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Value Chain Analysis Method of Smart Logistics Using Fuzzy Theory

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Abstract: The present study gives a Value Chain Analysis (VCA) method for Smart Logistics (SL), based on fuzzy theory. First, five major challenges in the supply chain is study and then relative demands are transformed into the SL system design using Quality Function Deployment (QFD) methodology and fuzzy group decision-making theory. Second, the Multi-objective SL model is given using multipurpose optimal theory to achieve the maximum value under constraints. Third, the evaluation method of SL solution is proposed based on benchmarking analysis and fuzzy Analytic Hierarchy Process (AHP) method. In the end, the paper point government should give priority to SL development in the logistics industry. The result of this study is useful for SL system design, implement and evaluation. This paper is useful as a decision support for practitioners to develop the SL systems according to the benchmarking results and VCA methodology.

Key words: Smart logistics, evaluation method, QFD, AHP

INTRODUCTION

A growing number of participants in transport operations have led to increasingly complex distribution setups with augmented needs for integration. The complex services that are given and the problems of exchange rate fluctuations, supply disruptions, transportation capacity constraints, order cancellations and a series of factors make the execution of value-added services difficult. To be able to solve some of the shortcomings in many of today's logistics, SL system has been developed (Lumsden and Mirzabeiki, 2008). SL is the oversight of materials, information and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. It involves coordinating and integrating these flows both within and among companies. Recent studies are investigating the benefits from SL are being applied for increasing the accuracy and timeliness of the information and reducing the costs in the logistics and transportation operations.

VALUE-CHAIN ANALYSIS

Value-chain analysis includes the whole cycle of the organization, production and delivery of products from inception to use and recycling, provides a tool for mapping these crucial domains of supply chain to value chain. There are five major business challenges in the supply chain: Cost Control, Process Visibility, Risk Management, Increasing Customer demands and Globalization according to "the world's chief supply chain officer survey" of IBM In 2009. Value-chain analysis is used to deal with these challenges to continually evaluate the current performance, identify areas for improvement and eventually set goals for the future. SL satisfaction measurement model is setup based on QFD methodology, originally from new product design, proved useful when applied to SL implementation. We take the material flow of the most excellent enterprise all over the world, such as the famous enterprise Apple, DELL and IBM as the benchmark to analyze logistics demands of Chinese enterprises. Through the quality of house, the demands of logistics can be transformed into the corresponding process design features that can be measurable, actionable and potential improved shown in Fig. 1.

In this hypothesis, m stands for the number of Logistics Demands (LD) and n stands for the design features corresponding to the process (DF), among which:

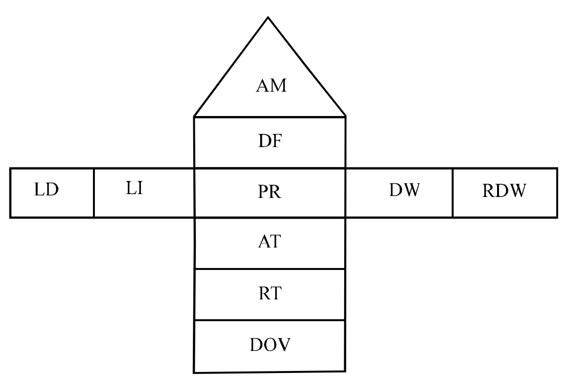

Fig. 1: Quality function deployment house

Wi = $(w_i)_{m\times 1}$: w_i is the degree of importance of number i logistics demand

LI = $(l_i)_{m\times 1}$: $l_i = w_i \times P\_MSI_i \times IF_i \times 100/\Sigma(w_i \times P\_MSI_i \times IF_i)$, l_i is the relative importance of number i logistics demand, P_MSI = MAX_MSI-CUR_MSI, MAX_MSI is the maximum market satisfaction degree under the cost constraint in enterprises, CUR_MSI is the current market satisfaction degree and P_MSI is the potential for process improvement. IF is the influence of the demand on the product value: generally (IF = 1.0), larger (IF = 1.5), largest (IF = 2.0)

PR = (R_{ij}): R_{ij} is the quantitative relation value between the numbers i logistics demand and design feature of number j process

AM = $(r_{ij})_{n\times n}$; r_{ij} is the association degree between design feature of number i and j process and d_i and d_j.

DW = $(dw_i)_{m\times 1}$: dw_i is the demand weight of number i logistics

RDW = $(rw_i)_{m\times 1}$: rw_i is the relative demand weight number i logistics demand; AT = $(at_j)_{1\times n}$: at_j is the absolute technical weight of number i logistics demand

RT = $(rt_j)_{1\times n}$: rt_j is the absolute technical weight of number j logistics demand

DOV is the design value. The relations of variables are as follows:

$$\sum_{i=1}^{m} l_i = 1, l_i \geq 0; dw_i = l_i \sum_{j=1}^{n} R_{ij}; rw_i = dw_i \Big/ \sum_{i=1}^{m} dw_i, i = 1, 2, \cdots, m;$$
$$at_j = \sum_{i=1}^{m} l_i R_{ij}; rt_j = at_j \Big/ \sum_{j=1}^{n} at_j, j = 1, 2, \cdots, n \quad (1)$$

The purpose of value analysis is to finally get RDW and RT, as a value measurement reference for logistics demands and processes design features. In this way, we can find out the major value-added and non value-added chain process and determine the objectives and priorities of the process integration. LD is derived from study on the benchmarking and DF is gotten from the pointed activities decomposition. W_i, MAX_MSI, CUR_MSI, IF and AM is designated by the logistics experts, where DI can be identified.

It is the most important thing now to determine the PR. The relationship intensity Rij in PR is determined by logistics expert who comes from different enterprises in different areas of expertise with different experiences. However, different team members tend to give their individual preferences in multiform at according to their different knowledge, backgrounds, abilities and experiences. It is a group decision-making problem in nature, by defining corresponding transforming functions, preferences in multi-format can be uniformed to fuzzy judgment matrices.The group preference aggregation and weights determination methods are adopted on the PR. M refers to a number of experts to assess the relationship intensity R_{ij}: (Pan, 2001).

Definition 1: Evaluation aggregate K = (k_n), 0 <n = 4, k_n stands for the result of the evaluation degree including strong, medium, weak and irrelevant.

Definition 2: Evaluation matrix $P_{m\times n} = \{ p_{mn} \}$, m, n∈N, p_{mn} stands for the membership of evaluation on the R_{ij} on k_n by the m people. Because there is no obvious division on the relationship intensity, there is a certain ambiguity. It is difficult to give a clear judge on the relationship intensity, whether strong, medium, weak or irrelevant. Thus the probability should be allowed, that is, the various levels of membership. In the evaluation matrix Pm×n, the fuzzy membership function replaces the single absolute value nature, in line with people's logical thinking.

Definition 3: The evaluators weight aggregate $A_{1\times m} = \{a_i\}$, 0<i = m ,a_i stands for weight of the number i.

Because the decision-making team members come from the various SL areas, they may differs in knowledge and experience on certain category of the problems. Thus, the reliability and the degree of influence on the conclusions are different, that is, with different degree of importance. Therefore, they are allocated to different weight values. Here, we use full weight method, which the team members assign weight to others and themselves. Each person assigns the scores with maximum of 100 scores to others according to his or her view on the importance of the evaluation results by others. Then the total score of each people is normalized as the weight of the member. That is S_{ij} stands for the score to the number i person by the number j person. The fuzzy evaluation set can be got after comprehensive evaluation on various decision-makers:

$$B = A_{1\times m} \bullet P_{m\times n} = (b_1, b_2, \cdots, b_n); b_j = \sum_{i=1}^{m} (a_i \bullet p_{ij}), j = 1, 2, \cdots n \quad (2)$$

Complying with the maximum membership degree method, the k_g corresponds to maximum max (b_j) as the final judge value of R_{ij}. There may be a certain degree of dependency between the design features of the process. In order to weaken the influence of AM and increase the independence of AT, linear plan process is made: AT = AT*AM^{-1}. F rom Rij, DI and AT, RDW and RT can be found.

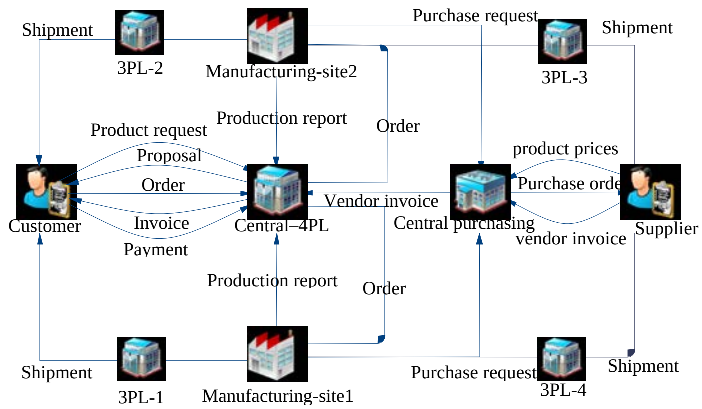

Fig. 2: Activities of SL business process

MULTI-OBJECTIVE SL MODEL

The SL business process can be divided into activities relevant with value in Fig. 2. It is the oversight of materials, information and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. SL involves coordinating and integrating these flows both within and among companies. It is said that the ultimate goal of SL is to reduce inventory (with the assumption that products are available when needed). As a solution for successful supply chain management, sophisticated hardware and software systems based on Internet of Things (IOT) are competing with Cloud Computing based application service providers who promise to provide part or all of the SL service for companies who rent their service. SL can be divided into three main flows: product flow, information flow and finances flow. The product flow includes the movement of goods from a supplier to a customer, as well as any customer returns or service needs. The information flow involves transmitting orders and updating the status of delivery. The financial flow consists of credit terms, payment schedules and consignment and title ownership arrangements. 4PL is the core platform to integrate and coordinate supplier, manufacturer and consumer and 3PL is responsible for providing a supply network.

According to benchmarking law principle, we form the quality house of demands and activities to analyze the difference between outstanding SL process and typical logistics process in China. From the multi-objective planning theory, we use mathematical method to analyze its value: Supposing y_i reflects the value of the number i logistics demand, x_j reflects the value of j for achieving y_i, f_i reflects the function relations between x_j of logistics procedures and logistics demand y_i, g_j reflects the function relations between x_j and $x_1, x_2, \ldots, x_{j-1}, x_{j+1}, \ldots, x_m$. F stands for the value of total logistics demands which is decided by each logistics demand membership, w_i is the weight (degree of importance) of the number i logistics demand membership. At this point, the process integration can be described as a multi-objective optimization problem: In the functional relationship Eq. 3 and other conditions (such as the time constraints of transport, transportation costs, etc.), the process optimization can change the value of activities $(x_1, x_2, \ldots, x_m)$ in order to make the maximum total value of f. (Shi-Hua and Yong-Lin, 2000).

$$\begin{array}{ll} F = (w_i \times y_i) & \Sigma w_i = 1,\ w_i \in [0,1] \\ y_i = f_i(x_1, x_2, \ldots, x_m) & i \in [1,n] \\ x_j = g_j(x_1, x_2, \ldots, x_{j-1}, x_{j+1}, \ldots, x_m) & j \in [1,m] \end{array} \quad (3)$$

Fuzzy evaluation on SL: According to the RDW and RT, we can determine the SL optimization goals and priorities and then SL solution is given in Table 1. As the solutions meet the optimization objectives differently, the evaluation on the various solutions is therefore multi-objective decision-making. A_i (i = 1, 2... m) stands for the number i program and X_j stands for optimization objectives. Then the multi-objective decision making problem can be expressed as $M_{ij} = (x_{ij})$. X_{ij} means that the number i solution contributes to the number j objective. It can be specified in the similar way as PR. The following is the value evaluation method for SL solution (Pan, 2004):

- According to the results of value analysis, hierarchical evaluation indicator system of objectives is setup as follows and shown in Table 1.

$$E_{sl} = [e_1, e_2, \cdots, e_m], e_i = [e_{i1}, e_{i2}, \cdots, e_{in}], e_{ij} = [e_{ij1}, e_{ij2}, \cdots, e_{ijp}]\ i \in [1,m];\ j \in [1,n] \quad (4)$$

- Using Hierarchy Analysis Process (AHP) to determine the weight of optimization objectives with all levels:

Table 1: SL optimization goal and priority

1st level	2nd level	3rd level	Priority level	Alternative plan BI
Procurement indicators	Cost control	Reduce procurement cost	Go down	Selectingsub-vendors; CloudComputing
	Process	Transport visible		GPS; AGPS; IOT
	Visibility	Order State visible		Contract tracking; Cloud Computing
	Risk	Specification and models		Approval procedure; sub-vendor
	Management	etc meet the requirement		selection; goods inspection
		Safety		Goods inspection; loan;
	Increasing	Synchronization and share of		IOT; Cloud Computing;
	Customer demands	supply and demand information		Business intelligence
	Globalization	Global purchasing; Global mannfacturing		Virtualenterprise; sub-vendorselection; contract tracking
Low carbon indicator	...	...		...
Geographical overage indicator	...	...		...

$$W_{opt} = \{w_1, w_2, \cdots, w_m\}, w_i = \{w_{i1}, w_{i2}, \cdots, w_{in}\}, w_{ij} = \{w_{ij1}, w_{ij2}, \cdots, w_{ijp}\}(i \in [1,m]; j \in [1,n])$$
$$\sum_{i=1}^{m} W_i = 1, \sum_{j=1}^{n} W_{ij} = 1, \sum_{k=1}^{p} W_{ijk} = 1, W_i \geq 0, W_{ij} \geq 0, W_{ijk} \geq 0, \tag{5}$$

- Determine the best and worst indicator set (E^+ and E^-) of optimized objectives of each level

$$E^+ = [e_1^+, e_2^+, \cdots, e_m^+], e_i^+ = [e_{i1}^+, e_{i2}^+, \cdots, e_{in}^+], e_{ij}^+ = [e_{ij1}^+, e_{ij2}^+, \cdots, e_{ijp}^+]$$
$$E^- = [e_1^-, e_2^-, \cdots, e_m^-], e_i^- = [e_{i1}^-, e_{i2}^-, \cdots, e_{in}^-], e_{ij}^- = [e_{ij1}^-, e_{ij2}^-, \cdots, e_{ijp}^-](i \in [1,m]; j \in [1,n]) \tag{6}$$

There are two types of the indicators' nature: numerical and non-numeric. As for non-numeric indicators (such as: the timely maintenance services and security etc.), the evaluation indicator is the fuzzy logic language such as satisfaction or dissatisfaction. We use scores ranging from 1 to 19 to describe the degree of satisfaction. As for the numerical indicators (such as: the procurement cycle), the limits can be used as best and worst value (if an indicator is efficiency-oriented, the maximum value is the best; if it is cost-oriented, the minimum value is the best).

- Define membership function to describe the effect of indicators

As the physical meaning, dimensionless and magnitude of the evaluation indicators are different and the effect on the evaluation object is also inconsistent, we must make non-dimensional processing for multi-index comprehensive evaluation. The dimensionless value should reflect the advantages and disadvantages of each indicator value. At the same time, it is difficult to quantify the effect of the indicators value strictly with ambiguous nature. Thus the membership function μ stands for the effect of indicator value after processing the dimensionless. μi stands for the scores or degree of satisfaction of the process design parameter corresponding to the number i evaluation objective, which can be defined as:

$$u_i = \begin{cases} 1, e_i \geq e_i^+ \\ \dfrac{e_i - e_i^-}{e_i^+ - e_i^-}, e_i^- < e_i < e_i^+, \text{Benefit} \\ 0, e_i < e_i^- \end{cases} \quad u_i = \begin{cases} 1, e_i \leq e_i^+ \\ \dfrac{e_i - e_i^-}{e_i^+ - e_i^-}, e_i^+ < e_i < e_i^-, \text{Cost} \\ 0, e_i \geq e_i^- \end{cases} \tag{7}$$

Among them, e_i is number i indicator value of the program. The single-objective evaluation matrix which is composed of membership function as follows:

$$U_{sl} = (u_1, u_2, \cdots, u_s)^T \tag{8}$$

According to the maximum membership principle, the best program is maxb_i, (1 = I = p):

$$B_{sl} = W \circ W_i \circ (W_{ij} \circ U_{sl}) = (b_1, b_2, \cdots, b_p) \tag{9}$$

The symbol "$\circ$" stands for the fuzzy generalized operators, such as taking maximum operation, minimum operation, ordinary addition, general multiplication and so on, which make rational choice according to the characteristics of evaluation problems.

Based on the fuzzy theory, the method unifies the qualitative and quantitative indicators and the membership function with optimal value, so that it solves the multi-objective decision making problem on optimization programs and lays theoretical basis for optimization of process integration.

CONCLUSION

With economic globalization, the modern logistics industry has been considered as a key of the national economic development. SL is conducive to faster and better realization of development goals in the "Logistics

Industry Restructuring and Revitalization Plan" of China. However, SL is a large and complex dynamic system based on IOT and Cloud Computing technology involving many factors. There are still many in-depth studies needed to be further explored including SL performance evaluation, association between SL and modern logistics, the effect of technological progress and knowledge progress on the development of SL. SL is bound to become the direction for Chinese transport enterprises and SL will be promising in future. Government should give priority to SL development in the logistics industry.

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