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Effective Marketing of a Closed-Loop Supply Chain Network: A Fuzzy QFD Approach

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ABSTRACT

Both consumer and government concerns for the environment are driving many original equipment manufacturers (OEM) to engage in additional series of activities stemming from the reverse supply chain. The combination of forward/traditional supply chain and reverse supply chain forms the closed-loop supply chain. Apart from its efficient design, the success of a closed-loop supply chain network depends on its marketing strategy as well. Hence, it is important that the planned marketing strategy be evaluated with respect to the drivers of public participation in the network. To this end, we identify the important drivers of public participation and propose a fuzzy Quality Function Deployment based methodology and method of total preferences to evaluate the marketing strategy of a closed-loop supply chain with respect to those drivers. A numerical example is considered to illustrate the methodology.

Key words: Closed-Loop Supply Chain, Marketing Strategy, Quality Function Deployment, Method of Total Preferences.

1. INTRODUCTION

Economic incentives, government regulations and customer perspective on environmental consciousness (EC) are some of the important reasons for the growing interest in reverse logistics thus driving more and more companies into the product recovery business [1]. EC, enforced primarily by government regulations, has become an obligation to the society itself [2], [3], [4], [5]. Many original equipment manufacturers (OEM) these days are engaged in additional series of activities stemming from the reverse supply chain that involves retrieving used products from consumers and remanufacture or recycle them to recover their left-over market value, at the same time, fulfilling the government regulations pertaining to the handling of used products. The combination of forward and reverse supply chains is called a closed-loop supply chain (CLSC).

Apart from its efficient design, the success of a closed-loop supply chain depends heavily on the level of public participation which in turn is governed by the marketing strategy of the supply chain program. Hence, it is important that the planned marketing strategy be evaluated with respect to the drivers of public participation in the network.

While the drivers for the local governments and companies to engage in the closed-loop supply chain program are environmental consciousness and profitability respectively, the drivers for public to participate in these programs are numerous and are often conflicting in nature. Studies (for example, see [6] and [7]) assess the level of participation of public in the respective reverse supply chain programs. Pochampally and Gupta [8] identified the important drivers of public participation in a reverse supply chain and evaluated the planned marketing strategy with respect to those drivers. We extend their work to a CLSC by identifying the important performance aspects and their respective enablers that aid in the success of the CLSC program. We employ a fuzzy Quality Function Deployment (QFD) and Method of Total Preferences approach to evaluate the planned marketing strategy with respect to those performance aspects and enablers.

2. FUZZY QFD & METHOD OF TOTAL PREFERENCES

“Performance aspects” are defined as the features the decision maker wishes to consider in the selection process and “enablers” are the characteristics possessed by the alternatives that can be used to satisfy the performance aspects. An important feature of QFD is that human input is used to determine both the importance value of each performance aspect and the relationship scores that identify the degree to which the enablers satisfies that performance aspect [9]. Since

human input is vague in nature, we use fuzzy set theory to convert the linguistic ratings into triangular fuzzy numbers (TFN's). These TFN's are then defuzzified for further usage in the QFD process.

The fuzzy set theory is primarily concerned with quantifying vagueness in human perceptions and thoughts. The transition from vagueness to quantification is performed by the application of fuzzy set theory as shown in figure 1. A triangular fuzzy number (TFN) [10] is a fuzzy set with three parameters (l, m, u), each representing a quantity of a linguistic value associated with a degree of membership of either 0 or 1. The parameters l, m, u denote the smallest possible, most promising and the largest possible quantity that describes the linguistic value.



Figure 1

The basic operations on TFN's are as follows [10], [11]:

For example, $P_1 = (a, b, c)$ and $P_2 = (d, e, f)$

$$P_1 + P_2 = (a+d, b+e, c+f) \quad \text{addition} \quad (1)$$

$$P_1 - P_2 = (a-f, b-e, c-e) \quad \text{subtraction} \quad (2)$$

$$P_1 * P_2 = (a*d, b*e, c*f) \quad \text{multiplication} \quad (3)$$

$$P_1 / P_2 = (a/f, b/e, c/d) \quad \text{division} \quad (4)$$

Defuzzification

Defuzzification is a technique to convert a fuzzy number into a crisp real number. There are several methods available for this purpose. The center-of-area method [12] converts a fuzzy number $P = (a, b, c)$ into a crisp number Q where

$$Q = \frac{(c-a) + (b-a)}{3} + a \quad (5)$$

The absolute technical importance ratings (ATIRs) that measure how effectively each enabler can satisfy all of the performance aspects are computed by:

$$ATIR_j = \sum_{i=1}^I d_i R_{ij} \quad \forall j = 1, \dots, J \quad (6)$$

where d_i is the importance value of performance aspect i relative to the other performance aspects, R_{ij} is the relationship score for performance aspect i and enabler j , d_i and R_{ij} are defuzzified numbers of the corresponding linguistic values. Since there is an ATIR for each enabler j , for the comparison of all the enablers, a normalized rating, relative technical importance rating (RTIR_j) is computed as follows:

$$RTIR_j = \frac{ATIR_j}{\sum_{j=1}^J ATIR_j} \quad \forall j = 1, \dots, J \quad (7)$$

Method of Total Preferences

Once the linguistic input from experts is quantified and an overall measure of how well each enabler satisfies the performance aspects is computed via the ATIRs and RTIRs, we could employ the method of total preferences that combines the RTIRs and additional human expert opinions to develop a single measure that reflects the rating of each alternative as follows [9]:

$$TUP_n = \sum RTIR_j WA_{nj} \quad \forall n \quad (8)$$

where TUP_n is the total user preference for alternative n and WA_{nj} is the (defuzzified) degree to which alternative n can deliver enabler j .

Finally, in order to compare the alternatives, the TUP of each alternative is normalized as follows:

$$NTUP_n = \frac{TUP_n}{\sum_{n=1}^N TUP_n} \quad \forall n \tag{9}$$

where $NTUP_n$ is the normalized total preference for alternative n , and N is the total number of alternatives. The alternative with the highest NTUP is considered as the one with highest potential.

3. EVALUATING THE MARKETING STRATEGY

The alternatives in the fuzzy QFD and method of total preferences considered are the available marketing strategies to be evaluated. The following are the performance aspects of the marketing strategies that we consider in the fuzzy QFD process.

- a) Program Simplicity (PS) (reflects the relative ease for the public to participate in the program)
- b) Manufacturing Practices (MP) (reflects the company’s green image, innovation and improvement capability compared to its peers)
- c) Government Issues (GI) (how stringent are the local government regulations)
- d) Incentives (reflects the incentives offered by the company and the local government to public for participating in the program)
- e) Public Knowledge (PK) (reflects the awareness among the public about the program being implemented)

The following are the enablers for the above listed performance aspects that we consider in the fuzzy QFD process:

- a) Program Simplicity (PS): Strategic location of collection centers (SL), Effectiveness of collection methods (ECM)
- b) Manufacturing Practices (MP): Green competency (GC), Innovation and Improvement capability (I&I)
- c) Government Issues (GI): Regulations (Reg.), company’s level of cooperation with local governments (Co-Op)
- d) Incentives: Disposal incentives by the local government and the company (DI), Incentives for buying remanufactured goods (BI)
- e) Public Knowledge (PK): Good advertisement of the program being implemented (AD), Socio-economic status of the society where the program is implemented (SES)

For the convenience of the reader, we represent the performance aspects and enablers as a four level hierarchy as shown in figure 2. The first level represents the goal (evaluating the marketing strategies), second level consists of the performance aspects, third level consists of the enablers of the performance aspects considered in the second level and the fourth level consists of the alternate marketing strategies being evaluated.

Illustrative Example

We illustrate the above discussed methodology with a numerical example by evaluating two available marketing strategies (S_1 and S_2).

Suppose that there are three experts for giving linguistic values to R_{ij} and d_i data. Table 1 shows linguistic scale for R_{ij} and d_i .

Table 1. Linguistic Weight Conversion Table for R_{ij} and d_i data

Linguistic Rating	TFN
Very Strong (VS)	(7.5, 10, 10)
Strong (S)	(5, 7.5, 10)
Medium (M)	(2.5, 5, 7.5)
Weak (W)	(0, 2.5, 5)
Very Weak (VW)	(0, 0, 2.5)

Tables 2, 3, 4, 5, 6 show the linguistic relationship scores (R_{ij}) as given by the three experts (E_i 's) to the enablers of PS, MP, GI, Incentives and PK respectively.

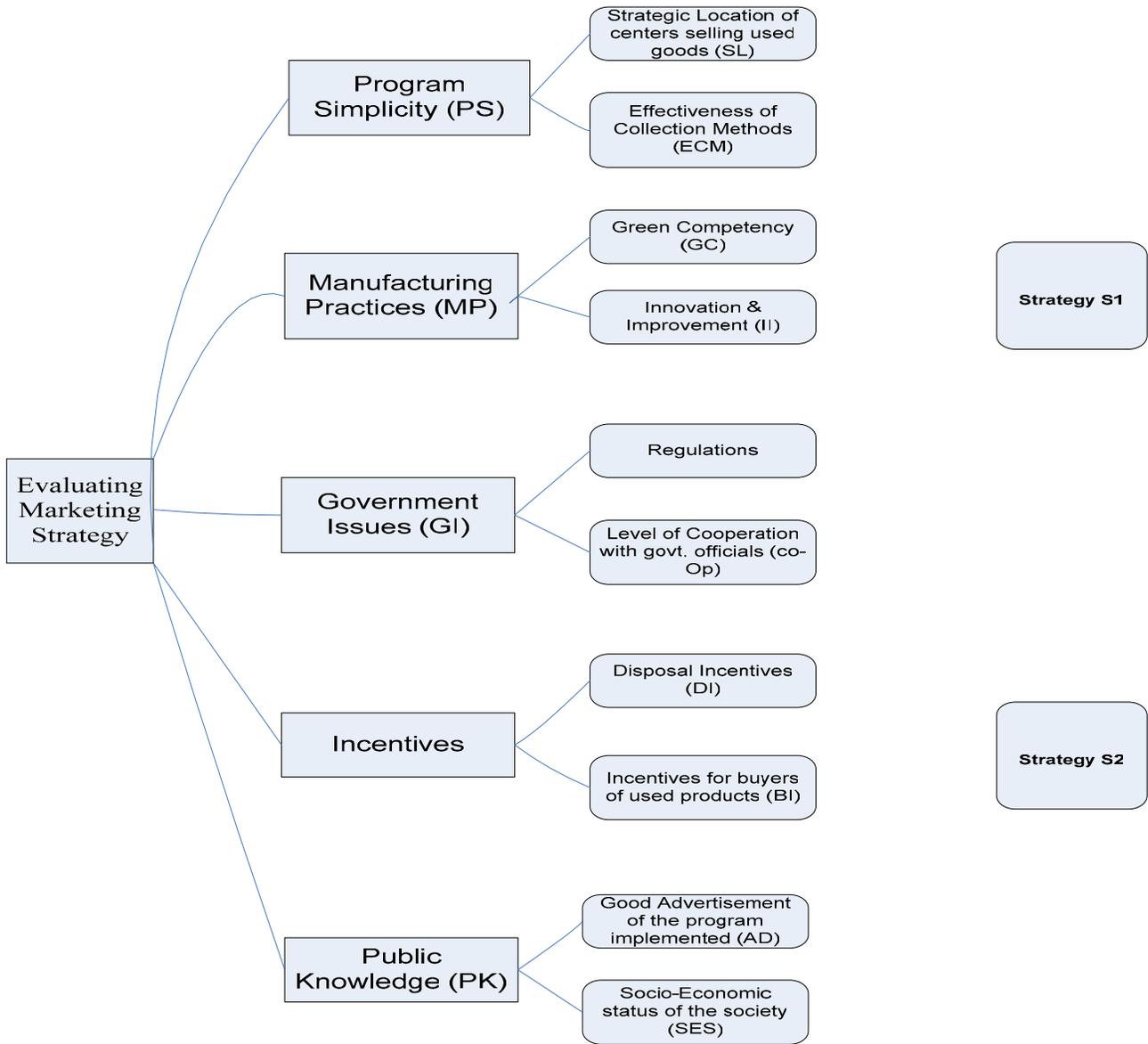


Figure 2. Performance Aspects and Enablers of Marketing Strategies Evaluated

Table 2. Linguistic relationship scores of PS and its enablers

	E ₁	E ₂	E ₃
SL	VS	S	VS
ECM	S	M	S

Table 3. Linguistic relationship scores of MP and its enablers

	E ₁	E ₂	E ₃
GC	VS	VS	S
I&I	S	S	VS

Table 4. Linguistic relationship scores of GI and its enablers

	E ₁	E ₂	E ₃
Reg.	S	VS	M
Co-Op	VS	M	M

Table 5. Linguistic relationship scores of Incentives and its enablers

	E ₁	E ₂	E ₃
DI	VS	S	VS
BI	S	M	S

Table 6. Linguistic relationship scores of PK and its enablers

	E ₁	E ₂	E ₃
AD	VS	M	VS
SES	M	S	S

Table 7 gives the linguistic importance values (d_i) of PS, MP, GI, Incentives and PK as given by the three experts.

Table 7. Linguistic relationship scores of Performance Aspects

	E ₁	E ₂	E ₃
PS	S	VS	VS
MP	S	S	M
GI	VS	VS	M
Incentives	S	VS	S
PK	S	M	M

The ATIRs and RTIRs of the enablers are then calculated using equations (6) and (7) respectively. The TFN's are averaged before defuzzifying. For example, consider SL, the linguistic relationship scores given by the three experts are shown in table 2. These linguistic scores are converted into TFN's using table 1. These TFN's are averaged using

equations (1) and (4). The average relationship score for SL is $\left(\frac{7.5+5+7.5}{3}, \frac{10+7.5+10}{3}, \frac{10+10+10}{3} \right) = (6.67,$

$9.17, 10)$. Defuzzified relationship score for SL calculated using equation (5) is 8.61. The linguistic importance values (d_i 's) of the performance aspects PS, MP, GI, Incentives and PK, as given by three experts (table 7) are converted into TFN's using table 1 again. The average relationship scores for PS, MP, GI, Incentives and PK are then calculated as (6.67, 9.17, 10) (defuzzified value = 8.61), (4.17, 6.67, 9.17) (defuzzified value = 6.67), (5.83, 8.33, 9.17) (defuzzified value = 7.78), (5.83, 8.33, 10) (defuzzified value = 8.05), (3.33, 6.83, 8.33) (defuzzified value = 5.83), respectively. ATIR of SL is then calculated using equation (6) as $8.61 \times 8.61 = 74.15$. The ATIRs of all the enablers are shown in table 8 and their corresponding RTIRs are calculated using equation (7) and are also shown in table 8.

Table 8. ATIRs and RTIRs of Enablers

Enabler	ATIR	RTIR
SL	74.151235	0.134292901
ECM	52.623457	0.095304639
GC	48.148148	0.087199553
I&I	42.592593	0.077138066
Reg.	66.975309	0.121296814
Co-Op	64.814815	0.117384013
DI	49.228395	0.089155953
BI	69.367284	0.125628843
AD	45.37037	0.082168809
SES	38.888889	0.070430408

Table 9 shows the scale for converting linguistic WA_{nj} value given by three experts (for arithmetic simplicity, we assume consensus among the experts).

Table 9. Conversion Table for Linguistic WA_{nj} data

Linguistic Rating	TFN
Very Good (VG)	(7, 10, 10)
Good (G)	(5, 7, 10)
Fair (F)	(2, 5, 8)
Poor (P)	(1, 3, 5)
Very Poor(VP)	(0, 0, 3)

The WA_{nj} linguistic values and the corresponding defuzzified TFNs, calculated using equation (5), for each alternative are shown in table 10.

Table 10. Linguistic and Corresponding Defuzzified WA values of alternate Marketing Strategies

Enabler	Marketing Strategy 1	Marketing Strategy 2
SL	VG	10
ECM	G	7.33333333
GC	VG	10
I&I	F	5
Reg	F	5
Co-Op	G	7.33333333
DI	G	7.33333333
BI	F	5
AD	P	3
SES	F	5

Using equation (8), we calculate the TUP values for each alternate marketing strategy. For example, the TUP for marketing strategy 1 is calculated using the $RTIR_1$ values from table 8 and the defuzzified WA_{1j} values from table 10 as: $(0.13)*(10) + (0.095)*(7.33) + (0.087)*(10) + (0.077)*(5) + (0.121)*(5) + (0.117)*(7.33) + (0.089)*(7.33) + (0.125)*(5) + (0.0821)*(3) + (0.07)*(5) = 6.64$. Similarly, TUP_2 is calculated as 6.621.

Finally, using equation 9, we calculate $NTUPs$ for each alternative marketing strategy. For example, $NTUP_1$ is calculated as: $\frac{6.64}{6.64 + 6.62} = 0.5007$. Similarly, $NTUP_2$ is calculated as 0.4992.

It's obvious that marketing strategy 1 has more potential than marketing strategy 2, hence the decision maker would choose strategy 1.

4. CONCLUSIONS

Apart from its efficient design, the success of any closed-loop supply chain program is dependent equally on the level of public participation. The level of public participation in turn depends on the marketing strategy adopted by the program administrators. To this end, in this paper we identified the important performance aspects and enablers of the marketing strategy adopted from a consumers perspective and proposed a fuzzy QFD and method of total preference approach to evaluate the planned marketing strategy. A numerical example was considered to illustrate the methodology.

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