divide spaces according to function. The analysis of objects with high BC values allows us to understand family habits and daily routines in the home more deeply. Thus, more flexible and behaviorally defined spaces shaped by the relational dynamics of objects come to the fore beyond physical boundaries.

In this context, it can be concluded that objects in the home play an important role in structuring spatial organization and family life, beyond being merely practical objects. Therefore, analyzing BC values of objects in the home will contribute to a more comprehensive understanding of home dynamics and user experiences.

This study uses DC as a measure to decode indoor activities based on object arrangement. However, it is seen that other standard metrics defined within the framework of graph theory are also applicable in such analyses. For example, closeness centrality (CC) determines the degree to which an object is central in terms of spatial arrangement and access by calculating the average shortest path distance of a node to all other nodes in the network. In this context, objects with high CC stand out as elements that play a key role in the flow of domestic activities. On the other hand, the difference between BC and CC is of great importance in terms of the analysis of object networks in the home environment. Although BC evaluates whether a certain object acts as a connector or bridge in the spatial order, CC analyzes the relational proximity of the object to other elements in the space.

Eigenvector centrality (EC) is a measurement that takes into account the number of connections a node has in a network and the importance of these connections. EC works by assuming that connections with nodes with high centrality have a greater impact. In this context, it is seen that EC makes important contributions to the analysis of domestic spatial order. Objects with high EC values are not only connected to many objects, but also to other central objects, indicating that they play critical roles in the functional and social dynamics of the home.

However, although EC and DC are both metrics that measure network centrality, the ways in which nodes are evaluated differ. Although DC only takes into account the number of connections an object has, EC also takes into account the quality and importance of connections. Therefore, EC is capable of identifying objects that are influential not only in terms of the number of connections but also in terms of their relationships with other important objects.

3. Analysis

The interaction between individuals and their environment plays a critical role in the formation of social, cultural, and traditional identities. The domestic space, one of the basic components of human settlements, is a concrete reflection of these identities. Physical elements make the relationships between individuals and the social structure visible on the material plane [8, 9]. The room layout and objects, which are among the basic elements of the domestic interior, are in a mutually dependent relationship. Because rooms provide a framework for the positioning of objects, the placement of objects also shapes spatial use. Thus, the cultural identity of the residents can be read through these physical components [10]. In particular, the placement and organization of home furniture have the potential to reflect social structures in certain historical periods. The way household items are arranged shows the interaction of daily life practices and technological developments [11]. In this context, indoor objects separated by closed walls function as nodes that facilitate the understanding of social relations and behavioral patterns. Although the modern lifestyle encourages a spatial organization where individuality is at the forefront, functional design processes generally show a unifying tendency. Although the decline of traditional local domestic activities indicates that the influence of social hierarchy on domestic space has decreased [12, 13], it is observed that a spatial organization understanding based on functionality is on the rise.

The globally standardized home design, which has replaced the spatial diversity specific to pre-industrialization periods, reveals the transformation of the relationship between function and object. This change derived from apartment layouts offers an important perspective for analyzing modern domestic environments. Today, analyzing the cultural practices of individuals living in apartment spaces divided by walls requires taking this function-object relationship into account.

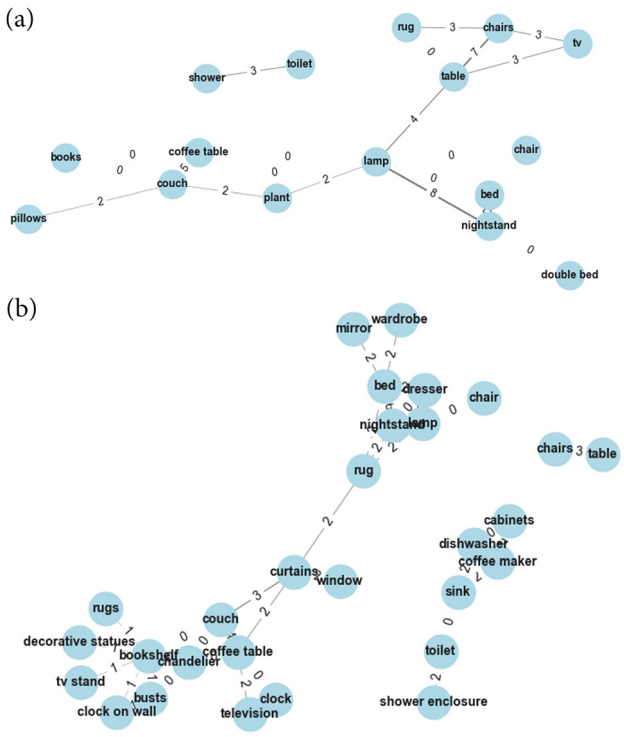
3.1. Behavioral integration between room types in Istanbul

This research examines the main room types in residences in Istanbul and examines how these spaces integrate with individuals' daily living habits. Basic sections such as the living room, dining room, kitchen, bathroom, and bedroom support different domestic activities from the perspective of traditional interior design and functionality. Comparative analyses reveal that the objects that stand out in certain rooms vary according to different housing types. The findings show that there are differences between districts. An example of the difference between districts can be evaluated using Figure 4.

Objects such as coffee tables, armchairs, televisions, chairs, and carpets in living rooms stand out as basic elements for individuals to establish social relationships, rest, and continue their daily routines. However, it is seen that certain objects play a more central role in different houses in Istanbul. For example, while "Curtains" and "Decorative Objects" emphasize the importance of aesthetic understanding, "Guest Armchairs" and "Coffee Tables" indicate the existence of an atmosphere focused on socialization. Figure 4 shows the distribution of household goods in two different districts in Istanbul. Figure 4(a) shows that Mecidiyeköy, and Figure 4(b) shows Fatih.

In dining rooms in Istanbul, the dining table stands out as the central element of the dining room and is directly connected to many

Figure 4
Differences in room type integration based on high degree centrality object according to Istanbul districts



objects around it. The most frequently observed connections include the relationships between the dining table and chairs (6.83%, 2,487 connections), plates (1.47%, 537 connections), and flowers (0.96%, 348 connections). Chairs are the object with the highest connection to the dining table, indicating that they are one of the most prominent structural elements of the dining room. The connections between objects are not only formed around the dining table. Chairs are frequently associated with plates (0.93%, 338 connections), carpets (0.64%, 233 connections), vases (0.60%, 217 connections), and curtains (0.58%, 210 connections). This situation reveals both the functional and decorative aspects of the room. The connections of the dining table with vases (0.81%, 296 connections), candlesticks (0.93%, 337 connections), and wine glasses (0.71%, 257 connections) show that decorative elements play an important role in dining rooms. In addition, the relationship of the dining table with mirrors (0.51%, 184 connections) and lamps (0.42%, 152 connections) reveals that the room is completed with lighting and aesthetic elements. It shows that a table-centered layout is common in dining rooms in Istanbul, and seating elements and objects necessary for table setting and decorative elements are positioned around it. The connections between objects support both functional and aesthetic usage scenarios.

Objects found in kitchens in Istanbul reveal the structural and functional characteristics of kitchen arrangements. According to the data, it is seen that the sink plays a central role in kitchen arrangement. The most frequently observed connections are the relationships between the kitchen cabinets and the sink (1.01%, 1,088 connections), the sink and the stove (0.91%, 985 connections), and the dishwasher (0.82%, 887 connections). These data show a usage area concentrated around the water source. The dishwasher, one of the most frequently used appliances in the kitchen, has a tight connection with both the sink and the kitchen cabinets (0.69%, 747 connections). In addition, the coffee machine has a high connection with the dishwasher (0.78%, 842 connections), the sink (0.70%, 754 connections), and the stove (0.45%, 491 connections).

The coffee machine also has connections with the toaster (0.48%, 517 connections), the microwave oven (0.41%, 444 connections), and the kettle (0.25%, 274 connections). This situation shows that a certain order has been formed for the preparation of coffee and hot drinks in the kitchen. The refrigerator is also a critical element in the kitchen, connected to the cabinets (0.63%, 678 connections), the sink (0.58%, 628 connections), and the dishwasher (0.60%, 647 connections). In addition, its relationship with the stove (0.46%, 492 connections) and the oven (0.33%, 357 connections) is also important in terms of the overall layout of the kitchen. The oven's connections with the sink (0.44%, 475 connections) and the stove (0.41%, 448 connections) indicate that the cooking area is arranged close to each other. The faucet is one of the elements most frequently associated with the sink (0.66%, 710 connections) and also has a high connection with the dishwasher (0.33%, 355 connections). This situation emphasizes how important water usage is in the kitchen. In the general layout of kitchens in Istanbul, the sink is seen to be in a central position, with basic elements such as the dishwasher, kitchen cabinets, and the stove positioned around it. The coffee machine and other small appliances also occupy a prominent place, indicating that the kitchen is optimized for both functionality and daily use.

When the most common furniture connections in the living room layout are examined, the strongest relationship is seen between the coffee table and the sofa. This connection was detected 5,832 times and occurred at a rate of 3.03%. This situation shows that it is a common preference to position the coffee table in front of or next to the sofa. The connection between the coffee table and the rug was detected 1,493 times and was at a level of 0.77%. Similarly, the relationship between the sofa and the rug was observed 1,478 times and was recorded at a rate of 0.76%. This shows that the rug is usually placed in harmony with the sofa and the coffee table in living rooms. The connection between the sofa and the curtains was detected 1,394 times and was measured at a rate of 0.72%. The relationship between the sofa and the television is at a level of 0.68% with 1,322 connections. This data indicates that there is a direct orientation between the sofa and the television in living rooms and that the curtains are usually located close to the sofa. There are 1,258 connections (0.65%) between the coffee table and the TV stand, and 1,249 connections (0.64%) between the coffee table and the TV stand. This shows that the TV stand and the coffee table are positioned close to each other in the living room. The connection between the sofa and the table was observed 1,253 times (0.65%), and the connection between the sofa and the TV stand was observed 1,150 times (0.59%). The connection between the sofa and the lamp was observed 1,142 times (0.59%). This data shows that the lighting in the living room is placed close to the sofa, and the seating areas are in close relation to the TV stand. The connection between the sofa and the sofa was observed 924 times (0.48%), and the connection between the coffee table and the chair was observed 745 times (0.38%). The connection between the armchair and the coffee table was detected 583 times (0.30%), indicating that there was more than one seating option in the living area. The connection between the couch and the painting was recorded 600 times (0.31%), and the relationship between the coffee table and the bookcase was recorded 589 times (0.31%). The connection between the air conditioner and the couch was detected 566 times (0.29%). The connection between the bookcase and the couch was observed 554 times (0.29%). The relationship between the television and the TV table was detected 537 times (0.28%), and the connection between the coffee table and the chandelier was detected 721 times (0.37%). In addition, the connection between the couch and the chandelier was observed 676 times (0.35%). The most common object relationships in the living room layout emphasize the strong connection between the couch and the coffee table. It is seen that the carpet, television, curtains, and lighting elements are also frequently repeated in this layout. It can be said that the arrangements that provide comfort and visual integrity in living rooms are shaped in light of this data.

There are 2,779 connections between the sink and the toilet, which accounts for 4.59% of all relationships. One of the strongest relationships in the bathroom is between these two elements. The mirror and the sink have a 3.74% relationship with 2,268 connections, which indicates that the mirror is usually positioned above the sink. The shower and the sink have a 2.24% relationship with 1,357 connections, while the shower and the toilet have a 2.23% relationship with 1,354 connections. This indicates that the sink and the toilet are positioned close to the shower in the bathroom. There are 1,351 connections between the mirror and the toilet, which accounts for 2.23%. The faucet and the sink have a strong relationship of 2.22% with 1,342 connections. The shower cabin and the toilet have 1,194 connections and a rate of 1.97%, which indicates that they are one of the elements that are frequently found together in the bathroom. There are 865 connections between the faucet and the mirror, which corresponds to a ratio of 1.43%. There are 685 connections between the sink and the soap dish, which corresponds to a relationship of 1.13%. There are 665 connections between the sink and the cabinet, which corresponds to a ratio of 1.09%. The faucet and the toilet are among the elements that are positioned close to each other with 634 connections, which corresponds to a ratio of 1.05%. The mirror has a relationship with the shower, which corresponds to a ratio of 0.99%, with 604 connections. The sink and the towel holder have a strong connection of 0.94%, with 570 connections. The faucet and the soap dish have a connection of 564, which corresponds to a ratio of 0.93%. There are 460 connections between the faucet and the shower, which corresponds to a ratio of 0.76%. The cabinet and the toilet have a positioning of 0.75%, with 453 connections. The mirror has a connection with the shower cabin, which corresponds to a ratio of 451, corresponding to a ratio of 0.74%. Similarly, the relationship between the mirror and the soap dish is at the level of 0.74% with 446 connections. The toilet and towel holder come together with 421 connections and 0.69%. The relationship between the cabinet and the mirror is at the level of 0.68% with 410 connections. The mirror is connected to the towel holder with 390 connections and 0.64%. The faucet and shower head are connected with 327 connections and 0.54%. The soap dish and toilet are connected with 313 connections and 0.52%. The sink and toilet paper holder are connected with 293 connections and 0.48%. The faucet and shower cabin show a relationship of 0.46% with 281 connections. The faucet and towel holder are connected with 273 connections and 0.45%. The faucet and shower head are connected with 261 connections and 0.43%. The sink and towels are connected with 240 connections and 0.40%. The bathtub and toilet have 238 connections and 0.39% close proximity. The toilet and trash can have 231 connections and 0.38%. Similarly, the mirror and toilet paper holder have 231 connections and 0.38%. The faucet and toilet paper holder have 219 connections and 0.36%. The sink and hair dryer have 215 connections and 0.35%. The shower and towel holder have 211 connections and 0.35%. The closet and shower have 207 connections and 0.34%. The toilet and towels have 199 connections and 0.33%. The bathtub and faucet have 198 connections and 0.33%. The toilet and washing machine have 191 connections and 0.32%. Finally, the closet and faucet have 191 connections and 0.32%.

The most frequent connections in the bedroom were between the bed and the nightstand, which was observed 3,098 times in total and represented 1.56%. The second strongest connection was between the bed and the lamp, which was observed 2,848 times and represented 1.43%. The connection between the bed and the pillow was found 2,364 times and represented 1.19%. The nightstand and lamp connection was also quite common, recorded 2,306 times, and represented 1.16%. The connection between the curtains and the bed was detected 1,941 times, corresponding to 0.98%. The headboard was also an important connection point, associated with bed 1,840 times and represented 0.93%. The connection between the headboard and the pillow was observed 1,432 times and represented 0.72%. The connection between the bed

and the window was recorded 1,370 times and represented 0.69%. The headboard and the nightstand were found 1,191 times and represented 0.60%. Similarly, the connection between the bed and the mirror was seen 1,189 times and was calculated as 0.60%. Other important elements in the bedroom include items such as carpets, curtains, chairs, wardrobes, and air conditioners. The connection between the bed and the carpet was found 923 times and was found as 0.46%. The connection between the bed and the wardrobe was found 899 times and was found as 0.45%. The connection between the curtain and the lamp was observed 879 times and was found as 0.44%. The connection between the curtains and the nightstand was recorded 852 times and was found as 0.43%. The connection between the curtains and the window was found 794 times and was found as 0.40%. Other important connections include bed and chair (736 connections, 0.37%), curtain and pillow (712 connections, 0.36%), double bed and nightstand (689 connections, 0.35%), air conditioner and bed (643 connections, 0.32%), and bed and table (627 connections, 0.32%). At the same time, relationships such as curtain and headboard (592 connections, 0.30%), bed and dresser (581 connections, 0.29%), and bed and table lamp (473 connections, 0.24%) were also observed at a significant level. In general, the strongest connections in the bedroom were established between the bed and the basic elements around it, which are the nightstand, lamp, pillow, and curtain. Second, connections with items such as windows, carpets, wardrobes, chairs, and dressers are noteworthy. Curtains, headboards, and lamps are also frequently associated with other elements and have an important place in the design of the room. The commonalities and differences between the objects in the rooms reveal the extent to which certain domestic behaviors are similar in various functional areas. The presence of objects such as "Guest Chairs" and "Table Sets," especially between the living and dining rooms, indicates that the use of these spaces together is common. The object-centeredness and integration patterns observed in houses in Istanbul provide important findings reflecting the social and cultural dynamics of the city. It is clear that a lifestyle focused on hospitality and socialization is a determining factor in interior design. These analyses provide important empirical data for future interior design and the evolution of urban life.

3.2. "Invisible" borders in domestic activities: the Istanbul example

Traditional domestic architecture has long relied on physical boundaries to define functional areas. However, contemporary housing arrangements in Istanbul show that these rigid distinctions are blurring. Rather than being defined solely by architectural elements such as walls and doors, room divisions increasingly emerge through clusters of objects and user interactions within domestic spaces. These "invisible" boundaries are particularly important in the context of urbanization and evolving housing designs, and shed light on the spatial organization of domestic life in Istanbul. The invisible boundaries are visualized in the room criterion based on objects in Figure 5.

Statistical analysis of domestic object relationships highlights the complex interplay between furniture and domestic activities. The dataset reveals that the most frequently co-located objects are "coffee table" and "sofa" (5,899 connections, 98.99%), "chair" and "table" (3,826 connections, 64.21%), and "bed" and "bedside table" (3,100 connections, 52.02%). These high-frequency matches highlight the spatial logic that governs household arrangements, reinforcing the idea that certain objects serve as spatial anchors around which domestic interactions revolve.

This phenomenon is particularly evident in the compact urban housing of Istanbul, where kitchens and bathrooms emerge as the most dynamically used areas. Although traditional living rooms and bedrooms maintain their structured arrangements, the fluid interaction of objects within kitchens and bathrooms suggests a high level of adaptability. For example, the connection between "sink" and "toilet" (2,789 connections, 46.81%), together with "mirror" and "sink" (2,295 connections, 38.52%), suggests that these areas support frequent and diverse activities. In addition, "tap" and "sink" (2,061 connections, 34.58%) further reinforce the centrality of the sink as a highly interactive area.

In contrast, living rooms, while still serving as social hubs, exhibit a different spatial usage pattern. The strong correlation between "sofa" and "carpet" (1,555 links, 26.09%), "sofa" and "curtains" (1,523 links, 25.56%) and "coffee table" and "carpet" (1,514 links, 25.41%) suggests that these objects contribute to defining the aesthetic and functional composition of the living space. The correlation between "sofa" and "TV" (1,379 links, 23.14%) further supports the idea that the television continues to be the focal point of social interactions in the home. Furthermore, the influence of cultural and technological changes can be observed in contemporary home organization. The presence of "bed" and "pillows" (2,371 links, 39.79%) and "headboard" and "pillows" (1,432 links, 24.03%) suggests an emphasis on comfort-oriented bedroom arrangements, in line with evolving preferences for personalized sleep environments. Additionally, the connection between "coffee table" and "TV stand" (1,261 connections, 21.16%) and "coffee table" and "curtains" (1,260 connections, 21.14%) demonstrates an effort to maintain consistency in living space arrangements despite the increasing flexibility of room functions.

The findings highlight the transformation of Istanbul's domestic spaces from rigid, room-based delineations to fluid, object-centered configurations. Although traditional spatial divisions persist, functional boundaries are increasingly dictated by object placement and interaction patterns. This evolution reflects broader sociocultural changes, technological advances, and the need for adaptability in urban housing. By examining these "invisible" boundaries, we gain valuable insights into the ongoing transformation of domestic life in Istanbul.

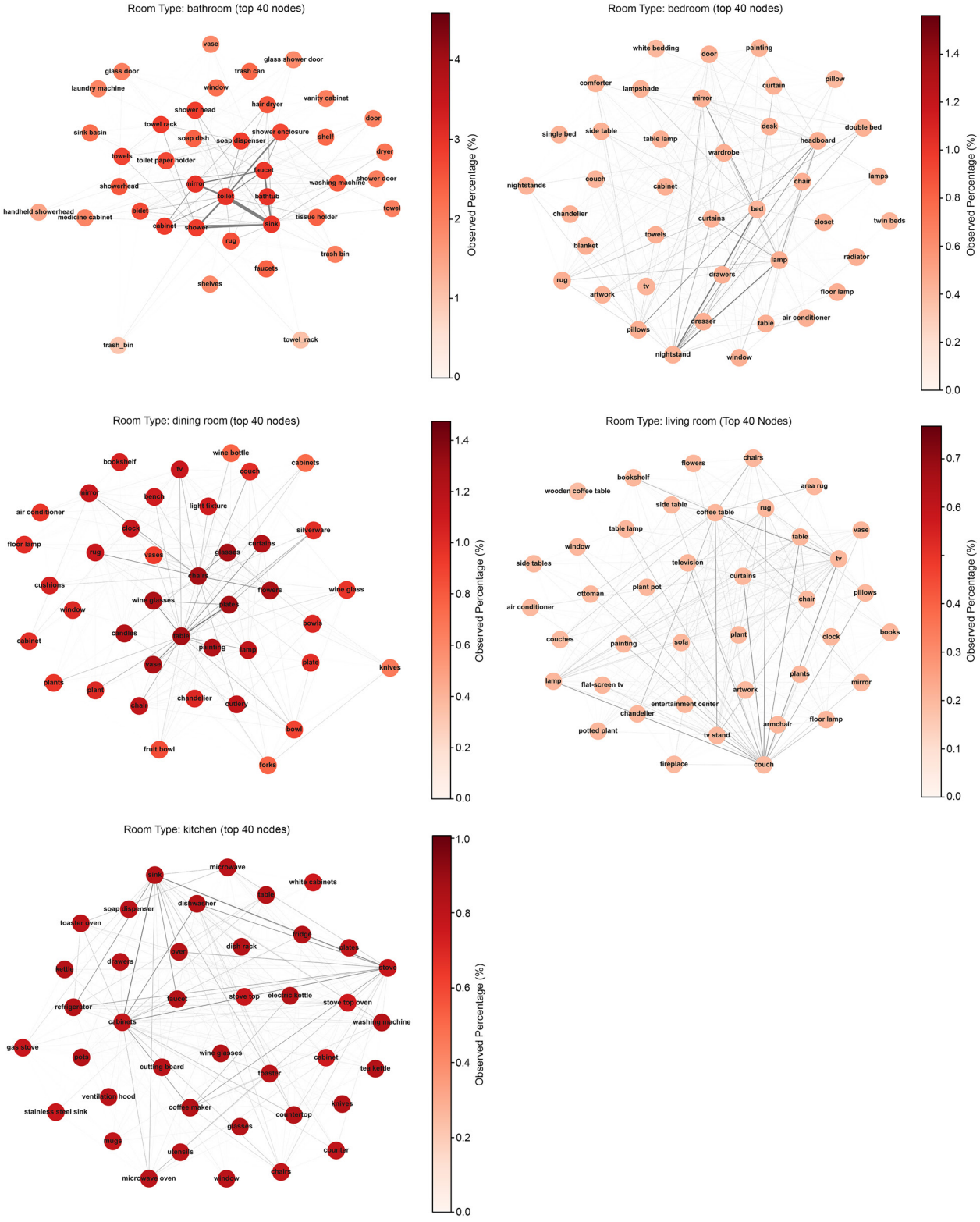
4. Conclusion

This study reveals the sociocultural and functional aspects of home interior arrangements by evaluating different room types in residences in Istanbul through object connections. The statistical data obtained within the scope of the research show that the connections between objects in basic living spaces, such as the dining room, kitchen, living room, bathroom, and bedroom, play an important role in spatial integration and shaping daily life activities. In dining rooms, the 6.83% connection between the dining table and chairs (2,487 connections) shows that it functions as the central element of the room, while the plates, flowers, vases, candlesticks, and other decorative elements around the table increase the aesthetic value of the room. This situation shows that dining rooms have a balanced arrangement in both practical and visual terms.

In the kitchen area, the relationships established by the sink with kitchen cabinets (1.01%, 1,088 connections), the stove (0.91%, 985 connections), and the dishwasher (0.82%, 887 connections) indicate that water use and food preparation processes are at the center. In addition, the connections formed by devices such as coffee machines, toasters, microwave ovens, and kettles show that functionality and practicality are evaluated together in the kitchen. This data clearly shows that the sink in the kitchen responds to the daily needs of the household as a central element and increases the ease of use of the area.

In the living room arrangements, the most obvious interaction is seen with 5,832 connections (3.03%) observed between the coffee table and the sofa. In addition, the connections between the sofa and elements such as carpets, curtains, televisions, tables, and lamps indicate that the seating area is organized based on comfort and aesthetic integrity.

Figure 5
Objects used based on room types



The obtained data reveal that living rooms depend on the harmonious placement of objects in supporting social interaction and functioning as a resting area.

In the bathroom, 2,779 connections (4.59%) between the sink and the toilet, and 2,268 connections (3.74%) between the mirror and the sink are among the strong relationships. The connections formed by other elements, such as showers, faucets, and soap dishes, show that cleanliness, hygiene, and ease of use are prioritized in bathrooms. These statistics prove that bathroom areas are optimized with functional and spatial arrangements that suit user needs.

In the bedroom, the most common connection was determined as 3,098 connections (1.56%) between the bed and the nightstand. The 2,848 connections (1.43%) between the bed and the lamp and the 2,364 connections (1.19%) between the bed and the pillow show that individuals organize their sleeping areas in line with their comfort and lighting needs. These findings reveal that the harmony between objects in the bedroom is decisive in optimizing personal space.

In addition, the study shows that the concept of "invisible boundaries" in domestic activities is defined through object clusters and user interactions rather than traditional physical boundaries. In Istanbul, spatial organization has gained flexible, fluid structures under the influence of factors such as cultural values, hospitality, and social interaction, and this situation has provided important empirical data for future interior design. All these data obtained clearly show that domestic arrangements in Istanbul constitute an integrated system in both functional and aesthetic terms and provide valuable clues about the evolution of urban life. These results show that home interiors in Istanbul have evolved based not only on mechanical layout but also on the social and cultural expectations of users. The analyzed statistics highlight the importance of integrated approaches in modern housing designs by revealing the unique functionality and aesthetic order of each room. These findings also shed light on future research, indicating that home interior design will become more dynamic and user-centered. As a result, home life is taking shape.

The applied method also allows the examination of different spaces, such as workplaces and public areas. In addition, it has been demonstrated that visual-based LLMs can be evaluated as an effective and powerful tool in various studies on interior spaces by using different prompts.

Conflicts of Interest

The author declares that he has no conflicts of interest to this work.

Data Availability Statement

Data are available on request from the corresponding author upon reasonable request.

Author Contribution Statement

Mansur Beştaş: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration.

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