日本オペレーションズ・リサーチ学会
2021年 秋季研究発表会

Hub Location Model of Platoon Formation Center for Truck Platooning

05001456 Tokyo Univ. of Marine Science and Technology *SAW Aung
01900990 Tokyo Univ. of Marine Science and Technology WATANABE Daisuke

1. Introduction

Truck platooning is a grouping of freight vehicles into connected vehicle convoys using electronic coupling as an application in automated driving technology for saving fuel, reducing travel cost and improving infrastructure efficiency. Therefore, it is critical to locate platoon formation centers (PFCs) for (de)forming platoons[1]. In this study, we will apply the hub location model to find the optimal location of PFCs. The objective is to minimize the total travel cost for each origin-destination pair via two PFCs.

2. Formulation

Most hub location models consider the discount factor due to the economies of scales. In this study, we will consider the discount factor thanks to the truck platooning for optimized location of PFC.

Two different assignment systems are used for PFCs formation – single assignment and multiple assignment. Single assignment is that trucks from a certain origin must (de)form a platoon only at a single PFC, while platoons can be created more than at a single PFC in multiple assignment. The optimization model by Skorin-Kapov et al.(1996) is used for single allocation, which is a LP relaxation of Campbell(1994b). For multiple allocation, a compact formulation of the model, known as the HUBLOC by Skorin-Kapov et al.(1997) is applied.

Discount Factor(α)

Discount factor estimation due to truck platooning by Watanabe et al. (2021) is applied as follows.

$$T_s = sn \quad (1)$$

$$T_p = a + (n-1)b \quad (2)$$

$$\alpha = \frac{T_p}{T_s} = \frac{a+(n-1)b}{sn} \quad (3)$$

where,

T_s= travel cost of trucks without platoon
s= travel cost per truck
n= number of trucks
T_p= travel costs of trucks with platooning
a = leading truck travel cost
b= following trucks travel cost

3. Numerical experiments

The ratio of the labor costs in the trucking industry is around 40% and this is related to the cost reduction for unmanned driving against manned driving. As for the reduction of fuel consumption, the leading vehicle is around 10% and that of the following vehicles is around 20%. The number of trucks *(n)* is hypothetically varied from 3 to 10 to allow a wider range of α value. Therefore, the following discount values as shown in Table 1 are used for platooning hub optimization.

We test our linearization using dataset with 20 cities, which is extracted from Turkish network dataset of 81 cities by Kara[4]. Travel demand of each node is shown in Table 2. We solve the model via XpressIVE 8.11 on an Intel Xeron Bronze 1.9 GHz computer with 32768 MB RAM, and 1 MB Cache.

Table 1. Discount factor α for truck platooning

Scenario		s	a	b	n	α
I	Platoon of all manned vehicles	1	0.9	0.8	3-10	0.8
II	Platoon with unmanned following vehicles	1	0.9	0.4	3	0.6
					4-10	0.5
III	Platoon of all fully automated vehicles (FAVs)	1	0.5	0.4	3-10	0.4

4. Findings

These are the following general characteristics found from our optimization. Figure 1 shows the total travel cost in each scenario. Increasing the number of platooning trucks cannot significantly reduce the inter-PFC travel cost. Semi or complete unmanned platooning and multiple allocation can reduce the cost dramatically. Multiple allocation can also bring down the cost significantly rather than single allocation.

Figure 2 shows the optimal location for single assignment with discount factor when the number of PFCs is 5. Lower discount factor means that truck platoons can enjoy more of the platooning benefit. Therefore, lower inter-PFC discount factor can generally lead to larger inter-PFC distance. This characteristic can be found more for single assignment and uniformly distributed data. In other words, optimal PFC location in multiple assignment is less sensitive to discount factor variation.

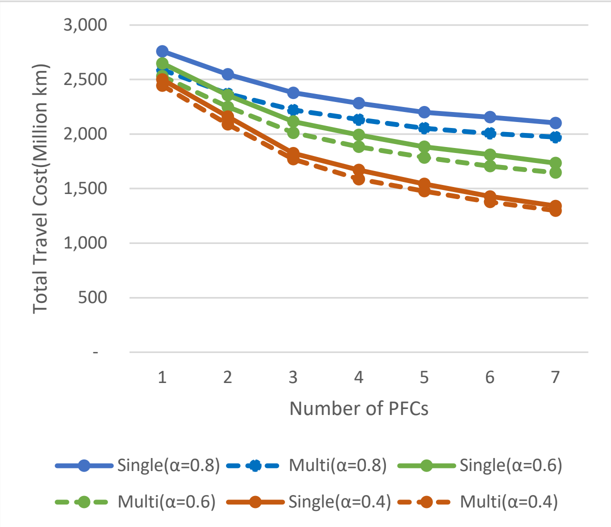

Figure 1. Objective cost values for single allocation and multiple allocation with different discount factor and number of PFCs

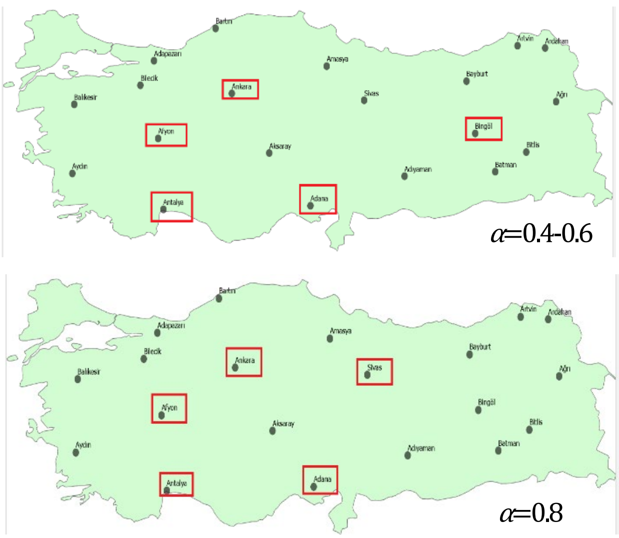

Figure 2. Hub Location for single assignment with discount factor(number of PFCs=5)

Table 2. Travel demand of each node and PFC location in optimization instances with the number of PFCs from 1 to 7

City	n of PFCs	Outflow	Inflow	Total
ANKARA	○	737202	704085	1441286
ADANA	○	389583	389236	778819
ANTALYA	○	364921	365405	730326
BALIKESİR	○	236571	239346	475917
AYDIN	○	210361	213233	423594
AFYON	○	181059	183908	364967
ADAPAZARI	○	169016	171817	340833
SİVAS	○	168785	171585	340369
ADIYAMAN	○	140386	142986	283372
AĞRI	○	119571	121949	241520
BATMAN	○	103664	105833	209497
AKSARAY		90174	92138	182312
BİTLİS		88521	90458	178979
AMASYA		83279	85129	168408
BİNGÖL	○	58180	59563	117744
BİLECİK		44689	45788	90477
ARTVİN		44144	45231	89375
BARTIN		42377	43425	85801
ARDAHAN		30852	31636	62488
BAYBURT		22497	23080	45576

Nodes with the larger flows appear as hubs repeatedly in almost all instances of linearization as shown in Table 2. This is more correct for uniformly distributed dataset.

References

[1] Watanabe, D., Kenmochi, T. and Sasa, K.: An Analytical Approach for Facility Location for Truck Platooning-A Case Study of Unmanned Following Truck Platooning System in Japan-, Logistics, 5(2), 27, https://doi.org/10.3390/logistics5020027, 2021.

[2] O'Kelly, M.E., Bryan, D., Skorin-Kapov, D. and Skorin-Kapov, J.:Hub network design with single and multiple allocation: a computational study. Location Science 4, 125-138, 1997

[3] Skorin-Kapov, D., Skorin-Kapov, J. and O'Kelly, M.E.: Tight linear programming relaxations of uncapacitated phub median problems. European Journal of Operational Research 94, 582-593, 1997

[4] Kara B.Y.: Turkish network dataset, https://ie.bilkent.edu.tr/~bkara/dataset.php