

# The Research on the Auto Parts' Inbound Logistics Based on the Underground Logistics Mode

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**Abstract:** Because of the huge number of variety auto parts, inbound logistics is considered to be the most complicated and technical operation in the automobile logistics system. In order to raise the logistics level, the automobile company needs to strengthen the management of inbound logistics. The purpose of this paper is to find out the way in optimizing inbound logistics modes through theoretical and practical method. In the beginning, this paper introduces the relative concept about the inbound logistics. Then it focuses on the underground logistics which is derived from the mode of direct delivery supplier to assembly automobile manufacturer. The paper illustrates the theoretical research and operation of domestic and international status of this logistics mode and raises the questions about the operation of this mode. After doing the research by mathematical mode and making an analysis of the current case about the underground logistics mode, it summarizes the solution for the inbound logistics system. GT company case has shown that the logistics cost using the underground logistics mode is much less.

**Keywords:** Auto parts; inbound logistics; underground logistics; logistics management

## I. Introduction

The auto parts inbound logistics is the activities of receiving, storage and providing parts for manufacturing, including the transporting, storage, vehicle dispatching, containers' recycling of the manufacturing materials. In other words, the auto parts inbound logistics is the logistics economic value increasing activity to ensure the auto parts transported between the providers, the logistics company and the manufacturer<sup>[1]</sup>.

The underground logistics system is an all-new transportation and supply system for the solid goods using the automated guided vehicle system (AGV) and Dual Mode Trucks (DMT)<sup>[2]</sup>. Since the 90th in the 20th century, the research on the underground logistics method to transport the goods is paid attention by the western countries gradually, and is treated as one high-tech sector in the future. In Holland, the professional underground logistics system has been set up. In the past, Amsterdam, the capital of Netherlands, has the biggest flowers supply market in the world, and all the flowers are transported by the road transport systems. The traffic jam is a big threat for those

flowers that requires high time demands. So, they build the professional underground logistics system between the airport and the flower market, which are under the ground mostly except for only some destination locations, to shorten the time and increase the safety attribute<sup>[3]</sup>. Besides Holland, Japan also developed its underground logistics systems widely, in which country it's treated as one of the high-tech sectors supported by the government in the next following ten years. There are already the underground tunnels 201 km long and 106 warehouses in Tokyo. The underground system is expected to transport 36% goods in Tokyo and can increase the vehicles' speed on ground by 30%. The total benefit can amount to 1.2 billion yen per year, including decreasing the vehicle's running cost, the running time and incidence rate and carbon dioxide emissions<sup>[4]</sup>.

In England, the ground logistics has been used for a long time. Since 1928, there is a mail transporting system running under the streets in London, connecting the 9 states between Paddington and White Chapel, dealing with more than 4 million posts<sup>[5]</sup>. And now there is a new auto underground logistics transportation system in London, in which the inside diameter is 2.74 meters, the maximum capacity is 1 ton per truck and the maximum speed is 60 km/h. England is the first country to do research on the tunnel transportation method and the best country to apply this way<sup>[6]</sup>.

In china, the underground logistics method isn't applied yet and the research in this field is very less, but in some cities the studying is gradually started. Some scholars proposed that the underground logistics maybe appropriate airport logistics center, for example the Beijing's Capital Airport<sup>[7]</sup>. First, the airport logistics center is fully-equipped public utility and infrastructure, with the functions of producing, transporting and distribution. If the underground logistics system is build there, the cost can be lower than others for the already existed land and facilities in the center. Second, the goods are very standard in the attributes of type, packing and delivery equipment, which are very suitable for the underground logistics way. Third, this way can void the unfavorable weather condition in Beijing. Though the project is not in process, relative research has started now<sup>[8]</sup>.

## II. The Operation Process of the Underground Logistics Mode

### The Fundamental Principle of the Underground Logistics Mode

In order to decrease the storage and shorten the procurement period, some auto parts providers usually build the automobile manufacturers near the car manufacturer, forming the supplier park. The auto parts are usually delivered in an order, which is the assembly line order. In order to increase the response speed, the tunnels are usually built connecting the auto parts supplier and the automobile manufacturer directly instead of the public road system. The auto parts suitable for this kind of transportation method are the very complicated professional module, or the ones that can be quickly assembled.

There are some differences between the underground logistics method and the milk run method: first, the main feature of the underground logistics mode is JIT, picking up the auto parts according to the assembly line order and delivering them just in time to the right place; second, the tunnels and the vehicles are special designed for the different auto parts and the accessory facilities are also needs special designed. Third, the automobile manufacturer should send the assembly line data to the provider in time to ensure that all the data the provider have are very new.

The underground logistics mode is run like the figure I.

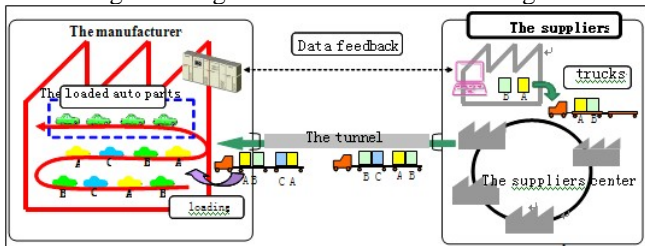


Figure I The Schematic Drawing of the Underground Logistics Mode

### The Implement Conditions of the Underground Logistics Mode

The underground logistics method is a very special way, so its applying conditions are very strict, which involve the transportation route, delivering equipment, loading platform and information system.

#### (1) The special auto parts transportation route

The underground logistics mode needs to be applied under the ground, using the tunnel, and the tunnel should satisfy the special vehicles running on the two-way road. The tunnels are usually used to connect the auto parts supplier and the automobile manufacturers, choosing the shortest way, so the factors about the drain, lighting, geological structure and other factors.

#### (2) The special delivering equipment

Because the special attribute of this logistics mode, the delivering equipments should be made special to work flexibly. So, the small towing vehicles are suitable for this mode. Besides the towing vehicle, the trailer also should be made special to store and deliver the auto parts to protect the goods and increase the loading and unloading speed.

#### (3) The special loading platform

At the provider location and the automobile manufacturer, special loading platforms are needed to load and unload the

auto parts. For the automobile manufacturer, the special loading platform can be set up near the assembly line to shorten the auto parts' transportation distance.

#### (4) The excellent information system

To achieve the purpose of transporting the manufacturing data, including the assembly order data to the auto parts provider quickly and precisely, the powerful information system is necessary and indispensable.

### The Features of Auto Parts Underground Logistics Mode

There are many features for the auto parts' underground logistics mode, which make the mode in auto parts' transportation is very unique and different.

#### (1) Picking up auto parts with high frequency, low volume and JIT

Because the underground logistics can avoid the traffic jam, bad weather condition and other things, the auto parts can be distributed immediately by the supplier when the automobile manufacturer's plan changed. This is a more optimized mode than others, for which the features are high frequency, low volume, non scheduled and quantified. The assembly schedule may change and the provider should deliver the goods as they ordered, and the underground logistics can deal with this problem and satisfy the JIT requirement.

#### (2) Point to point way transportation

The underground logistics can deliver the auto parts from the provider to the automobile manufacturer directly, the point to point way. And the underground logistics can also provide auto parts using the several-for-one way and the trucks can pick up the auto parts in different places.

The auto parts providers usually are located no more than 2 kilometers from the automobile manufacturer, connecting with the tunnels directly, so the transportation safety and efficiency can be satisfied.

#### (3) The strictly controlled running route

The underground logistics mode is based strictly on the running route schedule, controlling the driving speed, driving route and no stopping. So the traffic capacity should be designed more precisely, which was the difficulty for this logistics mode.

#### (4) Flexible production control

The underground logistics are more suitable for the flexible production, because the providers can response very quickly to the automobile manufacturer orders. The auto parts providers can stop the delivering immediately to avoid the big amount of storage and they also can control the inventory level.

#### (5) Transportation rhythm accord with the take time

The underground logistics mode transportation is in accordance with the take time to deliver the auto parts to the automobile manufacturer according to the order in time.

#### (6) High efficiency transportation speed

In the underground logistics mode, the auto parts are delivered directly to the automobile manufacturer's assembly line, so the processes of storing in the warehouse, delivering the auto parts from the warehouse to the

assembling line are saved and the underground logistics mode is more efficient.

### III. The Planning Method and Model for the Auto Parts' Inbound Logistics Based on the Underground Logistics Mode

#### The Planning Principle for the Auto Parts' Inbound Logistics Based on the Underground Logistics Mode

The construction for the underground logistics is very complicated, so the early planning is necessary, especially the tunnel entrance. When selecting the tunnel entrance position, we should follow those following principles.

##### (1) Economic principle

The logistics links include the tunnels at the automobile manufacturer and the suppliers' location, and the costs include the construction cost the logistics cost (the operating cost). To save the costs, only one or two tunnels are built between the automobile manufactures and auto parts supplier center.

##### (2) The natural environment accommodation principle

On the tunnel site selecting process, the factors of climate condition, geological condition and geographic condition should be considered very carefully. For example, the tunnel's ventilation condition, moisture controlling, whether there are the silt seam or the loose soil seam, whether it can influence the buildings on the ground and other things.

##### (4) The strategic consideration

The ordinance of the underground logistics system with the road transportation in the logistics center should be considered carefully, and the construction plan should be global and long-term.

##### (4) The dynamic principle

The construction plan should consider the changes in the future more and should do more searches on the demand in the future.

#### The Planning Model of the Underground Logistics

The planning for the underground logistics system should consider more about the economic principle, so the layout of the auto parts suppliers besides the automobile manufacturer is very important. The suppliers' center should line with the manufacturer rather than circling around it. It can be shown in the figure II.

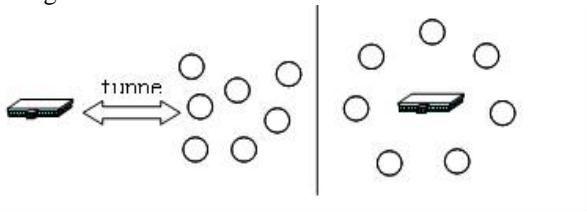


Figure II The Layout of the Suppliers Relative to the Manufacturer

The tunnel connects the automobile manufacturer and the supplier center, and the tunnel entrance site selecting in the suppliers center is the main task. It's a single facility location problem, which can be solved with the center of

gravity method.

The model can be described as follows. There are  $n$  suppliers as shown in figure III.

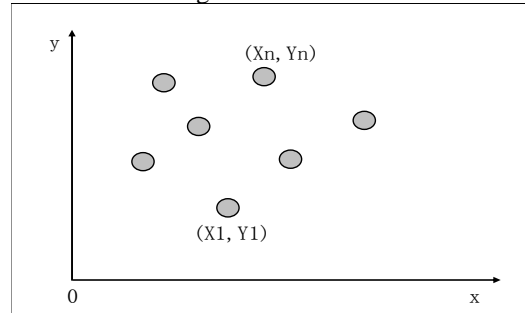


Figure III The Suppliers' Position

##### (1) The know conditions

- 1) The coordinate of each supplier is  $(X_i, Y_i)$  ( $i = 1, 2, 3, \dots, n$ );
- 2) The amount delivered from each auto parts supplier per day is  $V_i$  ( $j = 1, 2, 3, \dots, n$ );
- 3) The transportation rate in this supplier center is  $R_i$ ;
- 4) The tunnel entrance's coordinate in the supplier center is  $(X_0, Y_0)$ ;

##### (2) Assumptions

In order to simplify the single facility location problem, there are some assumptions:

- 1) The transportation cost is proportional to the distance;
- 2) The transportation route is straight;
- 3) The construction cost in different sites is equal;
- 4) Ignore the transportation changes in the future;
- 5) The tunnel entrance in the supplier center to other supplier's distance is  $D_i$ . The formula is:

$$D_i = k\sqrt{(X_i - X_0)^2 + (Y_i - Y_0)^2} \quad (1)$$

In this formula,  $k$  is the proportional scales of the coordinate unite with the real space distance.

##### (3) Mathematical model

The objective function of the model is minimizing of the total cost, i.e.:

$$\text{Min TC} = \sum V_i R_i D_i \quad (2)$$

In this formula,  $\text{TC}$  is the auto parts' total delivering out amount transportation cost of all the suppliers per day;  $V_i$  is the delivering amount for supplier  $i$  per day;  $R_i$  is the transportation rate from the tunnel entrance of the suppliers center to supplier  $i$ ;  $D_i$  is the distance from the tunnel entrance of the suppliers center to supplier  $i$ ;

Make out the derivative of the objective function and substitute the distance formula, and then equate the coordinate of the tunnel entrance of the suppliers' center as follows:

$$X_0 = \frac{\sum V_i R_i x_i / D_i}{\sum V_i R_i / D_i} \quad (3)$$

$$Y_0 = \frac{\sum_i V_i R_i y_i / D_i}{\sum_i V_i R_i / D_i} \quad (4)$$

(4) The solving steps of the center of gravity method

1) Determine the coordinate, delivering amount and transportation rate of the suppliers;

2) Making out the primary coordinate  $(\bar{X}_0, \bar{Y}_0)$  according to the formula (3) and formula (4). The distance is supposed to be 1, i.e.,  $D_i = 1$ ;

$$\bar{X}_0 = \frac{\sum_i V_i R_i x_i}{\sum_i V_i R_i} \quad (5)$$

$$\bar{Y}_0 = \frac{\sum_i V_i R_i y_i}{\sum_i V_i R_i} \quad (6)$$

3) Make out the distance  $D_i$  according to  $(\bar{X}_0, \bar{Y}_0)$ , where the scale coefficient  $k$  is not concerned.

4) Substitute the distance  $D_i$  into formula (3) and formula (4), and then make out the revised coordinate  $(X_0, Y_0)$ ;

5) Make out the distance  $D_i$  using the revised coordinate  $(X_0, Y_0)$ ;

6) Repeat the step 4) and step 5) until the changes of  $(X_0, Y_0)$  are less than the desired error range;

7) Make out the total transportation cost using the acceptable coordinate.

8) Fix the final coordinate of the tunnel entrance in the suppliers' center based on the real space condition and other influencing factors.

The passing ability is the maximum number of the vehicles passing through the tunnel's some place in a fixed time period limited by the road condition and traffic control, which is basic index for road planning and managing, and the unit is pcu/h.

The production ability of the automobile manufacturer can affect the frequency of the delivering times, so the tunnel's passing capacity can be influenced by the production ability. The tunnel's passing capacity model can be described as follows:

(1) Theoretical model

The headway distance is the distance between of the two cars' heads, and the tunnel's passing capacity can be made out using the headway distance algorithm.

Supposing the vehicles is running on the tunnel at a constant speed,  $v$  km/L one car by one car with the minimum vertical distance  $I$ , so the passing capacity is as follows:

$$N_p = \frac{1000V}{L} = \frac{1000V}{L_0 + \frac{v}{3.6}t + \frac{v^2}{254(\varphi \pm i)} + l'} \quad (7)$$

In this formula,  $V$  is the driving speed;  $L$  is the headway distance ( $L = L_0 + S_0$ );  $L_0$  is the car's length;  $S_0$  is the stopping sight distance which includes the response distance

$v/3.6t$ , the braking distance  $S = v^2/254(\varphi \pm i)$  and the

headway distance  $l'$ ; i.e.  $S_0 = \frac{v}{3.6}t + \frac{v^2}{254(\varphi \pm i)} + l'$ ;

$t$  is the driver's response time, which is usually 1.2 second;  $\varphi$  is the friction coefficient, which is usually range from

0.3-0.4;  $i$  is the road slope;  $l'$  is the distance between the front car back and behind car's head, which is usually 5 m.

(2) The passing capability model of the tunnel in the real condition

When testing the capacity model in the real condition, the theoretical result is prepared with the real condition result to check if the tunnel can satisfy the production ability of the automobile manufacturer.

The known conditions can be shown as follows: the automobiles' production number per day is  $M$ ; the types of the auto parts delivered through the underground logistics system is  $m$ ; the take time is  $t_0$ (s/veh); the driving speed is  $v$ (s/km); the carrying capacity per transportation car is  $q$  automobiles' auto parts; the distance from automobile manufacturer to the suppliers' center is  $D$ ; the unloading time in the manufacturer is  $t_1$ ; the loading time at the suppliers is  $t_2$ .

The assumptions are shown as follows: the each car's carrying capacity is the same; each kind of auto parts are delivered by only one car; the assembly line's work time is 24 hours per day; there are  $n$  suppliers in the suppliers center and each supplier can provide  $x$  kinds of auto parts ( $x=1, 2, \dots, x$ ); the road in the tunnel is two-way lanes.

The passing capacity model of the tunnel in the real condition is described as follows:

The delivering period of each truck for certain auto parts is  $T_{nx}$ , i.e.

$$T_{nx} = \frac{2D_{nx}}{v} + t_1 + t_2 \quad (8)$$

The trucks numbers of certain supplier for certain auto part is  $C_{nx}$ , i.e.,

$$C_{nx} = \frac{T_{nx}}{qt_0} \quad (9)$$

The total number of the trucks is  $C$ , i.e.,

$$C = \sum C_{nx} \quad (10)$$

The auto parts delivered to the assembly line per hour are:

$$M_0 = \frac{M}{24} \quad (11)$$

The trucks needed to transport the  $M_0$  amount of auto parts are:

$$N_a = \frac{M_0}{q} \sum C_{nx} \quad (12)$$

$N_a$  is also can be treated as the tunnel's passing capacity, i.e.:

$$N_a = \frac{M}{24q} \sum \frac{\frac{2D_{nx}}{v} + t_1 + t_2}{qt_0}$$

(13)

Comparing the formula (7) and formula (13), if  $N_p > N_a$ , the passing capacity can satisfy the production ability.

IV. The Example

In this part, the model build in the former part is applied on a real case to check its feasibility and advantage.

The Background of the Example

GT Company is an automobile manufacturer, for which the designed capacity is 200 hundred cars per year in the first stage and is 160 hundred cars per year in the second planning stage. The auto parts suppliers are distributed at Guangdong, Tianjin and Shanghai, among which the suppliers' number in Guangdong is more than 90, constituting 88% of the total number. The logistics mode of suppliers at Tianjin and Shanghai is milk run way, and 50% of all the suppliers are located in the suppliers' center. In the suppliers' center, there are 14 suppliers and 12 in them provide 97% of all the more than 100 kinds of auto parts. The total volume of the auto parts needed per day is 4000 M3, and all the suppliers are located no more than 2 km from automobile manufacturer.

It's seen that 44% of the entire auto parts provided by the suppliers in the suppliers' center, so the logistics mode

selecting is really a problem.

The Solution for the Example

Use the underground logistics mode to the GT Company, building the two tunnels between the automobile manufacturer and the suppliers' center to transport the auto parts, using the special vehicles with two trailers. It's assumed that there are 12 suppliers in the center as shown in the figure IV.

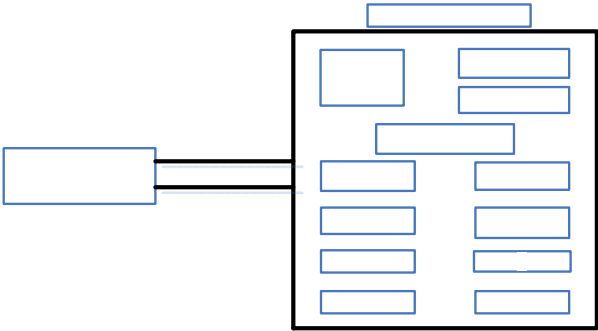


Figure IV The Suppliers' Position for GT Company

After the calculating, the results are compared with milk run way method, which is the present pattern for GT Company in the facility and staff occupying, project cost and transportation cost perspective.

Table I and table II are the facility and staff comparison of the underground logistics mode and the ground logistics method, from which we can see that the latter method is better.

Table I The Facility and Staff Occupation in Ground Logistics Way Mode

Auto parts	supplier	Demanding amount per day/M³	Project number	tractor	forklift					Traction battery car				carriages					People
					⑥	⑦	⑧	⑨	sum	⑩	⑪	⑫	sum	⑬	⑭	⑮	⑯	sum	
suspension girder	A	4000	6	18	6	12	12	4	34	26	11	37	200	152	60	412	168		
Oil tank	B																		
Exhaust pipe	C																		
...	...																		
...	...																		
...	...																		
Glasses	L																		
gates	M																		

Table II The Facility and Staff Occupation in Underground Logistics Mode

Auto parts	supplier	The demand	Project number	tractor		forklift	Traction battery		carriage	People number
				number	sum		number	sum		
Suspension	A	4000	6	1	18	0	1	18	0	54
Oil tank	B			2			1			
Exhaust	C			3			2			
...	...			...			...			
...	...			...			...			
...	...			...			...			
glasses	L			2			1			
gate	M			2			1			

The project cost is compared in table III.

Table III The Project Cost Comparison

Project	Cost (RMB/day)						Sum
	Vehicle Cost	Tractor Cost	Forklift Cost	Tractor Battery Car Cost	Carriage Cost	Staff Cost	
Ground Logistics	5070	0	4833	2027	452	10270	22652
Underground Logistics	0	3156	0	493	0	3510	7159

From table 3 we can see the underground logistics mode can save about more than 15 thousand RMB. The transportation cost is related with the transportation distance, so we can compare the transportation distance to compare the transportation cost. The data is shown in table IV and table V.

Table IV The Transportation Distance and Transportation Times of Ground Logistics Mode

supplier	Amount/M <sup>3</sup>	route	area	amount	Deliver amount	Deliver times	Deliver amount/time	distance/time (KM)	Distance /day
E	280	GT01	suppliers	600	40	16	37.50	4.3	68.8
F	232								
H	88								
K	310	GT02		470	40	12	39.17	7.5	90
L	160								
G	640	GT03		1110	40	28	39.64	5.6	156.8
I	410								
J	60	GT04		1090	45	24	43.75	4.0	96
D	1090								
A	230	GT05		680	40	18	37.78	7.10	127.8
B	300								
C	150								

Table V The Transportation Distance and Times of Underground Logistics Mode

end start	GT	Amount /day M <sup>3</sup>	Amount /car	Deliver times	Distance per car /day
L	2.2KM	160	12M <sup>3</sup> /car	14	61.6
K	2.0KM	130		26	104
D	1.0KM	1050		88	176
B	2.1KM	300		25	15
C	1.9KM	150		13	49.4
A	1.8KM	230		20	72
E	1.1KM	280		24	52.8
F	1.7KM	232		20	68
H	1.5KM	88		8	24
G	0.8KM	640		54	86.4
I	1.4KM	410		35	98
J	1.9KM	60		5	19

From the two tables above, it's shown that the transportation distance for the underground logistics mode is 540 kilometers and the transportation distance for the ground logistics way is 916 kilometers. In this case, we can see that the underground logistics mode is better than the ground logistics way method for GT Company.

V. The Conclusion

In this paper, it introduces the relative concept about the inbound logistics and it focuses on the auto parts' underground inbound logistics mode. Then it builds the

model to calculate the tunnel's entrance coordinate and the passing capacity of the tunnel. Finally, it applied the model to GT Company to check that the underground logistics mode is superior.

References

Please contact the author to get the reference lists.