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The research on green logistic network planning in manufacturing workshops

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ABSTRACT

As it involves many logistic activities, manufacturing workshops usually have higher logistic costs. The traditional logistic networks of manufacturing workshops normally pursue cost minimization while ignoring environmental protection. In the modern era filled with green logistic concepts, it is essential to transform traditional logistic networks in manufacturing workshops into a green logistic network with the characteristics of high economic benefit, full resource utilization and environmental protection. This paper analyzed the way to build green manufacturing logistic networks through adding recycle points and redesigning traditional logistic networks. Finally, it provided an example on how to set up greener logistic networks in manufacturing shops with concrete analysis and adopted heuristic algorithm to find out the best design solution.

KEYWORDS

Manufacturing workshops; Green logistic; Logistic networks; Heuristic algorithm.

INTRODUCTION

Manufacturing industry is a director indicator of a country's productivity whose development brings not only substantial economic profits but also severe environmental issues. Industrial manufacturing workshop in particular, with low energy efficiency, large amount of pollution, improper treatment and recycling of industrial wastes, posed a serious threat to eco-environment. Traditional logistic networks of manufacturing workshops focused only on cost minimization while ignoring collateral environment degradation. A wave of "green storm" has swept across the whole world since 1990s and the resulting "green reform" under the theme of sustainable development took place in different countries. Against this backdrop, a new concept of "green logistics" focusing on energy efficiency, pollution control and recycling has come into being. China has attached great importance to reform of traditional industries as well and put transformation of economic development pattern as its top priority in both "the 11th five-year-plan" and current "the 12th five-year-plan" advocating the building of energy saving and environmentally friendly society. Against this background, there comes the discussion on "green logistic in manufacturing sector". Establishing green logistic networks in manufacturing workshops and pursuing green logistic concept has become an unstoppable trend.

Study on green logistic should first begin in manufacturing workshops because the latter are the center of manufacturing enterprises representing the development productivity of a country. Manufacturing workshops featuring frequent logistic activities make up a higher percentage of overall production costs. There are many studies over manufacturing workshops in the rest of the world, focusing mainly on how logistic factors, routes and technologies could affect production efficiency, equipment layout and working sequence. Methodologies of study used in those studies include Dynamic Programming, Branch and Bound, Artificial Neural Network, Genetic Algorithm, Simulated Annealing and others. Similar studies in China consider more about macro-logistic from external perspective, such as study on the overall situation of a manufacturing enterprise, and less from internal perspective on micro-level, such as a workshop. There are a few studies on green logistic networks in workshops in both China and beyond. Nevertheless, green logistic has attracted attentions from across the world and many companies are realizing the crucial role played by the green logistic and starting to put more focuses on it. The US, Japan and EU were the earliest countries to start developing logistic sector and came up with the idea of "green logistic". Green logistic in the US is guaranteed mainly by macro-policies. According to US National Transportation Technology Development Strategy, strategic targets have been set to take modern logistic concept as the driving force to promote social-economic development till 2025 and various methods toward the targets have been rolled out[1]: using advanced technologies in logistic sector, designing an eco-supply chain to minimize environmental impacts and encourage the use of green packages. In Japan, green concept has been adopted in the whole historical cycle of logistic sector. Japanese government has supervised and regulated traditional logistics and set up new standards for green logistic development. Logistic material recycling has also been valued very much at the same time. Logistic companies in EU have also given much emphasis on environment protection and ecological balances to try to lower carbon dioxide emission and encourage the use of recyclable package and material.

China is a late starter in logistic industry and the concept of green logistic is still at a nascent stage, staying far behind of developed countries in manufacturing workshop logistic system. China's logistic sector is suffering from many problems such as obsolete equipment and outdated technology, unreasonable logistic design, higher energy consumption and heavy pollution[2]. We need not only suggestions on green logistics in manufacturing workshops in macro term[3][4]but also feasible resolutions. Therefore, this paper analyzed ways to build green logistic network in manufacturing workshop and improved design of traditional logistic networks in manufacturing workshops by adding more recycle points, and finally analyzed specific cases with heuristic algorithm method on how to set up a green logistic networks in manufacturing workshops.

GREEN LOGISTIC NETWORK PLANNING IN MANUFACTURING WORKSHOPS

The concept of building green logistic networks in manufacturing workshops is aiming at fully utilization of logistic resources, minimizing environmental damages during logistic process while pursuing maximum profits based on balanced considerations. The traditional logistic network is mainly trying to meet requirements of logistics. But under the green logistic concept, the traditional logistic system has to be reformed and improved to build, in a manufacturing workshop, a green logistic network that is energy efficient with low level of pollutant emission.

Traditional logistic networks in manufacturing workshops

The traditional logistic networks in manufacturing workshops are characterized by shortest transportation distance and lowest cost. The design is produced through considering real logistic demand and transportation distances between delivery points, using Scoring Method or Gravity and Iterative Method to select logistic facility sites, using System Layout Planning (SLP) and other methods to design layout of logistic facilities, so that cost and time could be saved and logistic networks be improved.

The logistic network of a manufacturing workshop is relatively complicated. To put it simple, it could be explained as purchasing material from outside and putting them into warehouses respectively before each processing procedure. After processing, it would be inspected in quality before being packaged and delivered. Please refer to Diagram 1 for the whole linear logistic material moving route if we regard each processing step as a logistic point.

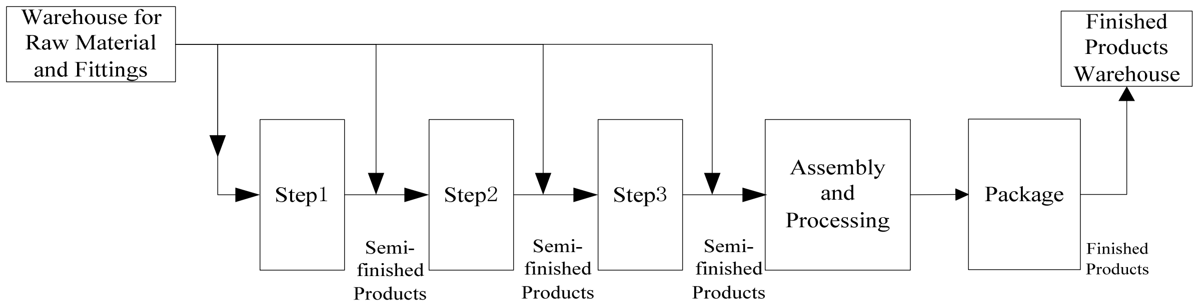


Diagram 1 : The whole internal liner logistic material moving route in manufacturing workshop

Green logistic network planning in manufacturing workshops

The traditional logistic network design hasn't considered environmental factors during logistic process and only focused on saving cost.

From macro points of view, to make the logistic process greener, we need, first of all, think more about how to make raw material, energy and packages greener; second, design a reasonable waste recycle network equipped with waste treatment centers in an effort to reuse renewable resources in production process.

Refer to Diagram 2 for the new macro logistic network with additional recycle and treatment centers.

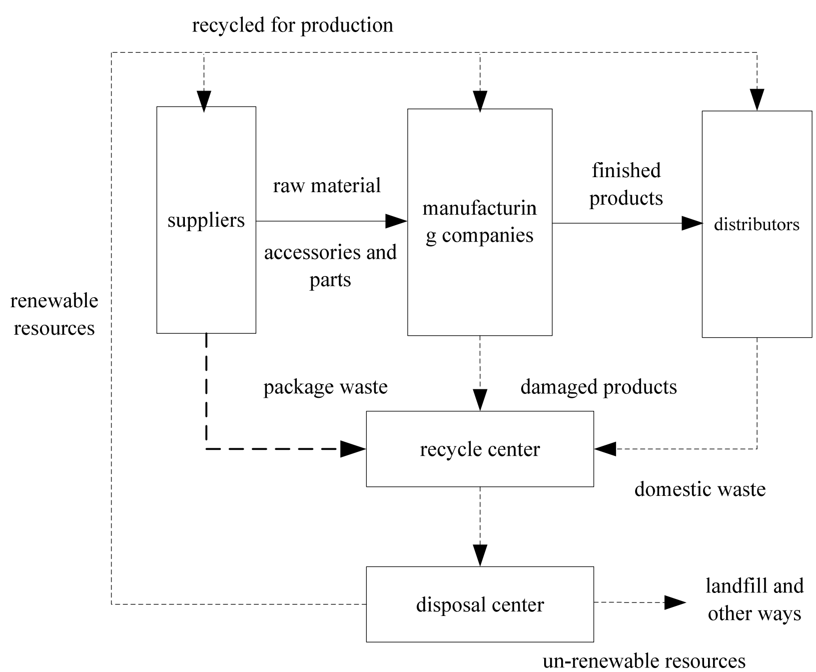


Diagram 2 : Indication on new macro logistic network with additional recycle and treatment centers

If we analyze manufacturing workshops internally, three requirements should be met to set up a green logistic network:

We need to make raw material, energy and packages greener.

Waste recycle center should be set up. Internal manufacturing process of a workshop only considers input of material to each processing step and doesn't consider waste generated accordingly. Improper waste treatment had caused higher cost that could have been avoided. It also affects normal productions. Therefore, original logistic network should and could be improved and made greener through adding recycle points. Please refer to Diagram 3 for internal logistic network of a manufacturing workshop with newly added recycle points.

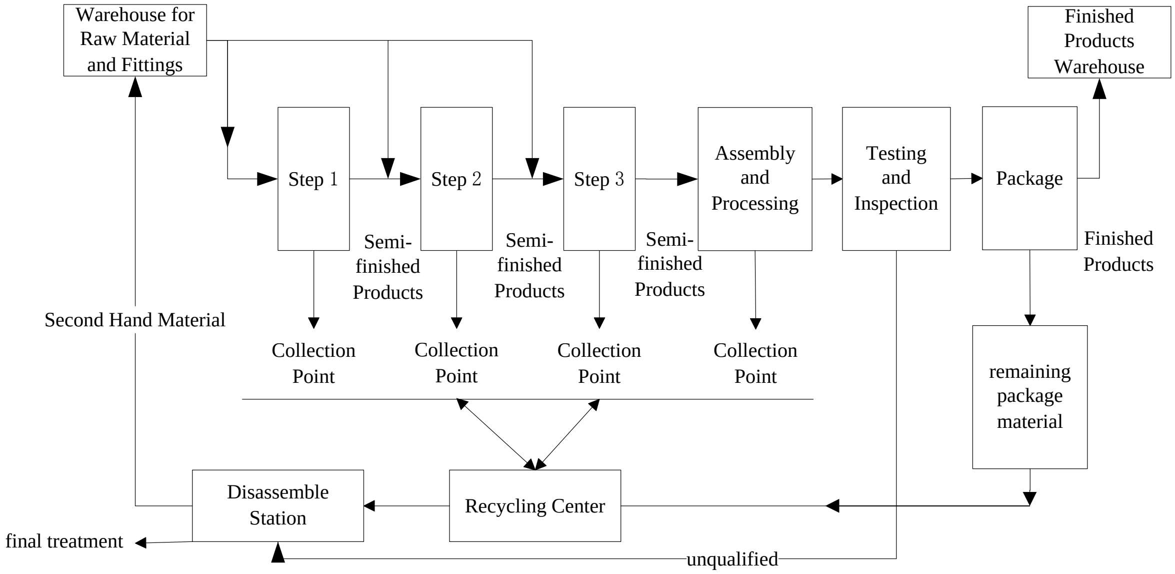


Diagram 3 : Indication on internal logistic network of a manufacturing workshop with newly added recycle points

We should design the best recycle routes inside manufacturing workshop. The best design should be with shortest transportation distance which can reduce consumption of fossil fuel by vehicles and reduce exhaust gas emission as well as improve recycle efficiency.

When we select recycle points, several locations could be selected as options first based on layout of facilities of manufacturing workshops before calculating delivery distance of each option. The best delivery route should be the one with shortest perimeter distance along the route. Heuristic algorithm would be used to calculate the whole circuit distance. The specific calculation process is showed as follow:

We first select a point (p) that is at the far most distance to the recycle point (0) to form a circuit O—P—O.

Based on the principle of proximity, we select a point (Q) that is the closest one to the point (P) to form another circuit O—P—Q—O.

Likewise, we insert all points into the circuit one by one to form many new circuits.

The principle of inserting points is: after inserting point X in between any two points in the circuit, the distance added $\Delta_{i,j}$ comparing the original distance linking two points with now linking three points should be the minimum. The equation is:

$$\Delta_{i,j} = l_{i,X} + l_{X,j} - l_{i,j} = \min$$

i,j are two random points in the circuit, $l_{i,X}$ 、 $l_{X,j}$ 、 $l_{i,j}$ is the distance between i and x, between x and j, and between i and j.

4) Calculation of Delivery Route Perimeter.

The sum of each distance between two points next to each other is the overall route perimeter starting from the recycle point and back to the recycle point along the whole circuit.

5) The last step is to compare each route perimeter of different options and select the shortest one as the best option.

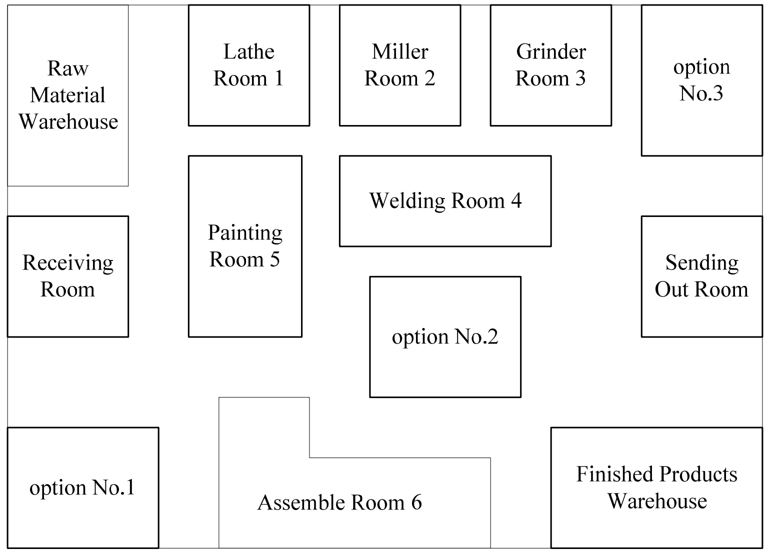
CASE ANALYSIS-GREEN LOGISTIC NETWORK PLANNING AND SOLUTION IN CERTAIN MANUFACTURING WORKSHOP

A manufacturing company plans to turn one of its internal logistic networks in manufacturing workshops into a greener one. They are going to add one recycle point in the network to recycle and reuse waste generated to make energy consumption more efficient and the network greener.

Network layout

Given the existing layout of facilities of the workshop, there are three unused houses can be used as recycle points, which are regarded as option No.1, option No.2 and option No.3. Assuming the recycle point to be chosen is marked as 0, and each processing step is marked as Lathe Room 1, Miller Room 2, Grinder Room 3, Welding Room 4, Painting Room 5 and Assemble Room 6.

Please refer to plan 4 for existing layout of each processing site and recycle point.



Plan 4 : Indication of existing layout of each processing site and recycle point

We have already known the shortest distance between 1 and 2 is 100m, the shortest distance between 1 and 3 is 200m, the shortest distance between 1 and 4 is 160m, between 1 and 5 is 120m, between 1 and 6 is 295m, between 2 and 3 is 100m, 2 and 4 is 95m, 2 and 5 is 160m, 2 and 6 is 290m, 3 and 4 is 115m, 3 and 5 is 240m, 3 and 6 is 320m, 4 and 5 is 145m, 4 and 6 is 210m, 5 and 6 is 185m.

Solving process

1）Confirm the shortest distances between any two delivery pints in each option

Based on figures known above and layout locations of the three options, the shortest distances between any two delivery points in each option are shown in following TABLE 1,2 and 3. In the forms, the shortest distance between j and i are marked as l_{ij}. The specific details of selecting best option is as follows:

TABLE 1 : The shortest distances between delivery points in option no.1 (measurement unit：meter)

l_{ij} **j i**	**0**	**1**	**2**	**3**	**4**	**5**	**6**
0	0	300	350	420	305	190	170
1	300	0	100	200	160	120	295
2	350	100	0	100	95	160	290
3	420	200	100	0	115	240	320
4	305	160	95	115	0	145	210
5	190	120	160	240	145	0	185
6	170	295	290	320	210	185	0

TABLE 2 : The shortest distances between delivery points in option no.2 (measurement unit：meter)

l_{ij} **j i**	**0**	**1**	**2**	**3**	**4**	**5**	**6**
0	0	220	180	195	90	150	130
1	220	0	100	200	160	120	295
2	180	100	0	100	95	160	290
3	195	200	100	0	115	240	320
4	90	160	95	115	0	145	210
5	150	120	160	240	145	0	185
6	130	295	290	320	210	185	0

TABLE 3 : The shortest distances between delivery points in option no.3 (measurement unit：meter)

	0	1	2	3	4	5	6
0	0	300	200	100	190	330	370
1	300	0	100	200	160	120	295
2	200	100	0	100	95	160	290
3	100	200	100	0	115	240	320
4	190	160	95	115	0	145	210
5	330	120	160	240	145	0	185
6	370	295	290	320	210	185	0

2) Calculation of Overall Route Perimeter and Distances in Each OptionCalculation of route perimeter and distances in option No.1

(1)We first select the point 3 that is at the far most distance to the recycle point 0 to form a circuit O—3—O.

(2)We select a point 2 that is the closest one to the point 3 to form another circuit O—3—2—O.

(3) We insert another point 1 into the circuit and calculate added distance after inserting of point 1 in different positions:

$\Delta_{0,3} = l_{01} + l_{13} - l_{03} = 300 + 200 - 420 = 80\text{ m}$ $\Delta_{3,2} = l_{31} + l_{12} - l_{32} = 200 + 100 - 100 = 200\text{ m}$

$\Delta_{2,0} = l_{21} + l_{10} - l_{20} = 100 + 300 - 350 = 50\text{ m}$

As $\Delta_{2,0}$ is the shortest, we should insert point 1 between delivery point 2 and recycle point 0 to form a circuit 0—3—2—1—0.

(4) We insert another point 4 into the circuit and calculate added distance after inserting of point 4 in different positions:

$\Delta_{0,3} = l_{04} + l_{43} - l_{03} = 305 + 115 - 420 = 0\text{ m}$ $\Delta_{3,2} = l_{34} + l_{42} - l_{32} = 115 + 95 - 100 = 110\text{ m}$

$\Delta_{2,1} = l_{24} + l_{41} - l_{21} = 95 + 160 - 100 = 155\text{ m}$ $\Delta_{1,0} = l_{14} + l_{40} - l_{10} = 160 + 305 - 300 = 165\text{ m}$

As $\Delta_{0,3}$ is the shortest, we should insert point 4 between delivery point 3 and recycle point 0 to form a circuit 0—4—3—2—1—0.

(5) We insert another point 5 into the circuit and calculate added distance after inserting of point 5 in different positions:

$\Delta_{0,4} = l_{05} + l_{54} - l_{04} = 190 + 145 - 305 = 30\text{ m}$ $\Delta_{4,3} = l_{45} + l_{53} - l_{43} = 145 + 240 - 115 = 270\text{ m}$

$\Delta_{3,2} = l_{35} + l_{52} - l_{32} = 240 + 160 - 100 = 300\text{ m}$ $\Delta_{2,1} = l_{25} + l_{51} - l_{21} = 160 + 120 - 100 = 180\text{ m}$

$\Delta_{1,0} = l_{15} + l_{50} - l_{10} = 120 + 190 - 300 = 10\text{ m}$

As $\Delta_{1,0}$ is the shortest, we should insert point 5 between delivery point 1 and recycle point 0 to form a circuit 0—4—3—2—1—5—0.

(6) We insert another point 6 into the circuit and calculate added distance after inserting of point 6 in different positions:

$\Delta_{0,4} = l_{06} + l_{64} - l_{04} = 170 + 210 - 305 = 75\text{ m}$ $\Delta_{4,3} = l_{46} + l_{63} - l_{43} = 210 + 320 - 115 = 415\text{ m}$

$\Delta_{3,2} = l_{36} + l_{62} - l_{32} = 320 + 290 - 100 = 510\text{ m}$ $\Delta_{2,1} = l_{26} + l_{61} - l_{21} = 290 + 295 - 100 = 485\text{ m}$

$\Delta_{1,5} = l_{16} + l_{65} - l_{15} = 295 + 185 - 120 = 360\text{ m}$ $\Delta_{5,0} = l_{56} + l_{60} - l_{50} = 185 + 170 - 190 = 165\text{ m}$

As $\Delta_{0,4}$ is the shortest, we should insert point 6 between delivery point 4 and recycle point 0 to form a circuit 0—6—4—3—2—1—5—0.

The whole route perimeter is:

$$L = l_{06} + l_{64} + l_{43} + l_{32} + l_{21} + l_{15} + l_{50} = 170 + 210 + 115 + 100 + 100 + 120 + 190 = 1005 \text{ m}$$

The same principle applies to Calculation of route perimeter and distances in option No.2

(1) We first select the point 1 that is at the far most distance to the recycle point 0 to form a circuit O—1—O.

(2) We select a point 2 that is the closest one to the point 1 to form another circuit 0—1—2—0.

(3) We insert another point 3 into the circuit and calculate added distance after inserting of point 3 in different positions: $\Delta_{0,1} = 175 \text{ m} \quad \Delta_{1,2} = 200 \text{ m} \quad \Delta_{2,0} = 115 \text{ m}$, we should insert point 3 between delivery point 2 and recycle point 0 to form a circuit 0—1—2—3—0.

(4) We insert another point 4 into the circuit and calculate added distance after inserting of point 4 in different positions: $\Delta_{0,1} = 175 \text{ m} \quad \Delta_{1,2} = 155 \text{ m} \quad \Delta_{2,3} = 110 \text{ m} \quad \Delta_{3,0} = 10 \text{ m}$, As $\Delta_{3,0}$ is the shortest, we should insert point 4 between delivery point 3 and recycle point 0 to form a circuit 0—1—2—3—4—0.

(5) We insert another point 5 into the circuit and calculate added distance after inserting of point 5 in different positions: $\Delta_{0,1} = 50 \text{ m} \quad \Delta_{1,2} = 180 \text{ m} \quad \Delta_{3,4} = 270 \text{ m} \quad \Delta_{4,0} = 205 \text{ m}$, As $\Delta_{0,1}$ is the shortest, we should insert point 5 between delivery point 1 and recycle point 0 to form a circuit 0—5—1—2—3—4—0.

(6) We insert another point 5 into the circuit and calculate added distance after inserting of point 5 in different positions: $\Delta_{0,5} = 165 \text{ m} \quad \Delta_{5,1} = 360 \text{ m} \quad \Delta_{1,2} = 485 \text{ m} \quad \Delta_{2,3} = 510 \text{ m} \quad \Delta_{3,4} = 415 \text{ m} \quad \Delta_{4,0} = 250 \text{ m}$, As $\Delta_{0,5}$ is the shortest, we should insert point 6 between delivery point 5 and recycle point 0 to form a circuit 0—6—5—1—2—3—4—0.

The whole route perimeter is: $L = l_{06} + l_{65} + l_{51} + l_{12} + l_{23} + l_{34} + l_{40} = 130 + 185 + 120 + 100 + 100 + 115 + 90 = 840 \text{ m}$ The same principle applies to Calculation of route perimeter and distances in option No.3

(1) We first select the point 6 that is at the far most distance to the recycle point 0 to form a circuit O—6—O

(2) We select a point 5 that is the closest one to the point 6 to form another circuit O—5—6—O.

(3) We insert another point 1 into the circuit and calculate added distance after inserting of point 1 in different positions: $\Delta_{0,5} = 90 \text{ m} \quad \Delta_{5,6} = 230 \text{ m} \quad \Delta_{6,0} = 225 \text{ m}$, As $\Delta_{0,5}$ is the shortest, we should insert point 1 between delivery point 5 and recycle point 0 to form a circuit 0—1—5—6—0.

(4) We insert another point 2 into the circuit and calculate added distance after inserting of point 2 in different positions: $\Delta_{0,1} = 0 \text{ m} \quad \Delta_{1,5} = 140 \text{ m} \quad \Delta_{5,6} = 265 \text{ m} \quad \Delta_{6,0} = 120 \text{ m}$, As $\Delta_{0,1}$ is the shortest, we should insert point 2 between delivery point 1 and recycle point 0 to form a circuit 0—2—1—5—6—0.

(5) We insert another point 3 into the circuit and calculate added distance after inserting of point 3 in different positions: $\Delta_{0,2} = 0 \text{ m} \quad \Delta_{2,1} = 100 \text{ m} \quad \Delta_{1,5} = 320 \text{ m} \quad \Delta_{5,6} = 375 \text{ m} \quad \Delta_{6,0} = 50 \text{ m}$, As $\Delta_{0,2}$ is the shortest, we should insert point 3 between delivery point 2 and recycle point 0 to form a circuit 0—3—2—1—5—6—0.

(6) We insert another point 3 into the circuit and calculate added distance after inserting of point 3 in different positions: $\Delta_{0,3} = 205 \text{ m} \quad \Delta_{3,2} = 110 \text{ m} \quad \Delta_{2,1} = 155 \text{ m} \quad \Delta_{1,5} = 185 \text{ m} \quad \Delta_{5,6} = 170 \text{ m} \quad \Delta_{6,0} = 30 \text{ m}$, As $\Delta_{6,0}$ is the shortest, we should insert point 4 between delivery point 6 and recycle point 0 to form a circuit 0—3—2—1—5—6—4—0.

The whole route perimeter is:

$$L = l_{03} + l_{32} + l_{21} + l_{15} + l_{56} + l_{64} + l_{40} = 100 + 100 + 100 + 120 + 185 + 215 + 190 = 1005 \text{ m}$$

Finally, we put the whole route perimeters of the three options together and find out the shortest one as the best.

Among the three options, option No.2 has the shortest whole route perimeter, 840m, so it is the best option. The recycle point should be put at the location of where option No.2 shows following the recycle circuit of "recycle center —6—5—1—2—3—4—recycle center".

Inspection on the improved logistic network

At the recycle point, renewable resources such as waste steel, rare metal and others could be picked out for technical treatment before being reused back in the production process. Therefore, resources could be used in a very efficient way. For those waste that cannot be reused, such as residual and pollutant, they would be stored and be sent to garbage disposal center to reduce impacts on environment. The green reform succeeds.

In addition, recycle points were set up at where delivery distance is the shortest, which reduced transportation distance and fossil fuel consumption substantially, minimizing exhaust gas emission. The whole logistic network is an effective measure to protect environment and is the optimal green logistic network.

Therefore, adding proper recycle points to logistic network will help company improve its green logistic network.

CONCLUSION

Continuous ecological environment degradation has warranted a special focus on environmental protection. Due to improper design and logistic cycle, industrial workshops pose a serious threat to environment.

The paper has found out a simple and effective way to improve existing logistic networks in manufacturing workshops and help companies make their logistic networks greener. It uses quantitative and qualitative methods to improve the logistic system and make it more energy efficient and less pollutant. Study shows that efficient use of raw material, energy efficiency and recyclable packages and adding recycle points along the logistic process could effectively promote the recycling of renewable resources and its overall utilization. At the same time, minimizing vehicle transportation distance will play an effective role in controlling exhaust gas and protecting environment.

Above all, there is still a large room for green logistic to develop in China. The paper only focuses on improving logistic networks in manufacturing workshops internally by adding recycle points. But in fact, there are many more aspects in the logistic system to be considered to improve the overall logistic process. We still have a long way to go to conduct many more researches and make the logistic network greener.

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