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DATA IMPACT IN URBAN PRACTICE: INSIGHTS OF KAYSERİ TRAM NETWORK

M.Sc. THESIS

SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE
AND THE GRADUATE SCHOOL OF ENGINEERING AND SCIENCE
OF ABDULLAH GUL UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE

By

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SCIENTIFIC ETHICS COMPLIANCE

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

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M.Sc. thesis titled Data Impact in Urban Practice: Insights of Kayseri Tram Network has been prepared in accordance with the Thesis Writing Guidelines of the Abdullah Gül University, Graduate School of Engineering & Science.

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ABSTRACT

DATA IMPACT IN URBAN PRACTICE: INSIGHTS OF KAYSERİ TRAM NETWORK

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May 2025

This thesis investigates how data-driven analysis tools can assess and improve urban quality through public transport infrastructure, focusing on the Kayseri light rail system in Kayseri. The study aims to develop a holistic design framework at the human scale by combining GIS-based spatial analyses, crowd flow (CFD) simulations, and passenger data visualizations. At the core of the analysis are three complementary urban characteristics -accessibility, visibility, and vitality- measured using data-driven techniques and supported by spatial and experiential assessments.

The four selected stations -Düvenönü, Cumhuriyet Meydanı, Hunat Hatun, and Büyükşehir Belediyesi- are examined in detail, spatial inefficiencies and access gaps are identified, and strategies to address these deficiencies are proposed. The methodological approach combines technical tools with on-site observations to provide a comprehensive view of the interaction of urban mobility systems with the physical environment. Furthermore, data constraints and contextual limitations are addressed, and the importance of local infrastructure and institutional collaboration is emphasized.

The findings provide applicable solutions for architects and planners by revealing inefficiencies in pedestrian flow, accessibility gaps, and ways to increase urban vitality. The thesis contributes to both academic literature and practical urban design processes by demonstrating the potential of data-driven methods in creating sustainable, inclusive, and optimized urban environments; thus, bridging the global smart city paradigm with local urban realities and providing a strategic roadmap aligned with the UN Sustainable Development Goals.

Keywords: Urban quality, Data-Driven Design, Smart Cities, Public Transportation, Sustainable Urban Planning

ÖZET

KENT PRATIĞİNDE VERİ ETKİSİ: KAYSERİ TRAMVAY AĞI OKUMASI

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Bu tez, Kayseri’deki KayseRay hafif raylı sistemi odağında, veri temelli analiz araçlarının kentsel kaliteyi toplu taşıma altyapısı üzerinden nasıl değerlendirebileceğini ve iyileştirebileceğini araştırır. Çalışma, CBS tabanlı mekânsal analizler, yaya akışı (CFD) simülasyonları ve yolcu verisi görselleştirmelerini bir araya getirerek insan ölçeğinde, bütüncül bir tasarım çerçevesi geliştirmeyi amaçlamaktadır. Analizin merkezinde birbirini tamamlayan üç temel kentsel karakteristik- erişilebilirlik- görünürlük, ve canlılık- bulunur; bu boyutlar, veri odaklı tekniklerle ölçülerek mekânsal ve deneyimsel değerlendirmelerle desteklenir.

Seçilen dört istasyon -Düvenönü, Cumhuriyet Meydanı, Hunat Hatun ve Büyükşehir Belediyesi- ayrıntılı biçimde incelenmiş, mekânsal verimsizlikler ile erişim boşlukları tespit edilmiş ve bu eksikleri gidermeye yönelik stratejiler önerilmiştir. Yöntemsel yaklaşım, teknik araçları yerinde gözlemlerle harmanlayarak kentsel hareketlilik sistemlerinin fiziksel çevreyle etkileşimine dair kapsamlı bir bakış sunar. Ayrıca, veri kısıtları ve bağlamsal sınırlamalar ele alınarak yerel altyapı ve kurumsal iş birliğinin önemi vurgulanmıştır.

Elde edilen bulgular, yaya akışındaki verimsizlikleri, erişilebilirlik eksikliklerini ve kentsel canlılığı artırma yollarını ortaya koyarak mimarlar ve planlamacılar için uygulanabilir çözümler sunar. Tez, veri temelli yöntemlerin sürdürülebilir, kapsayıcı ve optimize edilmiş kent ortamları yaratmadaki potansiyelini göstererek hem akademik literatüre hem de pratik kentsel tasarım süreçlerine katkıda bulunur; böylece küresel akıllı şehir paradigması ile yerel kentsel gerçeklikler arasında köprü kurar ve BM Sürdürülebilir Kalkınma Hedeflerine uyumlu stratejik bir yol haritası sunar.

Anahtar kelimeler: Kent Kalitesi, Veri Odaklı Tasarım, Akıllı Şehirler, Toplu Taşıma, Sürdürülebilir Kentsel Planlama

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LIST OF ABBREVIATIONS

API	Application Programming Interface
CFD	Computational Fluid Dynamics
GIS	Geographic Information System
ICT	Information and Connection Technology
IOT	Internet of Things
ITS	Intelligent Transportation System
SHP	Shapefile (commonly used format in GIS)



Chapter 1

Introduction

The importance of data analysis is increasing. The increase in the variety of digital tools, the Internet of Things (IoT), and similar appliances significantly contribute to creating smart cities. Studies focusing on humans show that data analysis has powerful outputs. A comparable situation is valid for the fields of cities and architecture. The features of the city areas with heavy pedestrian traffic, landmarks, etc., can be easily observed through smart urban applications prepared with the help of digital data. However, deeper insights can be gained with the help of studies on urban dynamics. The limits of the data that can be obtained from the city, which urban data is used, and which combinations are important for the results to be obtained (Tunçer, 2020). Electronic sources provide the majority of the big data obtained from the city, and experts from various engineering branches are conducting many studies on this point (Ibrahim et al., 2020). On the other hand, the limited common points of the obtained data and the data from traditional analysis techniques prevent the widespread use of the relevant data in urban design and architectural design. Therefore, when studies on big data are examined, the literature on design and data still needs to be developed. In addition, as seen in the literature review conducted by Akdamar (2017) targeting the master's thesis on using big data and smart cities in Turkey, the number of urban studies focused on big data is limited. This study will contribute to literature by including a bibliographic literature review and application on how big data can be used to analyze cities.

The use of big data is positioned at a critical point regarding urban sustainability. Although migration from rural to urban areas in Turkey has slowed, migration between cities remains significant (TÜİK, 2023). Due to this phenomenon, our cities with high populations continue to develop and overgrow. At this point, the use of data from new technologies for the efficient evaluation of the resources of cities and their optimization in every aspect has the potential to contribute significantly to the sustainability of cities (Bibri, 2018).

Kayseri, a metropolitan city with high trade, industry, and tourism potential, serves as the case study for this research. The city's development level was assessed as higher than its neighboring provinces (Acar et al., 2019). For this reason, it receives migration,

especially from neighboring provinces, and continuously expands the city borders. However, it has the feature of being a city whose planning has been made since the early years of the Turkish Republic (Kocatürk & Yılmaz Bakır, 2013). The study needs to be conducted to have a large data pool of the city. In this regard, Kayseri Büyükşehir Belediyesi (Kayseri Metropolitan Municipality) and central district municipalities maintain and upgrade GIS systems, smart city applications, transportation applications, and infrastructure data to document the city digitally. These features, which were developed to become a smart city, are considered big data (Gürsoy, 2019). In addition to these specific features, Kayseri is one of Türkiye's important metropolises in terms of population size and urbanization rate.

Bibliometric Review and Positioning in Literature: In the last five years, nearly 3700 academic publications containing the concept of “data-driven design” were obtained from the Web of Science database and keyword concurrency analysis was performed. In this analysis created through the VOSviewer software, only keywords with more than 50 repetitions were evaluated and four basic clusters based on conceptual relationships were obtained.

The red cluster represents the technical dimension of data-driven approaches, namely artificial intelligence-supported modeling, system simulations and performance analyses, by gathering around concepts such as “model”, “machine learning”, “simulation”, “performance”, “prediction”(Figure 1.1). The green cluster, on the other hand, reveals the structural transformation of cities and the connection of spatial effects related to data with planning with concepts such as “impact”, “city”, “urbanization”, “climate change”, “dynamics”. While the blue cluster is shaped by governance and smart city concepts such as “policy”, “management”, “smart city”, “big data”; The yellow cluster focuses on human-centered quality of life criteria such as “sustainability”, “behavior”, “health”, and “quality”.

While these thematic clusters reveal the reflections and methodological diversity of data-driven design in different disciplines, it is striking that the term “data-driven” is included in the visual in a relatively small size and with limited connections. This situation shows that the concept is used directly in literature at a low rate but is indirectly associated with many different technical and theoretical fields.

This thesis aims to provide a new context by associating the concept of data-driven design, which is mostly addressed within the framework of modeling, performance and big data techniques in existing literature, with human-centered urban quality components

Within this scope, this study's main purpose is to seek an answer to the question, **‘How can data-based analysis be used to improve the quality of urban life?’**. In line with this purpose, it primarily aims to conduct bibliographic research and evaluate local and international data-driven urban mobility analysis methods. In addition to this question, five sub-questions have been included to deepen the research. (Table 1.1)

First, the answer to the sub-question ‘How can key urban quality dimensions be measured and evaluated using data-driven tools?’ will be sought. Although it is generally parallel to the main question, it will help to reach more specific results for analysis and evaluation methods.

The secondary auxiliary question is, ‘How can data-driven tools and analyses enhance the design and evaluation of urban environments focusing on urban quality?’ At this point, research will be conducted to analyze the city's characteristics within the concept of data-driven analysis methods.

The other sub-question is, “What are the specific data metrics and tools most suitable for analyzing urban features?” In addition to scanning local and international resources, research will be conducted on the analyses that have already been conducted or are possible to be conducted in the target region, Kayseri. The data sets accessible for the city of Kayseri will be classified, and how studies can be created will be determined by considering urban characteristics.

Two case study centered questions which are ‘How do the selected KayseRay tram stops perform in terms of accessibility, visibility, and vitality?’ and ‘What insights from the KayseRay tram network study can inform broader urban design strategies in data-driven evaluation?’ Which will seek results for the selected public transportation system and city dynamics relation to clarify the relationship between these components.

Table 1.1 Research Framework: Questions, Objectives, and Assumptions

Research Questions	Research Objectives	Research Assumptions
How can key urban design characteristics be measured and evaluated using data-driven tools?	Establishing measurable indicators and methods for evaluating urban design characteristics.	Well-measured characteristics can bridge the gap between theoretical urban concepts and practical applications.
How can data-driven tools and analyses enhance the design and evaluation of urban environments focusing on urban quality around rail systems?	Exploring the role of data-driven tools in addressing key urban characteristics and improving urban design.	Data-driven analyses can identify urban characteristics more objectively, enabling more effective design decisions.
What are the specific data metrics and tools most suitable for analyzing urban features?	Identifying measurable indicators and tools for each characteristic to provide actionable insights for urban design.	Human scale, visibility, accessibility, and vitality are measurable through objective data and systematic analysis.
How do the selected KayseRay tram stops perform in terms of visibility, accessibility, and vitality?	Evaluating the current urban design performance of selected KayseRay tram stops using the identified metrics and tools.	Public transportation hubs significantly shape urban environments, influencing accessibility, human interaction, and economic activity. Well-designed stations enhance the vitality of adjacent areas, improve pedestrian spaces, and boost urban connectivity, contributing to sustainable, vibrant city life.
What insights from the KayseRay tram network case study can inform broader urban design strategies in data-driven evaluation?	Providing recommendations for urban design practices based on the KayseRay tram network analysis.	The KayseRay tram system case study identifies key urban design principles, particularly in accessibility, human scale, and vitality. These principles, once adapted, can be applied to other cities to improve public transport systems and foster more sustainable, human-centered urban environments.

In the case study, the analysis techniques reached will be applied in a framework to Kayseri City's Tram System, and the presentation of the results within the scope of the study will be provided. The boundaries of the study to be conducted in this section will be determined by the characteristics of the data infrastructure to be used for the analysis. The methods and outputs of the techniques applied to understand the dynamics of the city will be given in detail within the scope of the thesis.

This study will emphasize the importance of data analysis and investigate the potential of using this data in urban areas. The critical role of data analysis in creating smart cities and the purpose of this study are explained in detail. Focusing on a city with a prominent level of development and constant growth, such as Kayseri, will help explore big data's role in sustainable urban mobility. The study seeks an answer to. The study seeks an answer to enhancing urban mobility through data-driven methods.

In this context, a literature review aims to address technological infrastructure, urban mobility evaluation, and methodological approaches. In the later stages of the study, Kayseri tram system analysis results will be presented comprehensively. This study is expected to significantly contribute to the scientific literature in this field through its focus on data-driven urban strategies.

The main purpose of this study is to investigate the use of data-based analyses to improve the quality of urban spaces. A literature review and data-driven urban quality analyses at local and international levels. In addition, the study's objectives include examining data analysis methods and techniques in urban areas and determining their integration potential into urban design.

The ability to analyze cities efficiently is important for urban sustainability. Some studies analyze existing conditions with data-driven analysis techniques, solve the problems in urban social and physical structures, and predict how the city can adapt to future challenges. Within existing research, this study aims to compile data-driven analysis methods by addressing mobility problems in the city and presenting a Kayseri-based analysis.

Briefly, the main purpose of this master's thesis can be listed as follows,

- Investigating the impact of data-driven techniques on urban quality
- Conducting and evaluating bibliographic research of data-driven urban practice globally and locally
- Determining appropriate methods for data infrastructure analysis
- Examining Kayseri's urban challenges and propose solutions
- Evaluating optimization opportunities in urban systems

In this study, a variety of methods will explore how data-driven enhance urban quality. A literature review and evaluation of local and international research will form the foundation of this process.

The section on data infrastructure analysis will explore various analysis and evaluation methods. In addition, the academic background information to be created for the Kayseri example will be revealed in this review.

Finally, a methodological review will ensure the study aligns with its goals. By integrating architectural principles with smart city technologies, this study will bridge existing gaps in research.

With the growing interest in smart cities, many stakeholders, including local authorities, have begun to adopt information and communication technologies (ICT) to improve urban operations, such as public transportation, traffic management, and infrastructure efficiency (Papa et al., 2013). However, most of these studies are centered around technological and engineering optimizations, which focus on improving cities' operational efficiency without taking a holistic view of urban spaces.

While such optimizations are valuable, they often overlook the critical role of urban form, spatial design, and the human experience within the city. The absence of architectural insight results in fragmented solutions that may optimize specific systems (e.g., traffic flow or energy use) but fail to address how the built environment influences social behavior, civic engagement, or quality of life.

This research addresses this gap by approaching smart city development through an architectural lens. By integrating architectural principles with smart city technologies, this study will provide a more comprehensive understanding of urban dynamics and propose solutions that enhance the efficiency, livability, and spatial quality of urban environments.

This study aims to make an original contribution to the literature on urban planning and design by emphasizing the importance of using big data and data analytics in urban areas. It will investigate how big data analytics can be used to create sustainable urban mobility systems, smart cities, and the increased sustainability of cities. It will also present suggestions for increasing knowledge in this field. In addition, it is expected that the analyses conducted on an advanced city such as Kayseri will show its applicability in similar urban environments, thus making the original contributions of the study even more apparent.

This study proposes an original conceptual framework consisting of three basic dimensions, visibility, accessibility and vitality, for the purpose of assessing urban quality. Although these concepts are not usually defined together, they have their roots in the works of researchers Jane Jacobs, Jan Gehl and William Whyte, who emphasize the

principles of human-scale, inclusive and socially vibrant urban environments. In line with this theoretical background, a holistic assessment model is constructed in the thesis through data-driven tools such as GIS-based spatial analysis and crowd simulation. While the theoretical content of these dimensions is explained in the second section, the following sections reveal how these concepts are operationalized through the Kayseri tram system. Thus, the study aims to establish a measurable and structured link between abstract urban quality concepts and applied analysis.



Chapter 2

Dimensions of Urban Complexity

In the past decade, we have lived in cities that are still developing worldwide. This creates unique optimization problems for each. One of the crucial problems is not being able to move from one place to another. Now, mobility is deeply connected to income, public transport infrastructure, local government, highways, culture, and many other dynamics. When all the variables come together, they create unique congestion and mobility problems. Each city tries to solve its problems by taking different actions. Furthermore, congestion is the most prominent problem for personal vehicle users. This is occurring due to the increasing number of cars in traffic, highlighted by the extensive use of main arteries. Yet, it is not the only way people can travel, public transport is another means of mobility in the cities.

Public transport generally covers different vehicles, such as buses, trains, trams, ferries, or subways, that companies or governmental authorities can control. It is the primary choice for many people to move to most cities. They are usually designed to connect different city elements, such as residential areas, business districts, etc. It can also help reduce the number of car users and decrease traffic congestion. Also, public transportation has higher sustainability than private vehicle uses (Papa et al., 2013).

On the other hand, public transport has its problems. In most of the city layouts, public transportation systems follow the city's main arteries. This contributes to the congestion problem as it increases the load of the limited circulation capacity. Furthermore, its users are limited to the city's main arteries because the walking range is lower than that of vehicle users. At this point, policy-making is critical because the ability to add lines outside the main arteries is in the hands of the authorities (Gakenheimer, 1999).

Developing countries have a high rate of increase in the city sizes. This growth causes cities to change quickly and requires adaptation to an increased number of people. They might try to solve their problems by importing solutions from developed countries. Yet, they might not work as efficiently in the developing city. This can have many causes. Every city has a unique topography and layout, making it harder for other solutions to be

applied to the target city because cities have unique features like fingerprints (Gakenheimer,1999). Secondly, there can be differences in the hierarchical approach to the city. There are different authorities in terms of city policies and operations. There can be systems in which the central government has more power. There can also be some systems that are mostly ruled by local authorities. The city's position on this power balance can affect the success of the applied solution. Another criterion is the participatory approach. People all around the world have different attitudes towards participatory policies and expectations, it is hard to import a solution from a participatory city system to a non-participatory city system. Another significant factor is qualified human sources. In a natural process of improving city conditions, experts try to learn from their mistakes and adapt the solution to the city by trial and error. This allows architects, engineers, governors, and all other shareholders to learn knowledge and they do not repeat similar mistakes. On the other hand, when a solution is directly imported from another example civics do not have the required skills to foresee the potential problems and flaws.

The dimensions of urban complexity address distinct but interconnected challenges in contemporary cities. The human dimension emphasizes creating inclusive and accessible spaces that prioritize the needs of individuals and communities. Urban density builds on this by advocating for compact and efficient spatial arrangements that foster vibrant urban environments. A climate-responsive urban environment adds another layer, integrating sustainability and resilience to address environmental challenges while enhancing urban comfort. Finally, vitality ties these elements together by focusing on the creation of dynamic, active spaces that promote social interaction and community engagement. Together, these dimensions form a comprehensive framework for understanding and addressing the multilayered challenges of urban growth and development.

In the study conducted by (Speranza, 2017) over 15,000 social interaction observations were collected via mobile devices in approximately 50 public spaces within the superblocks in Barcelona, and these data were integrated with spatial layers such as sidewalk networks and urban facilities in a GIS (Geographic Information Systems) environment. The evaluation of spatial data together with qualitative indicators (type of activity, group size, etc.) and visualization with parametric tools revealed that pedestrian priority areas significantly increase the functionality of public spaces and the level of social interaction. This approach offers an alternative method to traditional urban analysis

tools (e.g., Space Syntax or classical survey techniques) by showing how human-scale qualities can be measured with innovative data collection methods.

In this thesis, a similar methodological framework was adopted, and the accessibility, liveliness and visibility levels of tram stop environments in Kayseri were evaluated. By bringing together observations and spatial analyses obtained from the field in a GIS environment, patterns that contribute to a human-centered and data-based urban design approach have been revealed.

Singapore is one of the pioneering cities where data-driven urban design practices are used in an integrated manner. Studies carried out on smart transportation systems, pedestrian mobility and microclimate regulations in particular both increase the efficiency of public services and enable human-centered design decisions to be based on objective data (O. L. Lee et al., 2019) revealed that Singapore manages its transportation systems with a “System-of-Systems” approach and within this framework, real-time traffic, public transportation and pedestrian data are integrated and included in urban decision-making processes. This approach aims to support not only a technical infrastructure but also governance and design with data in a holistic manner.

On the other hand, the “thermal affordance” model developed by Yang et al. (2024) enables the evaluation of public open spaces in Singapore based on parameters such as temperature, shading and pedestrian comfort. By combining field observations, street images and microclimate data, it has been possible to evaluate pedestrian routes not only in terms of physical accessibility but also climatic comfort. Such models contribute to the integration of elements that directly affect pedestrian mobility, especially in tropical climates, into the design.

These approaches constitute an example in the evaluation of the qualities such as accessibility, liveliness and human scale of the Kayseri tram stop environments examined within the scope of the thesis. Although they differ in terms of climatic and technological infrastructures, as in the Singapore example, combining field data with GIS-based analyses enables urban design to be reshaped based on user experience. This points to a holistic design approach where not only spatial arrangements but also user needs and environmental conditions are considered together.

Cities are not just buildings, roads or infrastructures; what makes them complex and livable are the human relationships, experiences and social interactions that develop within and around these physical structures. Therefore, when trying to understand cities, not only spatial analyses but also human-centered design principles should be considered.

Elements such as how people move around the city, how they use public spaces and how they live their daily lives are the basic factors that determine how livable a city is. In this context, three basic dimensions that help us understand the urban experience more closely stand out: human scale, visibility and livability. These concepts examine the relationship of individuals with the city from different perspectives and reveal the basic approaches that should be considered in urban design. First, we will focus on how cities can be shaped with an individual-centered approach through the human scale.

2.1 Human Dimension

Cities have grown rapidly, especially in the last hundred years. In this period, the human scale lost importance, and growing cities became less accessible. Physical setup for most cities evolved from interrelated design to individual building designs by dismissing the relations, public spaces, and pedestrians (Gehl, 2010). This issue leads many cities to be unable to meet with previous functions such as being the main space of meeting or being walkable.

Being at the human scale is crucial: Prioritizing pedestrian movement, having different functions in short distances, having short blocks, having dense urban environments, and hosting buildings from different periods are key elements to having a vibrant city (Degen & Rose, 2012; Jacobs, 1961).

Over the years, the rise of vehicular dependency has drastically shifted urban design priorities, impacting accessibility and mobility patterns in cities worldwide. As the importance of the human scale diminished, cars began to dominate urban landscapes, reshaping cities to accommodate vehicular traffic at the expense of walkability and human-centered design. This transition underscores the complex relationship between growing cities and evolving transportation needs (Xu, 2019).

With the scale of the city upgrading, people have become more dependent on vehicles, especially cars. Due to the limits of walking distance, which are between 800 m and 1200 m on average (Spooner, 2011), prioritizing car traffic has been perceived as a solution to make cities more accessible. However, it has affected the design principles of the cities, causing more dense and inaccessible city layouts.

In terms of the use of cars in city centers, various approaches have been used in various parts of the world, and some of the drastic ones will be mentioned in this part. With the increase of modern perspectives on the urbanization of cities and technological

improvements, the demand for mobility has increased even more. However, the characteristics of the American cities were seen as the main obstacle to achieving access to limitless mobility. A few different approaches were created in the US. Some of the population has moved to the suburbs to meet the need for mobility. The other way for the city to stop being an obstacle. For example, in New York, some city villages have been destroyed to create freeways. Similar approaches were also chosen to be used in Los Angeles, California. As another example, the city of Brasilia has been designed by prioritizing vehicle use, causing the city to struggle to travel on foot and forcing users to use public transportation to access daily needs (Hubbard, 2017).

On the other hand, due to car invasions and traffic problems in city life, reverse approaches were discussed in the second half of the 20th century. More cars will enter the equation in many big cities when more roads are built to solve the traffic problems. Another solution was to decrease the capacity of the roads. This approach has led to a decrease in traffic jams in many cities. There can be different changes for different arteries that can get tight, and some can be close to car traffic entirely (Figure 2.1).



Figure 2.1 Left: Amagertorv, Copenhagen, view from the south, 1953. Right: Amagertorv, Copenhagen, same view, 2013. (Source: Gehl, J., & Svarre, B. (2013). *How To Study Public Life*. Island Press/Center for Resource Economics. <https://doi.org/10.5822/978-1-61091-525-0>)

This shift highlights the importance of prioritizing alternative forms of mobility, such as walking and cycling, which promote sustainability and safety. The introduction of these changes reflects a broader effort to restore human-centric urban designs, emphasizing the balance between transportation efficiency and livability (Degen & Rose, 2012).

A decrease in the number of cars in civic areas leads to increased pedestrian mobility, cycling, and public transportation. In Copenhagen, this trend can be seen clearly after the measures of limiting traffic cycling activities have doubled (Gehl, 2010). Also,

people tend to spend more time in public areas as they walk and focus more on staying in activities (Whyte, 1980). These results emphasize that prioritizing human activities can help cities regain their human scale.

Human activities can be classified with various criteria and qualities. One of those classifications is the quality of the physical environment (Figure 2.2) of Gehl (2010). Activity types can be classified under three sub-categories. Necessary activities include activities in all conditions such as going to work, delivering goods, and walking to school. However, optional activities cover a variety of activities that occur only under good conditions. Stopping to watch the view, enjoying the weather or a walk to the promenade can be included in this category (Degen & Rose, 2012). Necessary activities do not significantly affect the quality of space. On the other hand, their attendance at the optional activities is significantly higher under the conditions of good physical environment quality (Lu et al., 2018). These staying activities are important to maintain a lively city life. Some applications like pedestrianizing streets can increase the vitality of the cities. These applications increase the usable space of the cities and allow people to have space to stay, walk, and socialize. The third activity type is social activities. Meeting with friends, children playing in parks, and people having small talk at bus stops can be included in this category. Those gatherings turn the city into a meeting space.

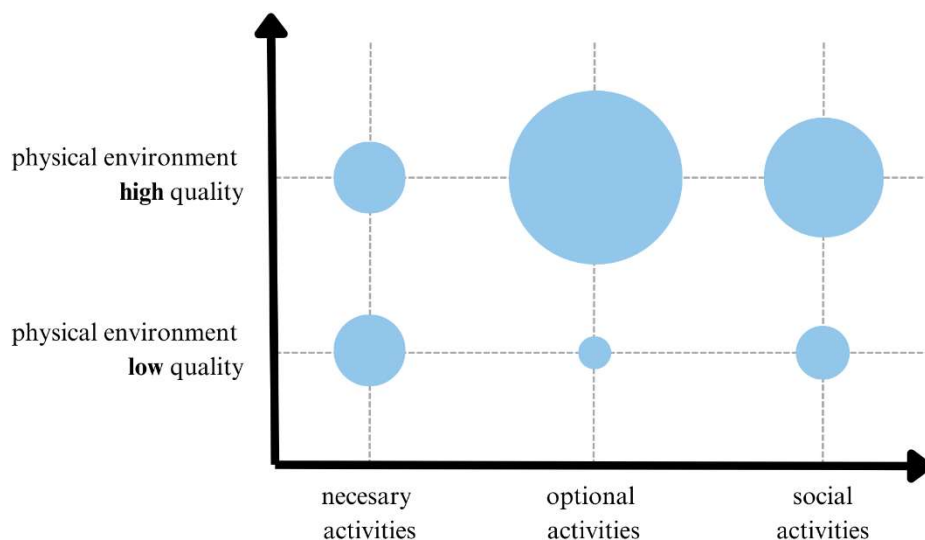


Figure 2.2 Quality of physical environment (Source: Adapted from Gehl, J. (2010). *Cities for people*, p. [21]. Island Press)

Urban density is vital in creating vibrant, functional cities by allowing social interactions, efficient land use, and inclusive public spaces. Density and human scale are closely related to social and interactive public spaces. Dense urban areas encourage people to walk, cycle, and use public transport for shorter distances. Furthermore, the density level should not be as high to cause overcrowding (Gehl, 2010; Jackson, 2003).

In dense urban areas, various functions are more likely to occur such as markets, plazas, and promenading behaviors. This trend enhances the possibility of living, working and socializing in a small area. Functional density also supports civic activity as it causes people to have things to do like shopping, etc. These compact spaces also support staying activities like watching street performers and sitting in cafes (Gehl, 2010; Montgomery, 1998).

Hall (1966) also supports that moderate density improves human comfort. Furthermore, density can cause problematic outcomes for humans by causing cultural and physical effects. Humans can experience stress and territorial behaviors. Overcrowding can cause people to stay away from social interactions. This behavior can cause a decrease in the quality of life. There should be zoning and crowd management strategies to control the populational issues.

Another factor to be considered is the culture. Bearable density for communities can differ. Rural areas tend to have different scales to the density compared to the perception of the people who live in metropolitan areas. Personal space is also important to understand how people navigate dense urban areas (Hall, 1966).

Climate is one of the critical dimensions to be considered in design. In urban planning practice, strategies should be developed to address climatic challenges, such as the formation of heat islands, energy efficiency, and sustainability goals. Integration of green elements can help with the heat islands as it helps control microclimatic heat problems (Gehl, 2010).

Furthermore, machine learning can help with the climatic models for the urban environment. With those technologies wind flows, heat islands, and other climatic outcomes can be considered to be used in data-driven urban planning (Zuo et al., 2023). Cities should be designed considering the need for ventilation, thermal comfort, shading, and civic health.

2.2 Visibility

Visibility, especially spatial perception of the urban environment, wayfinding, safety and comfort, has a critical importance on these experiences. How people perceive the city and behave accordingly is significantly related to their visual perceptions. Moreover, this situation is addressed within both spatial synthesis theory and urban legibility discussions. The basic urban elements defined by Lynch (1960)—roads, borders, regions, nodes and symbolic structures—are primarily perceived visually and take their place in mental maps. Therefore, visibility is not only a part of the physical order but also the basis of the individual's cognitive relationship with the environment. Visually clear and consistent spaces facilitate intuitive movement, encourage social interaction and strengthen the sense of security. Urban morphology is one of the most decisive elements of visibility. Street texture, building alignment and block scales directly affect what people see and how they move. Areas with high visual transparency are generally more walkable, livelier, and safer. Well-aligned streets and transparent facades increase user comfort and support daily control mechanisms (Carmona, 2021). In contrast, interruptions in sightlines and weakening of structural continuity lead to spatial confusion. It can cause psychological discomfort and a feeling of isolation.

One of the first theoretical approaches to measuring and analyzing visibility is the *isovist* concept defined by (Benedikt, 1979). Isovist covers the entire area that can be seen from an observation point, and the degree of spatial openness and closure can be determined by measurements of this area such as surface, perimeter, and radial variance. Extending this approach, Turner, Doxa, O'Sullivan, and Penn (2001) developed Visibility Graph Analysis (VGA) by modeling the space as a network of points that can see each other. With this analysis method, the visual continuity and complexity of the spatial structure can be evaluated by calculating measures based on network theory such as integration, average depth, and clustering coefficient.

Today, thanks to the advances in computational technologies, visibility analyses are not limited to just two-dimensional plans. New tools such as 3D spatial synthesis and Virtual Geographic Environments (VGE) offer the opportunity to analyze the effects of height, slope and multi-layered structures on visibility. In this context, the 3D embedded isovist method developed by Krukar, Gallaher and Roberts (2021) allows for a more realistic modeling of how space is perceived volumetrically by separating horizontal and vertical fields of view. In particular, elements such as ceiling height, sense of space and

vertical restrictions can be measured more accurately with this method. In this study, visibility was analyzed with a multi-layered and data-based method. First, viewshed maps were produced in a GIS environment (e.g., ArcGIS) using Digital Elevation Models (DEM) including structures and terrain slope, and visual access to the selected observation points was evaluated. To perform the visibility analysis, firstly, observation points were placed at 2-meter intervals and isovist polygons were created from these points. Basic spatial measures such as area, perimeter and average depth were calculated for each isovist using DepthmapX software (Benedikt, 1979; Turner et al., 2001). Then, in order to evaluate the volumetric dimension of visual perception, three-dimensional isovist indicators such as vertical-horizontal and upper-lower view ratios were obtained with the InSpace3D tool (Krukar et al., 2021).

The quantitative output obtained was interpreted to understand the impact of visibility on space use and user experience. While large isovist areas and high integration values indicate visually accessible and intuitively navigable areas, low clustering coefficients indicate intersection areas with high decision-making points or visual interaction potential. In 3D ratios, high vertical-horizontal values indicate spacious and voluminous spaces, while low ratios reflect the narrow and closed corridor effect.

In fact, in the example of Cumhuriyet Square Station, large isovist areas and high integration values coincide with the observed dense pedestrian flow and easy wayfinding behaviors. In contrast, Hunat Hatun Station has narrow viewing corridors and low visibility measurements. Therefore, it is an area with spatial congestion and orientation difficulties. The scope of visibility analyses is further expanded with artificial intelligence, augmented reality and real-time visualization technologies. Integrating analyses with pedestrian movement tracking and behavioral data has the potential to make public space usage predictable. In this way, it can contribute to the design of safer, more interactive and user-centered urban spaces.

2.3 Vitality

Vitality is an important aspect of urban design. Urban areas have become habitats for humans' spaces that are measured in terms of quality, including livability, engagement, and social productivity. These measures contribute to determining the quality of space as it creates interactivity by providing greater opportunities for its residents. The first term to be discussed is livability.

Livability refers to the quality of life experienced by individuals in urban environments, considering both physical and psychological dimensions. It emphasizes the importance of urban design that prioritizes human needs and supports well-being, health, and community connection. Some key factors contributing to livability include accessible public spaces, green and blue infrastructure, walkability, and opportunities for social interaction. By integrating these elements, cities can create environments supporting mental well-being, reducing stress, and enhancing residents' overall satisfaction with living conditions. Mental well-being is a criterion for livability as an urban environment creates a habitat for individuals. Increasing the green and blue elements improves mental health, reduces stress, and creates health-improving benefits (Labib et al., 2020). Also, creating human-scale environments can contribute to emotional well-being by allowing social interactions and relaxation (Ewing et al., 2013).

Civic activity in public areas is a sign of increased vitality. For instance, people spending their lunch hours on the streets chatting, picnicking, and sunbathing have considered points out that the space is strong in vitality aspect (Whyte, 1980). The design of the urban elements affects the approach of people to space. Especially junction spaces, seating elements, stairs, and separators as well as natural qualities like sun, wind, etc. affect the useability of the area. For example, if enough seating equipment has not been provided, people must spend less time in the selected area as it is harder to stand around for longer periods. Also, Whyte (1980) expresses that the design and placement of the urban seating areas affect the number of users for an area. The design of stairs instead of individually numbered seating units provides enormous amounts of possibilities in seating choices; the demand can adjust the number of people that can use the area and create possibilities for interactions. Whyte (1980) also underlined the importance of natural elements such as sun, wind, trees, and water. These elements can contribute to the creation of comfortable and manageable areas. For instance, trees create a variety of shading options for people to choose. Wind can decrease the feeling of heat along with the trees.

Vitality is not a static value. The vitality of areas can differ from time to time. There is a change in the activity depending on the time of the day and whether its weekend or weekday. Lighting choices are especially important to determine the activity at night times. Also, continuous street activity is important for safety and vibrant city life (Jacobs, 1961).

Quality of life is a significant element from the perspective of vitality. Accessibility, safety, and communal engagement are key factors in defining the quality of life (Gehl, 2010). Also, high-quality urban life should include vitality and promote social interactions. Furthermore, the relationship between activity vitality and diversity is quite strong. Having small businesses side by side with bigger businesses, or shops from various work fields increases vitality. Also, having different types of buildings such as residential, commercial, educational etc. side by side also increases the vitality of the areas (Montgomery, 1998).

On top of the physical features, the digital qualities of space can also affect the vitality of the areas. Digital interactions become increasingly important especially for the tourists and young people (Townsend, 2013). Features like Wi-Fi areas, AR installations, and social media use can affect urban interactions and vitality.

Demographic qualities can represent vitality. Having diverse group of people using the area is a positive feature because high vitality is in correlation with having different groups of people such as children, elderly, people with disabilities, and diverse socioeconomic backgrounds using the same area (Low et al., 2009).

Vitality is thus a multi-dimensional indicator of urban health, shaped by spatial design, environmental factors, temporal rhythms, and the social inclusivity of space.

This chapter examines the three fundamental dimensions of urban complexity: human scale, visibility, and vitality. These dimensions reveal that a city is shaped not only by its physical structure but also by user experience, spatial perception, and social interaction opportunities.

Human scale focuses on the principles of walkability, accessibility, and human-centered design, focusing on the relationship that the city establishes with individuals. The decreasing human scale with the increase in automobile use has caused the weakening of public spaces and social interaction. However, in recent years, pedestrianization projects, bicycle paths, and public space arrangements have been conducted to reverse this situation, supporting the city to regain a human-centered structure.

Visibility is a crucial element that ensures the perceptibility of urban space and ease of orientation. The visual permeability of areas makes it easier for users to feel safe in space and to establish social interaction. Visual arrangements that increase the readability of the city make it easier to navigate, especially in dense areas, and improve the user

experience. Thanks to developing digital technologies and spatial analysis tools, visibility analyses can now be performed more comprehensively and precisely.

Vitality is a multidimensional concept that shows how active and usable urban spaces are socially, economically and culturally. Pedestrian mobility, public space use, spatial diversity and socio-demographic participation are the basic indicators of vitality. Observing different usage patterns at various times of the day indicates the temporal rhythm and social dynamics of the city. In addition, with the development of digital infrastructure, it is seen that digital interactions in urban spaces also have an impact on vitality. As a result, when these three dimensions come together, it becomes clear that urban complexity should be evaluated not only physically but also in terms of human, perceptual and social aspects. Making cities sustainable, accessible and livable is possible by addressing these dimensions in a balanced and holistic manner.

Cities should be evaluated as complex organisms not only with their physical structures but also with the social, cultural and emotional layers they contain. Concepts such as human scale, visibility and vitality discussed in the previous section have revealed the spatial and experiential dimensions of urban complexity. However, a more in-depth analysis of this multi-layered structure and its transformation into effective design decisions becomes possible with data-supported approaches. Therefore, the next section will discuss data-based tools, technologies and methods that help understand and transform this complex structure of cities; thus, it will be examined how a bridge is established in the transition from theoretical approaches to practice.

Chapter 3

Data in Urban Scale

The search for a measure of human scale is continuing. Since Jacobs (1961) and Lefebvre (1962) defined the path for the issues of urban quality, many other researchers like Gehl (2011), Whyte (1980), Montgomery (1998) contributed to the topic in their perspectives by discussing urban dynamics. After their contributions, further exploration of human scale, physical form, and perceived quality has been conducted through quantitative studies. In contemporary research approaches, the usage of data prevails.

Data plays a key role in creating the urban environment by making the city elements more intelligent, sustainable, and responsive to human-centered perspectives. Using technology, urban shareholders can analyze and optimize the spatial, social, and functional parameters. Big data, sensors, and integrative frameworks can be used to monitor the needs of urban areas. Due to the complex nature of the cities, these tools can create efficient, inclusive, and adaptive versions of urban areas. Data provides environment to holistic and evidence based decision making across city systems and scales (Bibri, 2018). This chapter will discuss studies that merge urban planning and data-driven approaches, referencing research that used data sources such as cell phone data, social media data, and geotagged photographs to offer a human-centered perspective. These methods enhance urbanists' understanding of urban form's spatial and transient dynamics and its diverse dynamics.

Hancke & Silva's (2012) study systematically addresses advanced sensing technologies that form the basis of data collection in the context of smart cities, comprehensively demonstrating how cities can be made more sustainable, efficient, and human-centered. As emphasized in the study, urban data collection is not only carried out by relying on traditional methods (e.g., field observations or surveys) but also by integrating with different technological infrastructures. In this context, firstly, wireless sensor networks (WSN) enable the analysis of real-time status of infrastructures thanks to sensor nodes that continuously monitor physical variables (such as temperature, humidity, light, vibration, gas density) in the city. Secondly, smartphones, which are widely used today, enable participant-based data collection processes through sensors

such as GPS, accelerometer, microphone, and compass on them, thus providing valuable information on users' mobility, environmental comfort, and social behavior. In addition, urban management is becoming more data-driven, resource-focused, and effective through built-in sensor systems integrated into urban furniture and urban fixtures (e.g., occupancy sensors in trash bins, motion sensors in streetlights). Transferring this collected data to cloud computing infrastructures over the Internet (via IoT systems) enables the development of big data processing, spatial pattern analysis, and decision support systems. Finally, image processing and smart camera technologies enable continuous monitoring of issues such as pedestrian mobility, traffic density, and public safety, making the behavioral dimensions of urban spaces measurable. These advanced sensing mechanisms go beyond classical spatial planning approaches and enable the analysis of high-resolution, real-time, and continuously updated data on human behavior, environmental conditions, and infrastructure performance; thus, paving the way for a more sensitive, flexible, and data-driven urban design and management approach.

In order to translate the theoretical framework developed in the chapter into a workable model, this chapter introduces selected spatial and behavioral analysis tools to assess urban quality along three interrelated dimensions: visibility, accessibility, and liveliness. These dimensions are based on fundamental work in urban design and spatial analysis. For example, visibility is based on the concept of spatial legibility defined by Lynch (1960) and developed through spatial syntax theory (Conroy-Dalton & Bafna, 2003; Turner et al., 2001). In this study, visibility is measured by GIS-based viewshed analyses and isovist mapping techniques that quantitatively analyze openness, sightlines, and spatial closure (Batty, 2001; Benedikt, 1979). Accessibility, on the other hand, includes both physical and cognitive ease of passage as discussed by Whyte (1980) and Jacobs (1961). In this context, pedestrian route density is assessed through mapping of entry points and analysis of spatial network connections. These methods are based on the accessibility framework developed by Geurs and van Wee (2004) and supported by simulation models based on movement data (Helbing & Molnár, 1995).

The vitality dimension is related to the continuity of public life and user density; it is assessed through social interaction and time-based space use as defined by Gehl (2011) and Montgomery (1998). In this study, vitality is interpreted through behavioral observations, user presence and time-dependent activity patterns through simulation outputs (Gehl & Svarre, 2013; W. L. Wang et al., 2015).

Instead of isolating theoretical ideas from analytical and computational tools, this study adopts an integrated approach where each conceptual dimension (visibility, accessibility and vitality) is directly associated with measurable indicators. These indicators are obtained from spatial data, simulation models and human-scale observations, enabling multi-dimensional analysis of urban space. This integrated approach overlaps with Hillier's (2007) approach, which argues that space is not only a neutral ground but also an effective element in shaping social and spatial behaviors (Figure 3.1). It is also argued that spatial forms can be analyzed with systematic methods. By transforming theoretical concepts into measurable spatial patterns, this analytical framework combines design thinking with observational findings, enabling comparative and data-based evaluations in different urban contexts.

3.1 Data-Driven Urban Morphology

Data-driven tools can be used to analyze the morphological features of the urban areas. Urban morphology focuses on the form, structure and evolution of urban spaces. The traditional methods are slowly being abandoned as new methods evolve. The shift is through data driven and computational approaches. From the early space syntax and GIS studies newer methods have shifted towards the analytical perspectives. There are significant contributions from the technologies that evolve around big data, GIS, 3D modeling, remote sensing, urban growth simulations, and AI analysis of urban form.

There are some main data types to be used in similar studies. Geospatial data and remote sensing data are being used to assess 2D and 3D urban forms. There is a possibility of assessing the building footprints, land covers and elevation data. The use of 3D analysis techniques allows researchers to understand the human perspective in city spaces. Image recognition provides deep insights to analyze different elements of the city, such as buildings, roads, trees, sky, and streetlights, to assess the human perspective (Middel et al., 2019).

Open-source data-sharing platforms are also vital for analysis techniques. There are a few initiatives to provide data on a global scale, such as OpenStreetMap. Also, local authorities, researchers, planners and designers can create their data sets and contribute to the production of data infrastructure. Furthermore, mobile devices also create dynamic insights into the morphological features of the urban environment through an explanation of human movement patterns.

There are some analytical methods and tools that can be used to process data. Machine learning and neural networks can be used to create urban form clustering and metric optimization. Numerical taxonomy can be used to quantitative classification. Also, 3D morphometric analysis can be used to study metrics like building height, sky view factor and volume density (Ren et al., 2020).

As a tool, GIS is a system that stores and visualizes data with geographical marks. It can keep, change, and analyze geographic data. It can help with daily operations in urban environments. Using GIS systems allows urban patterns to be detected and analyzed, creating an environment for using data-driven solutions for urban environment planning (Bibri, 2018). GIS systems can be connected to various data, such as visual qualities. Data delivered from image sharing or social media platforms can be used to identify urban dynamics by cooperating with image recognition technologies (Zhou et al., 2014).

Data-driven morphology techniques can be applied to the urban context by typology mapping, scenario modeling and sustainability assessments. Also, simulations are created to foresee the development trends and climatic adaptations in planning. Furthermore, similar processes can lead to participatory and performance-based design methods (Ameijde, 2022). Also, data-augmented approaches to heritage and conservation focus on the integration of digital technologies to preserve and manage cultural and historical assets. Tools such as digital twins, GIS, and advanced visualization techniques enhance the understanding, planning, and protection of heritage sites while ensuring sustainable development.

Due to the availability of the data structures USA and European urban environments are more likely to be studied along with some of the Asian countries. The 3D urban block clustering model has assessed New York city. Similarly, China has powerful structure on data-driven studies. High resolution urban morphological studies are made by the use of data sets are used to assess the climatic and density patterns (Li et al., 2021).

There are limitations and risks that exist in this field of study. As mentioned before, the data availability limits the study areas. Most of the developing regions cannot provide detailed data sets so detailed analyses or predictions cannot be made. Also, the data infrastructure can cause the illusion of overprediction of reality. The cultural qualities or social contexts might be pushed aside. This kind of approach might cause problematic predictions or decisions. Another concern around this topic is the ethical issues of data.

The privacy, ownership and management of data is quite important in this morphological aspect (Kitchin, 2015).

In addition to traditional data collection methods, user-generated content on digital platforms is emerging as a powerful alternative data source in understanding the socio-spatial dynamics of urban spaces. Social media platforms such as Flickr, Instagram, Twitter, and Facebook in particular produce visual and textual data that reflect users' relationships with the city, their spatial preferences, daily practices, and emotional ties. Such data can be used for both quantitative and qualitative analyses in measuring concepts such as urban vitality, spatial belonging, public space use, and collective memory. As emphasized in the study by Wang and Vermeulen (2021), large data sets obtained from social media platforms provide the opportunity to analyze how intensively urban spaces are used, in which areas there is more interaction, and to which urban qualities users are sensitive. In their study, the density and tags of photographs obtained especially from Flickr were used to visualize the extent to which public spaces have become social attraction points. Similarly, Shelton, Poorthuis, and Zook (2015) analyzed urban spatial inequalities using Twitter data; and there have been studies documenting the transformation of public life through place-specific visual narratives on platforms such as Instagram (Toscano, 2017). Such user-generated large data sets enable real-time, large-scale, and behavior-based analysis of urban spaces, going beyond traditional survey or observation-based methods. Therefore, social media platforms should be considered not only as communication tools but also as a new data layer in human-centered urban analysis.

There are great opportunities for future studies in the use of data in urban morphology areas. Because of the recent increase in the use of AI technologies the urban generation and policy modelling integration improves. Also, increase of access to the open-source coding tools will contribute to the improvements in this field of research, developing connection between the spoken languages and coding can also remove barriers in access to the creation of newer application technologies.

3.2 Performance-Oriented Architectural Analysis

Performance-oriented architectural analysis indicates the evaluation of urban and architectural designs based on their energy efficiency, climate responsiveness, and alignment with human-scale principles. This topic includes data and technology to

enhance sustainability, functionality, and human-centricity in the built environment. The main focus is to design environments that adapt to local climatic and ecological conditions through dynamic material and spatial strategies (Hensel & Menges, 2008). This design perspective connects global environmental challenges and sustainability with architecture and urban design. Architecture has practice of performance-based thinking perspectives and responsive forms, yet nowadays, there are digital tools and environmental simulations that provide deeper understandings throughout the design and construction process. Parametric modeling has allowed designers to gain insights into the last result. Some performance aspects like daylight, ventilation, and energy consumption can be tested and optimized with the help of tools like Grasshopper, Radiance, and EnergyPlus (Shi & Yang, 2013).

In building scale, BIM technologies allow designers, constructors, and shareholders to foresee the qualities of the design, and the problems and intervene with them even before the construction starts (Bibri, 2018). Simulations can provide great insights to designers to increase spatial quality, optimize cost, and enhance functionality by predicting user behavior, improving safety, and reducing resource inefficiencies in urban and architectural spaces. Space Syntax is one of the most important methods on this topic. With the help of Space Syntax, transit network flows, pedestrian movement, accessibility, connectivity, and data-driven urban design can all be analyzed and optimized. These tools provide a deeper understanding of urban spaces, enabling cities to enhance accessibility, foster social interactions, and create more vibrant and inclusive public spaces. Additionally, Space Syntax allows planners to identify potential bottlenecks, optimize land use, and promote sustainable transport options, ultimately contributing to a more efficient, resilient, and people-centered urban environment.

Another simulation program is MassMotion, which is a crowd simulation program that can be used in diverse study fields such as urban design, architecture, and transportation planning. The program can create simulation sequences for a determined number of users in a period. This program can specifically be used in the project that is created for public spaces as it serves a high number of users. This program can improve the emergency planning processes, user experiences, and comfort. Additionally, the data provided by MassMotion can highlight the spaces that might effectively cause problems in an emergency. Risks can be assessed in this program and evacuation scenarios can be evaluated effectively. Another main benefit is the ability to forecast pedestrian flow and their attitudes towards navigation in the areas. Another benefit of this program is design

optimization and cost saving since the user density can be seen in these projects. It allows distinctive designs to be assessed. It can optimize the use of resources, reduce workload, and optimize the space use. Furthermore, MassMotion also provides detailed data that is supported by unique design features. Different scenarios can be evaluated, and the behaviors of people can be seen in the simulation outcomes. Simulating human behavior creates great benefits as it helps urban designs to be more sustainable and efficient (Marzouk & Daour, 2018).

Transportation projects provide a valuable opportunity to use crowd simulation programs in design processes. Crowd simulation ability to detect human movements in rush hours, and emergency situations. These tools can help designers and local governments to optimize design, costs, and accessibility.

Environmental, material and spatial performances are the main fields of study. Energy efficiency is a key topic in the environmental sustainability perspective, as cities are highly by the use of IoT technology can provide real-time data to lower the energy consumption in buildings and operational qualities (Bibri, 2018). Furthermore, the use of big data tools and revealing the consumption items capacity for energy use can help shareholders like architects and urban planners to reduce consumption levels by consideration of data in the design process (Cao et al., 2020).

Spatial performance is required to support user requirements and sensory experiences, which require adaptivity to the changing external qualities. Climate-responsive design is also a criterion for urban planning of climatic conditions such as heat and cold. To meet the requirements of these issues, the elimination of heat islands and urban cooling systems is significant. Design of effective landscape design choices, consideration of urban resilience, and ecological balances are key aspects (Borgström et al., 2006). The possibility of integration between the performance-oriented design and real-time environmental data can provide possibilities for dynamic adaptations to environmental changes and usage patterns.

Due to the interdisciplinary nature of the tools, it is important to acknowledge that there is a possibility of over-engineered results if the nature of the analysis tools is not understood properly. Similarly to the other tools of digital design it is important to acknowledge cultural and local values and not use analysis methods beyond the impact of primary values.

By the extensive use of performance-oriented analysis tools, simulation tools can engage with the design processes and become more user-friendly. This shift can provide better outcomes for the users of the designed elements.

3.3 Smart and Adaptive Urban Systems

Cities are complex structures that face problems each day. To decrease the problems in the city's daily operations and improve administrative qualities, city systems use innovative technologies. One of the important terms is the smart city approach, an extensive term used in various study fields such as “urban planning, information technology, public policy, public health, and other social and computer science” (J. Lee, 2021).

Smart and adaptive urban systems use technologies like IoT, AI, and data analytics to enhance urban sustainability, responsiveness, and service delivery. By the use of these systems, energy efficiency, mobility, emergency management, public safety, and waste management systems can be created (Bittencourt et al., 2024).

Smart city terms can be defined in many different ways by different stakeholders of the civic issues. ICT (information connection technologies) mainly consists of the base element of smart city projects. ICT technologies can create a network of information to increase efficient city operation management. Secondly, they can be used to develop efficient systems by using their network (J. Lee, 2021). Lastly, they can be used to create a feedback-centered system supported by the ideas of the civic.

IBM defined the smart city as having 3Is (instrumented, interconnected, and intelligent) in the 2010s. This was an important definition when it was created. Even though, it is not capable of representing today's conditions on the issue of smart cities. It highlights the intelligent cities idea. Intelligent cities use similar technologies and infrastructures as smart cities, but they lack some features. Smart cities focus on sustainability goals such as low energy consumption, responsive infrastructures, and environmental and real-time approaches to issues (Çınar Umdü & Alakavuk, 2020). On the other hand, an intelligent city mainly focuses on the optimization of services, quality of life, site uses, and economic growth.

Due to the nature of the term, there are various approaches to the smart city. In some studies, the city is an experimental ground to see the outcomes of the ICT and test big data and its extent. This approach is called a techno-centered approach. In some studies,

the main goal is to improve the quality of life and meet the requirements of the civic. This approach can be classified as human-centered. The last approach is the integrated approach. Which is standing in between the first two approaches. It considers smart cities as having technological and social features together (Papa et al., 2013).

The technological infrastructure is supported by the elements of IoT, artificial intelligence & machine learning, and distributed and collective systems. Those technologies allow systems to adapt and respond to the dynamic input. The IoT can be used to control lighting, traffic lights etc. The AI and machine learning can be used for forecasting, automatic responses and pattern recognition in urban spaces (Bittencourt et al., 2024). Similarly, the distributed and collective systems allow decentralization throughout the systems and adapt to scalability.

Mobility, energy and governance are the main application fields for the issue. Smart traffic signaling, adaptive lighting systems, and smart governance systems can be created. In terms of the urban planning perspective, adaptive urbanization can help the city to respond to seasonal demands, climatic impacts and growth. There are concepts of urban systems which allow urban systems to self-organize and adapt to the outcomes. Also, smart landscape policies can help to regulate microclimates and respond to the user's needs.

This issue has similar ethical concerns as data privacy and management. On top of that, acknowledging equity and inclusive considerations are vital to better development approaches. Also, adaptive governance frameworks are vital to accessing the best outcomes on this aspect.

The development of smart cities faces various challenges and limitations. Interoperability and integration of different systems and stakeholders are still a major problem (Nogueira et al., 2023). In addition, factors such as data governance, cybersecurity measures and resistance of existing infrastructures to change make it difficult to implement smart city applications. However, it should not be forgotten that cities should be transformed not only from a technical perspective but also through human-centered outcomes.

Future approaches are shaped by more holistic and adaptable systems. In this context, city models evolving through citizen, technology and policy collaboration come to the fore. The Smart City 5.0 vision aims to integrate multiple artificial intelligence agents with participatory governance structures (Svítek et al., 2019). Additionally,

themes such as climate change resilient, adaptive housing and responsive public spaces are also gaining more importance in the cities of the future.

3.4 User Experience

User experience for smart urban systems is a considerable issue in the aspects of emotional, behavioral, and functional interactions people have with digitalized urban environments. This perspective is important because the design of the system does become human-centered. The shift from technology-driven models to experience-driven models provides the background for the technology to be optimized for the human-centered approach by acknowledging the actual needs and emotions. The user experience (UX) uses methods of participatory design scenario planning to enhance inclusivity and contextual relevance (Schliwa, 2019).

The interactivity on urban systems like responsive lighting, QR codes and AR qualities can support the interaction between the users and urban elements. These interactions do support the bond between the residents and create a sense of belonging.

Passenger experience and mobility touchpoints are critical to users' first interaction with the city. Urban mobility systems such as transportation hubs and arrival areas determine individuals' first impressions of the city and directly affect the level of urban comfort. In this context, smart city applications and digital wayfinding tools increase accessibility within the city and provide a seamless and user-friendly navigation experience (Janošková et al., 2021).

Evaluating user experience in the context of smart cities requires frameworks that are not limited to measuring functionality alone, but also include multidimensional criteria such as usability, satisfaction, emotional impact, and inclusiveness (Fang & Shan, 2023). One of the environments where these evaluations can be made most effectively is "living laboratories" where users actively participate. These environments provide dynamic and real-time testing grounds that enable the joint development of user-centered services.

However, one of the main challenges encountered in smart city designs is that users' subjective and sensory experiences are often ignored. Designs that prioritize efficiency and data collection can overshadow human-centeredness and bring risks, especially the exclusion of vulnerable groups. This situation emphasizes the importance of implementing user-centered methods in an inclusive manner.

Future-oriented approaches bring the concept of “Human Smart Cities” to the forefront. This understanding aims to create emotionally connected, participatory and meaningful urban environments by bringing together design, interaction and technology. In this direction, the development of context-sensitive, flexible and inclusive digital infrastructures forms the basis of a responsive and user-centered urban design approach (Concilio et al., 2013).

This chapter discusses the transformative impact of technological developments and the use of big data on the planning, analysis and experience of cities. Data-driven approaches reshaping urban design with a multi-layered understanding from urban morphology to architectural performance, from smart systems to user experience.

Under the title of Data-Driven Urban Morphology, the use of data-supported tools and technologies that replace traditional morphological analysis methods is emphasized. With tools such as GIS, remote sensing, 3D analysis, and artificial intelligence, the formal structure of cities can be evaluated in a much more sensitive and human-centered way. These methods allow for more inclusive and sustainable designs by considering human mobility, density distributions, and environmental interactions.

In the Performance Oriented Architectural Analysis section, the integration of performance criteria such as energy efficiency, climate sensitivity and spatial functionality into the design process is detailed. Thanks to simulation tools such as BIM, Space Syntax, and MassMotion, user behavior can be predicted for both buildings and public spaces, security scenarios can be evaluated, and design quality can be increased. These analyses aim to improve not only technical efficiency but also user comfort and environmental sustainability.

The title of Smart and Adaptive Urban Systems addresses how cities can be made more flexible, efficient, and responsive with technologies such as IoT, artificial intelligence, and big data. Smart transportation systems, energy management, adaptive urban infrastructures, and data-based governance practices enable cities to respond to dynamic needs. The success of these systems is possible not only with technological competence but also with inclusiveness, data security, and ethical principles.

The subject of User Experience focuses on the emotional, functional and behavioral interactions of individuals with space in digitalized cities. The design approach, which is not technology-focused but experience-focused, aims to solve the problems users encounter in their daily lives and strengthen the sense of urban belonging. Participatory design methods, mobility touch points and approaches allow users to be directly involved

in the process. In addition, user experience should not only be evaluated with functionality, but also with emotional impact, accessibility and inclusiveness.

Urban data production is used intensively to increase the effectiveness of urban management and public services within the framework of smart city applications. However, these data production processes also bring with them important ethical and data security issues. In particular, the unknowing collection of sensitive data such as users' location information, biometric data, and behavioral patterns threatens the privacy of individuals and can damage trust in public projects (Zimmermann, 2023). This situation contradicts ethical principles, especially due to the lack of awareness and consent mechanisms. While the technological infrastructure of smart cities provides decision-makers with powerful tools, interventions made without the consent of individuals (e.g., behavioral guidance or surveillance systems supported by data) can damage user autonomy.

In addition, the security of data collected in smart cities is also a serious concern. The openness of digital data to unauthorized access increases the risk of misuse of personal information. In addition, the processing of data by private companies in a single-centered manner can lead to new social inequalities such as data monopolization and exclusion of city residents. In this context, data production processes need to be addressed not only in a technical but also in a socio-political framework. Designing urban data collection processes in accordance with ethical principles (such as respect, transparency, voluntariness and accountability) is critical for the sustainable and fair operation of smart cities.(J. Lee, 2021; Mark & Anya, 2019).

In conclusion, the topics discussed in this section reveal how cities can be redesigned in a more human-centered, flexible, measurable and responsive way in the data age. The potential provided by technological tools can only lead to meaningful and sustainable urban development's when combined with social context and ethical principles.

In the period data are reshaping urban design, supporting theoretical approaches with practical applications is significant. The data-based morphological analyses, performance-based architectural approaches, smart systems, and user experience, which were discussed in the previous section, provided a comprehensive framework on how cities can be made more sustainable, accessible, and human-centered. To evaluate how this framework is applied on a city scale through a concrete example, the Kayseri tram line and stations in Kayseri will be examined in detail in the next section. This case study

aims to reveal how data-driven approaches are implemented in transportation systems and how they transform urban mobility.



Chapter 4

Basic Aspects of KayseRay Tram System and Reviewing Methodology

This chapter provides an in-depth analysis of the KayseRay railway network system in Kayseri, Türkiye, as a case study to illustrate data-driven design approaches in urban mobility. By examining a real-world public transportation network, the study aims to understand how specific urban and transportation planning principles are applied and adapted to the unique context of Kayseri. This chapter explores the system's layout, its integration into the urban environment, and its role in enhancing urban mobility and accessibility within the city. This case study will evaluate the effectiveness of data-driven methods in addressing local mobility challenges.

To assess the data impact in Kayseri city by focusing on the public transportation element research on the data source infrastructure has been studied. Data sources, data formats, information categories, access levels and possible outcomes for the thesis have been collected. Kayseri Büyükşehir Belediyesi (KBB, Kayseri Metropolitan Municipality) has GIS (CBS) team and data infrastructure they mainly provide data for Kent Rehberi (City Guide), CitySurf, Açık Veri Platformu (Open Data Platform), Akıllı Şehir Kayseri App (Smart City Kayseri) KBB Trafik App, Kayseri Büyükşehir TV, and etc (Table 4.1).

Kent Rehberi is a web source that provides detailed information on zoning plans, addresses, buildings, landmarks, bazaar areas, night pharmacies, digital tours, death announcements, location of funeral houses, disaster assembly areas and more functions. Shp files can be uploaded to the system to preview the projects for designers and other individuals. Kent Rehberi is one of the most accessible services along with mobile apps.

CBS (GIS) program which is created by a Turkish company; through this app it is possible to review many urban features. They provide a similar data infrastructure to the Kent Rehberi website. Furthermore, users can create their study layers and create *shp* files. In this app, Kayseri city's aerial photos starting from 1947 and maps starting from 1921 can be viewed. Every building has detailed records in this app. Furthermore, some

of the GIS analyses supported in this app, such as visibility, and section with or without building heights. GIS office of KBB also shares data through Açık Veri Platformu (Open Data Platform). Which serves in the address of <https://acikveri.kayseri.bel.tr/>. Most of the data that is accessible by users on different websites and platforms mentioned above can be accessed in this web source. Data sources are provided in *shp*, and *api* file formats. And can be downloaded to be used in various analyses are available. The building 3D models and roads are not public data yet, the GIS office in KBB shares those data when asked.

Two main mobile apps are available in app stores *Akıllı Şehir Kayseri* and *KBB Trafik*. *Akıllı Şehir Kayseri* app supports similar data infrastructure as Kent Rehberi web page. Furthermore, the app supports the share of cultural events, publications of the municipality, job announcements, online access to services of municipality, etc. The other app is KBB Trafik created by the Ulaşım A.Ş. which is a company founded by Kayseri Metropolitan Municipality. The app essentially shows the bus, railways system, bicycle networks and car parking related data. The app provides locations of vehicles, stations, estimated wait times, ticket kiosks, travel plan, live traffic density, route recommendations etc.

Kayseri Büyükşehir TV serves in the web address of <https://tv.kayseri.bel.tr/> it provides live video footage for 81 separate locations across Kayseri. The cameras are located around landmarks such as Cumhuriyet Square, Mimar Sinan Park, Sivas Street, Osmanlı Street, Erciyes ski center and various municipality facilities.

There are different national data sources that are accessible such as Open Data Portal supported by Ulusal Akıllı Şehir Açık Veri Platformu (National Smart Cities Open Data Platform). Another source is Atlas Portal which is supported by Coğrafi Bilgi Sistemleri Genel Müdürlüğü (Geographical Data Systems General Directorate). Those sources contain regional data which are not in the scope of this study.

Numerous municipalities in Türkiye have adopted the concept of smart cities as a strategic goal and are actively working towards developing themselves in line with this vision. Kayseri is one of them in this perspective. Many services of Kayseri Municipality, like websites, GIS-based applications, and mobile apps, are being synchronized nonstop. Furthermore, transportation interfaces produce real-time data. Locations of each vehicle, whether bus or tram, and their routes can be accessed in KBB Trafik app. For instance, the app processes the location data of vehicles and shows estimated waiting period for any station can be previewed.

Table 4.1 Public Transportation Data Sources for the Kayseri City

Institution/ Organization	Data Source	Data Category	Types of Data	Data Form at	Access Level	Outcome for Study
Kayseri Metropolitan Municipality	CitySurf	Transportati on	- Transportation stops	GIS	Public	Analyze infrastructure and accessibility
			- Bicycle points with service availability (Kaybis)			
			- Ticket machine locations			
			- Roads			
			- Infrastructure quality			
			- Traffic accident locations (injuries/deaths)			
			- Train lines			
Kayseri Metropolitan Municipality	CitySurf	Maps	- Maps from 2011 to 2024	GIS	Public	Historical analysis of urban growth
			- Satellite images from 2002 to 2010			
			- Aerial photos from 1947 to 2005			
Kayseri Metropolitan Municipality	CitySurf	Population	- Population count	GIS	Public	Evaluate population distribution
			- Muhtar contact information			
Kayseri Metropolitan Municipality	CitySurf	Buildings	- Building coordinates	GIS	Public (to view) Restricted (file access)	Assess zoning and building density
			- Number of floors			
			- Building entrances			
			- Master plans			
			- Height information			
			- Neighborhood boundaries			
Kayseri Metropolitan Municipality	Açık Veri Platformu	GIS Resources	- Amenities	Web, GIS, API	Public	Evaluate urban characteristics
Kayseri Ulaşım A.Ş.	KBB Trafik App	Live Tracking	- Public transportation routes	API	Public	Monitor real- time public transport locations
			- Live tram and bus locations			
			- Arrival time estimations			
			- Bicycle and car parking availability			
Kayseri Metropolitan Municipality	Kayseri Ulaşım A.Ş.	Passenger Load	- Passenger passes	API	Restricted	Evaluate urban mobility characteristics
Ministry of Environment, Urbanization and Climate Change	Parsel Sorgu Website	Buildings	- Building information by zone	Web	Public	Evaluate zoning and building information
			- Number of independent sections			
			- Area (m ²) of each zone			
Coğrafi Bilgi Sistemleri Genel Müdürlüğü	Atlas Portal	GIS Resources	- Geospatial data layers	Web	Public	Support geographic analysis

Sivas Street is the main arterial road in the city center. Except for the public buildings, the ground floor of each building is covered with stores of different extents, such as food, clothing, local product sellers, etc. These features increase the walkability and vitality of the street and turn this street into an attraction point. Many public transportation lines serve this main artery road. Besides the bus system, the light rail system also serves in this main axis. Light rail system has access to many neighborhoods and has transfer links to other regions. The main axis that serves all the routes is in the heart of the city center.

The data infrastructure of the transportation system and the high vitality of Sivas Boulevard have led this study to be focused on the light rail system to measure urban quality. This transportation axis, which forms the main backbone of the city, and the intense pedestrian movement around it offers significant potential that allows for data-based analyses. The tram system is in a strategic position in terms of both accessibility and urban vitality. Thanks to real-time data production, the physical and social dimensions of the transportation system have become accessible in detail. In this context, spatial and social analyses on selected stops to measure urban quality constitute the basis of the study. In this analysis process, three basic criteria, namely accessibility, visibility, and vitality, were used, and an evaluation method was developed with subheadings determined for each criterion.

The KayseRay tram system, which is at the center of the transportation infrastructure in the city of Kayseri, is an element that directly shapes both the spatial development of the city and public transportation habits. The historical development of the system, the expansion processes of the line, the changes in the number of users and its technical equipment provide a basic background for understanding the interaction of this infrastructure with the city. Therefore, before moving on to detailed station analyses, the structural features of the KayseRay system, its operational processes and its role in urban transportation need to be addressed comprehensively.

4.1 Overview of the KayseRay System

This section introduces the KayseRay tram system, highlighting its history, operational structure, and core features. It provides an overview of the network's routes, coverage, and connections with other modes of transport, illustrating how KayseRay plays a crucial role in the city's public transportation network. By understanding the

design and objectives of the system, this section sets the stage for a more detailed analysis of its performance and impact on urban mobility in subsequent sections (Figure 4.1).

The use of public transport is a crucial element of urban mobility. Due to the dense characteristics of the city use of private vehicles causes traffic issues and covers a significant amount of area in urban space. Various urban mobility types are being used in different cities to solve mobility issues. In Kayseri bus and tram systems are the main elements of public transportation. Feasibility studies for the Kayseri tram system started in the year 2000 (Gündoğdu, 2012). In 2005, a construction project for tram infrastructure was put out to tender. In 2006 construction started. The first stage was completed by the year 2009. In the design of the tram line predictions of city growth, transportation needs were assessed, and questionnaires were applied to meet the needs of the city. As the demand for the movement was modeled it is estimated that the main requirement was in the west-east direction (Gündoğdu, 2012).

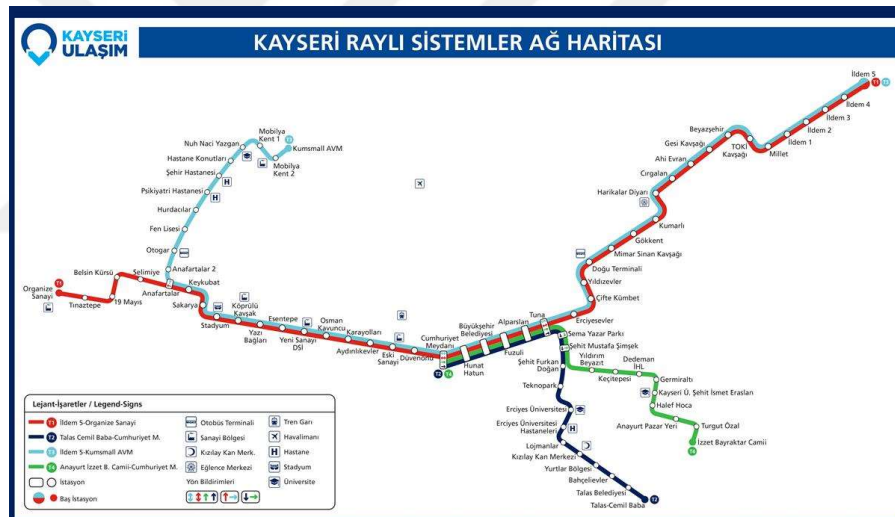


Figure 4.1 Kayseri Rail System Network Map (Source: Kayseri Ulaşım, <https://www.kayseriulasim.com/images/menuresim/223753952121000.>)

In the first stage of construction, the tram line was 17.5 km length with 28 stops and served one route. It connected the industrial zone, city center, and a bus transfer station (Doğu Terminali). In 2013, the line extended in the east direction by 9.5km and 15 more stations were added. The tram line has been extended to cover the residential areas on the east side of the city. In 2014, tram infrastructure extended in the south direction to serve Erciyes University and Talas district. At this stage 7 km line and 12 stations were added and two different routes were running. The tram system was operating with 52 vehicles until this point. In 2016 new vehicles produced in Türkiye started to

serve. In the year 2023, A new line, Kumsmall, in the direction of North, was constructed to connect production, hospital, and intercity transport stations, and a new route was added to the tram system. Also, in 2023 a new line, Anayurt, which serves another zone in the Talas district started running. It connected Kayseri University, and high-density residential areas to the city center. By 2024, the total length of the tram system is 46 km. It operates with 80 vehicles and serves 4 different routes (Table 4.2).

Main company to run the operation system is Kayseri Ulaşım A.Ş. which is a company founded by the Kayseri Metropolitan Municipality by following the railway systems construction in 2008. They also run the bus networks, car parking and Kaybis (bicycle sharing system) system. Daily use of the services is approximately 138.436 for the railway system, 257.739 for the bus network, 4000 for the bicycle system, and 9000 for the car parking services in 2023 (Kayseri Ulaşım A.Ş., 2024).

In the city of Kayseri, the use of public transport is majorly led by the bus system in numbers. The bus network covers rural areas and many surrounding areas to create accessibility for all residents. Characteristics and the large network of the bus system provides transportation to the city center. Furthermore, many bus systems do not bring the passengers to the city center. As the rail system expanded, the surrounding neighborhoods bus networks designed to provide rings and end their route in a transfer stop to railway system.

Table 4.2 Public Transportation Data Sources for the Kayseri City (Data Source: Kayseri Ulaşım, Yıllık Faaliyet Raporu 2023)

Phase	Route	Year	Track Length(km)	Station Count
1	Organize - Doğu Terminali	2013	17,5	28
2	Doğu Terminali - İldem 5	2014	9,5	15
3	Sema Yazar-Erciyes Üniversitesi-Talas Cemil Baba	2016	7	12
4	Anafartalar-Şehir Hastanesi-Kumsmall AVM	2023	6,5	11
5	Yıldırım Beyazıt-Kayseri Üniversitesi- Anayurt İzzet Bayraktar Camii	2023	5,5	9
	Total		46	75

The tram system covers various elements of the city as can be seen in Kayseri Rail System Network Map. Three of four Universities, two industrial zones, an intercity bus station, and many residential areas. There are 6 stations which are served by all 4 routes. Cumhuriyet Meydanı, Hunat Hatun, Büyükşehir Belediyesi, Fuzuli, Alparslan and Tuna stations. Except for the years 2020 and 2021 which are the years covid 19 heavily affected

the life of the people all around the globe, number of users for the tram system has trend of increase. The number of users almost doubled from 2012 until 2023. This trend can be explained by the impact of expansion on the rail system (Figure 4.2).

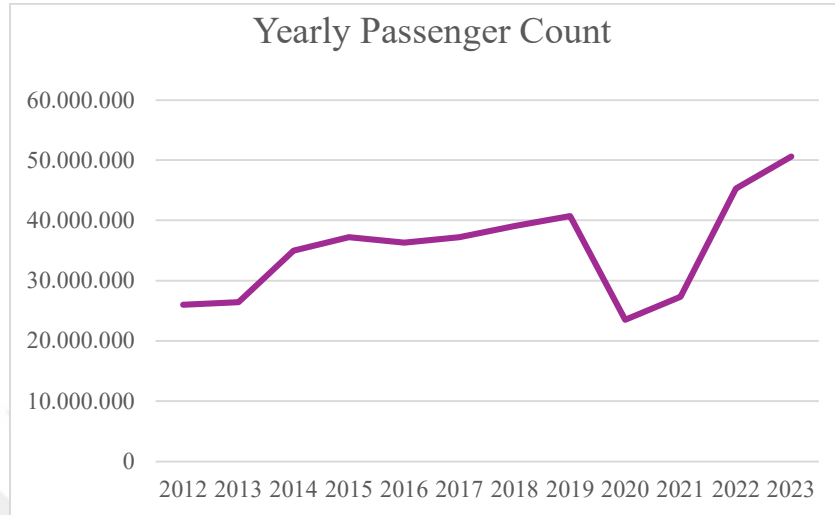


Figure 4.2 Passenger Count Per Year (Data Source: Kayseri Ulaşım, Yıllık Faaliyet Raporu 2023)

Tram Vehicles: The vehicles are another element of the transportation system that has been serving throughout the whole network. There are different vehicles that are ordered as the network expands. Two types of trams are Ansaldo Breda-Sirio and Bozankaya vehicles. The vehicles are approximately 32.5 meters long. Each station can have two vehicles at the same time. Ansaldo Breda-Sirio vehicles (Figure 4.3) have capacity to carry 273 passengers and Bozankaya vehicles (Figure 4.4) have 311 passenger capacity. Both vehicles have 68 seat capacity. There are two versions of Bozankaya vehicles with minor differences. Ansaldo Breda-Sirio vehicles have 10 doors, 5 on each side. It does have shifted doors in the middle of the vehicle. Since platform types can differ from station to station, older people and unfamiliar passengers might have a challenging time understanding which door opens at which station. And might not be able to get off the vehicle at their target station. To prevent this problem there are announcements to let people know which side will be available to access the platform. All the vehicles are accessible for wheelchair users, and each vehicle has space for wheelchair placements. Also, there are priority seats for disabled, old and pregnant people.

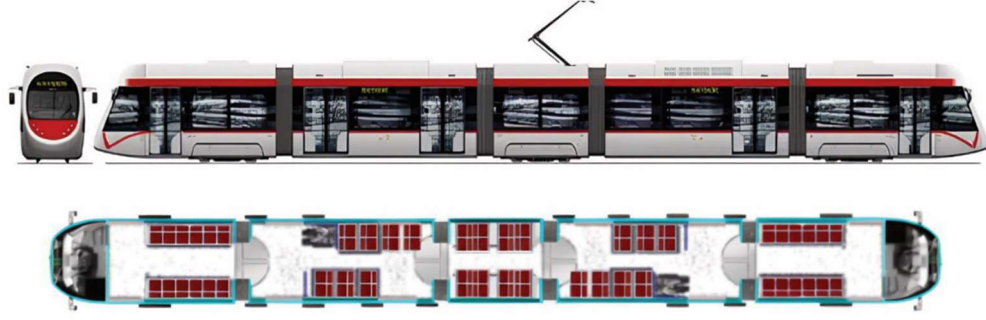


Figure 4.3 Ansaldo Breda-Sirio Vehicle (Source: Kayseri Ulaşım, Yıllık Faaliyet Raporu 2023)

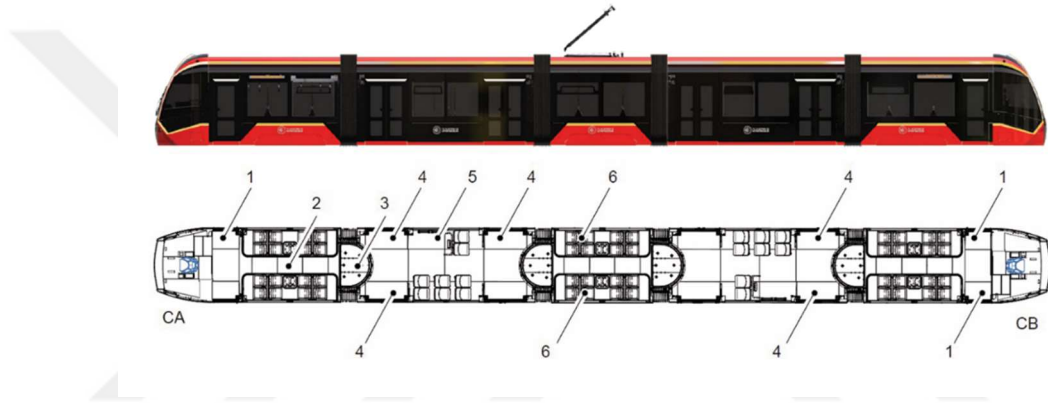


Figure 4.4 Bozankaya Vehicle (Source: Kayseri Ulaşım, Yıllık Faaliyet Raporu 2023)

Sociocultural Infrastructure of Kayseri: The sociocultural infrastructure of Kayseri has a multi-layered structure shaped by the influence of trade, industry and religious heritage throughout history. The city has been an important settlement and production center throughout the Seljuk, Ottoman and Republican periods. A controlled, innovative and opportunity-oriented economic actor type defined as “Homo Kaysericus” has developed, where the entrepreneurial spirit is widespread among the local population (Geçgin, 2015). This sociocultural structure has been supported by strong social capital networks and historically developed religious-civil architecture. For example, the tombs of Zeynel Abidin and Seyyid Burhaneddin built during the reign of Abdulhamid II attract attention with their architectural features bearing Westernization influences (Aydın, 2011). Kayseri has also developed in areas such as pharmacy and health services throughout history, and this has made significant contributions to the social life and economy of the province (Tekiner, 2006).

There are significant social segregations in the sociocultural structure of Kayseri. The entrepreneurial and industrial culture that emerged as a result of the economic development in the city brought about a class differentiation. There were significant differences between the middle and upper classes and the working class in terms of lifestyle, consumption habits and social environment (Geçgin, 2015). In addition, urban areas developed through state-supported housing cooperatives paved the way for spatial segregations where certain social groups were clustered (Onur & Duggan, 2017). In addition, there is a cultural tension between the traditional religious lifestyle and more modern and secular approaches. This situation manifests itself especially as differentiation in public spaces, education and daily life practices. All these dynamics show that the sociocultural structure in Kayseri is not a single type, but rather a pluralistic structure that differentiates between diverse groups.

Cumhuriyet Square in Kayseri functions as a key urban node that reflects the city's layered sociocultural structure through its diverse usage patterns. Elderly residents frequently utilize the square as a space for rest and socialization, often spending time there between or after religious activities due to its proximity to significant mosques. For working adults and younger populations, especially students and employees, the square serves as a practical transfer hub within the public transportation network, facilitating daily commuting. Additionally, the square holds commercial significance for local business owners and vendors, acting as a focal point for trade-oriented interactions. These varied functions demonstrate how Cumhuriyet Square accommodates different user groups simultaneously, reinforcing the pluralistic nature of Kayseri's public life shaped by intersecting social, economic, and religious dynamics.

Literature Review on the KayseRay Tram System: Spatial, Operational, and Environmental Perspectives: Since KayseRay is a significant element for Kayseri city, there have been many studies conducted on this topic. Relative research studies have been listed. Each of the selected studies has discussed various aspects from spatial and operational perspectives (Table 4.3). The earliest study that will be discussed in relevance to this thesis, was not directly created to focus of the tram system, the study have discussed the greenery elements around the main streets of Kayseri and studied them in the perspective of landscape design (Erdoğan & Özer, 2010). It is found that there are many green landscape elements throughout the tram system route. It has been found that green separation elements are not serving well in terms of safety and definition of uses in between the vehicle and pedestrian use of the spaces in the tram zone. Two other studies

were created by the Ulaşım AŞ itself. The first one focused on the design and construction of the line itself in the initial stages. Indeed, Gündoğdu (2012) has explained the methods for predictions for the expansion of the city and the determination of the needs in transportation requirements. Secondly, aesthetic and sustainable aspects have been explained to spread knowledge and increase awareness of the design choices behind the green element placements throughout the light rail system (Ulusoy & Gündoğdu, 2011). Power supply systems in light rail public transportation lines have been searched and tested with simulations and field studies (Terciyanli et al., 2012). There have been studies that are focused on the engineering aspects of the light rail systems by comparing them with similar examples around Türkiye (Vitoşoğlu et al., 2014). They followed a statistical method to examine selected systems and as a result, Kayseri scored in the middle. Noise effects of KayseRay system have been studied between the stations of Düvenönü and Cumhuriyet Meydanı (Erkaya et al., 2015). A network model has been created to provide more information about urban planning. Optimization of the sources for transportation systems remains a significant issue. Tapkan et al. (2018) have studied the optimization problem in the scheduling of the drivers in light rail system. The newest study that has been published in relation to the KayseRay system focuses on energy efficiency, sustainability and smart transportation applications in the city of Kayseri. This study has a quantitative approach to smart transportation problems and provides a broader perspective on the qualities and problems of transportation systems by focusing on to various groups of the society (Bayraktar, 2020).

There are various perspectives that have been taken by focusing on the KayseRay system as focus. Some of the studies have been focused on aesthetic or comfort aspects (Erdoğan & Özer, 2010; Erkaya et al., 2015; Ulusoy & Gündoğdu, 2011), other studies have focused on the optimization and performance-based aspects (Bayraktar, 2020; Gündoğdu, 2012; Tapkan et al., 2018; Terciyanli et al., 2012; Vitoşoğlu et al., 2014). The mosaic of the literature on this topic lacks a holistic understanding of the environmental effects of the transportation system that travels through the main axis of the transportation network. This research has the intent of revealing the relation between the city functions and the transportation system.

Table 4.3 Literature Sources for KayseRay Tram System

Paper Title & Author(s)	Year of Publication	Focus Area	Relevance to Thesis	Methods/ Tools Used	Data-Driven Design
Systems Factfile. No. 27 Kayseri, Turkey <i>Coleman & Johnston</i>	2009	Overview of Kayseray system	Provides operational context for Kayseray; highlights design aspects like grassed track.	System route map, operational metrics	Discusses system efficiency through commuter behavior data.
Aesthetical and functional evaluation of road side trees in the city Kayseri <i>Erdoğan & Özer</i>	2010	Aesthetic and functional analysis of roadside trees	Relevant for integrating greenery with urban transport design.	Field studies on green infrastructure density and species.	Highlights aesthetic and functional green space benefits.
Raylı Sistemlerde Yeşil Hat Uygulaması <i>Gündoğdu & Ulusoy</i>	2011	Green track application in rail systems	Valuable for understanding environmental integration.	Comparative analysis of costs and impacts.	Discusses user-centric benefits of preserving urban greenery.
Power Quality Solutions for Light Rail Public Transportation Systems Fed by Medium-Voltage Underground Cables <i>Açık, Çadircı, Çetin, Ermiş, Ermiş & Terciyanlı</i>	2012	Power quality and energy efficiency in rail systems	Indirectly relevant for technical energy analysis.	Simulation and field testing	Discusses the impact of energy systems on operational costs.
KayseRay: Başarılı Bir Proje Öyküsü <i>Gündoğdu</i>	2012	Implementation of Kayseri's rail system	Useful for case study with firsthand project insights.	Covers the full project cycle from feasibility to operation.	Highlights livability factors and system integration based on performance data.
Comparison of Light Rail Systems in Turkey Using Comparative Benchmarking <i>Bilgiç, Özden, Vitoşoğlu, Yalınız,</i>	2014	Comparative analysis of light rail systems in Türkiye	Useful for benchmarking Kayseray against other systems.	Method of Comparative Benchmarking	Provides data-driven efficiency insights for systems.
Modelling and Evaluation of Light Railway System's Noise Using Neural Predictors <i>Bostancı, Erkaya & Geymen</i>	2015	Noise pollution and mitigation in urban railways	Relevant for evaluating the environmental impact of tram systems.	Neural predictors, GPS-based noise data collection	Provides advanced modeling techniques for noise evaluation.
Modelling and Solving Railway Crew Rostering Problem <i>Kulluk, Özbakır, Tapkan & Telcioğlu</i>	2018	Crew scheduling and operational planning	Relevant for data-driven optimization of operations.	Multi-objective 0-1 mixed integer programming	Strong focus on operational efficiency metrics.
An Analysis of Energy Efficient Sustainable Smart Transport Planning and Applications: A Case Study of Kayseri Urban Transport <i>Bayraktar</i>	2020	Smart transportation and energy-efficient urban planning	Directly relevant for smart city concepts in transport design.	Case studies, semi-structured interviews, ITS evaluations	Discusses ITS contributions to sustainable transport planning.

In order to evaluate the impact of the KayseRay tram system on the city in more depth, not only the technical structure of the system but also the physical, functional and social performances of the stations should be systematically analyzed. In this context, the data-based analysis method, which is the basic evaluation approach of the study, is based on a multi-layered framework based on both spatial and user experience. The method section presented below explains in detail how this framework was created, which criteria were used for measurements and which tools were used.

4.2 Methodology

The spatial and functional quality of public transportation infrastructure is among the basic elements that directly affect user experience and urban life quality. Tram stations, beyond providing urban mobility, also play important roles in terms of the organization of public space, inclusiveness and spatial vitality. In this study, three basic urban criteria, namely accessibility, visibility and vitality, were taken as basis in order to systematically evaluate these multifaceted contributions of tram stations. These criteria were made measurable with comprehensive indicator sets that allow the analysis of the functions of stations as both transportation nodes and public spaces.

In this study, three main criteria were determined to evaluate the physical and functional characteristics of the selected tram stations: accessibility, visibility and liveliness. Each criterion consists of various subheadings that aim to examine the performance of the stations in a multidimensional manner. Most of the criteria were evaluated with categorical responses such as yes/partially/no and rare/moderate/frequent. However, some criteria were expressed with ratios, distance values (in meters), typological definitions or visuals based on spatial analyses. In addition, explanatory comments were added to some indicators in order to make a more in-depth evaluation.

The measurement table (Table 4.4), developed to evaluate the physical and functional characteristics of the selected tram stations, is an evaluation tool that systematically addresses the multidimensional criteria related to urban quality. The table is structured around the three main headings mentioned above (accessibility, visibility and liveliness) and there are detailed sub-criteria under each heading. In addition to categorical response-based criteria, indicators based on ratios, distance measurements, typological classifications and visual analyses (e.g., visibility maps) are also used.

The development of the table was based on the accessibility components framework proposed by Geurs and van Wee (2004). This framework emphasizes the concepts of spatial equality and mobility. In this context, accessibility was assessed under two main axes: environmental physical conditions and inclusiveness. Factors such as slope, pedestrian crossings, need for ramps or elevators, environmental barriers, platform types and distances between station entrances were examined in this context. In addition, inclusive design elements such as direct access for wheelchair users and perceptible surface coverings around the station were also included in the assessment.

The second main assessment criterion, visibility, addresses the visual perceptibility of the station within the city and ease of wayfinding. The visibility of the station in each exit direction was assessed separately, and the extent to which environmental factors such as vehicles, vegetation and other physical barriers restricted the field of view was analyzed. These criteria aim to reveal the visual continuity and spatial readability around the station.

Vitality is a criterion that evaluates whether stations function as social and economic centers that support public life, beyond being mere transportation points. In this context; the interaction density around the station and the level of contribution to urban dynamism were analyzed through indicators such as passenger diversity (student, elderly, disabled, etc.), frequency of commercial functions in the vicinity, diversity of building types (housing, public service, education, health, religious, etc.) and the presence of temporary public events.

In addition to the main headings, complementary indicators were also included in the table in order to evaluate other spatial factors affecting the user experience. The vegetation (trees, grass areas, etc.) around the station and comfort conditions such as shading, wind and noise control are the elements taken into consideration in this context.

Crowd simulations were also carried out to analyze the circulation behavior of pedestrians in order to evaluate the user experience in more detail. The simulations focused on evening peak hours for each station and were based on passenger data entering the stations. In order to model the exit flow, the morning passenger data was defined as agents exiting the stations. In the simulations, physical components such as platforms, pedestrian access roads, turnstiles, disabled entrance areas, as well as interior elements such as seating elements and columns were modeled. Average density, maximum density, agent exit time, non-zero density values, user experience density, time above the density

threshold, and space occupancy time maps were created for each station. This data provide detailed information about the spatial efficiency and comfort level of each station.

Thanks to this multi-dimensional evaluation approach, tram stations are considered not only as a part of the transportation infrastructure, but also as active elements of public life. This method, which brings together quantitative and qualitative elements, offers the opportunity to evaluate the spatial, social, and operational dynamics of each station in a holistic manner from a user-oriented perspective.

Passenger diversity, distribution of passengers in peak hours, commercial variety building type diversity, and occurrence of temporary events will be discussed. To evaluate other features that affect the sense of space in these conditions, other criteria have been added. Vegetation around the station and comfort conditions are also considered to be effective in the user experience.

To assess user experience in the stations crowd simulation techniques have been used. In the modelling process of the stations, the evening peak hours of each station are selected to be simulated. Passenger data only contains the entries to the station. To simulate the flow properly, the number of passengers in morning peak hours has been used as agents leaving the station. The platforms, pedestrian access routes, turnstiles, and disabled entry areas have been modelled as well as the in-station elements like seating units, columns etc. Average density, agent time to exit, maximum density, average non-zero density, experienced density, time above density, and time occupied maps have been created for each selected station.

In conclusion, the multidimensional assessment approach presented in this study reveals that tram stations are not only a part of the transportation infrastructure; they are also active, inclusive and user-oriented components of public life. This systematic analysis, which is created by combining various methods such as theoretical framework, spatial data, observational criteria and crowd simulations, allows for a holistic evaluation of the interactions between physical design, user experience and social functions. In addition to basic indicators such as accessibility, visibility and liveliness, this approach, which also includes planting and comfort conditions, offers concrete suggestions for urban decision-makers and planners to develop more inclusive, functional and livable transportation areas.

Table 4.4 Table of Measurements for the Tram Stations

Name of The Station				
Accessibility	ENVIRONMENT		measure(yes/partially/no)	
	Elevation	Being in Urban Level	yes/partially/no	
		Ramp Requirement and Access	yes/partially/no	
		Stair-Escalator-Lift Requirement and Access	yes/partially/no	
	Traffic Lights	Pedestrian Cross Requirement and Access	yes/partially/no	
		Synchronous Pedestrian Cross	yes/partially/no	
		Button Push Requirement for Green Light	yes/partially/no	
	Obstruction on Surrounding	Ramp Requirement and Access	yes/partially/no	
		Vehicle Obstruction on the Pedestrian Cross	yes/partially/no	
		Heavy Vehicular Traffic	yes/partially/no	
	Platform Type	Single Platform/Double Platform	Single Platform/Double Platform	
	Distance Between Station Entrances	In meters(West)	meter	
		In meters(East)	meter	
	INCLUSIVITY		measure(yes/partially/no)	
Direct Entrance for Wheelchair Users		yes/partially/no	notes	
Tactile Ground Coverings Surrounding the station	End of Platform	yes/partially/no	notes	
	Each Side of Pedestrian Cross	yes/partially/no	notes	
	Intersection with Rails	yes/partially/no	notes	
Visibility	STATION VISIBILITY		measure(yes/partially/no)	
	Station Visibility	Being in Urban Level	yes/partially/no	
	Radial Analysis in 500-meter Radius	West Exit	image	
		East Exit	image	
	LINE OF SIGHT		measure(rare/medium/frequent)	
	Obstructions on the Entrances of the Station	Car	rare/medium/frequent	
Vegetation		rare/medium/frequent		
Vitality	PASSENGER DIVERSITY		ratio	
		Standard	ratio	
		Student	ratio	
		Elderly	ratio	
		Disabled	ratio	
		Others	ratio	
	COMMERCIAL VARIETY		measure(rare/medium/frequent)	
		Restaurant and Café	rare/medium/frequent	notes
		Banks	rare/medium/frequent	notes
		Temporary Accommodation	rare/medium/frequent	notes
		Shops	rare/medium/frequent	notes
	BUILDING TYPE DIVERSITY		measure(rare/medium/frequent)	
		Commercial Buildings	rare/medium/frequent	notes
		Public Service Buildings	rare/medium/frequent	notes
		Educational Buildings	rare/medium/frequent	notes
		Residential Buildings	rare/medium/frequent	notes
		Religious Buildings	rare/medium/frequent	notes
		Health Service Buildings	rare/medium/frequent	notes
	EVENTS		measure(yes/partially/no)	
		Occurrence of Temporary Events	yes/partially/no	
EXTRAS	VEGETATION AND GREEN ELEMENTS IN ENVIRONMENT		measure(yes/partially/no)	
		Trees	yes/partially/no	notes
		Grass Areas	yes/partially/no	notes
	COMFORT CONDITIONS		measure(yes/partially/no)	
		Shading from Urban Environment	yes/partially/no	
		Platform Cover	yes/partially/no	
		Noise Precautions	yes/partially/no	
Wind Precautions		yes/partially/no		

4.2.1 Data Limitations, Accessibility, and Analytical Framework

To evaluate key urban design dimensions through a data-driven perspective, a comprehensive data requirement matrix was initially developed. This matrix aimed to map each urban quality to specific datasets, including available GIS data, vehicle traffic indicators, spatial use data, pedestrian flow statistics, architectural context, traffic signalization patterns, and user typologies. The intention was to adopt a holistic and multi-scalar approach that could integrate diverse data types to provide a layered understanding of the spatial dynamics around selected tram stations in Kayseri.

However, significant limitations emerged during the data acquisition process. Despite formal requests and clear documentation of the academic purpose of the study, the relevant municipal departments declined to provide access to most of the identified datasets. In particular, critical information such as detailed tramway performance data, land use maps, architectural plans, pedestrian flow patterns, user surveys and real-time video recordings were not made available. Only anonymized passenger entry data from the tram system -reflecting temporal and categorical user distributions, 3D building data, and street network was shared (Table 4.5).

Within the scope of the study, it was aimed to access passenger surveys conducted by local governments in order to better understand the satisfaction levels and experiences of tram users regarding the public transportation system. Since such surveys directly reflect the needs and expectations of users, they are an especially important data source in the evaluation of urban mobility systems. However, despite all the applications, this survey data was not shared with the research by Kayseri Metropolitan Municipality. As a result, direct data on user satisfaction and experience could not be obtained; this created a significant deficiency, especially in terms of evaluating the social dimension of the public transportation system. This situation limited the data-based support of human-centered analyses in the study and caused some comments on passenger behavior to be made only through indirect data.

As a result, scope of the analysis was narrowed considerably. The research had to focus primarily on interpreting station activity patterns using limited user data, rather than conducting a comprehensive spatial-behavioral assessment. While the available data still offered valuable insights into daily usage trends and partial demographic characteristics, the inability to cross-reference these findings with spatial or infrastructural datasets constrained the analytical depth and the ability to draw integrated conclusions. This

situation illustrates a broader challenge in urban research: the critical dependency on institutional data transparency and open-access policies for robust, evidence-based urban design evaluations.

Table 4.5 Overview of Requested Data Sets and Access Status

Category	Data Title	Description	Status
Tram Data	Tram Route and Performance Information	Information on tram line lengths, service frequency, vehicle capacity (per vehicle), travel durations, stop intervals, and station details.	Requested, Not Provided
Survey Data	Passenger Surveys	Survey results regarding passenger satisfaction, suggestions, and needs related to public transportation.	Requested, Not Provided
Density Data	Passenger Numbers	Passenger count data during peak weekday and weekend hours at Cumhuriyet Meydanı, Hunat, and Büyükşehir Belediyesi stations.	Access Granted
User Types	Passenger Types	Demographic details of users: students, elderly, adults, etc.	Access Granted
Fishbone Diagram	Public Transport Issues and Causes (if any)	Analysis or reports used or prepared by the company categorizing problems in the public transport system and their potential causes.	Requested, Not Provided
Traffic Flow & Adaptation	Traffic Flow and Signalization Principles	Signalization and traffic regulation methods to optimize pedestrian and vehicle flow during peak hours (07:00–09:00, 12:00–14:00, 17:00–19:00).	Requested, Not Provided
Camera Footage	CCTV Records	Observations made via street cameras in Cumhuriyet Meydanı and Sivas Street during one weekday and one weekend day (07:00–21:00).	Requested, Not Provided
Architectural Projects	Architectural Plans	Architectural plans, sections, and elevations of Cumhuriyet Meydanı, Hunat, and Büyükşehir Belediyesi station areas.	Requested, Not Provided

Due to this lack of data, the analysis process was continued by turning to alternative open data sources. In particular, the data accessible through the Kayseri Metropolitan Municipality Open Data Portal was examined, and the obtained open data sets were evaluated by classifying them according to categories related to tram user data. In

addition, OpenStreetMap (OSM) data was also used to better understand the physical and functional components of urban space. These data were evaluated as a complementary source in terms of building density around stations, road networks, distribution of commercial units, and use of public spaces.

However, both open data sources have certain limitations. The datasets in the Kayseri Açık Veri Portalı (Open Data Portal) are limited to the areas where the municipality has access, which prevents a comprehensive and up-to-date spatial representation. On the other hand, OpenStreetMap data has irregular coverage and consistency level since it was created with community contributions. For example, the distribution of elements that are indicators of urban vitality, such as restaurants, cafes, and stores, is insufficient to represent natural spatial distributions because it is based on individual contributions rather than a systematic inventory. This situation shows that the visualization and analysis results obtained can only show general trends and provide interpretations that are far from an absolute representation.

As a result, the datasets used in this study are limited to the most comprehensive open data sources available under current conditions. While these limitations narrow the scope of quantitative analyses, they clearly reveal the importance of data-based approaches and the contribution of data sharing to academic research. It has been understood once again in this process that design and planning proposals to be developed for cities to become more sustainable, accessible, and livable should be based on a strong data infrastructure.

Open Data Portal and OpenStreetMap (OSM) data were integrated into the analysis process by combining them under thematic headings in order to make sense of the urban characteristics of the station surroundings. The obtained data sets were classified under seven main categories: Education Facilities, Banks, Cafes, Green Areas, Shops, Mosques, and Public Buildings. This classification aimed to represent the functional diversity and spatial liveliness around the station.

In this study, QGIS software was preferred due to its widespread use, open-source structure, and free accessibility in performing the analyses. QGIS enabled the operations required within the scope of the research with its wide range of plugins offered for spatial data processing and thematic analyses. Data sets with the .shp (shapefile) extension obtained from Kayseri Metropolitan Municipality Open Data Portal were transferred to QGIS environment and processed by converting them into suitable formats for spatial analyses.

In addition, QuickOSM plugin offered by QGIS was used in order to benefit from OpenStreetMap (OSM) based data sources. With this plugin, the structures, roads, and various urban functions within the study area defined within the city center borders were filtered and obtained. The called data layers were grouped under the previously determined headings of educational facilities, banks, cafes, green areas, stores, mosques, and public buildings and made suitable for the analysis process.

The data layers in question were supported by both the official open data provided by Kayseri Metropolitan Municipality and the OSM data based on user contributions, in order to provide spatial representation of the functional densities and urban characteristics of the station surroundings. Thus, despite the limited data environment, an analysis infrastructure was created that allows inferences to be made about the environmental qualities of certain tram stations in the city center, using publicly accessible resources.

In line with the deficiencies and inconsistencies detected in the data sets, limited manual data entries were made in the areas where some structures were recorded incompletely; these additions were verified in line with on-site observations and existing spatial information and integrated into the data set. In this way, the representative power of the analyses was tried to be increased. The structures in question were modeled with circles with a radius of 200 meters in order to show their distribution within the urban space in a clearer and more comparable way. Each structure was represented on the basis of its area of influence by means of a circle created around its location; thus, density maps of distinct functions were created, and the functional richness and potential urban vitality levels of the station surroundings were visualized.

This approach ensured that spatial analyses were carried out at a meaningful level even in a limited data environment; it also provided an example of how open data-based methods can be used in urban assessment processes. However, the accuracy and up-to-dateness levels of the data used indicate that caution should be exercised in the final interpretations of the results and emphasize the necessity of institutional data collaboration for more reliable outputs.

In the process of visualizing, processing, and performing spatial analyses of the obtained data, QGIS, an open-source geographic information system software, was used. QGIS was chosen as the main analysis platform of this research due to its extensive plugin support in urban-scale data analysis, mapping, and thematic visualization. There are many plugins and auxiliary modules planned to be used in this study as well. While some of

these plugins are based on OpenStreetMap (OSM) based map infrastructure, some can work integrated with datasets provided by local governments.

To evaluate the walkability phenomenon in a data-supported manner and to reveal the spatial relationship between the obtained open datasets and this concept. In this direction, road network analyses were carried out in a way that will contribute to the understanding of urban mobility. However, both the road data accessed via OSM and the limited network structures provided by the municipality represent a predominantly vehicle-focused infrastructure, which causes significant deficiencies in terms of pedestrian mobility. In particular, the fact that pedestrian-focused elements such as pedestrian crossings, sidewalk connections, and underground passages are not represented in the road network has limited the accuracy and validity of walkability analyses.

In order to address these deficiencies, various attempts have been made to manually add pedestrian crossings to the road network and redefine connection points. However, the inconsistencies between the routes actually used by pedestrians and the official road network in the datasets prevented consistent results from being obtained in directionality, network connectivity, and proximity analyses performed via QGIS plugins. This situation has revealed that road data prepared according to vehicle traffic is insufficient for the spatial representation of pedestrian behaviors and that more qualified, user-based, and detailed datasets are needed in the evaluation of urban walkability.

In this study, visibility analysis was conducted in order to analyze how tram stations are perceived in the environmental context and their visibility levels within the city. The analysis in question was conducted based on three-dimensional building models and topographic data provided by Kayseri Metropolitan Municipality. In the analysis process, the CitySurf program, a local software included in the municipality's institutional Geographic Information System (GIS) infrastructure, was used. The visibility analysis tool in this software allowed visual accessibility assessments to be made by considering buildings and terrain slope within a 500-meter radius for each selected station.

The analyses for each station were conducted separately in two main directions, east and west, depending on the entrance directions. This approach aimed to reveal the impact of both the urban structure and topographic elements on visual connections in more detail. The analysis outputs were obtained as circular visuals representing visibility levels; in these visuals, green tones represent areas with high visibility, and red tones represent areas with invisible or limited visibility.

The obtained analysis outputs were integrated onto maps produced in the QGIS environment in order to better reveal the street and building relationships around the station. Thus, the visual accessibility level of each stop was evaluated through both numerical analyses and map representations; street names, orientations and environmental elements were shown in a way that would provide contextual depth to the analyses. This method was used as a valuable tool in terms of evaluating the perceptibility of the stations within the city and their potential contribution to pedestrian guidance.

Within the scope of the study, it was aimed to access passenger surveys conducted by local governments in order to better understand the satisfaction levels and experiences of tram users regarding the public transportation system. Since such surveys directly reflect the needs and expectations of users, they are an important data source in the evaluation of urban mobility systems. However, despite all the applications, this survey data was not shared with the research by Kayseri Metropolitan Municipality. As a result, direct data on user satisfaction and experience could not be obtained; this created a significant deficiency, especially in terms of evaluating the social dimension of the public transportation system. This situation limited the data-based support of human-centered analyses in the study and caused some comments on passenger behavior to be made only through indirect data.

Despite the numerous limitations encountered in the data acquisition process, the combination of available open-source datasets, manual verification efforts, and spatial analysis tools enabled the development of a foundational analytical framework. This framework, although restricted in scope, provided meaningful insights into the spatial dynamics and functional context of the tram stations. It also underscored the practical challenges of data-driven urban analysis in environments with limited institutional transparency. With this groundwork established, the next step of the study involved determining the criteria for selecting specific tram stations that would be examined in depth through the available data and spatial tools.

4.2.2 Criteria of Station Selection

In this section, the criteria used for selecting specific tram stations for further analysis are outlined. Key factors such as station location, user demand, connectivity with other transport options, and socio-economic characteristics of the surrounding areas are considered. By establishing these selection criteria, the study ensures that the chosen stations represent a range of conditions and challenges, allowing for a comprehensive

evaluation of the system's performance. This study will focus on 4 different stations. Düvenönü, Cumhuriyet Meydanı, Hunat, Büyükşehir Belediyesi. These stations are the most used stations according to 2024 passenger data (Figure 4.5). The stations are also consecutive to each other, as they are in the most active urban spaces. According to Walkscore which is a tool to assess if an area is walkable. Regions that cover all four focus stations had scores above 95 out of 100 (Walk Score, 2024).

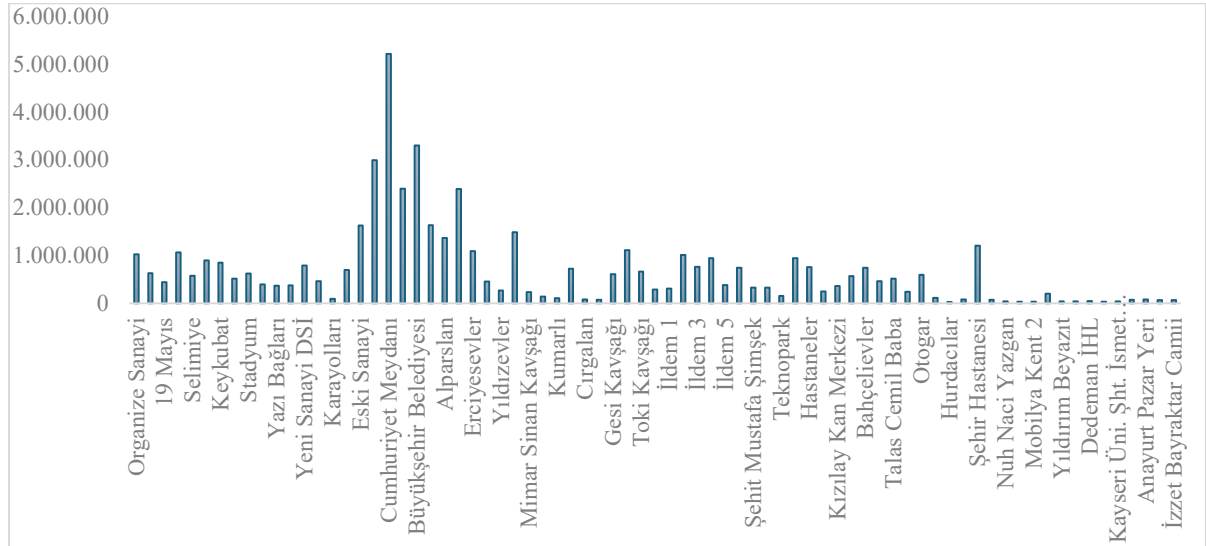


Figure 4.5 Number of Yearly Passengers by Station KayseRay Tram System, 2023 (Data Source: Kayseri Ulaşım, 2023 Yıllık Faaliyet Raporu.)

In this section, Kayseri's light rail system infrastructure, KayseRay tram system, is examined in detail and the role of the system on urban mobility is addressed with a data-driven design and analysis approach. The historical development of the tram system, its operational structure, technical and social components are evaluated; a multi-layered framework regarding the operation of the system is created in line with the information accessible through publicly available data sources, mobile applications and Geographic Information Systems (GIS).

Considering the possibilities and limitations offered by the data infrastructure, the analysis process was carried out through open data sets accessible at the local scale and verified observations. In this context, it was revealed that the tram system is not only a transportation infrastructure but also a social, cultural and spatial actor shaping public life. The findings revealed the decisive role of the tram system in the evaluation of basic urban quality indicators such as urban vitality, accessibility and visibility.

The methodological approach developed at the end of the section emphasizes the importance of data-driven urban analyses and clearly demonstrates the central role of inter-institutional data sharing in academic research. This analysis infrastructure formed the basis of both the spatial context of the KayseRay system and the evaluation method before moving on to detailed station analyses in the next section.



Chapter 5

Data-Driven Urban Mobility and Spatial Assessment of the KayseRay Tram System

This chapter presents a data-based analysis of the KayseRay light rail system, which forms the backbone of the urban transportation system of Kayseri. The analysis is conducted on four key stations located in the city center—Düvenönü, Cumhuriyet Meydanı, Hunat Hatun, and Büyükşehir Belediyesi. The stations are evaluated multidimensionally in terms of accessibility, visibility, liveliness, and spatial characteristics through passenger data, GIS (Geographic Information Systems)-based spatial analysis, and on-site observations. Demographic trends, urban functions, and transportation dynamics are brought together to reveal the functioning, inclusiveness, and design challenges of the public transportation infrastructure. These findings aim to provide a basic framework for a human-centered transportation design and policy development process in the city.

5.1 Passenger Data Evaluation and Routes of Selected Stations

This section presents a detailed examination of the selected stations, Düvenönü, Hunat, Meydan and Büyükşehir, within the KayseRay tram network. Each station's design, accessibility, connectivity, and user experience are analyzed to understand its role within the network. The analysis includes both quantitative and qualitative data, focusing on how each station contributes to or limits the efficiency and inclusivity of the tram system. This evaluation highlights areas for potential improvement and reveals insights into the relationship between station design and urban mobility.

Passenger Data Evaluation: In this study most of the open-source data have been used for analysis methods. Furthermore, some data types were not public. Traffic flow and adaptation principles, camera records for certain time periods, user survey outcomes, fishbone diagrams, architectural projects and passenger use data sets were asked from Ulaşım A.Ş. Research and Development department to be shared for the scope of this study. They shared data sets of passengers of light rail system for 4 stations which are Düvenönü, Cumhuriyet Meydanı, Hunat, and Büyükşehir Belediyesi stations for 14 days from 25th of November 2024 to 8th of December 2024. The data covers peak hours of the day, for morning from 7.00am to 11.00am for evening from 16.00pm to 19.00pm. Data sets include columns for dates, station info, hour, passenger count, and card types.

The dates that this data set has belonged to contain three days of snow holidays which are 25th, 26th and 27th of November 2024. Those days have less passenger counts in total. Also, students and elderly passengers were significantly lower in the data set in those three days. Another feature of this data set is due to the design of the system; passengers use their cards in the station when they enter the system and do not use their card when leaving the system.

The transportation company has inclusive card types and payment methods. They offer discounts or free passes to various groups of society. For these features to be used, passengers must be using their personalized transportation cards that they activated visa each year. The free pass features can be exemplified as, elderly passengers over the age of 65 have free pass rights, as well as veterans, their families and martyrs' families. The greatest group with discount rights are the students. They can use their cards at a discounted price which is around half of the regular price. There is a monthly subscription price tariff to have the right to use standard cards and student cards 150 times a month.

For the scope of this study, the card type column in the data set has 28 different card types. For example, when regular passengers used tram as second vehicle, transferred from another vehicle it is represented as "TAM_AKTARMA" or in data set. Also, if they have a monthly subscription it is represented as "ABONMAN_TAM". Furthermore, there is an option to use bank cards and NFC devices to be used as a payment method this is listed as "BANK_KART". This kind of card type classification was causing many small groups of passenger groups which was making data set not suitable for the data analysis.

As a result, another column named "category" has been added to the data set according to the persona types which are standard, student, elderly, disabled, and others.

Some card types did not have enough number of passengers and effects to the results and less than 1% in this data set have classified in “others” category.

This classification of category has provided results for the light rail system users ratios. Standard card users which will represent adult people below 65. Due to the discount offering in the students section the standard “TAM” card users are not in the education. The majority of tram passengers have standard cards with the 44.5% ratio. The second highest user group is the students they majorly represent the ages from 15 to 25, they cover 41.7% of total users. Elderly users who are aged over 65 cover 8% of the total passengers. Disabled card users represent the disabled people and their companions they cover 5.2% of the users in data set. Other categories represent a minor number of people that could not be included in other categories have a 0.5% share.

According to TÜİK population data of Kayseri when the ages from 0 to 14 excluded, adults between the ages from 25 to 65 is 67.2% of the selected population (Figure 5.1). From 0 to 14 they have been excluded from the population graph because it does not have proper representation in the public transport system data. People between the ages of 15-24 have 20% and 65+ people cover 12.8% of share in the graph. When these two charts compare each other even though elderly people and students have lesser ratio in the population from 14 to 65+ they have a greater number of users in passenger data despite the snow holidays effect in three days. Also, standard card users cover most of the population graph, it does not have that much representation in the passenger data. This reveals that adults do not use public transportation as much as students and elderly people which tends to be more dependent on the public transportation systems.

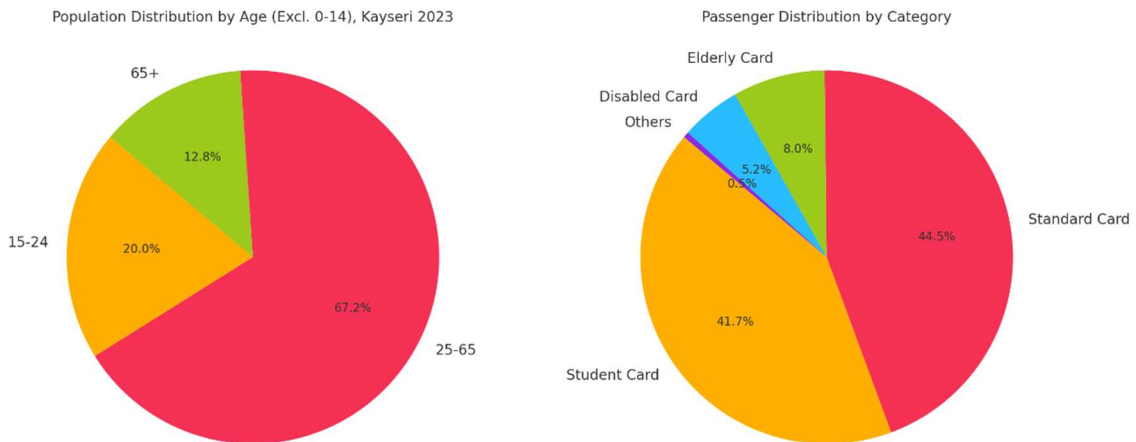


Figure 5.1 Left: Population data of Kayseri when the ages from 0 to 14 excluded, adults between the ages from 25 to 65 (Source: TÜİK, 2023) Right: Passenger Distribution by Category (Source: Kayseri Ulaşım AŞ, 2024)

This is passenger trends during morning hours graph that represents all the passengers in each hour that data shared, it is possible to see the student peak hour was in 8.00am as well as standard card user's peak hour (Figure 5.2). The total peak hour is in the 8 am period for the morning hours. Elderly users tend to travel later than the standard and student passengers.

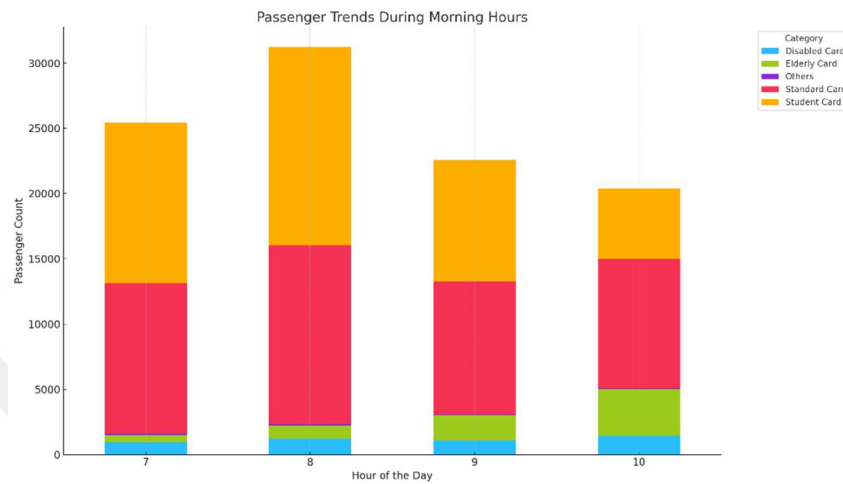


Figure 5.2 Passenger Trends During Morning Hours Graph (Source: Kayseri Ulaşım AŞ, 2024)

Evening peak hour graph shows students tend to have peak hours earlier than the standard users (Figure 5.3). Similarly, older passengers have peak hours at 16pm which decrease over time. To break out the data to see trends clearer, 15-minute intervals are created.

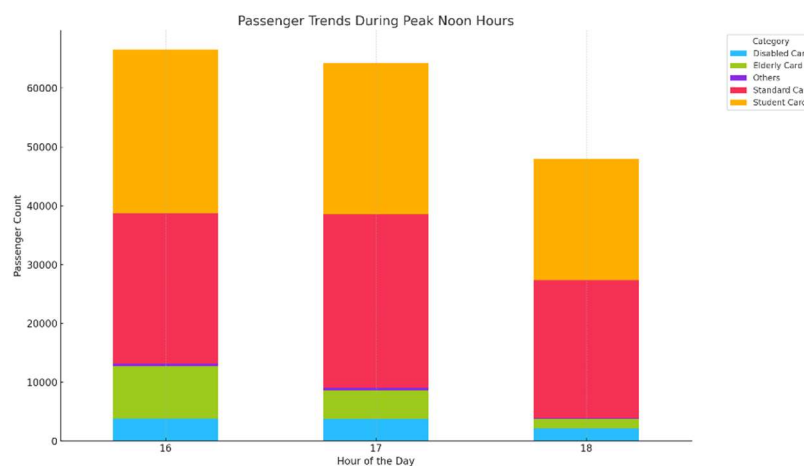


Figure 5.3 Evening Peak Hour Graph (Source: Kayseri Ulaşım AŞ, 2024)

The graph, which is created according to 15-minute periods for all passenger categories, shows the peak hours during the day for each card type (Figure 5.4). Since passengers only verify their cards at the station entrance and do not verify them at the exit, the graph only reflects the entrance data. The fact that the number of users is relatively low in the morning and higher in the evening indicates a tendency towards the city center in the morning hours and a distribution towards final destinations not included in the data set in the evening hours. This situation reveals that the examined stations function as attraction points in urban life in the morning hours.

In the morning hours, the highest density is observed for students and standard card users at 08.15 am. In the evening hours, the density peak for student card users is at 4.15 pm, which coincides with the period when the school day ends. For standard card users, the density peaks at 5.30 pm, which is consistent with the end of work hours in the winter season. On the other hand, elderly passengers prefer to travel after the morning rush and before the evening rush, which shows that they travel in calmer periods.

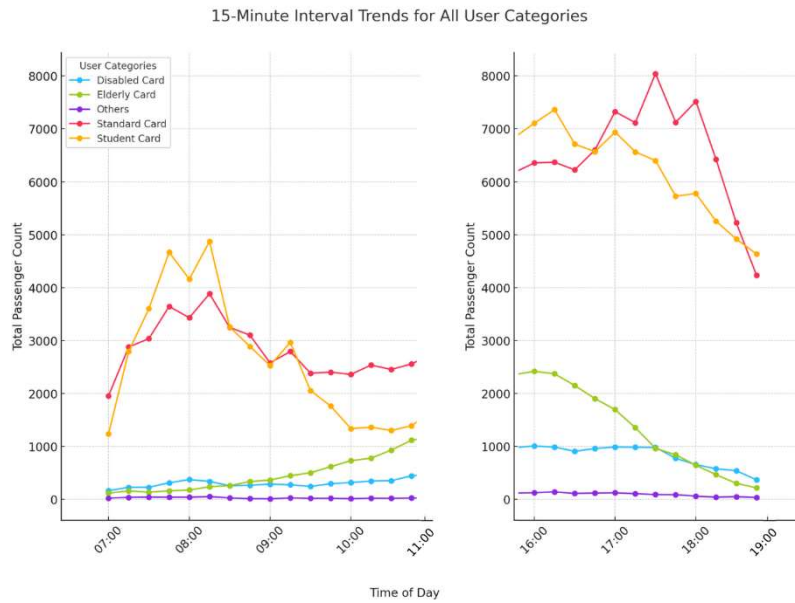


Figure 5.4 15 Minutes Interval Trends for All Passenger Categories Graph (Source: Kayseri Ulaşım AŞ, 2024)

Correlation representation shows the relation between diverse types of personas (Figure 5.5). Since the other group represents 0.5 percent of the passengers, its correlations do not cause a remarkable outcome. Another significant correlation is the difference between student and standard card users which points out to the peak hour being caused by both of those types. As mentioned in the previous graph, elderly

passengers have different trends compared to the main two passenger groups which are standard and student card users. Elderly passengers have low correlation with students which is 0.60 and with standard card users 0.58. This correlation data shows that elderly people tend to avoid the majority of the passengers.

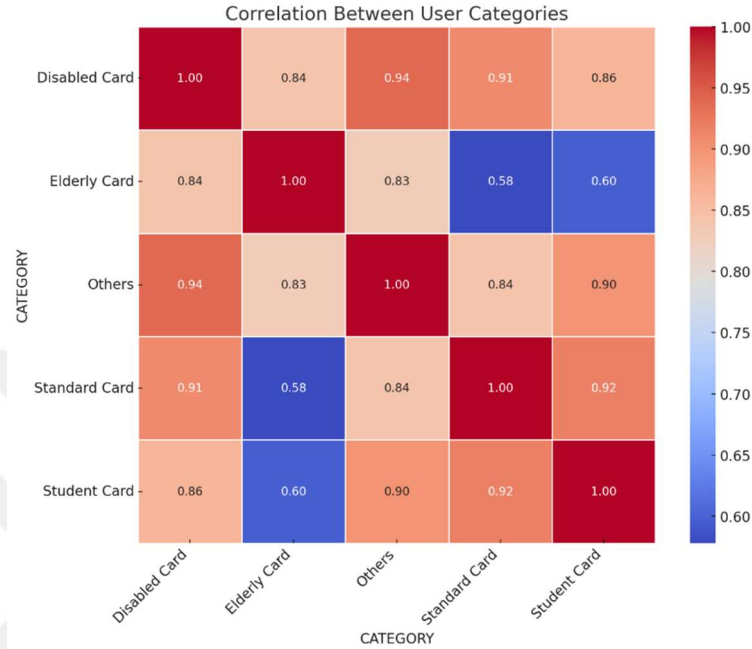


Figure 5.5 Correlation Between User Categories Graph (Source: Kayseri Ulaşım AŞ, 2024)

This passenger trends by category over time by date graph represents passenger trends of each category in each day for 14 days (Figure 5.6). Main significant feature is that from 25th to 27th of November 2024 was snowy days and local government have announced winter holiday for schools. So, students were not travelling for their routine school day. Also, even though elderly people tend not to travel on the weekends and prefer to travel on weekdays, they did not travel as much on the 25th of November due to the weather conditions. This also shows the effect of weather conditions on urban life (Gehl, 2010). Except for the snow holidays, the least travelled periods are the weekends, especially the Sundays. This data reveals that around 35% of the travels are necessary rather than optional.

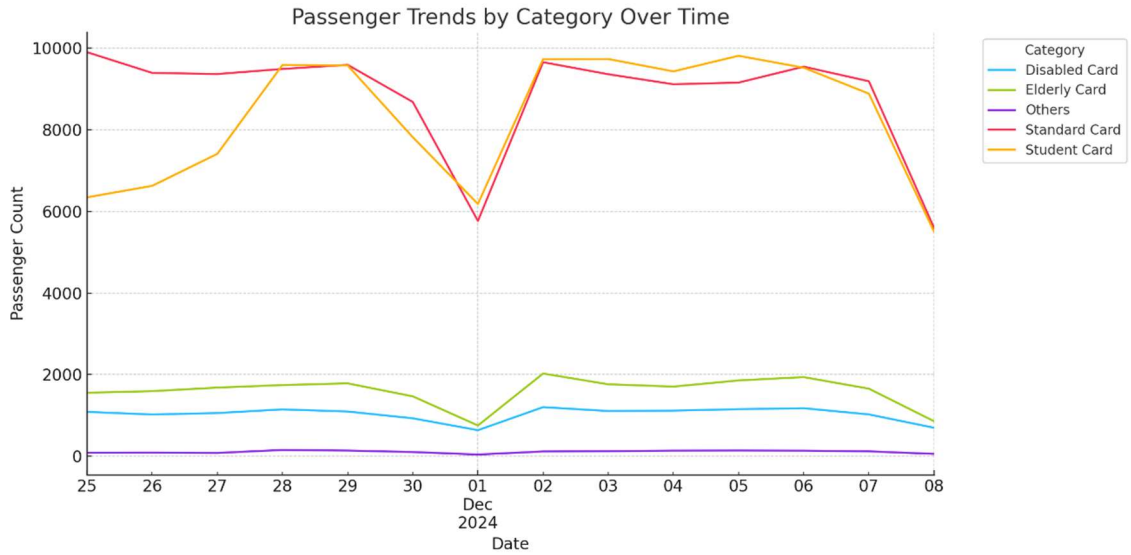


Figure 5.6 Passenger Trends by Category Over Time by Date Graph (Source: Kayseri Ulaşım AŞ, 2024)

This correlation of weather conditions with passenger categories graph shows the number of passengers by category represented in the column of the minimum temperature of each day (Figure 5.7). Since the data set was limited to 14 days, this graph does not provide correlation between the daily minimum temperature level with the number of the passengers. Considering the previous graph with this one snow had a greater influence on passenger behaviors compared to the temperatures. Similarly, even though Sunday last Sunday was significantly warmer, it did not cause an increase in the number of travelers.

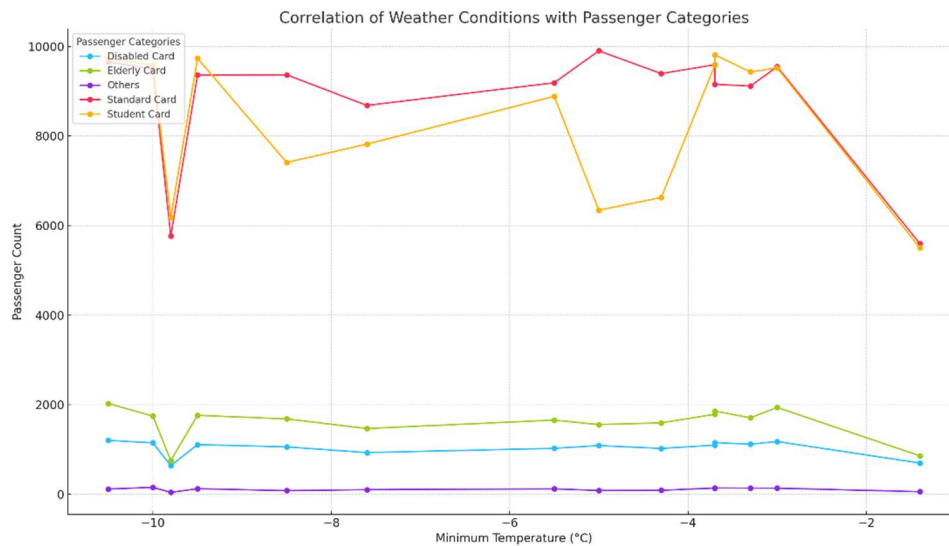


Figure 5.7 Correlation of Weather Conditions with Passenger Categories Graph (Source: Kayseri Ulaşım AŞ, 2024)

The passenger trends differ by station; some stations have more passenger traffic compared to other stations. This graph shows similar trends to the yearly passenger trends as the station graph. Cumhuriyet Meydanı station has the highest traffic of passengers among the selected 4 stations (Figure 5.8).

There are a few causes for it that can be listed below. First, it is the historical center for Kayseri city, and before the significant expansion of Kayseri in second half of the 20th century, Cumhuriyet Meydanı was the focal point of the city. It is surrounded by historical elements like the Grand Bazaar, the castle, mosques, a madrasa, and complexes. Furthermore, there are shops, a shopping center, cafes and an archeology museum. The second cause is the radial design of the transportation system of Kayseri. Many bus routes start from a close environment of Cumhuriyet Meydanı and collect large amount of their passengers from the stations around Cumhuriyet Meydanı. Similarly, two of the routes that connect Talas districts, end point is the Cumhuriyet Meydanı Station. Since passengers use their card when entering the system, this quality can increase the number of users in this station. The other three stations are also in highly vital areas and have distinctive features.

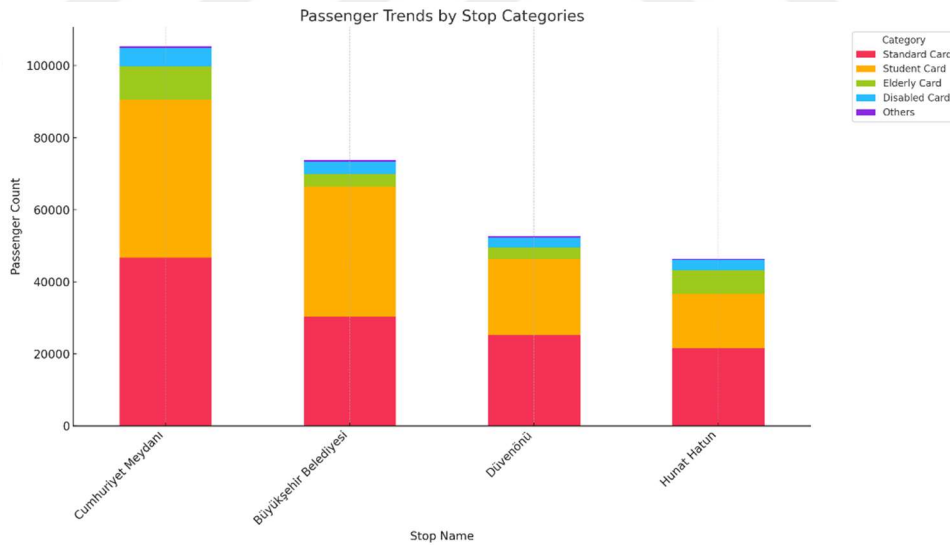


Figure 5.8 Passenger Trends by Station Categories (Source: Kayseri Ulaşım AŞ, 2024)

This heat map shows the peak hours for each station for selected peak hour data (Figure 5.9). With this map it is possible to see the differences between the peak hours of the stations. This heat map also shows the significant user load in the Cumhuriyet Meydanı Station. Cumhuriyet Meydanı has peak hour at 16pm like the Düvenönü and Hunat Hatun stations. On the other hand, Büyükşehir Belediyesi station has its peak hour

value at 17pm. Morning peak hours are 8am for three of the stations Büyükşehir Belediyesi, Cumhuriyet Meydanı and Düvenönü but Hunat Hatun Station has its peak hour at 10am.

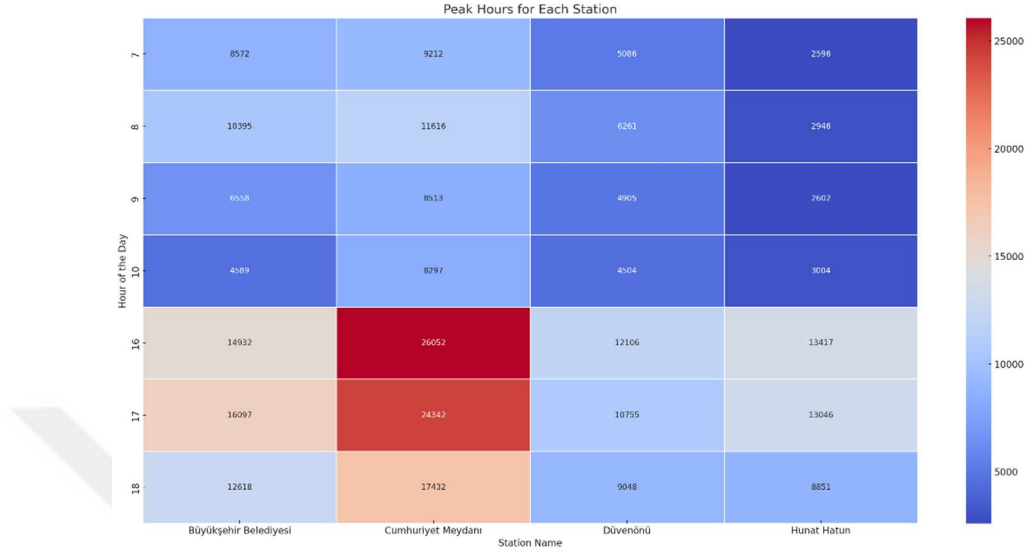


Figure 5.9 Peak Hours for Each Station (Source: Kayseri Ulaşım AŞ, 2024)

To see characteristics of stations a bar graph of each user category is shown (Figure 5.10). For all categories of passengers, the most preferred station is the Cumhuriyet Meydanı station. Furthermore, in three of the stations standard users are the primary users on the stations. On the other hand, in Büyükşehir Belediyesi Station students are the dominant group of users. Most elderly passengers in the data set prefer the stations of Cumhuriyet Meydanı and Hunat Hatun compared to the other two stations.

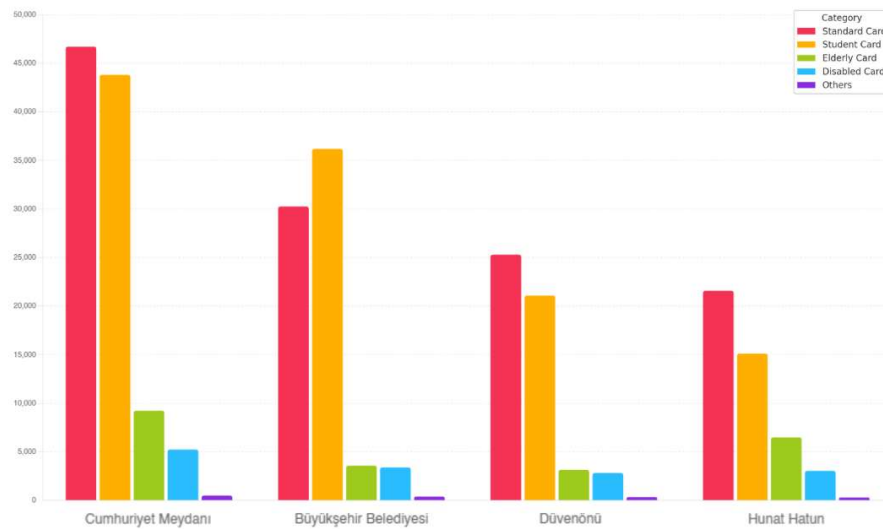


Figure 5.10 Passenger Trends by Categories for each Station (Source: Kayseri Ulaşım AŞ, 2024)

The number of passengers divided into categories changes over time, which is divided into 15 min intervals for each selected station represented above, some differences in trends are noticeable (Figure 5.11). Elderly people and disabled people do not prefer the Büyükşehir Belediyesi station noticeably. This outcome can be caused by Büyükşehir Belediyesi station is underground, requiring stairs and elevators to access the platform. Also, the entrance in the North, which leads to the Municipality itself and a shopping mall, has stairs to go to the platform and provides an escalator for the people who lead to the ground level. Even though one elevator at each exit is provided, the accessibility is harder in this station compared to the other stations selected, which serve on the ground level.

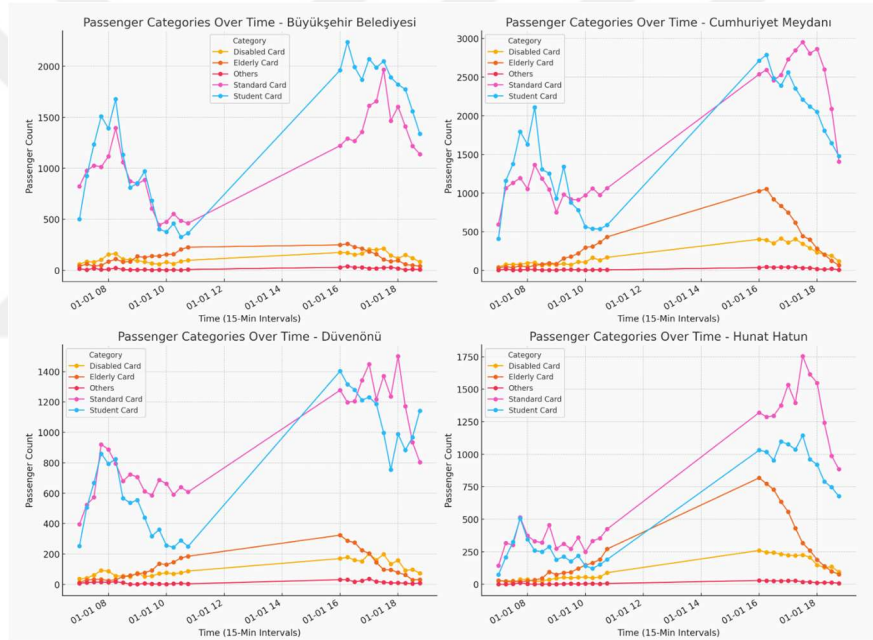


Figure 5.11 Passenger Categories Over Time for Büyükşehir Belediyesi, Cumhuriyet Meydanı, Düvenönü and Hunat Hatun Stations (Source: Kayseri Ulaşım AŞ, 2024)

Data Evaluation of Selected Stations: Data sources have been studied by use of open data sources of Open Street Map data and Açık Veri Platformu of Kayseri Municipality. To evaluate the data, Data sources have been overlapped. The limits of the study were having open-source data. Since the data source provided by the Open Street Map is also being edited by individuals, majority of the data sources have not been used.

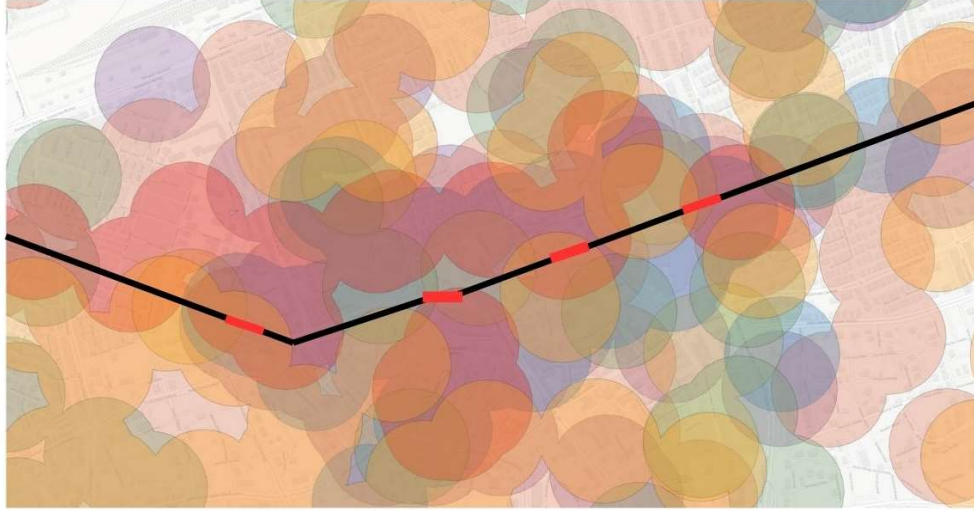
The data sets for schools, libraries, public service buildings, green areas, mosques, shops, banks, cafes and restaurants have been used to create the evaluation maps.

Libraries and schools have been merged, and education facilities layers have been created. Similarly, cafes and restaurants have been merged to represent the food places.

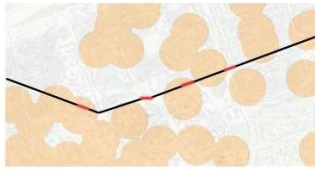
The center of each building or area has been used to create centroids. Then, circles with a radius of 200 meters have been created around the centroids. They diffused to show the impact area around them. Their opacity has been lowered by 20% and the tram route is marked as well as the position of the tram stations.

Categorized passenger data of the selected four stations provides essential information about temporal and demographic mobility trends. When these data are considered next to data from GIS (Geographic Information System) environment, patterns such as directional flows, transfer densities, and spatial demographic usage peaks become spatially analyzable. For example, by matching the geographical location of standardized user categories (student, elderly, standard, etc.) with specific tram stations and surrounding urban functions, it is possible to determine how spatial attributes such as schools, shopping malls, or public buildings affect user behavior. This spatialization process makes abstract numerical data meaningful in a geographical context, increasing the capacity to evaluate the relationship between urban form, land use, and infrastructure and public transportation use.

GIS (Geographic Information Systems) data visualizes the spatial distribution of service areas, public spaces, land uses, and transportation networks by providing a layered understanding of the urban environment around tram stations. When these spatial data are evaluated together with categorized passenger usage data, it is possible to analyze how certain spatial features shape public transportation demand. For example, the presence of educational institutions or commercial areas within a 200-meter radius around a station can explain the intensive use of students in the morning hours. Similarly, physical accessibility data obtained through route analyses can be used to explain why elderly or disabled passengers do not prefer certain stations (such as the Büyükşehir Belediyesi station, which has limited access due to its underground structure). From this perspective, GIS tools not only support the spatial interpretation of passenger data, but also serve as an important analysis tool in revealing the reasons for observed mobility trends and accessibility problems (Figure 5.12).



Map of Kayseri city center overlaid with seven spatial data layers representing key urban functions: education facilities, banks, cafes, green areas, shops, mosques, and public buildings. Each data layer is visualized using semi-transparent colored circles in radius of 200 meters to indicate the distribution and density of these urban elements across the city. The overlapping areas highlight zones with multiple urban functions, allowing for an analysis of urban intensity, accessibility, and multifunctionality within the central area of Kayseri.



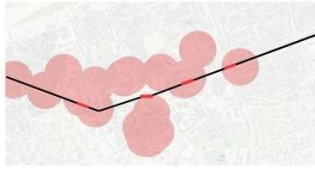
Map of Kayseri city center of education facilities



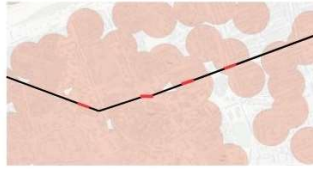
Map of Kayseri city center of public buildings



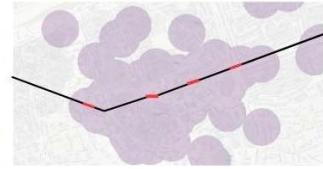
Map of Kayseri city center of green areas



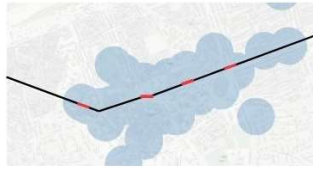
Map of Kayseri city center of bank offices



Map of Kayseri city center of mosques



Map of Kayseri city center of shops



Map of Kayseri city center of cafe and restaurants

Figure 5.12 Locations of the Düvenönü, Cumhuriyet Meydanı, Hunat Hatun and Büyükşehir Belediyesi Stations in Kayseri City Center (top), Kayseri City Center Map with Urban Elements with 200 meters Radius Overlapped with 20 Percent Opacity (middle), Individual Urban Element Layers of Education Facilities, Banks, Cafes, Green Areas, Shops, Mosques, and Public Buildings (bottom) (Source: Open Street Map and Kayseri Ulaşım AŞ, 2024)

Routes of Selected Stations: There are various uses of the city center. To assess the characteristics of the areas, a deeper representation of the space around each station was needed. For this purpose, routes around the Düvenönü, Cumhuriyet Meydanı, Hunat Hatun and Büyükşehir Belediyesi stations have created.

Düvenönü Station Routes:

This station is located between the highway lines and as a result requires crossing the highway for each one of the selected 6 Routes.

Route 1- This route leads to the clothing stores on the İnönü Boulevard. Along the path there are various shops such as jewelry, ice cream, café, bakery, etc. This walking route is around 240m meters and takes 3 minutes, except for the traffic light waiting periods (Figure 5.13).

Route 2- This route leads to the Tekden Hospital which is one of the private hospitals around this region. This walking route is around 350m meters and takes 5 minutes.

Route 3- This route leads to the Public Hospital which is one of the biggest hospital complexes with different blocks. This walking route is around 800m meters and walk takes 11 minutes.

Route 4- This route leads to the old industry region. This area is still active as they continue to trade activities and through this path there are also a few private hospital buildings as well as pharmacies. This route is also highly disrupted with the walking route is around 650m meters and walk takes 9 minutes.

Route 5- There are many hotels and dormitories in this district. One of the hotels in the perimeter is marked as a representation of an urban mobility type. This route is also highly disrupted by cars. This walking route is around 150m meters and walk takes 2 minutes.

Route 6- This route leads to the private teaching institutions in this area. There are also copy centers and stationaries to serve to the student users. This walking route is around 150m meters and walk takes 2 minutes.

routes lead to different districts of Kayseri. This walking route is around 270m meters and takes 4 minutes except for the traffic light waiting period.

Route 3- This route leads to the historic Grand Bazaar building. To access there a walk-in front of the Bürüngüz Mosque is required. Then the bazaar area is accessible. It is a highly active shopping region. There are various shops which sell clothes, shoes, jewelry, various traditional elements and many other materials that can be found. Especially in the street part, there are many pastrami sellers which is a food that has been paired with this city.

Route 4- This is a transit passenger connection route. The people who come from the tram system can transfer to the ‘Kaleönü Aktarma Durağı’ by a walk by the Kayseri Castle. This station serves 39 different bus routes. Majority of the routes lead to the Talas district. This walking route is around 270m meters and takes 4 minutes.

Route 5- This route leads to the public service area in the square. There is the Governor’s Building and Civil Registration and Citizenship Offices at the end of the route.

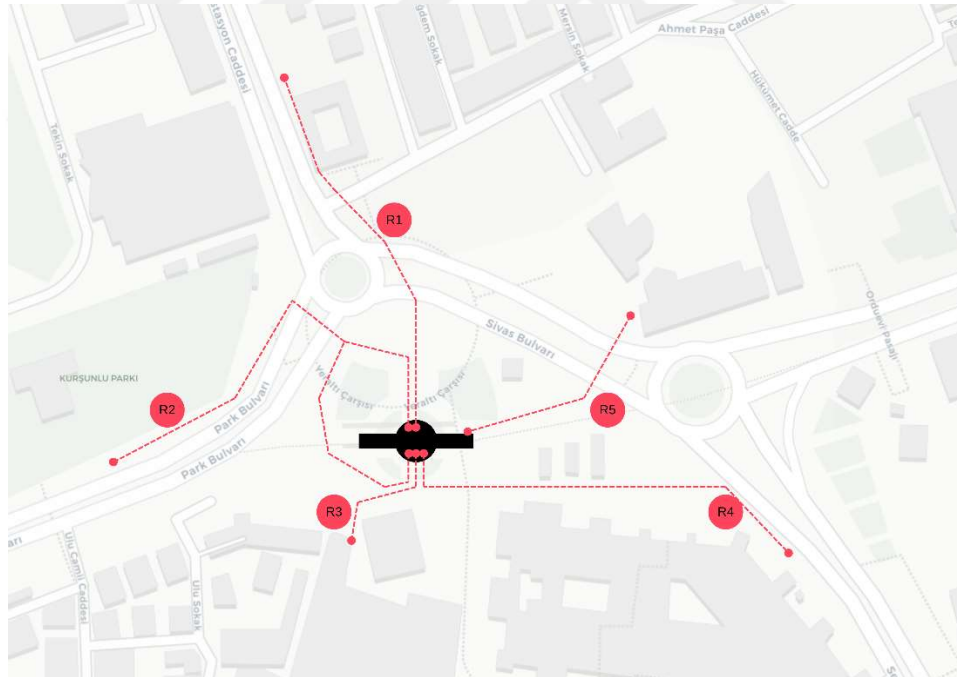


Figure 5.14 Location of the Cumhuriyet Meydanı Tram Station with Routes

Hunat Hatun Station Routes:

Routes 1, 2, 3 and 5 serve commercial activities in this region. Since the station is in the middle of the street each route requires a pedestrian crossing to leave the island of

the platform. Selected routes on this station are quite short because this station is close to neighboring stations (Figure 5.15).

Route 1- This route leads to the fish sellers' area near the station on Sivas Boulevard.

Route 2- This route leads to restaurants and cafes. The walking experience is mainly disrupted by the discontinuous walking paths and parked cars.

Route 3- This route leads to the secondhand book sellers' area in Birkan Street which is parallel to the Sivas Boulevard.

Route 4- There is a library building which is in actively used by students to study their exams which is named as Necmettin Feyzioğlu Halk Kütüphanesi

Route 5- This path leads to the multi-story car park building with commercial use on the ground floor. This route is also likely to be disrupted by parked cars.

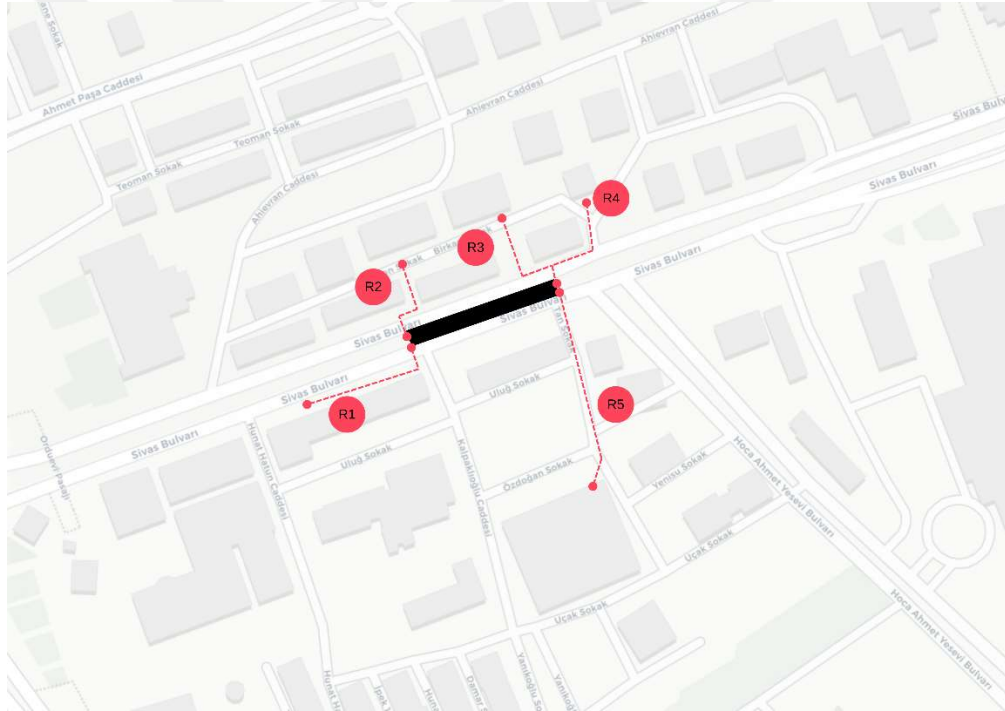


Figure 5.15 Location of the Hunat Hatun Tram Station with Routes

Büyükşehir Belediyesi Station Routes:

Route 1- This route leads to Kayseri Forum Shopping Mall. This building has various shops, cafes, restaurants, supermarkets etc. This is one of the main attractors for the Büyükşehir Belediyesi station (Figure 5.16).

Route 2- This path leads to the library of Kayseri Metropolitan Municipality. Many students use this building for their study activities.

Route 3- This path leads to a group of high school buildings at the end of the Ahmet Paşa Street. Due to the design of the transportation system, students tend to walk to the main Sivas Boulevard through the diagonal street to use public transportation. This walking route is around 1300m meters and takes 18 minutes.

Route 4- This route leads to the Kayseri Metropolitan Municipality front yard. This area is highly active on warmer days as it has green and water elements.

Route 5- This route leads to Ted Kayseri College, which is an education complex consisting of a couple of buildings. This walking route is around 550m meters and takes 7 minutes.

Route 6- This route leads to the commercial area with various shops such as electronic stores, fast food restaurants, hairdressers etc.

Route 7- This route leads to the public service buildings which are Melikgazi Municipality and KCETAS buildings at the South side of the station. This walking route is around 450 meters and takes 6 minutes.

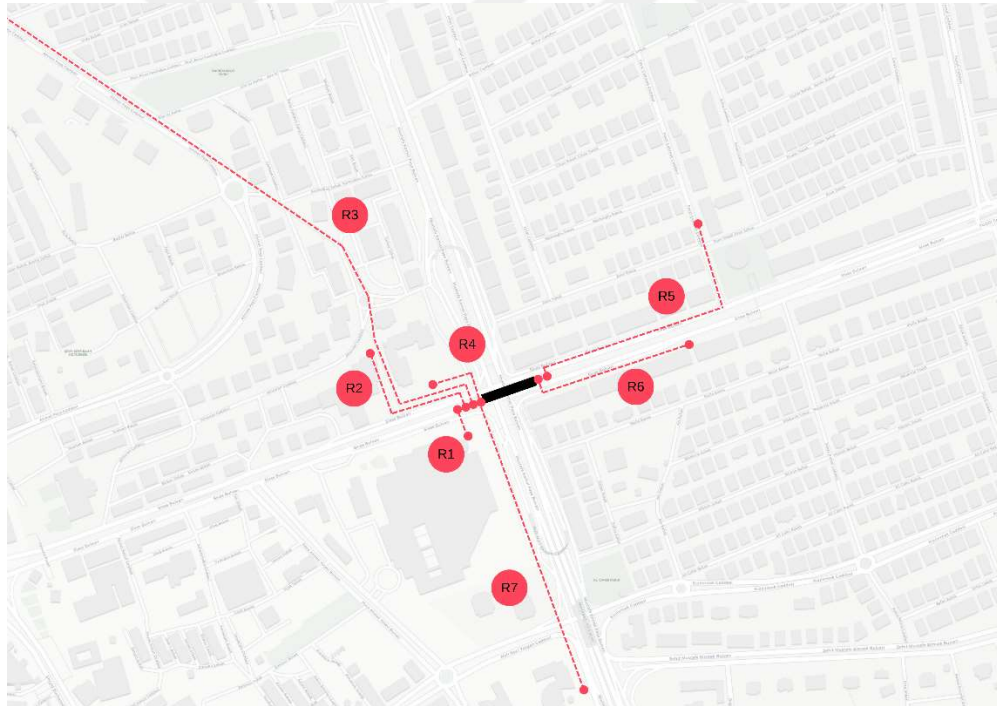


Figure 5.16 Location of the Büyükşehir Belediyesi Tram Station with Routes

5.2 Evaluation of Key Tram Stations in Kayseri:

Accessibility, Visibility, and Vitality

In this section, the four busiest and most representative stations of the Kayseri tram system, Düvenönü, Cumhuriyet Meydanı, Hunat Hatun and Büyükşehir Belediyesi, are comprehensively analyzed. The selected stations are of critical importance in terms of urban mobility and public life, and are evaluated multidimensionally in terms of both the physical environment and user profile within the framework of accessibility, visibility and vitality criteria. These analyses provide important inferences not only about transportation performance but also about the quality of use of public spaces, the experiences of different user groups and the interactions of stations with their environmental contexts. Each station assessment in the section is structured with the aim of identifying current problems and developing design and planning suggestions, supported by data-based spatial analyses and user-focused observations.

5.2.1 Düvenönü Station

The Düvenönü station is in the Osman Kavuncu Boulevard in the Northern part of the city square. This station serves shopping areas, health facilities and some parts of the industrial zone. Unlike other studied stations, this station has only served to İldem 5- Organize Sanayi and İldem 5- Kumsmall lines yet does have high numbers of passengers. Drawings of the station have been provided with the linear map scale and North signs (Figures 5.17, 5.18, and 5.19).

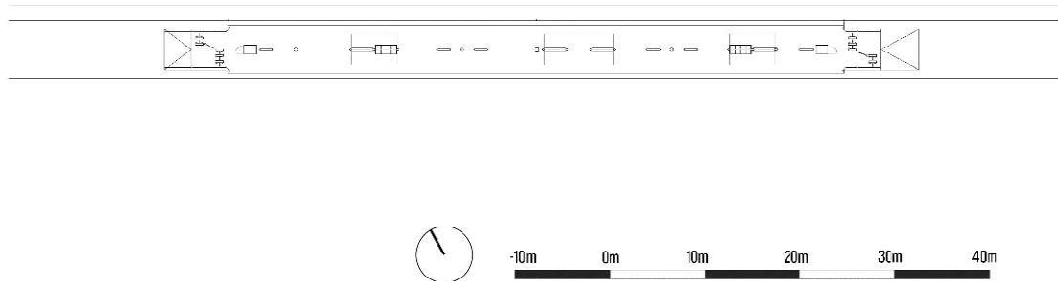


Figure 5.17 Drawing of Düvenönü Tram Station. Entrances, seating units, shading elements, and ramps have been represented. Drawing includes a north orientation arrow and a graphic scale bar of 10 meters for reference.



Figure 5.18 Sections of Düvenönü Tram Station. Drawing includes a graphic scale bar of 10 meters for reference



Figure 5.19 Düvenönü Tram Station Drawing overlapped with satellite image. Drawing includes north direction representation and a graphic scale bar of 10 meters for reference

Accessibility: The station is at the ground level and slightly elevated to match the level of the vehicle. Ramps are provided at the entrances of the station (Table 5.1). The station is in between the two directions of highway this feature requires people to use pedestrian crosses to travel between the platform and sidewalks. In this station there are no traffic light controls. Yet, there is heavy traffic flow constantly, and drivers are not prioritizing the pedestrians. This causes pedestrians to wait for a slow car or a polite driver to walk to the sidewalks. Thus, walking from one side of the street to the other one is disrupted by car traffic and tram activity. Yet, this is the only station that has served only two tram

routes, unlike other selected stations. This feature also represents heavy passenger traffic even though there are fewer route possibilities. When the surroundings of this station are evaluated, the connections of the pedestrian crosses at the entrances of the station do not have ramps for easy access. There is only ramp access on the North-East side of the station, yet there is a car parking slot in front of it (Figure 5.20). Another option for ramp access is when the station leaves from the East entrance and walks 80 meters until the traffic lights; ramps are provided on each side of the street. At the entrances of the station, pedestrian crosses are not well designed. Especially on the North side of the station, there are car parking slots at the end of the pedestrian cross. This feature, combined with the lack of ramps and traffic culture that prioritizes cars, is causing bigger accessibility issues for pedestrians. The platform type is a single platform, which is easier for navigation in the station. This station is located 510 meters away from the Cumhuriyet Meydanı station. On the other direction, the next station is Eski Sanayi station, which is 815 meters away from this station. This distance is the highest distance in the inspected region.

Table 5.1 Accessibility of Düvenönü Tram Station

ENVIRONMENT		measure(yes/no/partially)	
Elevation	Being in Urban Level	yes	
	Ramp Requirement and Access	yes	
	Stair-Escalator-Lift Requirement and Access	no	
Traffic Lights	Pedestrian Cross Requirement and Access	yes	
	Synchronous Pedestrian Cross	no	
	Button Push Requirement for Green Light	no	Is not restricted with traffic lights but heavy traffic and lack of prioritization of pedestrians cause delay and risk of accidents
Obstruction on Surrounding	Ramp Requirement and Access	no	
	Vehicle Obstruction on the Pedestrian Cross	yes	
	Heavy Vehicular Traffic	yes	
Platform Type	Single Platform/Double Platform	Single Platform	
Distance Between Station Entrances	In meters(West)	815	
	In meters(East)	510	
INCLUSIVITY		measure(yes/no/partially)	
Direct Entrance for Wheelchair Users		no	Requires 45 degree turn for disabled people to enter station
Tactile Ground Coverings Surrounding the station	End of Platform	yes	
	Each Side of Pedestrian Cross	yes	But it does not have any indication to leading pedestrian cross or station
	Intersection with Rails	yes	



Figure 5.20 Photos around Düvenönü Tram Station Left: Pedestrian crossing in the North-East of the station. Right: Pedestrian cross of North-West exit of the station

To access the platform, wheelchair or stroller users should turn 45 degrees to pass security. There are tactile ground coverings at the boarding side and entrances of the stations. The tactile ground coverings indicate the end of the walkable area and point out the start of the rails. On the other hand, after leaving the station island and accessing the sidewalks, there is tactile paving on the station's South side (Figure 5.21). Also, pedestrian crosses that lead to access to the station are not indicated with studs (Figure 5.22).



Figure 5.21 Photos from Düvenönü Tram Station Left: Tram and station interaction. Right: Pedestrian cross of East exit of the station.



Figure 5.22 Photo of Düvenönü Tram Station entrance

Visibility: This station is visible throughout the street it is located on. Yet, the radial analysis that is taken from each entrance of the station shows that the visibility from other directions is not highlighted. At the East entrance, there is higher visibility compared to the West since it is closer to the intersection comparatively (Table 5.2). The line of sight is disturbed by the cars parked on the side of the street and intersections with pedestrian crossings.

Table 5.2 Visibility of Düvenönü Tram Station

STATION VISIBILITY		measure(yes/no/partially)
Station Visibility	Being in Urban Level	yes
Radial Analysis in 500-meter Radius	West Exit	

			
	East Exit		
LINE OF SIGHT		measure(rare/medium/frequent)	
Obstructions on the Entrances of the Station	Car	yes	Car parking spaces located at the ends of the pedestrian crosses. Path cannot connect to a sidewalk
	Vegetation	no	

Vitality: Passenger ratios are different from other stations' profiles in some respects. Düvenönü station has the highest ratio of standard card users (Table 5.3). This correlates with this area's character being significant in shopping and business areas. Also, due to the high density of educational activities in this station, student card users also have a higher ratio. In terms of commercial variety, this area has activities that are highly diverse. There are fast food shops and bakeries. It is an area close to an industrial zone, and many banks have their offices around this station. Many hotel buildings and student dormitories are located nearby. There are many clothing stores, textile shops, phone stores etc. This area is highly active with various commercial activities. There are many course centers for educational purposes along with the student dormitories. Furthermore, there is a remarkable number of historical mosques, such as Camikebir and Güllük Mosques, as landmarks of the city. Many private and public hospitals are also located on the North side of the station. There are no temporary events organized.

Table 5.3 Vitality of Düvenönü Tram Station

PASSENGER DIVERSITY		ratio
Standard		47.4%
Student		35.5%
Elderly		7.4%
Disabled		8.0%
Others		1.1%
COMMERCIAL VARIETY		measure(rare/medium/frequent)

Restaurant and Café	medium	There are fast food shops and bakeries
Banks	frequent	It is an area close to an industrial zone and many banks have their offices around this station.
Temporary Accommodation	frequent	Many hotel buildings and student dormitories are located near by
Shops	frequent	There are many clothing stores, textile shops, phone stores etc.
BUILDING TYPE DIVERSITY		measure(rare/medium/frequent)
Commercial Buildings	frequent	This area is highly active with various commercial activities
Public Service Buildings	rare	
Educational Buildings	frequent	There are many course centers for educational purposes along with the student dormitories
Residential Buildings	medium	
Religious Buildings	frequent	There are many Republic Period mosques. Furthermore, there are remarkable amount of historical mosques such as Camikebir and Güllük Mosques.
Health Service Buildings	frequent	Many private and public hospitals are located on the North side of the station
EVENTS		measure(yes/no/partially)
Occurrence of Temporary Events	no	

The evaluated environment demonstrates a significant lack of vegetation and green elements, as both trees and grass areas are absent (Table 5.4). This absence suggests a visually hard, potentially heat-retentive urban space, offering minimal ecological or aesthetic benefits typically provided by greenery. In terms of comfort conditions, there is some positive contribution from urban shading, from surrounding buildings, which can help mitigate heat and improve pedestrian comfort. However, platform cover is only partial, providing incomplete protection from weather elements such as rain or sun. Additionally, the lack of noise and wind precautions indicates poor environmental buffering, which results in a noisy and uncomfortable atmosphere. Overall, while the presence of urban shading offers some relief, the absence of greenery and other comfort-enhancing features highlights the need for design improvements to create a more livable and inviting public space.

Table 5.4 Other Features of Düvenönü Tram Station

VEGETATION AND GREEN ELEMENTS IN ENVIRONMENT		measure(yes/no/partially)
Trees	no	
Grass Areas	no	
COMFORT CONDITIONS		measure(yes/no/partially)
Shading from Urban Environment		yes
Platform Cover		partially
Noise Precautions		no
Wind Precautions		no

According to the crowd simulations, this station is having lowest occupation among all stations. There are a high number of passengers compared to the majority of the stations (Figure 5.23). Yet, lowest density among the selected stations is in Düvenönü station. The fact that this station only serves two lines can be aligned with this outcome. This station also has a shorter agent time to exit, which shows that there is a quicker flow compared to the other stations with different entry designs.

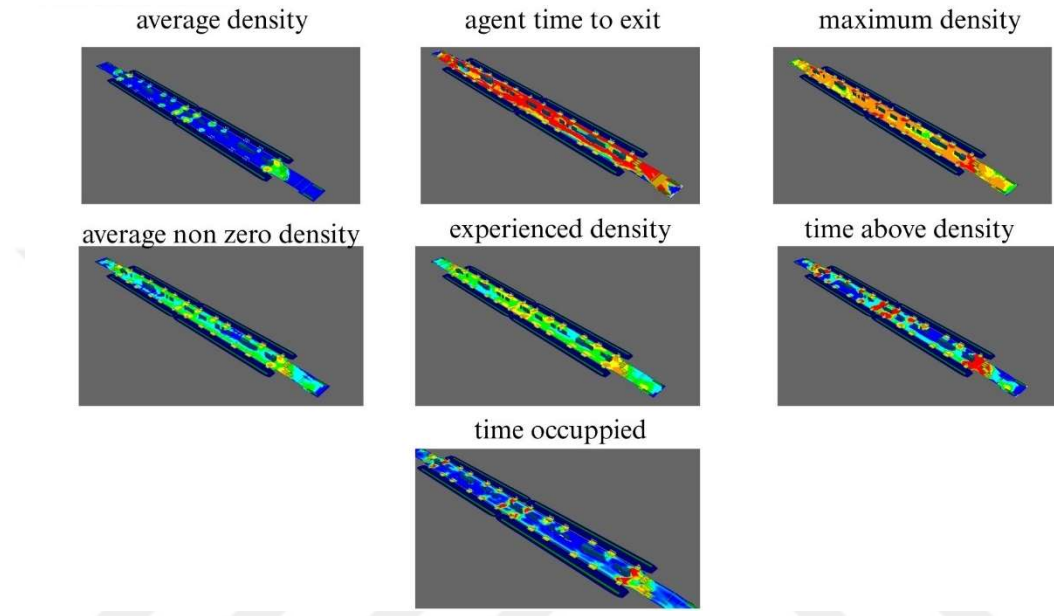


Figure 5.23 Düvenönü Station Simulation Outcomes

5.2.2 Cumhuriyet Meydanı Station

This station is in the main square of the city. There are four main arteries intersecting around this station, Sivas Boulevard, İstasyon Street, Seyyid Burhanettin Boulevard and Park Boulevard. This station is the terminal station for the Talas and Anayurt Districts. Also, majority of the bus lines start or end their journey around this square and head to their selected neighborhoods. This station is a highly preferred transfer station. Also, it has the highest number of users. There are Kayseri Castle, Archeology Museum, shopping districts, mosques, Kurşunlu Park, active streets, restaurants and cafes around the station. Drawings of the station have been provided with the linear map scale and North signs (Figures 5.24, 5.25, and 5.26).

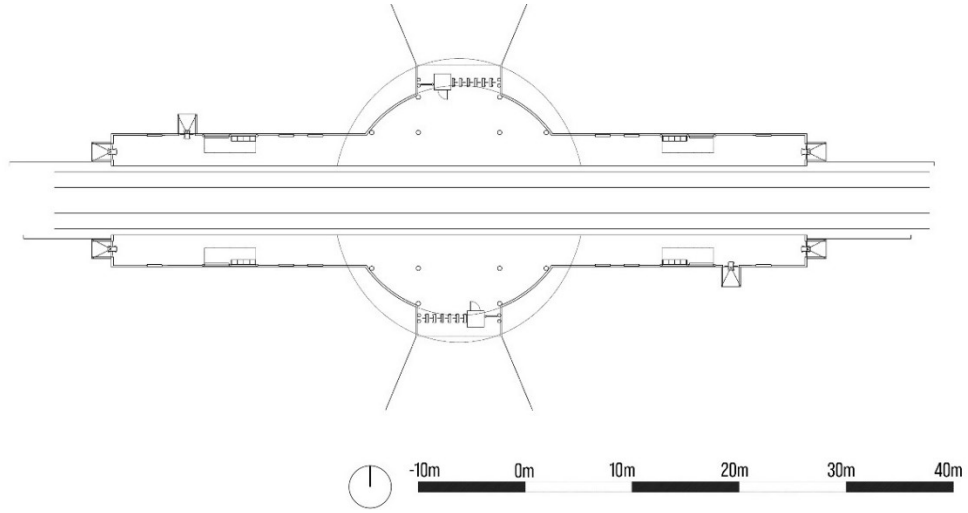


Figure 5.24 Drawing of Cumhuriyet Meydanı Tram Station. Entrances, seating units shading elements and ramps have been represented. Drawing includes a north orientation arrow and a graphic scale bar of 10 meters for reference

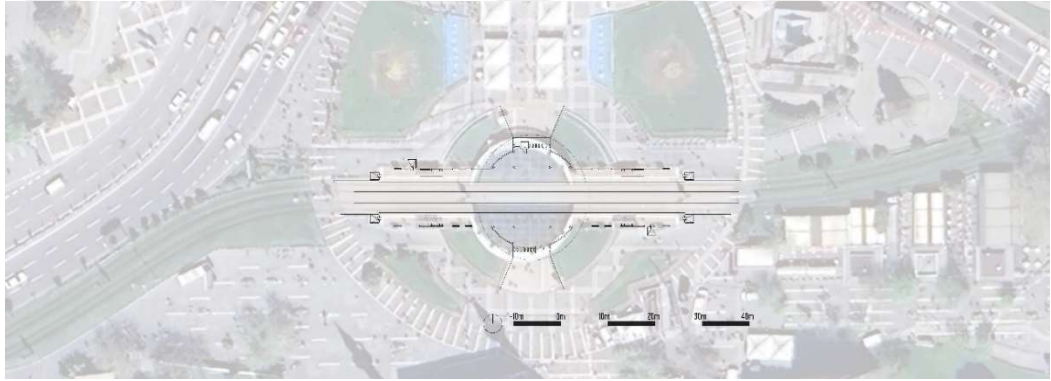


Figure 5.25 Cumhuriyet Meydanı Tram Station Drawing overlapped with satellite image. Drawing includes north direction representation and a graphic scale bar of 10 meters for reference

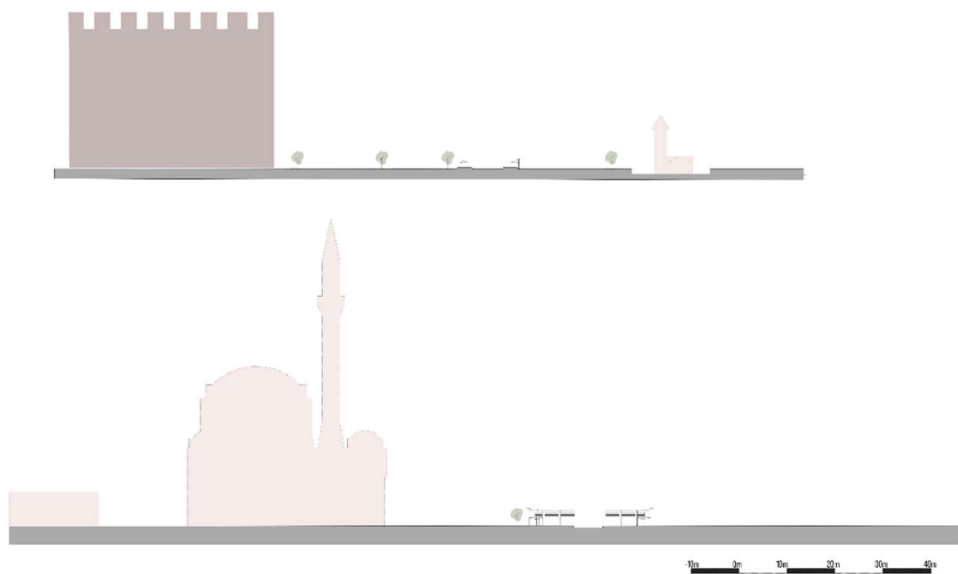


Figure 5.26 Sections of Cumhuriyet Meydanı Tram Station. Drawing includes a graphic scale bar of 10 meters for reference

Accessibility: Cumhuriyet Meydanı Station is in the intersections of Park Boulevard, İstasyon Street, Seyyid Burhanettin Boulevard, and Sivas Boulevard. The high number of buses start or end their routes around the square. So, this square is the main transfer area. The tram station is in the building block containing the Grand Bazaar, a Castle that hosts the Archeology Museum and cafes, Clock Tower, and multiple bus stops.

The station is located on the ground level, and it is easy to access because of this feature. Since this station is in a walkable area, users do not come into direct contact with pedestrian cross yet; the main transfer station to other lines requires a pedestrian cross. Some of the traffic lightings allow pedestrians to cross from one side to the other on one cycle. On the other hand, the majority of the time, the lighting periods are created depending on the traffic flow, which disrupts pedestrian accessibility. The entrance can only be made in the middle part of the station (Figure 5.27). If a person wants to go to the other direction, they should walk around the whole station or they should walk between platforms by walking through the middle of the rails, which is highly disrupted by the trams themselves as a tram comes to the station approximately in every 2 minutes and stay in the station up to a minute since it is the busiest station. The distance between this station and the station in the West is 535 meters and, in the East, its 480 meters. If entrance from the ends of the platforms would be possible, the distances would be slightly lower. Direct entrance to the station for wheelchair users is available. Tactile ground coverings are provided in and around the station (Table 5.5).



Figure 5.27 Photos from Cumhuriyet Meydanı Tram Station Left: Station South Entrance. Right: Pedestrian cross at the East exit of the station.

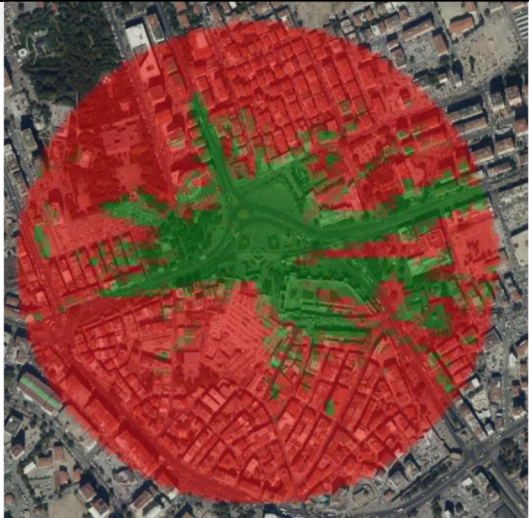
Table 5.5 Accessibility of Cumhuriyet Meydanı Tram Station

ENVIRONMENT		measure(yes/no/partially)	
Elevation	Being in Urban Level	yes	
	Ramp Requirement and Access	no	
	Stair-Escalator-Lift Requirement and Access	no	
Traffic Lights	Pedestrian Cross Requirement and Access	partially	Does not directly contact with pedestrian cross in the middle of the pedestrianized zone yet, main transfer station to other lines requires pedestrian cross
	Synchronous Pedestrian Cross	partially	
	Button Push Requirement for Green Light	no	
Obstruction on Surrounding	Ramp Requirement and Access	yes	
	Vehicle Obstruction on the Pedestrian Cross	no	
	Heavy Vehicular Traffic	yes	
Platform Type	Single Platform/Double Platform	Double Platform	
Distance Between Station Entrances	In meters (West)	535	
	In meters (East)	480	
INCLUSIVITY		measure(yes/no/partially)	
Direct Entrance for Wheelchair Users		yes	
Tactile Ground Coverings Surrounding the station	End of Platform	yes	
	Each Side of Pedestrian Cross	yes	Does not directly contact with pedestrian cross
	Intersection with Rails	yes	

Visibility: This station has the highest visibility among the evaluated stations, primarily because it is located within a majorly open square, which offers clear and unobstructed views from multiple angles (Table 5.6). The open spatial layout enhances wayfinding and provides visual access to the station from a distance, which is beneficial for both locals and visitors. While there are trees and green areas surrounding the station, these do not significantly hinder visibility, as they are likely positioned in a way that maintains open sightlines toward key station elements, such as entrances and platforms. In terms of station visibility metrics, the station is well integrated at the urban level, allowing for seamless visual and physical connection with the surrounding environment. Visibility from both the north and south exits is assumed to be sufficient, as the open space allows for clear views in multiple directions, although specific details for these exits were not provided. Regarding line of sight, visual obstructions from cars and vegetation are rare, further supporting the notion that the station is highly legible and easily identifiable within the urban fabric. The rare frequency of visual interference means pedestrians can navigate the area comfortably, with minimal confusion or need for additional wayfinding elements.

Overall, the station's strategic location within an open square, combined with minimal visual obstructions, positions it as a highly visible and accessible urban node, facilitating efficient movement and orientation for its users.

Table 5.6 Visibility of Cumhuriyet Meydanı Tram Station

STATION VISIBILITY		measure(yes/no/partially)
Being in Urban Level		yes
North Exit		
South Exit		
LINE OF SIGHT		measure(rare/medium/frequent)
Car		rare
Vegetation		rare

Vitality: This station has a balanced distribution, but Disabled and Elderly Card usage is slightly higher than in Düvenönü, possibly indicating better accessibility or proximity to medical or social facilities (Table 5.7). Still, students and regular passengers dominate. In the scope of commercial variety, this area is highly active. There is a shopping mall with fast food floor which is the biggest food attraction in this area. There are cafes in the

square itself and in the castle. There are many banks that are in the Cumhuriyet neighborhood. Traditional Kapalı Çarşı is located around this station as well as commercial district and shopping mall.

The area is also vibrant in terms of building type diversity. Traditional Kapalı Çarşı is located around this station as well as commercial district and shopping mall. The Governor's Office, Police Stations, Civil Registration and Citizenship Offices and Town Hall of Kocasinan are located nearby. There are two mosques which are Kurşunlu and Bürüngüz Mosques in the close perimeter of the station. There are many religious heritages around this area. There is high use of this area in terms of temporary events and gatherings. Meetings, sport events, social political parties occur.

Table 5.7 Vitality of Cumhuriyet Meydanı Tram Station

PASSENGER DIVERSITY	PASSENGER DIVERSITY ratio		
	Standard		44.2%
	Student		36.9%
	Elderly		8.6%
	Disabled		9.0%
	Others		1.2%
COMMERCIAL VARIETY	COMMERCIAL VARIETY	measure(rare/medium/frequent)	
	Restaurant and Café	medium	There is a shopping mall with fast food floor which is the biggest food attraction in this area. There are cafes in the square itself and in the castle.
	Banks	medium	There are many banks that are in the Cumhuriyet neighborhood.
	Temporary Accommodation	rare	
	Shops	frequent	Traditional Kapalı Çarşı is located around this station as well as commercial district and shopping mall.
BUILDING TYPE DIVERSITY	BUILDING TYPE DIVERSITY	measure(rare/medium/frequent)	
	Commercial Buildings	frequent	Traditional Kapalı Çarşı is located around this station as well as commercial district and shopping mall.
	Public Service Buildings	medium	The Governor's Office, Police Stations, Civil Registration and Citizenship Offices and Town Hall of Kocasinan are located near by
	Educational Buildings	rare	
	Residential Buildings	medium	
	Religious Buildings	frequent	There are two mosques which are Kurşunlu and Bürüngüz Mosques in the close perimeter of the station. There are many religious heritages around this area.
	Health Service Buildings	rare	
EVENTS	EVENTS	measure(yes/no/partially)	
	Occurrence of Temporary Events	yes	Meetings, sport events, social political parties, activities occur

The environment evaluated shows a visible presence of vegetation, as both trees and grass areas are available, contributing positively to the visual appeal and ecological value of space (Table 5.8). However, this greenery is not fully integrated into the functional design—particularly, grass areas are in direct contact with the station and disrupt the direct access to the entrance located at the center, which can hinder pedestrian flow and accessibility. While trees add environmental and aesthetic benefits, their impact may be limited if they do not also contribute to shading or comfort.

Regarding comfort conditions, the environment lacks features. There is no shading from surrounding urban structures like other stations, leaving the space at the sides of the platform exposed to direct sunlight, which can reduce comfort, especially in hot weather conditions. Platform cover is only partial, offering limited protection from weather elements. Additionally, no measures have been taken for noise or wind control, yet it does not cause comfort problems.

In summary, although the green elements are visually beneficial, their poor integration with circulation paths and the absence of comfort-enhancing measures result in a space that is aesthetically pleasant but functionally weak.

Table 5.8 Other Features of Cumhuriyet Meydanı Tram Station

VEGETATION AND GREEN ELEMENTS IN ENVIRONMENT		measure(yes/no/partially)
Trees	yes	
Grass Areas	yes	Green areas are in touch with the station which disrupts the direct path to the station entrance located in the middle of the station
COMFORT CONDITIONS		measure(yes/no/partially)
Shading from Urban Environment		no
Platform Cover		partially
Noise Precautions		no
Wind Precautions		no

According to the crowd simulations, this station has a higher occupation compared to the other stations (Figure 5.28). The evacuation from the station is comparatively higher than from other stations. Even though this station seems moderately placed among other stations, the creation of events in the main square can force the station's limits and might require other stations to take its load.

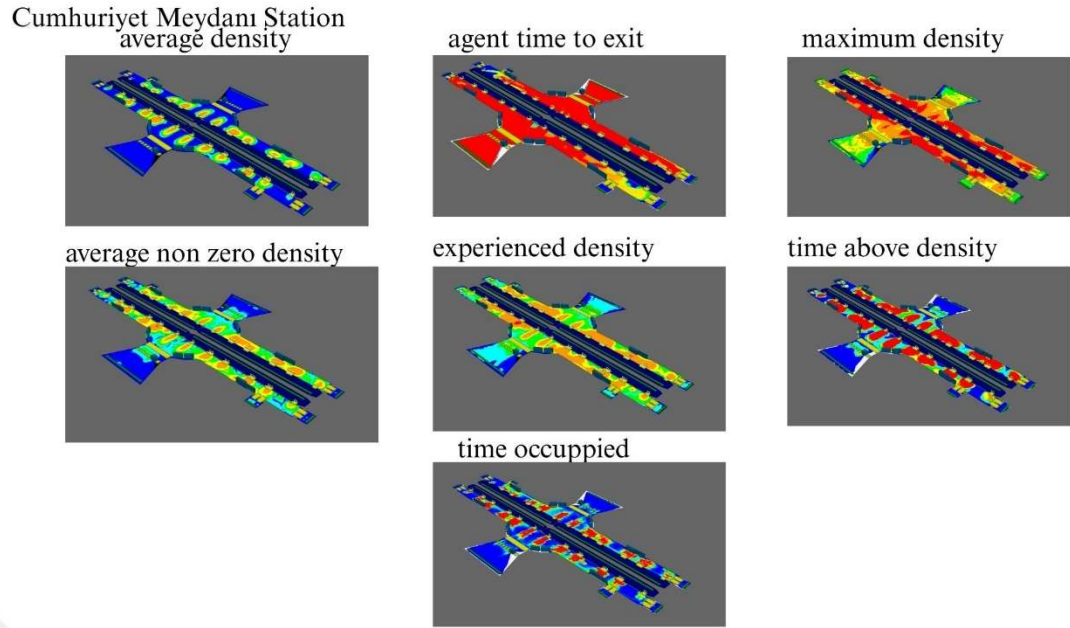


Figure 5.28 Cumhuriyet Meydanı Station Simulation Outcomes

5.2.3 Hunat Hatun Station

Hunat Hatun Station is located on Sivas Boulevard, which is one of the most active streets in the city. There are active shopping areas, libraries, specific shop groups such as fish shops and restaurants, first and second-hand booksellers, printing offices, etc. This station has the lowest user count compared to the other three stations. Drawing of the stations have been provided with the linear map scale and North signs (Figures 5.29, 5.30, and 5.31).

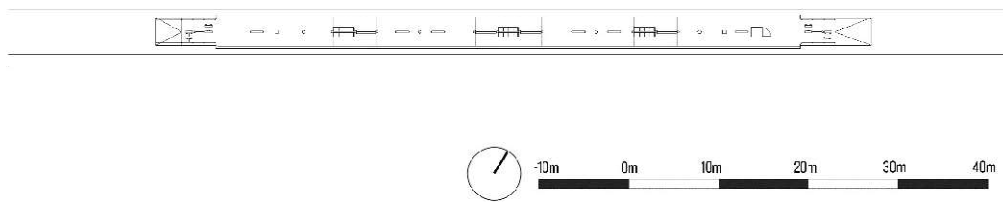


Figure 5.29 Drawing of Hunat Hatun Tram Station. Entrances, seating units shading elements and ramps have been represented. Drawing includes a north orientation arrow and a graphic scale bar of 10 meters for reference



Figure 5.30 Sections of Hunat Hatun Tram Station. Drawing includes a graphic scale bar of 10 meters for reference

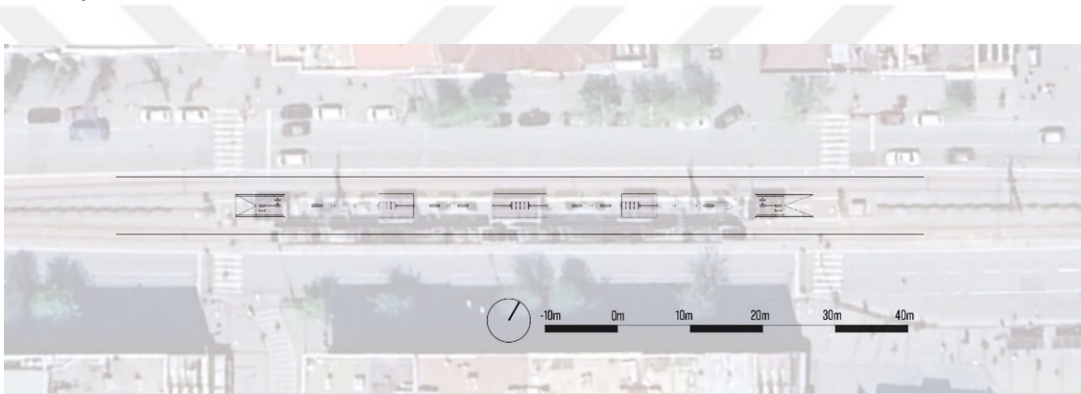


Figure 5.31 Hunat Hatun Tram Station Drawing overlapped with satellite image. Drawing includes north direction representation and a graphic scale bar of 10 meters for reference

Accessibility: Hunat station is located on the Sivas Boulevard. Between the tram stations of Cumhuriyet Meydanı and Büyükşehir Belediyesi. The station is located on the street level and accessed by ramps (Table 5.9). Also, stairs, escalators, or elevators are not used as it is designed to be at ground level. It is located in between the traffic flow. There is a need to pass the vehicle transportation lanes. There are pedestrian crossings in each direction at both ends of the station. They are controlled by traffic lights. They are not synchronized to provide an undisturbed pass from a sidewalk to the other sidewalk on the other side of the street. The traffic lights at the East side of the station are activated by the button push. The red light has 50 seconds of red-light duration when pressed to the button and provides 14 seconds of pedestrian priority in between the cycles. Since the waiting period is quite long and pedestrian activity is high in the area, people tend to cross in the red light or walk through the traffic lanes to slow down the traffic to pass to the tram station or other side of the street (Figure 5.32).

Table 5.9 Accessibility of Hunat Hatun Tram Station

ENVIRONMENT		measure(yes/no/partially)	
Elevation	Being in Urban Level	yes	
	Ramp Requirement and Access	yes	
	Stair-Escalator-Lift Requirement and Access	no	
Traffic Lights	Pedestrian Cross Requirement and Access	yes	
	Synchronous Pedestrian Cross	no	
	Button Push Requirement for Green Light	partially	
Obstruction on Surrounding	Ramp Requirement and Access	yes	
	Vehicle Obstruction on the Pedestrian Cross	partially	
	Heavy Vehicular Traffic	yes	
Platform Type	Single Platform/Double Platform	Single Platform	
Distance Between Station Entrances	In meters(West)	480	
	In meters(East)	400	
INCLUSIVITY		measure(yes/no/partially)	
	Direct Entrance for Wheelchair Users	no	Requires 90 degree turn to access the station
Tactile Ground Coverings Surrounding the station	End of Platform	partially	There are tactile ground coverings, but they do not show the end of platform or finish of the covering
	Each Side of Pedestrian Cross	partially	There are continuous tactile ground covering in the North side of the station but not the East side
	Intersection with Rails	no	There are no tactile ground elements in the entrance of the station where it came across with rails



Figure 5.32 Photo from Hunat Hatun Tram Station Pedestrian Cross at the North West Exit.

Each pedestrian cross has ramps at the beginning of the sidewalk. On the other hand. There are car parking lots on the North side of the street. Vehicle users tend to park their cars on the pedestrian crossing, which causes civics to walk around the vehicle in the short green light duration. The platform is single, which helps the users to navigate easily in the station.

This station entrance is 480 meters from the Cumhuriyet Meydanı station's entrance and 400 meters from the Büyükşehir Belediyesi station's entrance. Since the neighboring stations are quite close to this station, this station's impact area is quite limited. There is continuous tactile ground covering throughout the sidewalk on the North side of the station but not on the East side. There are no tactile ground elements in the entrance of the station where it came across with rails.

The platform is accessible from each end, has 4 turnstiles in each entrance along with single accessibility doors. The accessibility doors are controlled by the security personnel in each station. The wheelchair or stroller users should turn 90 degrees to enter the station (Figure 5.33). There are tactile ground coverings at the sides of the platforms and leads to the exits, yet. There are no tactile indications in the intersection with the railway at the exits of the station (Figure 5.33).



Figure 5.33 Photos from Hunat Hatun Tram Station Left: West Entrance. Right: East Entrance.

Visibility: Urban experience is highly related to visual characteristics. Visibility of the elements and relations between each other increases their noticeability and the image in the minds of the civic. To assess this measure, radial analysis in 500 meters radius has been created in GIS app that is used by the Kayseri Metropolitan Municipality, Citysurf-Kayseri (Table 5.10). Each entrance of the station has been selected as the center point, and buildings have been considered in the analysis.

Table 5.10 Visibility of Hunat Hatun Tram Station

STATION VISIBILITY		measure(yes/no/partially)
Station Visibility	Being in Urban Level	yes
Radial Analysis in 500-meter Radius	West Exit	
	East Exit	
LINE OF SIGHT		measure(rare/medium/frequent)
Obstructions on the Entrances of the Station	Car	rare
	Vegetation	rare

The station is visible throughout the street since it is on ground level. Radial analysis in a 500-meter radius is highly visible in the directions of South-West and North-East since the Boulevard is in this axis. Also, the West entrance is highly visible from the South-East direction. The East entrance is obvious in North and South-East directions. In terms of visibility, the placements of the entrances are quite visible.

In terms of the visual obstructions around the station, cars and vegetation have been considered as common disturbances in visibility. In the Hunat Hatun station, both criteria do not disturb the visual connection.

Vitality: In the Hunat Hatun Station, the number of elderly users is highest in the ratio compared to the other three stations (Table 5.11). This shows that elderly people tend to use this station for their daily activities. Also, student card owners have the lowest ratio compared to the other three stations.

In terms of commercial variety, restaurants and cafés, banks, temporary accommodation possibilities, and types of shops are considered to measure the characteristics of the area. There are many fish sellers which also have restaurants found close. There are cafes especially to be active in the morning as they serve breakfast. Also, there are many restaurants from different cuisines. There are bank offices around the area. There is one hotel building close by. Yet, its customer profile is high income groups, thus their contribution to vitality is expected to be low. Sivas Street and parallel streets all serve with commercial ground floors, making this area quite active.

Building type diversity has been considered under the classification of commercial buildings, public service buildings, educational buildings, residential buildings, religious buildings and health service buildings. There is commercial activity at the street level. Also, office buildings are found close by. There are small governmental units and notaries are found nearby.

There are two libraries and public education buildings nearby. The area is covered with high-rise buildings. The majority of them serve as residential buildings. There are two mosques on each side of the station, which probably correlates with the high ratio of the elderly passenger population. Around this station there are no temporary events occurring.

Table 5.11 Vitality of Hunat Hatun Tram Station

PASSENGER DIVERSITY		ratio
Standard		45.1%
Student		32.4%
Elderly		11.8%
Disabled		9.4%
Others		1.1%
COMMERCIAL VARIETY		measure(rare/medium/frequent)
Restaurant and Café	frequent	There are many fish sellers which also have restaurants located close. There are cafes especially to be active in the morning as they serve breakfast.

Banks	frequent	There are bank offices around the area.
Temporary Accommodation	rare	There is one hotel building close by.
Shops	frequent	Sivas Street and parallel streets are all served with commercial ground floors, which make this area quite active.
BUILDING TYPE DIVERSITY		
		measure(rare/medium/frequent)
Commercial Buildings	frequent	There is commercial activity at street level. Also, office buildings are located close by.
Public Service Buildings	rare	There are small governmental units and notaries are located nearby.
Educational Buildings	medium	There are two libraries and public education buildings near by.
Residential Buildings	frequent	The area is covered with high rise buildings. Majority of them serve as residential buildings.
Religious Buildings	frequent	There are two mosques on each side of the station.
Health Service Buildings	rare	
EVENTS		
		measure(yes/no/partially)
Occurrence of Temporary Events		no

Trees are present in the area, specifically located around Sivas Street, providing greenery and potential shade or aesthetic value (Table 5.12). There is no grass area available around this station. Shading (possibly from buildings or trees) is adequate, improving thermal comfort for passengers and pedestrians. The platform is not fully covered; There are no noise or wind precautions in this station.

Table 5.12 Other Features of Hunat Hatun Tram Station

VEGETATION AND GREEN ELEMENTS IN ENVIRONMENT		
		measure(yes/no/partially)
Trees	yes	Trees are located around the Sivas Street
Grass Areas	no	
COMFORT CONDITIONS		
		measure(yes/no/partially)
Shading from Urban Environment		yes
Platform Cover		partially
Noise Precautions		no
Wind Precautions		no

According to the crowd simulations, the simulation outcomes of Hunat Hatun station have shown high numbers of use but not overly crowded station characteristics (Figure 5.34). Especially, this station type has shown that there can be choke points, especially in the entrances and locations of the first doors when approached in the station.

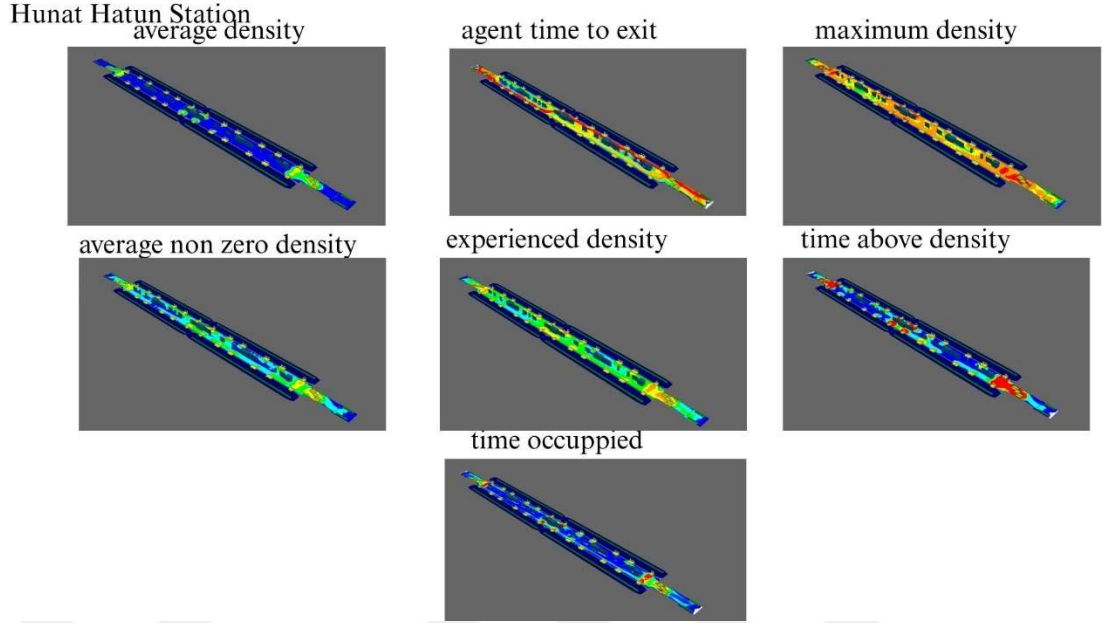


Figure 5.34 Hunat Hatun Simulation Outcomes

5.2.4 Büyükşehir Belediyesi Station

This station is on the Sivas Boulevard. The tram station is in underground under the intersections of the Mustafa Kemal Paşa Boulevard and Sivas Boulevard. There are municipality buildings, libraries, shopping centers, green areas and street activities around the station. Drawings of the station have been provided with the linear map scale and North signs (Figures 5.35, 5.36, 5.37 and 5.38).

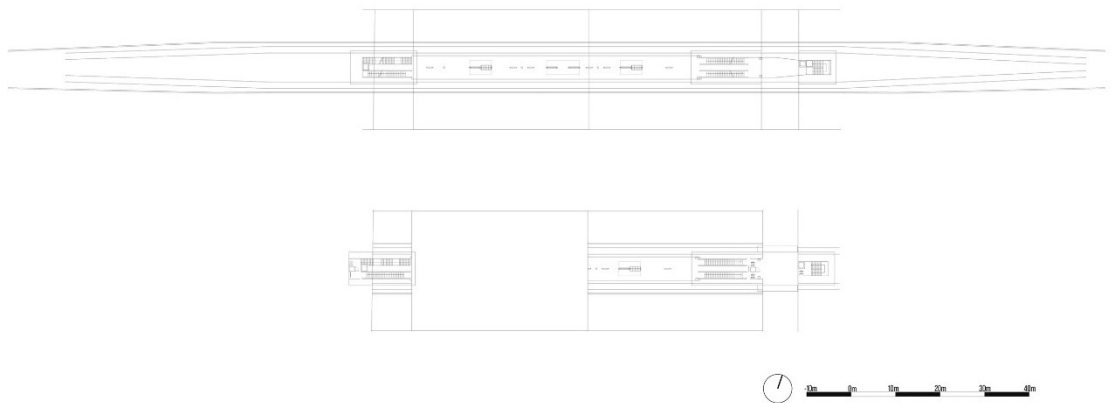


Figure 5.35 Drawing of Büyükşehir Belediyesi Tram Station. Entrances, seating units shading elements and ramps have been represented. Drawing includes a north orientation arrow and a graphic scale bar of 10 meters for reference.

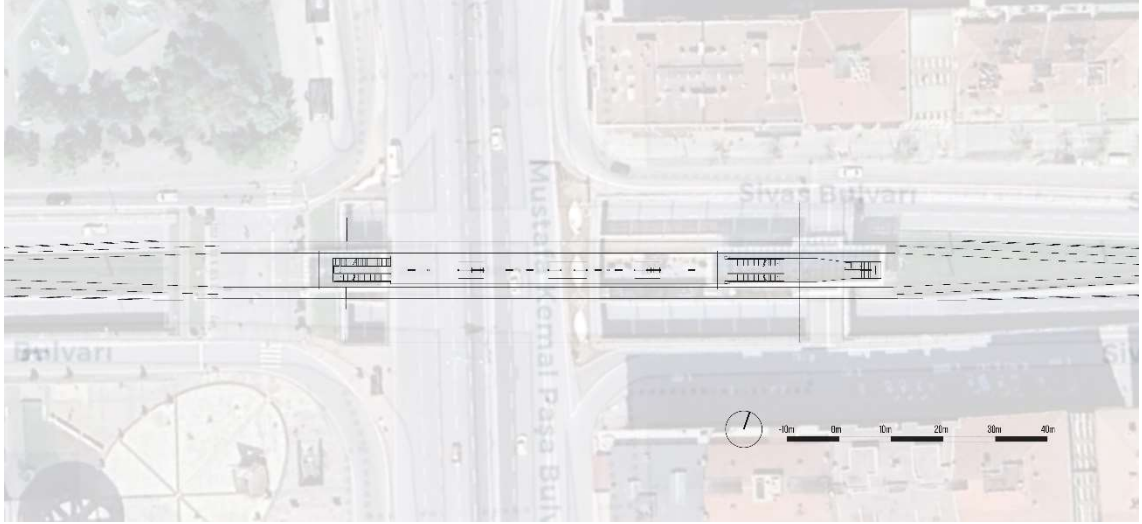


Figure 5.36 Büyükşehir Belediyesi Tram Station underground level drawing. The image overlapped with satellite image. Drawing includes north direction representation and a graphic scale bar of 10 meters for reference.



Figure 5.37 Büyükşehir Belediyesi Tram Station ground level drawing. The image overlapped with satellite image. Drawing includes north direction representation and a graphic scale bar of 10 meters for reference.

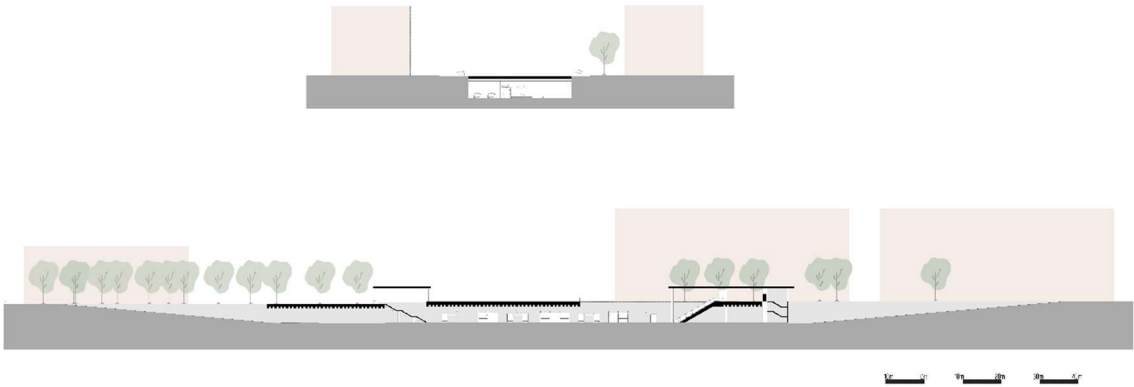


Figure 5.38 Sections of Büyükşehir Belediyesi Tram Station. Drawing includes a graphic scale bar of 10 meters for reference.

Accessibility: The station has two entrances on the ground level yet; the station is underground and invisible from the surroundings. To access the station, there are two elevators, and three escalators are placed (Table 5.13). The West entrance has higher passenger traffic compared to the East entrance. There are one stair, one escalator, and one elevator placed on the west side. The entrances of the stations are located between the car lanes, so to access the entrance, passing through the pedestrian crossing is required (Figure 5.39). The lights are not synchronized. Since the traffic lanes on the ground are only for cars turning in another direction the vehicle load is low compared to the other intersections in the rest of the tram stations. The lights do turn to green for 14 seconds for pedestrians and red for 50 seconds. The quality of vehicle-oriented traffic lighting persists in this station as well. This station is also a single platform. It is 400 meters away from the Hunat Hatun Station in the West and 680 meters away from the Fuzuli Station in the East. Between these three stations, the pedestrian access from one side of the Sivas Boulevard to the other side is harder. Since tram and car traffic moved underground, the ramps are quite long to dive in and up; movement cannot be done in the North-South axis. There are no pedestrian crosses between the Hunat Hatun and Büyükşehir Belediyesi Stations. Furthermore, Fuzuli Station is also located underground, and there are two underpasses. Only access for the pedestrians between those stations, which is 680 meters distance, is an overpass.

Inclusivity is another term to be considered in this subtopic. There is a direct entrance for disabled people in this station; there is tactile paving in the platform at the beginning and end of the vertical circulation units (Figure 5.40). The placement of the tactile ground covering is in line with the tree base in the North-East end. Does not lead the disabled civics properly. Besides, on the North-West entrance the paving is not continuous (Figure 5.39). In this station, different from the other station's, passengers do not come into direct contact with the rails.

Table 5.13 Accessibility of Büyükşehir Belediyesi Tram Station

ENVIRONMENT		measure(yes/no/partially)
Elevation	Being in Urban Level	no
	Ramp Requirement and Access	no
	Stair-Escalator-Lift Requirement and Access	yes
Traffic Lights	Pedestrian Cross Requirement and Access	yes
	Synchronous Pedestrian Cross	no
	Button Push Requirement for Green Light	no

Obstruction on Surrounding	Ramp Requirement and Access	yes	
	Vehicle Obstruction on the Pedestrian Cross	no	
	Heavy Vehicular Traffic	no	
Platform Type	Single Platform/Double Platform	Single Platform	
Distance Between Station Entrances	In meters (West)	400	
	In meters (East)	680	
INCLUSIVITY			
		measure(yes/no/partially)	
Direct Entrance for Wheelchair Users		yes	
Tactile Ground Coverings Surrounding the station	End of Platform	yes	
	Each Side of Pedestrian Cross	yes	Placement of the tactile ground covering is in line with tree base in the North East end
	Intersection with Rails	no	Does not directly contact with rails



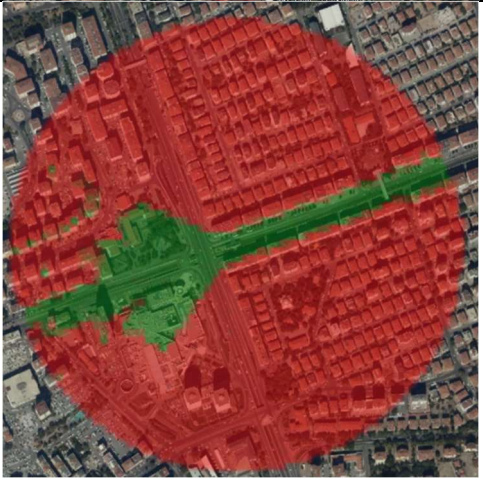
Figure 5.39 Photos from Büyükşehir Belediyesi Tram Station Left: South-West Pedestrian Cross connection. Right: North-West Pedestrian Cross connection.



Figure 5.40 Photos from Büyükşehir Belediyesi Tram Station Left: South-East Pedestrian Cross Connection. Right: Elevator on the South Entrance.

Visibility: Since the station is not visible from the surrounding areas it lacks connection with the urban environment. The radial analysis for this station is done from the entrances of the station (Table 5.14). The West entrance has higher visibility as it is highly visible from the two main streets intersecting. East entrance is highly visible in the direction of Sivas Boulevard. Moreover, the intersection itself is highlighted. Placements of vehicles, the vertical green elements etc. around the station disrupts the visibility mildly.

Table 5.14 Visibility of Büyükşehir Belediyesi Tram Station

STATION VISIBILITY		measure(yes/no/partially)	
Station Visibility	Being in Urban Level	yes	
Radial Analysis in 500-meter Radius	West Exit		
	East Exit		
LINE OF SIGHT		measure(rare/medium/frequent)	
Obstructions on the Entrances of the Station	Car	rare	
	Vegetation	medium	

Vitality: This station has the highest student card usage among all stations (Table 5.15). The younger commuter dominance here could reflect proximity to universities or student housing. lower elderly card usage aligns with the outcome of the youth-centric

demographic. Commercial variety is vibrant around this station. There is a shopping mall, and there are many buildings that serve as offices along with the active streets. Kayseri Metropolitan Municipality and Melikgazi Town Hall are nearby. The Municipality's Library and City Library can be accessed when this station is used. Lastly, there are residential districts around this station. There are quite few temporary events like exhibitions or some public services.

Table 5.15 Vitality of Büyükşehir Belediyesi Tram Station

PASSENGER DIVERSITY		ratio
Standard		43.5%
Student		39.5%
Elderly		7.4%
Disabled		8.3%
Others		1.1%
COMMERCIAL VARIETY		measure(rare/medium/frequent)
Restaurant and Café	frequent	There is a shopping mall with fast food floor which is the biggest food attraction in this area. There is a shopping mall with many cafes
Banks	rare	
Temporary Accommodation	rare	There is one hotel building close by.
Shops	frequent	The street is highly active also there is a shopping mall
BUILDING TYPE DIVERSITY		measure(rare/medium/frequent)
Commercial Buildings	frequent	There is a shopping mall and there are many buildings serve as offices
Public Service Buildings	frequent	Kayseri Metropolitan Municipality and Melikgazi Town Hall are nearby
Educational Buildings	medium	Municipality's Library and City Library can be accessed when this station is used
Residential Buildings	frequent	There are residential districts around this station
Religious Buildings	rare	
Health Service Buildings	rare	
EVENTS		measure(yes/no/partially)
Occurrence of Temporary Events		yes

There is front yard of Kayseri Metropolitan Municipality which is in active use by the civics (Figure 5.41). There is no shading from the urban environment for the above - round elements (Table 5.16). Yet, the underground part is partly covered. There are wind and noise precautions in the station because of the car traffic around the station.

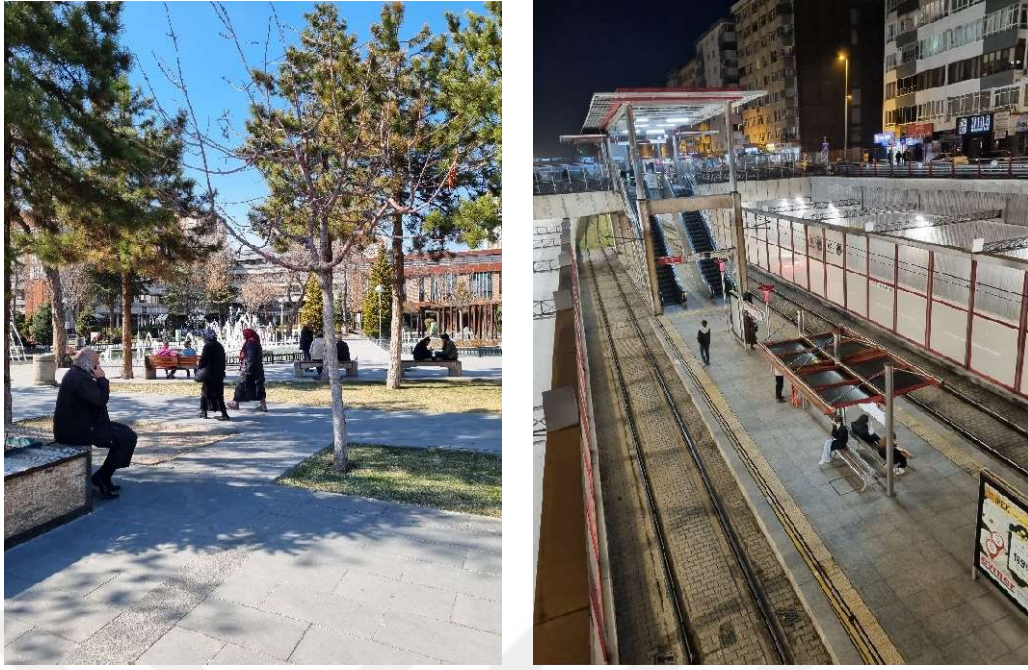


Figure 5.41 Photos from Büyükşehir Belediyesi Tram Station Left: Park in front of the Büyükşehir Belediyesi (Kayseri Metropolitan Municipality) Building in the North-West entrance of the station. Right: Eastern part of the station

Table 5.16 Other Features of Hunat Hatun Tram Station

VEGETATION AND GREEN ELEMENTS IN ENVIRONMENT		measure(yes/no/partially)
Trees	yes	Kayseri Metropolitan Municipality has a park which has highly active use in warmer seasons
Grass Areas	No	
COMFORT CONDITIONS		measure(yes/no/partially)
Shading from Urban Environment		No
Platform Cover		Yes
Noise Precautions		Yes
Wind Precautions		Yes

According to the simulation data, the Büyükşehir Belediyesi Station has the highest density values among the four analyzed stops (Figure 5.42). The average density and experienced density maps show that this stop is exposed to high pedestrian density. The maximum density map reveals that the crowd level of the station increases significantly, especially during peak hours, and that the capacity limits are reached. The agent's time to reach the exit is quite high at this stop; this can be explained by the insufficient number of exit routes or inadequate pedestrian guidance. Time-based maps, such as the time above density and the time occupied, reveal that there is a constant flow of users in this area and that the stop is frequently occupied. These data suggest that the station functions not only as a transition point but also as a waiting and interaction area. In general, it can

be said that the Büyükşehir Belediyesi Station needs strategic interventions to distribute the density in terms of both physical design and orientation.

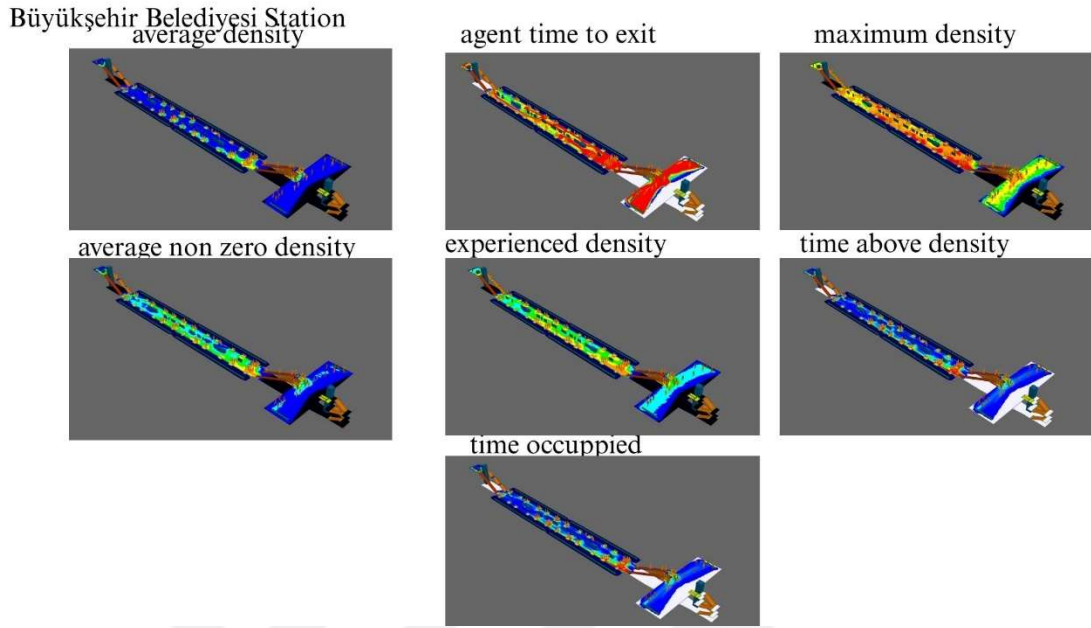


Figure 5.42 Simulation Outcomes of Büyükşehir Belediyesi Station

5.3 Chapter Review

This section comprehensively examines the KayseRay tram line, which is at the heart of Kayseri's public transportation system and evaluates the impact of data-driven approaches on urban mobility through a concrete example. Four main stations located along Sivas Street, the city's busiest and most functional axis – Düvenönü, Cumhuriyet Meydanı, Hunat Hatun and Büyükşehir Belediyesi – are analyzed within the framework of accessibility, visibility and vitality criteria.

The analyses show that, while some stations (such as Cumhuriyet Meydanı) provide physical accessibility, others (especially underground stations) have significant problems such as inadequate access ramps, unsynchronized traffic lights and poor pedestrian crossing safety. This situation directly affects the transportation experience of vulnerable user groups such as the elderly and disabled people.

In terms of visibility, stations located in open squares are more integrated with the environment and have a stronger perceptual position. On the other hand, underground stations appear disconnected from urban fabric, making it difficult for users to find their way. It has been determined that visual obstacles (car parks, billboards, etc.) negatively

affect the wayfinding experience around the station. Furthermore, visibility from vehicles is worth considering as it can create spectacular experiences.

Visibility from Vehicle: Since the network system travels through the most vital streets of Kayseri and travels at medium speeds, the trip has a great possibility of spectacle. On the other hand, the majority of vehicles are covered with ads. These coverings decrease visibility and cause a lack of connection between the interior and exterior spaces (Figure 5.43). Especially the façade, which is exposed to direct sunlight, does disrupt the activity of the spectacle deeply.



Figure 5.43 Left: KayseRay Tram Glass with Ad Covering in Shadow, 2025.01.10-11.28 Right: KayseRay Tram Glass with Ad Covering in Under Direct Sunlight, 2025.01.10-11.28

In some cases, the covering causes thick shadows inside the vehicle, and interior lights are lit in the middle of the day to increase visual quality for the passengers (Figure 5.44).



Figure 5.44 Left: Photo from Ansaldo Breda-Sirio Tram Covered with Ads with open lights in the middle of the day, 10.01.2025-11:29 Right: KayseRay Tram Façade with Ad Covering Cumhuriyet Meydanı Station West End, 2025.01.31

By design choice all the vehicles have indicative design to increase the visibility of the doors. Yet, the ads are not designed with the same perspective this issue decreases the noticeability of the doors. People start to approach the door after the door opens (Figure 5.45).



Figure 5.45 Left: KayseRay Tram Door with Ad Covering, 2024.12.24 Right: KayseRay Tram Door with Ad Covering, 2024.12.26

In vitality measurements, commercial diversity, user profile distribution and building typologies around the station play a significant role. Particularly, Cumhuriyet

Meydanı and Düvenönü stations offer a lively and interactive public space with shopping areas, historic buildings, public services, and high pedestrian density. The Büyükşehir Belediyesi station stands out with its young user profile and student density (Table 5.17).

Passenger data indicated that different user groups peaked at various times in the morning and evening hours and showed that students and the elderly especially use the public transportation system more intensively than other groups. In addition, elements such as the limitation of external view in tram vehicles due to advertising coatings weaken the user experience and the visual relationship with the city.

This case study has revealed how transportation systems should be evaluated not only in terms of technical performance criteria but also in terms of user behavior, connection with the city and social inclusiveness. Data-supported analyses provide a strong basis for both identifying existing problems and developing improvement strategies. The KayseRay example clearly demonstrates the need for a human-centered and integrated transportation planning that is sensitive to the local context.

The evaluations made at the Düvenönü, Cumhuriyet Meydanı, Hunat Hatun, and Büyükşehir Belediyesi stations have revealed a series of spatial and functional deficiencies that are specific to this context. For Düvenönü Station, the most pressing issues are related to unsafe pedestrian crossings, limited ramp access, and the lack of visual clarity and access due to parked cars. It is recommended to redesign the pedestrian crossings with proper curb ramps, enforce parking restrictions near crosswalks, and enhance tactile wayfinding for inclusive mobility. As well as some alterations to improve the traffic decisions and create slower traffic to allow passengers to move in and out of the station safely. At Cumhuriyet Meydanı Station, despite its strong visual integration and spatial openness, pedestrian circulation is frequently disrupted by unsynchronized traffic signals and insufficient shading. Improvements here should include reprogramming traffic light cycles to prioritize pedestrians. Hunat Hatun Station, while compact and located in a vibrant corridor, suffers from inconsistent tactile infrastructure, obstructive parking behaviors, and limited pedestrian mobility. Targeted interventions could involve redesigning sidewalk interfaces, regulate on-street parking, and introduce continuous tactile paving at rail-platform intersections, in particular. Also, redesigning the traffic lighting cycles can improve the safety of the high number of passengers and pedestrians, as the traffic lighting system prioritizes car traffic over pedestrians.

Table 5.17 Measurements for Düvenönü, Cumhuriyet Meydanı, Hunat Hatun and Büyükşehir Belediyesi Tram Stations

	STATION		DÜVENÖNÜ	HUNAT HATUN	CUMHURİYET MEYDANI	BÜYÜKŞEHİR BELEDİYESİ
Accessibility	ENVIRONMENT		measure(yes/no/partially)			
	Elevation	Being in Urban Level	yes	yes	yes	no
		Ramp Requirement and Access	yes	yes	no	no
		Stair-Escalator-Lift Requirement and Access	no	no	no	yes
	Traffic Lights	Pedestrian Cross Requirement and Access	yes	yes	partially	yes
		Synchronous Pedestrian Cross	no	no	partially	no
		Button Push Requirement for Green Light	no	partially	no	no
	Obstruction on Surrounding	Ramp Requirement and Access	no	yes	yes	yes
		Vehicle Obstruction on the Pedestrian Cross	yes	partially	no	no
		Heavy Vehicular Traffic	yes	yes	yes	no
	Platform Type	Single Platform/Double Platform	Single Platform	Single Platform	Double Platform	Single Platform
	Distance Between Station Entrances	In meters(West)	815	480	535	400
		In meters(East)	510	400	480	680
Visibility	INCLUSIVITY		measure(yes/no/partially)			
	Direct Entrance for Wheelchair Users		no	no	yes	yes
	Tactile Ground Coverings Surrounding of the station	End of Platform	yes	partially	yes	yes
		Each Side of Pedestrian Cross	yes	partially	yes	yes
		Intersection with Rails	yes	no	yes	no
	STATION VISIBILITY		measure(yes/no/partially)			
	Station Visibility	Being in Urban Level	yes	yes	yes	yes
	Radial Analysis in 500 meter Radius	West Exit				
		East Exit				
	LINE OF SIGHT		measure(rare/medium/frequent)			
	Obstructions in the Entrances of the Station	Car	yes	rare	rare	rare
		Vegetation	no	rare	rare	medium
Vitality	PASSENGER DIVERSITY		ratio			
	Standard		47.4%	45.1%	44.2%	43.5%
	Student		35.5%	32.4%	36.9%	39.5%
	Elderly		7.4%	11.8%	8.6%	7.4%
	Disabled		8.0%	9.4%	9.0%	8.3%
	Others		1.1%	1.1%	1.2%	1.1%
	COMMERCIAL VARIETY		measure(rare/medium/frequent)			
	Restaurant and Café		medium	frequent	medium	frequent
	Banks		frequent	frequent	medium	rare
	Temporary Accomodation		frequent	rare	rare	rare
	Shops		frequent	frequent	frequent	frequent
	BUILDING TYPE DIVERSITY		measure(rare/medium/frequent)			
	Commercial Buildings		frequent	frequent	frequent	frequent
	Public Service Buildings		rare	rare	medium	frequent
	Educational Buildings		frequent	medium	rare	medium
	Residential Buildings		medium	frequent	medium	frequent
	Religious Buildings		frequent	frequent	frequent	rare
	Health Service Buildings		frequent	rare	rare	rare
	EVENTS		measure(yes/no/partially)			
	Occurrence of Temporary Events		no	no	yes	yes
EXTRAS	VEGETATION AND GREEN ELEMENTS IN ENVIRONMENT		measure(yes/no/partially)			
	Trees		no	yes	yes	yes
	Grass Areas		no	no	yes	no
	COMFORT CONDITIONS		measure(yes/no/partially)			
	Shading from Urban Environment		yes	yes	no	no
	Plaform Cover		partially	partially	partially	yes
	Noise Precautions		no	no	no	yes
	Wind Precautions		no	no	no	yes

Lastly, Büyükşehir Belediyesi Station, though rich in amenities and attracting the highest footfall, is challenged by its underground configuration, visibility limitations, and crowd management during peak hours. Recommendations include enhancing vertical circulation capacity (additional escalators or exits), improving entrance visibility through urban design markers, and deploying dynamic signage for more efficient passenger flow. Together, these station-specific strategies not only aim to solve existing issues but also enhance the experiential and functional quality of urban mobility infrastructure in central Kayseri.

In this section, it is shown that urban mobility can be evaluated holistically with spatial and user data through the example of the KayseRay tram line. The timing, spatial preferences and mobility patterns of different user groups reveal that transportation infrastructure is not only a means of transportation, but also a part of social interaction, wayfinding and public life experience. Analyses conducted in four main stations in particular have shown that not only infrastructural but also perceptual, social and administrative weak points can be detected with data-based methods. With this approach, it is emphasized that concepts such as spatial justice, accessibility and user experience should be prioritized in the future designs of transportation systems. The developed analysis framework shows that data-based design provides a strong basis for local context-sensitive, human-centered and sustainable urban transportation policies.

Chapter 6

Conclusion

This study aims to investigate the potential of data-based urban analysis methods to increase the quality of urban life. Supported by a literature review, theoretical infrastructure, and practical examples, this thesis presents multi-layered research based on the integration of smart city technologies and architectural principles.

In the application part of the thesis, the analysis conducted on the KayseRay tram system in Kayseri city has presented important findings in terms of making the effects of data-based measurement techniques on urban life visible. In the analysis conducted under the titles of accessibility, visibility, and vitality, the environmental qualities of the stations, their relationship with the human scale, and the potential they carry in terms of user experience were evaluated in detail.

These findings reveal that urban transportation systems are not only a technical infrastructure but also a fundamental tool in the formation of public life. In this context, it is seen that the methods used in the study are effective tools for developing sustainable and livable city strategies, especially in medium-sized developing cities.

6.1 Overview of the KayseRay System

The case study has been chosen to understand dynamics of urban qualities. Kayseri city can provide data infrastructure and be a sample for many other developing cities of same size. The KayseRay tram system, operated by the Kayseri Metropolitan Municipality, serves as the backbone of urban transportation in the city. With the city's expanding boundaries and growing population, the need for sustainable and accessible mobility solutions has become increasingly urgent. In response, KayseRay was developed as a strategic rail network connecting the city center along the east-west axis. KayseRay goes through the main arteries of the city, which allows the urban mobility to flow through the light rail system.

The system plays a significant role not only in passenger transportation but also in shaping urban spatial dynamics. Used by thousands of civic daily, KayseRay facilitates

access to the city center for various social groups, thereby enhancing urban mobility. At the same time, the pedestrian flow generated around its stations boosts the social and commercial vitality of surrounding areas. In this regard, the system acts not merely as a transportation infrastructure but also as a catalyst for urban transformation.

Selected stations have been evaluated in terms of accessibility, visibility, and vitality. This study has provided deeper insight into the relationship between the urban environment and mobility trends. Station performance was analyzed using data-supported methods, including digital mapping and on-site observations. These analyses allowed for a deeper understanding of user experience, pedestrian behavior, and the spatial interactions in the station surroundings.

To assess the features of GIS, mobility data, measurements, and visibility analyses have been used. For GIS studies data infrastructure private and public data from global sources like Open Street maps and local sources like City Surf and Açık Veri Platformu has been used. The Ulaştırma AŞ has provided mobility data and contributed to the study. By evaluation of this data, passenger trends around different regions of the city center have been revealed. Visibility analyses have shown the visual connection for the mobility elements. All the tools, together with the physical features of stations, vehicles, environment, vitality, visual connections, and variety in various aspects, have been assessed to reveal the experience of urban connections through the mobility aspect.

In conclusion, the KayseRay system stands out as a strong example of planned urban development, data-driven assessment techniques, and sustainable transportation policies. This case study offers transferable methodologies that can be applied in similarly developing metropolitan contexts, helping to integrate mobility infrastructure with urban quality strategies.

6.2 Societal Impact and Contribution to Global Sustainability

Data-driven urban design approaches directly affect not only physical arrangements but also social interaction, inclusiveness and quality of life. This study demonstrates how urban spaces can become more livable, safe and accessible through the example of KayseRay, a transportation infrastructure that re-centers the human scale.

The findings obtained in this thesis not only provide an academic assessment, but also provide directly applicable insights in terms of urban design and architectural practice. The multi-layered analysis approach created by evaluating different types of data (e.g. pedestrian mobility, fields of view, user density) together allows designers to make decisions that focus not only on physical form but also on user experience. Especially in public transit areas such as tram stations, evaluation of concepts such as accessibility, wayfinding, spatial comfort, and liveliness supported by measurable data enables design processes to progress in a more holistic and data-driven manner. In this context, the thesis contributes to the consideration of urban interventions with an understanding that is not only aesthetic or functional approach, but also from social inclusion perspective: It provides a practical framework for designers on how to produce data-based strategies in the local context.

The access opportunities provided by the KayseRay system not only facilitate urban mobility but also support social equality and encourage equal access to urban opportunities for different segments of society. In this respect, it is seen that data-driven planning and design processes contribute to the principles of social justice and inclusiveness.

In addition, the role of public transportation systems in reducing private vehicle use directly contributes to environmental sustainability in terms of reducing carbon emissions and increasing energy efficiency. In this context, the outputs of the study are related to the UN Sustainable Development Goals, especially Goal 11: Sustainable Cities and Communities.

Finally, the fact that the methods developed in this thesis can be applied in other cities shows the potential of the research to produce effective results not only locally but also on a global scale. In this way, data-based, human-centered and sustainable urban transformation models can be developed for cities in different geographies.

6.3 Conclusions & Future Research Directions

This thesis has demonstrated how big data and digital analysis methods can be used as an effective tool in the process of improving the quality of urban life. The analysis conducted on the KayseRay tram line example has revealed the impact of transportation infrastructure on urban dynamics with both spatial and social dimensions. The findings of the study have revealed that data-based approaches have high potential in measuring and evaluating basic urban quality indicators such as accessibility, visibility and vitality.

This thesis contributes to the expanding body of literature on data-informed urbanism by demonstrating how urban quality indicators—such as accessibility, visibility, and vitality—can be evaluated through a multidisciplinary, data-driven framework. By applying methods like GIS analysis, crowd simulations, and spatial visibility mapping to a real-world case in a mid-sized Anatolian city, this study provides a rare empirical contribution from a non-Western context. Furthermore, the integration of architectural thinking into digital urban analysis offers a valuable perspective for both researchers and practitioners seeking to bridge design sensitivity with computational methods.

The findings of this study not only reveal the spatial dynamics specific to the Kayseri tram network, but also overlap with the current global discussions on urban design and data-driven planning. The adaptation of used methods such as GIS-based spatial analyses, crowd simulations, and urban quality indicators to the specific context of Kayseri reveals the potential of global knowledge to produce solutions to local urban problems. The interaction of universally valid analysis tools with the sociocultural, spatial and administrative conditions specific to the region emphasizes the importance of contextual intelligence in urban applications. In this perspective, the study contributes to both the smart city applications and human-centered urban analysis literature; it also presents a methodological framework that shows how methods developed on a global scale can be transformed into strategic design decisions that can be applied on a local scale. Thus, a mutually reinforcing flow of information is provided between global urban research and local design and management practices.

According to the results obtained, for smart city technologies to be successfully implemented, not only the technical infrastructure but also the social and spatial context should be considered. The KayseRay example has provided an effective ground where data can be brought together with user experience and human-scale sensitive design principles. This approach has the potential to produce holistic solutions by building a bridge between disciplines such as architecture, urban planning and transportation engineering.

Several suggestions for future research are highlighted:

- Increase of data diversity: Integration of more data sources such as social media data, mobile application analytics, sensor data, and user surveys can expand the scope of spatial analyses.

- Systems based on user participation: By combining data-driven analyses with participatory planning approaches, designs that are more responsive to public needs and expectations can be developed
- Real-time analysis systems: Collection of instant city data with IoT-supported monitoring and analysis infrastructures can enable dynamic and adaptive planning solutions.
- Extensibility: The applicability of the methods proposed in this study can be investigated in cities of varied sizes and different socio-cultural structures.
- Policy and management integration: Governance models can be developed for the direct integration of data-driven analyses into decision-making mechanisms.

In conclusion, this thesis demonstrates that data-driven urbanism approaches provide a solid basis for future research and urban policies, both theoretically and practically. Increasing the number of such studies is significant in line with the goal of creating human-centered, inclusive, and sustainable cities.

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