Research on Optimization of Hub-And-Spoke Logistics Network Design with Impedance Effect

Sun Li, Zhao Lindu*

Institute of Systems Engineering, Southeast University
Nanjing, Jiangsu, 210096, China
*Corresponding author. ldzhao@seu.edu.cn, +86-25-52090759
sunsuper@126.com

POMS 20th Annual Conference
Orlando, Florida, U.S.A
May 1 to May 4, 2009
Abstract: Hub-and-spoke pattern is one of the most important forms of modern logistics network. In order to treat with the capacitated single allocation p-hub problem, this paper presents a new non-linear programming model to design the network. Due to the fact that the current researches have some limitations, the capacity of materials disposal at hubs and the capacity limit of courses between hubs are treated as constraints in the model based on the analysis of characteristics of hub-and-spoke logistics network. In the process of optimization, an impedance function is introduced to balance some local logistics quantity properly in order to avoid congestions. Additionally, we provide a genetic algorithm that finds high-quality solutions within reasonable time. Then an example and simulation is given to verify the validity of the model. The results of the model provide new and realistic insights into the hub-and-spoke network design problem.

Keywords: Hub-and-spoke network design; Impedance function; Non-linear programming; Genetic algorithm
1. Introduction. With the rapid development of the global economy, the huge economic value of logistics, which is treated as “the third spring of profit”, is appearing gradually. Because of this, logistics draws more and more attention of governments and enterprises. For many years, logistics has been one of the hottest issues which are concerned by academe. The research results of various problems in the field of logistics emerge in endlessly. Among the issues, the hub-and-spoke network is a special construction of logistics networks. It plays an important effect in practical production and life. It is also one of the current research objects of academe.

With the development of logistics industry, the scale of logistics networks is extending all the time. The traditional logistics pattern, such as “one-to-one” and “many-to-many”, can not cover a wide area effectively because of the factors of costs, time limit and so on. So they can not construct a wide spoke network of logistics. Therefore, the multi-level logistics pattern, which is represented by LD-LED model, has become the trend of the development of logistics system. The hub-and-spoke logistics network is one of the manifestations of LD-LED model [1]. Its appearance is due to the enterprises’ pursuits for scale economic benefits [2]. The hub-and-spoke logistics network collects a great deal of dispersed point-to-point logistics operations to few hub nodes and main stems by some spoke nodes in order to utilize the advantages of the hub nodes’ ability of materials disposal and main stems’ transportation. By this way, a certain degree of scale economic benefits can be obtained. The redundancy costs and wastages of the system can be reduced. So the operation efficiency of the whole logistics network can be improved. This pattern of
logistics network is widely used in the airline industry, telecommunications [3] and postal delivery systems.

A typical hub-and-spoke network is composed by plentiful demand nodes and a certain number of hub nodes which have transfer function. There are a certain number of materials flows between each pair of demand nodes. The materials flows must route all their traffic from origin nodes to destination nodes indirectly via one or more hubs. There are no direct connects between any demand nodes. The operation costs of whole of the hub-and-spoke logistics network are made up of the distances between nodes and the expenses of transportations of materials.

Because of its wide usage, the hub-and-spoke network is worthy studying. Many home and broad scholars have many researches in the field. O’Kelly [4] developed a quadratic programming model and proposed two enumeration heuristics. Campbell [5] presented integer programming formulations for four types of discrete hub location problems. He also introduced discrete hub center and hub covering problems, basic formulations and formulations with flow thresholds for spokes. Ernst and Krishnamoorthy [6] considered that each non-hub node may be allocated to multiple hubs rather than sending and receiving all of its flow to and from a single hub. They presented a new MILP formulation for the multiple allocation p-hub median problems. Matsubayashi [7] studied a cost allocation problem arising from hub–spoke network systems and formulated this problem as a cooperative game and analyze the core allocation, which was a widely used solution concept. Elhedhli and Hu [8] considered a hub-and-spoke network design problem with congestion. They proposed a model
extending current models by taking congestion effects into account, which was achieved through a non-linear cost term in the objective function. Lin and Chen [9] proposed a generalized hub-and-spoke network in a capacitated and directed network configuration that integrated the operations of three common hub-and-spoke networks: pure, stopover and center directs. Klincewica [10] described an algorithm, based on dual ascent and dual adjustment techniques within a branch-and-bound scheme, for the uncapacitated hub location problem (UHLP). Jeong [11] addressed a hub-and-spoke network problem for railroad freight, where a central planner was to find transport routes, frequency of service, length of trains to be used, and transportation quantity.

The most current researches on optimization of hub-and-spoke network concentrate at the uncapacitated hubs allocation problem. However, in the actual process of logistics, each hub node has a certain capacity of materials transfer. This makes each hub node can only dispose finite materials in a certain time segment. If the limitation of capacity of hub nodes is neglected in the optimization model, the applicability of the model will be influenced in a certain degree. From the perspective of the transportation system, the carrying capacity of a road is one of the most important elements. It influences the result of optimization in a certain degree. In the field of logistics planning, it can be interpreted as the materials capacity of a section. When the materials quantity on a section is bigger than its capacity, congestion will be caused and even paralysis of the logistics network will happen. In addition, most of current researches focus on the goal of reducing the building and the operation costs
of a logistics network. The caused result is that they paid much attention on improving economic benefits of the logistics network itself while neglecting the possible reduction of the performance of the network caused in the process of pursuits for economic benefits. It should be known that a hub-and-spoke logistics network built on the goal of lowest costs may in a certain degree has some hidden troubles of paralysis caused by too much local materials. Therefore, this paper adds the constraints of hub nodes’ capacity of materials disposal and sections’ capacity of materials in the new optimization model. Besides, we also try to balance some local materials quantity in order to improve the whole performance of a logistics network. So we can increase the whole stability of the network while optimizing the operation costs of the network. We treat the operation costs as two parts: building costs and congestion costs. Elhedhli [8] managed to balance the materials quantity by adding congestion costs in the objective function. But we try to use the section impedance function in the theory of transportation as the congestion costs function. Because the building costs and the congestion costs have different dimensions, we build a multi-objective model to solve the problem.

The paper is structured as follows. In the next section we provide the description of the hub-and-spoke logistics network optimization problem. In Section 3 we present our new nonlinear multi-objective programming model. In Section 4 we design a genetic algorithm to solve this model. We also give an example and simulation of the model in Section 5. Finally we make some concluding remarks in Section 6.
2. Description of hub-and-spoke network optimization problem. For a common hub-and-spoke network $G(V, A)$, the set of demand nodes is $N$ and the set of hub nodes is $M$. $M \cup N = V$, $M \cap N = \emptyset$. There is a certain materials quantity between each demand node pair. Any demand node can be the original node of a material flow and it can also be the destination node. When a material flow will be delivered between a pair of demand nodes, after leaving from the original node, it must arrive at the corresponding destination node via one or more hub nodes. There are no logistics flows between demand nodes directly. In a common sense, the functions of a hub node are collection, sorting and transfer. The materials coming from multiple origins are collected and sorted in term of their different destinations at a hub node. Then the materials which have the same destination orientation are combined and transported by transportation tools which have better transportation ability through main stems. After arriving at the target hub node, the combined materials will be sorted again in term of their final targets and then be sent to the destination nodes respectively. Take the postal logistics network for example. The postal logistics network is a typical hub-and-spoke network. The demand nodes are equal to the small areas’ post offices and the hub nodes are equal to large areas’ sorting offices. After collecting a certain number of mails which come from dispersed customers and fixed mail boxes, a post office delivers the mails to the large area’s sorting office which it belongs to. The sorting office classifies the mails in term of their destination addresses and the congener mails are collected and sent to the corresponding large area’s sorting office through fixed route. Based on the detail of destination addresses, the mails are sorted
at sorting office again and are delivered to the destinations eventually. The structure of a typical hub-and-spoke network is shown in Figure 1.

FIGURE 1. Structure of a hub-and-spoke network

There are a lot of research orientations about the optimization of the hub-and-spoke network. This paper mainly focuses on the optimization problem of the logistics routes between demand nodes where the demand nodes and hub nodes are already provided. Given the set of demand nodes $N$ and the set of hub nodes $M$, we try to allocate $p$ proper hub nodes $k_1, k_2, \ldots, k_p \in M$ for each pair of demand node $(i, j), i, j \in N$ in order to implement the transfer of the materials and optimize the performance of the whole logistics network. For increasing the practicality of the model, we consider the influences on the optimization result caused by the capacity of materials disposal at hub nodes and the time limit of logistics. It should be pointed out that optimizing the performance of logistics network dose not mean to only pursue the lowest operation costs. It is necessary to ensure a certain degree of stability of network for improving the service level of a logistics system. A logistics network which often be congested and can not transport swimmingly will not satisfy
customers’ basic demands even its operation costs are lowest. Most of the former researches’ goals are obtaining the lowest costs. The optimization results always make some individual routes which have “better” transportation conditions take on huge amount materials quantity. Obviously, the more materials taken on, the more likely congestion and paralysis will happen in the section. This goes against ensuring the stability of the logistic network. Therefore, it is needed to balance some materials quantity properly. But it will increase logistics costs. It is clearly that the stability of a logistics network and the logistics costs are contradicted. This paper tries to present a method to balance the pair of the two contradicted factors.

3. Parameters configuration and model building. This paper proposes a nonlinear multi-objective 0-1 programming model in order to realize the optimization of the hub-and-spoke network’s performance.

As the above paragraph expatiates, we assume that $N$ is the set of $n$ demand nodes, $i, j \in N$. $M$ is the set of $m$ candidate hub nodes and $H$ is the set of hub nodes, $H \subset M$, $k, l \in H$. $p$ is the number of hub nodes. Let $d_{ik}$ is the distance between demand node $i$ and hub node $k$ as well as $d_{kl}$ is the distance between hub node $k$ and $l$. $W_{ij}$ is the materials quantity to be transported from demand node $i$ to demand node $j$. Considering the actual situation, $W_{ij}$ is not required to equal to $W_{ji}$. $F_k$ is the disposal and transfer capacity of materials at hub node $k$. $X_{ijkl}$ is the decision variable representing whether the route of $i$-$k$-$l$-$j$ is selected. If a materials flow $W_{ij}$ starts from demand node $i$ and ends at demand node $j$, via hub node $k$ and $j$ by order, the route of $i$-$k$-$l$-$j$ is selected.
and $X_{ijkl}$ is 1. If else, $X_{ijkl}$ is 0.

The model is built under the following assumptions:

(1) Each materials flow must be transported via one or two hub nodes from its origin node to destination node. For the decision variability $X_{ijkl}$, $k=l$ is allowed. It represents that materials flow $W_{ij}$ starting from origin node $i$ can be transported to destination node $j$ directly via hub node $k$;

(2) There must be one route between each pair of demand nodes $(i, j)$ and the route is unique;

(3) A demand node is allowed to be connected with multiple hub nodes. The former constraint that a demand node must be connected with one hub node is removed;

(4) Due to that the materials on the sections between demand nodes and hub nodes are rather small, we consider that these sections will not be congested. The section paralysis could only happen on the main stems between hub nodes because of their huge materials quantity.

It is obvious that the more times for which a main stem is chosen, the more frequent the cargo movements on it will be. Due to this it will be easier that congestion and even paralysis happen on the main stem. So it is necessary to describe the relationship between materials quantity and congestion degree on a section quantitatively. In this paper, we use typical impedance function, Davidson function. The function is as follows:

\[
c_a(x_a) = c_{a0} \{1 + J[x_a / (R_a - x_a)]\}
\]  

(1)
In the above formulation, $c_{a0}$ is the impedance on section $a$ when there is no traffic flow (min); $x_a$ is the traffic flow on section $a$ (unit per day); $K_a$ is the capacity of section $a$ (unit per day); $J$ is a parameter of the model which is related to characterizes of the section. The curve of the function is shown in Figure 2.

As Figure 2 shows, the delay time increases with the traffic flow. When traffic flow tends to the capacity of the section, delay time increases rapidly. In order to avoid rapid increase of delay time, we should keep the traffic flow at a low level. In this paper, we set the research object to be materials flow but not vehicle flow. So we can get:

$$x_{kl} = \sum_{i\in N} \sum_{j\in N} x_{ijkl} W_{ij}$$

Then we can change formulation (1) as follows:

$$c_{kl}(x_{kl}) = c_{kl0} \cdot \left(1 + J \frac{x_{kl}}{(R_{kl} - x_{kl})}\right) = c_{kl0} + c_{kl0} J \frac{R_{kl}}{(R_{kl} - \sum_{i\in N} \sum_{j\in N} x_{ijkl} W_{ij}) - 1}$$

Based on the above research, we build a nonlinear multi-objective 0-1 programming model which is shown as follows:
\[
\begin{align*}
\text{Min } & \sum_{i \in N} \sum_{j \in N} \sum_{k \in H} \sum_{l \in H} (d_{ik} + \alpha d_{kl} + d_{lj})X_{ijkl} & \quad (4) \\
\text{Min } & \sum_{k \in H} \sum_{i \in N} c_{kl0} + c_{kl0}J[R_{kl} / (R_{kl} - \sum_{i \in N} \sum_{j \in N} X_{ijkl}W_{ij}) - 1] & \quad (5)
\end{align*}
\]

s.t. \[
\begin{align*}
\sum_{k \in H} X_{ijkl} = 1, & \quad \forall i, j \in N, j \neq i & \quad (6) \\
\sum_{k \in H} H_k = p, & \quad (7) \\
\sum_{l \in H} X_{ijkl} \leq H_k, & \quad \forall i, j \in N, k \in H & \quad (8) \\
\sum_{k \in H} X_{ijkl} \leq H_l, & \quad \forall i, j \in N, l \in H & \quad (9) \\
\sum_{i \in N} \sum_{j \in N} X_{ijkl}W_{ij} \leq C_{kl}, & \quad \forall k, l \in H & \quad (10) \\
\sum_{i \in N} \sum_{l \in H} \sum_{k \in H} X_{ijkl}W_{ij} \leq F_k, & \quad \forall k \in H & \quad (11) \\
X_{ijkl} \in \{0,1\}, & \quad \forall i, j \in N, k, l \in H & \quad (12)
\end{align*}
\]

In the model, \( \alpha \) is the proportion of the transportation costs of lateral and main stem. \( c_{kl0} \) is the impedance on section between hub node \( k \) and \( l \) when there is no traffic flow. \( R_{kl} \) is the capacity of section between hub node \( k \) and \( l \). \( H_k \) shows whether candidate node \( k \) is chosen as a hub. If node \( k \) is chosen, \( H_k = 1 \); otherwise, \( H_k = 0 \).

Formulation (4) and (5) are two objectives of this model. Formulation (4) optimizes the transportation costs of a logistics network and formulation (5) optimizes the impedance costs in the network. Constraint (6) ensures that each demand node pair \((i, j)\) has only one route. Constraint (7) ensures that the number of hubs is \( p \).

Constraint (8) and (9) ensures that node \( k \) and \( l \) must be chosen if route \( i-j-k-l \) exists. Constraints (10), (11) add the restriction of capacity of sections and disposal capacity of materials at hub nodes. Constraint (12) regulates the 0-1 value of the decision variable.

4. Genetic algorithm
For the model we built is non-linear, we develop a genetic algorithm to solve it.

The algorithm is described as follows.

Step 1: Select $p$ nodes in $M$ to form a new hub set $H$ randomly;

Step 2: Generate the original population based on the coding rule;

Step 3: Estimate that whether every chromosome in the population satisfies the constraints (10) and (11) in the model. If yes, turn to step 4. Otherwise, delete the chromosome and generate a new one and repeat step 3;

Step 4: Using the fitness function to evaluate fitness value for every chromosome in population;

Step 5: Calculate selection probability for each chromosome based on its fitness value;

Step 6: Choose chromosomes prepared to be crossed using selection function;

Step 7: Cross the population using the custom crossover function;

Step 8: Mutate the population using the custom mutation function;

Step 9: If the number of iteration is enough, turn to step 10; otherwise, turn to step 4;

Step 10: Save the solution represented by the population. If there is possible $H$ which is different from formers, turn to step 1; Otherwise, over.

Some rules and functions referred in the above algorithm are expressed infra.

(1) Coding rule: Using a $2n^2$ dimension vector to as a chromosome. We select a hub node in $H$ randomly as the value for each element in the vector. In the vector, two adjacent elements represent a route. Figure 3 gives a $2n^2$ vector. From left to right,
every 2n elements belong to a demand node which is as the start. In the 2n elements, every 2 elements belong to a demand node which is as the end. In the 2 elements, the left one represents the first hub and the right one represents the second hub. So we can represent a whole route. Take the 2n elements belong to demand node S1 for example. They represent n route. The n routes totally start from S1. In the 2n elements, the first 2 elements belong to demand node D1. This means that the route represented by the 2 elements ends at D1. So the start and end of the route are confirmed. Which hubs dose the route contain? It depends on the values of the 2 elements themselves. According to the rule, we can denote a route for each demand node pair (i, j). Therefore the whole factor represents a solution.

(2) Fitness function: For the two objectives (3) and (4) have different dimensions, we can not simply add them as a solutions’ fitness value. So we take a dimensionless method to solve the problem. We take the dimension of objective (3) as cost and that of objective (4) as time. We can calculate the cost and time for each chromosome in the population respectively and then get the biggest cost and the biggest time. Denote them as cost_max and time_max. Afterwards, we denote chromosome i’s fitness value.
like this:

\[ \text{Fitvalue}(i) = \frac{\text{cost}(i)}{\text{cost \_ max}} + \frac{\text{time}(i)}{\text{time \_ max}} \]  \hspace{1cm} (13)

(3) Crossover function: In the population we select two chromosomes randomly. Then choose a certain number of demand node pairs to exchange their routes. First, find the elements representing the route between a node pairs in two chromosomes. Second, exchange the values. Then we can obtain two new chromosomes. If the two new chromosomes both satisfy constrains in the model, we select two chromosomes with smallest fitness value in the 2 new chromosomes and 2 old chromosomes; If not, repeat this operation. Figure 4 shows the process of crossover.

![Crossover Process](image)

FIGURE 4. The process of crossover

(4) Mutation function: After a certain number of iterations, we choose a demand node pair randomly and change the route of it by selecting hub nodes in \( H \) randomly. Of course this operation must ensure the new chromosome satisfy constraints in the model.

5. **Example and simulations.** In order to verify the validity of the model and the
algorithm we designed in the above paragraph, we give an example in this section. We use Matlab 7.1 to do numerical simulation.

We design an initial network including 15 demand nodes and 6 candidate hub nodes, as shown in Figure 5. In the 6 candidate hub nodes, we will select 4 hubs. The materials quantity from demand node \(i\) to demand node \(j\) and the distances between demand nodes and hub nodes are shown in Table 1. Table 2 gives the distances and the capacities of the section between hub nodes. Besides, Table 3 gives the impedances on sections between hub nodes when there is no traffic flow on sections. Because of the scale advantage, we assume that the proportion of the transportation costs of lateral and main stem \(\alpha\) is 0.5. For simplification, we set \(J\) to be 1.

<table>
<thead>
<tr>
<th>Demand</th>
<th>Materials Quantity between Demand Node</th>
<th>Distance to Hub Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0 23 31 40 53 24 19 22 20 32 34 50 29 15 25</td>
<td>46 120 96 150 120 65</td>
</tr>
<tr>
<td>2</td>
<td>28 0 22 31 28 41 38 47 27 22 34 14 32 18 23</td>
<td>38 120 94 160 130 85</td>
</tr>
<tr>
<td>3</td>
<td>24 28 0 31 19 25 29 36 40 39 27 32 24 27 23</td>
<td>25 70 65 120 120 100</td>
</tr>
<tr>
<td>4</td>
<td>30 23 26 0 18 20 32 24 35 21 33 27 29 35 25</td>
<td>70 38 64 100 120 140</td>
</tr>
<tr>
<td>5</td>
<td>25 22 32 31 0 45 21 38 34 28 32 28 20 23 31</td>
<td>85 16 56 85 110 140</td>
</tr>
<tr>
<td>6</td>
<td>26 21 35 26 21 0 18 38 21 25 30 28 23 21 42</td>
<td>140 57 96 90 130 180</td>
</tr>
<tr>
<td>7</td>
<td>24 23 31 21 37 43 0 20 24 22 32 19 25 23 30</td>
<td>110 29 61 60 98 140</td>
</tr>
<tr>
<td>8</td>
<td>36 32 29 19 23 22 35 0 42 34 29 38 40 31 30</td>
<td>140 63 82 47 98 160</td>
</tr>
</tbody>
</table>
### TABLE 2. Distances and transportation capacity between hub nodes

<table>
<thead>
<tr>
<th>Hub Node</th>
<th>Distance between Hub Node</th>
<th>Capacity between Hub Node</th>
<th>$F_k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0      81      55      120      100      77      0      600      650      650      600      580      1200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>81      0      43      70      95      130      650      0      600      600      650      620      1200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>55      43      0      60      61      85      610      670      0      600      590      630      1200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>120     70      60      0      50      120      600      620      600      0      650      600      1200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100     95      61      50      0      75      600      630      590      600      0      610      1200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>77      130     85      120     75      0      620      600      600      610      630     0      1200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 3. Impedances without flow between hub nodes

<table>
<thead>
<tr>
<th>Hub Node</th>
<th>Impedance between Hub Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0      81      55      120      100      77      0      600      650      650      600      580</td>
</tr>
<tr>
<td>2</td>
<td>81      0      43      70      95      130      650      0      600      600      650      620</td>
</tr>
<tr>
<td>3</td>
<td>55      43      0      60      61      85      610      670      0      600      590      630</td>
</tr>
<tr>
<td>4</td>
<td>120     70      60      0      50      120      600      620      600      0      650      600</td>
</tr>
<tr>
<td>5</td>
<td>100     95      61      50      0      75      600      630      590      600      0      610</td>
</tr>
<tr>
<td>6</td>
<td>77      130     85      120     75      0      620      600      600      610      630     0</td>
</tr>
</tbody>
</table>

TABLE 2. Distances and transportation capacity between hub nodes

TABLE 3. Impedances without flow between hub nodes
For the number of candidate hub nodes are 6 and we must select 4 hubs in them, we have $C_6^4 = 15$ different combining forms of hub nodes for $H$ to choose. For each $H$, we set a population which contains 100 chromosomes in order to obtain a rather better result. In addition, we let each population iterate 200 times. Take the first $H$ for example. Among 200 times iteration, the maximum fitness value of the total chromosomes in the population which is normalized has the trend shown in Figure 6. From the curve we can recognize that the algorithm convergences after about 80th iteration. For at the late stage the most chromosomes are the same and the fitness value is constituted by normalized cost and time, the fitness value will trend to 2.
From Figure 7 and Figure 8, it is obviously that the cost and time both converge after about 100\textsuperscript{th} iteration. The result is in accordance with the trend of fitness value shown in Figure 6. It can illustrate that our genetic algorithm is effective.

By simulation, we obtain some important data for each $H$. The simulation result is shown in Table 4. After calculating for each $H$, we get the best solution with lowest fitness value respectively. Here we think the cost and time to have equal weight. So we put them together as the fitness value just after normalization. In practice, if the any part takes a more important role in improving the performance of network, it may have bigger weight. In our example, as shown in Table 4, the solution of the second $H$ has the lowest fitness value. Fortunately, this solution both has the lowest cost and time, so it is obviously the best choice. Figure 8 shows the best solution.

<table>
<thead>
<tr>
<th>TABLE 4. Simulation results for 15 $H$s</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H$</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>----</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Though the solution shown in Figure 8 is the best among the solutions we get, it
is seemingly not good enough. We think the problem may be at the process of generate initial population. We generate the chromosomes totally randomly. This may lose some opportunities to obtain better results. If we take some effective methods in the process of initialization, our work can be improved.

6. Conclusions. Many factors should be considered in the design problems of hub-and-spoke logistics network. When we are pursuing the optimal operation costs of logistics network, the caused negative effects, such as too much materials at local parts of the network, are easily neglected. This paper considers many actual factors and selects the capacity of sections logistics network and capacity of materials disposal at hub nodes as constraints. When we are building a new optimization model to design a logistics network, we pay attention on ensuring a certain level of performance of the whole network by reducing the impedance on sections. We also present a genetic algorithm to solve the model. Through numerical simulations, we verify the effectiveness of the model and the algorithm. This paper tries to propose a new method to improve former researches and there is still a lot of work to do in the future, such as the timeliness which we didn’t consider in our model as well as how to improve our genetic algorithm.

Acknowledgements. This work was supported by National Natural Science Foundation of China (70671021) and the National Key Technology R&D Program of China during the 11th Five-Year Plan Period (No.2006BAH02A06).
REFERENCES


