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A Review and Case Analysis of the Impact of Weather Factors on Public Transportation in Singapore

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Abstract: As one of the most popular modes of public transportation around the world, taxi services often see their effectiveness impeded by weather elements such as rainfall, which makes it difficult for people to get a taxi. Existing literature has examined the relationship between taxi demand and rainfall, revealing a lack of understanding of the connection between rainfall and taxi supply. Moreover, Singapore remains underrepresented in studies on this relationship. This study contributes to the literature by providing nuance to the commonly held belief that rain value is negatively correlated with lower taxi availability. Further research may consider exploring the alternative causes of decreased taxi availability and incorporating private ride-hailing services in their investigations.

Keywords: Rainfall; Correlational analysis; Taxi supply; Public transit

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1. Introduction

Weather elements have significant impacts on the operation and ridership of public transportation with existing wide-ranging studies that have attempted to specify the nature of these effects. For instance, Arana et al. employed data collected from smart cards utilized for public transit fare payment in Gipuzkoa, Spain to conclude that rainfall, along with wind, was related to the decrease in the number of trips citizens made with public buses [1]. Similarly, Zhou et al. also analyzed smart card data in Shenzhen, China, and found that not only does rainfall affect public transit by decreasing ridership, its impact is more significant in comparison with other weather elements [2]. Thus, current research corroborates that rainfall emerges as the weather element with the most impact on public transportation and typically serves as a hindrance to the public transit system as it reduces ridership.

In addition to wide-ranging examinations of the relationship between weather elements and public transportation, past research also investigated the connection between rainfall and taxi services, a specific mode of public transit. However, though these studies likewise find a relationship between the two, there appears to

be a lack of focus on rainfall's impact on taxi supply. For instance, Brodeur and Nield conducted a study on the interconnected relationships between rainfall, taxi, Lyft, and Uber services in New York City, and concluded that rainfall prompted an increase in taxi rides [3]. In addition to this finding, Guo et al. found in a study conducted in Zhuhai, China that rainfall tends to diminish the distance and temporal duration of taxi trips [4]. However, even though the aforementioned studies have acknowledged rainfall's impact on taxi ridership, passenger tendencies, as well as taxi demand, there remains a scarcity of studies that specifically examine taxi supply with rainfall, even though this knowledge is equally important due to its potential to enhance urban transportation planning. Thus, existing literature demonstrates the need to investigate the relationship between taxi supply and rainfall.

Furthermore, there is a lack of understanding of the relationship between taxi services and rainfall in the specific location of Singapore. Though there exists research conducted in Singapore that examines taxi services, these studies have typically attempted to create prediction models for the taxi services sector. Specifically, Balan et al. utilized historical taxi data to construct a model to forecast taxi services' trip times and fares in Singapore [5]. Though these studies do acknowledge weather's impact on the taxi data collected, this knowledge was only utilized to exclude any collected data that could have been influenced by weather. As a result, past studies on taxi services conducted in Singapore essentially disassociated weather from the taxi services they investigated and thus, there remains a lack of conclusions regarding the relationship between rainfall and taxi services in a Singaporean context.

Overall, existing literature reveals that despite a notable relationship between rainfall and taxi services, there remains a lack of understanding of the specific connection between rainfall and taxi supply, and Singapore persists as an underrepresented location for studies on this relationship. Thus, there is a clear need for research investigating the relationship between rainfall and taxi supply in Singapore

2. Quantitative correlational analysis

This study is quantitative in nature. Specifically, this study chose to utilize a method of correlational analysis, where the strength of the relationship between two or more variables is determined through a statistical test [6]. This study aimed to determine the nature of the relationship between rainfall and taxi supply, while also observing how it varied across space and time. As a result, correlational analysis is likewise performed on data that has been divided spatially and temporally, such that regions and periods with similar taxi behavior are studied concurrently. This method can determine the correlation between rainfall and Singaporean taxi services, how this correlation was affected by time, as well as whether any identified relationships were significant. This methodology is designed following that of a seminal source, a quantitative study on the relationship between rainfall and taxi operations conducted by Sun et al. in Shanghai, China that analyzes the relationship in a particularly thorough manner [7]. Due to the established nature of correlational analysis as an effective method of determining the strength and significance of the relationship between specified variables, it is an optimal method for this study.

3. Results

In choosing to study rainfall and taxi supply from a spatiotemporal perspective, it was assumed that the relationship between rainfall and taxi supply varied based on location and time. This assumption is supported by the research of Sun et al., which has identified that not only does rainfall drastically affect the spatial distribution of taxi demand, but the strength of this effect is also influenced by the time of day [7]. These conclusions suggest that it is reasonable to assume the existence of similar spatiotemporal variations in the

relationship between rainfall and taxi demand's counterpart, that is taxi supply. It was hypothesized that taxi supply would be significantly reduced under rainy conditions, especially in locations with higher average taxi supply and during evening rush hour.

The line graphs of Spearman's rank correlation coefficients by time are reflected in **Figure 1** and **Figure 2**. This study reached the broad conclusion that despite a generally weak correlation between taxi supply and rainfall, rainfall reduces taxi supply in Singapore. Additionally, other notable findings include the fact that Spearman's rank correlation coefficient between rainfall and taxi supply was strongest during the time from 18:00 to 21:00 on both weekdays and weekends and that the correlation did not vary notably from region to region. Though some of these findings aligned with the hypothesis, it was still largely disproven due to key differences concerning the spatial relationship and the strength of the correlation. Specifically, though this study had correctly hypothesized the general and temporal relationship between taxi supply and rainfall, location's influence on the correlation between the two variables was much weaker than expected. Furthermore, this study also hypothesized a much stronger correlation between rainfall and taxi supply in comparison to the actual findings. While previous studies, such as those conducted by Sun et al. and Chen et al., claim that rainfall significantly impacts taxi operations, this research provides a more nuanced understanding of these dynamics [7–8]. In particular, the primary finding of this study is that though rainfall decreases taxi supply, it is not the primary driver of these reductions.

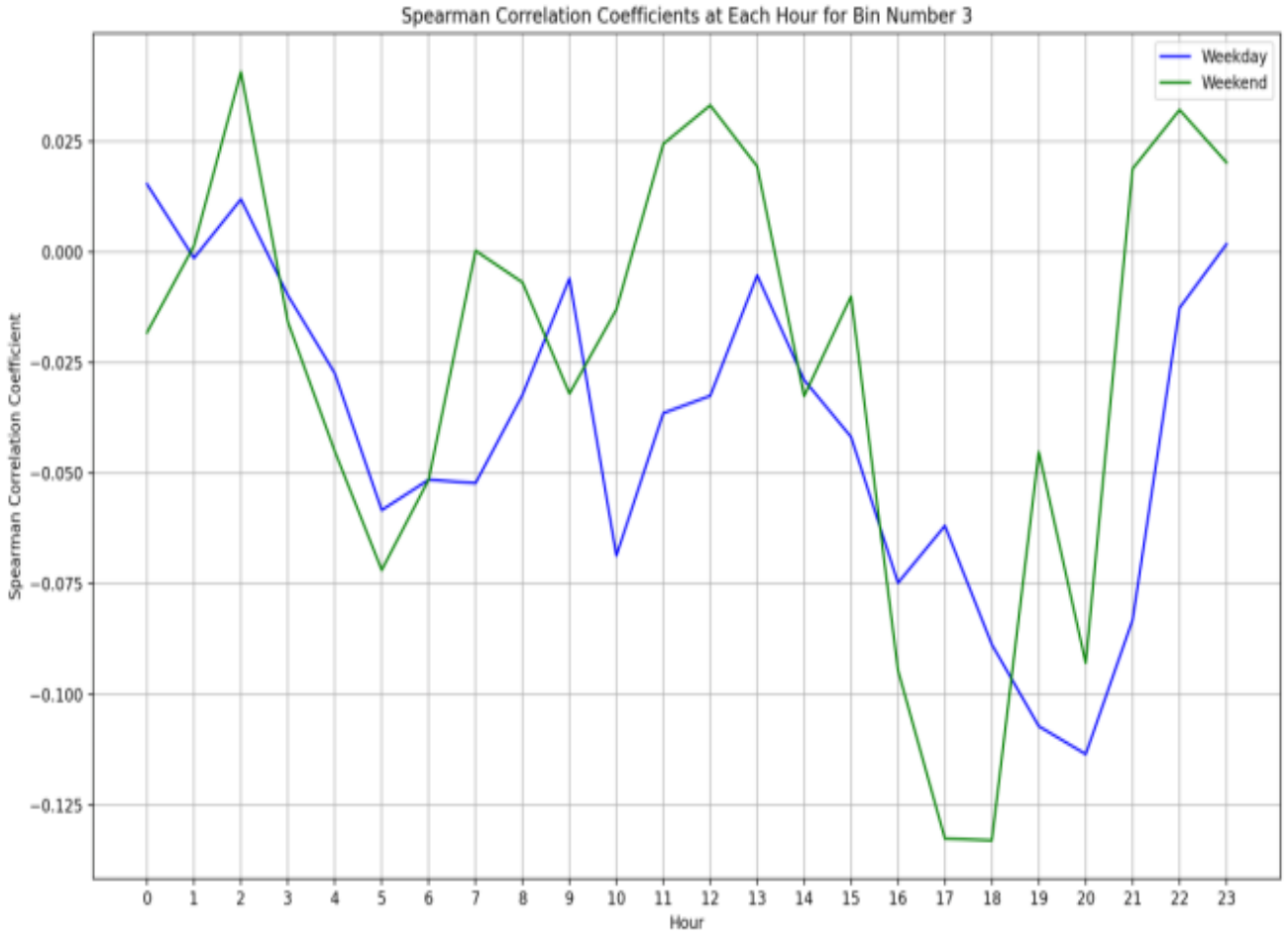

Figure 1. Spearman's rank correlation coefficients for bin 3 by time

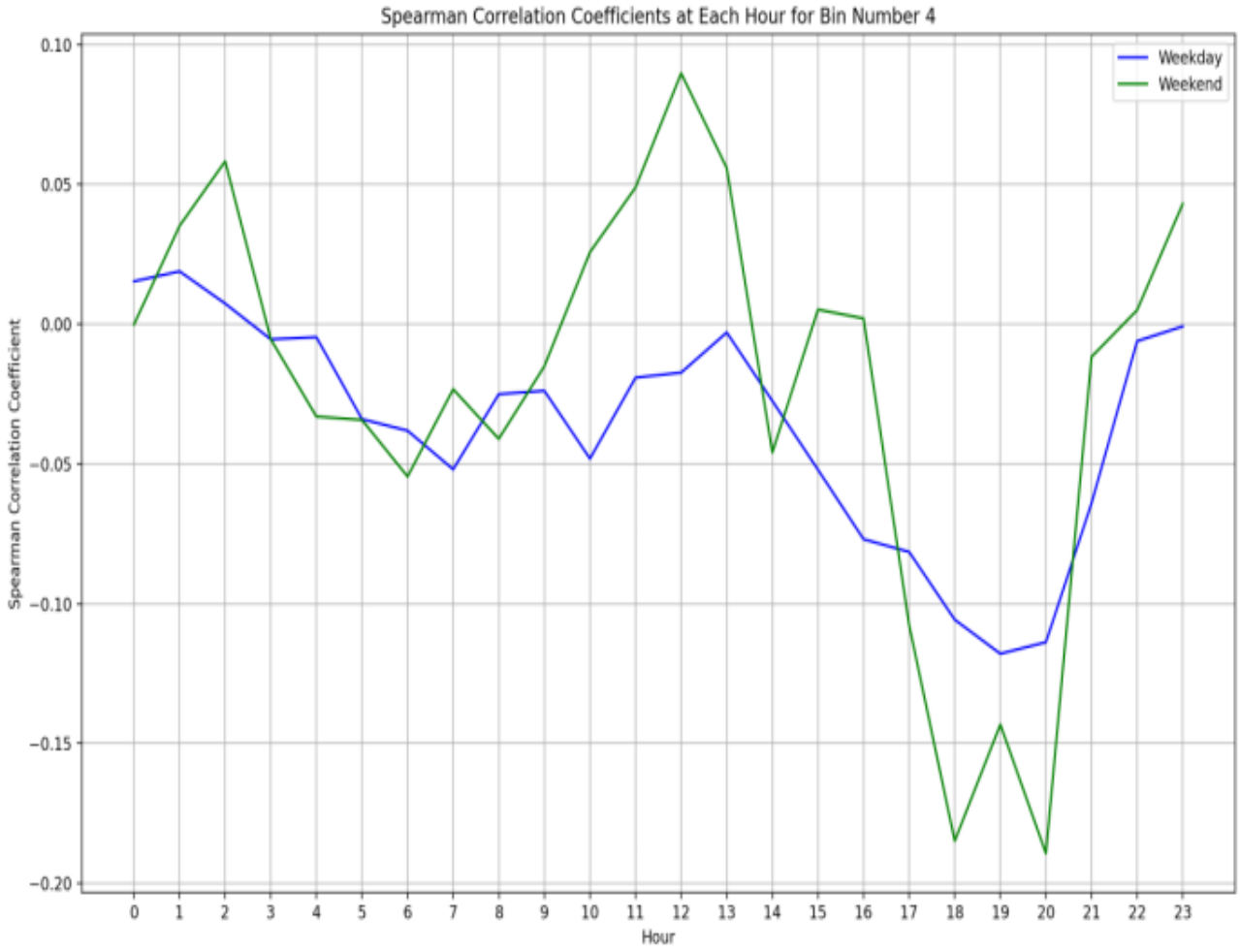

Figure 2. Spearman's rank correlation coefficients for bin 4 by time

The behavior of Singaporean taxi supply strongly aligns with a model of income targeting, where taxi drivers will quit upon meeting their daily earning target [9]. As a result, taxi supply is reduced more quickly on days when taxi demand is high due to drivers meeting their earning targets earlier, and thus, fluctuations in taxi demand may be one of the factors that crucially influence taxi supply. Furthermore, taxi demand is more significantly affected by the temperature, as well as the time of day [10]. As such, the diminished influence of rainfall on taxi supply may have been a result of other more influential factors such as taxi demand and by extension, rain and time of day.

Moreover, this theory would likewise explain the discrepancy between the current literature and the current findings regarding the influence of region on the relationship between rainfall and taxi supply. Sun et al. concluded that in regions where taxis were more readily available, rainfall is most correlated with the reduction in taxi supply during morning peak hours [7]. Conversely, this study found that the relationship between rainfall and taxi supply did not notably differ across regions of different average taxi supply. Factors such as temperature and time of day, which have been previously established as potentially having a greater influence on taxi supply, do not change significantly from region to region. Therefore, their influence on taxi supply would likely overshadow any region-specific impacts of rainfall, accounting for the lack of spatial discrepancy between rainfall-taxi supply correlations.

Finally, this study demonstrated that the rainfall-taxi supply correlation reached a maximum during Singapore's evening rush hour, defined as the time from 18:00 to 21:00. The principal contributor to this finding is likely the simultaneous increase in both taxi demand and traffic congestion within this period. In this context, evening rush hour is uniquely characterized by a large number of commuters simultaneously traveling from work [11]. Thus, this time of day often results in greatly increased taxi demand, notably lowering the available taxi supply in most regions. Additionally, rainfall is correlated with particularly serious traffic congestion during evening rush hour [12–13]. This, in turn, lengthens the time required for taxi drivers to complete a trip and become available once again, lowering the taxi supply even further. Thus, this study's findings about the temporal aspect of the correlation between rainfall and taxi supply are corroborated by existing literature [14–20].

4. Discussion

Generally, due to various discrepancies between the expected and actual results, this study was not successful at proving the hypothesis. Though some of this study's findings do not perfectly align with those of existing literature on the factors that influence taxi services, they can all be explained with previous research. As a result, this study's conclusions still contribute to a more nuanced understanding of the relationship between weather elements and taxi services. The principal conclusion reached by this study was that rainfall was negatively correlated with taxi supply regardless of location or time, though it is not a significant influencing factor. This not only emphasizes the need to compensate for a reduced taxi supply during rainy conditions but also the necessity to account for a myriad of other factors when optimizing the distribution of taxi services. Further, the spatiotemporal conclusions present in this study may offer more concrete suggestions for the achievement of these optimizations. Specifically, as rainfall was shown to reduce taxi supply most notably from 18:00 to 21:00 on all days of the week, it may be beneficial for taxi service providers to deploy additional resources to maintain an adequate level of service during this period. Likewise, the lack of region-related variation of the rainfall-taxi supply correlation suggests that the factors primarily influencing taxi supply may not significantly vary spatially. This constraint allows both transportation planners and taxi service providers to more easily identify the key factors that hinder taxi operation, enabling a more efficient optimization process. Overall, through enhancing understanding of the factors that influence taxi services, this study provides valuable insights for transportation planning, ultimately allowing transport providers to better the experience of commuters.

However, it is also important to acknowledge that this study has several limitations. Firstly, it does not analyze the relationship between rainfall and private ride-hailing services. Due to the widespread usage of private ride-hailing services, this study would have provided more valuable insight into transport optimization if it had obtained a more generalizable conclusion by investigating rainfall's influence on both taxi and private ride-hailing services. Additionally, though this study's findings were able to demonstrate the presence of other factors that more notably reduce taxi supply, it was beyond the scope of this study to accurately identify these factors and to investigate the strength of their relationships with taxi services. Recognizing this limitation, several possible such factors were proposed in this study's discussion section as a potential starting point for future research.

5. Conclusion

Future research may consider examining the influence of rainfall on both taxi and private ride-hailing services, to obtain a more comprehensive understanding of the relationship between weather elements and ride-hailing. This awareness of the factors that may hinder private ride-hailing operations is critical, especially as

these services grow in popularity. Only with this knowledge can private ride-hailing services be optimized accordingly, ultimately improving the experience for commuters. Moreover, though this study has established the probable existence of other factors that significantly reduce taxi supply and hinder taxi operations, it has yet to analyze them comprehensively. Thus, further investigative studies are needed to identify these factors and examine their specific relationship to taxi supply, to facilitate a more comprehensive understanding of the elements that must be considered when optimizing taxi commuter experience.

Disclosure statement

The author declares no conflict of interest.

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