"Measuring Performance of Reverse Chain System through Fuzzy Comprehensive Analysis"

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Abstract
Reverse Logistics has become buzzword in today's industrial word and big differentiating factor in quest of success for any organization word wide. Whole world is suffering from scarcity of resources and we have finite area available for the waste disposal. One of the sustainable solutions is to design product in such a way so that we can maximize its reuse through reverse logistics. Reverse logistics is fast becoming industrial design standard for majority of organizations worldwide. Reverse logistics has become a need of an hour. Some of the organization do it voluntarily and some because of the environmental rules and legislations. In order to achieve total customer satisfaction, one has to take care of product for its entire life cycle through activities of reverse logistics. So a need is felt to evaluate the reverse chain performance of Indian automotive industry in relation to customer satisfaction. Methodology used for measuring reverse chain performance is fuzzy comprehensive analysis. Variable affecting reverse chain performance is reduced to most important four factors. With the help of multiple regression model the relative importance of these factors are ranked, which facilitates the judgment in multi criteria decision making process.

Keywords: Analytic hierarchy process (AHP), Multiple Regression, Factor Analysis, Consistency Ratio, Fuzzy Comprehensive Analysis.

1. Introduction

Resources are scarce in nature and we got limited disposal capacities. Some times it is economical to reuse the product rather going for its disposal. Growing environmental concern and population emphasizes the reuse of products and materials. Some of the countries have gone to extent of charging manufacturer for the entire life cycle of their product. In near future the worlds is going to witness explosive growth of product recovery activities and at the same companies are recognizing opportunity to access this new market segment combining with environmental stewardship.

The focus of product recovery is more on engineering and its logistics issues has been ignored. It is only in the recent past need to investigate logistics aspects of product recovery and unsold merchandise have been acknowledged. The concept of reverse logistics was newly added to Supply Chain Operation Reference Model (SCORE), recognizing its importance for efficient and effective supply chain management in future. Some of the companies are forced to take the product back while others do it willingly recognizing the value in the used product. Thus the reverse logistics has become an important parameter to judge the efficiency and effectiveness of the modern supply chain.

Like any other concept the reverse logistics is also kept continuously evolving over the period of time. The new concept of reverse logistics is different from traditional concept as process of recycling product. The new definition is comprehensive and wider in scope. Reverse logistics is defined as "The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal (Dale & Ronald, 1999)"

Reverse logistics can be used to enhance the organization's customer service capabilities. By communicating and convincing the message to the market place your organization can add to the stature of the organization.

Benefits

In general, regardless of the stature of the organization, the following is the most far and wide recognized benefits derived from reverse logistics----

- Improved customer contentment and retention.
- Reduction in the acquisition of parts and subassemblies.
- Enhance revenue and profitability of organization through increased availability of product/service.
- Improved efficiency and effectiveness of the organization, which led to significant improvement in the efficiency of the organization.
- Improved time bound sensitivity towards listening to the voice of the customers.
- Results in anticipation of needs and wants of the customer much ahead before actually they could actually realize it .
- Development of intellectual and emotional bonding with the customers which led to a belief that they made right choice in selecting you.
- Development of interactive partnership with the customer instead of proactive or reactive partnership with the customer.

Understanding factors affecting reverse chain performance in relation to customer satisfaction is a complex problem. The complexity of the problem is due to presence of large number of factors and interaction amongst the factors. Identification of these direct and indirect factors is a tedious job. Factor analysis is used in identification of most important factors. Multiple regression model is framed taking these factors as independent variables and customer satisfaction as dependent variable. Multiple regression model facilitates in assessing the relative importance of the factors. This is further facilitates the judgment in multi criteria decision making using fuzzy comprehensive analysis.

2. Literature Survey

2.1 About Fuzzy Comprehensive Analysis

Fuzzy comprehensive evaluation system is based on mathematics used for complete evaluation of objects in a real world situation that are vague and difficult to define by using the thinking and methods of fuzzy mathematics. Fuzzy mathematics was first noticed in 1965, and pioneer is professor Chad (LAZadeh) who possesses substantial expertise in the area of automatic control mechanism. Like any other concept the fuzzy mathematics also kept evolving for

near 38 years. Over the years fuzzy mathematics has witnessed a rapid advancement both in theory and practical. Fuzzy comprehensive analysis is based multi criteria decision making. Through the fuzzy evaluation information about the priority of various alternatives can be served as a reference for decision makers to make decision[1].
you need to select the suitable appraisal indicators, these indicators can be from a different point of view, reflecting different aspects of the evaluation index system of evaluating objects. Fuzzy comprehensive evaluation needs the use of the indicator system comprises of multiple index. Evaluation should follow the principles of purpose, objectivity, comprehensiveness, sensitivity and mutual independence, the comparability and should be easy to operate. In the fuzzy comprehensive evaluation, the importance of weighing the value of different projects is called the weight [2].

2.2 Analytic Hierarchy Process (AHP)

AHP facilitates users to access the relative weight of multiple criteria or multiple options in an intuitive manner. If quantitative ratings are not available, experts or policy makers still in a position to assess if one criteria more important than other [3].

AHP Formulation:

$$Mt = \prod_{j=1}^{n} Xij \quad i, j = 1,2,3\text{------}n \text{ (Matrix row multiplication)} \qquad (1)$$

$$\overline{Wt} = \sqrt[n]{M_t} \qquad (2)$$

$$Wt = \overline{Wt} \,/\, \sum_{j=1}^{n} \overline{Wj} \qquad (3)$$

Table-2.1: AHP Formulation

Consistence Test:

Calculate the consistency index CI = (λmax - M)/(M-1), Where λmax= Max eigen value.The smaller the value of CI, the smaller is the deviation from the consistency. Obtain the random index (RI) for the number of attributes used in decision making. Refer to table 2.2 for details, in which the upper row denotes the order of the matrix, and the lower is the corresponding index. Then calculate the consistency ratio CR= CI/RI. Usually, a CR of 0.1 or less is generally considered as acceptable [4].

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table- 2.2: Random Index

2.3. Factor Analysis

Factor 1 (service quality and service recovery)

- V1: (We are prepared to devote people and resources to the reverse logistics activities we conduct with this customer)
- V28: (Handle the return without customer intervention)
- V7: (Offer meaningful guarantee to our customer)
- V14: (We respond quickly towards the customer's return needs)
- V9: (we are with the customers indefinitely.)

Factor 2 (Standardization of reverse logistics process)

- V26: (Reverse logistics program evaluations in our firm are based on written standards).
- V23: (Duties, authority, and accountability for reverse logistics are documented in policies and procedures)
- V29: (Written procedures and guidelines are available for most reverse logistics related work situations)
- V2: (Consistency of return procedure)
- V15: (Availability of collection centres)

Factor 3 (customer's involvement)

- V5: (Filling out return form is easy for me)
- V13: (Variety of options available to me for returning product.)
- V3: (It is convenient to contact and reach return service personnel.)
- V27: (Preparing the product for return is easy)
- V4: (We tell the truth to our supplier)

Factor 4 (Reverse logistics' strategy)

- V24: (We address reverse logistics issues mainly with technologies we have developed)
- V12: (We incur lower compliance costs with environmental regulations due to our returns handling method)
- V18: (We recognize our returns policies to be liberal)
- V25: (We are realizing cost savings because of our reverse logistics activities)
- V20: (Our strategy for dealing with returned merchandise improves our cost position relative to our closest competitors.)

2.4. Multiple Regression Analysis

Y=.074+.528*X1+.217*X2+.179*X3+.097*X4

Y= Overall customer satisfaction

X1= Service quality and recovery

X2= Standardization of reverse logistics process

X3= Customer's involvement

X4= Reverse logistics strategy [5]

3. Methodology

Step-1: A.H.P formulation

Step-2: Determine factor sets in evaluating relationship

Step-3: Determine evaluation set to judge performance known as evaluation grade

Step-4: Determine single factor evaluation matrix using step-2 & 3

Step-5: Determine the weight of the index

Step-6: Get the conclusion

4. Data Analysis & Interpretation

Performance of Reverse Logistics F = [F1, F2, F3, F4] (Factor Set-Refer 2.3)

$V = [V_1, V_2, V_3, V_4, V_5]$

V_1 – Excellent, V_2- Good, V_3- Above Average, V_4-Average, V_5 - Poor

From multiple regression [refer 2.4.]

W_t (Geometric Mean) = $\begin{pmatrix} .528 \\ .217 \\ .179 \\ .097 \end{pmatrix}$

Weight W = $\begin{pmatrix} .517 \\ .215 \\ .175 \\ .095 \end{pmatrix}$

$\lambda max = 4.1346$, CI = (4.1346 – 4)/(4 – 1) = 0.04486, CR = .04486/0.9 = 0.04985

Since the value of CR is less than .1, matrix formation of the factor set and its relation is consistent.

Factor	F1	F2	F3	F4
Weight	0.517	.215	.175	.095

F1 = [V1,V28,V7,V14,V9]

	V1	V28	V7	V14	V9
V1	1	.9	.4	.8	.3
V28	.9	1	.3	.9	.2
V7	.4	.3	1	.2	.2
V14	.8	.9	.2	1	.3
V9	.3	.2	.2	.3	1

Refer Correlation Matrix

$$W_1 = \begin{pmatrix} .26, .23, .15, .22, .14 \end{pmatrix}$$

Relationship Matrix R1 Based on survey =

$$\begin{pmatrix} .2 & .18 & .3 & .23 & .09 \\ .14 & .26 & .21 & .39 & 0 \\ .13 & .27 & .31 & .22 & .07 \\ .15 & .24 & .27 & .25 & .09 \\ .11 & .34 & .31 & .23 & .11 \end{pmatrix}$$

$$B_1 = W_1 * R_1 = \begin{pmatrix} .15, .21, .27, .27, .07 \end{pmatrix}$$

F2 = [V26, V23, V29, V2, V15]

	V26	V23	V29	V2	V15
V26	1	.9	.9	.7	.3
V23	.9	1	.9	.8	.2
V29	.9	.9	1	.8	.2
V2	.7	.8	.8	1	.7
V15	.3	.2	.2	.7	1

$$W_2 = \begin{pmatrix} .22 & .2 & .2 & .25 & .13 \end{pmatrix}$$

Relationship Matrix R2 Based on survey =

$$\begin{pmatrix} .15 & .22 & .37 & .19 & .07 \\ .08 & .11 & .41 & .31 & .09 \\ .11 & .28 & .45 & .12 & .04 \\ .11 & .34 & .32 & .23 & 0 \end{pmatrix}$$

.15 .28 .32 .21 .04

$$B_2 = W_2 * R_2 = \begin{pmatrix} .12 & .25 & .37 & .21 & .045 \end{pmatrix}$$

F3 = [V5, V13, V3, V27, V4]

	V5	V13	V3	V27	V4
V5	1	.2	.2	.2	.2
V13	.2	1	.8	.2	.2
V3	.2	.8	1	.3	.2
V27	.2	.2	.3	1	.2
V4	.2	.2	.2	.2	1

$$W_2 = \begin{pmatrix} .17 & .22 & .25 & .19 & .17 \end{pmatrix}$$

Relationship Matrix R3 Based on survey =

$$\begin{pmatrix} .13 & .46 & .32 & .09 & 0 \\ .19 & .44 & .30 & .07 & 0 \\ .14 & .29 & .44 & .13 & 0 \\ .03 & .36 & .51 & .10 & 0 \\ .12 & .26 & .43 & .19 & .03 \end{pmatrix}$$

$$B_3 = W_3 * R_3 = \begin{pmatrix} .125 & .36 & .4 & .11 & .005 \end{pmatrix}$$

F4 = [V24, V12, V18, V25, V20]

	V24	V12	V18	V25	V20
V24	1	.7	.2	.7	.8
V12	.7	1	.2	.9	.9
V18	.2	.2	1	.2	.2
V25	.7	.9	.2	1	.9
V20	.8	.9	.2	.9	1

$$W_4 = \begin{pmatrix} .21 & .23 & .096 & .23 & .23 \end{pmatrix}$$

Relationship Matrix R4 Based on survey =

$$\begin{pmatrix} .25 & .14 & .36 & .23 & 0 \\ .19 & .36 & .27 & .18 & 0 \\ .05 & .51 & .31 & .11 & .02 \\ .07 & .45 & .29 & .19 & 0 \\ .07 & .45 & .33 & .15 & 0 \end{pmatrix}$$

$$B_4 = W_4 * R_4 = \begin{pmatrix} .133 & .37 & .31 & .18 & .002 \end{pmatrix}$$

The comprehensive result of experts in evaluating the reverse chain performance is as follows: B= W•R

Evaluation Grade $V = [V_1, V_2, V_3, V_4, V_5]$

V_1 – Excellent, V_2- Good, V_3- Above Average, V_4-Average, V_5 - Poor

$$B = \left(.14, .26, .32, .22, .06\right)$$

The result showed that 14 percent of the experts believe that the performance of reverse logistics in Indian automotive industry is excellent, 26% believe good, 32% believe above average, 22% believe average, and 6% believe poor.

5. Conclusion

The sum of the weight in the results set B-vector is 1 and meets the normalized conditions. According to the principle of maximum subordination, the Reverse chain performance level is "above average" which corresponds to the maximum subordination in set B and should be the performance level of Reverse chain in Indian automotive industry.

Reverse logistics a relatively new phenomenon is the context of Indian automotive industry. Results are encouraging and fast picking up. This shows that majority of players in Indian automotive industry taking seriously the reverse chain activities.

References

1. Xiu-zhen Li , Chang-ci Pang. Mathematical experiment [M]. Beijing: China Machine Press, 2008.3.
2. Lun-biao Yang, Ying-Yi Gao. Fuzzy Mathematics and Application [M]. Guangzhou: South China University of Technology, 2008.2.
3. Yan Pang, Lihui Hu, Hongxia Li "Construction and Evaluation of Environment-friendly Green Supply Chain in Steel and Iron Manufacturing Industry" Management & Engineering 02 (2011) 1838-5745.
4. Bozóki, S. and Rapcsák, T. [2008] On Saaty's and Koczkodaj's inconsistencies of pairwise comparison matrices, journal of global optimization,42(2), pp-157-175.
5. Rupesh Kumar Tiwari "Reverse Logistics: A strategy to achieve total customer satisfaction and enhancing competitive performance" Inventi Impact : Journal of Supply Chain and Logistics (Published by INVENTI INDIA PVT LTD.), April-June, Volume-2013, Issue-02, www.inventi.in, Research Paper ID: Inventi: msc/48/13, E-ISSN: 2250-0219, P-ISSN: 2249-0981.