

# Development of Model of Remanufactured Product Competencies using DeMATEL

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**Abstract.** A product reestablished to its original form and retailed in conjunction with its newfangled version is challenged with various constraints of comparison. This paper identifies the price differentiation, warranty offered, servicing and brand reputation as key parameters from literature to help the Original Equipment Manufacturers strategize the operations to meet the customer expectations. The study is carried through the survey of experts in automobile sector and analyzed to derive a structural model using DEMATEL methodology. The model measures the prominence of factors and provides insights into relationships driving the system.

**Keywords:** Design for Remanufacturing, New Product Development, Mathematical Modelling

## Introduction:

Remanufactured product is not easily accepted by customers due to a poor perception of its quality. However, the strongest strategy out of the four End-of-Life options -Repair, Recondition, Remanufacture and Recycle. Original Equipment Manufacturer's (OEMs) have better opportunity than the third-party manufacturers due to the expertise and experience in making the product for the first time. Fear of cannibalisation is considered a primitive reason for not adopting remanufacturing. In a study conducted on multiple life cycle design it was proposed that consumer's evolve through three stages as they buy and sell a product to purchase a restored product over a period of time [1]. In the first two stages, the OEMs can develop their strengths to compete better in the last stage of purchase of remanufactured product by end-user where the OEMs may need to compete with third-party remanufacturers while ensuring the best sales of the new version of their own product being sold alongside.

## Remanufacturing Competencies:

For high tech electronic products the technology obsolescence is faster resulting in multiple generations of products being simultaneously available in the market [2]. Refurbished products offered by OEMs or third party remanufacturer's are also vended. The difference in the prices offered may be highly influential for sales. The inherent value of the used product reduces the remanufacturing costs and thus it can be offered at a lower price. In an extensive study, it was found that there may be two different segments of customers – one of which makes no distinction between the new and restored product categories being sensitive to price only, while the other segment strongly prefers new products to remanufactured ones.

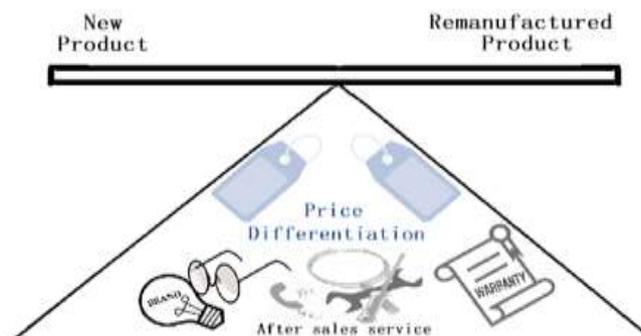


Fig.1 : Remanufactured Product Competency: Price Differentiation, Brand, After Sales service, Warranty

The study also recommended an increase in price of the new product line to mitigate the risk of cannibalization. [3]. To keep the remanufacturing costs under control requires a supply of used products and remanufactured or new products could be traded in instead. The price differentials are generally 28 percent for industrial products and vary from 18 to 43 percent across various product categories and customers prefer highly charged remanufactured product from OEMs irrespective of the warranty of offered [4]. The brand image is highly influenced when the OEMs sell remanufactured product. In an experimental study carried across three different product lines, it was found that for high end products having an emotional brand value there may be adverse consequence on the apprehended value of their new products resulting in the conclusion of presence of independent remanufacturers being beneficial to OEMs[5]. However, from environmental standpoint, it is observed that remanufacturing done by OEMs should be fortified in lieu of third party remanufacturers [6]. Literature suggests that creating awareness on environmental benefits such as conservation of material resources and energy can increase the inclination of customers to bargain the remanufactured product [7]

Remanufacturing is a sustainable manufacturing methodology which thus can help gain some benefits from the social order creating a positive branding for the OEM.][Quality comparison of offered merchandise is evident and thus the diagnosis of the used product as a raw material and testing of the final re-vamped product will help offer equal warranty after replacing any parts that cannot sustain multiple life cycle. Offering the right warranty is a recommended strategy to surge the confidence of the customers.[8]. With higher warranty offered a better prices for the products can also be expected [9]. By numerical mathematical modelling it has been demonstrated that working out the right warranty through appropriate parameters can make remanufacturing beneficial economically as well as environmentally. [10].Preventive maintenance is an activity allied with warranty and the recent technology of embedded sensors for monitoring can help the right end-of-life strategies for profit [11]. While investigating the opinions of Indian origin consumers residing in USA, it was found that they considered the refurbished products being offered of better value due to the after sales service associated [12]. For automotive sector after-market strategic factors were explored indicating that the design process should concentrate on the service factors including core acquisition and reverse logistics [13, 14]. While inspecting the Chinese automotive spare part industry through structural equation modelling, it was recommended to setup after-sales service stations for remanufactured products for better promotion [15]. After the product is passed on to the end-user, the product may not work as expected or there may be better versions of the product that may be launched causing obsolescence. In case of electronic products such as mobile phones, the company offers free software updates even if it was developed after the product was sold to the customer which helps the product keep its pace in the race. Free replacements and maintenance services to renew the product helps reduce customer dissonance. However, once the product is brought in for damage correction the offers may change. The transparency of these services may gain customer loyalty. Annual Maintenance Contracts at nominal prices may help assess the OEMs monitor the condition of the product and recommend a trade in at the right time so that they can obtain a core for future production. With the advent of the artificial intelligence technologies, remote monitoring may also be soon possible for automotive sector products. Offering better terms in after-sales service for multiple product life cycles is a prospect at improving the remanufacturability success. The relation between the four aspects of price differential, brand value, warranty and after-sales service (as shown in Fig.1) would be weighed to derive remanufacturing strategies for driving the remanufactured product alongside their updated new versions.

**Methodology:**

Decision Making Trial and Evaluation Laboratory developed in early 1976 would be useful to resolve the issue [16]. To investigate the relationship between the factors a survey was carried out in the automobile sector using expert opinion from Marketing, On-field Maintenance and Design Departments who have more than 3 years of experience of active collaboration with consumers. The method is based on pairwise comparison.

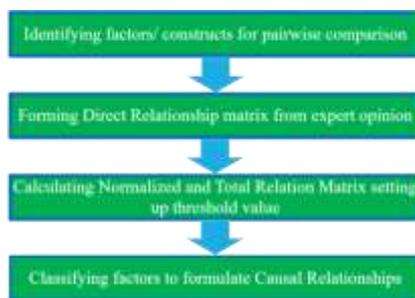


Fig. 2 :Steps in DEMATEL Approach

Table 1: Questionnaire for comparison

Code		According to your experience and judgment, rank the effect of factor in left column on the right column from the perspective of gaining end-user support for successful remanufacturing							
P/B	Price differentiation	has	No	low	medium	high	very high	effect on improving perception of	Brand Image
B/P	Brand Image		No	low	medium	high	very high		Price differentiation
P/W	Price differentiation	has	No	low	medium	high	very high	effect on improving perception of	Warranty
W/P	Warranty		No	low	medium	high	very high		Price differentiation
P/A	Price differentiation	has	No	low	medium	high	very high	effect on improving perception of	After sales service
A/P	After sales service		No	low	medium	high	very high		Price differentiation
B/W	Brand Image	has	No	low	medium	high	very high	effect on improving perception of	Warranty
W/B	Warranty		No	low	medium	high	very high		Brand Image
B/A	Brand Image	has	No	low	medium	high	very high	effect on improving perception of	After sales service
A/B	After sales service		No	low	medium	high	very high		Brand Image
W/A	Warranty	has	No	Low	medium	high	very high	effect on improving perception of	After sales service
A/W	After sales service		No	Low	medium	high	very high		Warranty

As recommended in literature [17] for the expert opinion questionnaire, the ranking structure for each pair of criterion used is as shown the figure in table 1. As per the scale for every pair the participants rank the effect of factor on i on j as 0 (No effect), 1 (low effect), 2 (medium effect), 3 (high effect) and 4 (very high) effect.

The first column of table 1 is coded as i/j which implies effect of factor i on factor j. For every participant the responses can be arranged in the format of a matrix as below. The summarised results are represented in the table 2 indicating the responses. The count of Low, medium, high and very high responses for each factor is denoted by a<sub>1</sub>, a<sub>2</sub>, a<sub>3</sub>, and a<sub>4</sub> respectively.

$$X_i = \begin{bmatrix} 0 & \frac{P}{B} & \frac{P}{W} & \frac{P}{A} \\ \frac{B}{P} & 0 & \frac{B}{W} & \frac{B}{A} \\ \frac{P}{W} & \frac{W}{P} & 0 & \frac{W}{A} \\ \frac{P}{A} & \frac{A}{P} & \frac{A}{W} & 0 \end{bmatrix}$$

It may be noted that the DEMATEL is mostly employed with limited number of respondents, generally experts who may be provided with a compensation for filling the survey. However, the survey instrument is too complex, especially with increased number of criterion.

Table 2: Summary of Responses:

Code	a <sub>1</sub>	a <sub>2</sub>	a <sub>3</sub>	a <sub>4</sub>	Rel. Rank	Rel. Imp. Index
P/B	4	16	3	1	12	0.51041
B/P	3	8	5	8	3	0.6875
P/W	1	10	9	4	5	0.66666
W/P	2	8	7	7	2	0.69791
P/A	1	8	12	3	4	0.67708
A/P	3	12	4	5	7	0.61458
B/W	1	3	16	4	1	0.73958
W/B	8	5	8	3	10	0.5625
B/A	4	9	10	1	8	0.58333
A/B	7	7	8	2	11	0.55208
W/A	3	12	8	1	9	0.5729
A/W	5	4	12	3	6	0.6354

. In this study, we try to adopt a different method of calculating the initial comparison matrix based. In most DEMATEL research papers, the responses of every participant is considered in the form of a matrix and the means of the corresponding comparisons are used for Direct relation matrix [18,19]. However, in this paper we have used Relative Importance Index (RII) to represent the direct relation matrix. It offers a direct evaluation of relativity between the pairwise comparisons. Hence, we calculate RII for every effect using the formula:

$$RII = \frac{1 x a_1 + 2 x a_2 + 3 x a_3 + 4 x a_4}{4 x n}$$

$$R = RII \begin{bmatrix} 0 & \frac{P}{B} & \frac{P}{W} & \frac{P}{A} \\ \frac{B}{P} & 0 & \frac{B}{W} & \frac{B}{A} \\ \frac{W}{P} & \frac{W}{B} & 0 & \frac{W}{A} \\ \frac{A}{P} & \frac{A}{B} & \frac{A}{W} & 0 \end{bmatrix}$$

Direct Relation Matrix can be written as the Relative important index for corresponding ratios as shown in Table 3. The normalized relation matrix computed by both the methods is found to be same and is shown in Table 4.

Table 3: Direct Relation Matrix (R)

	P	B	W	A
P	0	0.73958	0.5625	0.58333
B	0.510417	0	0.55208	0.57291
W	0.6875	0.69791	0	0.63541
A	0.666667	0.67708	0.61458	0

The operations applied to the to obtain the Normalized Relation matrix (NR) and Total Relation matrix are as follows:

$$c = \max \{ \max \sum_{j=1}^f x_{ij}, \sum_{i=1}^f x_{ij} \}; NR = \frac{1}{c} * R ;$$

Where f- no. of factors compared, c = maximum of the total of the sum of the rows and columns of matrix R

Table 4: Normalized Relation Matrix (NR):

		B	W	A
P				
P	0	0.349754	0.26601	0.275862
B	0.241379	0	0.261084	0.270936
W	0.325123	0.330049	0	0.300493
A	0.315271	0.320197	0.29064	0

For Table5 , we use  $TR = NR \times (I - NR)^{-1}$

Table 5: Total Relation Matrix (TR)

		B	W	A
P				
P	1.704677	2.149942	1.826448	1.877449
B	1.731831	1.701961	1.662977	1.709517
W	2.053115	2.251022	1.712631	1.991385
A	2.003951	2.197212	1.896706	1.718064

The threshold value calculated for this study from the average of the matrix TR is 1.886805

**Results and Discussion:**

Table 6: Cause and Effect Categorization

	Ri	Ci	Ri + Ci	Ri - Ci	Classificaiton
P	7.558516	7.493574	15.05209	0.064942	Cause
B	6.806285	8.300137	15.10642	-1.49385	Effect
W	8.008153	7.098762	15.10692	0.909391	Cause
A	7.815934	7.296415	15.11235	0.519519	Cause

Table1 to Table 5 illustrate the steps of DeMATEL Method. Result obtained in Table 6 suggest that factors of Price Differentiaion, Warranty, After-sales service can be considered in the “cause” category driving the factor in the “effect” category – Brand value. Brand value is thus the key factor which may be considered directly proportional to the response we desire from the system viz., acceptability of the remanufactured product.

Table 7: Values greater than Threshold value

	P	B	W	A
P	0	2.149942	0	1.877449
B	0	0	0	0
W	2.053115	2.251022	0	1.991385
A	2.003951	2.197212	1.896706	0

Based on the analysis of Table 7 considering the relations emerging from significance of threshold value of the total relation matrix, figure 3 is plotted graphically to depict the cause and effect classification while figure 4 demonstrates the diagraph.

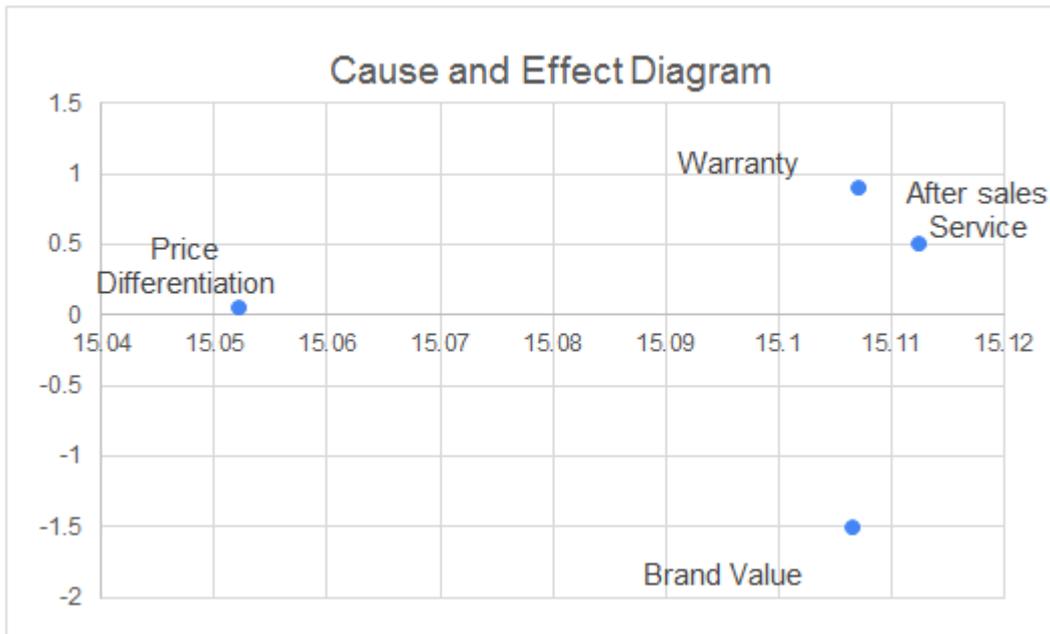


Fig.3: Cause and Effect Diagram

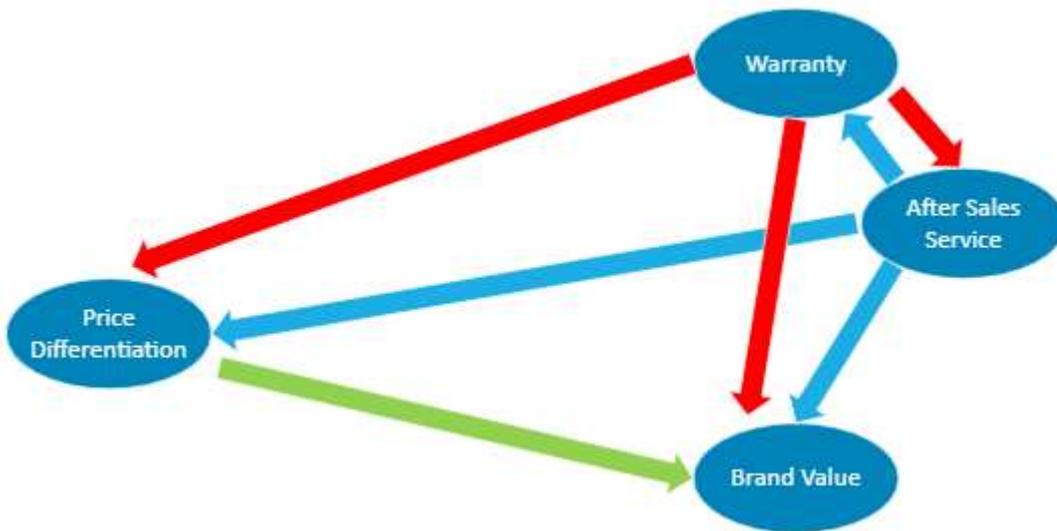


Fig.4 : Diagram of Causal Relationships

The horizontal axis depicts the degree of importance of the factor. After Sales Service is ranked first followed by Warranty, Brand Value and Price Differentiation. Warranty and After-sales service appear to be the key driving factors while price differentiation mediates their effect on brand value.

**Conclusion:**

The model developed in this study focused on increasing the remanufactured product acceptability by prioritizing the parameters of warranty, after-sales service, price – differentiation. Price differentiation was found to be having the least effect on the system while quality of after-sales service was found to be the most important contributor. All the factors together improve the perception of the brand which may subsequently result in increase in the acceptability of remanufactured product. DEMATEL was used as an effective approach to identify significant directional relationships resulting in a model. However, the model needs to be validated for the significance of the relationships.

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