Moving Towards Sustainable Transportation: Integrating Rail and Ferry Transportation for a Connected and Smart Istanbul Mobility

Ilgin Gokasar[1](✉), Ece Ozcan[2], Muhammet Deveci[1], and Mincong Tang[3]

[1] Department of Civil Engineering, Bogazici University, Istanbul, Turkey
ilgin.gokasar@boun.edu.tr
[2] Department of Industrial Engineering, Turkish Naval Academy, National Defence University, Tuzla, Istanbul, Turkey
[3] ICIR, Beijing JiaoTong University, Beijing, China

Abstract. Cities that have the means for ferry and rail transportation options for their urban mobility have high levels of potential benefits in terms of economy, environment, and sustainability. However, to take full advantage of these systems' benefits, the integration between these different modes of public transportation systems must be improved. In this study, the goal is to optimize the integration between rail and ferry transportation modes using a developed innovative advanced traveler information system. By using historical data (such as ridership, and weather) from the corresponding authorities and conducted revealed preference survey results, insight into the current state of the rail and ferry transportation systems can be obtained using machine learning and pattern recognition methods. With the constraints and the objective function obtained from the current state diagnosis, the integration between the rail and ferry transportation systems can be optimized by using different optimization methods. Hence, public buses and alternative transportation modes such as bike- sharing can also be utilized to further improve the integration between rail and ferry transportation systems and make them more sustainable.

Keywords: Urban transport · transportation modes · ferry and rail transportation

1 Introduction

Istanbul is a metropolitan city with a population of over 15 million [1]. There are 2759 people per km^2 over an area of 5461 km^2 [2]. The city is divided by the Bosphorus along 30 km as Asian and European sides. The two sides of the city are connected with three bridges among which one has a BRT system and one subway. The high population of the city creates the 6th most congested traffic in the world [3]. Therefore, public transportation is a very important topic for the city authorities. According to the transportation plan of the municipality, the share of the rail and ferry transportation within the city is aimed to be increased. Currently, the share of road transportation in public transport is 75.2% which increases the congestion within the city even more [4]. Even though

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the Bosphorus creates a huge potential for urban ferry transportation, the utilization of the opportunity is questionable. Ferry transportation covers only 4.3% of public transportation. According to the recent actions of İstanbul Metropolitan Municipality (IBB), the projects to increase the daily share of ferry transportation are in priority. Moreover, the current situation in rail transportation in Istanbul can't meet the demand, therefore, the government and municipalities have vigorous efforts to increase the rail network. The municipality has launched a future vision for 2023 to increase rail transportation and almost half of the municipality budget is separated for rail investments in the city [5, 6]. As a result, the rail network boomed in recent years and the share of rail public transportation reached 18.6%.

This study's motivation is to optimize the integration between rail and ferry transportation modes by utilizing a developed innovative advanced traveler information system. This goal is following the objectives of the municipality, which this study was designed to support. The goal is to achieve sustainable mobility in Istanbul by increasing connectivity between rail transportation and boat transportation. This will be accomplished by optimizing time and route schedules, as well as adding new lines to the system. Passengers can be provided with the information that was collected through integrated optimization. Because of the findings of the study, one challenge would be shifting the focus of transportation away from automobile travel and toward environmentally friendly modes of public transportation.

In addition to the optimization of the network connections, *another aim* is to inform the users properly via real-time passenger information (RTPI) displays that are placed in ferries and rail vehicles. Previous research shows that people don't prefer to travel without consulting with an information system unless one is not familiar with the route [7]. Here, the RTPI is the most effective tool for most users to decide their routes among other alternatives such as smartphones or paper-based schedules [8]. The elements like news on disruption, estimated time of arrival, real-time location, and connecting services information are of high importance to screen respectively. The most important aspect of RTPI is that it covers the vulnerable groups in society who can't use or reach smartphones as an option. So that the usage of the network can be increased by expanding the span of participation.

There are several *objectives* related to the study to obtain the presented goals. The first objective is to provide information flow and communication among passengers in an innovative way by using historical data (such as weather conditions, and ridership) obtained from authorities and preference survey results. An insight into the current situation of rail and ferry transportation can be obtained using machine learning and pattern recognition methods. So, the integration between rail and ferry transportation networks can be optimized. Another objective is to consider bike routes and bike-sharing options in the system to promote bike usage, especially for the already-existing waterfront lines. While optimizing the network, public buses can be utilized if necessary to create a connection between sustainable mobility systems. Buses can be an alternative if there is no direct connection between rail and ferry systems.

Here, one of the primary objectives is to reschedule and rearrange the routes of the ferry lines in a way that can be compatible with rail lines and walking travel time in between two services. To obtain public perception, stated preference surveys can be

conducted to identify the benefits of the proposed system [8, 9]. Stated preference surveys are widely used for public transportation projects to determine the best-fit solution.

The findings show that passengers tend to prefer eco-friendly transportation modes and carbon emission is an important part of today's world. A study showed that the CO2 emission of a ferry is much smaller for the same route as a car [10]. This is especially valid for short distances rather than long ones which makes ferry transportation even more attractive for urban areas. Besides, E-ferries are gaining popularity around the world due to their advantages in many areas such as cost-effectivity, environment-friendliness, marine biodiversity, climate change, and public health. Currently, there are some electric ferries in Bosphorus. Even though the ferry systems offer a huge potential for public transportation, relevant research is quite limited to the subject. Especially, the integration of sea and rail transportation is only considered for freight transportation and logistics rather than urban perspective. Research shows that the linear urban ferry systems that are especially suitable to the Bosphorus due to a 30 km long way are considered to improve economic development, commuting, public transport, and tourism [11]. Due to the easy configurability and minimal capital requirements, the relatively low risk of ferry systems makes them more attractive to implement.

Moreover, the lack of information, missing coordination, timing, and long walking distance directly affects the travel behavior of passengers and public transportation usage. Except for its logical superiority in cost and environment, ferry transportation has positive effects on psychology as well, by creating higher well-being and relief [12]. As a result, proper integration and real-time information for rail and ferry transportation come to the front to encourage passengers to consider ferries as a part of public transportation. As a result of the optimizations, the ridership can increase and the added high-capacity options can result in more efficiency in urban mobility.

The study aims to understand how the connection between rail and ferry transportation can be achieved by utilizing past data to find out effective interventions. The interaction between different modes of mobility can be investigated by considering passengers and public demand through surveys. Since the goals of the municipality coincide with the study outcomes, the implementation of the innovative advanced traveler information system can be applied and the municipality can be a partner throughout the study. As a result of the objectives and goals, the study follows an "innovation pathway". Yet, it includes some aspects of the "research pathway" as well, since it aims to understand the function of the network. Also, the study is case- specific, however, it can be transferred to other similar cities.

1.1 Key Activities

1. Data collection: To obtain an insight into the current state of the public transportation systems in the city, historical data (such as ridership information, weather data, ferry, and rail system routes and schedules) can be obtained from the authorities.
2. Revealed preference survey: By conducting a revealed preference survey, further information about the problems and demands of the public transportation system can be collected.

3. Diagnosing the current state of the public transportation system of the city: by using these previously mentioned data and machine learning and pattern recognition methods (i.e. fused lasso, decision trees, random forest algorithms), the traveler behavior patterns and ferry and rail transportation system performance patterns can be analyzed.
4. By diagnosing the current state of the system, the constraints and the objective function of the optimization problem can be determined. After this is done, with different optimization methods (i.e. linear optimization, heuristic optimization) the development of an innovative advanced traveler information system can be conducted. The public buses and alternative transportation modes (i.e. bike-sharing systems) can be organized in a way that the integration between rail and ferry systems is optimized and the increase of their daily usage.
5. The public opinion of this developed system and the results of these optimizations can be evaluated by using a stated preference survey.

2 Data Management

The vast majority of the data to be used in this study is already available in the municipality. The results of this study can be used to support to achieve the goals of IBB for improvements in transportation systems. Therefore, all necessary data can be willingly shared by IBB for this study without violating the privacy and confidentiality of the individuals. Istanbul Card data (both for rail and ferry), passenger transfer between ferry and rail transport data, timetable, and other transportation modes connected to the docks, bicycle routes, and planned metro lines can be obtained from the municipalities. Historical weather data can also be easily accessed via the Internet. The only type of data that requires more effort in terms of data collection in this study is the survey. After collecting the data, surveys can be used to understand the perceived situation of the current integration and efficiency of ferry transportation. The remaining data obtained from the municipality can be pre-processed to determine the actual situation. During pre-processing, possible issues to occur concern varying periods and indexes of different datasets. The pre-processed data is then combined to understand the patterns of commuter choice for ferry transport.

The planned techniques during the analysis are classifications by machine learning (clustering or random tree algorithms) and regression algorithms (many of them can be tested) and if necessary, deep learning algorithms that require much more processing power and time. Depending on the results, an optimal way to model the ferry transportation can be chosen and the optimization process can be performed accordingly. The system can be updated even after the optimization process, as the municipality can continue to store the data.

3 Policy Implications

A metropolitan city that has the means for rail and ferry transportation must make use of this opportunity. Considering the capacity and service standards of these systems, the integration of these systems must be improved for making urban physical mobility more

sustainable. The city of Istanbul has 170.05 km long rail transportation systems as of 2018 and the Bosphorus [13], provides significant opportunities for ferry transportation. However, the ferry and rail transportation mode share percentages among other public transportation systems are 4.3 and 18.6% [4] respectively. Considering the mode share of the motorway public transportation and the level of traffic congestion in this city, the daily usage of ferry and rail systems must be increased. IBB has set itself the goal of improving the integration, accessibility, and level of service of public transportation systems. They also aim to increase the mode share of ferry and rail systems. Therefore, the integration of these systems can aid the goals of the municipality. With the results of this study, the mode shares of ferry and rail systems can be increased in any city that has the means for ferry and rail transportation systems. It must be noted that the system can be transferable as long as the required data is available. The fact that the municipality of a city with a very large population has set these goals, shows the relevance of this study. In addition, the study goal can be able to benefit other cities as well.

4 Conclusion

With a well-integrated transportation system, all parties of a city can be able to benefit from environmental and economic improvements. With the increased demand for transportation, given the increasing population of the cities, the living conditions of the citizens of a city may deteriorate. Alternative and public transportation systems, which must be both environmentally friendly and sustainable, are the key solutions to this potential problem.

By improving the integration between these different systems, which must be done by prioritizing the passengers, the potential benefits of these transportation systems can be fully achieved. However, the proposed system must also be transferable. Different cultures and city structures may require different approaches to find solutions. Before proposing an integration method, it is important to determine which approaches can work for which kinds of cities and communities. With a revealed preference survey the necessary information about the city structure and the behavioral habits of its population can be collected.

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