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Measurement of Integration of Shared Bicycle Stations to Rail System in Providing Sustainable Mobility; Examining Examples from Turkey

Oğuz Fatih BAYRAKTAR[1,*], Hayri ULVİ[2]

[1] *0000-0003-3848-3485, Graduate School of Natural and Applied Sciences, Department of City and Regional Planning (PhD Student), Gazi University, Ankara*

[2] *0000-0003-2988-6215, Faculty of Architecture, Department of City and Regional Planning, Gazi University, 06570 Maltepe / Ankara*

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Abstract

In recent years, the paradigm shift towards sustainable mobility in transportation planning has led to an acceleration in scientific studies aimed at improving the performance of sustainable urban transport modes. The aim is to increase sustainability performance by facilitating the transition between sustainable modes within sustainable mobility systems. The concept of intermodality is key to overcoming the origin and destination transport problem (the first and last mile problem) in public transport. Shared bicycle systems, which support rail public transport, are a tool that can increase the performance of sustainable urban mobility as an intermodal travel model, overcoming the first and last mile problem. Well-planned shared bicycle systems that are well-integrated with rail systems increase the success of rail systems in cities and enhance their sustainability impact. This paper aims to present literature on the integration of shared bicycle stations into rail systems, evaluate the level of integration of urban rail systems with shared bicycle systems in Turkey and provide recommendations for transport policies to increase the sustainability impact of rail systems. Additionally, measuring the spatial accessibility of shared bicycle stations within a pedestrian access distance of rail system stations using the isochron mapping method provides a suggestion that can be used elsewhere in the world to measure the level of intermodality between rail systems and shared bicycle systems.

Note: This article is based on the topics covered in the doctoral dissertation of Oğuz Fatih Bayraktar at Gazi University, Institute of Science, Department of Urban and Regional Planning.

1. INTRODUCTION

Since the mid-19th century, the bicycle has been used as a means of urban transportation in Europe, especially in France. The inability to easily purchase automobiles has allowed the bicycle to become an effective mode of transportation in urban areas. During this same period, the bicycle played an important role in the memory of urbanization due to the accelerated trend of urbanization resulting from the Industrial Revolution. However, the increasing production of private vehicles after World War II, coupled with the separation of workplace and residential functions in spatial planning, led to a decline in cycling's importance in urban spaces. Consequently, cycling evolved into a recreational activity. In the 1980s, the concept of sustainability emerged, and sustainable urban and transportation planning paradigms that prioritize pedestrians and bicyclists over traditional approaches based on the convenience and speed of motorized transportation gained importance. Advances in information and communication technologies in the 2000s led to the development of intelligent transportation systems, which provide real-time traffic information and shared bicycle infrastructure, bringing a new dimension to urban cycling mobility.

The concept of bicycle culture has undergone a series of transformations in its perception and application. During the Industrial Revolution, it was primarily utilized as a fundamental mode of transportation. Following the Second World War, it emerged as a secondary transportation option, particularly appealing to individuals with lower and middle incomes. Subsequently, from the 1980s onwards, it gained

* Corresponding author: oguzfatihbayraktar@gmail.com

prominence as a clean and sustainable form of transportation. In the 2000s, it evolved into a paradigm of smart mobility, and in the 2020s, it has re-emerged as a popular choice for healthy mobility.
While transportation policies aimed at augmenting infrastructure and superstructure capacity with a singular focus on the expansion of motor vehicle infrastructure have yielded immediate solutions to transportation challenges, these measures have concomitantly engendered novel issues, namely the proliferation of automobile ownership, a phenomenon that has emerged in the long term. The increase in automobile ownership has provided people with unlimited access, and individuals' drive for unlimited access has accelerated the consumption of limited resources, creating negative impacts on the sustainability of the urban environment. In this context, scientific studies on urban mobility with a focus on sustainability have become increasingly prevalent.

According to the United Nations Human Settlements Programme's Global Human Settlements Report, a paradigm shift in transportation planning is underway. The traditional approach to transportation planning, which prioritizes the efficiency of motorized traffic based on speed and convenience, is being superseded by a new paradigm focused on sustainable mobility. This new approach emphasizes accessibility, aiming to minimize the need for long-term movement, reduce the number of motorized trips, shorten urban travel distances, and modify the mode split. The objective of sustainable urban mobility is to encourage mobility patterns that curtail automobile dependency and promote non-motorized and collective transportation options [1].

Intermodality, defined as the utilization of multiple transportation modes for a single journey, is frequently discussed as a pivotal measure to enhance sustainable mobility, particularly in urban areas [2].

In recent years, the concept of intermodality—defined as the integration of sustainable mobility modes to reduce access times—has emerged as a new research topic in urban and transportation planning. Intermodality has been demonstrated to enhance accessibility to origin and destination points (i.e., first and last destination points) in urban journeys made by public transportation. Intermodality has also been demonstrated to increase the use of sustainable modes by increasing the "symbiotic" relationality of modes [3]. Given that public transportation commences and concludes at the origin and destination points on foot, respectively, the accessibility of stops or stations exerts an influence on the travel times of public transportation modes [4]. While walking is the most prevalent mode of transportation to reach public transportation, the restriction of the velocity of pedestrian transportation for extended distances and durations diminishes its appeal.

A fundamental distinction between urban rail systems and public transportation by bus is the reliance on a fixed network. Public transportation by bus is a more advantageous and convenient sustainable mobility mode for providing access to neighborhood units, as it has a more flexible structure compared to rail systems. Conversely, rail systems offer the advantage of traversing greater distances than buses, facilitating expeditious transit and seamless integration between urban activities. Despite the potential weakening of rail integration with certain neighborhood units due to their dependence on a fixed network, enhancing rail accessibility can be achieved through the augmentation of intermodality by means of shared bicycle systems. The integration of shared bicycle systems as a complementary mode of transportation to rail public transportation has been identified as a strategy to enhance the overall performance of sustainable urban mobility as an intermodal travel model.

ITDP 2018 underscores that, particularly in European cities, enhancing the reach of public transportation can be achieved by strategically positioning bike-sharing stations in close proximity to bus and rail stations. This approach ensures seamless connectivity between the origin and destination of urban journeys. In particular, Germany and the Netherlands have implemented shared bicycle stations at bus and rail stops to address the challenges associated with the first and last mile of public transportation [5].

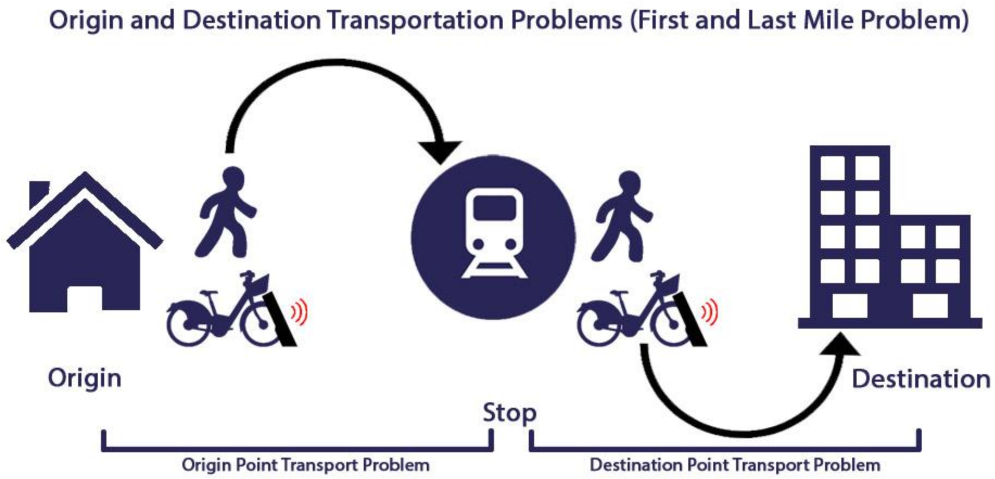


Figure 1. *Origin and Destination Transport Problem in Public Transport (Figure produced by the authors)*

The term "first and last-mile problem" refers to the disconnection between public transportation and the accessibility level at origin or destination. This parameter is of significant importance in determining whether passengers prefer public transportation for their daily commutes [6]. Hussin et al. (2021) defined the first mile as the journey from the initial starting point to the public transportation stop, and the last mile as the journey from the public transportation stop to the desired destination. As metropolitan areas expand, urban transportation becomes increasingly challenging for individuals who do not possess private vehicles. Given that public transportation systems are designed around fixed stops at specific locations, the development of first- and last-mile mobility solutions is crucial for facilitating access to these stops. [7]

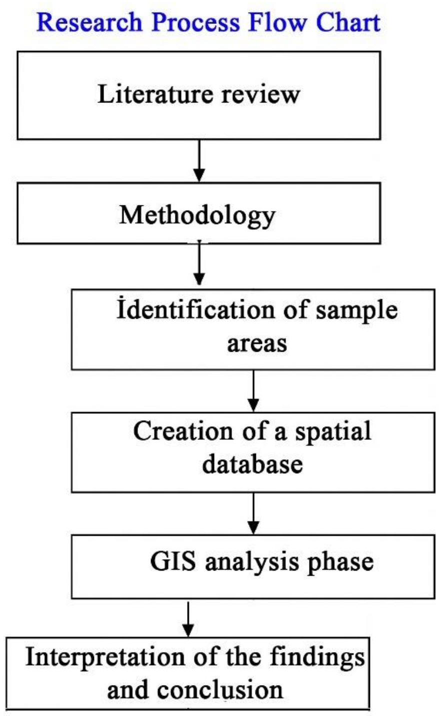


Figure 2. *Research Process Flow Chart*

1.1. LITERATURE REVIEW

The foundation for the bicycle-sharing system was initially developed in Amsterdam in 1965 as part of the White Bike Plan, which provided complimentary bicycles. The inaugural paid bicycle-sharing system was initiated in Copenhagen in 1995 and has since evolved into a sophisticated bicycle rental system [8].

Birkholz (2009) posits that it is not always feasible to ride a bicycle on rail and public transportation, and to have a secondary bicycle at the beginning or end of the journey. In response to these challenges, Birkholz (2009) emphasized the benefits of bicycle rental systems or public bicycles as a solution for bicycling in all circumstances [9].

A meticulously designed shared bicycle system can serve as a pivotal integrated transportation mode, facilitating seamless mobility for urban rail systems. This is particularly crucial in addressing the so-called "first and last mile problem" in rail transportation, which pertains to the challenges of commuters navigating from their origin points to transfer stations and subsequently to their final destinations [10]. Recent research on bicycle-based transit-oriented development (B-TOD) has demonstrated that the estimated access distance for cyclists to access rail transit is 1.96 km (1.2 miles). [11].

Jonkeren et al. (2019) found in their study of bicycle-train passengers in the Netherlands that improving the availability of shared bicycle systems at the activity end of train journeys could make bicycle-train integration more attractive [10]. It has been posited that, given the fact that the speed of a bicycle is approximately three times that of walking speed, a bicycle can travel three times the distance of a walker, thereby connecting to nine times the total access coverage area. This would enable rail system stations to connect to more residential areas (Fleming 2016 and Jonkeren et al.) [12], [13].

Griffin and Sener (2016) state that rail public transportation has a special relationship with shared bicycles, that the high speed of rail and the lack of distance between stops can be compensated by bicycle sharing, and that bicycle rail integration can provide long-term lasting effects due to the permanence of rail stations compared to buses [14].

According to Kager et al. (2016), the integration of bicycles and rail systems within a travel chain through intermodality fosters a significant synergy. This synergy fosters the development of an integrated transportation system, one that combines the flexibility of bicycles with the efficiency of rail systems. The integration of bicycles into the rail system serves to expand the spatial accessibility scope, thereby extending the reach of the rail system to areas that were previously inaccessible. This augmentation in accessibility facilitates the rail system's access to a more extensive population base. The integration of bicycles and public transportation has been shown to create a symbiotic structure that results in a new mode of transportation [3].

According to the findings of Martens (2007), the integration of public transportation and bicycles in the Netherlands resulted in a notable increase in both rail travel and bicycle utilization. The survey, administered as a component of the study, revealed that 15% of the participants indicated that the integration of bicycles and rail systems had supplanted previous commuting methods that relied on private vehicles. Van Mil et al. (2020) posited that the flexibility of bicycles, when combined with the speed and comfort of public transportation, has the potential to emerge as a competitive sustainable multimodal transportation alternative to cars [15].

Cervero et al. (2013) posit that the implementation of shared bicycle facilities could assist in addressing the "last-mile" challenge experienced by individuals exiting rail station complexes [16]. The ITDP (2013) proposes the integration of shared bicycles within public transportation systems as a potential solution to the "last-mile" problem for trips that are not within walking distance of stations [5]. Mahajan et al. (2024) contend that to effectively address the "last-mile" challenge in rail systems, it is essential to strategically locate a substantial proportion of shared bicycle stations within a 5-minute walking distance (400 meters) from public transportation hubs. Improving accessibility from public transportation stops to bicycle stations also supports a sustainable transportation network that can reduce traffic congestion and carbon emissions while promoting a healthy lifestyle [17].

The efficacy of bicycle-sharing systems is contingent upon the strategic placement of a substantial number of stations, with the objective of minimizing the distance that passengers must traverse on foot to retrieve or deposit bicycles in proximity to their ultimate destinations. In Paris' Vélib bike-sharing system, stations are located at a rate of 300 meters per station, while in Europe and North America, the rate is 300 to 400 meters per station [5]. Bike-sharing stations function as complementary links in the travel chain between origin and destination points, thereby serving as an effective feeder mode that contributes to the effectiveness of sustainable mobility systems. In the extant literature, the maximum distance between stations recommended by shared bicycle system operators is defined as 400 meters [14, 18].

A study conducted in North America examined station location issues to encourage multimodal cross-flow between public transportation and bike-sharing systems. The study revealed that 53% of bike-sharing operators preferred a distance of 275-400 meters between stations, and that bike stations should be located no more than 400 meters away from public transportation. [18].

Ma, Liu, and Erdoğan (2015) conducted a study in Washington to ascertain the extent to which bike-sharing systems benefit public transportation systems. The researchers found that a 10% increase in the Capital Bikeshare (CaBi) bike-sharing system resulted in a 2.8% increase in subway trips. Moreover, it has been asserted that bicycle-sharing systems do not constitute a comprehensive replacement for public transportation; rather, they function as a complementary element [19].

Shu et al. (2019) stated that the distance between the shared bicycle station and the user is an important factor in the desire to use bicycles in the Chinese sample, that a long walking distance reduces the desire to use public bicycles, and that, according to system operators, the appropriate distance between bicycle stations and public transportation stations should be 120 meters [20]. In Paris, shared bicycle stations are planned to be located at a maximum distance of 300 meters, with one station for every four residential blocks [8].

Table 1. *Accepted Optimal Distances Between Shared Bicycle Systems and Rail System Stops in the Literature*

Literature Findings	Ideal distance to shared bike stations
Banerjee vd.[6]	300m.
ITDP Paris VELİB System [5]	300m.
ITDP (Europe and North America) [5]	300-400m.
Mahajan et al. [15]	400 m.
Shahen Cohen ve Martin [16]	400m.
Shu et al.[18]	120m.

A study conducted in Palermo using GIS on intermodality between bicycles and rail systems indicates that combining public transportation and bicycles can significantly reduce private vehicle use, peak hour traffic congestion, air pollution, and noise pollution. In this study, a buffer analysis of rail system and bicycle integration was conducted to calculate the population accessing intermodality. Integration between rail system vehicles and the bicycle sharing system is achieved through bicycle stations located near rail system stations. [21]

This article aims to provide various benefits to transportation policies aimed at increasing the sustainability effects of rail systems by evaluating the integration levels of urban rail systems with shared bicycle systems in Turkey. Additionally, by measuring the spatial accessibility of shared bicycle stations within walking distance of rail system stations using the isochrone mapping method, it proposes a methodology that could be applied in other global case studies to assess the intermodal integration levels between rail systems and shared bicycle systems.

2. METHOD

Cities in Turkey with urban rail public transportation systems and cities with shared bicycle rental systems were selected for comparison. A total of 12 cities in Turkey currently have urban rail public transportation systems and 10 of these cities have shared bicycle rental systems.

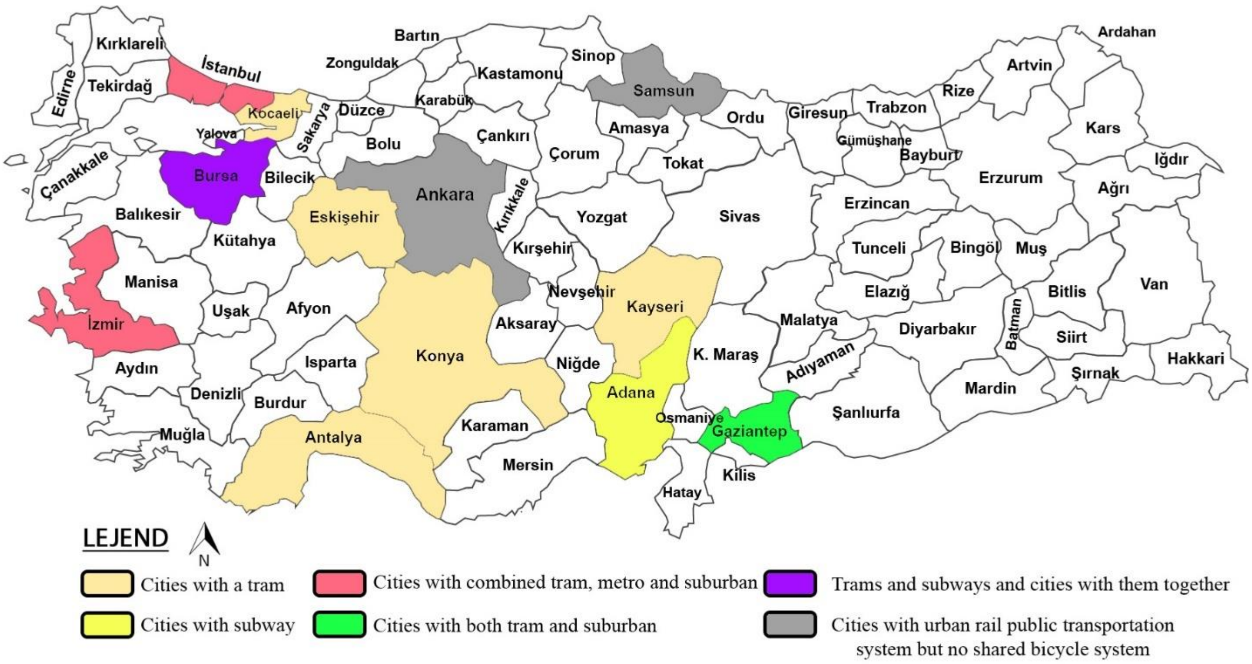


Figure 3. *Types of Rail Systems of Sample Cities in Turkey (Figure produced by the authors)*

Table 2. *Transportation Data for Cities in Turkey with Urban Rail Public Transportation and Shared Bicycle Systems*

City	Rail System Type	Shared Bicycle System Feature
Adana	Metro (13 Stations -Adana Metro)	9 Stations 82 Bikes
Antalya	Tram (68 Stations -AntRay)	9 Stations 90 Bikes (Antbis)
Bursa	Metro (40 Stations -Bursaray) Tram (36 Stations)	37 Stations (Nilespit)
Eskişehir	Tram (77 Stations -ESTRAM)	3 Stations 30 Bikes (Espedal)
Gaziantep	Suburb (16 Stations Gaziray) Tram (47 Stations)	7 Stations 101 Bikes (Gazibis)
İstanbul	Metro (130 Stations) Suburb (48 Stations Tram (81 Stations)	120 Stations (ISBIKE)
İzmir	Metro (24 Stations) Suburb (41 Stations İZBAN) Tram (46 Stations)	60 Stations (Bisim)
Kayseri	Tram (75 Stations) Kayseray	80 Stations 1000 Bikes (Kaybis)
Kocaeli	Tram (21 Stations)	74 Stations 550 Bikes (Kobis)
Konya	Tram (40 Stations)	80 Stations 1000 Bikes (Aarbike)

Note: Since the accessibility analysis will be carried out by accepting the intersecting duplicate stops on different rail system routes as a single stop, they are counted as a single stop in the list.

A Geographic Information System (GIS) database has been developed for 10 cities in Turkey to assess the degree of integration between urban rail systems and bicycle-sharing systems. The database encompasses rail system stations, lines, and bicycle-sharing stations. The data collection utilized for geographic analysis was obtained from the ULASAV open data portal [20], the open data portals and servers of metropolitan municipalities [22], [23], [24], [25], [26], the OpenStreetMap Overpass Turbo application [27], municipalities' official websites, and shared bicycle service providers' applications and websites. The most recent route and stop data were stored in the Shapfile format using QGIS 3.36 software, and a spatial database specific to 10 cities was created (see Appendix). Subsequently, an isochrone map method was applied as a GIS analysis.

Isochronous map method

Conventionally, accessibility measurements in GIS environments have been derived using the buffer analysis method, which calculates a bird's-eye view buffer area at an accessibility radius distance that is independent of the network. Recent progress in network analysis has given rise to the development of software capable of facilitating network-focused morphological urban analysis within the GIS environment. The isochrone map method is employed to analyze the actual service area by combining polygons formed by points that can be reached within a specified time or distance based on the urban network. The utilization of the isochron map method traces its origins to the early 20th century, having been employed in the context of inter-city transportation in London and in the measurement of the access area of the public transportation network in Toronto in the 1940s [28].

The fundamental principle of isochronous map creation entails the calculation of all endpoints that can be reached from a designated starting point within a specified time or distance (e.g., 5 minutes or 400 meters) on a real spatial network. These endpoints are then transformed into a convex hull, thereby forming a buffer polygon that represents all accessible areas [28], [29]. The basic inputs are a defined starting point, road network data, travel time, and mode of transportation.

The isochrone map method will be used to measure the pedestrian accessibility coverage area of shared bicycle stations within a 5-minute time frame. An isochrone map can be generated using the Open Route Service ORS Tools plugin [30], an open-source GIS software tool, based on OSM map road network data. By opening the QGIS plugin ORS Tools, the locations of shared bicycle stations processed into the spatial database are selected. After selecting the mode of transportation (pedestrian, bicycle, private vehicle, etc.), a metric based on time or distance is selected, parameters are defined, and the isochrone map analysis is applied. The isochrone map outputs for each point, corresponding to a 5-minute walking distance, are displayed as layers in the QGIS layers section.

The QGIS ORS Tools plugin employs the Range-Dijkstra (time-controlled propagation) algorithm to generate isochrone maps. The algorithm functions on a road network (graph) based on the principle of accessibility coverage from a designated starting point to a specified time or distance limit. ORS employs OSM data to generate a directed and weighted road network structure. Nodes (V) are indicative of road junctions or decision points, edges (E) are indicative of road segments, and weights represent estimated travel times based on distance, time, or modes.

Steps:
1. Select the starting point: $d(n_0)=0$
2. Nodes are kept in a priority queue
3. The distance to each new node is calculated as follows: $d(n)=min(d(n), d(current)+ w(current\text{-}n))$
4. If $d(n)>T$, propagation stops (T: threshold time or distance)
5. Nodes satisfying the condition $d(n)\leq T$ form the isochronous area. [31], [32], [33], [34]

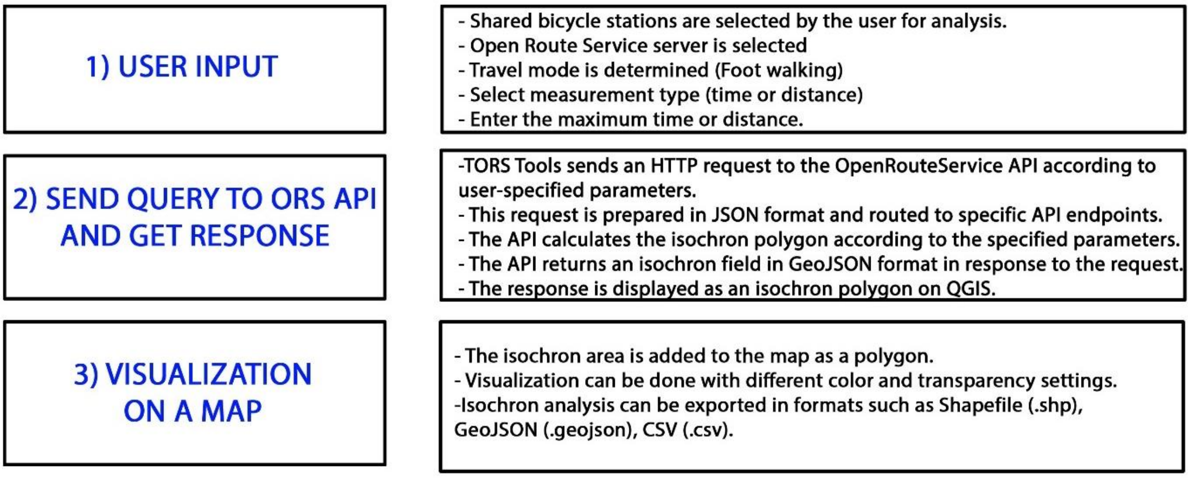


Figure 4. *Isochron Map Creation Stages of ORS Tools Plugin (Figure produced by the authors)*

The aforementioned method was implemented through the utilization of the QGIS ORS Tools plugin, with the objective of identifying areas within a 5-minute access radius of each shared bicycle station within a spatial database created for ten cities in Turkey. The definition of integrated stations encompasses railway stations within a 5-minute access distance that enable intermodal transfers. Conversely, stations that are located more than 5 minutes away were classified as non-integrated stations.

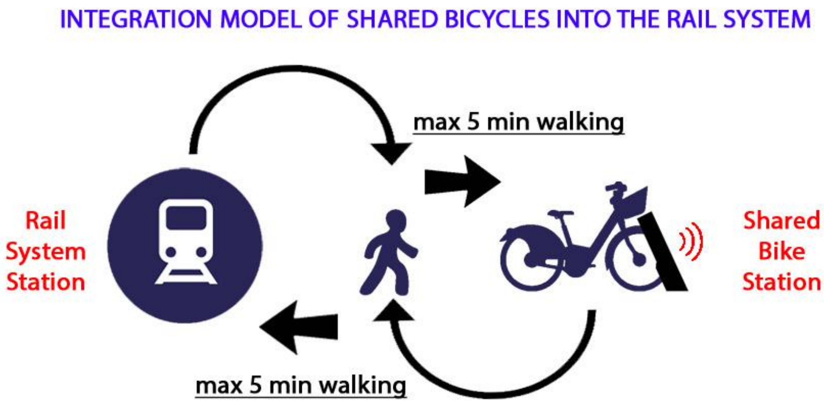


Figure 5: *Integration Model of Shared Cycling into Rail System (Figure produced by the authors)*

In order to measure the level of integration of urban rail and shared bicycle systems in Turkey, the share of the number of rail stops within 5 minutes walking distance of each bicycle station in the total number of rail stations was calculated by counting the number of stops per isochron polygon for each city through QGIS (Select By Area).

The classic location theory assumption posits that accessibility is determined by dividing space into circular buffers. Conversely, the isochronous mapping method delineates the tangible scope of accessibility in relation to spatial and urban network configurations.

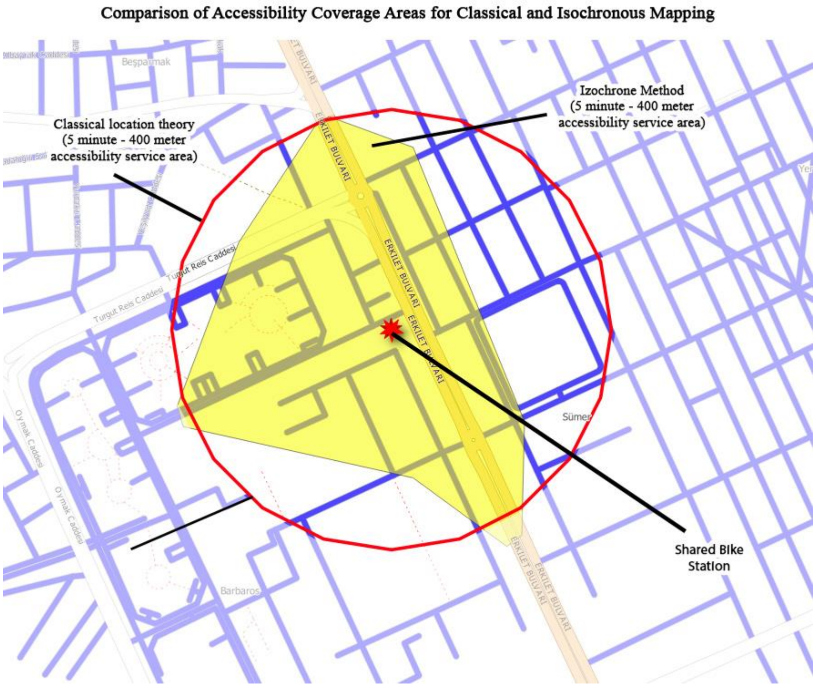


Figure 6: *Comparison of Accessibility Covearege Areas for Classical and Isochronous Map*

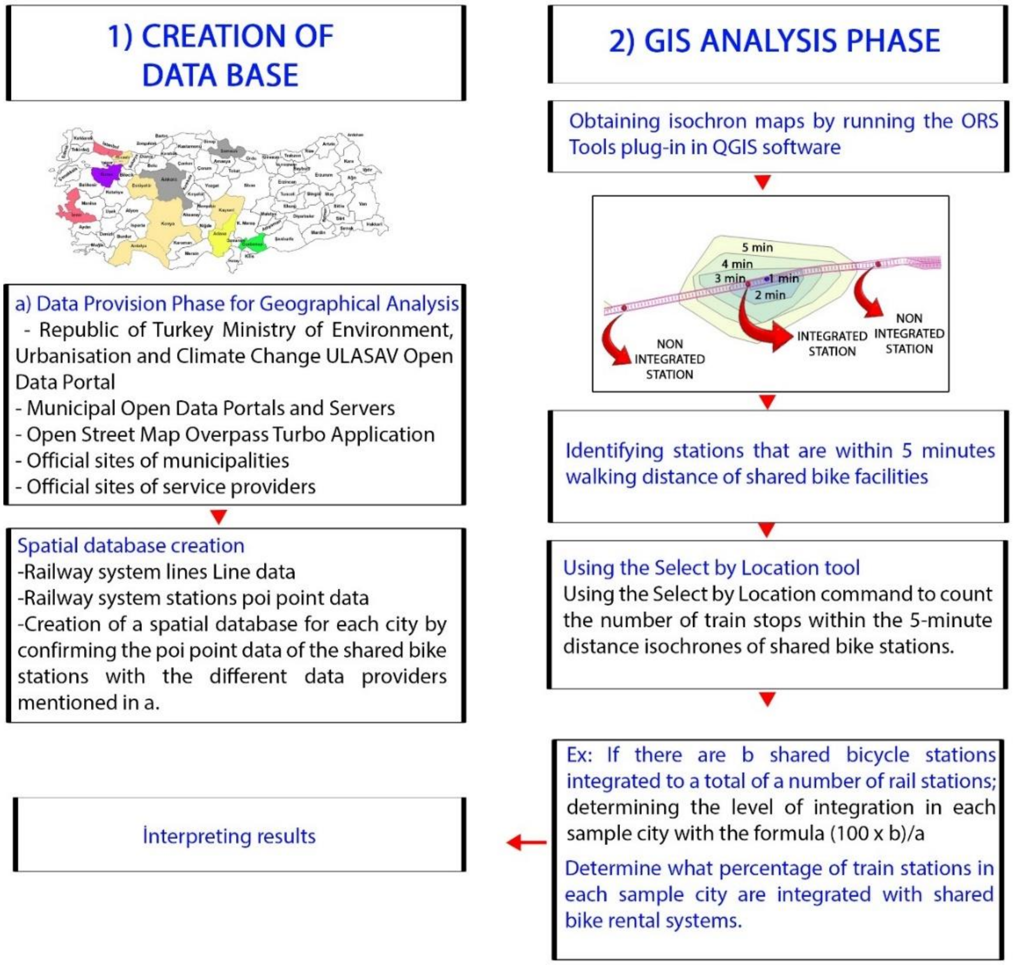


Figure 7. *GIS Analysis Process Flowchart (Figure produced by the authors)*

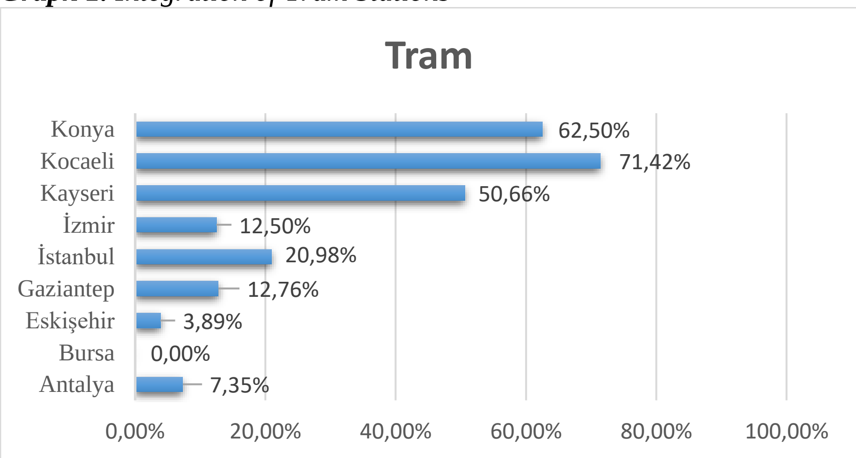
4.FINDINGS (BULGULAR)

The methodology delineated in the article was employed to assess the integration levels of urban rail systems with shared bicycle systems within a 400-meter walking radius in Turkey. An analysis was conducted on a total of 10 cities that have both rail systems and shared bicycle systems. The integration percentages were calculated separately for tram, metro, and suburban rail systems, as well as for the total integration percentage.

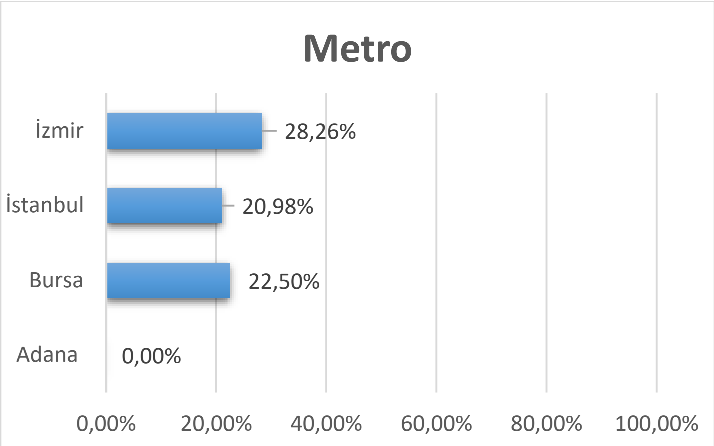
Table 3. *Results of Integration Measurement of Shared Bicycle Systems with Rail System Stops in Turkey (Table produced by the authors)*

City	**Number of Rail System Stations**	**Number of Shared Bicycle Stations within 400 m.**	**Integration Level (%)**	
Adana	13 Stations -Adana Metro	0	%0	%0
Antalya	68 Stations -AntRay	5	%7,35	%7,35
Bursa	40 Stations -Bursaray	9	%22,5	%11,84
	36 Stations -Tram	0	%0	
Eskişehir	77 Stations -ESTRAM	3	%3,89	%3,89
Gaziantep	16 Stations -Gaziray	0	%0	%9,52
	47 Stations - Tram	6	%12,76	
İstanbul	130 Stations -Metro	5	%3,84	%9,65
	81 Stations -Tram	17	%20,98	
	48 Stations -Suburb	3	%6,25	
İzmir	24 Stations -Metro	3	%28,26	%15,31
	46 Stations -Tram	13	%12,5	
	41 Stations -İZBAN	1	%2,43	
Kayseri	75 Stations - Kayseray	38	%50,66	%50,66
Kocaeli	21 Stations -Tram	15	%71,42	%71,42
Konya	40 Stations -Tram	25	%62,5	%62,5

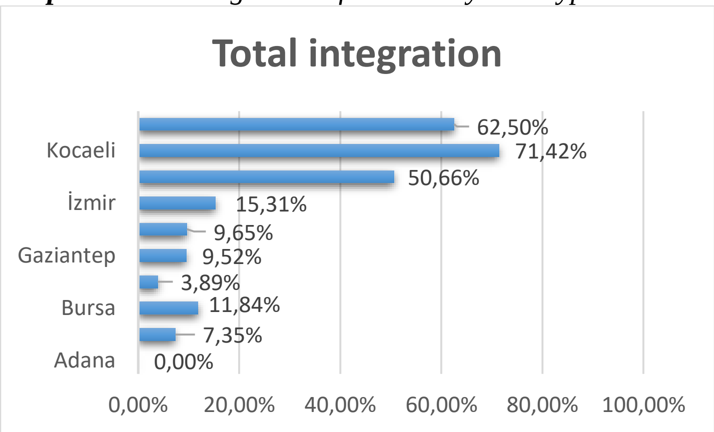
Graph 1. *Integration of Tram Stations*



Graph 2. *Integration of Metro Stations*



Graph 3. *Total Integration of All Rail System Types*



5. CONCLUSION

One of the main findings of the spatial analysis conducted on samples in Turkey regarding the integration of sharing bicycle systems into rail systems is that there are shortcomings in addressing intermodality in order to increase the sustainability impact of rail systems. In particular, the weaknesses in the integration level of shared bicycle systems into rail systems in most of the samples are among the weaknesses in promoting non-car public mobility.

The isochron mapping analysis revealed that the integration levels of shared bicycle systems with the rail system exceeded 50%, particularly in Kocaeli (71.42%), Konya (62.5%), and Kayseri (50.66%). However, the integration level was found to be low in larger metropolitan areas, such as Istanbul and Izmir.

The suitability of the urban morphological structures of some samples studied in Turkey may be a factor in the high levels of integration with bicycle and rail systems. The morphological structures of Konya and Kayseri, which share similarities in terms of topography and urban fabric, provide opportunities for the spread of shared bicycle systems in urban spaces, making their integration levels with rail systems higher than those of other cities. However, the low level of integration in cities like Adana and Eskişehir, which have topographies suitable for bicycles and rail systems, can be attributed to insufficient investments in shared public bicycle systems.

The number of shared bicycles and stations in the sample cities of Kayseri, Kocaeli, and Konya is higher than in other cities. One of the main reasons for the high level of integration found in these cities is the higher number of shared bicycles and stations compared to other cities. This finding is consistent with the quantitative findings in the literature, such as those reported by Martens (2007) and Ma, Liu, and Erdoğan (2015), which indicate that an increase in the number of bicycles is associated with an increase in the use of rail systems.

Findings in other studies in the literature that the high speed of rail systems makes pedestrian access difficult due to insufficient distance between stops are consistent with the findings in the Istanbul and Izmir samples. The morphological structure of these cities, with its topographical difficulties and scattered settlements, negatively affects the linear development of rail systems. Additionally, the complexity of these cities' transportation identities negatively impacts the integration of transportation modes. In cities like Istanbul and Izmir, which have high-speed rail systems, the lack of adequate distances between stations can be addressed through shared bicycle systems, thereby enhancing sustainable mobility.

The results show that the level of integration of shared bike stations with the tram is higher than with the metro, but the level of integrated design of shared bike stations with metro stations is low. This situation has a negative impact on the objectives of increasing the sustainability impact by expanding the scope of access to metro and suburban stations in an integrated manner with bicycles, as it allows a faster transit passage compared to the tram.

In this context, it can be seen that most of the sample cities are not sufficient to meet the expected sustainability impact objectives of the rail system, such as accessibility to a larger population and reduction of motorized vehicle use. Holistic urban transport policies need to be developed to extend the spatial coverage of a well-designed shared bike system, enabling the rail system to reach more land use types such as housing, workplaces, etc., i.e. more population. By integrating public shared cycle systems with the rail system, it may be possible to increase the expected sustainability impacts of the rail system by eliminating the first and last mile problem.

Considering the potential of bike-sharing systems to overcome the first and last mile problem of rail systems, sustainable mobility policies should be developed. Policies should be developed to improve sustainability performance by integrating bike-sharing systems into rail system lines designed as a mode of public transportation, and the provision of public bike-sharing systems should be improved.

While most studies in the literature focus on improving pedestrian accessibility to rail systems, this study distinguishes itself from others by highlighting the powerful role of shared bicycles in increasing accessibility coverage by serving as a bridge between pedestrian and public transportation modes in two-way transportation, and by assessing the first and last mile mobility problem. In the context of improving sustainable transportation in Turkey, the widespread adoption of shared bicycle systems is essential for developing initiatives aimed at addressing the disconnect in accessibility levels between rail systems and their starting or destination points.

The article presents an original method that can be used in national and international literature to measure the spatial accessibility of shared bicycle stations to the rail system using the isochron mapping method. This enables the intermodality levels of rail systems with shared bicycle systems to be determined. This method can be used to determine the level of access to public transport stops for shared bicycles, and can be applied to other urban areas to measure the level of intermodality for sustainable mobility.

Limitations; The isochronous mapping method used in this study more accurately represents 2D coverage, which is sensitive to the urban network pattern, than traditional buffer analysis methods. However, studies should be developed to produce 3D access coverage maps that include the effects of topography.

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REFERENCES

[1] Ghonimi, I., El Zamly, H. (2017, September). Sustainable Urban Mobility: Assessing Different Neighbourhood Models in Greater Cairo Region, Egypt. In *REAL CORP 2017–PANTA RHEI–A World in Constant Motion. Proceedings of 22nd International Conference on Urban Planning, Regional Development and Information Society* (pp. 561-575).

[2] Goletz, M., Haustein, S., Wolking, C., & l'Hostis, A. (2020). Intermodality in European metropolises:The current state of the art, and the results of an expert survey covering Berlin,Copenhagen, Hamburg and Paris. Transport Policy, 94, 109–122. doi:10.1016/j.tranpol.2020.04.011.

[3] R. Kager, L. Bertolini, M. Te Brömmelstroet, Characterisation of and reflections on the synergy of bicycles and public transport, Transportation Research Part A: Policy and Practice, Volume 85, 2016, Pages 208-219, ISSN 0965-8564, https://doi.org/10.1016/j.tra.2016.01.015.

[4] Foda, Mohamed A & Osman, Ahmed O. 2010. Using GIS for Measuring Transit Stop Accessibility Considering Actual Pedestrian Road Network. Journal of Public Transportation, 13 (4): 23-40. DOI: http://doi.org/10.5038/2375-0901.13.4.2

[5] Yanocha, D., Allan, M., & Hook, W. (2018). *The Bikeshare Planning Guide*. Institute for Transportation and Development Policy. https://itdp.org/publication/the-bike-share-planning-guide/

[6] Kåresdotter, E., Page, J., Mörtberg, U., Näsström, H., & Kalantari, Z. (2022). First Mile/Last Mile Problems in Smart and Sustainable Cities: A Case Study in Stockholm County. Journal of Urban Technology, 29(2), 115–137. https://doi.org/10.1080/10630732.2022.2033949

[7] Hussin, H., Osama, A., El-Dorghamy, A., & Abdellatif, M. M. (2021). Towards an integrated mobility system: The first and last mile solutions in developing countries; the case study of New Cairo. Transportation Research Interdisciplinary Perspectives, 12, 100469. https://doi.org/10.1016/j.trip.2021.100469

[8] Snehanshu Banerjee, Md. Muhib Kabir, Nashid K. Khadem, Celeste Chavis, Optimal locations for bikeshare stations: A new GIS based spatial approach, Transportation Research Interdisciplinary Perspectives, Volume 4, 2020, 100101, ISSN 2590-1982, https://doi.org/10.1016/j.trip.2020.100101.

[9] Birkholz, Tim. "Intermodal connections between cycling and public transport : A Stockholm case study." Thesis, KTH, Urban and Regional Studies, 2009. http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-24855.

[10] Yanjie Ji, Yingling Fan, Alireza Ermagun, Xuening Cao, Wei Wang & Kirti Das (2017) Public bicycle as a feeder mode to rail transit in China: The role of gender, age, income, trip purpose, and bicycle theft experience, International Journal of Sustainable Transportation, 11:4, 308-317, DOI: 10.1080/15568318.2016.1253802.

[11] Lee, J., Choi, K., & Leem, Y. (2015). Bicycle-based TOD as an alternative to overcome the criticisms of the conventional TOD. International Journal of Sustainable Transportation, 10 (10), 975–984.

[12] Jonkeren, O., Kager, R., Harms, L. et al. The bicycle-train travellers in the Netherlands: personal profiles and travel choices. Transportation 48, 455–476 (2021). https://doi.org/10.1007/s11116-019-10061-3

[13] Fleming, S.: How the Dutch do it: fewer train stations with bicycle-centric catchments, blogpost on http://cycle -space .com/fiets -professor/ (2016)

[14] Griffin, Greg P & Sener, Ipek N. 2016. Planning for Bike Share Connectivity to Rail Transit. Journal of Public Transportation, 19 (2): 1-22. DOI: http://doi.org/10.5038/2375-0901.19.2.1

[15] Karel Martens, Promoting bike-and-ride: The Dutch experience, Transportation Research Part A: Policy and Practice, Volume 41, Issue 4, 2007, Pages 326-338, ISSN 0965-8564, https://doi.org/10.1016/j.tra.2006.09.010.

[16] Robert Cervero, Benjamin Caldwell, Jesus Cuellar, Bike-and-Ride:Build It and They Will Come, Journal of Public Transportation, Volume 16, Issue 4, 2013, Pages 83-105, ISSN 1077-291X, https://doi.org/10.5038/2375-0901.16.4.5.

[17] Mahajan, S., Argota Sánchez-Vaquerizo, J. Global comparison of urban bike-sharing accessibility across 40 cities. *Sci Rep* **14**, 20493 (2024). https://doi.org/10.1038/s41598-024-70706-x

[18] Shaheen, S. A., A. P. Cohen, and E. W. Martin. 2013. "Public Bikesharing in North America." *Transportation Research Record*, 2387: 83-92. doi:10.3141/2387-10.

[19] Ma, T., Liu, C., & Erdoğan, S. (2019). Bicycle Sharing and Public Transit: Does Capital Bikeshare Affect Metrorail Ridership in Washington, D.C.? *Transportation Research Record*, *2534*(1), 1-9. https://doi.org/10.3141/2534-01

[20] Shu S, Bian Y, Rong J, Xu D (2019) Determining the exact location of a public bicycle station—The optimal distance between the building entrance/exit and the station. PLOS ONE 14(2): e0212478. https://doi.org/10.1371/journal.pone.0212478

[21] Capodici, A. E., D'Orso, G., & Migliore, M. (2021). A GIS-Based Methodology for Evaluating the Increase in Multimodal Transport between Bicycle and Rail Transport Systems. A Case Study in Palermo. *ISPRS International Journal of Geo-Information*, *10*(5), 321. https://doi.org/10.3390/ijgi10050321

[22] Ulasav Smart City Open Data Platform, Url: https://ulasav.csb.gov.tr/, Access Date: March 2025

[23] Kocaeli Open Data Portal, Url: https://veri.kocaeli.bel.tr/, Access Date: March 2025

[24] Izmir Metropolitan Municipality Open Data Portal, Url: https://acikveri.bizizmir.com/ Access Date: March 2025

[25] IBB Open Data Portal, Url: https://data.ibb.gov.tr/dataset Access Date: March 2025

[26] Konya Open Data Portal, Url: https://acikveri.konya.bel.tr/tr/group/hareketlilik?page=2

[27] Url: https://overpass-turbo.eu/

[28] Allen, J. (2019). Using network segments in the visualization of urban isochrones. Cartographica: The International Journal for Geographic Information and Geovisualization, 53(4), 273-287. https://doi.org/10.3138/cart.53.4.2018-0013

[29] Bolzoni, Paolo, Sven Helmer, and Oded Lachish. 2016. "Fast Computation of Continental-Sized Isochrones." International Conference on GIScience Short Paper Proceedings 1(1): 21–24. https://doi.org/10.21433/B31171h533kp

[30] Url: https://www.qgistutorials.com/en/docs/3/service_area_analysis.html.

[31] Baum, M., Buchhold, V., Dibbelt, J., Pajor, T., Wagner, D., & Zündorf, T. (2015). Fast computation of isochrones in road networks. In Experimental Algorithms: 14th International Symposium, SEA 2015, Paris, France, June 29–July 1, 2015, Proceedings (pp. 15–27). Springer. https://doi.org/10.1007/978-3-319-20086-6_2

[32] Hart, P. E., Nilsson, N. J., & Raphael, B. (1968). A formal basis for the heuristic determination of minimum cost paths. IEEE Transactions on Systems Science and Cybernetics, 4(2), 100–107. https://doi.org/10.1109/TSSC.1968.300136

[33] Heidelberg Institute for Geoinformation Technology. (n.d.). OpenRouteService developer documentation. OpenRouteService. https://openrouteservice.org/dev

[34] GIScience Research Group Heidelberg University. (n.d.). QGIS ORS Tools plugin. GitHub. https://github.com/GIScience/qgis-ORS-tools

APPENDIX

Spatial database created for 10 sample cities (consisting of vector lines and rail system line data for rail system stations and shared bike stations).