FACTORS AFFECTING REMANUFACTURING OF E-WASTE IN DEVELOPING COUNTRIES

[1]SWATANTRA KUMAR JAISWAL1, [2]ANIMESH AGRAWAL, [3]SURAJ KUMAR MUKTI

[1,2,3]Mechanical Engineering Department, NIT Raipur, C.G., India -492010
E-mail: [1]jaiswalswatantra2011@gmail.com, [2]animeshgrw@gmail.com, [3]skmukti.mech@nitrr.ac.in

Abstract - In the last few decades, there is massive growth in the electrical and electronic industry as a result of these more products are getting obsolete, hence, there is rapid growth in the electrical and electronic waste, demand of electronic product growing enormously resulting more amount of e-waste. E-waste management can be achieved through reuse, refurbished, remanufacturing and recycling. Remanufacturing is effectively conducted in developed countries such as the United States, the United Kingdom, and Germany for a variety of products, while developing countries such as India, Brazil, and China are at nascent stage (Singhal, Tripathy, and Jena 2020). Remanufacturing is a method for transforming End of use product (EOU) or End of life product (EOL) to the given standards or specifications of the original product, remanufacturing is at an emerging stage in India. In this study, author aims to detect the critical factors, which will affect the success of e-waste remanufacturing and find out the logical relationship between them by using interpretative structural modelling (ISM). Ten factors have been taken using of literature survey and experts in the respective field. Further, these ten factors are divided into six levels based on the logical relationship among them or by using ISM model, top levels show strong dependence power and the bottom level shows strong driving power. The result shows that government support (GS), timing of return (TR) and marketing strategies (MS) are the major critical factors in the hierarchy and shows strong driving power in remanufacturing, market access (MA), product design (PD), collection strategies (CS), return intension (RI), consumption attitude (CA), assured warranty (AW) and workforce and technology (WT) shows strong dependence power as they are in top levels of ISM model. Government support (GS) are at level six of ISM model shows strong driving power it is one of the critical factors, which strongly effects the remanufacturing of e-waste, government, have to come onward and offer subsidy to both manufacturer and consumer to encourage remanufacturing. This study promotes the manufacturer for sustainable e-waste remanufacturing in India.

Keywords: E-Waste, Remanufacturing, ISM.

I. INTRODUCTION

Electronic waste is an electronic item that is undesirable and not working and approaching or toward the finish of their specified "valuable life." Computers, VCRs, TVs, sound systems, fax machines, and copiers are ordinary electronic waste. Electronic waste/e-waste is any electrical hardware that has been disposed of. This incorporates broken and working things that are tossed in the trash or given to a cause affiliate like Goodwill. Frequently, if the items go unsold in the market, they will be discarded. Electronic waste/e-waste or electronic waste is especially hazardous because of harmful synthetics that normally drain from the metals inside when covered.

Products that were once the rage of the times and were available to just a select few have vanished from the market and the manufacturers have either shifted to better technologies or have shut down shop. For instance, pagers were once considered to be at the forefront of instant communication but are not even supportable by today's technologies.

The electrical and electronic products so discarded are termed e-waste (electronic waste) (Kiddee, Naidu, and Wong 2013). In European Union, electrical and electronic waste products are coined as Waste Electrical and Electronic Equipment (WEEE). The rapid growth of technology, high rate of obsolesce, short life span, attractive consumer design, and market compatibility issues are some of the key reasons for e-waste generation. The waste created by parts of products or products as a whole, running on electricity, or electronic equipment, upon completion of their lifecycle or utility, or eventual obsolescence due to upgradation of technology comes under the category of e-waste or WEEE. Refrigerators, televisions, cameras, air conditioners, mobile phones, etc., and their components, assembly, subassembly are some examples of e-waste. Remanufacturing is a series of technical measures/techniques or engineering tasks to carry out extensive repairs, transformations, and performance upgrades on the device and its parts that have been discarded (Fatimah & Biswas, 2016). High efficiency, energy conservation, high quality, and environmental protection are its guiding principles. Remanufacturing, a way of changing End of Use (EOU) or End of Life (EOL) products to the necessary standards or specifications of the original product, is an industrial process that restores a worn-out product to nearly new state (Singhal, Tripathy, and Kumar 2019). Remanufacturing initiatives are frequently connected with countries like the USA, Germany, and the UK in industries like electronics, automotive, furniture, and medicine (Kang et al., 2016). But despite its potential benefits, remanufacturing is still in its infancy in India (Sharma et al., 2016). Most e-waste management

techniques used in underdeveloped countries only include non-sustainable methods like recycling and landfilling (Kumar and Dixit, 2018). After reviewing the e-waste literature, it was discovered that relatively few studies on e-waste remanufacturing had been done in India. The author of this study determines the potential or crucial aspects of remanufacturing of e-waste in developing countries like India. In this study author identify the critical factors affecting e-waste remanufacturing and determine the interrelationship among them for developing countries. This paper includes introduction of e-waste and remanufacturing, then literature related to e-waste management, remanufacturing and e-waste remanufacturing. After that research methodology is there in which identification of factors has been done, then determine the interrelationship among them. Next section is result and discussion, at last conclusion of study.

II. LITERATURE REVIEW

Electronic waste contains a range of toxic substances which affects social health and contaminate the surroundings if proper disposal protocol is not managed (Kiddee, Naidu, and Wong 2013). Remanufacturing is developing a key plan which can decrease the influence on the environment (Singhal, Tripathy, and Kumar 2018). In India management vision and collection centers are the key influential factors for e-waste remanufacturing (Singhal, Tripathy, and Kumar 2019). Unclear government policies (Mukti and Rawani 2016) and regulation, lack of management foresight and negligence of the environment are the main hurdles of remanufacturing (Singhal, Tripathy, and Kumar 2018). The prominent external barriers of remanufacturing are the absence of collection channels for used product and consumer opposition to return the product, the casual barriers of remanufacturing are the timing of return product and uncertainty in quantity (A. Kumar and Dixit 2018). In Malaysia, the potential challenges of remanufacturing are (a) Marketing and Competition (b) raw material collection (c) skill manpower and expert (d) product design (e) environmental and government (f) technology and method (Shamee, &Shamsuddin, 2019)

In India the major drivers (Animesh and Mukti 2019) of remanufacturing can be categorized into three parts- (a) economic drivers (b) social drivers (c) environmental drivers is the potential economic driver of remanufacturing, the social driver of remanufacturing is more job opportunity and the best way of product recovery is the important environmental driver of remanufacturing (Sharma, Garg, and Sharma 2016). Here Table 1 shows the factor which affects e-waste remanufacturing in India, ten factors were taken by using literature survey and taking expert advice. This are the some of the literatures related to remanufacturing of e-waste in developing countries.

III. RESEARCH METHODOLOGY

In this study, author has followed a series of steps, the first identification of critical factors which influence the e-waste remanufacturing then ISM model is used to find out the contextual relationship among factors.

A. Identification of Factors

First, author have done a literature survey on the topics like e-waste management, remanufacturing, e-waste remanufacturing and find out the critical factors which effects the e-waste remanufacturing in Indian context, then factors are sent to specialists for final assessment. Finally, ten factors have been identified which effect the remanufacturing practices in India. After factor identification, a set of questionnaires were made based on ISM model and the response of a group of experts were taken.

S.No.	Factors	Author/Year
11	Timing of Return (TR)	Singh & Srivastava, (2018), Wang et al. (2021)
2.	Assured Warranty (AW)	Shi, Zhou, & Zhu, (2019), Pan, Wong, and Li (2022)
33.	Marketing Strategies (MS)	Singhal et al.,(2019), Xu et al. (2022)
44.	Government Support (GS)	Kumar & Dixit, (2018), Kiddee et al., (2013), Garg (2021)
55.	Market Access (MA)	Sharma et al., (2016), Jeyaraj (2021), Thongkaow, Prueksasit, and Siriwong (2022)
66.	Workforce and Technology (WT)	A.Shamee and A.Shamsuddin, (2019),Kumar & Dixit, (2018)
77.	Collection strategy (CS)	Singhal et al., (2019),Singh & Srivastava, (2018)
88.	Return intention (RI)	Singhal et al., (2019),Sharma et al., (2016)
99.	Consumption attitude (CA	Singh & Srivastava, (2018), Sabbir et al. (2022), Dhir et al. (2021)
110.	Product Design (PD)	Shamee &Shamsuddin, (2019), Agrawal, Kumar, and Mukti (2021)

Table 1 Factors affecting e-waste remanufacturing

B. Interpretative structural modelling (ISM)

ISM is a reliable way for building logical connections between variables to assess the driving and dependent power of a component. The initial phase in the ISM process was identifying the factors, the structural self-interaction matrix (SSIM), the reachability matrix, the level partition, and the ISM model. Four symbols are used in this study to illustrate the logical relationship between the factors i and j) as they were developed in the SSIM response of a group of experts: (a) V, if j is affected by i (b) A, if j is affected by i (c) X, if i and j are both affected by j; (d) O, if i and j are unaffected by j. In reachability matrix binary codes are used in place of V, A, X and O. If the response is V, then (i,j) will be 1 and (j,i) will be 0, if the response is A, then (i,j) will be 0 and (j,i) will be 1, if the response is X, then (i,j), (j,i) will be 1 and, if the response is O then the code is 0 in both the cases. The reachability matrix is used to determine the level partition antecedent, reachability, and intersection set for each component. The intersection set contains the factors that are present in both the antecedent and the reachability set. The factors are given at the top level if the reachability set and intersection set are identical. Subsequent iterations were performed to obtain the levels of the factor, and with the aid of level partition, an ISM model was constructed to demonstrate the dependence and driving force of the factors.

Factors	TR	AW	MS	GS	MA	WT	CS	RI	CA	PD
TR		V	V	A	V	X	V	X	O	V
AW			X	A	V	X	O	O	V	X
MS				A	V	V	X	X	V	V
GS					V	X	V	V	V	V
MA						X	X	A	A	X
WT							V	O	V	V
CS								X	X	V
RI									X	V
CA										X
PD										

Table 2 Structural Self-Interaction Matrix

Factors	TR	AW	MS	GS	MA	WT	CS	RI	CA	PD	DRP
TR	1	1	1	0	1	1	1	1	0	1	7
AW	0	1	1	0	1	1	0	0	1	1	6
MS	0	1	1	0	1	1	1	1	1	1	8
GS	1	1	1	1	1	1	1	1	1	1	10
MA	0	0	0	0	1	1	1	0	0	1	4
WT	0	1	0	1	1	1	1	0	1	1	7
CS	0	0	1	0	1	0	1	1	1	1	6
RI	1	0	1	0	1	0	1	1	1	1	7
CA	0	0	0	0	1	1	1	1	1	1	6
PD	0	1	0	0	1	0	0	0	1	1	4
DEP	3	6	6	2	10	7	8	6	8	10	

Table 3 Reachability Matrix

Factors	Reachability set	Antecedent sets	Intersection set	Level
TR	1,2,3,5,6,7,8,10	1,4,8	1,8	**V**
AW	2,3,5,6,9,10	1,2,3,4,6,10	2,3,6,10	**III**
MS	2,3,5,6,7,8,9,10	1,2,3,4,7,8	2,3,7,8	**IV**
GS	1,2,3,4,5,6,7,8,9,10	4,6	4,6	**VI**
MA	5,6,7,10	1,2,3,4,5,6,7,8,9,10	5,6,7,10	**I**
WT	2,4,5,6,7,9,10	1,2,3,4,5,6,9	2,4,5,6,9	**III**
CS	3,5,7,8,9,10	1,3,4,5,6,7,8,9,	3,5,7,8,9	**II**
RI	1,3,5,7,8,9,10	1,3,4,7,8,9	1,3,7,8,9	**II**
CA	5,6,7,8,9,10	2,3,4,6,7,8,9,10	6,7,8,9,10	**II**
PD	2,5,9,10	1,2,3,4,5,6,7,8,9,10	2,5,9,10	**I**

Table 4 Level Partition

IV. RESULT AND DISCUSSION

In this study, author identify the factors which effect the e-waste remanufacturing practices in India, ten factors are identified through previously published articles and expert's opinion etc. as shown in Table 1, after factor identification, logical relationship were developed by the experts using symbols as shown in Table 2. Thereafter researcher prepared a reachability matrix by replacing the symbol with the binary codes (1 and 0) as per the rules According to Table 4 of the ISM model, the factors are divided into six levels, with the top levels exhibiting strong dependence power and the bottom levels exhibiting strong driving power. Government support (GS), return timing (TR), and marketing strategies (MS) all exhibit significant propulsion a s they are at the highest levels of the ISM model, market access (MA), product design (PD), collection methods (CS), return intention (RI), consumption attitude (CA), assured warranty (AW), workforce and technology (WT) all exhibit substantial interdependence. Government support (GS) is at level 6 of the ISM model, indicating that it is one of the crucial elements that has a significant impact on e-waste remanufacturing. The government must step up and provide subsidies to both manufacturers and consumers to promote remanufacturing.

Additionally, level five includes timing of return (TR), which demonstrates strong driving force and illustrates that there is uncertainty in the timing of used product returns, which directly impacts remanufacturing. Level 4 of the marketing strategies, which is the lowest level, demonstrates the driving force behind low prices, long warranties, and the need for effective advertising to market remanufactured goods. At levels two and three, the following components are highly dependent on the other factors at the bottom of the model: assured warranty (AW), workforce technology (WT), collection strategy (CS), return intention (RI), and consumption attitude (CA). At level one of the model, market access (MS) and product design (PD) are strongly dependent on one another. The easier accessibility of remanufactured products to the market or customers would eliminate market access.

V. CONCLUSION

Remanufacturing is a process that restores End of Use (EOU) or End of Life (EOL) products to the specifications or standards of the original product. This study uses interpretative structural modelling to pinpoint and examine the key elements influencing e-waste remanufacturing in India and determine how they are related logically (ISM). Ten factors have been selected after consulting relevant literature and subject-matter specialists. Additionally, these ten components are broken down into six tiers using the ISM model or logical linkages between them. The outcome reveals that market access (MA) and product design (PD) are at level one, indicating that these factors depend on all other factors, while government support (GS), timing of return (TR), and marketing strategies (MS) are the major critical factors in the hierarchy that have strong driving power or these influences the other factors, as shown in figure 1. This study helps the manufacture to increase the production by using remanufacturing in developing countries.

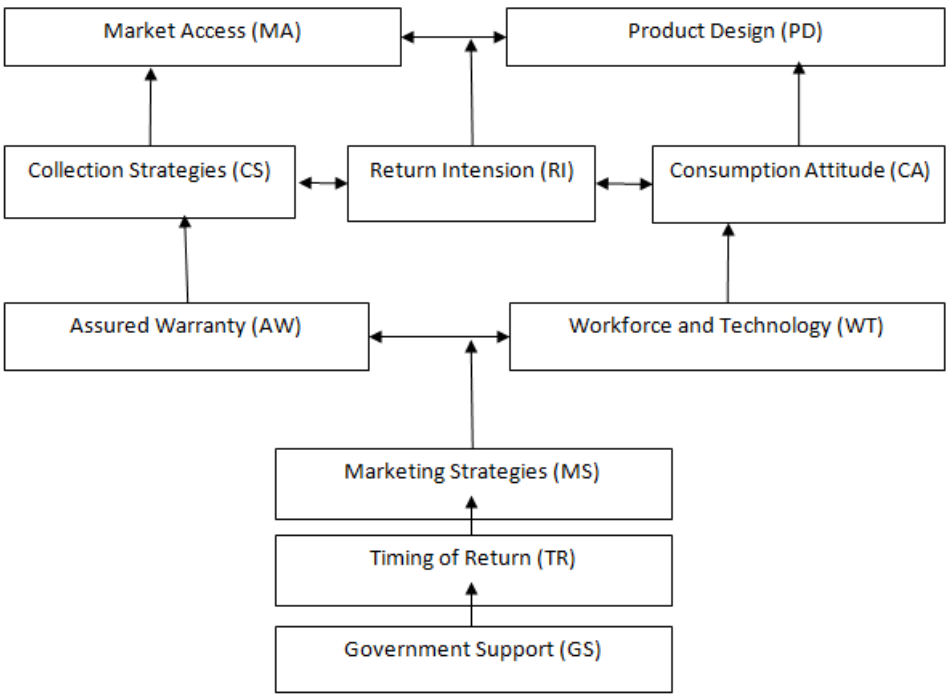


Figure 1 ISM Model

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