Optimization of parts logistics network in East China based on multiple delivery methods

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Abstract. This paper mainly discusses the optimisation strategy of FAW Logistics in parts logistics network management. For the pickup programme of parts logistics, it combines multimodal transport and third-party logistics. For orders from different suppliers, diversified pickup methods are adopted, mainly including direct delivery, circular pickup, and transshipment through distribution centres. For orders with large volumes, direct trucking is used to reduce transit and improve efficiency. For orders from suppliers in Hubei Province, circular pickup is used. For large-volume orders, large transport vehicles are chosen to be used directly to reduce costs and transport time. Most orders from Wenzhou and Taizhou are transshipped through Zhejiang or Shanghai distribution centres. By optimising the scheme, a 24.84% reduction in cost was achieved for the same order cycle, significantly improving logistics efficiency and economy. This study not only has practical guidance significance for the enhancement and change of FAW Logistics' development strategy, but also promotes the company's sustainable development.

Keywords: FAW Logistics, Logistics Network Planning, Parts Logistics, NSGA-II Algorithm.

1. Introduction

FAW Logistics Co., Ltd [1] (hereinafter referred to as FAW Logistics) is a professional logistics enterprise of China First Automobile Group Corporation (FAW Group), a wholly-owned subsidiary of FAW Group. FAW Logistics is a leading comprehensive solution provider in the domestic automotive logistics industry, providing customers with professional pre-production, production and post-production integrated whole value chain logistics services. The business scope of FAW Logistics includes automobile vehicle logistics service, parts logistics service, warehouse management service, international logistics service, supply chain management service and value-added service.

Although there are eight collection centres in the current parts logistics network, many collection centres have too large a pick-up radius [2], so this paper mainly discusses the strategy and practice of FAW Logistics East China Regional Company in the optimization of the parts logistics network, focusing on two core issues: firstly, the straight-line transport distance from the supplier to the OEM, and secondly, the scientific selection of sites for the collection and distribution centres [3]. In order to significantly improve logistics efficiency and compress costs, the optimal supply chain nodes are screened out by precisely calculating the straight-line distances from 360 suppliers to the Shanghai base [4], and efficient transshipment solutions for distribution centres are designed for those suppliers that are not suitable for direct transport.

This paper takes the data of FAW-Volkswagen in parts logistics network as an example for research, and the data comes from http://www.clpp.org.cn.

2. Optimisation of parts logistics network of East China Regional Company

2.1. Model assumptions

This section details the assumptions made about Lorries, containers and their associated transport costs, details of which are shown in Table 1.

Table 1. Trucks and containers and transport costs.

Parameter	Numerical value
40ft container size	11.8m*2.13m*2.18m
Volume	$54m^3$
Unit Transport Cost	5.278 Yuan/km
Start-up cost	200RMB
Railway transport costs	532 Yuan/box, 3.357/box-kilometre

In the study, this paper selects 40-foot container as the standard transport unit to better adapt to the demand of intermodal transport. Considering the actual loading rate [5], this paper takes the 85 per cent volume fill rate as the criterion for determining full and non-full loads, i.e., 45.9 m^3 as the full load limit. This assumption is intended to simplify transport costing and standardise transport to ensure adaptability and flexibility to multiple transport modes.

2.2. Comparison of three modes of transport

For the logistics transport of parts and components in East China, this paper mainly discusses three modes as shown in Table 2.

Table 2. Comparison of the three modes of transport.

	Pick-up mode	Scope of application
A	Point-to-point direct mode	Large volume of goods from a single supplier, direct delivery of full trucks
B	End-to-end distribution mode[6]	The number of suppliers, small volume, long distance, not full of trucks
C	Cyclic pickup direct mode[7]	The scale of supply is located in the middle level of the region, a number of suppliers take turns to supply, full trucks and long-distance transport

Regarding the three pickup modes for comparison, a point-to-point direct delivery mode is very suitable for full truck direct delivery. For the two pickup modes B and C, this paper will establish a multi-objective model to go for the quantification of specific scenarios.

2.3. Supplier planning using model A

In planning for suppliers using the Class a point-to-point direct delivery mode, the first concern of this paper is to determine the specific transport distance between the supplier and the OEM.

Considering that the actual road transport is not a straight line, this paper introduces a detour coefficient [8] (denoted by β) to adjust the calculation results to be closer to the actual transport distance. Within China, this coefficient is approximately 1.265. In addition, the average radius of the earth is considered to be 6371.004 kilometres, which in turn allows this paper to apply the following formula to estimate the distance between latitude and longitude:

$$S_{AB} = R \times \arccos\left[\sin(wA)\sin(wB) + \cos(wA)\cos(wB)\cos(jA - jB)\right] \times \beta \tag{1}$$

$$wA = LatA \times \frac{\pi}{180} \tag{2}$$

$$jA = LngA \times \frac{\pi}{180} \tag{3}$$

Where Lat the latitude of the coordinate point is, Lng is the longitude of the coordinate point.

Secondly, this paper based on the annual cargo volume selected weekly cargo volume as the reference value of the carrying capacity [9] for the weekly cargo volume is greater than 45.9m3 suppliers, directly choose a kind of point-to-point direct mode of transport, part of the data see Table 3.

Table 3. Vendors that opted for the direct point-to-point delivery model of type A.

vendor	Trunk 1	Trunk 2	Destinations	Weekly cargo volume (m³/year)
1010	Chuzhou	Changchun	Destinations	93.70
…	…	...	...	…
1175	Cixi	Changchun	Destinations	701.38
1179	Ningbo	Changchun	Destinations	70.95

With regard to the mainline transport mentioned in the table, that is, the long-distance transport between two cities, railway transport is a feasible and economical option, provided that no special emphasis is placed on transport time. This mode not only effectively reduces logistics costs, but also reduces reliance on road transport, thereby alleviating road congestion and reducing carbon emissions to a certain extent, which is in line with the development trend of green logistics.

2.4. Supply programmes for vendors unable to use type A point-to-point transport

For cannot use A kind of point-to-point transport supplier supply programme to cost and timeliness, this paper establishes a multi-objective planning model [10].

Vehicle travelling distance and comprehensive cost as the objective function, X_{ij} to indicate the decision variables, if the vehicle i service the customer point j , then the decision variables take the value of 1, and vice versa take the value of 0; I indicates the distribution vehicle set, J indicates the distribution customer node set, D_{jg} indicates the distribution customer node node j and g between the distance. In the logistics distribution task, fixed costs refer to all the regular overheads that the enterprise must bear to complete the transport task, which includes but is not limited to the driver's salary, the daily maintenance and repair costs of the vehicle, and so on. In addition, variable costs such as fuel consumption and wear and tear of vehicles increase significantly as the transport distance increases.

$$\min F = \sum_{i \in I} \sum_{j \in J} \sum_{g \in J} X_{ijg} D_{jg} \tag{4}$$

$$\min G = \sum_{i \in I} \sum_{j \in J} X_{ijg} + \sum_{i \in I} \sum_{j \in J} C_i X_{ij} \tag{5}$$

$$s.t. \begin{cases} \sum_{n \in N} h_n x_{ij} \le R, \forall i \in I \\ \sum_{g \in J} X_{ijg} - \sum_{v \in J} X_{ijv} = 0, \forall i \in I \\ A_n \le t_n \le B_n, \forall n \in N \end{cases} \tag{6}$$

Some of the calculation results are shown in Table 4.

Table 4. Straight-line distance from suppliers to Shanghai distribution centre.

Supp lier	Supplier Address	Distance to Shanghai collection point(km)
1001	No.159, Jingqi Road, Dingmao Development Zone, Zhenjiang, China	185.129
1002	No.60, South Quanquan Road, Economic and Technological Development Zone, Wuhan, Hubei, China	687.292
1003	No.599, Hehai West Road, Haimen City, Jiangsu Province, China	66.168
1004	No.99, Yuxi East Road, Qiandeng Town, Kunshan City, Suzhou, China	16.663
1005	No.660, Lushan Road, Hi-Tech Zone, Suzhou, Jiangsu, China	65.893

Table 5 below shows 20 representative transport arrangements for suppliers that can use the B end-to-end consolidation mode and the C recycle pickup mode for direct shipment.

Table 5. Transport Arrangements for Type B or Type C Pickup Mode.

Supplier	City	Direction	Cargo volume (m^3/year)	Weekly Order Quantity	Transport method
1001	Zhenjiang	Chengdu	2.65	0.66	Firstly by road to Shanghai distribution centre, then by rail to Chengdu, and finally by road for local distribution to reach
…	...	...	...	...	...
1119	Jiading	Dalian	0.44	0.11	First transported to Shanghai distribution centre by road, then transported to Dalian by rail, and finally delivered locally by road.
1034	Nanjing	Foshan	110.65	27.66	First by road to Shanghai distribution centre, then by rail to Foshan, and finally by road for local delivery.

For those suppliers who are not suitable for the three standard pick-up modes A, B and C, this section proposes two special arrangement strategies with cost-effectiveness at the core: ① Establishing a new secondary distribution centre; ② Incorporating flexible logistics solutions such as third-party logistics.

2.4.1. Establishment of new secondary distribution centres

Considering that many suppliers are concentrated in Zhejiang Province, it is recommended that a secondary distribution centre be set up here to optimise the overall logistics layout [11].

(1) Establishment of secondary distribution centres in Zhejiang Province

In order to determine the location of the secondary collection centre more accurately, the alternative locations are set as all county-level cities in Zhejiang Province, as shown in Table 6.

Table 6. County-level cities in Zhejiang Province.

serial number	County-level cities	serial number	County level city	serial number	County level city
1	Jiande	2	Shengzhou	3	Shengzhou
…	.....	…	…	…	…
13	Yueqing	14	Dongyang	15	Dongyang
16	Zhuji	17	Yongkang	18	Yongkang

The model is built with the minimisation of pick-up cost as the objective function as follows.

$$\min Cost = \gamma_{ij} + \alpha_{ij} \times GASS\left(d_{ij} - \beta_{ij}\right) \tag{7}$$

The driving distance d_{ij} between the supplier i and the alternative secondary distribution centre j, the cost per unit mile between the supplier i and the alternative secondary distribution centre j is α_{ij}, the starting volume for the section is β_{ij}, and the starting price is γ_{ij}. The function $GASS\left(d_{ij} - \beta_{ij}\right)$ converts negative numbers to zero.

Calculate the cost of picking up goods delivered by Zhejiang's suppliers to each prefecture level city as shown in Table 7.

Table 7. Pick-up costs for each prefecture level city.

prefecture level city	Pick-up costs (¥)	prefecture level city	Pick-up costs (¥)	prefecture-level city	Pick-up costs (¥)
Jiande	699.63	Shengzhou	634.52	Yiwu	640.52
...	…	...	…	...	…
Yueqing	620.21	Dongyang	672.32	Yuhuan	647.32
Zhuji	621.36	Yongkang	652.31	Longquan	657.92

Quantitative analysis according to the above table can be seen that the difference between each prefecture-level city is not big, so for the above prefecture-level cities and then qualitative analysis.

Combined with the relevant land prices and policies, the county-level city is determined to be Yueqing City, and through quantitative and qualitative analysis, this paper determines that the construction of the secondary distribution centre in Yueqing City is the optimal solution.

(2) Examination of land prices in Yueqing City, Zhejiang Province

According to the document [Le Zheng Fa [2023] No. 12], it can be found that the price of Grade I storage land is RMB 1,030 per square metre, and the price of Grade VIII storage land is RMB 420 per square metre.

(3) Calculation of the area of the secondary distribution centre in Yueqing, Zhejiang Province

In order to estimate the area of a secondary distribution centre, this paper adopts a method based on the ratio of the suppliers' annual shipment volume [12] to the total number of weeks to determine the reference footprint. This method takes into account the variability of annual shipments among suppliers and introduces a correction factor (λ) through the standard deviation (σ) and mean (μ) of the samples to achieve a more accurate area estimation. The correction factor (ψ) is calculated as follows:

$$\psi = \frac{\sigma}{\mu} \tag{8}$$

Where σ represents the standard deviation of the annual volume of goods/total number of weeks for all suppliers and μ represents the mean. This correction factor λ will be used to adjust the initial estimated footprint to account for the volatility and heterogeneity of the distribution of shipments in the supply chain.

S_{wl} Is calculated as follows:

$$S_{\text{wl}} = \frac{S_{\text{sas}}}{58} \times \psi = \frac{\sum_{i=1}^{13} x_i}{58} \times \frac{\sigma}{\mu} \tag{9}$$

S_{estimate} Is calculated as follows:

$$S_{\text{estimate}} = \frac{\sum_{i=1}^{13} x_i}{58} \times \frac{\sigma}{\mu} + S_{\text{o1}} \tag{10}$$

Substituting the referenced data, the estimated area of the secondary distribution centre can be obtained as follows:

$$\begin{aligned} S_{\text{estimate}} &= \frac{6231.903622}{58} \times \frac{873.4630566}{432.844144} + 30 \\ &= 246.8231899109565662 \approx 247 \end{aligned} \tag{11}$$

The reference coordinates of the specific Yueqing secondary distribution centre are $(120.967147, 28.116083)$.

In Equation (9) (10) (11), S_{wl} denotes land for warehousing, S_{sas} denotes annual volume of supplier's goods, S_{estimate} and denotes estimated land.

From the map, the reference location is Huitou Village, which is close to Yueqing East Station and can be used for railway transport.

Combined with the land price, it can be concluded that the land cost of building a secondary distribution centre in Yueqing is $247 \times 1030 = 254410$ ¥

2.4.2. Use of third-party logistics for transport

With the establishment of the new secondary distribution centre, there will still be a proportion of vendors that are not suitable for the standard A, B and C pick-up patterns. These suppliers are widely distributed, with a distance of more than 300km from the secondary distribution centre; the pick-up volume is small. For such suppliers, third-party logistics services [13] (e.g., Cargo Lara) are considered to ensure the comprehensive coverage and efficient operation of the logistics network, while reducing operating costs. Based on this, the pickup scenarios using third-party logistics derived in this paper are shown in Table 8.

Table 8. Pick-up options using third-party logistics transport.

Supplier	City	Direction	Volume (m^3/year)	Weekly Order Quantity	Pick-up method
1014	Anqing	Chengdu	2.278	0.569	Delivery to Chengdu
…	...	...	…	…	...
1319	Wenzhou	Changchun	25.963	6.491	Delivery to Zhejiang Distribution Centre
1320	Wenzhou	Changchun	3.356	0.839	Delivery to Zhejiang Distribution Centre

2.5. Component logistics pick-up options and freight analysis

Based on the trunk distance d_i , annual cargo volume x_i , establish an integrated logistics cost model on the cost function φ . Let the weekly order quantity be $\frac{x_i}{54}$, and the container is a 40-foot standard container with a capacity of 54m³. Considering the actual situation, the container loading rate cannot reach 100%, so this paper is based on 85% loading rate (i.e. 45.9m³) can be used as the standard of the whole container transport to ensure the authenticity and reasonableness of the cost data [14]. Therefore, the number of standard containers is $\frac{x_i}{54\times 45.9}$, according to the research and the data of China Railway Network and the relevant platform of maritime transport, the expected cost of trunk transport in this paper is $532\times\frac{x_i}{54\times 45.9}+3.357\times d_i$. For all the feeder transport, because of local distribution, 40km is selected as the reference value, so the cost of local distribution is calculated as $40\times\frac{x_i}{54\times 45.9}$.

Therefore, the integrated logistics cost model can be expressed as:

$$\varphi = 532\times\frac{x_i}{54\times 45.9}+3.357\times d_i+40\times\frac{x_i}{54\times 45.9} \tag{12}$$

By calculating the cost of all orders, the total distribution cost of all suppliers' orders is obtained. For suppliers who are not suitable for using the AB two pick-up modes, this paper adopts the third-party logistics service to go to the distribution centre based on the principle of economic optimality. A secondary distribution centre has been set up in Huitou Village, Yueqing City, Zhejiang Province. In order to minimize the cost, this paper chooses to transport the goods of suppliers in Zhejiang Province to the secondary distribution centre in Huitou Village, Yueqing City, through third-party logistics. For suppliers in Anhui and Hubei, because the volume of goods cannot meet the requirements of the establishment of the distribution centre, and these two suppliers have a supply plan to the same destination, and the distance from the existing distribution centre is farther, so the use of circular pick-up method of the lowest cost. For the remaining suppliers with smaller supply volumes, this paper chooses to use third party logistics services to deliver directly to the destination. Through comparison, this paper finds that the Cargo Lara platform is the most cost-effective, so this paper can choose the Cargo Lara platform for third-party logistics transport.

Based on the above discussion, the partial order pickup methods for some of the 20 suppliers are obtained as shown in Table 9.

Table 9. Partial order pickup method for some suppliers.

Supplier	Direction	Cargo volume (m^3/year)	Pick-up mode
1010	Changchun	5059.69	A point to point direct mode
1001	Chengdu	2.6451	First to Shanghai distribution centre, then rail to Chengdu.
…	...	…	...
1014	Chengdu	2.2777	Delivery to Chengdu
1332	Qingdao	125.9260	Circular pickup in Anhui

Combining all the above pickup methods, we adopt diversified pickup methods for orders from different suppliers. For orders with large volume and shipped directly to Changchun, direct use of trucks directly, reducing transit to improve efficiency. Supplier orders from Hubei Province are picked up in a circular manner, especially for large orders, choosing to use large transport vehicles [15] directly to reduce costs and transport time. Most orders are transshipped through Zhejiang or Shanghai distribution centres. The aim of this strategy is to minimise logistics costs and ensure transport efficiency through the flexible use of multiple modes of transport, adopting the most appropriate logistics strategy for different suppliers and order situations.

In the economic calculation section, the analysis is based on a one-week ordering cycle, and before the optimisation, the logistics cost of parts for one ordering cycle is estimated to be RMB 2,775,777.695. After applying the optimisation solution in the report, the logistics cost for the same ordering cycle was reduced to RMB 2,086,448.134, achieving a cost reduction of 24.84%. The comparison of logistics costs of parts before and after optimisation is shown in Table 10 below.

Table 10. Comparison of parts logistics costs before and after optimization.

Project	Pre-optimisation costs	First year costs after optimisation	Costs in the second year after optimisation and beyond
Weekly Logistics Costs	2,775,777.69	2,086,448	2,086,448
Annual Logistics Cost	144,460,440.0	108,495,296	108,495,296
Container Cost	-	+6,000,000	-
Total Cost	144,460,440.0	114,495,296	108,495,296

(Unit: yuan)

3. Conclusions

Based on the actual logistics management needs of FAW-Volkswagen in East China, this study proposes an integrated logistics network optimisation scheme, aiming to solve the problems of inefficiency, high cost and unreasonable resource allocation in the existing logistics network.

In this paper, the operation mode of the existing logistics network is first thoroughly analysed and evaluated. Through the use of line standardised transport, combined with multimodal transport and third-party logistics, diversified pick-up methods are adopted for orders from different suppliers, including direct delivery, circular pick-up, and transshipment through distribution centres, and other strategies.

This study not only has practical guiding significance for the promotion and reform of the development strategy of FAW Logistics Company, and promotes the sustainable development of the company, but also provides a reference for other auto parts enterprises in the same industry to adjust their own strategies according to similar methods. In the increasingly fierce market competition, continuous strategic adjustment and innovation is the only way for the long-term stable development of enterprises.

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