Proposal and Application of Parking Area Performance Measurement Methodology

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Abstract
The function of parking areas at expressway rest stops is to provide drivers with opportunities to park their vehicles for their own purposes, so the number of parking spots has been discussed. However, as the number of parking spots increases, the parking area becomes maze-like and the use of the parking spots becomes inefficient. This leads to skepticism that an increase in parking area capacity will contribute to enhancing parking area performance. Meanwhile, one vehicle is able to park in a parking spot when another vehicle exits the area that is fully occupied, so the condition of drop-by traffic at a rest stop can be discussed using the queuing theory by viewing a rest stop as a warehouse. Thus, this study aims to determine the applicability of the queuing theory when discussing drop-by traffic situations, while assuming a first-in first-out (FIFO) condition. For the applicability of the queuing theory of describing parking area performance, this study employed the ETC probe time-stamp data. The observed values from the ETC probe time-stamp data and FIFO assumed time lags are described, and the applicability of the observed ETC time-stamp data to representing the exact conditions was determined by comparing the number of vehicles parked on the hour every hour and those counted by the observed ETC probe time-stamp data. Finally, the applicability of the FIFO assumption was discussed using the correlation between the observed ETC probe time-stamp data and the FIFO assumed time lags calculated by the data. The results indicate that a FIFO assumption could alternate the observed ETC probe time-stamp data. The number of vehicles staying on the hour every hour can be represented by the calculation results from FIFO assuming time lags. These findings show that it could be possible to determine the congregative situations of an expressway rest stop analyzed by the ingress and egress time-stamp records. Also, this result assumes any contribution to assessing the functional performance by measuring only the number of vehicles entering and exiting a parking area.

Keywords: Parking area, First-in first-out (FIFO), Queuing theory, Time-stamp data, Performance
1 Introduction

The function of parking areas at expressway rest stops is to provide drivers with opportunities to park their vehicles for their own purposes, so highway administrators or operators have focused on how many vehicles can park in a parking area, which means that the capabilities of parking areas have generally been discussed based on capacity or the number of parking spots. For example, the design specification for the rest stop of Japanese expressways prescribes only the capacity of a parking area, width of an access aisle, and the dimensions and angle of a parking spot. As the specification, the capacity, which is the number of parking spots, is supposed to be calculated based on the traffic volume on the main line. Thus, many parking spots are required for rest stops in sections with heavy traffic. Therefore, as the number of parking spots increases, the parking area becomes maze-like and the use of the parking spots becomes inefficient. For example, Ebina Service Area (SA) on the Tomei Expressway, which was opened in 1968, expanded its parking area capacity in 1991, because there was no suitable location to develop an alternative new rest stop on the route. As a result, there are many invisible parking spots that have been developed farther from the entrance, and those are not effectively used even during busy hours, while closer zones are always full, which frequently leads to long queues near the entrance. This leads to skepticism that an increase in parking area capacity will contribute to enhancing parking area performance.

For this inefficiency problem, some research has been conducted and measures taken to enhance traffic conditions inside a huge parking area. For example, Muramatsu et al. (2011) indicated that information delivery to drivers contributes to increasing parking spot use, specifically in invisible parking zones on the farther side of the entrance, and Muramatsu and Tada (2012) reported that more detailed information provided in a closer zone contributes to reducing travel time to park in a parking spot. Some research is available that is related to available parking spot choice behavior or to prediction models for parking area occupancy and parking demand control. Other researches focused on the drop-by demand allocation for several rest stops on the route. However, the aspects of those research projects focused more on vehicle travel behavior than the functional performance of parking areas.

Essentially, each driver has a different purpose and a different expected time of stay, so the duration of stay by drop-by vehicles fluctuates. Meanwhile, it can be seen that one vehicle is able to enter a rest stop and park in a parking spot if another vehicle exits the area, which means that the condition of drop-by traffic at a rest stop can be discussed using the deterministic queuing theory by viewing a rest stop as a warehouse, without identifying each vehicle license plate. Thus, this study aims to determine the applicability of the queuing theory when discussing drop-by traffic circumstances, while assuming a first-in first-out (FIFO) condition.

2 Queuing Theory Application to Time Series Analyses

The function of parking areas at expressway rest stops is to provide drivers with opportunities to park their vehicles for their own purposes, so expressway operators are required to provide vehicle drivers with enough parking spots as well as smooth and safe moving conditions. This means that the parking area performs the same functions as both a traffic facility that provides vehicles with efficient and safe travel, and a warehouse that accumulates vehicles whose drivers want to stay (how long and how many). Both of these phenomena are often analyzed using the queuing theory.

2.1 Queuing Theory Applied to Traffic Flow Analysis

The deterministic queuing theory is applied to the traffic flow analysis, because traffic demand changes depending on the time, and it is convenient to describe changes in congestion from moment to
moment by showing the number of vehicles in a queue and the travel time delay. Figure 1 shows a perspective cumulative curve at a highway bottleneck. The red line in Figure 1 is the arrival traffic flow rate upstream from the bottleneck that is arriving at the bottleneck \( A(t) \) shown as the red dashed line). This \( A(t) \) represents traffic demand at the bottleneck. On the other hand, the departure traffic flow rate \( D(t) \) shown as the blue line), is controlled by the capacity of the bottleneck, so \( D(t) \) becomes constant when the traffic flow rate upstream \( A(t) \) exceeds the capacity of the bottleneck. The gap between \( A(t) \) and \( D(t) \), which is the gray shaded area in Figure 1, causes a queue. The length of the x-axis equals the travel time delay at the time, and the height of the y-axis describes the number of vehicles caught in the queue. Thus, a descriptive cumulative curve applied using the queuing theory easily describes the characteristics of traffic congestion at a highway bottleneck.

![Figure 1: Cumulative arrivals and departures as viewed in a deterministic queue](image)

### 2.2 Queuing Theory Applied to Inventory Control

The queuing theory is applied to other issues, an example of which is shown in Figure 2. This shows a cumulative curve between demand and supply regarding inventory control related to supply chain management. Suppliers might minimize their stock in order to optimize inventory management, so a supplier might produce its products on demand. However, a supplier of on-demand production might forfeit customers because they might place orders with a competitor, so suppliers would keep stock in inventory in order to avoid a stock shortage. The blue line in Figure 2 shows the demand for a product, and the red dashed line shows the stock of the product in inventory. Demand fluctuates depending on the customers’ needs, while supply is controlled by the production capacity of the supplier’s factory. It is desirable for the total amount of stock produced by overtime production and that in inventory be the same as the sum of the peak demand, which might temporarily skyrocket. If the peak demand exceeds the sum of overtime production and inventory stock, shown as the gray shaded area, the supplier would face a stock shortage, and might lose the customer. However, maintaining such a stock requires an internal interest expense on inventory, so supply chain operation is trying to optimize the stock in inventory.
3 Methodology and Framework

3.1 FIFO Assumption

FIFO means that the nth vehicle entering a parking area exits in nth. However, the function of a parking area at expressway rest stops is to provide drivers with opportunities to park their vehicles for their own purposes, so the duration of each vehicle’s stay naturally fluctuates. Some drivers driving alone on a business trip might stop at a rest stop in order to call their office or a customer, or to use the restroom, while other drivers taking their families to enjoy a holiday might stop at the area to eat lunch or supper, or to purchase gifts. Some other drivers carrying packages or containers might stop in order to rest or take a nap. Thus, the duration of vehicle stays do not fall under FIFO conditions, so license plate number matching between the entrance and the exit is required in order to understand the exact duration of each vehicle’s stay, and a field survey is sometimes required.

However, if a FIFO assumption could be applied to understand the congregate situation in a parking area, the situation could be understood just by counting the number of vehicles at the entrance and the exit using vehicle detectors. After counting the number of vehicles, the count data at the entrance can be plotted by the time, and this is called the cumulative arrival curve. Also, a cumulative departure curve plot using the count data at the exit can be described. The congregate duration of stay and the number of vehicles in the parking area at certain times can be described by overlapping both cumulative curves. This assumption is not exact, but it could be useful in understanding the congregate situation in a parking area.

The concept of a cumulative vehicle arrival curve and an exact duration of stay using accumulative first-out (FO) assumed departure curve is shown in Figure 3. A cumulative curve can be developed by simply plotting the duration of time that drop-by vehicles stay in a parking area, and accumulated from the time the vehicles enter the area, as shown by the bold arrows in the figure. This accumulation is actually a step function when treating a small number of vehicles from a microscopic point of view.
On the other hand, this study focuses on the congregative parking area situation with a large number of vehicles observed using the ETC probe time-stamp data, so the steps of individual vehicles can be small enough to be ignored. Thus, the cumulative curves are treated as a smooth function in this section, although Figure 1 shows only several vehicle stays.

The bold arrows in Figure 1 are the exact duration of vehicle stays, and the thin line connecting the beginning of vehicle stays describes the cumulative vehicle arrival curve. An individual vehicle stays as long as it wants, so the exact departure time, shown as the edge of the arrows, fluctuates. The gray triangles show the FO assumed departure time, and the bold dashed line connecting the gray triangles describes the cumulative FO assumed departure curve. The (n)th vehicle stays for a long time, and the FO assumed departure time is shown in the middle by a gray triangle, but this time is the exact departure time of the (n+2)th vehicle. On the other hand, the FO assumed departure time of the (n+2)th vehicle is the exact departure time of the (n)th vehicle. The durations between the triangles and the exact departure times for the (n)th and (n+2)th are equal. This phenomenon can be seen among the (n+3)th, the (n+4)th, the (n+5)th, the (n+6)th and the (n+7)th. Also, the sums of both exact duration of stays and FO assumed duration of stays becomes equal. This means that the FIFO assumption can be applied to understand the congregative parking area situation. The duration between the cumulative arrival curve and the FO assumed departure curve is called the FIFO time lag.

![Cumulative Vehicle Arrival Curve and Exact Duration of Stay with Cumulative First Out Departure Curve](image)

**Figure 3:** Concept of cumulative vehicle arrival curve and exact duration of stay with cumulative First Out departure curve.

In order to discuss the applicability of a FIFO assumption to the exact vehicle time-stamp data, the authors used time-stamp data from the Electric Toll Collection (ETC) probe system, which was provided specifically for the purpose of this study by NEXCO-Central. This time-stamp data included matched timestamps at both the entrance and exit of eight parking areas. The duration was 24 hours on both a holiday and a weekday when a field survey was conducted. The authors calculated the FO assumed departure time \( t_{\text{FO}} \) by extracting the exit timestamps \( t_{\text{eo}} \) from the ETC probe data and sorting them by time. The FIFO time lag \( d_{\text{FIFO}} \) was calculated by subtracting the nth entrance timestamps \( t_{\text{in}} \) from the FO assumed departure time \( t_{\text{FO}} \). After the FIFO assuming time lags were calculated, the data was analyzed to determine the characteristics of vehicle stay and how long vehicles tended to stay, and this information was compared to the characteristics of actual vehicle stay time and the FIFO assumed vehicle stay.
\[ d_{\text{FIFO}} = T_{\text{FO}} - T_{\text{in}} \]  

The sum of \( d_{\text{FIFO}} \) is equal to the sum of \( d_{\text{ex}} \), where \( d_{\text{ex}} \) is defined as the exact duration of vehicle stay \((t_{\text{eo}} - t_{\text{in}})\). Thus, the application of a FIFO assumption can contribute to understanding the congregative situation in a parking area much more easily, just by recording times at the entrance and exit of the area without recording and matching the license plate numbers.

3.2 Application of Queuing Theory to Parking Management

This study focuses on parking spots in an intercity expressway rest stop. The function of parking areas at expressway rest stops is to provide drivers with opportunities to park their vehicles for their own purposes, so the duration of each vehicle’s stay differs. Some drivers driving alone on a business trip might stop at a rest stop in order to call their office or a customer, or to use the restroom. Other drivers taking their family to enjoy a holiday might stop at the area to eat lunch or supper, or to purchase gifts. Some other drivers carrying packages or containers might stop in order to rest or take a nap. Thus, there are many reasons to stop at an expressway rest stop, and a parking area functions as like storage facilities by accumulating a fluctuating number of vehicles whose drivers want to stay for different lengths of time. Also, the focus is just on vehicle activity, such as when one vehicle enters the parking area to take advantage of a service and another vehicle that has finished taking advantage of a service exits the area. Thus, if a parking area is assumed to count as storage, and both vehicles entering and exiting the area are assumed to equal supply and demand, the situation in a parking area can be discussed like inventory control with FIFO conditions.

Thus, this study discusses the applicability of the queuing theory to parking area circumstance while assuming FIFO entering and exiting for analysis of congregative vehicle drop-by behavior from a macroscopic point of view. A parking area is assumed to have the following conditions:

- Each parking area has both one entrance and one exit;
- Each parking area has one huge mass parking area, and a vehicle can park in any spot in which a driver wants to park;
- Each vehicle is assumed to drive the same distance with the same travel time, and the customers’ walking times are also assumed to be same.

A perspective of the circumstances of an expressway parking area can be described as a cumulative curve, as shown in Figure 3. The black line starting at zero in both axes (A) means that the cumulative curve of a vehicle entering, and its rate increases during \( t_{\text{M1}} \) and \( t_{\text{M2}} \). Line D means that the cumulative curve of a vehicle exiting and its y-intercept are below zero, because parking areas are generally operated around-the-clock and some vehicles will already be parked in the area. The parking area congestion level is assumed to be split into three levels; “vacant,” “crowded,” and “full.”

When \( t \) is less than \( t_{s1} \), the parking area level is “vacant,” which means that it has enough available parking spots for vehicles entering the area to park wherever they want, without any queues or waiting time at the beginning of the day. Also, vehicles that want to exit the area can do so without any obstacles. The entering rate begins to rise, and the number of vehicles in the area gradually increases (N), but the travel time to park (d) is stable.

When \( t \) is located between \( t_{s1} \) to \( t_{M1} \), the parking area level becomes “crowded,” which means that the area still has enough parking spots, but some vehicles are not able to park where they want and need to look for another acceptable parking spot. The number of vehicles is increased to (N+B), but some vehicles are still driving in area (B). The rates of vehicles entering and exiting are both increasing, but the travel time to park also increases (d+e) due to vehicles searching for acceptable parking spots.

When \( t \) falls between \( t_{M1} \) and \( t_{M2} \), the area is at the “full” level, which means that there are only a few available parking spots, most of which are invisible from the parking area entrance, and this
condition causes queues at the entrance and in the parking area. Also, vehicles must search for an available parking spot after getting through the queue, or must drive around if the area is built in circuit style. Thus, the number of vehicles at this time is the sum of vehicles parked (N), those looking for an available parking spot (B), and those waiting in the queue at the entrance or in a parking area. Also, the total travel time to the spot includes waiting time in the queue (w) in addition to the time spent searching an available parking spot (e) and the natural driving time it takes to park a vehicle (d).

After \( t_{M2} \), the vehicle entering rate declines, which resolves the queues. The parking area congestion level changes to “crowded.” At the end, the rate of vehicles entering decreases enough after \( t_{s2} \) to drop the congestion level to “vacant,” and vehicles are able to park where they want.

3.3 The Duration of a Parking Area Stay

A view of parking area circumstances, from “vacant” to “full” levels, was discussed, and vehicles were assumed to spend time parking, searching for a parking spot, and waiting to enter the parking area. In addition, drivers also spend time walking from their vehicles to the parking area facilities, in addition to whatever time they spend using those facilities. Thus, a drivers’ total expended duration in a parking area (T) is the sum of those times.

However, the total expended duration (T) can be divided into two groups. The first is the time normally required, such as the time to drive (\( T_d \)) to the parking spot, the time to walk from the vehicle to the rest stop facilities (\( T_w \)) and the time spent on activities, such as using the restrooms, restaurants and so on (\( T_s \)). The other group includes flexible times based on parking area congestion levels, such as the extra time required to search for an available parking spot (\( T_e \)) and the waiting time in a queue if a queue exists (\( T_w \)). \( T_d, T_f \) and \( T_s \) are enclosed in parentheses because they are independent of parking area congestion levels, and are affected by the parking area location and layout. \( T_e \) and \( T_w \) change depending on how congested the parking area is. Therefore, T can be described using the following formula.

\[
T = (T_d + T_f + T_s) + T_e + T_w
\]  

(2)
3.4 Data Collection and Set

The ETC time-stamp data was provided especially for the purpose of this research by NEXCO-Central, with four major service areas (SA) in both directions (east bound and west bound) used for the analysis. These SAs are frequently busy during the day because they are on the Tomei Expressway and the Shin Tomei Expressway, both of which are major routes in Japan, connecting the Tokyo metropolis and the Nagoya region, so NEXCO-Central conducted field surveys in order to understand conditions in these areas, specifically after the Shin Tomei Expressway opened, and ETC probe data collection systems were installed in those SAs to collect the ETC probe time-stamp data.

The field surveys were conducted at the eight parking lots for 24 hours on both a weekday and a holiday, and ETC probe time-stamp data was collected during the same period. The date and hours surveyed were:

- 28 November 2012, Wednesday, 7:00a.m. to 7:00a.m. the next day
- 02 December 2012, Sunday, 12:00a.m. to 12:00a.m.

The field survey included surveyors counting the number of vehicles parked in the parking lots on the hour every hour, and a count of continuous traffic for 24 hours on both the main line and the entrance ramp to the SAs, except for at the Ebina SA. Traffic counts on both the main line and the entrance ramp of the Ebina SA were calculated using the ETC probe time-stamp data.

Either of the entrance or the exit ETC probe antennas was located on the ramp and the other one was on the main line before the entrance ramp appeared or after merging the exit ramp, as shown in Figure 5. This means that the duration between the time a vehicle passed the ingress antenna and the egress antenna was a little longer than the exact vehicle stay. Also, the ETC probe time-stamp data did not record 100% of drop-by vehicles, since the rate of ETC utilization was about 90% (Oct. 2012, within the jurisdiction of NEXCO-Central). However, this extra duration between the antennas is quite short, and the 90% ETC utilization is quite high, so these differences are not considered to affect the results of this study.

This study focuses on the congregative parking area situation and applicability of the queuing theory with FIFO assumption. Also, this paper specifically focused on the daytime performance of a parking area in Japan, because there are a lot of passenger vehicles dropping by a parking area in the daytime, and parking areas are so congested. Thus, ETC probe timestamps for passenger cars, trucks,
tractors and busses were extracted and those of motorcycles were omitted. Also, the vehicles that entered after the start time of the survey and exited before the end of the survey were omitted from the extracted ETC probe timestamps as a data set for this study. Finally, the FO assumed departure time was extracted, sorted and attached to the data set.

4 Applicability of Observed Data and Discussion

The focus of this study is the applicability of FIFO conditions to drop-by vehicles entering and exiting parking areas. The observed values provided by the ETC probe time-stamp data and FIFO assumed time lags are described first. Second, the applicability of the observed ETC time-stamp data to representing the exact conditions was determined by comparing the number of vehicles parked on the hour every hour and those counted by the observed ETC probe time-stamp data. Finally, the applicability of the FIFO assumption was discussed using the correlation between the observed ETC probe time-stamp data and the FIFO assumed time lags calculated by the ETC probe time-stamp data.

4.1 Drop-by Vehicle Characteristics and FIFO Assumed Time Lags

The duration of drop-by vehicles staying in the Ebina SA on the holiday during the selected hours of 7 a.m. and after and until 8 p.m. was accumulated using the time stamped at the ingress antenna from the observed ETC probe time-stamp data. The Ebina SA is one of the busiest rest stops in the country, and the first major rest stop before entering Tokyo, so it contains 481 parking spots in total, and more than 13,000 vehicles stopped on the day of the study. The cumulative drop-by vehicle stays were developed using 11,218 of the timestamps taken at the entrance and exit, and the calculated FO assumed departure time, and the analysis. The selected hours in this study were extracted based on relatively busy hours, including mealtimes, because the parking area situation at night is generally vacant and drivers can choose wherever they want to park, and the number of vehicles observed by ETC probe timestamps was 8,426.

The accumulated drop-by vehicle stays are shown by the gray lines on the left in Figure 6. The clock hour is on the x-axis and the cumulative number of drop-by vehicles is shown on the y-axis. The left side edge of the gray lines, which is the accumulated drop-by vehicle timestamps at the ingress antenna, is called the cumulative vehicle arrival curve. The FIFO assumed departure time that was developed by sorting the observed ETC timestamps at the egress antenna by time is shown as a bold black line, and this line is called the cumulative FO assumed departure curve.

The cumulative FO assumed departure curve is smooth and rather parallel to the cumulative vehicle arrival curve, while the durations of individual drop-by vehicle stays fluctuate greatly. It is assumed that many vehicles stop only briefly, because the total duration of the FIFO assumed vehicle stays is equal to the total duration of the exact duration of vehicle stays. The gap between the cumulative vehicle arrival curve and the cumulative FO assumed departure curve looks wider around lunchtime and dinnertime, and this can be assumed to mean that the purpose for stopping at these times is to eat. This does not hold for breakfast, presumably because drivers want to reach their destinations earlier.

The right chart in Figure 6 shows a boxplot chart developed using the same data in the left chart. This boxplot is based on hourly Turkey boxplots, and the FIFO assumed time lags drawn with gray lines, the hourly means shown by a black x, and the daily average duration of stay calculated by the observed ETC probe time-stamp data with chain lines overlap. The range for duration of stay, shown in the y-axis, is from 0 to 120, but the 54 vehicles that stayed more than 120 minutes, which comprised approximately 1% of the total samples, are not shown in the figure.

The figure shows gaps between the daily mean and the hourly mean, which fluctuate, and this seems to show that the daily mean does not represent the nature of duration of stay. There are many
outliers above the whiskers, and those outliers affect the daily mean increase, so it might difficult to say that the daily mean describes the congregative characteristics of vehicle stay. On the other hand, the hourly mean and FIFO assuming time lags during mealtimes (specifically morning on holidays, and noon and early evening) surpass the daily mean, which could mean that vehicles parked around mealtime spend more time in the SA, and the main purpose of the vehicle drop-by would be to have a meal. Moreover, the fluctuations of FIFO assuming time lags are similar to those of the hourly median, and they almost overlap the hourly mean. This shows that the FIFO assuming time lag could describe the transition of comprehensive circumstances of natural vehicle stays.

![Figure 6: Cumulative curves with FIFO assumed time lag (left), boxplot with means and FIFO assumed time lag (right), (Ebina SA East bound on the holiday)](image)

### 4.2 Applicability of ETC Time-stamp Data and FIFO Assumption

The focus of this study is the applicability of FIFO conditions in understanding the congregative situation in a parking area in an expressway rest stop, with the observed time-stamp data collected at the ingress and the egress of the area, and to show how ETC probe time-stamp data can represent exact parking area conditions. Thus, the correlation was analyzed between the number of vehicles parked in a parking area counted by surveyors and those counted by the observed ETC probe time-stamp data.

The correlation of the number of vehicles staying on the hour every hour from 7 a.m. to 7 p.m. on both a holiday and a weekday (26 plots in total) is shown on the left in Figure 7. The number of vehicles counted during the field survey is on the x-axis and the number of vehicles counted by the observed ETC time-stamp data is shown on the y-axis. The numbers of vehicles on the holiday are plotted by circles, these on the weekday are plotted by triangles, and the regression lines through the origin by a chain line. The regression line crosses the origin because none of the vehicles were counted by the ETC probe if there were no vehicles in an SA.

The inclination of the regression line was 0.921, which was extremely high even if surveyors might have miscounted the number of vehicles staying or the ETC utilization rate of 90% influenced the inclination. The adjusted coefficient of determination was 0.997, which means that the correlation can be strongly assumed and the observed ETC probe time-stamp data can demonstrate the parking area circumstances as an excellent substitute of the measurements by surveyors.

The next focus point of this study was on the applicability of a FIFO assumption, which means how accurately the FIFO assuming time lag calculated by the sorted ETC egress timestamps and the ETC ingress observed timestamps represent actual conditions, so the correlation of the number of vehicles on the hour every hour between the observed ETC timestamps and the FIFO assuming time
lags with plotting for the same time range of the left chart, is shown on the right in Figure 7. The result of the total 26 plots was completely overlapped. This result clearly describes the FIFO assumption discussed in 3.1. This chart obviously show that the analytical results of the observed duration of stay recorded on ETC timestamps are completely equal to these of the FIFO assuming time lags calculated by the ETC timestamps, which means that the FIFO assumption could alternate the observed ETC probe time-stamp data while discussing the number of vehicles in a parking area at a certain time.

The FIFO assuming time lags can be an alternative to discuss the number of vehicles staying in SA, and it was available to analyze the FIFO assuming time lags when discussing the comprehensive circumstances of vehicles in the expressway rest stops. The results shown on both charts indicate that a FIFO assumption can alternate the observed ETC probe time-stamp data with an exact field survey when the number of vehicles in a parking area is discussed.

![Figure 7: Correlations of the number of vehicles on the hour every hour, between field survey and observed ETC time-stamp data (left), and observed ETC time-stamp data and FIFO assumed ETC time lags (right), (Ebina SA East bound on the holiday)](image)

5 Conclusion

This research focused on the applicability of the FIFO assumption to describe congregative vehicle drop-by behavior from a macroscopic point of view, and the authors used both the results of a field survey and the data of vehicles entering and exiting an SA collected by ETC probe timestamps. The results of this study indicate that a FIFO assumption could alternate the observed the matched time-stamp data collected at both the ingress and egress of a parking area, when focusing on the number of vehicles staying in a parking area in the daytime. This is because FIFO assuming time lags can overlap the transitions of an hourly mean of duration of stay, and in addition can be followed by the transition of hourly characteristics of an SA parking area. Furthermore, the number of vehicles staying on the hour every hour can be represented by the calculation results from FIFO assuming time lags. These findings show that it could be possible to determine the congregative circumstances of an expressway rest stop analyzed by the ingress and egress time-stamp data collected by vehicle detectors, which could also contribute to reducing the workload of conducting field surveys in order to assess the objective circumstances of an expressway parking area.

This result assumes any contribution to assessing the functional performance by measuring only the number of vehicles entering and exiting a parking area. Thus, these results might be a clue to
parking area performance. However, the duration of stay did not match in this study, so further study regarding the applicability of the FIFO assumption with focusing on the duration of stay will be conducted.

References

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