BILINGUAL PUBLISHING GROUP

Journal of Computer Science Research

https://journals.bilpubgroup.com/index.php/jcsr

ARTICLE

Research on the Spatiotemporal Distribution Relationship between Regional Rainfall and Taxi Supply in Singapore

Yuqi Wang

Singapore American School, 40 Woodlands Street 41, Singapore 738547, Singapore

ABSTRACT

This quantitative correlational study intends to investigate the spatiotemporal relationship between rainfall and taxi supply in Singapore. Over the period of 4 months, coordinates of all available taxis in Singapore, as well as rain value data from 66 weather stations located around the island, were collected every minute from public Application Programming Interfaces (API). Singapore was divided into a grid of 3km by 2km rectangles, with each region minutely assigned a taxi supply count and a rain value weighted based on distance to the weather station. To obtain groups where taxis behaved similarly, the data on weekends and weekdays were separated, then divided spatially and temporally. A non-linear correlation coefficient was calculated for each category. It was hypothesized that rainfall notably reduces taxi supply in most regions, an effect most pronounced in the evening rush hours (18:00 – 21:00) on all days of the week. The results do not fully validate this hypothesis, displaying that though taxi supply levels were generally decreased in situations with rainfall, they could likewise reach low levels in scenarios without.

Keywords: Rainfall; Taxi supply; Spatiotemporal distribution; Public transi

1. Introduction

Public transportation, generally defined as land transportation services available to the public for "hire and reward", plays a crucial role in connecting residents in cities around the world, particularly in populated metropolitan areas [1]. Not only are public transit systems valuable due to their improvement of the efficiency of transportation by reducing traffic congestion, they also promote sustainability by decreasing pollution [2]. Clearly, public transit systems are a beneficial component of many urban systems.

*CORRESPONDING AUTHOR:
Yuqi Wang, Singapore American School, 40 Woodlands Street 41, Singapore 738547, Singapore; Email: wang778737@sas.edu.sg

ARTICLE INFO
Received: 14 May 2024 | Revised: 10 June 2024 | Accepted: 25 June 2024 | Published Online: 30 June 2024
DOI: https://doi.org/10.30564/jcsr.v6i2.6619

CITATION
Wang, Y.Q., 2024. Research on the Spatiotemporal Distribution Relationship between Regional Rainfall and Taxi Supply in Singapore. Journal of Computer Science Research. 6(2): 18–23. DOI: https://doi.org/10.30564/jcsr.v6i2.6619

Taxi services are one of the most popular modes of public transportation due to their widespread availability and the convenience that they offer in transporting passengers directly from one point to another. Unlike many forms of public transportation, taxi services have no fixed route, and thus provide the benefit of being able to consistently and flexibly respond to new demand [3]. However, despite its utility, taxi services, like many modes of public transportation, are influenced by weather elements. In particular, passengers typically find it increasingly difficult to hire a taxi during conditions with rainfall. Chen et al. shed light on this phenomenon through a study on rainfall and the spatiotemporal distribution of taxi passengers, affirming the substantial impact of rainfall on taxi service demand [4]. Similarly, Kamga et al. found through a New York City study that rainfall resulted in shorter but more frequent taxi trips, also corroborating rainfall's influence on taxi services and offering a potential explanation for the difficulty of hailing taxis in the rain [5].

As illustrated, rainfall has a notable adverse influence on taxi services, which negatively impacts many commuters due to the popularity of taxi services as a mode of public transportation. Thus, this study intends to contribute to a more thorough understanding of the relationship between rainfall and taxi services, which will potentially be paramount to tailoring effective strategies to minimize the adverse effects of weather elements on the lives of commuters.

2. Methods

2.1 Research question and hypothesis

With an examination of the literature, I formulated the following research question to guide my research: Through quantitative correlational analysis, what is the relationship between regional rainfall and the spatio-temporal distribution of taxi supply in Singapore? It was hypothesized that rainfall would generally reduce taxi supply, with the effect being strongest at locations with higher average taxi supply and during evening rush hour, defined as the time period from 18:00 to 21:00. It was also hypothesized that these trends would be observed in the data, regardless of whether it was collected during the weekend or the weekday.

2.2 Study area

This study was conducted in the location of Singapore due to two principal factors: the wide usage of taxi services on the island and the location's tropical climate. Taxi services play an especially important role for commuters in densely populated cities, and as one of the cities with the highest population densities in the world, Singapore is no different in this respect [6]. Many residents of the island rely on the affordable taxi system to commute, with more than 1 million taxi trips made daily by approximately 28,000 taxis and 99,000 licensed taxi drivers [7–9]. Further, Singapore is an island characterized by a tropical climate and as a result, "precipitation is abundant over the whole year" [10]. Singapore's climate conditions offer a satisfactory number of observations of taxi conditions under different rainfall levels and makes the island an optimal location to investigate the focus of my study.

2.3 Data preparation

Data collection occurred over the span of approximately four months. In particular, the months from September 2023 to early January 2024 were selected as the study period as they coincide with the Singaporean monsoon season, the time when rainfall is more abundant on the island [11]. Rainfall was measured as the rain levels determined by Singaporean weather stations, while taxi supply was measured as the aggregation of available taxis on the island. Taxi availability data was obtained each minute from the Singaporean government's public data API, which supplied the geographical coordinates of all available taxis in Singapore at a specified time, excluding any taxis that are "Hired" or "Busy". Attributes include timestamp in SGT, longitude, and latitude. Regional rainfall data was likewise collected each minute from another public API offered by the Singaporean government, which in this case supplied numerical readings of rain levels at 66 weather stations distributed around the island of Singapore, as well as the weather stations' IDs and geographical coordinates. The data contains the following attributes: weather station ID, rain value, latitude, longitude, and timestamp in SGT. Both taxi and rainfall data was collected from their respective APIs through the continuous execution of a python script. After removing missing values, 186,054 minutes of data were available for use.

2.4 Statistical analysis

In accordance with Sun et al.'s study on rainfall and taxi operations, the study region of Singapore was divided into small rectangular cells of size 3 km x 2 km to observe the spatial variations of the relationship between rainfall and taxi supply [12]. The data for weekdays and weekends were analyzed separately to account for the difference in taxi operations [13]. Using Inverse Distance Weighting, weighted rain values for each cell were calculated based on distance from its centroid to the weather station [14]. Then, as illustrated in **Table 1** and **Table 2,** these cells were grouped based on their average taxi supply under non-rain conditions into 8 bins. This was performed using Equal Width Binning, which divides a set of data into equally spaced intervals, with the objective of obtaining collections of cells where taxis behaved similarly [15–17]. Bins where the average taxi supply was shown to be 0 on either the weekends or weekdays were excluded from the final data analysis; as a result, the data from cells assigned to bins 0 through 2 were removed. In order to determine the correlation between taxi supply and rainfall at each cell, the available taxis in Singapore at each minute were each assigned to a cell based on their spatial proximity to the centroids of the respective cells. Finally, the data was subdivided based on time periods, ensuring that there were segments representing each hour of the day. This allowed for the analysis of the correlation between each cell's taxi supply and rainfall within precise hourly intervals, enabling an understanding of the temporal aspect of the relationship between these variables.

Table 1. Cell count and average taxi supply within bins for weekdays.

Bin Index	Cell Count	Average Taxi Supply
0	80	0
1	16	0
2	16	1
3	16	3
4	16	8
5	16	17
6	16	30
7	16	64

Table 2. Cell count and average taxi supply within bins for weekends.

Bin Index	Cell Count	Average Taxi Supply
0	80	0
1	16	0
2	16	0
3	16	2
4	16	6
5	16	14
6	16	26
7	16	52

The minutely data for each cell consisted of the following attributes: (1) cell index, (2) timestamp, (3) rain values, and (4) number of available taxis. Statistical analysis was then performed for the 1-hour segments of data for each bin to determine the spatiotemporal relationship between taxi supply and rainfall. As both the rain values and the number of available taxis were numerical, it was possible for correlational analysis to be performed on the rain values and the number of available taxis. Specifically, a Spearman's Rank Correlation Coefficient, denoted as ρ, was calculated for each 1-hour segment within every subdivision. ρ values range from +1 to –1, with a ρ value of 1 indicating a consistently positive relationship, a ρ value of 0 indicating no correlation and a ρ value of -1 indicating a consistently negative relationship between the variables [16,18–19].

3. Results

Regarding the spatial relationship, the Spearman's Rank Correlation Coefficients don't show significant variations based on location, implying that the relationship between rainfall and taxi supply did not notably vary from region to region. Specifically, as demonstrated in **Figure 1** and **Figure 2**, the average correlation values were similar for both the weekend and the weekday, and the range of the correlation coefficient remained relatively consistent between regions.

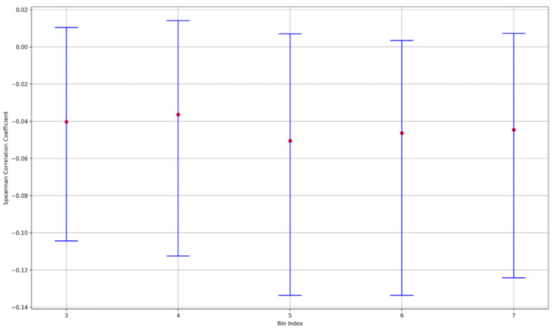

Figure 1. Distribution of spearman's rank correlation coefficient for different bins on weekdays.

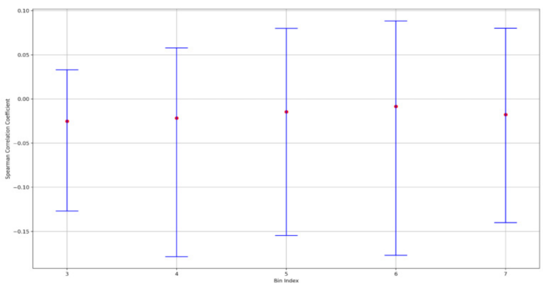

Figure 2. Distribution of spearman's rank correlation coefficient for different bins on weekends.

The only notable exception was that the range of correlation values for bin 3, which included cells with less average taxi supply, were slightly lower than that of other bins for data collected on the weekends. **Figure 1** includes the mean Spearman's Rank Correlation Coefficient for each bin. Each plot's upper and lower bounds are the 95th and 5th quantile of its corresponding set of coefficients. **Figure 2** likewise utilizes this format.

On weekdays, it was shown that, regardless of the location and day of week, the absolute value of the negative Spearman's Rank Correlation Coefficient was greatest during the hours between 18:00 and 21:00; additionally, most of the correlation values were found to be negative. For weekends, there appeared to be a greater range of correlation values, which was further reflected in the existence of a notable amount of both positive and negative correlation values. However, the overall pattern between time and correlation value remained largely consistent. Overall, as reflected in **Figures 3–5**, the data for weekends and weekdays both showed noticeable variance, suggesting that the relationship between taxi supply and rainfall varied based on time period.

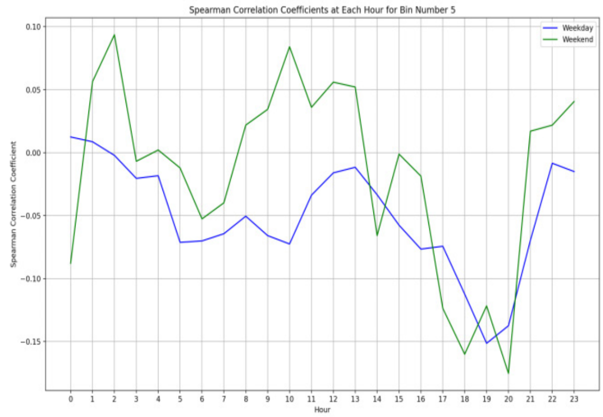

Figure 3. Spearman's rank correlation coefficients for bin 5 by time.

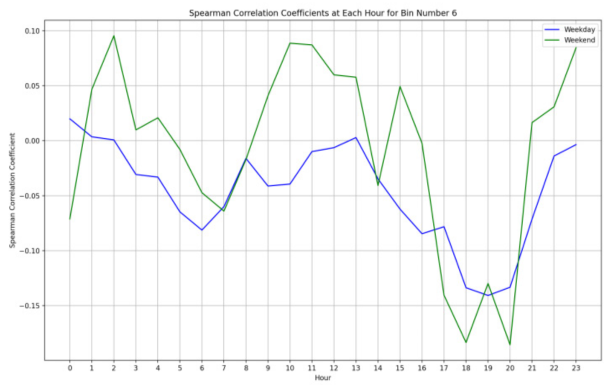

Figure 4. Spearman's rank correlation coefficients for bin 6 by time.

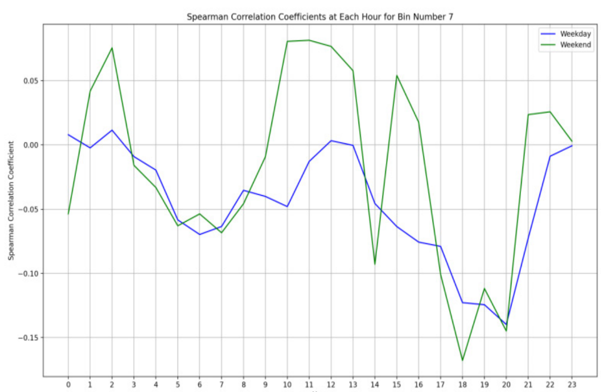

Figure 5. Spearman's rank correlation coefficients for bin 7 by time.

Generally, the Spearman Rank Correlation Coefficients derived were relatively close to 0, with the absolute value of the maximum correlation never exceeding 0.2. This implies that there was not a strong correlation between rainfall and taxi supply in the majority of the subdivisions used in this study. For each specific subdivision, it was found that taxi supply reached extremely low values in conditions with and without rainfall, as exemplified by **Figure 6**. However, it must be noted that as rainfall increased, each subdivision consistently saw a decrease in its maximum and mean taxi supply, suggesting that rainfall still reduces taxi supply, though its impact is somewhat limited as it is not the only factor that can result in this reduction [20–23].

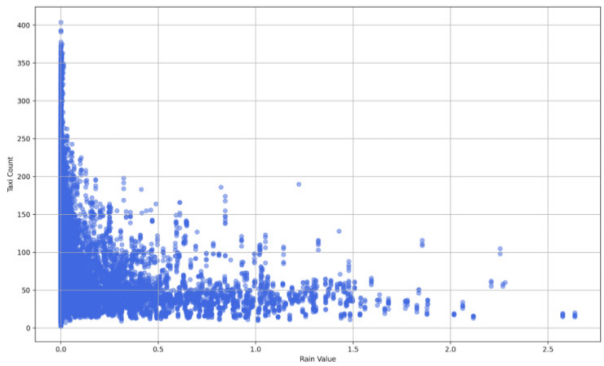

Figure 6. Taxi supply by time in Bin 7, from 18:00 to 19:00 during weekdays.

4. Conclusions

As taxi services continue to play a prominent role in the lives of innumerable commuters around the world, it is increasingly important to understand the influence of external factors on their operation. This study aimed to obtain an understanding of the spatiotemporal relationship between regional rainfall and taxi supply, thereby informing the efforts of taxi service providers and transportation planners to optimize the taxi hailing experience for commuters. Utilizing quantitative correlational analysis, it was concluded that: (1) though rainfall is negatively correlated with taxi supply, its effects are often overshadowed by those of other, more influential factors; (2) rainfall's correlation with taxi supply does not vary significantly from region to region; and (3) the negative correlation between rainfall and taxi supply is strongest during evening peak hours across all days of the week. This study enriches current literature by contributing to a more nuanced understanding of the interaction between weather elements and taxi services; as a result, it offers important insights into the maintenance of taxi service quality during rainy conditions.

Conflict of Interest

There is no conflict of interest.

References

[1] Hörcher, D., Tirachini, A., 2021. A review of public transport economics. Economics of Transportation. 25, 100196.
DOI: https://doi.org/10.1016/j.ecotra.2021.100196

[2] İmre, Ş., Çelebi, D., 2017. Measuring comfort in public transport: a case study for istanbul. Transportation Research Procedia. 25, 2441–2449.
DOI: https://doi.org/10.1016/j.trpro.2017.05.261

[3] Aarhaug, J., 2016. Taxis as a Part of Public Transport. Sustainable Urban Transport Project.

[4] Chen, D., Zhang, Y., Gao, L., et al., 2017. The impact of rainfall on the temporal and spatial distribution of taxi passengers. PLOS ONE. 12(9).
DOI: https://doi.org/10.1371/journal.pone.0183574

[5] Kamga, C., Yazici, M.A., Singhal, A., 2013. Hailing in the rain: temporal and weather-related variations in taxi ridership and taxi demand-supply equilibrium. In Proceedings of the 92nd Annual Meeting of Transportation Research Board. Transportation Research Board. Washington, DC, USA.

[6] Liu, Q., Ding, C., Chen, P., 2020. A panel analysis of the effect of the urban environment on the spatiotemporal pattern of taxi demand. Travel Behaviour and Society. 18, 29–36.
DOI: https://doi.org/10.1016/j.tbs.2019.09.003

[7] Balan, R.K., Nguyen, K.X., Jiang, L., 2011. Real-time trip information service for a large taxi fleet. Proceedings of the 9th International Conference on Mobile Systems, Applications, and Services.
DOI: Https://doi.org/10.1145/1999995.2000006

[8] Land Transport Authority, 2023. Point-to-Point

transport sector Statistics 2023. Land Transport Authority.

[9] Wang, Y., Zheng, B., Lim, E.-P., 2018. Understanding the effects of taxi ride-sharing — a case study of Singapore. Computers, Environment and Urban Systems. 69, 124–132.
DOI: https://doi.org/10.1016/j.compenvurbsys.2018.01.006

[10] Beck, F., Bárdossy, A., Seidel, J., et al., 2015. Statistical analysis of sub-daily precipitation extremes in Singapore. Journal of Hydrology: Regional Studies. 3, 337–358.
DOI: https://doi.org/10.1016/j.ejrh.2015.02.001

[11] Li, X., Zhang, K., Babovic, V., 2019. Projections of future climate change in Singapore based on a multi-site multivariate downscaling approach. Water. 11(11), 2300.
DOI: https://doi.org/10.3390/w11112300

[12] Sun, J., Dong, H., Qin, G., et al., 2020. Quantifying the impact of rainfall on taxi hailing and Operation. Journal of Advanced Transportation. 2020, 1–14.
DOI: https://doi.org/10.1155/2020/7081628

[13] Wemegah, T. D., Zhu, S., Atombo, C., 2018. Modeling the effect of days and road type on peak period travels using structural equation modeling and big data from radio frequency identification for private cars and taxis. European Transport Research Review. 10(2).
DOI: https://doi.org/10.1186/s12544-018-0313-9

[14] Shepard, D., 1968. A two-dimensional interpolation function for irregularly-spaced data. Proceedings of the 1968 ACM National Conference, New York, 27–29 August 1968, 517–524.

[15] Ryzin, J.V., 1973. A histogram method of density estimation. Communications in Statistics-theory and Methods. 2, 493–506.

[16] Heinen, A., Valdesogo, A., 2022. The Kendall and spearman rank correlations of the bivariate Skew Normal Distribution. Scandinavian Journal of Statistics. 49(4), 1669–1698.
DOI: https://doi.org/10.1111/sjos.12587

[17] Arana, P., Cabezudo, S., Peñalba, M., 2014. Influence of weather conditions on transit ridership: A statistical study using data from Smartcards. Transportation Research Part A: Policy and Practice. 59, 1–12.
DOI: https://doi.org/10.1016/j.tra.2013.10.019

[18] Zhou, M., Wang, D., Li, Q., et al., 2017. Impacts of weather on public transport ridership: results from mining data from different sources. Transportation Research Part C: Emerging Technologies. 75, 17–29.
DOI: https://doi.org/10.1016/j.trc.2016.12.001

[19] Brodeur, A., Nield, K., 2018. An empirical analysis of taxi, lyft and uber rides: Evidence from weather shocks in NYC. Journal of Economic Behavior and amp; Organization. 152, 1–16.
DOI: https://doi.org/10.1016/j.jebo.2018.06.004

[20] Guo, P., Sun, Y., Chen, Q., et al., 2022. The impact of rainfall on urban human mobility from taxi GPS Data. Sustainability, 14(15), 9355.
DOI: https://doi.org/10.3390/su14159355

[21] Chou, Y. K., 2002. Testing alternative models of labour supply: Evidence from taxi drivers in Singapore. The Singapore Economic Review. 47(01), 17–47.
DOI: https://doi.org/10.1142/ s0217590802000389

[22] Lepage, S., Morency, C., 2020. Impact of weather, activities, and service disruptions on Transportation Demand. Transportation Research Record: Journal of the Transportation Research Board. 2675(1), 294–304.
DOI: https://doi.org/10.1177/0361198120966326

[23] Zhou, Y., Mao, S., Zhao, H., et al., 2022. How Rainfalls Influence Urban Traffic Congestion and Its Associated Economic Losses at Present and in Future: Taking Cities in the Beijing-Tianjin-Hebei Region, China for Example?
DOI: Https://doi.org/10.21203/rs.3.rs-1442299/v1