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ORIGINAL PAPER

POTENTIAL OF TRUCK PLATOONING FOR TRANSPORTING EMPTY TRUCKS CONSIDERING INTERCITY FREIGHT DEMAND IMBALANCES

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ABSTRACT. **Background:** In Japan, nearly 30% of trucks run empty despite the recent difficulties in recruiting truck drivers, especially in the intercity freight transport market. If we consider the inevitable imbalance in intercity freight demand, the efficient transport of empty trucks becomes necessary to a certain extent. One such promising technology is truck platooning, which enables trucks to automatically follow the lead vehicle while maintaining minimal headway to reduce fuel consumption and minimize the burden imposed on drivers. This study proposes a new business model to utilize truck platooning technology to transport empty trucks, based on the intercity freight demand imbalances.

Methods: After analyzing the actual intercity freight transport demand imbalance in Japan, we developed an analytical model to quantify the impact of truck platooning to transport empty trucks on labor and vehicle costs. We further analyzed its impact on the intercity freight transport market and applied the model to the actual intercity freight transport market data (logistics census) in Japan.

Results: From the analysis results using the actual freight flow data collected through surveys within 3 days in Japan, the cost reduction is estimated to be 16% in the required number of trucks and 44% in the number of taking a rest time in a truck. They indicate that the proposed empty truck platooning operation has significant benefits for inter-regional freight transport, including transport-related cost and working environment of the truck drivers on long-haul routes.

Conclusions: In this paper, we proposed a new operational concept to utilize truck platooning technology for transporting empty trucks based on the intercity freight demand imbalances. Although the proposed operation has potential significant benefits, the operation assumes the relaxation of "on-duty time" regulation in the labor standard act by considering the future introduction of autonomous driving and truck platooning. As the benefit of the pro-posed operation is significant according to our analysis, this relaxation of the labor regulation is worth considering by carefully investigating the safety of the platoon operation and its impact on the driver's working environment.

Key words: truck platooning, empty truck, intercity freight demand imbalances, on-duty time regulation, working environment of the truck drivers, vehicle cost.

INTRODUCTION

In Japan, long-haul trucking faces severe driver shortage due to harsh working conditions and an aging population. Meanwhile, the average load factor, empty running rate, and utilization rate of truck freight transport in Japan was approximately 40%, 30%, and 65%, respectively, in 2017 [Ministry of Land, Infrastructure, and Transport, 2017]. These figures show that freight transport efficiency for trucks is presently very low, and improvement in freight transport efficiency for trucks is essential to overcome the severe problem of driver shortage as well as to reduce CO_2 emissions. Regarding the empty trucks being run, this problem was created owing to the difficulty in finding loads for returning vehicles, since a fundamental difference between passenger and freight transport is that people generally return to their starting point. In contrast, almost all freight consignments move in one direction,

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from the point of production to the point of consumption [McKinnon, Ge, 2006]. The past several studies identified the factors concerning the empty running of trucks [McKinnon 1996] to examine trends and assess the potential for further reduction [McKinnon, Ge, 2006] and proposed optimization models to minimize empty truckloads [Patrick 2013]. One of the main factors for empty truckloads is the geographical imbalance in traffic flow [McKinnon, Ge, 2006]. This study assumes that the efficient transport of empty trucks itself is necessary to a certain ex-tent if the macroscopic situation of the geographical imbalance in in-ter-regional road freight flows. This study proposes a novel idea to transport empty trucks as well as truck drivers efficiently by utilizing truck platooning technology, which has been recently developed and tested on highways worldwide (e.g. CHAUFFEUR [Fritz et al, 2004], California PATH Program, SARTRE, COMPANION, Energy ITS in Japan [Shladover 2010, Tsugawa et al. 2016], and European Truck Platooning Challenge). Truck platooning is one of the most promising technologies which comprises virtually linked trucks that drive closely behind one another using automated driving technology. The benefits of truck platooning include cost savings, reduced emissions, and more efficient use of road capacity [Bhoopalam et al. 2018]. Regarding fuel saving reported from field experiments, for example, fuel savings of 10-12% and 5-10%, respectively, for the trailing truck and leading truck when the intervehicle spacing was 3-10m in a two-truck platoon system [Browned et al. 2004]. Recently, several studies have proposed methodologies and models for better planning of vehicles, accommodating for truck platooning to maximize benefits, such as fuel and CO_2 emission reductions [Lars-son et al. 2015, Bhoopalam et al. 2018, Zhang et al., 2020]. Zhang et al [2017] propose a platoon coordination and departure time scheduling problem under travel time uncertainty for off-road coordination that is cost minimization framework accounting for travel time cost, schedule miss penalties and fuel cost. From their results, it indicates that travel time uncertainty reduces the threshold schedule difference for platooning to be beneficial and platooning in networks is less beneficial on converging routes than diverging routes. Regarding the aspects to diminish the benefit of platooning, Boysen et al. [2018] investigates the impact of the diffusion of platooning technology, the maximum platoon length, and the tightness of time windows and shows that these factors can considerably reduce the positive effects of truck platooning especially with regard to fuel saving alone from comprehensive computational study. Also they point out that only if all follower trucks to the lead vehicle in platoon will be able to be unmanned driving, the additional wage savings seem substantial enough to justify the investment into platooning technology, but driverless follower trucks lose a lot of flexibility such as heading further to their next destinations after they have left a platoon. However, to the best of our knowledge, a study is yet to investigate the potential of truck platooning for improving the efficiency of truck freight transport, considering empty truck forwarding and related “Hours of Service” regulations for truck drivers in the labor standard act. In contrast, most papers deal with coordination, scheduling, and optimization of multiple trucks loaded with goods.

With this background, this study aims to investigate the potential benefit of introducing truck platooning technology to the long-haul freight transport market considering the geographical imbalance of inter-regional freight volume. In the following chapters, first, the actual situation surrounding the geographical imbalance in the inter-regional freight volume in Japan is investigated by using the inter-regional freight transport census. Next, a simple analytical model is developed to quantify the benefit of introducing truck platooning in terms of truck utilization and driver’s working environment. Finally, the developed model is applied to actual city pairs in Japan, and the benefits of introducing truck platooning for transporting empty trucks are assessed.

GEOGRAPHICAL IMBALANCE ANALYSIS IN INTER-REGIONAL FREIGHT VOLUME IN JAPAN

Before analyzing the benefits of introducing truck platooning, the actual situation surrounding the imbalance in inter-regional freight in Japan is investigated by using freight census data. The data used is the inter-regional freight census, which was conducted in 2015 in Japan. The data include the volume, type of items, origin and destination, time of departure and arrival, and transport mode of goods transport-ed on October 20–22, 2015, around the country. We aggregated the OD (Origin-Destination) freight volume (ton) for items that can be transported, mainly by a van-body truck type, between the Tokyo metropolitan area (TMA: Tokyo, Kanagawa, Saitama, and Chiba Prefectures) and five major local regions (i.e., Aichi, Osaka, Ishikawa, Niigata and Miyagi prefecture). Table 1 shows the results of the imbalance in inter-regional freight volume for each city pair. Among the city pairs, a substantial freight volume can be observed in the direction of the TMA, which is the most significant point of consumption in Japan, rather than in the return direction to each local region. This implies that the empty trucks or low load factor trucks tend to be operated along the route from the TMA to local cities in Japan.

Table 1. Geographical imbalance in actual inter-regional freight volume between the Tokyo Metropolitan Area (TMA) and major local regions in Japan (2015)

Origin-Destination	Freight ton	Origin-Destination	Freight ton
Aichi-TMA	10,626 (t)	TMA-Aichi	8,457 (t)
Osaka-TMA	7,633 (t)	TMA-Osaka	4,780 (t)
Ishikawa-TMA	1,178 (t)	TMA-Ishikawa	605 (t)
Niigata-TMA	4,497 (t)	TMA-Niigata	2,943 (t)
Miyagi-TMA	5,370 (t)	TAM-Miyagi	3,710 (t)

DEVELOPMENT OF THE NOVEL CONCEPT OF EMPTY TRUCK FORWARDING BY TRUCK PLATOONING CONSIDERING GEOGRAPHICAL IMBALANCE IN FREIGHT FLOW

According to the aggregate analysis of the geographical imbalance in inter-regional freight flows, it appears that a certain number of empty vehicles are operated owing to the lack of backloads (no return cargo). If the driver or logistics firm believes that it is better to transport some cargo than return empty, they often search for cargo even in it results in an extra running distance, increasing the burden on the driver. In long-haul freight transportation, after completing the outbound transportation, drivers are often forced to stay in their trucks or locations other than their homes. This constitutes a disadvantage while recruiting drivers. If the geographical imbalance in inter-regional freight flow is inevitable, no matter how much intelligent cargo search systems are promoted through inter-company cooperation or IT system utilization, a certain number of empty or low load-factor trucks will follow.

It is possible to utilize platooning technology to solve the problem of empty truck forwarding. For example, as shown in Figures 1 and 2, during a return trip from the Tokyo metropolitan area to a local area, instead of competing for a limited size of cargo (small pie), is it possible to send forward a certain number of empty trucks by means of platooning, immediately after finishing an outbound transportation?

This operation can reduce driver fatigue by having a sleep at home more frequently. Since empty trucks carry no cargo, the arrival time constraints are relatively loose, and it is easier to adjust the time re-quired to schedule for platooning. The returned empty trucks can immediately be used again for outbound transportation demands to the metropolitan area, and thus vehicle utilization efficiency can also be improved. Even if autonomous vehicles are to be introduced in the future, the cost of introducing such advanced vehicles for platooning might be high. Therefore, the fixed cost of the vehicle would be a burden on financial management, and improving vehicle utilization efficiency will be necessary to ensure price competitiveness.

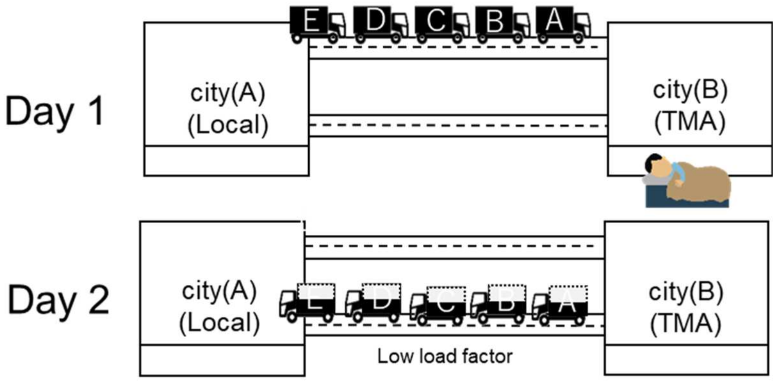

Fig. 1. Current normal operation in the case where the return cargo volume is 60% of outbound (all drivers must stay in the city (B) during rest hours for the next shift and low load factor on a return route)

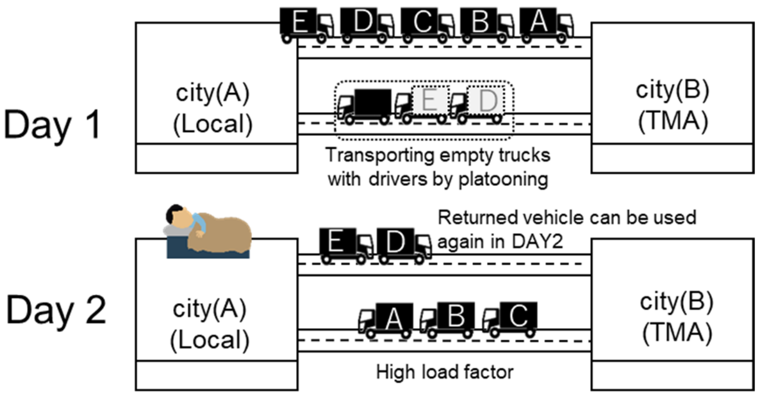

Fig. 2. Proposed operation employing empty truck forwarding with drivers by means of truck platooning in cases where the return cargo volume is 60% of the outbound (driv-ers returned with platooning truck can rest in their homes, and the returned vehicles can be used the next day, ensuring high load factor on return route)

However, for this proposed operation, Hours of Service regulations for truck drivers, provided in the labor standard act, can be a possible bottleneck, especially for long-haul routes. This regulation limits the number of daily and weekly hours spent driving and working and regulates the minimum amount of time drivers must spend resting be-tween driving shifts. In Japan, the maximum "on-duty time" is 13 hours and minimum "off-duty time (resting time)" until the next shift is 8 hours. Therefore, for example, in the case of an outbound route (e.g., city (A) to city (B)) that takes 7 hours, counted as on-duty time, drivers cannot return to their home city (A) without resting for more than 8 hours in city (B), if the time taken during autonomous platooning driving is regarded as "on-duty time." However, if the time spent during automated driving, while platooning, can be regarded as "quasi-resting time" and is exempted from the "on-duty time" regulation, especially in the case that drivers can have a normal rest at home after "quasi-resting time", drivers and trucks can be returned to their home city (A) without spending resting at city (B). Similar concept regarding resting in platoon is also discussed in the existing study [Bhoopalam et al., 2018] that proposes the classification to describe different levels of human involvement in platooning (Human driven platooning with in-platoon resting, Hybrid platooning, and Driverless platooning) and discusses about the benefit of travel time saving by finishing required break time as a following truck of the platoon ("in-platoon resting"). Although our proposing concept of platoon operation is similar to this existing idea, platooning for transporting empty trucks considering geographical imbalance in inter-regional freight flow is unique idea. In this study, we assume this special exemption for the regulation of "on-duty time" can be applied to drivers in autonomously driven vehicles employing platooning (followers).

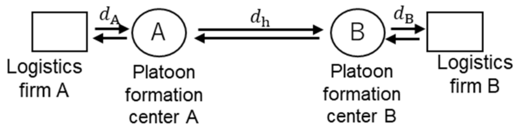

Fig. 3. Case (1): Non-consolidated cargo flow case (one driver runs from logistics firm A to B)

MODELS FOR THE EVALUATION OF THE BENEFIT OF EMPTY TRUCK PLATOONING

In this chapter, simple models are formulated for evaluating the benefits of introducing empty truck platooning. There are two main types of transport for long-haul trucks, one is non-consolidated transport (Case (1)) and the other is consolidated transport (Case (2)) as shown in Figures 3 and 4. In case (1), we assume that one driver operates throughout, from logistics firm A to logistics firm B, and the driver then proceeds to the dedicated point where the platoon is formed. In case (2), we assume that there are logistics bases where cargo is consolidated, and platoon formation can also be implemented, with dedicated drivers operating between the logistics bases.

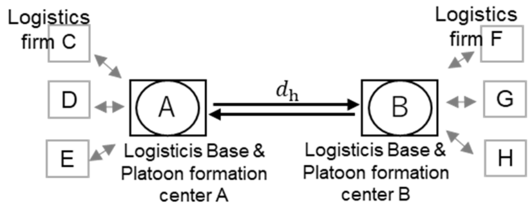

Fig. 4. Case (2): Consolidated cargo flow case (dedicated drivers operating between logistics bases)

For these two cases, we formulate models to calculate the travel time by considering both empty truck forwarding by means of platooning and normal operation without platooning, as shown in equations (1) - (8).

Platooning – Case (1):

$$T_{emp}^{pl(1)} = t_{l(A)} + \frac{d_A}{v_G} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + \frac{d_B}{v_G} + t_{u(B)} + \frac{d_B}{v_G} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + \frac{d_A}{v_G} + t_{s(A)} \tag{1}$$

$$T^{pl(1)} = t_{l(A)} + \frac{d_A}{v_G} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + \frac{d_B}{v_G} + t_{u(B)} + t_{s(B)} + t_{l(B)} + \frac{d_B}{v_G} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + \frac{d_A}{v_G} + t_{u(A)} + t_{s(A)} \tag{2}$$

Platooning – Case (2):

$$T_{emp}^{pl(2)} = t_{l(A)} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + \frac{d_B}{v_G} + t_{u(B)} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + t_{s(A)} \tag{3}$$

$$T^{pl(2)} = t_{l(A)} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + t_{u(B)} + t_{s(B)} + t_{l(B)} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + t_{u(A)} + t_{s(A)} \tag{4}$$

Normal – Case (1):

$$T_{emp}^{nor(1)} = t_{l(A)} + \frac{d_A}{v_G} + \frac{d_h}{v_h} + \frac{d_B}{v_G} + t_{u(B)} + t_{s(B)} + \frac{d_B}{v_G} + \frac{d_h}{v_h} + \frac{d_A}{v_G} + t_{s(A)} \quad (5)$$

$$T^{nor(1)} = t_{l(A)} + \frac{d_A}{v_G} + \frac{d_h}{v_h} + \frac{d_B}{v_G} + t_{u(B)} + t_{s(B)} + t_{l(B)} + \frac{d_B}{v_G} + \frac{d_h}{v_h} + \frac{d_A}{v_G} + t_{u(A)} + t_{s(A)} \quad (6)$$

Normal – Case (2):

$$T_{emp}^{nor(2)} = t_{l(A)} + \frac{d_h}{v_h} + t_{u(B)} + t_{s(B)} + \frac{d_h}{v_h} + t_{s(A)} \quad (7)$$

$$T^{nor(2)} = t_{l(A)} + \frac{d_h}{v_h} + t_{u(B)} + t_{s(B)} + t_{l(B)} + \frac{d_h}{v_h} + t_{u(A)} + t_{s(A)} \quad (8)$$

$T_{emp}^{pl(i)}$ travel time for a round trip of an empty truck in platooning in case (*i*) (hour),
$T^{pl(i)}$ travel time for a round trip of a loaded truck in platooning in case (*i*) (hour),
$T_{emp}^{nor(i)}$ travel time for a round trip of an empty truck in normal operation in case (*i*) (hour),
$T^{nor(i)}$ travel time for a round trip of a loaded truck in normal operation in case (*i*) (hour),
$t_{l(j)}$ loading time at center $j = \{A, B\}$ (hour),
$t_{u(j)}$ loading/unloading time at center $j = \{A, B\}$ (hour),
$t_{s(j)}$ resting time at $j = \{A, B\}$ (hour),
t_{pc} time for platoon formation (hour),
d_j distance between logistics firm $j = \{A, B\}$ to platoon formation center (km),
d_h distance between platoon formation centers (km),
v_g travel speed on-road (=30 km/h),
v_h travel speed on highway (=80km/h),
t_{ps} time for platoon decoupling (hour).

With these formulations, we can obtain the travel time for each driver in each case and correspondingly the number of necessary trucks with frequency of resting at home for a given inter-regional car-go volume by considering Hours of Service regulation in Japan, such as the maximum on-duty time and the minimum amount of resting time. Table 2 shows an example of the calculation results for different distances. In the case where the cargo volume for an outbound route is 60 trucks and that for return route is 30 trucks (half of outbound) and departure time should be between 4:00 and 6:00 pm as is the usual case shown in the next chapter. From this simple calculation, we can find that empty truck platooning has significant benefits in reducing the required number of trucks for any route distance and also for reducing the number of drivers for relatively shorter distances. These benefits can link to improvements in vehicle utilization efficiency and drivers' working environment. For longer distances, the benefits re-duce because the returned vehicles and drivers cannot be employed the next day due to long travel time and departure between 4-6 pm.

Table 2. Example of calculation results of the required number of trucks and drivers for different distances

	Normal Operation		Empty Truck Platooning: Case (1)		Empty Truck Platooning: Case (2)	
Distance between platoon formation centers (km)	Required number of trucks	Required number of drivers	Required number of trucks	Required number of drivers	Required number of trucks	Required number of drivers
240 km	360	360	270	270	270	270
320 km	360	360	270	270	270	270
400 km	360	360	270	330	270	270
480 km	360	360	270	360	270	270
560 km	360	360	270	360	270	330
640 km	360	360	-	-	270	360
720 km	360	360	-	-	270	360

BENEFIT EVALUATION OF TRUCK PLATOONING: A CASE STUDY

In this chapter, we apply the abovementioned model to inter-regional freight transport in the real world. We select the inter-regional freight data between Tokyo and Aichi (around 300 km distance) as a case study OD pair since the distance is in the optimal range, from the analysis results in the previous chapter, and the OD pair is one of the largest freight transport markets in Japan. Figures 5 and 6 show the aggregate data of the departure time distribution of the actual freight volume from Tokyo to Aichi and Aichi to Tokyo, respectively, in 3 days (Oct. 20–23, 2015), which is the latest survey period of the inter-regional freight transport census in Japan. The freight volume is converted to the number of trucks by assuming that all the cargo was transported by a 15-ton heavy truck. As shown in these figures, we can find the geographical imbalance in freight volume in different directions and the concentration of the departure time of freight transport on late evening time. Although this three-day survey is too short to draw general conclusions, especially on long-term phenomena such as seasonality of demand, we try to grasp the order of the benefit of introducing empty truck platooning operation due to the data limitation (there is no other freight transport data available in Japan). Additionally, the concentration of the departure time of freight transport on late evening time seems to be a common phenomenon in other days, which is important factor for our pro-posed operation.

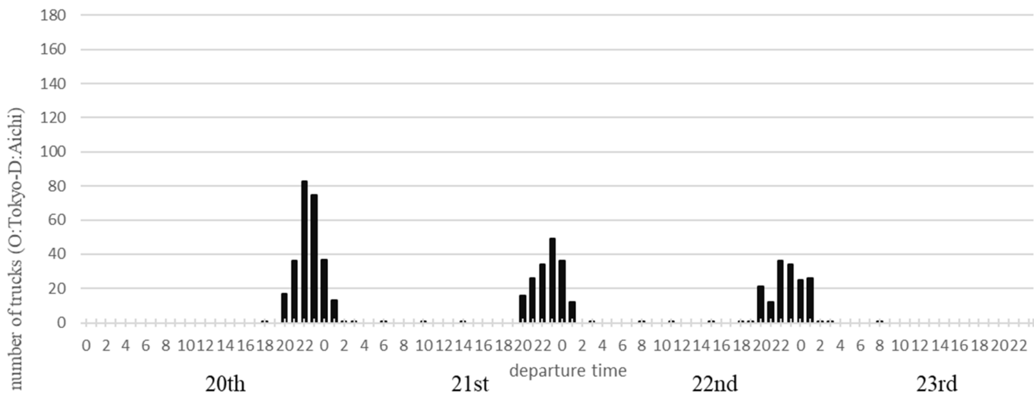

Fig. 5. Departure time distribution of the actual freight volume from Tokyo to Aichi in 3 days (Oct. 20–23, 2015)

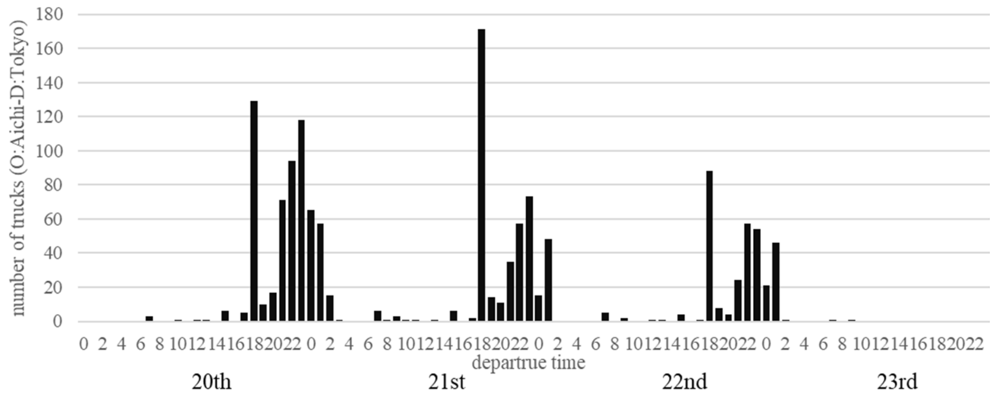

Fig. 6. Departure time distribution of the actual freight volume from Aichi to Tokyo in 3 days (Oct. 20–23, 2015)

Based on this inter-regional freight volume between Aichi and Tokyo, we calculated the required number of trucks and the total amount of rest taken in the truck or Tokyo, during these 3 days. The results are shown in Figures 7 and 8. The required number of trucks can be reduced by 16% and the total number of taking a resting time in a truck can be also reduced by 44%, based on the three-day inter-regional freight volume between Aichi and Tokyo. These results show that the proposed empty truck platooning operation has a significant benefit for inter-regional freight transport, including transport-related cost and the working environment of the truck drivers on long-haul routes.

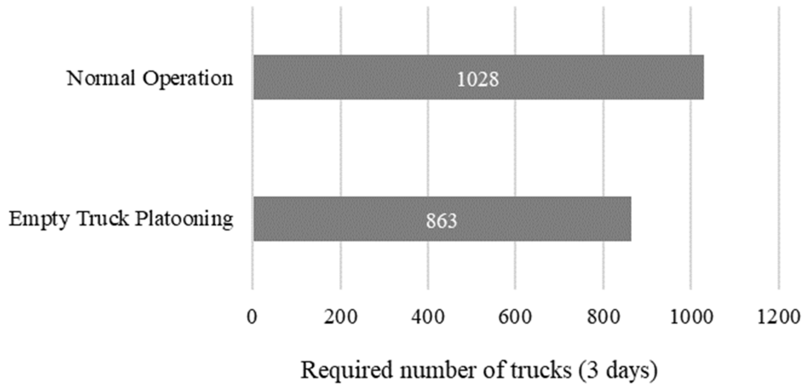

Fig. 7. Comparison of the required number of trucks (3 days between Tokyo and Aichi region)

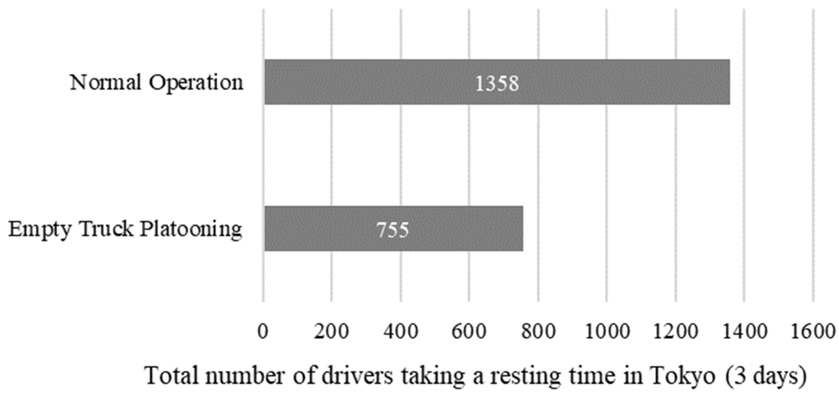

Fig. 8. Comparison of the total number of trucks taking a resting time in Tokyo (3 days between Tokyo and Aichi region)

To determine the total cost of inter-city freight transport, we define four cost as shown in the following equations. The total cost consists of highway toll fee, fuel cost, driver's cost, and truck cost (equation (9)). Highway toll fee is calculated based on the policy of Central Nippon Expressway Company (NEXCO) (a Japanese highway company) as shown in equation (10). The reduced fuel consumption, due to the reduction in air-drug owing to truck platooning, is considered in the calculation as shown in equation (11) (the coefficient is assumed to be 0.88 with reference to Browned et al. (2004). Finally, the cost of each truck is assumed to be a constant value, calculated from the standard price of a heavy truck (Hino Motors, Ltd.) and its durable life in a depreciation policy (5 years) (around 79,000 yen/week/vehicle).

$$\text{TotalCost} = \sum_i c_{h(i)} + \sum_i c_{f(i)} + \sum_j c_{d(j)} + \sum_k c_{v(k)} \quad (9)$$

$$c_{h(i)} = 150 + (24.6 \times 1.65 \times \sum_i d_{h(i)}) \quad (10)$$

$$c_{f(i)} = a \times w_f \,/\, \text{fuel\_eff.} \times \sum_i d_{h(i)} \quad (11)$$

$$c_{d(j)} = w_c \times w_d \times \sum_j t_{d(j)} \quad (12)$$

$c_{h(i)}$	highway toll fee for truck travel *i* (yen)
$c_{f(i)}$	fuel cost for truck travel *i* (yen)
$c_{d(i)}$	driver's cost for truck driver *j* (yen)
$c_{v(k)}$	vehicle cost for truck *k* (yen)
$d_{h(i)}$	driving distance on highway of truck travel *i*
a	air drug reduction coefficient (0.88)
w_f	fuel price (115.6 yen/l)
fuel_eff	fuel efficiency (4.05 km/l)
w_c	wage reduction coefficient (0-1)
w_d	hourly wage (3.323 yen/hour)
$t_{d(j)}$	on-duty time of driver *j* (hour)

Figure 9 shows the result of calculating the total cost in both scenarios, normal and platooning operation. It indicates that a large portion of the cost reduction is in the driver and truck cost, but the drive's cost is dependent on the reduction coefficient. In this analysis, the highway toll fee in the platooning case is the same as that of the normal case (e.g. three times of one vehicle if the platooning consists of three vehicles). Again, the truck cost can be significantly reduced by using the proposed new operation model.

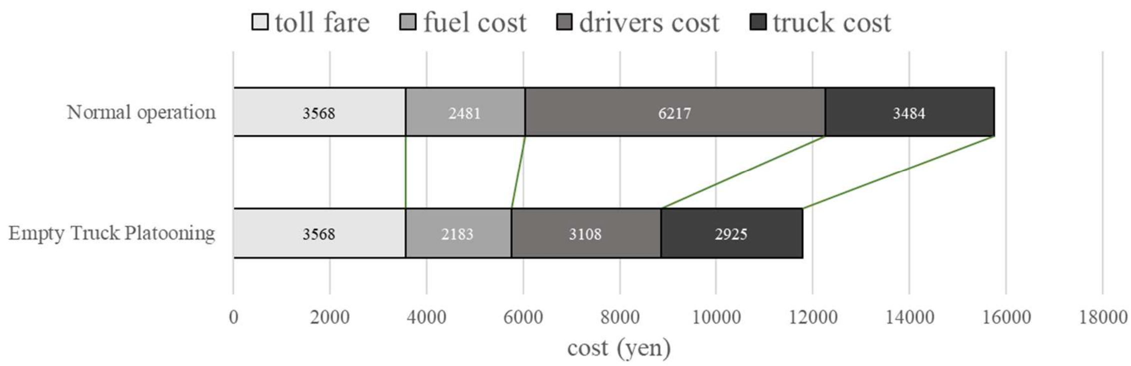

Fig. 9. Comparison of the total cost (3 days between Tokyo and Aichi region)

CONCLUSIONS

In this paper, we proposed a new operational concept to utilize truck platooning technology for transporting empty trucks based on the intercity freight demand imbalances in Japan and then analyzed the potential benefit of the proposed model, in terms of labor cost, efficiency of truck use, and drivers' working environment. From the analysis results using the actual freight flow data collected through surveys within 3 days in Japan, the cost reduction is estimated to be 16% in the required number of trucks and 44% in the number of taking a rest time in a truck. These results are some of the examples from the analysis using the 3-day freight transport survey data. However, they indicate that the proposed empty truck platooning operation has significant benefits for inter-regional freight transport, including transport-related cost and working environment of the truck drivers on long-haul routes. Although the proposed operation has potential significant benefits, the operation assumes the relaxation of "on-duty time" regulation in the labor standard act by considering the future introduction of autonomous driving and truck platooning. As the benefit of the proposed operation is significant according to our analysis, this relaxation of the labor regulation is worth considering by carefully investigating the safety of the platoon operation and its impact on the driver's working environment.

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SZANSA WYKORZYSTANIA TRUCK PLATOONING DLA TRANSPORT PUSTYCH SAMOCHODÓW W OBLICZU BRAKU RÓWNOWAGI ILOŚCI PRZEWOZÓW

STRESZCZENIE. **Wstęp:** W Japonii prawie 30% ciężarówek jeździ bez ładunku pomimo trudności w rekrutacji odpowiedniej ilości kierowców, szczególnie zjawisko to występuje w transporcie międzymiastowym. Biorąc pod uwagę nierównomierne rozłożenie potrzeb przewozowych, wydaje się nieuniknione występowanie pustych przewozów bez ładunków. Obiecującą technologią dla rozwiązanie tego problemu jest truck platooning (zintegrowane konwoje), dzięki które samochody dostawcze automatycznie podążają za pierwszym pojazdem, dzięki czemu umożliwiają oszczędność zużywanego paliwa oraz ograniczają konieczny wkład ze trony kierowcy. W pracy zaproponowano model biznesowy umożliwiający zastosowanie technologii truck platooning do transportu pustych samochodów, istnieje, których wynika z niezrównoważonego zapotrzebowania na transport ładunków.

Metody: Po przeanalizowaniu popytu na usługi transportowe w Japonii, wykazujący brak równowagi, stworzono model analityczny określający wpływ zastosowania truck platooning do przewozu pustych samochodów na koszt robocizny oraz samochodów. Następnie przeanalizowano wpływ na rynek transportowy i przetestowano model na danych pochodzących z obecnego rynku transportowego w Japonii.

Wyniki: Na podstawie wyników analizy, w której użyto danych pozyskanych przez okres 3 dni w Japonii, oszacowano redukcję kosztów o 16% odnośnie zapotrzebowania na samochody oraz o 44% odnośnie czasu odpoczynku. Zaproponowany model operacyjny truck platooning dla pustych samochodów daje więc istotne benefit w transporcie międzyregionalnym, obejmując koszty transportowe oraz środowisko pracy kierowców na długich trasach.

Wnioski: W pracy zaproponowano nową koncepcję zastosowania technologii truck platooning dla transportu pustych samochodów wynikającą ze niezrównoważonego popytu na usługi transportowe. Aczkolwiek proponowana operacja daje potencjalnie istotne benefity, metoda ta zakłada poluzowanie regulacji czasu pracy poprzez uwzględnienie autonomicznych przewozów i truck platooning. Uzyskane benefity z zastosowania tej metody są istotne i w związku z tym warte jest rozważenie poluzowania regulacji dotyczących czasu pracy, uwzględniając bezpieczeństwo operacji truck platooning i jej wpływu na środowisko pracy kierowcy.

Słowa kluczowe: truck platooning, pusty przewóz, nierównomierne rozłożenie potrzeb przewozowych, regulacja czasu pracy, środowisko pracy kierowców, koszt samochodu

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