International Journal of Smart Home
Vol. 10, No. 9 (2016), pp. 59-68
http://dx.doi.org/10.14257/ijsh.2016.10.9.06

Research on Model of Vehicle Logistics Transportation Plan

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Abstract

The vehicle logistics is a complex branch in the field of logistics. Because of vehicles and vehicle transporters have a variety of specifications, the current logistics company make transportation plan mainly depends on scheduling personnel's experience, in the face of complex transportation tasks, however, are often inefficient, and transportation cost is not ideal. This paper used the E problem dates of the National Mathematical Modeling Contest for Postgraduates in 2014 to study the mathematical model is established to solve the problem of loading method of vehicles and transportation plan. Firstly, 2207 vehicles can be divided into four categories, we used MATLAB to calculation the loading method of vehicles for 10 types of vehicle transporters, then we take vehicle transporter minimum number as optimization objective, with vehicle demand and the proportion of vehicle transporters as the constraint conditions, to establish the integer programming model, and finally we used LINGO programming to calculate the optimal transport plan is: vehicle transporter minimum number is 127.

Keywords*: Vehicle logistics; Transportation plan; Integer programming model*

1. Background

The automobile industry is rapidly developed along with the rapid development of Chinese economy. As a result, the automotive logistics sharply rises in the market segment of Chinese logistics industry and the industry position thereof is also continuously enhanced. As the most complex logistics field, the vehicle logistics has high technical contents not only for transportation and storage, but also for loading and unloading. In recent years, besides the requirement for continuously improving logistics service, many enterprises also have strong requirement for reducing logistics cost[1]. Specifically, the vehicle logistics cost is composed of transportation cost, storage cost and management cost, wherein the transportation cost has the highest proportion among the above three items and occupies more than 40% of the total logistics cost[2]. Therefore, the transportation cost reduction is especially important for the vehicle logistics.

A passenger vehicle manufacture usually issues the task to a logistics company for transporting the passenger vehicles all over the country according to the vehicle purchase orders of the clients in the country, and then the logistics company makes the corresponding transportation plan to deliver this batch of passenger vehicles according to the task issued above. Therefore, the logistics company needs to firstly select some vehicle transporters among the available “vehicle transporters” at that time and then provide the passenger vehicle loading scheme and the destination for each vehicle transporter in order to ensure the completion of the transportation task. At present, due to such reasons as multiple specifications of vehicle transporters and passenger vehicles, the logistics company mainly relies on the experiences of the dispatching personnel to make the transportation plan. However, in case of complex transportation task, the above method usually has low efficiency and dissatisfactory transportation cost.

ISSN: 1975-4094 IJSH

2. Domestic and International Research Status and Research Object

After being firstly proposed by Dantzing and Ramser[3] in 1959, VSP (Vehicle Scheduling Problem) has been highly concerned by the experts, the transportation planners and the mangers in such disciplines as operational research, applied mathematics, combinatorial mathematics, network analysis, graph theory and computer application. Meanwhile, a great progress has been achieved through a lot of theoretical researches and experimental analysis carried out thereby. The research contents can be roughly divided into two parts:

2.1. Vehicle Transporter Stowage Problem

Tang Zhizhong, *et al*. (2012)[4] have developed a set of auxiliary stowage dispatching decision analysis system.

Yuan Zhenglei (2008) [5] has adopted the "clustering" thought to reduce the problem scale and meanwhile adopted the existing VRP algorithm to solve large-scale problem.

2.2. Vehicle Transporter Dispatching and Route Optimization Problem

Sally Kassem and Mingyuan Chen(2013)[6] have developed a heuristic method to solve such n-p difficulty as vehicle dispatching problem.

Roberto Baldacci(2011)[7], *et al*. have adopted an accurate algorithm to solve the capacitated vehicle routing problem with time window.

Behnam Vahdani(2012)[8] has proposed a new mixing heuristic vehicle route dispatching and cross delivery system for solving the delivery time optimization problem.

Zhang Tengsong (2012)[9] has analyzed the vehicle logistics route status of SQ Company, solved the capacitated routing problem, namely CVRP, and adopted the specific calculation instance to verify the effectiveness and the applicability of the model and the algorithm so as to obtain the optimized result.

Ma Shihua, *et al*. (2006)[10] have designed a heuristic algorithm used for generating the vehicle logistics distribution plan and meanwhile adopted relevant calculation instance to prove that the algorithm could be used to rapidly process the orders and generate the vehicle logistics distribution plan.

Jia Yunmei, *et al*. (2009)[11] have established the dual-objective mathematical model to divide the problem into two stages: in the first stage, the improved dynamic clustering algorithm is adopted to assign the delivery tasks of the vehicles; in the second stage, the dynamic planning method is adopted to obtain the sequence of the demand points passed by the vehicles in various regions so as to minimize the route.

The data of Question E in 2014 National Postgraduates' Mathematical Contest in Modeling are adopted in the paper. Specifically, the reduction of the vehicle transporter quantity and the logistics cost is taken as the optimization objective to establish the corresponding integer programming model in order to research the optimal loading schemes for the vehicle transporters and the transportation planning problem.

3. Model Hypothesis

The vehicle logistics cost is assumed to be firstly influenced by the vehicle transporter quantity. Under the condition of the same vehicle transporter quantity, the use costs of the three types of vehicle transporters are ranked in a descending order as follows: Type 2-2, Type 2-1 and Type 1-1; under the condition of the same vehicle transporter quantity and the same transporter type, the vehicle transporter with short route has low cost; the vehicle transporters do not need to be unloaded or driven back after arriving at the destinations, and the unloading cost is ignored.

4. Modeling and Solution

4.1. Passenger Vehicle Classification and Full Loading Schemes of Vehicle Transporters

Lengths, widths and heights of 45 types of 2,207 passenger vehicles and the demand quantities of the five destinations ---- ***A*** , ***B*** , ***C*** , ***D*** **and** ***E*** are as shown in Table 1. There are many types of passenger vehicles, so these passenger vehicles are firstly divided into four major types, as shown in the following table.

Table 1. Passenger Vehicle Classification and Demand Quantities of Various Destinations

Passenger Vehicle Type	Length (m)	Width (m)	Height (m)	Demand Quantity ***A***	Demand Quantity ***B***	Demand Quantity ***C***	Demand Quantity ***D***	Demand Quantity ***E***	Type No.
Ⅰ	5.16	1.895	1.93	87	53	47	50	47	(2, 4, 15, 17, 19, 23-25, 28, 33, 34, 41, 43)
Ⅱ	4.67	1.84	1.86	133	106	110	96	91	(1, 6, 9-13, 16, 21, 22, 26, 31, 32, 35-38, 42, 45)
Ⅲ	4.42	1.785	1.77	70	52	95	88	78	(3, 5, 7, 8, 14, 18, 20, 27, 29, 30, 39, 40)
Ⅳ	6.831	1.98	1.478	2	0	0	1	1	44

Types, specifications and quantities of 10 types of 151 vehicle transporters are as shown in Table 2.

Table 2. Vehicle Transporter Specification and Quantity

No.	Vehicle Transporter Type	Upper-Lower Length (m)	Upper Width (m)	Lower Width (m)	Height (m)	Quantity (PCS)
1	Eight-position Dual-bridge Edge-wheel Van Type 1-1	19	2.7	2.7	4.35	21
2	Ten-position Dual-bridge Dual-wheel Van Type 1-1	18.3	2.9	2.9	4.4	18
3	Twelve-position Dual-bridge Dual-wheel Van Type 1-1	24.3	2.7	2.7	4.3	22
4	Ten-position Dual-bridge Edge-wheel Van Type 1-1	22	2.7	2.7	4.35	15

No.	Vehicle Transporter Type	Upper-Lower Length (m)	Upper Width (m)	Lower Width (m)	Height (m)	Quantity (PCS)
5	Nineteen-position Dual-bridge Dual-wheel Framework Type 1-2	23.7	3.6	2.8	3.9	10
6	Ten-position Single-bridge Dual-wheel Framework Type 1-1	18.2	2.7	2.7	3.6	25
7	Ten-position Single-bridge Dual-wheel Framework Type 1-1	21	2.7	2.7	3.6	4
8	Ten-position Single-bridge Dual-wheel Framework Type 1-1	21	2.7	2.7	3.9	16
9	Nineteen-position Dual-bridge Dual-wheel Framework Type 2-2	19	3.5	3.5	3.4	5
10	Seventeen-position Dual-bridge Dual-wheel Framework Type 1-2	23.3	3.5	2.7	4.35	15

MATLAB software is adopted for programming to calculate the full loading schemes of the ten types of vehicle transporters as shown in Table 1 to transport Types I, II and III passenger vehicles (there are only four Type IV passenger vehicles with special specifications, so these passenger vehicles are independently loaded and delivered). The full loading schemes of No.1~10 vehicle transporters are respectively as follows: 27, 22, 42, 35, 16, 20, 35, 35, 1, 15. The massive data are not tabled.

4.2. Transportation Plan Optimization Modeling and Solution

The transportation route diagram is as shown in Figure 1, wherein the lengths of various segments are as follows: OD=160, DC=76, DA=200, DB=120, BE=104 and AE=60.

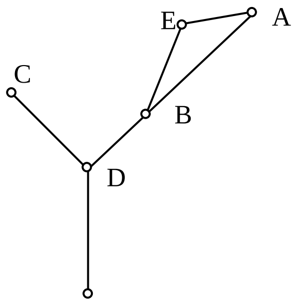

Figure 1. Transportation Route

Three transportation routes are assumed as follows: $\boldsymbol{O-D-C}$ is the first transportation route; $\boldsymbol{O-D-B-A}$ is the second transportation route; $\boldsymbol{O-D-B-E}$ is the third transportation route. According to Figure 1, the three transportation routes all pass $\boldsymbol{OD}$ segment, the second and third transportation routes both pass $\boldsymbol{ODB}$ segment. $\boldsymbol{a_i}$, $\boldsymbol{b_i}$, $\boldsymbol{c_i}$, $\boldsymbol{d_i}$ and $\boldsymbol{e_i}$ are respectively assumed as the demand quantities of Types I, II and III passenger vehicles at Points $\boldsymbol{A}$, $\boldsymbol{B}$, $\boldsymbol{C}$, $\boldsymbol{D}$ and $\boldsymbol{E}$; $\boldsymbol{r_{i1}}$ is the quantity of Type I passenger vehicles unloaded at Point $\boldsymbol{D}$ on the $\boldsymbol{i}$ th transportation route, $\boldsymbol{r_{i2}}$ is the quantity of Type II passenger vehicles unloaded at Point $\boldsymbol{D}$ on the $\boldsymbol{i}$ th transportation route, and $\boldsymbol{r_{i3}}$ is the quantity of Type III passenger vehicles unloaded at Point $\boldsymbol{D}$ on the $\boldsymbol{i}$ th transportation route; $\boldsymbol{s_{i1}}$ is the quantity of Type I passenger vehicles unloaded at Point $\boldsymbol{B}$ on the $\boldsymbol{i}$ th transportation route, $\boldsymbol{s_{i2}}$ is the quantity of Type II passenger vehicles unloaded at

Point $\boldsymbol{B}$ on the $\boldsymbol{i}$ th transportation route, and s_{i3} is the quantity of Type III passenger vehicles unloaded at Point $\boldsymbol{B}$ on the $\boldsymbol{i}$ th transportation route; $\boldsymbol{aa_{ij}}$ is the quantity of Type I passenger vehicles loaded by the $\boldsymbol{i}$ th type of vehicle transporters in the $\boldsymbol{j}$ th full loading scheme, $\boldsymbol{bb_{ij}}$ is the quantity of Type II passenger vehicles loaded by the $\boldsymbol{i}$ th type of vehicle transporters in the $\boldsymbol{j}$ th full loading scheme, and $\boldsymbol{cc_{ij}}$ is the quantity of Type III passenger vehicles loaded by the $\boldsymbol{i}$ th type of vehicle transporters in the $\boldsymbol{j}$ th full loading scheme; $\boldsymbol{x_{ijk}}$ is the quantity of the $\boldsymbol{k}$ th type of vehicle transporters used for loading the passenger vehicles on the $\boldsymbol{i}$ th transportation route according to the $\boldsymbol{j}$ th full loading scheme. Subsequently, according to the subject meaning, the minimization of the quantity of the vehicle transporters used for finishing the transportation tasks for the five destinations is taken as the objective, the demand quantities of the passenger vehicles on the three transportation routes and the condition that the quantity of Type 1-2 vehicle transporters is at most 20% of the quantity of Type 1-1 vehicle transporters are taken as the constraint conditions. Correspondingly, the integer programming model of the transportation plan is as follows:

$$\min = \sum_{j=1}^{27}\sum_{i=1}^{3} x_{ij1} + \sum_{j=1}^{22}\sum_{i=1}^{3} x_{ij2} + \sum_{j=1}^{42}\sum_{i=1}^{3} x_{ij3} + \sum_{j=1}^{35}\sum_{i=1}^{3} x_{ij4} + \sum_{j=1}^{16}\sum_{i=1}^{3} x_{ij5} + \sum_{j=1}^{20}\sum_{i=1}^{3} x_{ij6} + \sum_{j=1}^{35}\sum_{i=1}^{3} x_{ij7} + \sum_{j=1}^{35}\sum_{i=1}^{3} x_{ij8} + \sum_{j=1}^{1}\sum_{i=1}^{3} x_{ij9} + \sum_{j=1}^{15}\sum_{i=1}^{3} x_{ij10}.$$

$$s.t.\ \sum_{j=1}^{27} x_{ij1}\cdot aa_{1j} + \sum_{j=1}^{22} x_{ij2}\cdot aa_{2j} + \sum_{j=1}^{42} x_{ij3}\cdot aa_{3j} + \sum_{j=1}^{35} x_{ij4}\cdot aa_{4j} + \sum_{j=1}^{16} x_{ij5}\cdot aa_{5j} + \sum_{j=1}^{20} x_{ij6}\cdot aa_{6j} + \sum_{j=1}^{35} x_{ij7}\cdot aa_{7j} + \sum_{j=1}^{35} x_{ij8}\cdot aa_{8j} + \sum_{j=1}^{1} x_{ij9}\cdot aa_{9j} + \sum_{j=1}^{15} x_{ij10}\cdot aa_{10j} = c_i + r_{1i} \quad i = 1,2,3 \tag{1}$$

$$\sum_{j=1}^{27} x_{ij1}\cdot bb_{1j} + \sum_{j=1}^{22} x_{ij2}\cdot bb_{2j} + \sum_{j=1}^{42} x_{ij3}\cdot bb_{3j} + \sum_{j=1}^{35} x_{ij4}\cdot bb_{4j} + \sum_{j=1}^{16} x_{ij5}\cdot bb_{5j} + \sum_{j=1}^{20} x_{ij6}\cdot bb_{6j} + \sum_{j=1}^{35} x_{ij7}\cdot bb_{7j} + \sum_{j=1}^{35} x_{ij8}\cdot bb_{8j} + \sum_{j=1}^{1} x_{ij9}\cdot bb_{9j} + \sum_{j=1}^{15} x_{ij10}\cdot bb_{10j} = a_i + r_{2i} + s_{1i} \quad i = 1,2,3 \tag{2}$$

$$\sum_{j=1}^{27} x_{ij1}\cdot cc_{1j} + \sum_{j=1}^{22} x_{ij2}\cdot cc_{2j} + \sum_{j=1}^{42} x_{ij3}\cdot cc_{3j} + \sum_{j=1}^{35} x_{ij4}\cdot cc_{4j} + \sum_{j=1}^{16} x_{ij5}\cdot cc_{5j} + \sum_{j=1}^{20} x_{ij6}\cdot cc_{6j} + \sum_{j=1}^{35} x_{ij7}\cdot cc_{7j} + \sum_{j=1}^{35} x_{ij8}\cdot cc_{8j} + \sum_{j=1}^{1} x_{ij9}\cdot cc_{9j} + \sum_{j=1}^{15} x_{ij10}\cdot cc_{10j} = e_i + r_{3i} + s_{2i} \quad i = 1,2,3 \tag{3}$$

$$\left(\sum_{j=1}^{27}\sum_{i=1}^{3} x_{ij1} + \sum_{j=1}^{22}\sum_{i=1}^{3} x_{ij2} + \sum_{j=1}^{42}\sum_{i=1}^{3} x_{ij3} + \sum_{j=1}^{35}\sum_{i=1}^{3} x_{ij4} + \sum_{j=1}^{20}\sum_{i=1}^{3} x_{ij6} + \sum_{j=1}^{35}\sum_{i=1}^{3} x_{ij7} + \sum_{j=1}^{35}\sum_{i=1}^{3} x_{ij8}\right)\cdot 0.2 - \sum_{j=1}^{16}\sum_{i=1}^{3} x_{ij5} - \sum_{j=1}^{15}\sum_{i=1}^{3} x_{ij10} \ge 0 \tag{4}$$

$$\sum_{j=1}^{3} \boldsymbol{r_{ij}} = \boldsymbol{d_i} \quad \boldsymbol{i} = 1,2,3 \tag{5}$$

$$\sum_{j=1}^{2} \boldsymbol{s_{ij}} = \boldsymbol{b_i} \quad \boldsymbol{i} = 1,2,3 \tag{6}$$

$$\sum_{j=1}^{27}\sum_{i=1}^{3} x_{ij1} \le 21\ ;\ \sum_{j=1}^{22}\sum_{i=1}^{3} x_{ij2} \le 18\ ;\ \sum_{j=1}^{42}\sum_{i=1}^{3} x_{ij3} \le 22\ ;\ \sum_{j=1}^{35}\sum_{i=1}^{3} x_{ij4} \le 15\ ;\ \sum_{j=1}^{16}\sum_{i=1}^{3} x_{ij5} \le 10\ ;$$

$$\sum_{j=1}^{20}\sum_{i=1}^{3}x_{ij6}\leq 25;\sum_{j=1}^{35}\sum_{i=1}^{3}x_{ij7}\leq 4;\sum_{j=1}^{35}\sum_{i=1}^{3}x_{ij8}\leq 6;\sum_{j=1}^{1}\sum_{i=1}^{3}x_{ij9}\leq 5;\sum_{j=1}^{15}\sum_{i=1}^{3}x_{ij10}\leq 15 \quad (7)$$

Where all variable are positive integers and the constraint conditions therein are explained as follows: ① represents the demand quantity constraints of the three types of passenger vehicles on the first transportation route ($\boldsymbol{O}-\boldsymbol{D}-\boldsymbol{C}$); ② represents the demand quantity constraints of the three types of passenger vehicles on the second transportation route ($\boldsymbol{O}-\boldsymbol{D}-\boldsymbol{B}-\boldsymbol{A}$); ③ represents the demand quantity constraints of the three types of passenger vehicles on the third transportation route ($\boldsymbol{O}-\boldsymbol{D}-\boldsymbol{B}-\boldsymbol{E}$); ④ represents the vehicle transporter dispatching proportion constraint, and Type 1-2 vehicle transporters have high transportation cost, so the quantity of Type 1-2 vehicle transporters shall not be more than 20% of the quantity of Type 1-1 vehicle transporters at each time in order to conveniently arrange the subsequent tasks; ⑤ represents the demand quantity constraints of the three types of passenger vehicles at Point $\boldsymbol{D}$; ⑥ represents the demand quantity constraints of the three types of passenger vehicles at Point $\boldsymbol{A}$; ⑦ represents the quantity constraints of the ten types of vehicle transporters.

LINGO software is adopted for programming to obtain the globally optimal solution of the model, namely 126. The dispatching summary result is as shown in Table 3 (according to the dispatching result, No.6 vehicle transporters are surplus, so one No.6 vehicle transporter is dispatched to load four Type IV passenger vehicles, and such result is also included in the summary table, so the total quantity of the vehicle transporters is 127, namely the optimal dispatching scheme):

Table 3. Dispatching Result Summary

No.	Vehicle Transporter Type	Transportation Route			Total
		O-D-C	O-D-A	O-D-E	127
1	Eight-position Dual-bridge Edge-wheel Van Type 1-1	16	0	5	21
2	Ten-position Dual-bridge Dual-wheel Van Type 1-1	8	7	3	18
3	Twelve-position Dual-bridge Dual-wheel Van Type 1-1	0	20	2	22
4	Ten-position Dual-bridge Edge-wheel Van Type 1-1	0	14	1	15
5	Nineteen-position Dual-bridge Dual-wheel Framework Type 1-2	1	2	3	6+1
6	Ten-position Single-bridge Dual-wheel Framework Type 1-1	3	0	1	4
7	Ten-position Single-bridge Dual-wheel Framework Type 1-1	0	4	0	4
8	Ten-position Single-bridge Dual-wheel Framework Type 1-1	9	0	7	16
9	Nineteen-position Dual-bridge Dual-wheel Framework Type 2-2	1	0	4	5
10	Seventeen-position Dual-bridge Dual-wheel Framework Type 1-2	4	7	4	15

Table 4. Full Loading Combination of Ten Types of Vehicle Transporters and Transporter Quantities on Three Transportation Routes

Vehicle Transporter No.	Full Loading Mode No.	Quantity of Type I Vehicles Loaded	Quantity of Type II Vehicles Loaded	Quantity of Type III Vehicles Loaded	Vehicle Transporter Quantity under Same Full Loading Mode			
					Total	O-D-C	O-D-A	O-D-E
1	16	2	0	5	16	16	0	0
	13	0	8	0	5	0	0	5
2	10	3	1	3	15	8	7	0
	3	0	2	6	3	0	0	3
3	26	1	9	0	20	0	20	0
	25	1	8	1	1	0	0	1
	27	2	5	3	1	0	0	1
4	35	4	4	0	15	0	14	1
5	5	0	4	11	1	1	0	0
	16	4	0	10	2	0	2	0
	10	1	3	11	2	0	0	2
	12	2	0	13	1	0	0	1
6	8	3	0	4	4	3	0	1
7	35	4	4	0	4	0	4	0
8	35	4	4	0	12	9	0	3
	24	4	3	1	4	0	0	4
9	1	0	0	16	5	1	0	4
10	14	3	1	10	8	3	1	4
	15	4	0	10	7	1	6	0

5. Conclusion

Firstly, the passenger vehicles are classified in the paper; secondly, Matlab software is adopted for programming to find the full loading scheme of each type of vehicle transporter so as to significantly reduce the number of the model variables, and the integer programming model is established to solve the transportation plan problem; thirdly, LINGO software is adopted for programming to solve the above model to obtain the globally optimal solution (the passenger vehicle classification can also influence the result, and the more detailed classification can result in more full loading schemes and more model variables, so the result less than 127 can be theoretically obtained). In conclusion, the whole calculation process is convenient and efficient, and the model has wide applicability. For example, if transportation demand points and quantities & types of passenger vehicles and vehicle transporters are increased, the globally optimal solution can be also found through changing some variable values and adding some constraint conditions on the basis of the established model.

Acknowledgement

The research is supported by Dr. special funds of the Corps in Xinjiang (2013BB013) and PhD project of Principal Funds in Tarim University(TDZKBS201205)

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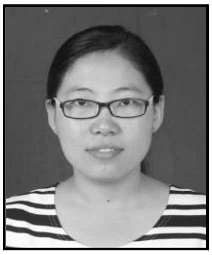

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