Transportation Demand Management (TDM) of Large Vehicle parking spaces in expressway rest areas: Evidence from Japan

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1. Introduction

The purpose of this study is to summarize the current shortage in parking spaces for large vehicles in expressway rest areas, to analyze the factors influencing this shortage, and to evaluate the transportation demand management (TDM) measures required in the future.

In recent years, Japan has been facing a truck driver shortage. According to the Rail Freight Association (2019), which analyzed the supply and demand of truck drivers, there is a shortage of about 144,000 truck drivers in FY2020, and the shortage is expected to worsen to about 278,000 by FY2028. The long working hours and low wage levels of truck drivers have been pointed out as the cause for this truck driver shortage.

The Japanese government has been taking various measures to address this shortage of truck drivers. One of the representative measures is to reduce working hours for non-driving operations. A survey conducted by the Ministry of Land, Infrastructure, Transport and Tourism and the Ministry of Health, Labour and Welfare pointed out that the long working hours of truck drivers are caused by the long hours spent working and waiting for loading and unloading of cargo. It is hoped that shippers and logistics companies will work together to improve business practices. The other measure is the strict enforcement of labour standards. The labour standards stipulate working hours, break periods, and rest periods for truck drivers in their driving operations. However, in the past, they were not sufficiently thorough and as a result, the working environment for truck drivers has worsened. Therefore, logistics companies are required to ensure that truck drivers can take breaks and rest during their

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driving operations as stipulated by labour standards. Also, labour standards tend to become stricter in recent years. For example, according to the 2019 revision of the Labour Standards Law, overtime hours for truck drivers will be capped at 960 hours per year from fiscal 2024.

However, in recent years, it has been pointed out that there is a shortage in parking spaces for large vehicles, such as heavy-duty trucks and large buses, in some expressway rest areas including those around major cities. Since the shortage in parking spaces makes it difficult to take a break and rest as required by the standards described above, a quick solution is needed. But the land for expressway rest areas is limited, and it is difficult to solve the shortage of parking spaces only by adding a new parking spaces. Therefore, consideration of TDM for parking spaces for large vehicles is required.

To address the challenges, this study summarizes the current state of shortage in parking spaces for large vehicles in expressway rest areas, analyzes the factors influencing this shortage, and derives suggestions for TDM measures that will be needed in the future.

2. An Overview of Japan's National Expressway and Rest Areas

In Japan, the road categories are divided into four. The most high-standard road category is the national expressway (the maximum speed is 100 km/h and more than 90% of all sections are toll roads). The actual length of the national expressway is 8,922 km, which accounts for 0.7% of the total road length, but 15.7% of the traffic volume in Japan (Figure 1, Table 1).

The national expressway was previously operated by the Japan Highway Public Corporation but was privatized in 2005. At present, three Nippon Expressway Companies, NEXCO East, NEXCO Central Japan, and NEXCO West, are responsible for the construction, renewal, management, and tolling of expressways, while the Japan Expressway Holding and Debt Repayment Agency owns and repays expressway debt.

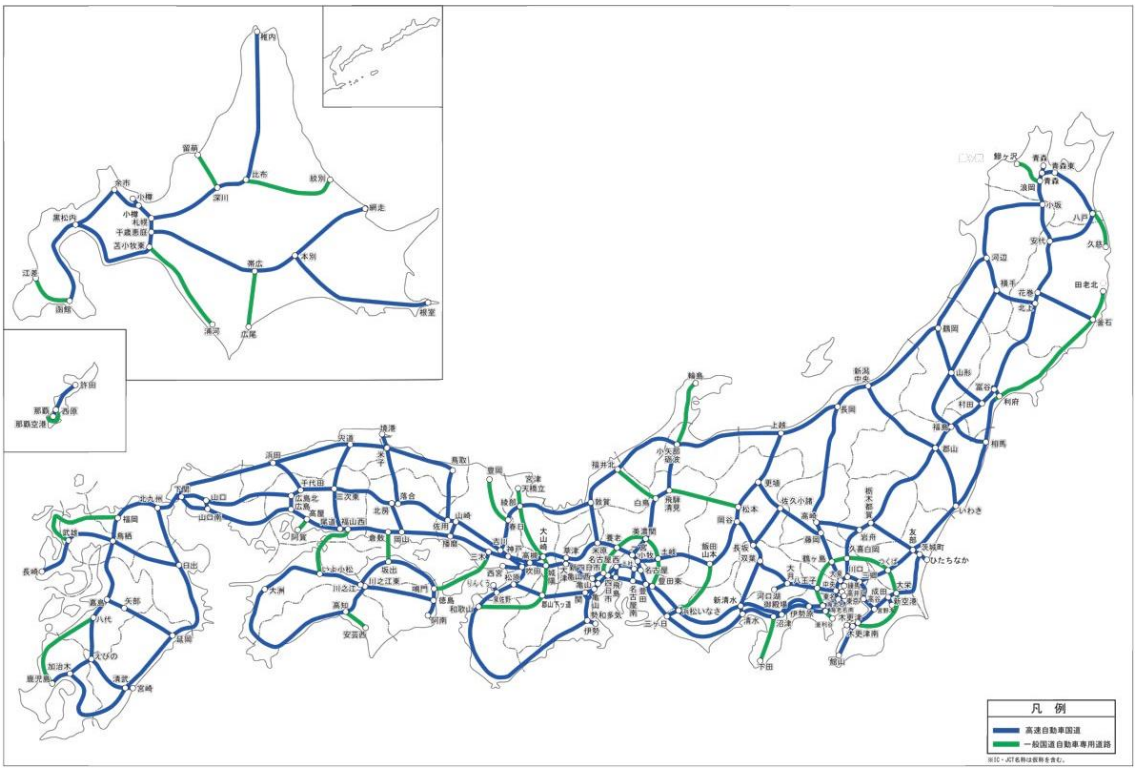

Figure 1: National expressway (blue line)

Source: Ministry of Land, Infrastructure, Transport and Tourism

Table 1: Road category by actual length and traffic volume

Road category	Actual Length (km)	Traffic Volume (1,000s of vehicle kilometre)
National Expressway	8,922 (0.7%)	230,694 (15.7%)
General National Roads	55,697 (4.5%)	622,995 (42.5%)
Prefectural Roads	129,720 (10.6%)	612,565 (41.8%)
Municipal Roads	1,030,423 (84.1%)	n/a
Total	1,224,765 (100.0%)	1,466,254 (100.0%)

Note: Actual length is from the "Annual Road Statistics Report 2019"; traffic volume is from the "Traffic Census 2015"

The national expressway has rest areas of two types: one is the “Service Area: SA” and the other is the “Parking Area: PA”. The SA is a relatively large rest area; it is located about 50 km apart and has parking spaces, rest facilities, toilets, stores, cafeterias, fuel stations, etc. The PA is a relatively small rest area; it is located about 15 km apart and has parking spaces, toilets, and a small store. There are 818 rest areas in total, operated by the NEXCO East, Central, and West (as of April 2020).

3. The Problem of Parking Space Shortage at National Expressway Rest Areas

3.1 Parking Demand for National Expressway Rest Areas

The parking demand by heavy-duty trucks for expressway rest areas can be divided into two types. The first is the parking demand for time adjustment. The unloading time is generally strictly regulated and delays due to traffic congestion are not allowed. For this reason, truck drivers tend to adjust their times in expressway rest areas close to their destinations. The second is the parking demand for break and rest periods during trunk line transportation. In Japan, labour standards have been established for each type of work to prevent work-related accidents. The labour standards for truck drivers include maximum working hours, rest period, driving time, continuous driving time, and break period, etc (Table 2).

In addition, there are two types of trunk line transportation. The first type is the consolidation of multiple shippers' cargo, "special loading motor truck transportation." The second type is the chartered transportation for a specific shipper's cargo. The former is a form of transport that operates late at night between locations hundreds of kilometres apart and requires a short break in expressway rest areas. The latter type includes transportation of more than 1,000 km, and in such cases, involves not only taking rest in expressway rest areas but also taking a break.

Table 2: The Labour standards for truck driver

Maximum working hours	293 hours per month, 13 hours per day in principle, 16 hours maximum
Rest period	at least 8 hours in duration
Driving time	within 9 hours per day for an average of 2 days less than 44 hours per week for an average of 2 weeks
Continuous driving time / Break period	up to 4 hours (with a minimum 30-minute break period before driving again)

Source: Ministry of Health, Labour and Welfare

3.2 Current Shortage of Parking Spaces: Examples of the Tomei and Shin-Tomei Expressways

In recent years, the shortage of parking spaces has become a problem in expressway rest areas.

We interviewed the Tokyo branch of NEXCO Central to find out more about this problem. The office manages most of the Tomei and Shin-Tomei expressways, which are the largest network of arterial roads in Japan (Table 3).

Table 3: Overview of Tomei Expressway and Shin-Tomei Expressway

	Tomei Expressway	Shin-Tomei Expressway
Opened	1968	2012
Section	Tokyo IC (Tokyo) - Komaki IC (Aichi Prefecture)	Ebina Minami JCT (Kanagawa Prefecture) – Toyota-higashi JCT (Aichi Prefecture)
The section managed by the NEXCO Central Tokyo Branch	Tokyo IC - Toyokawa IC	Gotemba JCT - Shinshiro IC
Route length	346.8 km	253.2 km
Traffic volume	about 44,000 vehicles per day	about 40,000 vehicles per day

There are 35 rest areas managed by the Tokyo branch of NEXCO Central on the Tomei Expressway and 14 on the Shin-Tomei Expressway. Table 4 shows the rest areas of Tokyo-bound on the Tomei and Shin-Tomei Expressways.

Table 4: The rest areas on the Tomei and Shin-Tomei Expressways, Tokyo-bound
(4a: Tomei Expressway)

	The Number of Parking Spaces			
	Small vehicle	Large vehicle	Dual-use	Total
Kohoku PA	58	19	4	81
Ebina SA	337	90	58	485
Nakai PA	96	69	0	165
Ayuzawa PA	71	145	26	242
Ashigara SA	231	168	104	503
Komakado PA	4	8	15	27
Ashitaka PA	27	37	15	79
Fujikawa SA	87	40	68	195
Yui PA	35	10	0	45
Nihondaira PA	75	40	15	130
Nihonzaka PA	30	36	33	99

Makinohara SA	195	183	35	413
Ogasa PA	30	6	62	98
Enshu-toyoda PA	77	67	34	178
Mikatahara PA	25	24	1	50
Hamanako SA	127	33	44	204
Shinshiro PA	14	27	0	41

(4b: Shin-Tomei Expressway)

	The Number of Parking Spaces			
	Small vehicle	Large vehicle	Dual-use	Total
Surugawan-Numazu SA	99	79	0	178
Shimizu PA	34	41	42	117
Shizuoka SA	105	85	0	190
Fujieda PA	40	81	0	121
Kakegawa PA	40	86	0	126
Enshu-Morimachi PA	37	81	0	118
Hamamatsu SA	93	95	0	188

In addition, according to the interview with the Tokyo branch of NEXCO Central, the problem of packing space shortage is characterized by the following three points. The first is the time of day, and congestion is particularly severe, late at night. The second is location, especially in the rest areas close to major cities and midway between major cities, since they are severely congested. The third is the inappropriate use of parking spaces.

3.3 Factors and Existing Measures of the Problem of Parking Space Shortage: Factor 1 Increase in demand

There are two possible factors influencing the problem of parking space shortage.

The first factor is the increase in parking demand. As shown in 3.1, the parking provided for heavy-duty trucks is based on the regulation of the Labour Standards Act for truck drivers. The enforcement of the Labour Standards Act have become stricter in recent years. As a result, the parking demand in rest areas is likely to increase.

The design guidelines of NEXCO Central provides the following formula for the number of parking spaces in rest areas[6].

[6] The parameters used are specified in the design guidelines, but in recent years, they are

The number of parking spaces
= Traffic volume of the expressway x Stopover Rate x Rush Rate / Turnover rate

Each variable is as follows; traffic volume of the expressway is the design traffic volume per day. The top 10% of traffic volume for 365 days per year after 10 years of operation (average design traffic per day x 1.15-1.40) is used. The stopover rate is the number of stopovers (vehicles/day) / traffic volume of the expressway (vehicles/day). An empirical value of 0.125 is used. The rush rate is the number of vehicles per hour during rush hour / the number of stopovers (vehicles/day). An empirical value of 0.075 is used. The turnover rate is the inverse of the average parking time (hours). For heavy-duty trucks, 2.0 is used. This assumes an average parking time of 30 minutes.

The number of parking spaces is basically calculated for each type of vehicle.

We assume that the stricter Labour Standards Act in recent years has increased the stopover and night-time rush rates, and decreased the turnover rate.

In response to this, NEXCO has increased its parking spaces in recent years (Table 5).

Table 5: Increase in Parking Spaces by NEXCO East, Central, and West

2018 FY	2019 FY	2020 FY (planned)
about 500 vehicles	about 1,350 vehicles	about 810 vehicles

Source: NEXCO Central Tokyo Branch

In addition, the Tokyo branch of NEXCO Central plans to increase parking spaces for small vehicles and large vehicles by 9% and 16%, respectively, between fiscal year 2017 and 2021 on the Tomei and Shin-Tomei Expressways.

3.4 Factors and Existing Measures of the Problem of Parking Space Shortage: Factor 2 Unevenly Distributed Parking Demand

The second factor is the uneven distribution of parking demand in terms of time and space.

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sometimes calculated based on actual parking conditions, through surveys of neighbourhood usage, for instance.

Figure 2 shows the total parking demand and total parking capacity for all the rest areas on the Tomei and Shin-Tomei Expressways, based on the survey data for 2016 provided by the Tokyo branch. Figure 2 shows that the total parking demand is lower than the total parking capacity, both on weekdays and weekends.

Figure 3 also shows the average utilization ratio for each rest area. From Figure 3, it can be seen that only a small percentage of rest areas have average utilization ratio above 100%; most rest areas have ratios below 100%[7].

In addition, Figure 4 shows the average utilization by the time of day, based on the survey data for 2016 provided by the Tokyo branch. From Figure 4, we can see that the utilization ratio that exceeds 100% is only between 20:00 and 4:00 on weekdays for large vehicles on the Tomei Expressway, and between 20:00 and 3:00 on weekdays for large vehicles on the Shin-Tomei Expressway.

From the above, we can see that the cause of the parking space shortage is the uneven distribution of demand for parking spaces, in terms of time and space.

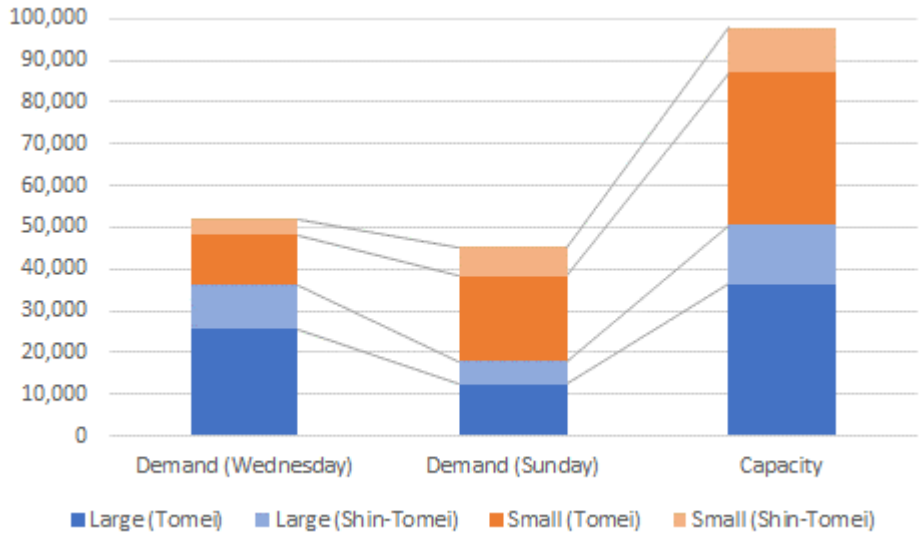


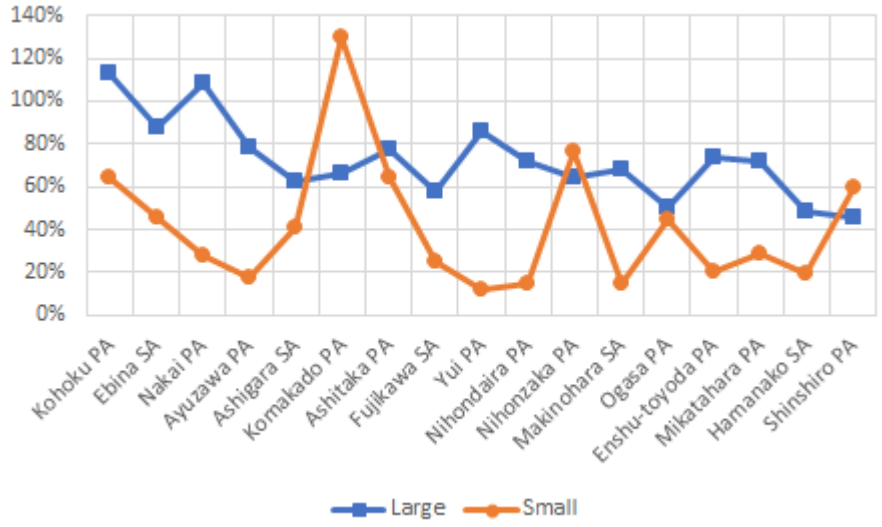
Figure 2: Total Parking Demand and Total Parking Capacity on the Tomei Expressway and

[7] NEXCO Central shows the utilization ratio of parking spaces by dividing the number of parking vehicles by the number of parking spaces. For NEXCO Central, a utilization ratio of 95% or more is indicated as full, while a utilization rate of 85% or more but less than 95% is indicated as congested.

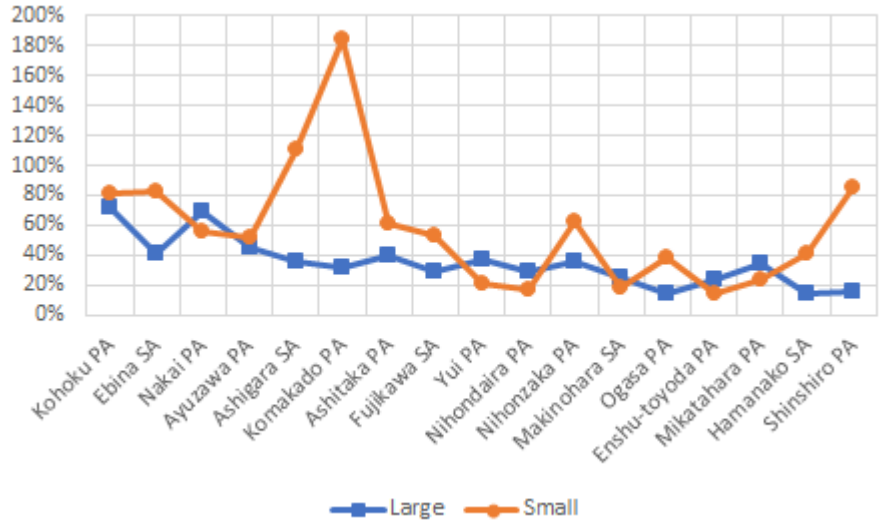
Shin-Tomei Expressway

Unit: Vehicle-hours

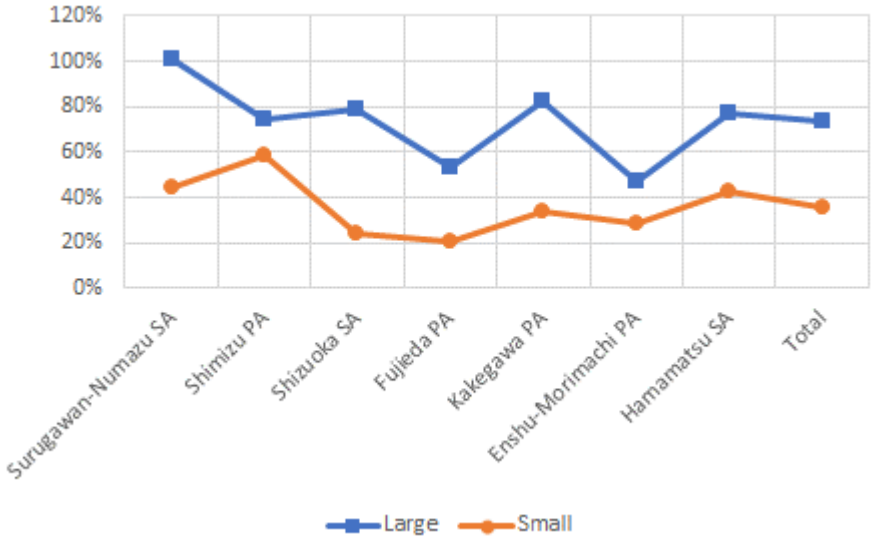
Note: The large vehicle parking space includes the dual-use parking space; two small vehicles can be parked in the large vehicle parking space.



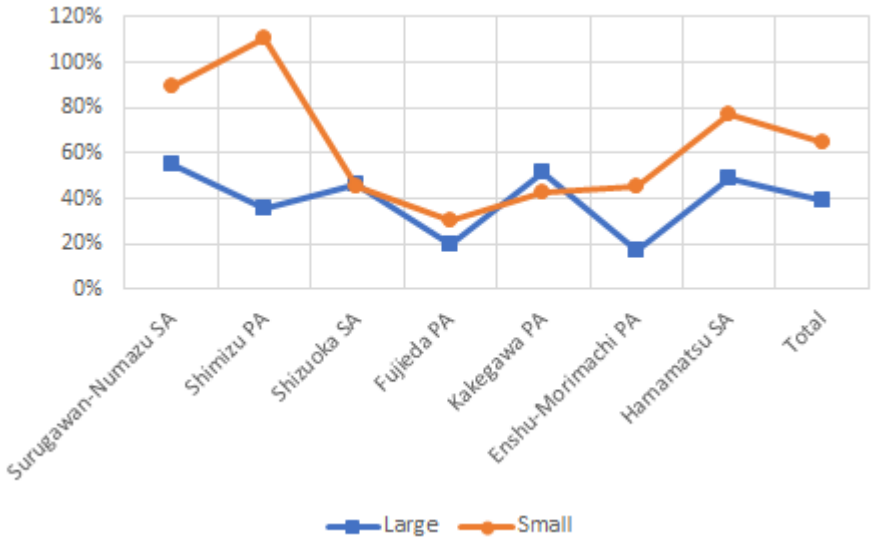
(3a: Tomei Expressway, Wednesday)



(3b: Tomei Expressway, Sunday)

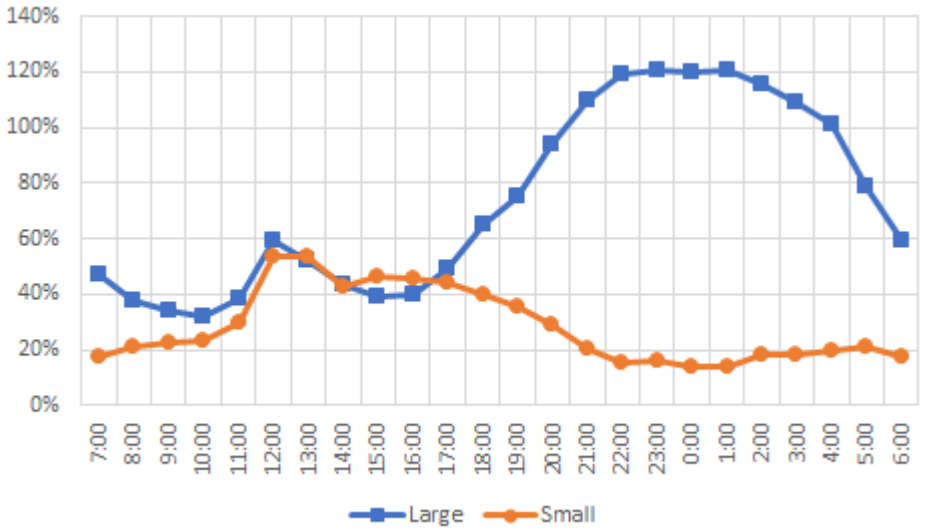


(3c: Shin-Tomei Expressway, Wednesday)

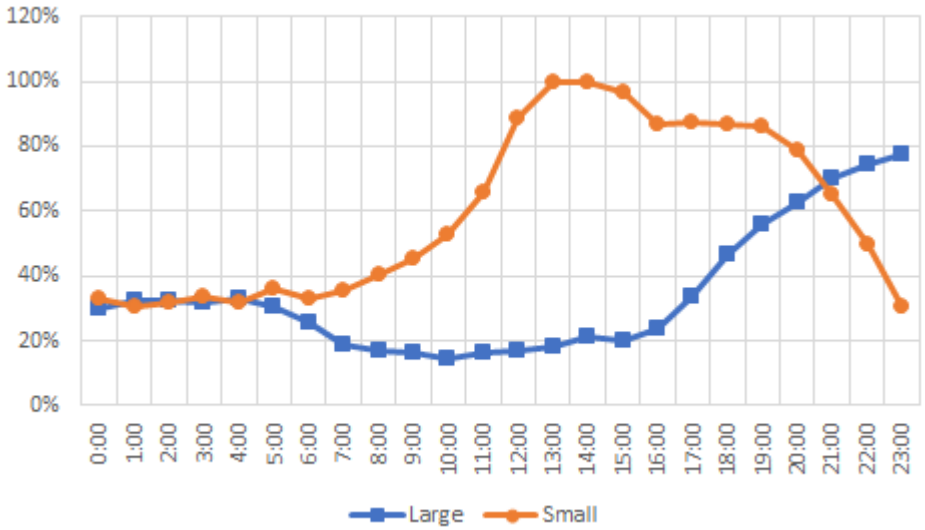


(3d: Shin-Tomei Expressway, Sunday)

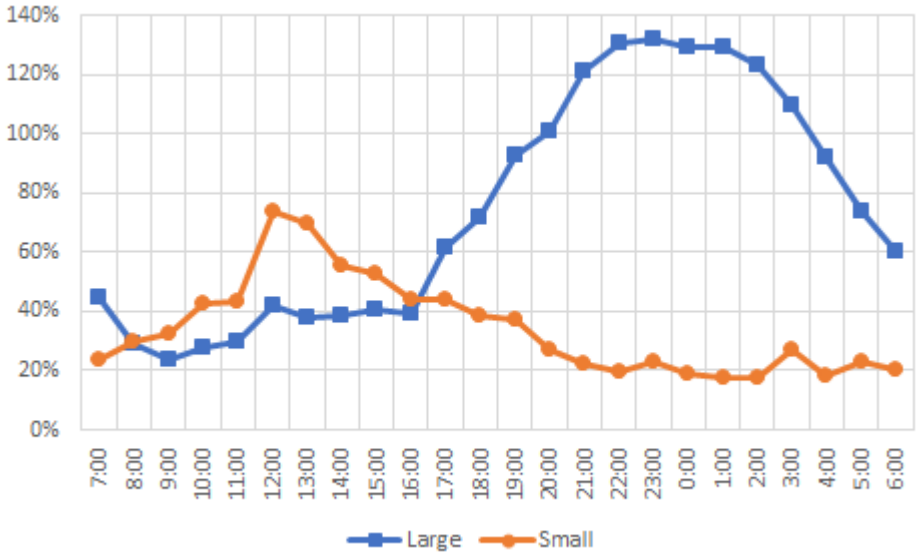
Figure 3: The Average Utilization Ratio of Parking Space by Rest Area



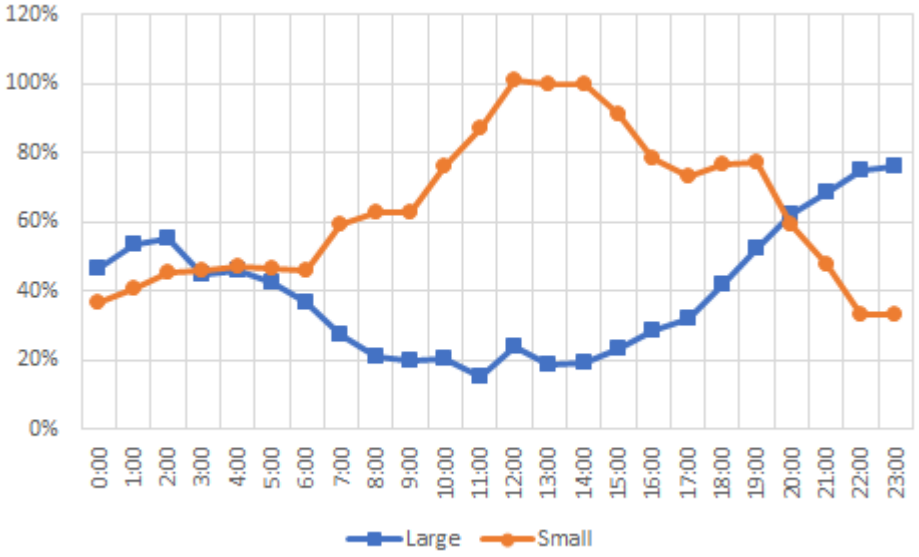
(4a: Tomei Expressway, Wednesday)



(4b: Tomei Expressway, Sunday)



(4c: Shin-Tomei Expressway, Wednesday)



(4d: Shin-Tomei Expressway, Sunday)

Figure 4: The Average Utilization Ratio of Parking Space by the time of day

To address this factor of unevenly distributed parking demand, NEXCO has taken several measures. The first measure is to introduce a dual-use parking space (Figure 5). The dual-use parking space is available for both regular and large vehicles; this is expected to be an efficient use of the parking capacity.

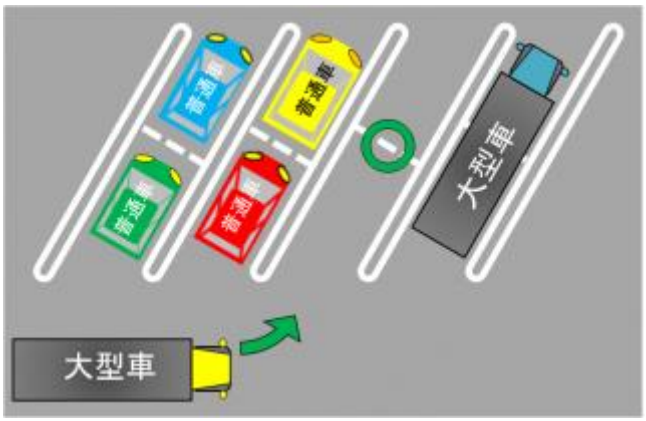


Figure 5: Image of a Dual-use Parking Space for Small and Large Vehicles
Source: NEXCO Central Tokyo Branch

The second measure is to provide more information. Specifically, congestion information on parking spaces by type of vehicle is displayed on display boards on the expressway (Photo 1). The purpose is to direct vehicles to vacant rest areas.

経路分岐部の車種別満空表示板　広域満空情報（ディスプレイ型）

エリア案内型
（これまで全車の表示であったところを車種別表示）

Photo 1: Displaying Information on Parking Spaces: Full, Congested, or Vacant
Source: NEXCO Central Tokyo branch

The third measure is a toll adjustment for a temporary breakaway from the expressway. The expressway toll consists of terminal (per use) and distance-based tolls. In addition, long-distance discounts (25% discount for over 100 km and up to 200 km, 30% discount for over 200 km) are applied to the distance-based toll, making it disadvantageous to exit the expressway in the middle of a journey. However, in some sections of the expressway, the intervals between rest stops are more than 25 km apart, making it impossible for drivers to take a break. To address this problem, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is conducting a social experiment in which terminal charges are not

recharged and long-distance discounts are applied to drivers who leave the expressway temporarily in order to ensure that they take a rest or a break[8][9]. On the Shin-Tomei Expressway, temporary exits from the Shinshiro Interchange to the roadside station Mokkulu Shinshiro have been allowed since June 2017.

However, the problem of parking space shortage has not yet been resolved. This situation means that the existing measures mentioned above are insufficient to solve the shortage in parking spaces. In chapter 4, we will systematically examine TDM measures for parking spaces.

4. Evaluation of TDM Measures to Address the Problem of Parking Space Shortage

4.1 Capacity Increase and TDM

In general, there are two measures to deal with the road congestion problem. The first measure is to increase capacity. NEXCO Central's measure, shown in section 3.3, is one of the ways to increase capacity. The second measure is Transportation Demand Management (TDM). NEXCO Central measure, shown in section 3.4, is one of the TDM measures. In this chapter, the TDM measure of the parking space is examined.

4.2 Existing Studies

No existing studies have analysed the TDM for expressway parking spaces. However, there are several relevant existing studies. First, there are studies on providing information on congestion in parking spaces. Fujii et al. (2015) focus on the discrepancy between the congestion information on the expressway information boards and the actual congestion when vehicles arrive in the rest area. And they build a model to predict the congestion situation in expressway rest areas using the parking status data of multiple rest areas and traffic volume data on the expressway. It is stated that the model can improve the discrepancy in the information about congestion by predicting the parking ratio of expressway rest areas.

Secondly, there are studies on the efficiency of parking space utilization. Iwasawa (2019) and Akagawa et al. (2017) examined the impact of providing information about available parking spaces on vehicle behaviour. Of these, Iwasawa (2019) found that, in addition to variable display boards, an inviting light guidance system, installed along the parking spaces to indicate the fullness of the parking spaces with red (present) and blue (empty) lights, was

[8] https://www.c-nexco.co.jp/corporate/pressroom/news_release/4052.html

[9] https://www.mlit.go.jp/report/press/road01_hh_001296.html

effective.

Third, there are studies on the time spent in parking spaces. Wu et al. (2018) found that stopovers and stays at rest areas are different between small and large vehicles, and varied by season and time of day.

4.3 Categorization and Evaluation of TDM Measures for addressing the Problem of Parking Space Shortage

The total demand for parking on the Tomei and Shin-Tomei Expressways as a whole, as shown in Figure 2, is less than the total parking capacity. Nevertheless, the reason for the shortage problem in parking spaces is the uneven distribution of parking demand in time and space. Therefore, TDM measures could be temporal equalization, spatial equalization, or a combination of both. In addition, spatial equalization could include equalization within the same rest area, equalization between nearby rest areas, and equalization between the rest area of the expressway and the off-expressway rest facilities.

Table 6 summarizes the TDM measures, as well as the burden on users and NEXCO for these TDM measures.

Table 6: Categorization of TDM measures to address the problem of parking space shortage

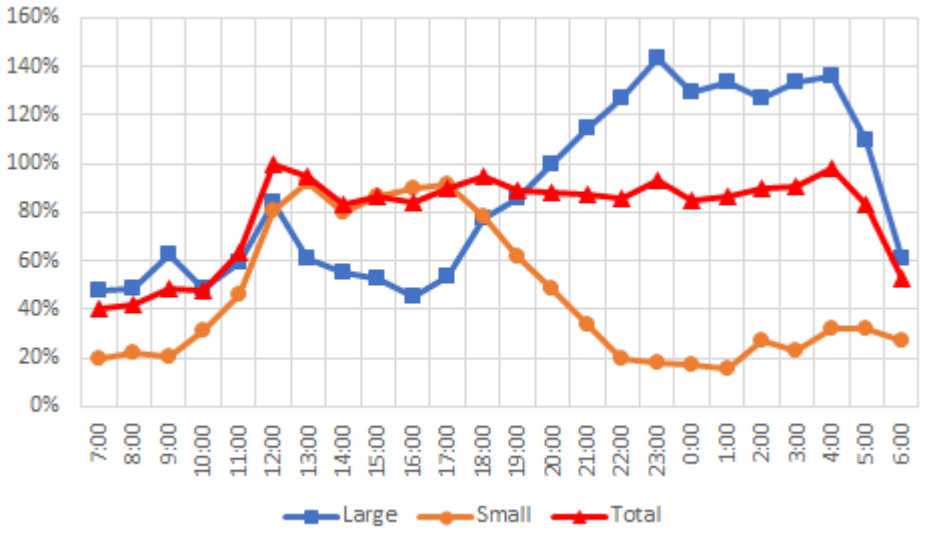
Category		TDM measures	Parking users		NEXCO
			Short-time users	Long-time users	
Temporal equalization		Advance information on parking spaces	Difficult	Difficult	Possible
		Charging	Increased burden	Increased burden	Need to consider
Spatial equalization	within the same rest area	Dual-use parking spaces	No burden	No burden	Easy
	between nearby rest areas	Realtime information on parking spaces	No burden	No burden	Small burden
		Charging	Increased burden	Increased burden	Need to consider

	between the rest area of an expressway and the off-expressway rest facilities	Toll adjustment for a temporary breakaway from the expressway	Difficult	Small burden	Small burden

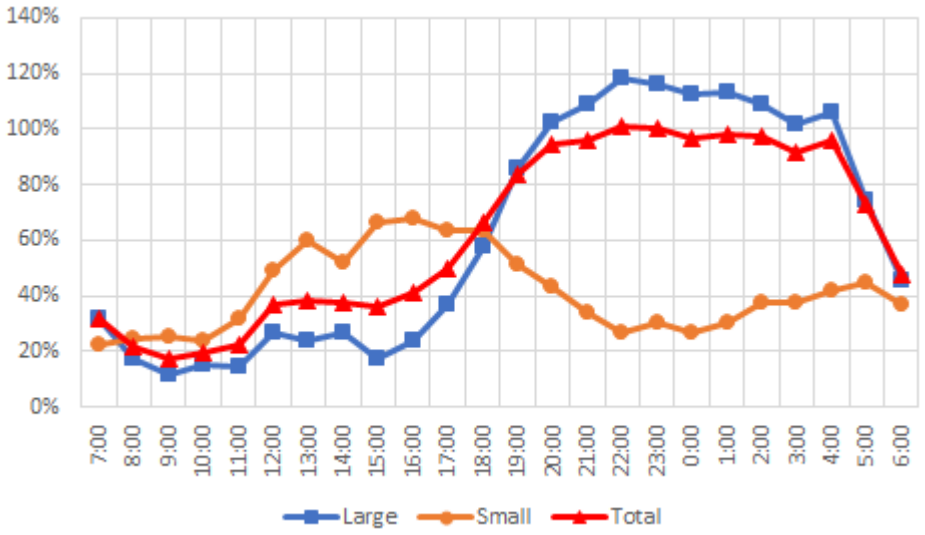
TDM measures of temporal equalization include the provision of advance information on parking spaces and charging. Although the burden on users and NEXCO is small, it is not easy to achieve, since logistics is a derived demand and transport times are specified by shippers. Although there have been no examples of charging for parking spaces at rest areas, it may be possible to charge for parking spaces over a certain period (e.g., more than two hours) in combination with the measures to induce users to visit nearby expressway rest areas and off-expressway rest facilities, which will be discussed later. In interviews with some logistics companies for "special loading motor truck transportation," who do not take a rest at rest areas, many of them were in favour of charging for parking spaces.

A TDM measure of spatial equalization within the same rest area is to introduce a dual-use parking space. Due to physical limitations and the safety of the rest areas, it is difficult to introduce dual-use spaces for all parking spaces, but it is relatively easy to implement.

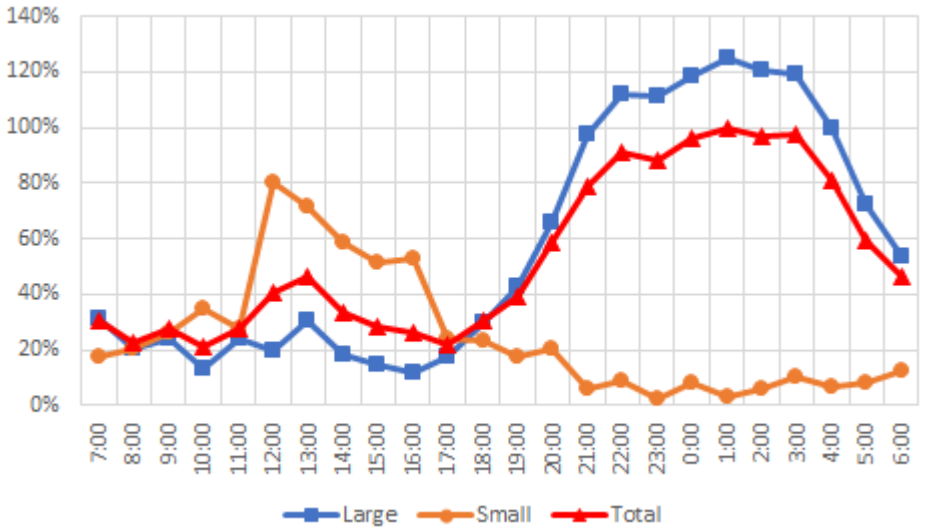
Figure 6 shows the overall utilization ratio of the parking spaces by the time of day for each "SA" of the Tomei and Shin-Tomei Expressways, when it is assumed that the parking space for small vehicles is converted to dual-use parking space (three parking spaces for small vehicles equal one dual-use parking space). Figure 6 shows that it is generally possible to keep the utilization ratio for each "SA" of the Tomei Expressway below 100% by introducing dual-use parking spaces. On the contrary, it is difficult to keep the utilization ratio for each "SA" on the Shin-Tomei Expressway below 100% by introducing dual-use parking spaces alone.



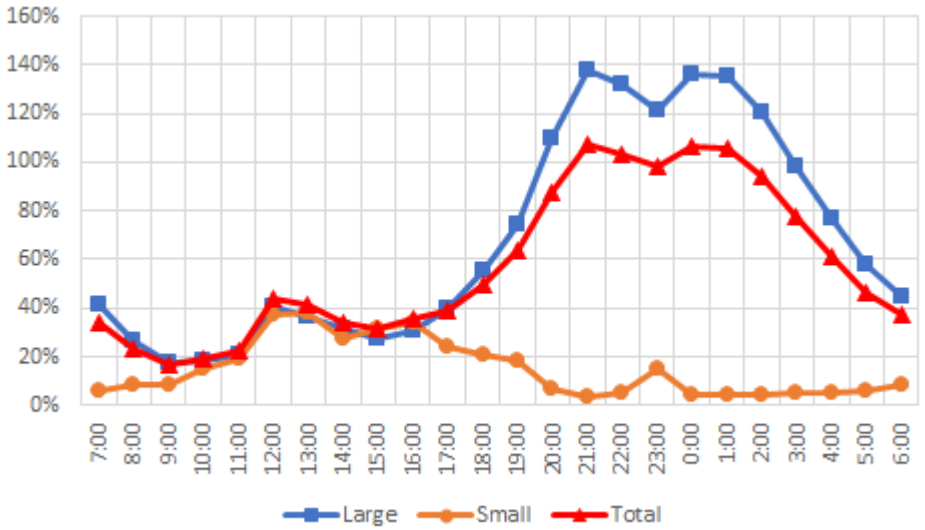
(6a: Ebina SA, Tomei Expressway)



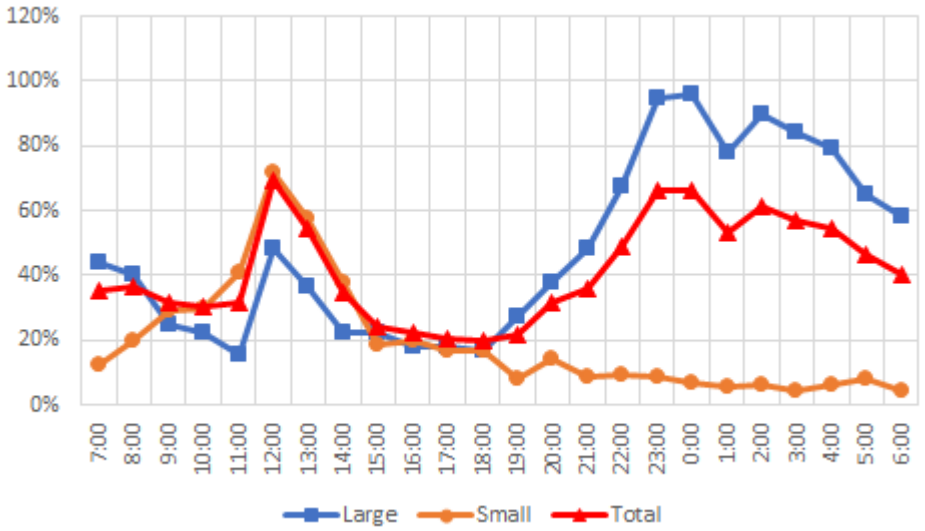
(6b: Ashigara SA, Tomei Expressway)



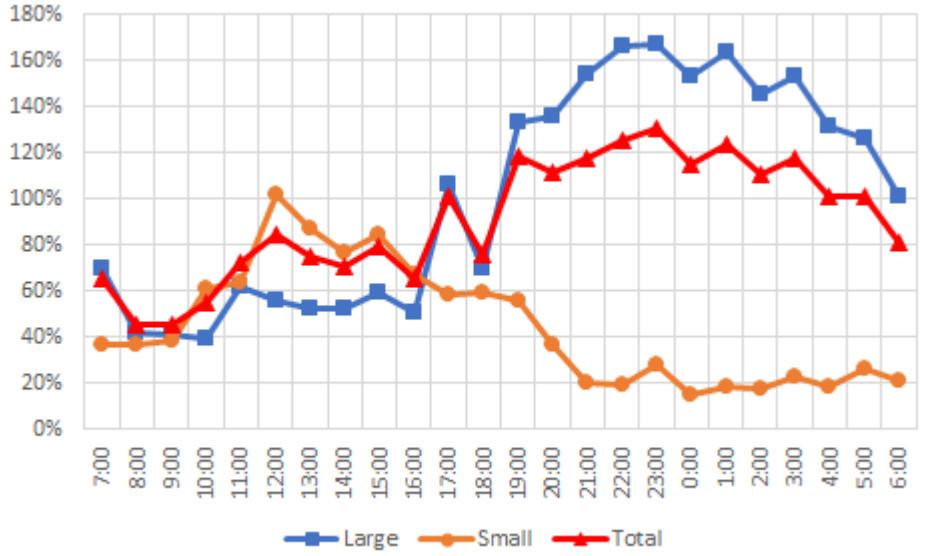
(6c: Fujikawa SA, Tomei Expressway)



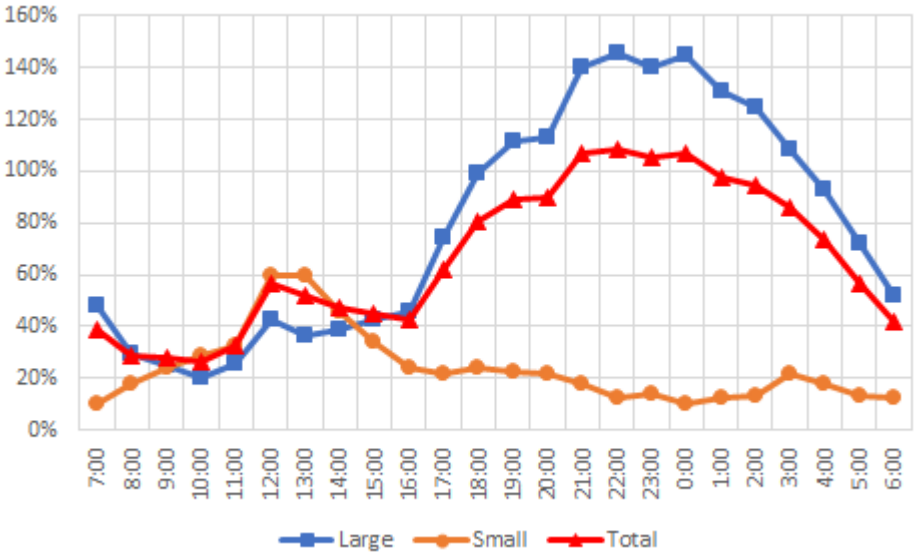
(6d: Makinohara SA, Tomei Expressway)



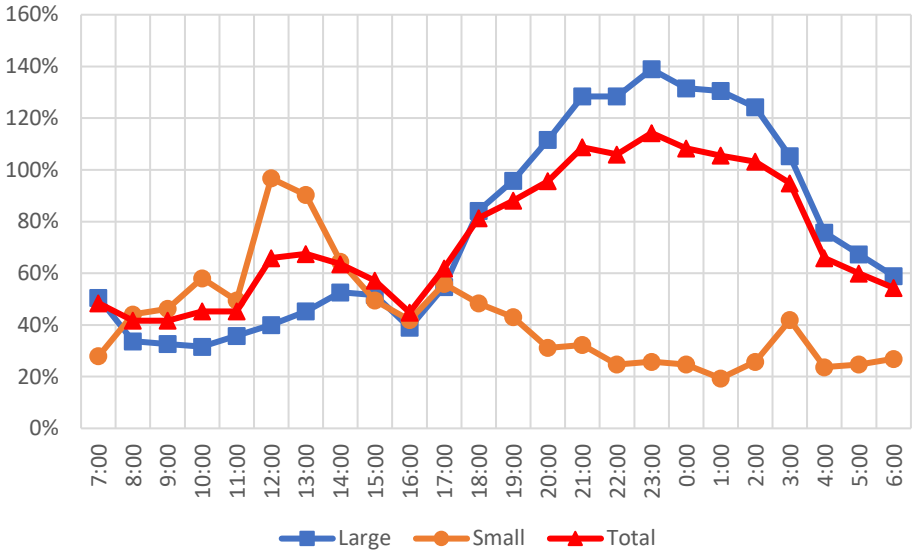
(6e: Hamanako SA, Tomei Expressway)



(6f: Surugawan-Numazu SA, Shin-Tomei Expressway)



(6g: Shizuoka SA, Shin-Tomei Expressway)



(6h: Hamamatsu SA, Shin-Tomei Expressway)

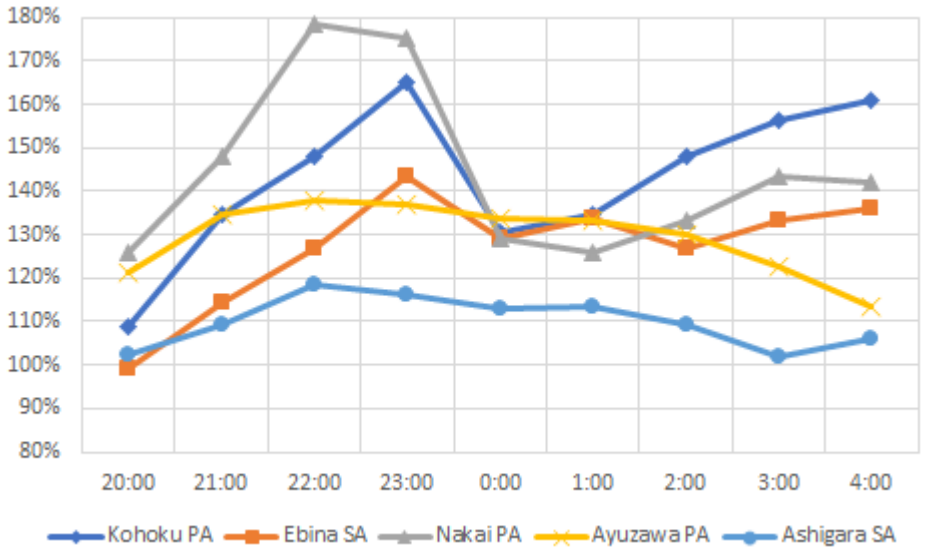
Figure 6: The Utilization Ratio of Parking Space by "SA" and time of day

TDM measures of spatial equalization between nearby rest areas include the display of real-time availability information and charging for congested parking spaces. The display of real-time availability information is already in place, and the burden on users and NEXCO is small.

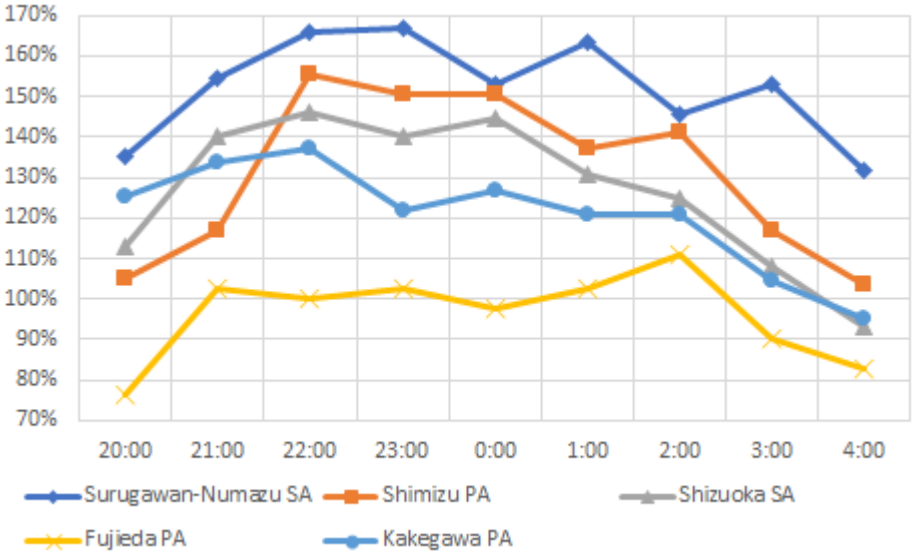
However, in order for this measure to be effective, there must be nearby rest areas with

utilization ratios below 100% during the same time period. Figure 7 shows the utilization ratio of rest areas near Tokyo on the Tomei and Shin-Tomei Expressways from 20:00 to 4:00, when Ebina SA and Surugawan-Numazu SA are extremely congested. From Figure 7, we can see that although the utilization ratio of almost all rest areas is above 100%, there is a variation in the utilization ratio; it is lower for rest areas that are farther away from Tokyo. Therefore, while this measure is not as effective as the introduction of dual-use parking spaces, it can be complementary to it.

In addition, charging for parking spaces in rest areas needs careful consideration.



(7a: Large Vehicle, Tomei Expressway)



(7b: Large Vehicle, Shin-Tomei Expressway)

Figure 7: The Utilization Ratio of Rest Areas near Tokyo on the Tomei and Shin-Tomei Expressways from 20:00 to 4:00

Another TDM measure of spatial equalization between the expressway rest area and the off-expressway rest facilities is toll adjustment for a temporary breakaway from the expressway. Toll adjustments for temporary breakaways are already in place. It is difficult for short-time users to visit the outside rest facilities for the break period. However, it is less burdensome for long-time users to visit it for the rest period. In addition, the burden on NEXCO is also small.

According to NEXCO Central[10], about 60% of the total parking demand (vehicle-hours) at Ebina SA is made up of users who use the service for more than six hours. If these users visit rest facilities outside of the expressway, it will be effective in reducing the overall utilization ratio. If comfortable off-expressway facilities are provided and the temporary breakaway rule is applied, the access and egress time to the off-expressway facilities (about 30 minutes in total) should not feel like a major burden, although the rest period required will be at least 8 hours.

In addition, NEXCO Central has already implemented a parking space reservation system. This reservation system is a system in which users who want to use a parking space reserve the parking space they want to use, online, between two weeks and five hours before their

[10] https://www.c-nexco.co.jp/corporate/pressroom/news_release/4819.html

use[11]. This measure is commendable in that it ensures that drivers can take a break. However, from a TDM perspective, the effect is small.

5. Conclusion

In this study, we have clarified the structure of the problem of parking space shortage in expressway rest areas and evaluated TDM measures. The two main findings are as follows.

First, there are differences in the demand for parking spaces for different types of vehicles, even at the same rest area and at the same time of day. Therefore, the introduction of dual-use parking spaces as "spatial equalization within the same rest area" is effective. In addition, "spatial equalization between nearby rest areas" has the effect of complementing the introduction of dual-use parking spaces.

Secondly, about 60% of the total parking demand is for long-time users. As a countermeasure to this problem, "spatial equalization between expressway rest areas and off-expressway rest facilities" is effective.

There are three four issues to be addressed in the future.

First, in this study, temporal equalization was treated as difficult. This problem needs to be examined in terms of logistics conditions (specified unloading time) in commercial transactions.

Second, the late-night discount system of expressway tolls has been pointed out as a factor in the late-night parking demand for large vehicles, but this study has not been able to examine this issue. It needs to be examined in the future.

Third, in Germany, information technology is used to increase the capacity of parking spaces as a countermeasure against congestion on the autobahn “compact parking”. This also needs to be examined in the future, as it was not included in this study.

Fourth, although not discussed in this study, in recent years the Japanese government has been working to promote the use of articulated trucks (25m in length) to increase the

[11] https://www.c-nexco.co.jp/corporate/pressroom/news_release/4517.html

transportation volume per truck driver. The payload capacity of the articulated truck is about twice that of a heavy-duty truck (12m in length), and its widespread use is considered to be an effective measure to solve the shortage of truck drivers. Meanwhile, in expressway rest areas, special parking spaces with an area twice as large as that of the parking spaces for large vehicles are required, and this could be a factor that accelerates the shortage of parking spaces for large vehicles. It needs to be examined in the future.

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