

Ergonomic Conditions in Public Transportation Spaces: The Case of Istanbul

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ABSTRACT

This study evaluates the ergonomic performance of Istanbul's three primary public transport modes—Metrobus (Söğütlüçeşme), Metro (Kadıköy), and Ferry (Kadıköy Pier)—through the lens of user experience, accessibility, and spatial comfort. Drawing on interdisciplinary frameworks such as environmental psychology, spatial justice, and inclusive design, the research applies UNCRPD and ISO standards to assess real-world performance.

Using a mixed-methods approach that combines field observations, spatial measurements, and user surveys (N=900), the study identifies critical ergonomic disparities: Metrobus exhibited peak densities of 6.8 persons/m², exceeding Fruin's standard by 127%; Metro users experienced a 40% reduction in walking speed during stairwell congestion; and Ferry terminals provided only 0.8 m² per passenger, falling 33% below IMO standards. Accessibility deficits were observed across all systems, including excessive ramp slopes, elevator delays, and a lack of multisensory guidance.

By linking these findings to systemic design gaps, the study provides actionable recommendations for enhancing inclusive, user-centered mobility planning in dense urban contexts. The research offers a scalable framework for diagnosing ergonomic performance in public transit systems, supporting both academic inquiry and real-world transport policy reform.

KEYWORDS

Public transportation, ergonomics, accessibility, user experience, spatial justice, public space.

INTRODUCTION

Public transportation systems are fundamental infrastructures in urban life, offering mass mobility through fixed routes and schedules. Yet beyond their logistical function, they serve as dynamic public spaces that shape the rhythms and experiences of daily life (Sheller & Urry, 2006). The rising urban population, environmental concerns, and increasing demands for social inclusion necessitate more human-centered approaches to transportation design (Şişman, 2015). In this context, the discipline of ergonomics—originally rooted in military engineering and industrial productivity—gains renewed significance through its evolving emphasis on user experience, accessibility, and spatial justice.

As of 2025, Istanbul — a metropolis of approximately 15.7 million people — operates an integrated public transportation network with over 8 million daily trips; around 5 million of these are made via IETT-operated buses and the Metrobus system, while over 3 million trips are recorded on rail systems such as metro, tram, and funicular lines (IETT, 2024; Metro Istanbul, 2023). These conditions present not only physical demands but also psychological and social challenges, including fatigue, stress, lack of privacy, and gender-based vulnerability. Such factors reveal the insufficiency of design strategies focused solely on efficiency or standardization. This study investigates the ergonomic conditions of urban transit spaces in Istanbul through a multidimensional lens, proposing a critical reevaluation of how inclusivity, comfort, and user engagement are—or are not—integrated into current transportation infrastructure.

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THEORETICAL FRAMEWORK

The theoretical basis of this study lies in the interdisciplinary evolution of ergonomics, which has shifted from a productivity-centered model to one that incorporates sensory, cognitive, and social dimensions (Karwowski, 2006). This shift aligns with broader design discourses that emphasize emotional wellbeing, user participation, and spatial equity (Norman, 2002; Costanza-Chock, 2020). Inclusive and participatory design approaches challenge traditional top-down practices by advocating for systems that reflect the diversity of users in terms of age, gender, physical ability, and cultural background (Imrie, 2012).

Public transportation is increasingly understood not just as a logistical service but as a “moving public space” (Sheller & Urry, 2006), wherein interactions, perceptions of safety, and feelings of belonging are continuously negotiated. Within this framework, accessibility transcends technical compliance to become a social right, as enshrined in international conventions such as the UNCRPD (United Nations Convention on the Rights of Persons with Disabilities) (2006). Moreover, concepts of spatial justice (Soja, 2010) and the right to mobility (Lefebvre, 1991; Harvey, 2008) provide normative foundations for evaluating how transportation systems enable or inhibit full participation in urban life.

In the Turkish context, public transit evolved from central planning initiatives in the late Ottoman era to more data-driven and technocratic approaches post-1980 (Şişman, 2015). However, existing infrastructures often neglect the ergonomic needs of marginalized users. This study proposes a holistic framework that incorporates anthropometric compatibility, sensory comfort, inclusive signage, and co-design practices as integral components of equitable transportation design. The Istanbul case serves as a lens to critique current practices and imagine new paradigms that prioritize human dignity and urban inclusiveness.

METHODOLOGY

This study evaluates the ergonomic performance of Istanbul’s public transportation systems through a comparative analysis of three major transit modes: **Bus Rapid Transit (BRT)**, **metro**, and **ferry** services. The research employs a **mixed-methods approach**, integrating both **quantitative** and **qualitative** data sources to provide a multidimensional assessment of physical, environmental, and psychosocial ergonomic factors.

RESEARCH SETTING AND SELECTION CRITERIA

The study was conducted at three high-density transit nodes in Istanbul, selected for their distinct physical configurations, user demographics, and modal characteristics:

- **Söğütözü BRT Station** (bus-based surface transit)
- **Kadıköy Metro Station** (subway system)
- **Kadıköy Ferry Terminal** (urban maritime transport)

These sites were chosen based on the following criteria: high passenger volume, diversity of spatial conditions, service frequency, and modal distinctiveness. Each system provides a unique ergonomic context in terms of vehicle type, station architecture, and passenger movement patterns.

Table 1. *Key Characteristics of Selected Transportation Systems.*

Criteria	BRT	Metro	Ferry
Mode of Transport	Rubber-tired articulated buses	Underground rail system	Sea-based vessels
Station Type	Open-air platform	Enclosed underground station	Coastal terminal (pier)
Space and Vehicle Type	Busway, asphalt platforms	Tunnel station, train wagons	Ferryboat with terminal
Service Frequency	Very frequent; peak congestion	Regular; rapid transit	Scheduled trips; longer intervals
Primary User Profile	Lower- to middle-income commuters	Diverse socioeconomic groups	Middle-income, comfort-seeking users
Observation Location	Söğütlüçeşme BRT Station	Kadıköy Metro Station	Kadıköy Ferry Terminal

A comparative overview of three public transportation systems in Istanbul is provided in [Table 1](#), highlighting differences in transport modes, station types, space and vehicle configurations, service frequencies, and user profiles. These varying spatial and operational characteristics enable a detailed ergonomic comparison across systems. The selected locations, known for their high user density and diverse physical and mobility conditions, provide a comprehensive basis for this analysis.

Data Collection Methods

Two primary methods were used for data collection: systematic field observations and user surveys, conducted between **May and August 2023** to capture both peak and off-peak travel patterns in seasonal conditions.

Field Observations

Structured ergonomic observations were conducted by the research team during both **peak (07:30–09:00 / 17:00–19:00)** and **off-peak** hours. A **semi-structured observation protocol** was developed, based on ISO 26800:2011 and EN 16584-1:2017 ergonomic standards for transport environments. Observation themes included:

- **Physical adequacy:** spatial layout, seating ergonomics, circulation space, signage
- **Environmental conditions:** lighting, thermal comfort, ventilation, acoustic factors
- **User behavior:** movement under congestion, posture while waiting, navigational patterns

Photographic documentation, time–motion recording, and checklist scoring were used to ensure systematic data capture.

User Survey

A structured, 16-item **Likert-scale questionnaire** was administered to assess user experiences and perceptions of ergonomic performance. Survey items were categorized under three dimensions.

Table 2. Ergonomic Evaluation Criteria Used in Survey Instrument.

Evaluation Dimension	Description
Physical Environment	Seating usability, spatial freedom, anthropometric fit, circulation width
Comfort Factors	Thermal comfort, crowd density, cleanliness, acoustic and visual comfort
Psychosocial Aspects	Staff conduct, navigational clarity, noise/vibration, technical reliability

Table 2 outlines the key evaluation dimensions used to assess the ergonomic conditions of public transportation spaces, encompassing physical environment characteristics, comfort parameters, and psychosocial factors that collectively shape user experience.

Each item was rated on a **5-point scale** (1 = Strongly Disagree; 5 = Strongly Agree). Prior to distribution, the instrument was **pilot-tested** with 30 users and validated by a panel of ergonomics and urban mobility experts. Survey administration was conducted **in-person** using stratified sampling to ensure modal and demographic balance.

- **Sample size:** 450 users (150 per system)
- **Sampling confidence:** 95% confidence level with $\pm 4.5\%$ margin of error
- **Inclusion criteria:** Age ≥ 18 , uses selected transit system ≥ 3 times per week
- **Collected demographics:** Age, gender, education level, income bracket, usage frequency

RESULTS AND DISCUSSIONS

In the case studies conducted on the bus rapid transit (BRT), metro, and ferry transport systems, the observation and evaluation of factors such as user ergonomics, accessibility, and comfort within Istanbul's public transportation systems hold significant importance.

SOGÜTLÜÇESME BUS RAPID TRANSIT (BRT) STATION

"Bus Rapid Transit (BRT) systems deliver the speed and comfort of rail-based transport at comparatively lower cost and with quicker implementation (Güven & Şahin, 2009). Istanbul's Metrobus BRT corridor, in operation since 2007, now spans approximately 52 km with 44 stations, and carries an estimated 1 million passengers per day—positioning it among the world's busiest BRT networks (İETT, 2024; Metrobus Istanbul, 2025)."

Söğütlüçeşme Station alone handles 300 vehicles and transports approximately 715,000 passengers daily, indicating that the system operates near its full capacity.

Waiting and Seating Areas

Although the seating areas around Söğütlüçeşme Station are designed to be sheltered, their use is limited due to the high frequency of bus service—approximately one departure every 30 seconds. Observations indicate that passengers mostly use these seats for short-term rest or while waiting for companions.

Table 3. *Ergonomic Evaluation of Seating in Waiting Areas at Söğütlüçeşme BRT Station.*

Feature	Current Status	Recommended Standard	Reference
Seat height	42 cm	40–45 cm	Toka (1978); ISO 5970:1979
Seat depth	38 cm	≥40 cm	Toka (1978); ISO 5970:1979; ISO 9241-5:1998
Space per person	50 cm	≥60 cm	Toka (1978); ISO 5970:1979

The ergonomic evaluation of seating in the waiting areas at Söğütlüçeşme BRT Station is presented in Table 3, comparing current conditions with recognized standards for seat height, seat depth, and individual space. These recommendations are based on both national ergonomic references (Toka, 1978) and international standards such as ISO 5970:1979 (*Furniture — Seating — Determination of dimensions*) and ISO 9241-5:1998 (*Ergonomic requirements for office work with visual display terminals – Part 5: Workstation layout and postural requirements*).

Additionally, nearby food and beverage vendors are frequently used by passengers as informal rest points, offering shaded, semi-private, and less crowded seating alternatives outside the main station premises.

Circulation and Passage Areas

The multi-layered structure of the station leads to significant congestion during peak periods. Limited turnstile access results in circulation issues in both platforms and pedestrian passages. These problems extend beyond transport capacity, affecting basic spatial and functional elements essential for user movement.

Table 4. *Peak-Hour Congestion Analysis of Söğütlüçeşme BRT Station.*

Parameter	Current Status	Recommended Standard
Walking speed	0.8 m/s	1.2 m/s (Fruin, 1971)
Density	4.5 persons/m ²	≤3 persons/m ² (Fruin, 1971)
Waiting time	2.5 min	≤1.5 min (TRB, 2013)

The congestion conditions at Söğütlüçeşme BRT Station during peak hours, as shown in Table 4, reveal reduced walking speed, higher crowd density, and longer waiting times compared to recommended standards, indicating decreased pedestrian movement efficiency.

Table 5. *Wayfinding System Usability Evaluation of Söğütlüçeşme BRT Station.*

Metric	Measured Value	Standard	Compliance	Reference
Digital display height	160–185 cm	150–175 cm	Partially compliant	ISO 9241-303:2011
Font size	12 pt	≥14 pt	Non-compliant	ISO 9241-171:2008; ADA Guidelines
Color contrast	Estimated: 70%	100% WCAG Level AA	Non-compliant	ISO/IEC 40500:2012; WCAG 2.1

As shown in Table 5, the wayfinding system at Söğütlüçeşme BRT Station meets minimum display height recommendations but falls short in terms of font size and visual contrast. The current signage does not fully satisfy **ISO (International Organization for Standardization)** and **WCAG (Web Content Accessibility Guidelines)** accessibility standards, suggesting a need for redesign to enhance readability and inclusive navigation.

Accessibility for Disabled Users

The accessibility of Söğütlüçeşme BRT Station remains limited, with multiple infrastructural and communicative deficiencies that undermine barrier-free mobility and inclusive design principles. As shown in Table 6, observed issues include excessive ramp inclines, long elevator waiting times, and damaged or ineffective wayfinding supports such as Braille signage and tactile surfaces. These findings reflect a divergence from internationally recognized accessibility standards.

Table 6. Accessibility Assessment of Söğütlüçeşme BRT Station for Users with Disabilities.

Accessibility Feature	Observed Value	Required Standard	Compliance Status	Reference
Ramp Slope	40% exceed 8% incline	Max 5% without handrails; up to 8.3% with handrails	Non-Compliant	ISO 21542:2011; ADA 2010
Braille Signage	40% missing or non-functional	100% available, durable, and properly located	Non-Compliant	ISO 23599:2012; ADA 2010
Elevator Waiting Time	8.3–12 minutes	≤ 3 minutes during peak hours	Non-Compliant	ISO 4190-1:2010; UITP
Tactile Walking Surface	15% damaged or blocked	Continuous, non-slip, and fully intact	Non-Compliant	ISO 23599:2012; ISO 21542:2011
Audible Announcements	70% clarity rate	≥ 90% clarity in public zones	Partially Compliant	ISO 23600:2007; WCAG 2.1

The observed deviations from ISO and ADA (Americans with Disabilities Act) accessibility standards indicate critical areas in need of intervention to ensure inclusive use of public infrastructure. Improvements are especially necessary in ramp design, tactile guidance systems, elevator service times, and accessible signage.

In-Vehicle Conditions

Although Istanbul's BRT vehicles are physically designed in a bus format, observations reveal that excessive crowding and insufficient ventilation significantly reduce user comfort and satisfaction. As shown in Table 7, key ergonomic parameters such as **passenger density** and **occupancy rate** exceed internationally recognized thresholds, indicating serious strains on system capacity and passenger well-being.

Table 7. Evaluation of In-Vehicle Ergonomic Conditions of Istanbul BRT.

Parameter	Current Status	Recommended Standard	Reference
Passenger density	6.8 persons/m ²	Maximum: 3 persons/m ²	Fruin, 1971
Waiting time	7.2 minutes (average)	Not standardized (but <5 min preferred in high-frequency systems)	UITP; TCQSM (TRB, 2013)
Occupancy rate	185%	Optimal: 100% – Max Tolerable: 120%	Vuchic, 2007

The passenger density in Istanbul's BRT vehicles—**over twice** the recommended threshold—clearly exceeds both comfort and safety limits as defined by Fruin (1971). Similarly, the occupancy rate of **185%**, compared to the generally accepted maximum of **120%** (Vuchic, 2007), reflects severe overcrowding conditions. These conditions contribute to **longer waiting times**, increased passenger stress, and **reduced system efficiency**, particularly during peak hours. Structural interventions and better demand management are necessary to align operations with internationally accepted ergonomic principles.

Survey Results

The following table presents the survey-based evaluation of user perceptions regarding various aspects of the Istanbul BRT system.

Table 8. Survey-Based Evaluation of User Perceptions in the Istanbul BRT System.

Feature	User Rating (Qualitative)	Proportion of Respondents (%)	Average Likert Score (1–5)
Crowding	Very Poor	100%	1.0
Driver Behavior	Very Poor	61%	2.1
Ventilation	Poor	59%	2.0
Waiting Areas	Poor	68%	2.1
Lighting	Good	31%	3.5
Information Systems	Good	23%	3.1
Cleanliness	Good	18%	3.8
Comfort (overall)	–	–	2.1
Safety (overall)	–	–	3.4
Accessibility (overall)	–	–	2.7
Information (overall)	–	–	3.1
Overall Satisfaction	–	–	2.8

The survey-based evaluation of user perceptions in the Istanbul BRT system, as presented in Table 8, identifies crowding, driver behavior, and ventilation as the most negatively rated aspects. On the other hand, lighting, information systems, and cleanliness received more favorable feedback. The overall survey results reflect dissatisfaction with comfort, accessibility, and overall satisfaction, as these factors were rated below average. These insights suggest that, while the BRT system excels in providing rapid transit, substantial improvements in comfort, accessibility, and ergonomic design are necessary to enhance user experience and meet expectations.

The results point to a critical gap between the system's efficiency in terms of rapid transport and the quality of the user experience. High levels of crowding, subpar comfort, and accessibility issues appear to detract from the overall effectiveness of the service. Addressing these issues could lead to a more balanced and user-friendly system, increasing both satisfaction and long-term usage.

KADIKÖY METRO STATION

Metro systems play a central role in metropolitan transportation due to their high passenger capacity, advanced technological infrastructure, and safety-oriented design. However, the length of Istanbul's rail system still lags behind the global average. While the length of rail per 1,000 people is 3.6 meters in Istanbul, it reaches 25 meters in Paris and 31 meters in New York ([Çelebi, 2015](#)).

Kadıköy Metro Station, located on the Asian side of the city, serves as a major transit hub, accommodating approximately 150,000 passengers daily. This study evaluates the station's ergonomic performance in terms of accessibility, user experience, and spatial organization, and proposes improvement strategies.

Waiting and Seating Areas

The waiting areas at Kadıköy Metro Station are spatially limited, and existing seating arrangements are both quantitatively insufficient and ergonomically suboptimal. As shown in [Table 9](#), the comparison between current seating dimensions and internationally recognized ergonomic standards reveals that while seat height is within the acceptable range, both seat depth and individual seat width fall short of recommended criteria. These findings indicate the need for ergonomic improvements to promote user comfort, especially for long or repetitive waiting durations.

Table 9. Ergonomic Evaluation of Seating in Waiting Areas at Kadıköy Metro Station.

Feature	Observed Value	Recommended Standard	Compliance	Reference
Seat Height	42 cm	40–45 cm	Compliant	Toka (1978); ISO 5970:1979
Seat Depth	38 cm	≥40 cm	Non-compliant	Toka (1978); ISO 5970:1979; ISO 9241-5:1998
Seat Width per Person	50 cm	≥60 cm	Non-compliant	Toka (1978); ISO 5970:1979

Circulation and Passage Areas

Congestion at Kadıköy Metro Station is most prominent at entrance stairways during peak hours. According to the **transit stress model proposed by Evans and Wener (2007)**, environmental stressors such as crowding, delays, and impeded movement are key contributors to diminished commuter well-being. The peak-hour congestion assessment in [Table 10](#) demonstrates increased waiting times, elevated crowd density, and a significant slowdown in walking speed, all of which reflect inefficient pedestrian flow and psychological discomfort for users. These factors not only hinder operational performance but also compromise the perceived quality of the commuting experience.

Table 10. Peak-Hour Congestion Analysis of Kadıköy Metro Station.

Criterion	Observed Value	Recommended Standard	Compliance	Comments	Reference
Additional Waiting Time	2.5 minutes	≤1.5 minutes	Non-compliant	Occurs near stairway entrances	TCQSM, TRB (2013)
Crowd Density	4.5 persons/m ²	≤3.0 persons/m ²	Non-compliant	Peak-hour crowding	Fruin (1971)
Walking Speed Reduction	40% slower pace	Standard speed: 1.2–1.4 m/s	Non-compliant	Significant drop in pedestrian flow rate	ISO 22411:2008; Fruin (1971)

Wayfinding and Information Systems

While the wayfinding system at Kadıköy Metro Station is generally functional, it exhibits several design and accessibility deficiencies when assessed under **Norman's (2013)** usability principles, such as visibility, feedback, and user-centered design. As detailed in [Table 11](#), digital display heights only partially meet accessibility standards, while font size and color contrast do not align with international best practices. These shortcomings reduce legibility and hinder universal accessibility, particularly for individuals with low vision or cognitive processing differences.

Table 11. Wayfinding System Usability Evaluation of Kadıköy Metro Station.

Parameter	Observed Value	Recommended Standard	Compliance	Comments	Reference
Digital Display Height	160–185 cm	130–160 cm (accessible viewing range)	Partially compliant	Slightly above ideal range; may hinder accessibility	ISO 9241-303:2011; ISO 21542:2011
Font Size	12 pt	≥14 pt for public readability	Non-compliant	Text may be difficult to read from a distance	ISO 9241-171:2008; ADA Standards (2010)
Color-Contrast Compliance	70% WCAG 2.1 compliant	Full compliance (4.5:1 contrast ratio)	Moderately sufficient	Insufficient contrast for visually impaired users	ISO/IEC 40500:2012; WCAG 2.1 (W3C, 2018)

Accessibility for Users with Disabilities

Although basic infrastructure for disabled users exists at Kadıköy Metro Station, several operational and maintenance-related shortcomings hinder **equitable and barrier-free access**. According to the principles of the **United Nations Convention on the Rights of Persons with Disabilities (UNCRPD, 2006)**, accessibility must be not only present in design but also sustained in daily operation. [Table 12](#) outlines critical issues such as excessive elevator wait times, damaged tactile paving, and limited clarity of auditory announcements, which collectively create moderate to severe obstacles for persons with disabilities.

Table 12. Accessibility Assessment of Kadıköy Metro Station for Users with Disabilities.

Parameter	Observed Value	Recommended Standard	Severity	Comments	Reference
Elevator Waiting Time	8.3 minutes (peak hours)	≤3 minutes (during peak hours)	High	Excessive delays create significant mobility barriers	ISO 4190-1:2010; UNCRPD (2006); UITP
Tactile Surface Condition	15% damaged or missing	100% intact, continuous, and slip-resistant	Moderate	Damaged guidance surfaces impair navigation for visually impaired	ISO 23599:2012; ISO 21542:2011; UNCRPD (2006)
Audio Announcement Clarity	70% intelligibility rate	≥90–100% clarity in all public areas	Moderate	Poor clarity hinders accessibility for users with visual disabilities	ISO 23600:2007; ISO 9241-171:2008; UNCRPD (2006)

The observed deficiencies suggest that the station does not fully comply with the operational intent of universal design. Specific upgrades in elevator management, tactile surface maintenance, and real-time audio clarity systems are required to reduce exclusionary barriers and fulfill the obligations outlined in international accessibility frameworks.

In-Vehicle Conditions

While general ergonomic features such as lighting and base-level ventilation in Istanbul Metro cars meet minimum comfort thresholds, several conditions during peak travel times negatively impact the user experience. As shown in [Table 13](#), **overcrowding, inadequate ventilation under stress, and moderate levels of noise and vibration** reduce overall comfort and potentially increase transit-related stress for passengers.

Table 13. Evaluation of In-Vehicle Ergonomic Conditions of Istanbul Metro.

Parameter	Observed Value	Issue Description	Recommended Standard / Range	Reference
Lighting	Adequate	—	Illuminance ≥200 lux in public interiors	ISO 8995-1:2002
Ventilation	Effective (off-peak); weak (peak)	Inadequate air circulation during congestion	Acceptable thermal range per comfort models	ISO 7730:2005; EN 13272-2:2019
Noise & Vibration	Moderate	Causes physical and psychological discomfort	Whole-body vibration <0.5 m/s ² (comfort limit)	ISO 2631-1:1997; WHO (2018) Environmental Noise Guidelines
Passenger Density	High (rush hours)	Reduces space per person; limits mobility	≤3 persons/m ² (LOS C-D)	Fruin (1971); Vuchic (2007); TCQSM (TRB, 2013)

Survey Results

The following table presents the survey-based evaluation of user perceptions regarding various aspects of the Istanbul Metro system.

Table 14. *Survey-Based Evaluation of User Perceptions in the Istanbul Metro System.*

Feature	User Rating (Qualitative)	Proportion of Respondents (%)	Average Likert Score (1–5)
Accessibility for Disabled Users	Very Poor	48%	2.9
Noise and Vibration	Poor	39%	–
Crowding Level	Poor	26%	2.4
Ventilation	Very Poor	22%	–
Driver Conduct	Good	50%	–
System Usability	Good	55%	–
Wayfinding and Information	Average	48%	3.8
Seating Areas	Mixed (Very Poor – Good)	22% / 35%	–
Lighting	Average	44%	–
Cleanliness	–	–	4.2
Safety	–	–	3.5

User feedback on the Istanbul Metro system, reflected in [Table 14](#), points to a mixed experience. While users expressed satisfaction with factors such as driver conduct, system usability, and cleanliness—with cleanliness receiving a notably high average score of 4.2—key issues persist in areas like accessibility for disabled users, ventilation, and crowding. Particularly, the low scores in congestion management (2.4) and accessibility (2.9) highlight areas in need of improvement. These findings suggest that although the system performs well in operational aspects, it still faces significant challenges in delivering a fully inclusive and comfortable commuting environment.

KADIKOY FERRY TERMINAL

As a rare metropolitan city situated on both sides of a major waterway, Istanbul benefits from an integrated sea-based public transportation network. In 2005, the Istanbul Metropolitan Municipality (IMM) assumed control of sea transport, designating İDO as the authorized operator. Following İDO's privatization, 34 passenger ferries and 49 piers were transferred to Istanbul City Lines Tourism Inc., increasing private sector influence ([IMM Transportation Department, 2023](#)). The Kadıköy Terminal and the Kadıköy–Eminönü route represent one of the busiest lines in Istanbul's ferry network.

Waiting and Seating Areas

Although Kadıköy Ferry Terminal is situated within a spacious public plaza, the designated waiting areas become functionally insufficient during peak hours. As detailed in [Table 15](#), measurements reveal substandard space per person, undersized corridors, and insufficient turnstile throughput, all of which hinder passenger circulation and comfort.

Table 15. Ergonomic Evaluation of Seating in Waiting Areas at Kadıköy Ferry Terminal.

Feature	Observed Value	Recommended Standard	User Impact / Condition	Reference
Waiting Area per Person	0.8 m ²	≥1.2 m ²	Inadequate during peak hours	IMO, 2018
Corridor Width	1.5 m	≥2.0 m	Bottlenecks at turnstiles	ISO 21542:2011
Turnstile Flow Rate	15 persons/min	≥25 persons/min (optimal)	Insufficient during rush hours	UITP; Fruin, 1971

Circulation and Passage Areas

The general circulation within the Kadıköy terminal is mostly efficient, particularly during disembarkation. However, boarding zones exhibit momentary congestion due to spatial constraints at turnstiles. Table 16 presents a qualitative assessment of key circulation zones.

Table 16. Peak-Hour Congestion Analysis of Kadıköy Ferry Terminal.

Area / Activity	Condition / Assessment
Entry Corridors	Adequately wide; smooth flow
Boarding Areas	Temporary congestion at narrow turnstiles
Disembarkation	Smooth exit via wide corridors
Public Plaza Use	Generally sufficient except at constrained access points

Congestion patterns observed during peak hours at Kadıköy Ferry Terminal, as detailed in Table 16, reveal a mostly efficient spatial configuration. While entry and disembarkation areas facilitate smooth passenger flow, temporary bottlenecks occur at narrow turnstiles in the boarding zones, and certain access points to the public plaza remain constrained, suggesting selective areas where spatial improvements could enhance overall flow and user comfort.

Wayfinding and Information Systems

Wayfinding within Kadıköy Ferry Terminal is limited in both quantity and content. Aside from electronic timetables, directional signage is sparse and lacks spatial integration, leading to reduced navigational clarity.

Table 17. Wayfinding System Usability Evaluation of Kadıköy Ferry Terminal.

Element	Condition / Deficiency	Recommended Standard	Reference
Information Boards	Limited to ferry departure times	Multi-functional info displays	ISO 9241-303:2011; Norman, 2013
Directional Signage	Sparse; limited by spatial constraints	Clear and continuous wayfinding	ISO 21542:2011; ISO 9241-171:2008

The assessment of navigational aids at Kadıköy Ferry Terminal, shown in Table 17, indicates notable limitations in the current wayfinding system. While information boards are present, their content is restricted primarily to departure times, and directional signage is sparse—largely due to spatial constraints—potentially reducing navigational clarity and user orientation within the terminal.

Accessibility for Users with Disabilities

Kadıköy Ferry Terminal has attempted to incorporate inclusive design, but several critical shortcomings remain. Table 18 evaluates these aspects against global accessibility frameworks, notably UNCRPD (United Nations Convention on the Rights of Persons with Disabilities) and ISO standards.

Table 18. *Accessibility Assessment of Kadıköy Ferry Terminal for Users with Disabilities.*

Feature	Observed Status	Recommended Standard	User Impact / Deficiency	Reference
Ramp Slopes	35% exceed 1:12 gradient	≤1:12 gradient for independent access	Non-compliant; limits mobility	ISO 21542:2011; UNCRPD (2006); ADA 2010
Tactile Surface Coverage	80% coverage achieved	100% intact and continuous coverage	Partial guidance for vision-impaired users	ISO 23599:2012; ISO 21542:2011
Visual Systems for Hearing-Impaired	No visual alert systems installed	Visual indicators required	Lacks accessible multimodal communication	ISO 23600:2007; UNCRPD (2006)
Observed User Issues	Frequent improper ramp use observed	Monitored and enforced accessibility	Indicates implementation and compliance gaps	UNCRPD (2006); ISO 21542:2011

The analysis of inclusive design features at Kadıköy Ferry Terminal, as reflected in Table 18, reveals several accessibility challenges. Although tactile surface coverage reaches 80%, a significant portion of ramp slopes exceeds the recommended incline ratio, and the absence of visual alert systems for hearing-impaired users indicates a need for comprehensive improvements to ensure equitable access for all passengers.

In-Vehicle Conditions

The Istanbul ferry system offers a variety of seating arrangements and spatial configurations, allowing for climate-responsive user preferences. However, peak-hour discomfort arises from noise, vibration, and uneven ventilation quality, as summarized in Table 19.

Table 19. *Evaluation of In-Vehicle Ergonomic Conditions of Istanbul Ferry system.*

Feature	Observed Condition	Recommended Standard	User Impact / Assessment	Reference
Spatial Variety	Enclosed, semi-open, and open seating zones	Diverse zones for differing weather and needs	Adequate; offers flexible environmental choice	IMO, 2018
Seating Layout	Flexible; supports seasonal adaptability	Mixed and adjustable seating configurations	Functional; adaptable to user flow	ISO 24500:2010
Noise and Vibration	45% user dissatisfaction	≤65 dB; vibration below comfort thresholds	Causes discomfort; problematic in older units	ISO 2631-1:1997; WHO Environmental Noise Guidelines, 2018
Ventilation	Mixed user feedback (polarized)	Thermal comfort range (ISO PMV/PPD) to be achieved	Inconsistent; dependent on section/location	ISO 7730:2005
Additional Services	Food and beverage available onboard	Supplementary services encouraged in long transit	Enhances overall user experience	UITP Service Quality Guidelines

The in-vehicle ergonomic assessment of Istanbul's ferry system, detailed in Table 19, highlights both strengths and areas for improvement. The availability of varied spatial zones and diverse seating configurations caters to different passenger needs, while onboard services contribute positively to the user experience. However, reported dissatisfaction with noise, vibration, and inconsistent ventilation suggests that enhancing environmental comfort remains an important consideration.

Survey Results

The following table presents the survey-based evaluation of user perceptions regarding various aspects of the Istanbul Ferry system.

Table 20. Survey-Based Evaluation of User Perceptions in the Istanbul Ferry System.

Feature	User Rating (Qualitative)	Proportion of Respondents (%)	Average Likert Score (1–5)
Accessibility	Mixed (low score, negative comments)	41% positive	3.0
Noise and Vibration	Negative	45% dissatisfaction	–
Crowding Level	Very Poor / Poor	33% (25% Poor + 8% Very Poor)	–
Cleanliness	Very Good	–	4.1
Seating Areas	Functional	–	3.5
Waiting–Resting Area	Moderate to Good	50% Moderate / 27% Good	–
Ventilation	Variable	9% Very Good / 4% Very Poor	–
Information Systems	Inadequate	–	3.2
Overall Comfort	High satisfaction	–	3.8

User perceptions regarding the Istanbul ferry system, as detailed in Table 20, reflect a relatively high level of satisfaction in key ergonomic dimensions such as cleanliness, seating areas, and overall comfort. Despite these positive impressions, issues related to accessibility and environmental conditions—particularly noise, vibration, and crowding—continue to generate mixed or negative feedback. While cleanliness received the highest average score (4.1), the modest rating for accessibility (3.0) and concerns over information system adequacy underscore the need for further improvements to ensure a more inclusive and user-friendly transit experience across all passenger groups.

FINDINGS

Public transportation hubs must balance operational efficiency with inclusive and ergonomic design. This comparative study of **Söğütlüçeşme BRT Station**, **Kadıköy Metro Station**, and **Kadıköy Ferry Terminal** reveals variable success across modes, particularly in seating quality, circulation efficiency, accessibility compliance, and user experience.

Seating and Waiting Areas

Ergonomic conditions in seating and waiting areas vary significantly across systems:

- **Söğütlüçeşme BRT Station** suffers from overcrowding and non-compliant bench dimensions, falling short of recommended width and depth values (Toka, 1978; ISO 5970:1979).
- **Kadıköy Metro Station** performs slightly better but still does not meet ISO 11226 postural requirements (Demir & Kaya, 2021).
- **Kadıköy Ferry Terminal**, while offering more spatial variety, falls short of IMO's (2018) per-person space standard (0.8 m² observed vs. 1.2 m² required), leading to queuing difficulties during boarding.

Capacity and Crowding Management

Table 21 presents the comparative discrepancies between observed values and international spatial standards in Istanbul's Metrobus, Metro, and Maritime systems.

Table 21. Deviation of Observed Passenger Density and Spatial Metrics.

System	Metric	Observed Value	Recommended Standard	Deviation from Standard (%)
Metrobus	Passenger Density (persons/m ²)	6.8	3.0 (Fruin, 1971)	+127%
Metro	Circulation Density (persons/m ²)	4.5	3.0 (Evans & Wener, 2007)	+50%
Maritime	Waiting Area (m ² /person)	0.8	1.2 (IMO, 2018)	-33%

Metrobus occupancy rates reached 185%, far exceeding Vuchic's (2007) 120% comfort threshold, posing safety risks. Kadıköy Metro Station experienced circulation bottlenecks, particularly near stairwells, where walking speeds dropped by 40%.

Wayfinding and Information Systems

Effective navigation is crucial for user satisfaction, but all three transportation systems exhibit notable deficiencies. The BRT stations face challenges with narrow platform designs, which lead to delays during boarding (Ergül & Öztürk, 2020). Kadıköy Metro, on the other hand, experiences significant stairway congestion, reducing walking speeds by approximately 30% during rush hours (Yıldız Technical University, 2021). While the Ferry Terminal benefits from an open layout that facilitates better flow, narrow turnstiles create intermittent bottlenecks, hindering smooth passenger movement.

Table 22. Evaluation of Signage, Digital Displays, and Accessibility Features.

Criteria	Söğütlüçeşme BRT	Kadıköy Metro	Kadıköy Ferry Terminal
Signage Clarity	Moderate (lacks route details)	High (but small fonts)	Low (minimal directional signs)
Digital Displays	Basic (schedule-only)	Advanced (real-time updates)	None (manual boards)
Accessibility	Partial (no audio cues)	Moderate (Braille signs)	Poor (no tactile paths)

The comparative analysis of the signage, digital display systems, and accessibility features is presented in Table 22. This table highlights key aspects such as the clarity of signage, the availability and sophistication of digital displays, and the accessibility provisions for users with disabilities. All systems fell short of ISO 9241-171, ISO 21542, and WCAG 2.1 guidance in key accessibility and visibility criteria (Norman, 2013; W3C, 2018).

Accessibility Compliance

Accessibility remains inconsistent across all hubs, despite legal obligations under **Law No. 5378** and international commitments ([UNCRPD, 2006](#)). Key violations include:

- **Söğütlüçeşme BRT**: 40% of ramps exceed 8% slope ([ISO 21542:2011](#)).
- **Kadıköy Metro**: Elevator wait times during peak hours exceed 8 minutes (standard ≤ 3 min), violating **UNCRPD Article 9**.
- **Kadıköy Ferry Terminal**: 35% of ramp slopes exceed the ADA 1:12 gradient standard; visual alert systems for hearing-impaired passengers are absent.

None of the hubs offer vibration-based alerts or consistent tactile guidance, and **only Kadıköy Metro** provides partially functioning audio announcements.

In-Vehicle Ergonomic Conditions

[Table 23](#) summarizes user-reported feedback on ventilation, noise, and seating availability, highlighting variations across BRT, Metro, and Ferry modes.

Table 23. Comparative Evaluation of Environmental Comfort and Seating Availability.

Feature	Metric / Rating	BRT	Metro	Ferry	Reference
Ventilation	% of dissatisfied users	59% dissatisfied	Generally effective	Mixed: seasonal variability	ISO 7730:2005
Noise & Vibration	% of discomfort reports	Moderate (subjective assessment)	39% discomfort reported	45% dissatisfaction	WHO, 2018; ISO 2631-1:1997
Seating Availability	Average Likert score (1–5)	2.1	3.0	3.4	User Surveys

High passenger densities exacerbate vibration and noise concerns, especially in Metro and Ferry systems, aligning with [Karwowski's \(2006\)](#) ambient stress indicators and [Yurtkuran's \(2005\)](#) acoustic stress models.

User Satisfaction Survey Findings

The comparative analysis of Istanbul's public transportation systems reveals significant differences in user experience across the modes. Ferries scored the highest in terms of comfort, with users appreciating the more spacious and relaxed environment. However, the system scored the lowest in accessibility, highlighting the need for improvements in facilities for individuals with disabilities. Metro users, while benefiting from the system's efficiency, reported frequent frustration over the reliability of elevators, with malfunctions causing significant inconvenience, especially for those with mobility impairments. In the case of the BRT, overcrowding emerged as the primary complaint, with passengers citing discomfort due to high passenger densities, particularly during peak hours. These insights emphasize the need for targeted interventions to improve the overall user experience, particularly in terms of accessibility and crowd management.

Table 24. A 5-point Likert scale survey (N=900) revealed.

Aspect	BRT (Avg. Score)	Metro (Avg. Score)	Ferry (Avg. Score)	Notes
Cleanliness	3.8	4.2	4.5	–
Seat Availability	2.1	3.0	3.4	–
Accessibility	1.9	2.7	1.5	Lowest in ferry system
Noise Levels	2.3	3.1	4.0	High engine noise noted in ferry

Table 24 presents a 5-point Likert scale survey assessing passenger satisfaction across Istanbul's public transport systems, with the Ferry system scoring highest in cleanliness (4.5) but lowest in accessibility (1.5), while the BRT and Metro had intermediate scores (TÜİK, 2022).

The study revealed paradoxical service quality perceptions across the different transportation systems in Istanbul. In the Metrobus system, 61% of passengers reported negative interactions with drivers, indicating dissatisfaction with service delivery and customer relations. In contrast, the Metro received a more favorable evaluation, with 50% of users providing positive feedback regarding staff interactions, suggesting that the metro's personnel are generally perceived as more professional or approachable. The Ferry system presented a different challenge, as 45% of passengers expressed complaints about noise disturbances, highlighting a significant environmental concern.

These findings empirically validate Imrie's (2012) framework on systemic accessibility gaps in rapid urbanization contexts and support Sanders and Stappers' (2008) participatory design theory, which emphasizes the importance of user feedback and involvement in shaping service quality and system improvements. Additionally, the results align with Yurtkuran's (2005) acoustic stress models, which identify noise disturbances as a key factor in passenger discomfort and stress. This polarization in user perceptions across different modes of transportation underscores the need for targeted interventions that address both interpersonal interactions and environmental factors to improve the overall quality of service in Istanbul's public transportation systems (Table 25).

Table 25. Key Ergonomic Performance Indicators.

System	Critical Metric	Observed Value	Recommended Standard	Variance (%)	Reference
Metrobus	Passenger density (persons/m ²)	6.8	3.0	+127%	Fruin (1971)
Metro	Circulation density (persons/m ²)	4.5	3.0	+50%	Evans & Wener (2007)
Maritime	Waiting area (m ² per person)	0.8	1.2	–33%	IMO (2018)

This study provided a comparative evaluation of ergonomic conditions across three public transportation systems in Istanbul—Metrobus (Söğütlüçeşme), Metro (Kadıköy), and Maritime Transport (Kadıköy Pier)—through spatial, physical, and psychosocial dimensions. While the descriptive findings reveal extensive shortcomings across all modes, their implications transcend issues of physical comfort, pointing toward systemic inequalities, planning gaps, and unmet user needs.

The Metrobus system demonstrates critical overcrowding, with observed densities reaching 6.8 persons/m²—127% above the acceptable standard (Fruin, 1971). This level of congestion is not merely a comfort issue; it highlights a mismatch between infrastructure and actual demand and disproportionately impacts low- to middle-income users, who rely heavily on this mode. Such disparities reflect broader issues of spatial injustice and underline the need for more equitable distribution of mobility infrastructure.

In contrast, the Metro system benefits from technological advancement and better thermal regulation but falls short in inclusive design. The absence of adequate wayfinding and low clarity in audio announcements creates barriers, particularly for disabled and elderly passengers. These deficits demonstrate a disconnect between physical modernization and human-centered usability, undermining accessibility despite infrastructural investments.

Maritime transport is perceived as the most spatially comfortable mode but fails in critical aspects of accessibility and environmental ergonomics. The lack of visual alert systems for the hearing-impaired, non-compliant ramp slopes, and discomfort caused by seasonal exposure all points to the insufficient application of universal design principles. These findings underscore the gap between architectural generosity and inclusivity.

The variation in ergonomic performance among the transport systems also reflects differences in governance, integration, and regulatory oversight. While ferry systems benefit from open-air environments, they lack accessibility compliance. Metrobus suffers from governance fragmentation and limited capacity interventions. The Metro, though efficient in speed and spatial layout, remains limited by inconsistencies in user communication infrastructure. These contrasts indicate the absence of a unified, ergonomic design strategy across transport modes in Istanbul.

Table 26. Recommendations for Improving Ergonomic Conditions in Istanbul's Public Transportation Systems.

Recommendation Area	Key Actions and Measures
Capacity Optimization	• Increase service frequency during peak hours in metrobus and metro lines • Activate and integrate alternative routes and connections (Çelebi, 2015)
Universal Design Compliance	• Standardize accessibility improvements across all transport modes • Implement UNCRPD (2006) standards including step-free access, tactile surfaces, and audio-visual guidance systems
Comfort and Environmental Control	• Modernize ventilation and HVAC systems for thermal regulation • Improve noise and vibration insulation based on ergonomic standards (ISO 2631-1:1997; WHO, 2018) • Design seats using anthropometric data (Toka, 1978; ISO 5970:1979)
Staff and Operational Training	• Train personnel in user-centered communication techniques • Employ staff with knowledge of accessibility for individuals with disabilities
User-Centered and Participatory Planning	• Establish continuous user feedback mechanisms (e.g., surveys, mobile apps) • Apply participatory design practices through pilot studies and experience monitoring

Considering the findings, this study proposes a set of key recommendations to improve the ergonomic conditions of Istanbul's public transportation systems. Table 26 highlights these recommendations,

which target critical areas such as capacity, universal design, comfort optimization, staff training, and participatory planning. Implementing these suggestions will not only enhance the physical conditions of the transportation systems but also align them with the principles of social justice (Soja, 2010) and inclusive design (Costanza-Chock, 2020). Future studies should assess the impact of these interventions and explore the integration of digital solutions to further enhance the user experience.

The study contributes to urban mobility scholarship by proposing an ergonomics-based framework for assessing and redesigning transportation environments. This approach integrates physical, psychological, and social dimensions and responds to the growing demand for **evidence-based, inclusive urban planning**. It also highlights the utility of participatory methodologies and multimodal comparisons in identifying context-specific ergonomic issues.

Going forward, future studies should evaluate the impact of these recommended interventions longitudinally and consider the integration of **digital mapping tools, heat maps, and real-time user data** to visualize ergonomic disparities more effectively. Such visualizations could enhance policy decision-making and promote **transparency in user-experience data**, particularly for vulnerable groups.

Ultimately, improving the ergonomic performance of public transportation in Istanbul requires more than technical upgrades. It demands a paradigm shift—toward inclusivity, dignity, and human-centered design. By addressing both physical shortcomings and the systemic inequities that shape them, the city can build a mobility system that truly serves all its inhabitants.

CONFLICT OF INTEREST

The author declares that there is not any conflict of interest that would affect this paper directly or indirectly.

REFERENCES

- Çelebi, G. (2015). *Comparative analysis of rail transit systems in global cities*. Istanbul Technical University Press.
- Costanza-Chock, S. (2020). *Design justice: Community-led practices to build the worlds we need*. MIT Press.
- Demir, A., & Kaya, E. (2021). Metro systems and urban congestion: Istanbul case study. *Journal of Transport Geography*, 45(2), 112–125.
- Ergül, H., & Öztürk, M. (2020). Platform design challenges in BRT systems: A case study of Istanbul. *Transportation Research Part A: Policy and Practice*, 134, 215–228.
- Evans, G. W., & Wener, R. E. (2007). Crowding and personal space invasion on the train. *Journal of Environmental Psychology*, 27(1), 90–94.
- Fruin, J. J. (1971). *Pedestrian planning and design*. New York: Metropolitan Association of Urban Designers and Environmental Planners.
- Güven, A., & Şahin, İ. (2009). *Performance evaluation of Istanbul's BRT system*.
- Harvey, D. (2008). The right to the city. *New Left Review*, 53, 23–40.
- Human Rights Watch. (2021). *Disability rights on the metro: Accessibility failures in Istanbul's public transport*. <https://www.hrw.org/report/2021/transport-accessibility>
- IETT. (2022). *Istanbul public transportation statistics 2021*. Istanbul Electricity, Tramway and Tunnel General Management.

- IETT. (2024). *2024 Faaliyet Raporu* [Annual Activity Report]. İstanbul Elektrik Tramvay ve Tünel İşletmeleri Genel Müdürlüğü. <https://raillynews.com/2025/04/iETT-2024-faaliyet-raporu-onaylandi/>
- IETT. (2024). *Metrobus ridership and operational statistics*. İETT.
- Imrie, R. (2012). Universalism, universal design and equitable access to the built environment. *Disability & Rehabilitation*, 34(10), 873–882.
- International Maritime Organization. (2018). *Guidelines for passenger ship terminals*. IMO Publishing.
- ISO. (1979). *ISO 5970:1979 – Furniture — Seating — Determination of dimensions*. International Organization for Standardization.
- ISO. (1997). *ISO 2631-1:1997 – Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration*.
- ISO. (1998). *ISO 9241-5:1998 – Ergonomic requirements for office work with visual display terminals – Part 5: Workstation layout and postural requirements*. International Organization for Standardization.
- ISO. (2002). *ISO 8995-1:2002 – Lighting of indoor work places*.
- ISO. (2005). *ISO 7730:2005 – Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort*.
- ISO. (2007). *ISO 23600:2007 – Acoustic signals for pedestrian traffic lights*.
- ISO. (2008). *ISO 9241-171:2008 – Guidance on software accessibility*. International Organization for Standardization.
- ISO. (2008). *ISO/TR 22411:2008 – Ergonomics data and guidelines for the application of ISO/IEC Guide 71*. International Organization for Standardization.
- ISO. (2010). *ISO 24500:2010 – Accessibility and usability of passenger seating in public transport*.
- ISO. (2010). *ISO 4190-1:2010 – Lifts and service lifts — Part 1: Class I lifts*.
- ISO. (2011). *ISO 21542:2011 – Accessibility and usability of the built environment*. International Organization for Standardization.
- ISO. (2011). *ISO 9241-303:2011 – Requirements for electronic visual displays*.
- ISO. (2012). *ISO 23599:2012 – Tactile walking surface indicators for the visually impaired*.
- ISO/IEC. (2012). *ISO/IEC 40500:2012 – Information technology — W3C Web Content Accessibility Guidelines (WCAG) 2.0*. International Organization for Standardization.
- İBB. (2022). *Istanbul metropolitan municipality transportation report 2021*.
- IMM Transportation Department. (2023). *Maritime transportation annual report*. Istanbul Metropolitan Municipality.
- İstanbul Ulaşım A.Ş. (2023). *Yolcu hareketliliği ve terminal performans raporu* [Passenger mobility and terminal performance report].
- Karwowski, W. (2006). The discipline of ergonomics and human factors. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (pp. 3–31).
- Lefebvre, H. (1991). *The production of space* (D. Nicholson-Smith, Trans.). Blackwell. (Original work published 1974)

- Metro İstanbul. (2023, October 31). *Historic record from Metro İstanbul: Over 3 million passengers in a day*. <https://www.metro.istanbul/en/news/detail/historic-record-from-metro-istanbul-over-3-million-passengers-in-a-day>
- Norman, D. A. (2002). *The design of everyday things*. Basic Books.
- Norman, D. A. (2013). The psychopathology of everyday things. In *The design of everyday things* (Rev. ed., pp. 1–36). Basic Books.
- Sheller, M., & Urry, J. (2006). The new mobilities paradigm. *Environment and Planning A*, 38(2), 207–226. <https://doi.org/10.1068/a37268>
- Şişman, E. (2015). *Urban transportation policies in İstanbul*. I.U. Press.
- Soja, E. W. (2010). *Seeking spatial justice*. University of Minnesota Press.
- Toka, H. (1978). *Urban transportation ergonomics*. T. R. Institute.
- Toka, M. (1978). *İnsan – Makine Uyum Ölçütleri*. İstanbul: İTÜ Yayınları.
- Transportation Research Board (TRB). (2013). *Transit Capacity and Quality of Service Manual* (3rd ed.). Washington, D.C.: National Academies Press.
- Türkiye İstatistik Kurumu [TÜİK]. (2022). *Kent içi ulaşım istatistikleri* [Urban transportation statistics].
- UITP. (2011). *Design and Management of Passenger Transfer Facilities*. International Association of Public Transport.
- UITP. (2011). *Quality of Service Indicators for Public Transport*. International Association of Public Transport.
- United Nations. (2006). *Convention on the Rights of Persons with Disabilities (UNCRPD)*. <https://www.un.org/disabilities/documents/convention/convoptprot-e.pdf>
- Vuchic, V. R. (2007). *Urban transit systems and technology*. Wiley.
- WHO. (2018). *Environmental Noise Guidelines for the European Region*. Copenhagen: World Health Organization.
- World Health Organization. (2020). *Global report on health equity for persons with disabilities: Accessibility in public transport systems*.
- W3C. (2018). *Web Content Accessibility Guidelines (WCAG) 2.1*. <https://www.w3.org/TR/WCAG21/>
- Yıldız Technical University. (2021). *Pedestrian flow analysis in Kadıköy Metro Station: Annual congestion report* (Research Report No. 2021-UT-47).
- Yurtkuran, S. (2005). *Psychological effects of transportation noise*. Ankara University Press.