Current Status and Demand Patterns of Shared Bicycles in Jersey City

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Abstract. This paper, using New Jersey as a case study, examines the spatial allocation issues of shared bicycles. Utilizing data from New Jersey City for the months of January to July 2023 and employing Python scientific computing libraries, we conducted kernel density analysis to generate visualizations and analyze demand patterns in the selected New Jersey shared bicycle data. Three key findings emerged from our research, categorized as geographical demand, temporal trends, and cross-regional cycling. Regarding the geographical demand, it was evident that the demand for shared bicycles in the city center exceeded that at the city's outskirts, potentially linked to urban planning within the city. The temporal trends, showed a steady increase in bicycle rides to New York from January to July, with the peak demand occurring during the summer months. This aligns with existing research and common knowledge, as riders tend to prefer cycling in more comfortable weather conditions, which are prevalent in the summer. The phenomenon of cross-regional cycling is particularly intriguing, the destination points were often in New York. The significance of this phenomenon lies in the potential resource shortage within the shared bicycle system if a large number of bicycles are ridden in New Jersey but left in New York for extended periods. This issue could result in spatial allocation challenges and may also incur substantial costs for bicycle redistribution and management by the government. Therefore, this paper presents recommendations and suggestions for coordinating the allocation of shared bicycles between New Jersey and New York City.

Keywords: Geographical demand, Temporal trends, Cross-regional cycling, Shared bicycle, New Jersey City.

1. Introduction

Many cities in the United States have long grappled with the issue of traffic congestion, which has not only negatively impacted the efficiency of urban residents' travel but also posed a threat to environmental quality and sustainability [1]. The severity of traffic congestion has led to continuous exploration and innovation in transportation modes. In this context, the rise of shared bicycles represents an emerging urban travel solution. By providing short-term bicycle rental services, these shared bicycle systems offer an environmentally friendly solution for the first and last miles of commuting, helping bridge the gap between existing transportation modes such as subways and buses. This, in turn, alleviates urban traffic pressure, reduces environmental pollution, and promotes urban sustainability.

However, the emergence of shared bicycles also comes with a series of challenges and controversies. The dynamic nature of human mobility often leads to inevitable imbalances in bicycle supply and demand. Issues like regional "tide-like" supply shortages become increasingly prominent. Due to the separation of residents' commuting behavior and the functional division of cities, such problems frequently occur during fixed time periods (weekday rush hours) and specific areas (near subway stations and bus stops) [2]. These phenomena not only affect the user experience and operational efficiency of shared bicycle systems but also hinder the efficient operation of transportation systems as a whole.

In some areas of the U.S. state of New Jersey, particularly in central Jersey City and areas near New York City, cross-border commuting phenomena are more pronounced (Figure 1). Many residents choose to live in Jersey City but work in New York City, resulting in a significant commuting flow. Especially during peak working hours, when New York City's shared bicycle

system is already nearing saturation, Jersey City residents still rely on this mode of transportation. This behavior can lead to saturation in the New York City shared bicycle system, bringing instability and efficiency issues to the entire shared bicycle system. Moreover, the high cost in terms of manpower and resources required for bicycle redistribution is a significant concern. Research has shown that thousands of bikes need to be rebalanced every day in the Vélib' bike-sharing system, with a cost of three dollars to rebalance one bike [3]. Therefore, for shared bicycle service providers, proactive bicycle redistribution between stations is crucial to ensure the effective operation of the system.

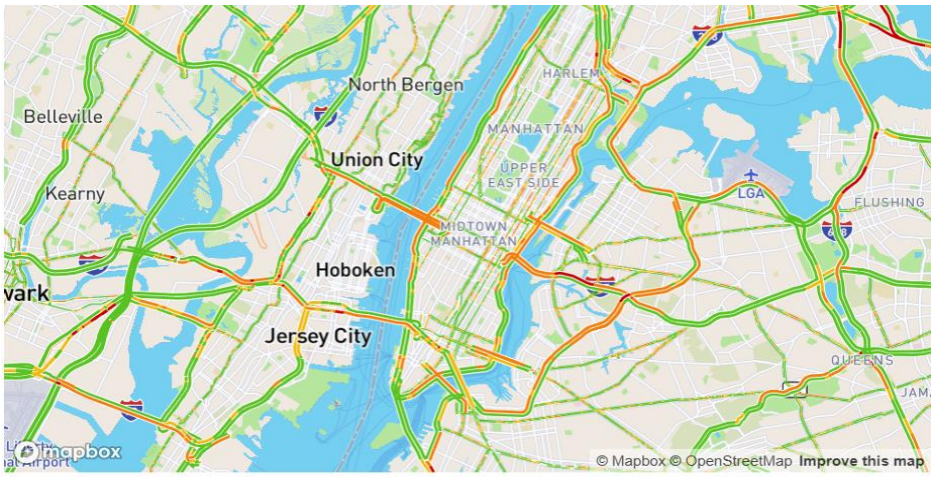

Figure 1. Traffic Congestion between Jersey and New York City
(Available at: New York City Road Conditions with Driving and Traffic Flow - LocalConditions.com)

To gain deeper insights into the changing trends in shared bicycle demand and the underlying reasons for this phenomenon, this study collected shared bicycle data from New Jersey for the months of January to July 2023. By employing a kernel density model for data visualization and analysis, this paper aims to uncover the hidden trends, patterns, and correlations within this data. These analytical findings are expected to enhance our understanding of the usage patterns of shared bicycles in New Jersey and potentially provide robust support and guidance for future transportation planning and improvements in shared mobility systems.

2. Literature Review

Existing research on shared bicycle demand forecasting typically employs complex mathematical models to identify demand hotspots and relationships among various factors. The methodologies for studying shared bicycle demand encompass multiple aspects, including data analysis, machine learning, and geographic information systems (GIS) technologies. For instance, Zhou utilized spatiotemporal data modeling techniques, integrating sequential information on user travel and relationships between stations, to create a spatiotemporal network for a better understanding of the spatiotemporal patterns of user journeys [4]. They also introduced a "temporary link prediction strategy" to analyze the dynamic connections between stations, resulting in a more accurate prediction of ride demand at different times and locations. Liu adopted a comprehensive and targeted approach, including similarity-based K-nearest neighbor algorithms, consideration of weather factors, analysis of trip history records, and station rebalancing optimization strategies [5]. Through these methods, the research improved the accuracy and practicality of shared bicycle demand forecasting, encompassing weather, user journeys, traffic patterns between stations, and bicycle distribution optimization, offering more precise solutions for the operation of shared bicycle systems.

On the other hand, Wang proposed a data-driven bicycle rebalancing application called BRAVO, which utilized user trip data, station status data, rebalancing data, and weather data to predict the safe rebalancing range for each station, minimizing rebalancing costs [6]. Despite significant

advancements in existing research methodologies regarding shared bicycle demand analysis, addressing the demand for shared bicycles in a cross-commuting context has been largely overlooked. In fact, cross-commuting is becoming increasingly common, particularly in the outskirts of major cities [7]. This trend presents additional challenges, as cross-commuting requires more human and material resources, and current research has primarily focused on cross-border rail studies [7,8], neglecting the demand in the realm of shared bicycles. Therefore, it is necessary to conduct an in-depth examination of the current state of cross-commuting and explore how to optimize the deployment strategies for shared bicycles to meet this growing demand. Furthermore, the use of shared bicycles involves multiple stakeholders, including riders, bicycle operators, government officials, and urban planners, among others. However, existing research often fails to adequately consider the needs and interests of these stakeholder communities in demand analysis and spatial layout recommendations. In the context of cross-commuting, this issue becomes even more complex, as the interests of different cities and regions may influence each other. Therefore, there is a need for more in-depth research to coordinate the interests of all parties and establish a more effective cross-commuting shared bicycle system that offers better solutions for urban travel.

In summary, despite the valuable methodologies and insights provided by existing research for shared bicycle demand forecasting, there is still a need for further research in the field of cross-commuting. Future research should better adapt to the diversity and differences in demand between different cities while taking into full consideration the interests of all stakeholders, thereby promoting the wider application of shared bicycles in cross-commuting. This will help fill the research gaps in existing literature and provide more in-depth and practical solutions for cross-commuting.

3. Methods

3.1. Shared Bicycle Dataset

The raw data used for spatial distribution analysis is sourced from two primary repositories, one being the Jersey City Geographic Data. Geographic data related to Jersey City was retrieved in Shapefile format from the official Jersey City Open Data Portal. This dataset includes geographical boundaries of Jersey City and census tract polygon information, providing essential spatial references and mapping foundations. Regarding the collection of shared bicycle data in Jersey City, we obtained Citi Bike trip data for the period from January to July 2023 from the official Citi Bike website in New York City (Citi Bike System Data | Citi Bike NYC). This dataset is distributed in the format of seven separate CSV files, one for each month (Table 1).

Table 1. Jersey City January 2023 Raw Bike Share Data Sample

Items	Sample-1	Sample-2	Sample-3	Sample-4
ride_id	0905B18B365C9D20	B4F0562B05CB5404	5ABF032895F5D87E	E7E1F9C53976D2F9
rideable_type	classic_bike	electric_bike	classic_bike	classic_bike
started_at	2023/1/28 9:18	2023/1/23 20:10	2023/1/29 15:27	2023/1/24 18:35
ended_at	2023/1/28 9:28	2023/1/23 20:18	2023/1/29 15:32	2023/1/24 18:42
start_station_name	Hoboken Terminal - Hudson St & Hudson Pl	Hoboken Terminal - Hudson St & Hudson Pl	Hoboken Terminal - Hudson St & Hudson Pl	Hoboken Terminal - Hudson St & Hudson Pl
start_station_id	HB101	HB101	HB101	HB101
end_station_name	Hamilton Park	Southwest Park - Jackson St & Observer Hwy	Marshall St & 2 St	Hamilton Park
end_station_id	JC009	HB401	HB408	JC009
start_lat	40.73593758	40.73593758	40.73594391	40.73598564
start_lng	-74.03030455	-74.03030455	-74.03038311	-74.03036356
end_lat	40.72759597	40.73755127	40.740802	40.72759597
end_lng	-74.04424731	-74.04166371	-74.042521	-74.04424731
member_casual	member	member	member	member

Based on the collected data, data preprocessing was carried out, converting the data in YY/MM/DD format into a time duration format. By subtracting the end time from the start time, the overall ride duration was calculated. This data format facilitates the analysis of user ride durations (Table 2).

Table 2. Revised Sample of Jersey City Bike Share Data for January 2023

Items	Sample-1	Sample-2	Sample-3	Sample-4
ride_id	0905B18B365C9D20	B4F0562B05CB5404	5ABF032895F5D87E	E7E1F9C53976D2F9
rideable_type	classic_bike	electric_bike	classic_bike	classic_bike
started_at	9:18:10	20:10:12	15:27:04	18:35:08
ended_at	9:28:52	20:18:27	15:32:38	18:42:13
Trip duration	0:10:42	0:08:15	0:05:34	0:07:05
start_station_name	Hoboken Terminal - Hudson St & Hudson Pl	Hoboken Terminal - Hudson St & Hudson Pl	Hoboken Terminal - Hudson St & Hudson Pl	Hoboken Terminal - Hudson St & Hudson Pl
start_station_id	HB101	HB101	HB101	HB101
end_station_name	Hamilton Park	Southwest Park - Jackson St & Observer Hwy	Marshall St & 2 St	Hamilton Park
end_station_id	JC009	HB401	HB408	JC009
start_lat	40.73593758	40.73593758	40.73594391	40.73598564
start_lng	-74.03030455	-74.03030455	-74.03038311	-74.03036356
end_lat	40.72759597	40.73755127	40.740802	40.72759597
end_lng	-74.04424731	-74.04166371	-74.042521	-74.04424731
member_casual	member	member	member	member

3.2. Basic Data of Jersey City Users

As shared bicycles serve as essential tools for residents' short-distance travel, they are often influenced by the urban spatial structure and built environment. Detecting the spatial community structure of shared bicycles contributes to understanding the spatial clustering of residents' rides and assists in the planning of bicycle lane networks. Basic information related to land use types in Jersey City was collected from websites (e.g., the Home-page — Jersey City Open Data (jerseycitynj.gov), the Land Use Element | Jersey City Master Plan Vision (arcgis.com), and ZoLa | NYC’s Zoning & Land Use Map). Additionally, external factors such as housing prices in different cities were collected from websites (e.g., Douglas Elliman | Luxury Real Estate and Homes for Sale | Homepage). These external factors were considered as objective influencing factors in analyzing the differences in shared bicycle demand in Jersey City, aiming to explore their inherent connections.

4. Results

Figure 2 illustrates the usage patterns of shared bicycles in Jersey City from January to July 2023.

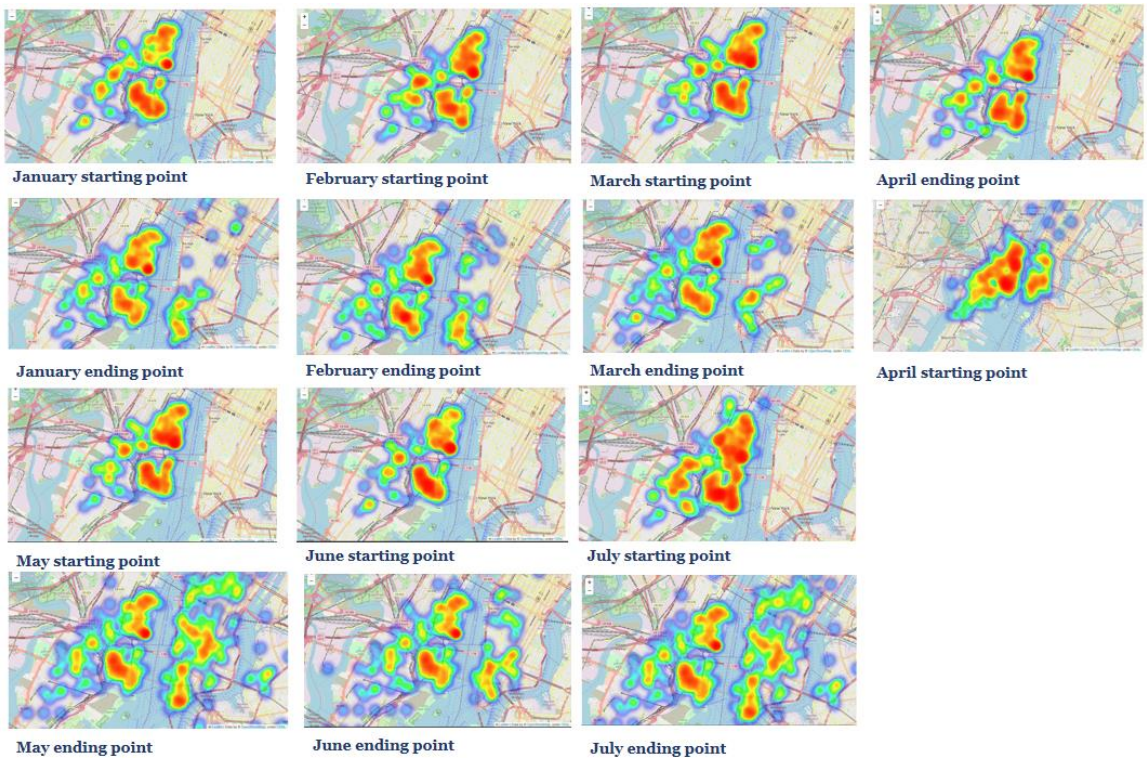

Figure 2. Heat Map of Bike Sharing Start and End Point Usage in Jersey City 202301-202301

Through an analysis of this data, we have derived the following three key findings.

(1) Regional Demand Variations: It was observed that there are significant variations in the demand for shared bicycles in different areas of Jersey City. Specifically, the demand in the eastern region is noticeably higher than in the western region. This finding may be influenced by factors such as geography, economics, and population distribution, which will be further researched and explained in the following sections.

(2) Temporal Trends: An analysis of the temporal trends in demand revealed a gradual increase from January to July. This trend can be observed not only from the range of colors on the heatmap but also from the changing sizes of the heatmap's hotspots. This suggests that shared bicycle services gained more popularity during this period, presumably due to seasonal factors, as the weather conditions in summer are more favorable for commuting compared to winter.

(3) Cross-Regional Riding Phenomenon: The most striking discovery among all findings is that, although the data collected pertains to shared bicycles in Jersey City with starting points within Jersey City, an analysis of the endpoints revealed a phenomenon where some trips originated in Jersey City but ended in New York City. This can be considered as cross-regional riding, indicating interoperability of the shared bicycle system between cities. Of particular note, based on the endpoint heatmap for July, we can observe that this cross-regional riding occurs over a relatively wide area, which warrants further investigation into its underlying reasons.

5. Discussion

The following discussion section sequentially delves into the three conclusions drawn from the kernel density analysis maps above.

5.1. Regional Disparities

Upon closer examination of the city's land use map (Figure 3), it is evident that the central region is primarily designated for residential use. This finding to some extent validates the residents' commuting needs. Urban land-use planning directly reflects people's residential and work patterns in different areas, to some extent indicating the centrality of the city and the direction of population

movement. People's commuting generally starts from home and involves cycling to reach subway stations or bus stops, confirming the demand range observed in the heatmap.

Figure 3. Jersey City Landuse

(Available at: Land Use Element | Jersey City Master Plan Vision (arcgis.com))

5.2. Temporal Differences

Based on the heatmap's range, we can clearly observe a significant upward trend in biking demand over time, steadily increasing from January to July. Several factors contribute to this trend, with meteorological factors such as temperature, humidity, and wind speed playing a crucial role.

The gradual increase in biking demand can be attributed to a close correlation with seasonal changes. In the cold winter months, temperatures are lower, humidity may be higher, and wind speeds can be greater—factors that affect people's interest and desire for biking. However, as the seasons transition to warmer summer months, temperatures rise, humidity decreases, and wind conditions become more stable, creating more favorable conditions for outdoor biking activities [9]. Therefore, it is reasonable to infer that this seasonal increase in biking demand is closely related to changes in meteorological conditions.

This observation not only aids in understanding the seasonal fluctuations in shared bicycle usage but also contributes to urban transportation planning and the optimization of shared bicycle services. A deeper understanding of seasonal demand can help decision-makers better adjust the supply of shared bicycles to meet the needs of users during different periods, while also providing a more comfortable and secure biking experience for users.

5.3. Cross-Regional Riding Phenomenon

Figures 3 and 4 present land-use planning maps for the bordering areas between Jersey City and the western part of New York City. It illustrates the land-use layouts in different cities, reflecting the purposes and characteristics of various regions within the cities. In Jersey City, commercial activities are primarily concentrated in the eastern and western ends of the city, while the central area of the city is predominantly residential, occupying the largest proportion of overall land use. The western part of New York City, adjacent to Jersey City, is characterized mainly by commercial office buildings. This may be related to the proximity of New York City's central business district to the border of Jersey City, and such land-use planning might be designed to accommodate a significant volume of commercial activities and office spaces.

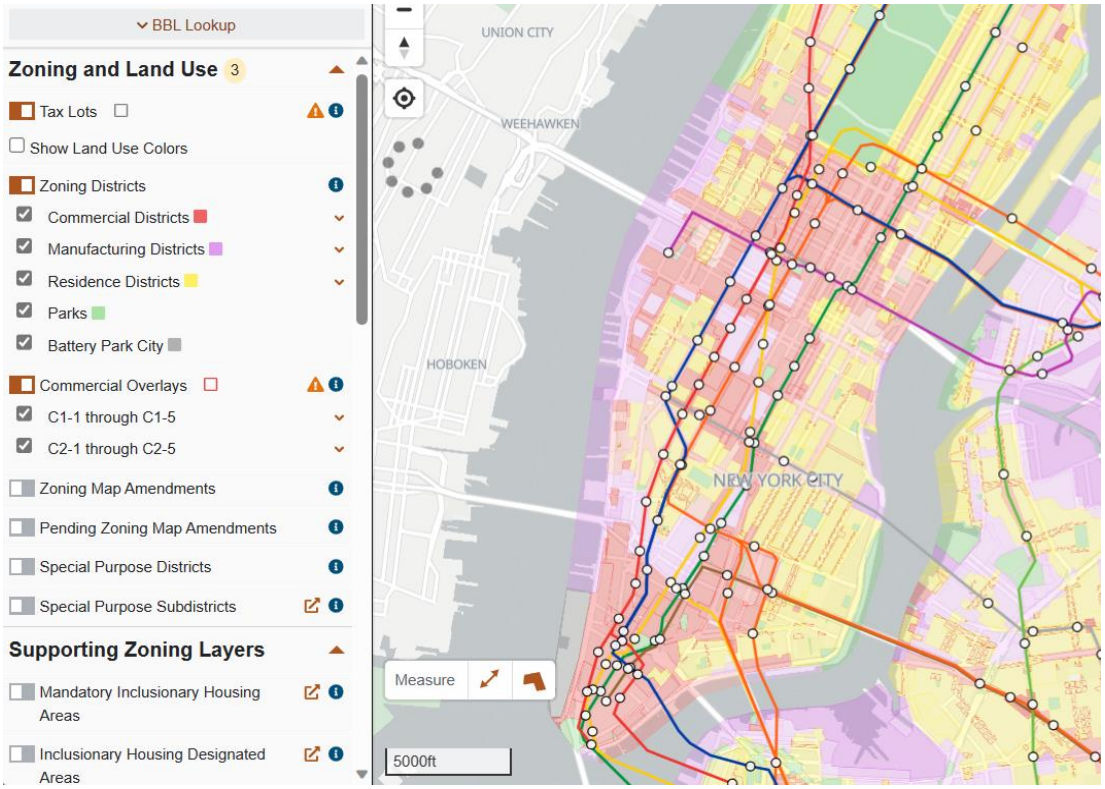

Figure 4. New York's landuse

(Available at: ZoLa | NYC's Zoning & Land Use Map)

Furthermore, upon closer comparison between Jersey City and New York City, it becomes apparent that residential prices in Jersey City are relatively lower (Figure 5). This may attract more people to settle in Jersey City in search of more affordable housing options. Additionally, based on the planning maps, Jersey City boasts a relatively large green space area, implying a superior living environment with more opportunities for outdoor leisure and recreation. Moreover, the distance from the easternmost point of Jersey City to the southernmost point of New York City is only 1.8 km, and considering estimated cycling speeds, it would take approximately ten minutes of cycling to quickly reach New York City from Jersey City. This short cycling time underscores the geographical advantage of Jersey City's proximity to New York City, allowing residents to enjoy the convenience and culture of both cities seamlessly.

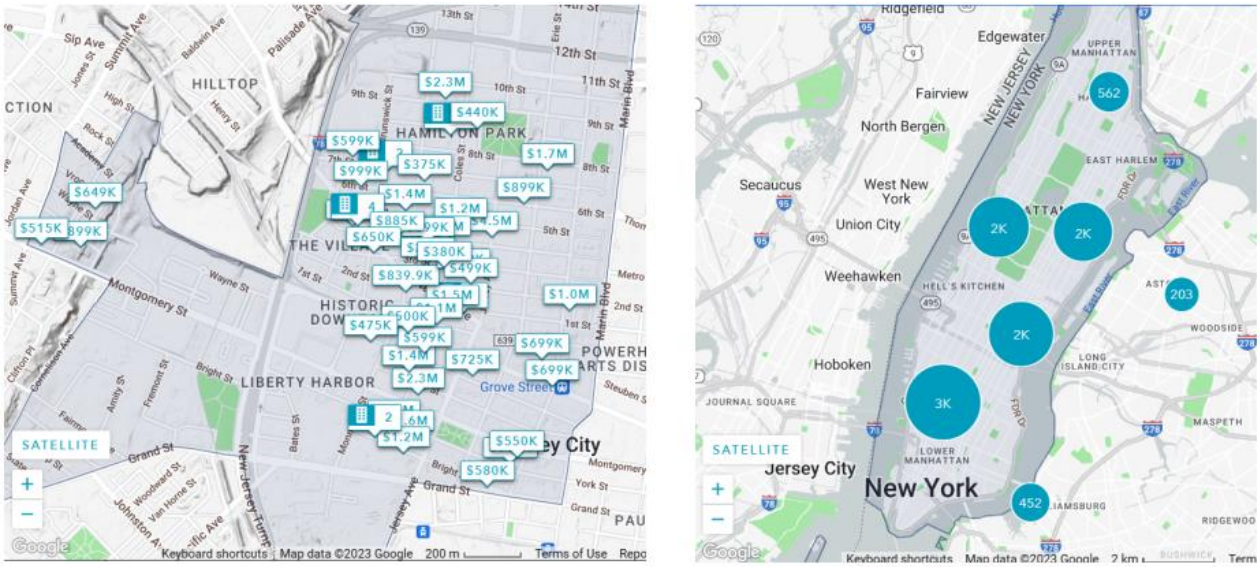

Figure 5. Jersey City vs. New York City Housing Prices

(Available at: Douglas Elliman | Luxury Real Estate and Homes for Sale | Homepage)

This paper not only contributes to our understanding of urban land-use planning and characteristics but also provides valuable insights for residents and urban planners. Jersey City's affordability in housing, abundant green spaces, convenient commuting, and the distribution of commercial activities collectively make it an attractive city, offering residents a comfortable and affordable way of life.

6. Suggestions

Based on the above situation and problems, this paper proposes several suggestions:

(1) Optimize Station Distribution: Considering regional disparities and commuting needs, it is recommended to increase the number of shared bicycle stations in the central area to meet the commuting demands of residents. This can improve biking convenience, reduce commuting costs, and alleviate traffic congestion. Additionally, more bike docks can be installed at termination points in New York City to address the issue of bike shortages due to excessive demand around subway and bus stations.

(2) Introduce Regular Commuting Packages: For daily commuters, introducing regular commuting packages can encourage more people to use shared bicycles as a commuting option. Such packages may include discounted prices or monthly/yearly membership plans.

(3) Smart Scheduling System: The shared bicycle system can invest in developing a smart scheduling system to dynamically adjust the distribution of bicycles based on real-time demand and weather conditions. This will ensure an adequate supply of bicycles for users during peak hours and adverse weather conditions.

(4) Integration of Weather Information: The system can integrate weather information and provide users with real-time weather data relevant to biking, including temperature and precipitation probability, on the bike rental page. Additionally, it can offer users an analysis of how weather conditions may impact their biking experience, helping them plan their trips better.

(5) Cross-City Collaboration Agreements: The shared bicycle system can actively enter into agreements with cross-city partners to ensure a seamless riding experience for users between different cities. These agreements can include consistent pricing strategies, interoperable membership plans, and cross-city bicycle scheduling.

(6) Tourism Promotion: Encourage tourists and city residents to explore different cities' cultures and attractions by using the shared bicycle system to cross city borders. The system can provide tourism-related information and promotional activities to attract more participants.

(7) Community Collaboration Projects: The shared bicycle system can collaborate with communities to launch community biking initiatives, encouraging residents to actively participate.

This may include regular community biking events, biking training, and reward programs to increase biking rates within residential areas.

By collaborating with various interest groups and innovating, the shared bicycle system can better meet the diverse needs of the city, promote collaborative development between cities, and achieve sustainable urban transportation and lifestyles. These recommendations contribute to a more comprehensive service for the shared bicycle system, enhancing urban sustainability and residents' quality of life.

7. Conclusion

In this study, we conducted an in-depth analysis of the shared bicycle system, exploring its spatial distribution characteristics, the reasons behind this phenomenon, and the recommendations proposed to address these challenges. Firstly, we discovered that there is a clear geographical disparity in the demand for shared bicycles within the city, with significantly higher demand in the city center compared to the suburbs. This phenomenon may be attributed to urban planning and population distribution. To better meet residents' commuting needs, we recommend increasing the number of bicycle stations in the central area, thus enhancing convenience and alleviating traffic congestion.

Secondly, we observed temporal trends in bicycle rides, revealing a steady increase in ride frequency from January to July, with a peak during the summer months. This aligns with common knowledge, as individuals tend to opt for cycling during more favorable weather conditions in the summer. To effectively address seasonal fluctuations in demand, we suggest introducing regular commuting packages to incentivize more people to choose shared bicycles as their preferred commuting mode.

Lastly, we placed particular emphasis on the phenomenon of cross-regional cycling, noting that destination points often lead to New York City. This occurrence may potentially lead to resource shortages within the shared bicycle system, necessitating solutions for spatial allocation challenges and management costs. To mitigate this issue, we recommend establishing collaboration agreements with other cities to ensure consistency and interoperability in cross-city cycling, thereby enhancing the overall user experience.

In conclusion, this study has provided valuable insights into the geographical demand, temporal trends, and cross-regional cycling within the shared bicycle system. By implementing recommendations such as optimizing station distribution, introducing regular commuting packages, developing smart scheduling systems, and integrating weather information, we can enhance the efficiency of the shared bicycle system, improve the quality of life for urban residents, and promote sustainable urban development. This comprehensive research serves as a strong foundation for the future advancement of Jersey City’s shared bicycle systems.

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