Logistic System Evaluation Scheme Based on Time Model

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Abstract—The idea of this paper is derived from the clock model. Based on the symbiotic strategic performance system, we present the logistics enterprises integrated performance evaluation system, which is composed of financial performance, management performance and social performance. By establishing the objective function of finance, management and contribution to the society, this paper proposes the model indices such as costs, profits, time, customer satisfaction and regional contribution rate and so on. Moreover, further discussion on evaluation methods about the optimum effects of the logistical express system is carried out.

Keywords—logistics; time model; performance system; fuzzy due-time; network sharing

I. INTRODUCTION

The symbiosis means that different living creatures live together. Now, the symbiotic relation has gradually exceeded the biological field and got into sociology, management and economics. The clock model is based on the symbiosis theories, and it puts forward strategic performance evaluation system according to the financial performance, management performance and the social performance. In the clock model, the financial performance, management performance and social performance become one closed circulation system. The management performance drives financial performance, which drives social performance further. Then the level of the social performance again affects the management performance in the next period[1]. Based on this, this paper puts forward the comprehensive performance evaluation system which can be actually used by logistics and express enterprises. This paper is based on other scholars’ works, aiming at financial appraisal, management appraisal etc., and puts forward the model indices, such as cost, profits, time and customer satisfaction...etc. We hope to provide some reference to logistical performance evaluation system.

II. THE COMPREHENSIVE PERFORMANCE EVALUATION SYSTEM

To make the above-mentioned system numerical here, we can use a series of indices, like efficiency etc., to subdivide financial performance, management performance and social performance.

For an individual enterprise, a supply chain or a strategic alliance formed by some enterprises, we also can use a similar system above to evaluate the performance of the system’s operating as a whole. Specially, for the express and the logistics enterprises, we can give the Table I below on the basis of the performance system mentioned above. Here we give the referenced value of each weight instead of actual value because it needs a lot of operating data.

We usually use the Delphi method, AHP method and Entropy method to get the values of weights and the Delphi method is of higher subjectivity. Here use the following method to calculate the weights of the indices[2]: if \( w_1 \) is the weight made out by the AHP method, \( w_2 \) is the weight made out by the Entropy method and \( \rho \) is equilibrium weight between the subjectivity and objectivity for the enterprises, the gross weight of the system is

\[ w = \rho w_1 + (1 - \rho) w_2 \quad (0 < \rho < 1) \]
TABLE I Table of the Comprehensive Performance Evaluation System for the Logistics Enterprises

<table>
<thead>
<tr>
<th>Comprehensive Index</th>
<th>Evaluation Index</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finance Performance</td>
<td>the profit rate</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>the profit growth rate</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>the costs decrease rate</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>the net capital increasing</td>
<td>0.08</td>
</tr>
<tr>
<td>Management Performance</td>
<td>The business process</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>performance</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>the customer service</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>satisfaction rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the accident rate</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>the intellectual and capital</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>ratio</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the employees’ suggestions</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>growth rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the employee training total</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>time growth rate</td>
<td></td>
</tr>
<tr>
<td>Social Performance</td>
<td>the number of the</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>employees growth rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the business credit degree</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>the regional economy</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>growth contribution rate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the pollution treatment</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>expense growth rate</td>
<td></td>
</tr>
</tbody>
</table>

But in a model network, we can’t get all of the indices to evaluate the result of the improvement, only needing to use what we need.

III. THE MODEL INDEX AIMING AT THE LOGISTIC NETWORK

The model indices here are the same with the functions which can be the expression of the network’s service capacity. These functions usually appear in the optimization of a network, representing a state of an enterprise or a network. That is, if the operating states of a network or an enterprise are known, the function values are known, and then the functions can be the evaluation indices.

With the discussion above, the model indices will be discussed from three aspects: the financial performance, management performance and social performance. The model assumptions are as follows:

- The number of the network nodes is \( n \), and between any two nodes can have the logistical links. Establish the transportation matrix as shown in Table II.

<table>
<thead>
<tr>
<th>TABLE II the Transportation Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>out node 1 node 2 ... node i ... node n</td>
</tr>
<tr>
<td>in node 1 ( O_{12} \ldots O_{1i} \ldots O_{1n} )</td>
</tr>
<tr>
<td>node 2 ( O_{21} ) 0 \ldots ( O_{2i} \ldots O_{2n} )</td>
</tr>
<tr>
<td>... \ldots \ldots \ldots \ldots \ldots \ldots</td>
</tr>
<tr>
<td>node i ( O_{ii} ) ( O_{i2} ) ... 0 \ldots ( O_{in} )</td>
</tr>
<tr>
<td>... \ldots \ldots \ldots \ldots \ldots \ldots</td>
</tr>
<tr>
<td>node n ( O_{ni} ) ( O_{n2} ) \ldots ( O_{nn} ) ... 0</td>
</tr>
</tbody>
</table>

- In a fixed express network \( Q_{ij} \) is a constant, and it can be 0.
- The batch of the goods transported from node \( i \) to \( j \) is fixed for a long period of time.

A. The Cost Model

The cost function, which is the easiest and the most commonly used objective function, is regarded as the main financial performance index. Here, the transportation cost and labor cost are considered as variable costs. Then the cost function can be expressed as:

\[
Z_1 = \sum_{i=1}^{n} \sum_{j=1}^{n} Q_{ij} r_{ij} d_{ij} + \sum_{i=1}^{n} (a_i C_{1i} + C_{2i})
\]

(2)

Here:
- \( Q_{ij} \) —— the transportation freight volume from node \( i \) to \( j \);
- \( r_{ij} \) —— the delivery fees rate from node \( i \) to \( j \);
- \( d_{ij} \) —— the distance between node \( i \) and \( j \);
- \( a_i \) —— the number of the employees at node \( i \);
- \( C_{1i} \) —— the average manual cost at node \( i \);
- \( C_{2i} \) —— the fixed costs such as space cost and fixed equipment depreciation cost at node \( i \).

In the cost function above, the \( a_i \) in the labor cost is
separated from other costs because it can use the random services theory to get an optimal value with the queuing model and marginal analysis. At the same time we can get a further profit function:

$$Z_1 = \sum_{i=1}^{n} \lambda_i G - \left[ \sum_{i=1}^{n} \sum_{j=1}^{n} Q_i f_{ij} d_{ij} + \sum_{i=1}^{n} \left( a_i C_i + C_2 \right) \right]$$

(3)

Here, $\lambda_i$ is the average number of customers in the unit time for each node. Focusing on the logistics process, customers’ arrival generally meets Poisson flow, and $\lambda_i$ is its average value. $G$ is the servicing fee for each customer. And usually, $G$ is a quality and distance function. In order to simplify the model we use the average expectation of $G$ here.

B. The Time Model

1). The Simple Time Model

In a logistic network, time is always a key index to evaluate the performance of it, and it is the main index of management performance here.

As $t_{ij}$ is the average time transporting goods from node $i$ to $j$, $v$ is the average speed of conveyance under the normal conditions and $m_{ij}$ is the value of the goods transportation (not empty) batches from node $i$ to $j$ in unit time.

In the one city express, considering that the transporting time will be longer because of traffic jams at some sections of the road in reality, we use the concept of bending coefficient to modify the time parameter. Use $f(f \geq 1)$ to express the bending coefficient and let $f = \frac{1}{t}$ the unit time / the unit time except how long the traffic is not jam. The larger bending coefficient is, the longer transport time is, conversely the shorter (In practice, $f$ can be got with traffic statistics). The time function after amendment is as follows:

$$Z_2 = \sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij} f_{ij} = \frac{1}{v} \sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij} d_{ij} f_{ij}$$

(4)

2) The Weighted Time Model

Compared with total transporting time, the time model considers the time between any two points equally. Under the condition of uneven demand distribution, we use the proportion of the goods flow at one node to the total transportation volume of a network ($Q$) in unit time to weight the time function. It’s more likely to express the operating status of the network system and it’s better for the managers to make a better choice. The weighted time model is as follows[3]:

$$Z_2 = \frac{1}{v} \sum_{i=1}^{n} \sum_{j=1}^{n} m_{ij} d_{ij} f_{ij} \times \frac{Q_i + Q_j}{2Q}$$

(5)

3) The Further Discussion about the Time Model Based on the Fuzzy Due Time

There always are opposition effects between the time and cost. The shorter time is required, the higher cost is often paid, namely the contradiction between the flexibility and cost. Logistics is a kind of service industry, and the enterprise's business objective is to meet the needs of customers while their operating costs are the minimum. In some logistic service systems, people do not need to make the time function minimum to achieve optimization, but balance the time and cost to get the highest customer satisfaction.

After reserving a product or service, customers hope to get the goods or services in a specific period. If a product or service is arrived in the period he hopes, the customer is satisfied with the service. On the contrary, customers’ satisfaction to the enterprise will reduce[4]. This is the rough description about the fuzzy due time. Assume the customer satisfaction function is $x(t)$:

![Customer Satisfaction Function](image)

As two different preferred models shown above, customers reserve goods or services at time 0. Figure (a) expresses a
customer satisfaction function of clear due time. During $t_1$ to $t_2$, the customer satisfaction is the highest (up to 1), otherwise the satisfaction decreases gradually (the minimum is zero). Specially, figure (b) expresses the customer satisfaction of the express and logistical enterprise. During 0 to $t_1$, the customer satisfaction is the highest, and beyond the scope of the time, the customer satisfaction gradually turns into 0.

To (a) model, $x(t) = \begin{cases} \frac{k_1 t + b_1 t_0}{t_1 - t_0}, & t \leq t_1 \\ \frac{1}{t_1 - t_2}, & t_1 \leq t \leq t_2 \\ -\frac{k_2 t + b_2 t_2}{t_2 - t_0}, & t_2 \leq t \leq t_3 \\ 0, & \text{the others} \end{cases}$ (6)

Here $k_1 = \frac{1}{t_1 - t_0}, k_2 = \frac{1}{t_1 - t_2}$,

$\begin{cases} b_1 = \frac{t_0}{t_1 - t_0}, b_2 = \frac{t_2}{t_2 - t_0} \end{cases}$

To (b) model, $x(t) = \begin{cases} \frac{k t + b t_1}{t_2 - t_1}, & t_1 \leq t \leq t_2 \\ 1, & t \geq t_2 \end{cases}$ (7)

Here $k = \frac{1}{t_2 - t_1}, b = \frac{t_2}{t_2 - t_1}$.

If every customer satisfaction function obeys $x(t)$, several customer satisfaction functions obey:

$Z_3' = \sum x(t)$ (8)

The $t_i$ here is different from the $t_i^*$ mentioned in the time model. It is a period from customers reserving goods or services to receiving them. The bigger $Z_3'$ is, the higher customer satisfaction is. The essence of $Z_3'$ is a kind of time model based on customer satisfaction. So the same with the time model, $Z_3'$ also is one of the key indices of management performance. However, we can see that the variable $t_i^*$ in the customer satisfaction function is not easy to be calculated, so it needs to make different analysis for different problems.

To standardize the model further, we assume that there is a logistic system as follows, and $x(t)$ is same with figure (b):

a) There are $L$ network terminals (terminal services centers) in the network. Because the general logistic enterprise has promises on service time limit to customers, the deadline ($t_f$) that the customers expect goods to be sent is generally not shorter than the logistical enterprise's commitment, namely not too short.

b) Each customer satisfaction function begins from the time goods arriving at the terminal node and ends when the goods reach another terminal node (That is the range of $t_g$). So:

$Z'_3 = \sum_{i=1}^{L} \sum_{j=1}^{L} m_{ij} x(t_g), (i \neq j)$ (9)

If goods are transported from $i$ to $j$ and must passed by the node 1, node 2... node $k$...node $n$, then

$t_g = \sum(t_{i1} + t_{12} + \ldots + t_{k-1,k} + \ldots + t_{nk}) + \sum t_k$ (10)

Here, $t_{k-1,k}$ —— the goods transporting time from node $k-1$ to $k$;

$t_k$ —— the goods waiting time at node $k$, which can be calculated by the model of queuing theory.

Example: Figure 2 is a simple logistic network, in which the transporting time between any two nodes is signed. Here $x(t)$ is the same with fig 1 (b). If $t_1 = 24h, t_2 = 28h$, each transportation batch is 1 and no waiting time at each node. Then:

$Z'_3 = x(t_{12}) + x(t_{13}) + x(t_{23})$

$= x(12) + x(12) + x(16)$

$= 1 + 1 + 1 = 3$

C. The Objective Function Based on the Social Performance

In order to improve its own profit level and service efficiency, the logistical and express enterprise on market often has its own basic network. From the micro view, the resources' contribution to the individual profit is undeniable, but from the macro view, the resources idle rate in logistical industry is high generally, such as the no-load of vehicles and the idle time at network nodes. To the overall benefit of a network, the disusing of resources means wasting.
1) The No-Load Rate Model

The lower no-load rate is, the higher resource utilization rate is.
The decrease of no-load rate is not only to reduce operating
costs for the enterprise, but also the embodiment of the efforts
to green logistics for the enterprise, such as environment
protection and wastage decrease. Also it’s one of the main
social performance indices here. If the number of the
conveyance from node  to  is . And the largest freight
transporting volume of each vehicle is . Assume the no-load
rate is , then:

\[
Z_4 = \sum_{i \in I} \sum_{j \in J} (n_{ij}d_{ij}o_{ij}) - \sum_{i \in I} \sum_{j \in J} \left( \frac{Q_{ij}}{h} d_{ij} \right)
\]

(11)

Under the condition that transportation routes and rules are
known,  is easy to be calculated, then so is the no-load
rate. If the network and the rules are fixed, no-load rate is
established as an index of social performance for a logistics
and express enterprise.

2) The Discussion about the Social Performance Function
Based on Network Sharing

Based on the discussion above, assume further that the
operation based on network sharing among the express
enterprises can be actualized. (The business of network sharing
is interpreted as the business transfer among the companies
simply.) Create the related mathematical model from the
whole region’s profit level.

If each express enterprise has its own express network in a
regional of which the amount of nodes is . Then combine
different companies’ business-net spots to one network.

To one of the companies in the network, considering the
business transfer is because that some nodes’ profit rates are
negative or lower than the expected ones or the costs are much
too high. This part of the business transfer is significant
helpful for the profit increase and the costs decrease. And other
companies accept the business transfer also because of the
impact on the profit rate. After the business transfer, the
enterprises’ profits need re-distribution. This paper only makes
assumptions about the feasibility of the re-distribution and
expresses it with a simple linear relationship.

If the average operating cost is  and the average sales
volume is , we can make the following assumptions further
about node  of the network:

a) The number of the nodes in the network is , the
number of the nodes  can be chosen by node  for business
transfer is and the amount of business transferred from
node  to  is . (The proportion of  to all the
business at node  is ).

b) At node , the unit variable cost is . The business  is
transferred from node  to  because:

\[
c_{im} = c_{jm} = c_{m}
\]

(12)

Here  is the cost with the decreasing customer
satisfaction, and

\[
c_{im} = \begin{cases} M, & \text{when customers run off} \\ 0, & \text{the others} \end{cases}
\]

(M is an
integer large enough).

For the  business needing transferred from  to , the
reason why to be transferred is:

\[
c_j = \sum_{m=1}^{n_1} c_{jm} \geq \sum_{m=1}^{n_1} c_{jm} = c_j
\]

(13)

In addition while the business, the proportion of which to
the whole business at  is , are transferred from  to ,
there are business transferred from  to , the proportion of
which to the whole business at  is . Under the normal
conditions and are the functions of the profits
distribution, which are expressed by linear constants here.

After the business transfer,  is the decreasing part of
the cost in the network. With the increasing profit
\[(1-\varphi)(g_j - c_j) + \omega(g_k - c_j),\] this part is the main part of the
increasing gross profits.

According to the above discussion, the gross profit of the
network is:

\[
\sum_{j=1}^{n} \left[ \varphi(c_j - c_j) + (1-\varphi)(g_j - c_j) + \omega(g_k - c_j) \right]
\]

(14)

Under the condition of business transfer, if one enterprise
has  of the  nodes in the region, its contribution to the
increase of the gross profit rate for the region is:

\[ Z'_{1} = \sum_{i=1}^{n} \left[ \phi(c_i - c_j) + (1 - \phi)(g_i - c_i) + \omega(g_i - c_i) \right] \]

\[ Z'_{2} = \sum_{i=1}^{n} \left[ \phi(c_i - c_j) + (1 - \phi)(g_i - c_i) + \omega(g_i - c_i) \right] \]

\[ \eta_i = \frac{Z_{y}(T_0) - Z_{y}(T_x)}{Z_{y}(T_0)} \quad (i = 1, 2, 3) \quad (16) \]

Other indices can be draw by analogy, thus the comprehensive weighted index model of system is:

\[ \eta = \alpha \eta_1 + \beta \eta_2 + \gamma \eta_3 \quad (17) \]

\[ \alpha, \beta \text{ and } \gamma \text{ are the weighted coefficient} \]

\[ \text{We can calculate the weights once again with the method in part two,} \]

\[ \text{or use the number of the Comprehensive Performance} \]

\[ \text{Evaluation System in Table I after normalization. The larger} \]

\[ \text{parameter is, the better system will be.} \]

V. ENDING WORDS

Aiming at the financial, management and social indices of

logistical system performance evaluation, this paper

establishes some reasonable models like costs, profits, time,

customer satisfaction, no-load rate, regional contribution rate

and so on. Based on this, the paper establishes a

comprehensive weighted index model, lays out an effective

scheme to evaluate the status of the logistic system, and

provides a referable proposal about establishing the objective

function in LRP model. Because of the complexity of

logistical system and the difference among the prioritization

schemes, there are some disadvantages in this index model,

such as the cumbersome data required. In view of these

inadequate, we will improve the model in the further research.

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