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Challenges in Management of E-waste using Game Theory: A Strategic Approach

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Abstract—*This paper highlights the adverse effects of electrical and electronic waste (e-waste), if not handled appropriately. Those electronic materials/products which have reached their end of life and aren't suitable for further use, falls under the category of e-waste. 'New for Old' product scheme has been discussed under which manufacturer gives incentives to the consumer. Different ways of dumping e-waste and their effects has also been discussed. The Government, Manufacturer, Recycler and Consumer (GMRC) approach, a win-win situation has been explored by author using game theory for better management of e-waste. Also the conclusions and suggestions have been derived for the same.*

1. INTRODUCTION

Today's fastest growing solid waste is electronic waste or e-waste. Eliminating solid and electronic waste is a top priority today, since it creates an imbalance in the ecosystem that is almost irreparable[1]. Cellphones, computers and household appliances are the major contributors in e-waste production. Short life span of electronic gadgets, like smartphones etc. makes them a major contributor to e-waste. Most recent report of Environment Protection Act (EPA) shows that society discards more than 416,000 cellphones and 42,000 computers every day. The main sources of e-waste are households, hospitals and industries. Disposal of e-waste in an improper manner will directly affect air, water, land, soil and humans. Different ways of dumping e-waste and their effects are explained in fig 1. It is been predicted that approximately 16-28% of the e-waste is being increased every year globally[2]. This is because of the lack of awareness in consumers; they don't know the side effects of discarding e-waste and if this continues then e-waste stream will continue to be dumped into the landfills. Due to the lack of government legislations on e-waste and the absence of any standards for their handling, recycling or disposal, these toxic hi-tech products mostly end up in the hands of informal operators for recycling and recovery of metals and other byproducts, through rudimentary and risky processes, under unhygienic, uncontrolled and open environment[3]. Non-government organizations play a major role in the awareness among people to sell their discarded electrical equipments to formal recycling yards. They can also improve the transportation of electronic waste. In India, according to Central Pollution Control Board (CPCB), Mumbai is on the top position for generating e-waste and it is estimated that in year 2020 Mumbai will generate 2.29 lakh t of electrical waste.

In game theory approach, the four players i.e. Government, Manufacturer, Recycler and Consumer (GMRC) play a key role in the management of e-waste which is illustrated in fig 2. Game theory studies multiple-person decision problems involving conflict, competition, and cooperation[4]. Game theory is the formal study of decision-making where several players must make choices that potentially affect the interests of the other players[5]. Government should impose tax or penalty on the manufacturer, in case, it fails to apply take back scheme from the consumers. Consumers should also be penalized for discarding e-waste directly into landfills and not giving it to the recyclers. In the take back system, manufactures should set up collection points/bins near public places such as curbsides, restaurants, malls, offices etc. and connect them to their authorized individual collection centers. Authorized collection agencies with their contact details should be printed on these bins for the purpose of general public.

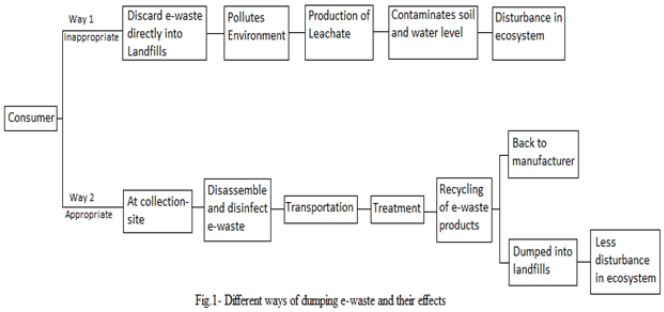

Fig.1- Different ways of dumping e-waste and their effects

Consumers have two choices- First; giving their waste products to the manufacturer or recycler. Manufacturer should

give some discount on 'New for Old' products to the consumer so that he/she will not discard e-waste into the landfills and pollute the ecosystem. However, recycler has two choice of collecting e-waste either from consumer or from manufacturer. Active participation should be there between consumer to recycler and manufacturer to recycler.

2. LITERATURE REVIEW

Around worldwide, these are the best policies about e-waste management processes which are briefly discussed. (He.et al. 2006) [6] Suggested that one cell phone contains a sufficient amount of cadmium which has the potential to pollute approximately 600,000 L of water. Besides water, it can pollute other vital components of

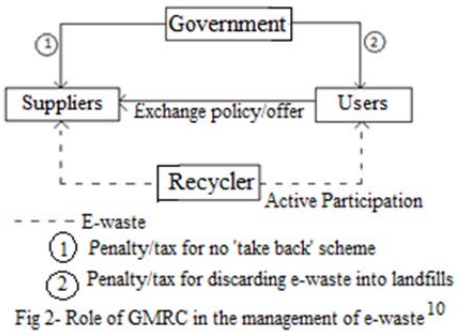

Fig 2- Role of GMRC in the management of e-waste [10]

environment, like air when burnt in incinerators, by leaching into the soil. This can deteriorate the quality of drinking water adversely (SEP 2009) [7]. The best suitable management method for hazardous batteries is to reuse and recycle them in an authorized way. (Sakultung et al. 2007) [8] Suggested that valuable metals like cobalt and nickel can be recovered from spent mobile phone batteries by the acid-leaching process. In India, take back scheme is being followed for the management of e-waste. Now, companies like Acer, Nokia, Motorola and HCL are participating in the take back policy. Getting back their old products from consumers, manufacturer should also give discount on new product under the 'New for Old' exchange scheme. This return back scheme will help recycler in recycling process, if implemented successfully; as shown in fig 2.

This return back scheme will only be successful if the customers are motivated enough to return their old product to the suppliers. The above studies elaborate that, if we are not serious about the management of e-waste then how adversely it will affect the environment. Game theory suggested the understanding of complex management of e-waste and creates win-win situation for all the stakeholders.

3. STRATEGIES FOR GMRC

A game is prepared between (GMRC) players; each player has two strategies/choices. Government has two strategies/choices: First; Government should impose penalty on the manufacturer for not following the take back scheme. Government should also ensure that manufacturer is making less hazardous devices which will not harm living organisms and the environment. Second; Government should give the subsidy to the manufacturer i.e. when manufacturer gives the recycling fee to the recycler for recycling the e-waste then some amount of fee is paid as a subsidy by the government for the manufacturer. This initiative step by the government will increase the interest and spirit of the manufacturer.

Consumer has two strategies/choices: First; he sells the electronic waste to the manufacturer and manufacture gives incentives to the consumer, then it will be a positive payoff for himself. Second: he/she chooses to give e-waste to the recycler and in return recycler gives incentive to consumer, then it will be a positive payoff for himself.

The recycler has two strategies/choices: First; he collects the electronic waste from manufacturer, receiving the recycling fee along with it will be a positive payoff to the recycler, but if recycler chooses the second strategy i.e. collecting of e-waste from the consumer then transportation cost will be a negative payoff for him. The producer responsibility principal has been recently reinforced in the new directive for e-waste with the introduction of the EPR (Extend producer responsibility) principal, comprising waste management obligation and efficient use of resources during the whole life-cycle of products, including design and production, use and re-use, disassembly, and recycling[9].

Table 1: Table of Input Parameters

Price of Computer, [Rs.]	Ic	70000
Penalty to Producer (if Consumer select LD) [%]	Gp	20
Subsidy to Recycler (if Consumer select LD) [%]	Gs	15
EPR Free-Extended producer responsibility [%]	EPR	3
ARF - Advanced Recovery Fee [%]	ARF	4
Collector Charges [%]	Cc	1.5
Recycling Fee paid by Manufacturer to Recycler [%]	Rf	2
Incentives to Consumer [%]	Icr	25
Trans. Cost (for Cons.) to bring E-waste to Manufacturer. [%]	Tc	1.667
Selling Price of Recycled Material	Sr	20

Similarly, same as the manufacturer has two choices/strategies: First; manufacturer should collect Advanced Recovery Fee (ARF) from a consumer as a recycling fee though it will be a positive payoff for him. But if he chooses recycler for recycling the e-waste, then recycling and transportation fee given by manufacturer to recycler will be a negative payoff for the manufacturer.

The above example is explained by the assumed values in the table 1. Equations from 1-4 shows the payoffs to (GMRC) which involves the management of e-waste and depends upon the factor, such as penalty on producer if, consumer chooses

land disposal, EPR fee, subsidy to the manufacturer to the government, selling price of recycled material, incentives to consumer and collecting charges.

4. PAYOFFS FORMULATION EQUATION

Manufacturer's payoff

$$\pi_{mf} = Cc - R_F - I_{CR} - A_{RF} - G_P - E_{PR} + S_R \quad \ldots (1)$$

Recycler's payoff

$$\pi_{rc} = T_C - G_S - Cc - I_{CR} + S_R + R_F \quad \ldots (2)$$

Consumer's payoff

$$\pi_{cn} = T_C - I_{CR} - E_{PR} - A_{RF} \quad \ldots (3)$$

Government's payoff

$$\pi g = G_P - G_S \quad (4)$$

5. ASSUMPTIONS

- The government will charge penalty on those manufacturers producing hazardous products.
- The collector of discarded computers either recycles or manufacturer can afford the recycling cost.
- If consumer opts the land disposal option then penalty will be charged by the government.
- In a take-back scheme manufacturer will provide the incentive to the consumer.
- Incentives will be provided only in case when consumer chooses the return back option.
- Transportation cost charges would not be paid to the consumers.
- Collection and recycling fee will be paid by manufacturer, if the recycler collects the discarded computers from the manufacturer.
- Manufacturer will then take the selling price of recycled material.

Table 2: Payoffs to GMRC

our Player Game (Strategic Form)							
Player's Strategies				Player's Payoff			
I	II	III	IV	Player I Govt.	Player II Manuf.	Player III Recycler	Player IV Consumer
1	1	1	1	14000	-350	1400	-2100
1	1	1	2	0	-2800	1400	15400
1	1	2	1	14000	-11900	11550	-2100
1	1	2	2	0	2100	-4900	14233.1
1	2	1	1	14000	350	1400	-2800
1	2	1	2	0	-2100	1400	14700
1	2	2	1	14000	-11200	11550	-2800
1	2	2	2	0	2800	-4900	13533.1
2	1	1	1	-10500	13650	11900	-2100
2	1	1	2	0	-2800	1400	15400
2	1	2	1	-10500	2100	22050	-2100
2	1	2	2	0	2100	-4900	14233.1
2	2	1	1	-10500	14350	11900	-2800
2	2	1	2	0	-2100	1400	14700
2	2	2	1	-10500	2800	22050	-2800
2	2	2	2	0	2800	-4900	13533.1

6. RESULTS

The above example is solved by using game theory approach. The results show that by changing values of the factors, it will directly effect on the GMRC. However, by using those strategies, the players, which have more positive value is taken.

7. CONCLUSIONS

- Government should impose tax on those companies, whose products are excessively found in the e-waste/discarded waste.
- Subsidy must be provided by Government to the manufacturer as recycling fee; this will encourage them and provide the motivation for recycling purpose.
- Manufacturer plays a major role in production of e-waste because if the manufactured products are less hazardous then, we will not face the health and pollution issues causing e-waste.
- Government should keep a check on manufacturers if they are following the norms like amount of harmful chemical in their respective products. This can be done by help of employing agents/experts who will help in regulating the system.

  Profit plays a major role in the deposition of e-waste from consumers so, greater margin should be provided to consumers to encourage them to give their stuff to recycler instead of dumping it in landfills.

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