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On Exploring the Various Challenges Faced during the Plastic Waste Management and the Inter-relationship amongst them using ISM Methodology

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ABSTRACT
Like any other country, waste management is a pressing issue in India, especially with the unceasing growth of consumerism throughout the nation. Interestingly, almost 60% of the total plastic waste generated in India gets recycled while the remaining escapes into the environment. However, most of this plastic is down-cycled. At this juncture, India needs robust and stringent waste management tools to substantially improve the situation.

Keywords
Plastic waste; ISM methodology; Hazardous; Non-hazardous

1. INTRODUCTION
Plastics are inexpensive, lightweight and durable materials, which can readily be moulded into a variety of products that find use in a wide range of applications . Today, plastics are almost completely derived from petrochemicals produced from fossil oil and gas. Approximately, 25,940 tons per day (TPD) of plastic waste is generated in India, according to the Central Pollution Control Board's (CPCB), 2015 report on assessment and quantification of plastics waste generation in major cities. Of this, around 15,600 TPD (60 %) gets recycled, still leaving behind nearly 10,000 tons of it. As the manufacture of plastics also requires energy, its production is responsible for the consumption of a similar additional quantity of fossil fuels. However, it can also be argued that use of lightweight plastics can reduce usage of fossil fuels, for example, in transport applications when plastics replace heavier conventional materials such as steel (Andrady & Neal 2009; Thompson *et al*. 2009b). Approximately 50 % of plastics are used for single-use disposable applications, such as packaging, agricultural films and disposable consumer items, between 20 and 25% for long-term infrastructure such as pipes, cable coatings and structural materials, and the remainder for durable consumer applications with intermediate lifespan, such as in electronic goods, furniture, vehicles, etc. Post-consumer plastic waste generation across the European Union (EU) was 24.6 million tonnes in 2007 (Plastics Europe, 2008b). Even degradable plastics may persist for a considerable time depending on local environmental factors, as rates of degradation depend on physical factors, such as levels of ultraviolet light exposure, oxygen and temperature (Swift & Wiles, 2004), while biodegradable plastics require the presence of suitable micro-organisms. Therefore, degradation rates vary considerably between landfills, terrestrial and marine environments (Kyrikou & Briassoulis, 2007).

1.1 Recycling of plastic is clearly a waste-management strategy
- Broadly speaking, waste plastics are recovered when they are diverted from landfills or littering. Plastic packaging is particularly noticeable as litter because of the lightweight nature of both flexible and rigid plastics.
- For organic materials like plastics, the concept of recovery can also be expanded to include energy recovery, where the calorific value of the material is utilized by controlled combustion as a fuel, although this results in a lesser overall environmental performance than material recovery as it does not reduce the demand for new (virgin) material.
- This thinking is the basis of the 4Rs strategy in waste management parlance—in the order of decreasing environmental desirability—reduce, reuse, recycle (materials) and recover (energy), with landfill as the least desirable management strategy.
- A well-managed landfill site results in limited immediate environmental harm beyond the impacts of collection and transport. (Oehlmann *et al.* 2009; Teuten *et al*. 2009).

------ Re-use of plastic packaging
- Take-back and refilling schemes do exist in several European countries (Institute for Local Self-Reliance 2002), including PET bottles as well as glass, but they are elsewhere generally considered a niche activity for local businesses rather than a realistic large-scale strategy to reduce packaging waste.
- There is considerable scope for re-use of plastics used for the transport of goods, and for potential re-use or re-manufacture from some plastic components in high-value consumer goods such as vehicles and electronic equipment.

--------Plastics recycling
- Recycling is one of the most important actions currently available to reduce these impacts and represents one of the most dynamic areas in the plastics industry today. Recycling provides opportunities to reduce oil usage, CO_2 emissions and the quantities of waste requiring disposal.
- Plastics recycling is categorise in to four categories *viz*. primary (mechanical reprocessing into a

product with equivalent properties), secondary (mechanical reprocessing into products requiring lower properties), tertiary (recovery of chemical constituents) and quaternary (recovery of energy) (Fisher, 2003).

- Chemical or feedstock recycling has the advantage of recovering the petrochemical constituents of the polymer, which can then be used to re-manufacture plastic or to make other synthetic chemicals (Patel *et al*. 2000).

1.2 Systems for plastic recycling

- Plastic materials can be recycled in a variety of ways and the ease of recycling varies among polymer type, package design and product type. For example, rigid containers consisting of a single polymer are simpler and more economic to recycle than multi-layer and multi-component packages.
- Thermoplastics, including PET, PE and PP all have high potential to be mechanically recycled. Thermosetting polymers such as unsaturated polyester or epoxy resin cannot be mechanically recycled, except to be potentially re-used as filler materials once they have been size-reduced or pulverized to fine particles or powders (Rebeiz & Craft, 1995).
- A major challenge for producing recycled resins from plastic wastes is that most different plastic types are not compatible with each other because of inherent immiscibility at the molecular level, and differences in processing requirements at a macro-scale.

Paper is arranged as follows : Section 2 covers the recycle plastic waste and its strategies etc. Section 3 deals with ISM methodology . section 4 represents the case example. Section 5 the conclusions and future directions .

2. LITERATURE REVIEW

Following section deals with various barriers to plastic recycle or waste management.

1. **Lack of significant infrastructure [LSI] :** Recycling in these situations relies on significant infrastructure for sorting and processing plastic waste by polymer type, capable of producing recycled plastic suitable for reuse by manufacturers. These countries also use measures to increase the cost of traditional processing solutions, in the form of taxes on landfill and incineration. Countries in this category can attain recycling rates in the order of 30%.
2. **Low recycling rates and limited market share [LRR/LMS]** : highlight the poor functioning of markets for recycled plastics : market volume and liquidity are limited , trade flows are small as a proportion of total plastics waste generation, and market prices are highly volatile . Global plastic recycling rates , and the share of recycled production in total plastic output , also remains low. Current recycling rates are thought to be 14-18% at the global level. Recycling rates for polyethylene terephthalate (PET) and high density polyethylene (HDPE) commonly exceeds 10 % , while those for Polystyrene (PS) and Polypropylene (PP) are closer to zero.
3. Trade in plastics waste is limited and increasingly hindered by **trade restrictions [TR]**: allowing plastic waste to flow towards jurisdiction with a comparative cost advantage in sorting or recycling can help to boost recycling rates , while also generating increased shared economic benefits and improving environmental outcomes [48] . For exporters of plastic waste , China’s import restrictions are leading to growing domestic waste stockpiles and diversion of material into other export markets. Domestic prices for waste plastics have fallen as a result.
4. **Problem in meeting the pre-existing and disposable targets [PEDT]:** Increased incinerations and landfilling of plastic waste has implications for meeting pre-existing disposal and recycling targets. Many G7 countries have regulatory requirements , at the national or sub-national level, in the form of constraints on material that can be incinerated or landfilled , as well as recycling targets for plastics. In many cases, the waste plastics that were formerly shipped to China were included in the recycling targets.
5. **Poor functioning of domestic markets [PFDM]** : the disruptions resulting from recent restrictions on the import of plastic waste to China highlights the poor functioning of domestic markets for recycled plastics. Potential suppliers of recycled plastics do not invests sufficiently in sorting and recycling capacity because the profitability of these operation is limited.
6. **Concern over additives [COA] :** there are also concerns over additives (e.g. colors , plasticizers , flame retardants) used in the manufacture of some virgin plastics that complicate recycling or pose risks to human or ecological health. For manufacturers of recycled plastics, uncertainty about the presence of these additives in plastic waste can hinder recycling altogether (because the resulting output may be of low quality or pose significant health risks in certain food related applications such as food packaging and children’s toys .
7. Reducing the cost of recycled plastic production / **cost difference from virgin plastics [CD]** : Virgin plastic is mostly made in North America (18%), Europe (19%) and Asia (50%, with China accounting for 29%). The cost structure of recycled plastics production is different from that of virgin production and is , at current oil prices , often higher. Reasons could be that plastic waste generation is geographically dispersed and aggregating waste materials into economically viable quantities incurs considerable collection and transport cost.
8. **Poor International Co-operation [PIC]** : Increased international cooperation is needed to boost innovation and support improved environmental standards in fast growing markets . Government of G7 countries can also address the barriers that hiders markets for secondary plastics

through various forms of international co-operation.

Economic issues relating to recycling

9. **Economic issues [EI]:** Two key economic drivers influence the viability of thermoplastics recycling. These are the **price of the recycled polymer** compared with virgin polymer and the **cost of recycling** compared with alternative forms of acceptable disposal.

10. There are additional issues associated with **variations in the quantity and quality of supply [VQQS] compared with virgin plastics.**

11. **Lack of information [LoI]** : about the availability of recycled plastics, its quality and suitability for specific applications, can also act as a disincentive to use recycled material.

12. **Low cost of landfill [LCOL]:** Historically, the primary methods of waste disposal have been by landfill or incineration. **Costs of landfill** vary considerably among regions according to the underlying geology and land-use patterns and can influence the viability of recycling as an alternative disposal route.

13. **Low population density [LPD]:** Collection of used plastics from households is more economical in suburbs where the population density is sufficiently high to achieve economies of scale. The most efficient collection scheme can vary with locality, type of dwellings (houses or large multi-apartment buildings) and the type of sorting facilities available.

3. INTERPRETIVE STRUCTURAL MODELLING METHODOLOGY

Interpretive structural modelling methodology or ISM [1974] is a known technique to map the relationships amongst the relevant elements as per decision maker's problems in a hierarchical manner. Starting with the identification of elements , it proceeds with establishing the contextual relationships between elements (by examining them in pairs) and move on towards developing the structural self-interaction (SSIM) matrix using VAXO [1974] and then initial reachability matrix and final reachability matrix and rearranging the elements in topological order using the level partition matrices . A Mic-Mac analysis is performed afterwards which categorize the variables as per the driving and dependence power in to autonomous, dependent, driver and linkage category. Finally, a diagraph can be obtained.

4. DEVELOPMENT OF ISM MODEL : CASE EXAMPLE

Around 13 challenges viz . Lack of significant infrastructure (LSI) ; Low recycling rates and limited market share [LRR/LMS] ; Trade restrictions [TR] ; Problem in meeting the pre-existing and disposable targets [PEDT] ; Poor functioning of domestic markets [PFDM]; Concern over additives [COA] ; Reducing the cost of recycled plastic production / cost difference from virgin plastics [CD] ; Poor International Co-operation [PIC] ; Economic issues [EI] ; variations in the quantity and quality of supply [VQQS] compared with virgin plastics ; Lack of information [LoI]; LOW Cost of landfill [LCOL] and Low population density [LPD] described in section 2 above have been studied for possible inter-relationships amongst them using ISM methodology in this section.

4.1 Construction of Structural self-interaction Matrix (SSIM)

This matrix gives the pair-wise relationship between two variables *i.e. i and j* based on VAXO. SSIM has been presented below in Fig 1.

4.2 Construction of Initial Reachability Matrix and final reachability matrix

The SSIM has been converted in to a binary matrix called the initial reachability matrix shown in fig. 2 by substituting V, A, X, O by 1 or 0 as per the case. After incorporating the transitivity, the final reachability matrix is shown below in the Fig 3.

S. No.	Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13
		LSI	LRR	TR	PEDT	PFDM	COA	CD	PIC	EI	VQQS	LoI	LCOL	LPD
1	LSI		A	A	V	V	V	V	X	A	X	X	V	O
2	LRR			A	V	X	V	V	V	A	V	O	V	A
3	TR				V	V	V	V	V	A	V	O	V	A
4	PEDT					A	V	A	A	A	A	A	O	A
5	PFDM						V	V	X	X	X	X	X	X
6	COA							A	A	A	A	A	A	A
7	CD								O	A	V	O	X	A
8	PIC									O	V	O	O	O
9	EI										V	O	O	O
10	VQQS											A	A	A
11	LoI												O	O
12	LCOL													O
13	LPD													

Fig 1: SSIM matrix for pair wise relationship amongst barriers

S. No.	Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13
		LSI	LRR	TR	PEDT	PFDM	COA	CD	PIC	EI	VQQS	LoI	LCOL	LPD
1	LSI	1	0	0	1	1	1	1	1	0	1	1	1	0
2	LRR	1	1	0	1	1	1	1	1	0	1	0	1	0
3	TR	1	1	1	1	1	1	1	1	0	1	0	1	0
4	PEDT	0	0	0	1	0	1	0	0	0	0	0	0	0
5	PFDM	0	1	0	1	1	1	1	1	1	1	1	1	1
6	COA	0	0	0	0	0	1	0	0	0	0	0	0	0
7	CD	0	0	0	1	0	1	1	0	0	1	0	1	0
8	PIC	1	0	0	1	1	1	0	1	0	1	0	0	0
9	EI	1	1	1	1	1	1	1	0	1	1	0	0	0
10	VQQS	1	0	0	1	1	1	0	0	0	1	0	0	0
11	LoI	1	1	0	1	1	1	0	0	0	1	1	0	0
12	LCOL	0	0	0	0	1	1	1	0	0	1	0	1	0
13	LPD	0	1	1	1	1	1	1	0	0	1	0	0	1

Fig 2: Initial reachability matrix

S. No.	Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	D.P
		LSI	LRR	TR	PEDT	PFDM	COA	CD	PIC	EI	VQQS	LoI	LCOL	LPD	
1	LSI	1	0	0	1	1	1	1	1	1	1	1	1	0	10
2	LRR	1	1	0	1	1	1	1	1	1	1	1	1	1	12
3	TR	1	1	1	1	1	1	1	1	1	1	1	1	0	12
4	PEDT	0	0	0	1	0	1	0	0	0	0	0	0	0	2
5	PFDM	1	1	0	1	1	1	1	1	1	1	1	1	1	12
6	COA	0	0	0	0	0	1	0	0	0	0	0	0	0	1
7	CD	1	0	0	1	1	1	1	0	0	1	0	1	0	7
8	PIC	1	1	0	1	1	1	1	1	1	1	1	1	1	12
9	EI	1	1	1	1	1	1	1	1	1	1	1	1	0	12
10	VQQS	1	1	0	1	1	1	1	1	1	1	1	1	1	12
11	LoI	1	1	0	1	1	1	1	1	1	1	1	1	1	12
12	LCOL	1	1	0	1	1	1	1	1	1	1	1	1	1	12
13	LPD	1	1	1	1	1	1	1	1	1	1	1	1	1	13
	De.P	11	9	3	12	11	13	11	10	10	11	10	11	7	

Fig 3 : Final reachability matrix

D.P : Driving power ; De.P : dependence power

4.3 Level Partition

From the final reachability matrix, reachability and final antecedent set for each factor are found. The elements for which the reachability and intersection sets are same are the top-level element in the ISM hierarchy. After the identification of top level element, it is separated out from the other elements and the process continues for next level of elements. Reachability set, antecedent set, intersection set along with different level for elements have been shown below in table 4.

Table 4.3.1: Iteration I

S.No.	Reachability set	Antecedent set	Intersection set	Level
1.	**6**	1,2,3,4,5,6,7,8, 9,10,11,12,13	**6**	
2.	4,6	1,2,3,4,5,7,8,9, 10,11,12,13	4	
3.	1,4,6,10,5, 7,12	1,2,3,5,7,8,9,1 0,11,12,13	1,10,5,7,12	
4.	1,4,5,6,7,8, 10,12	1,2,3,5,8,9,10, 11,12,13	5,8,10,12	
5.	1,2,4,5,6,7, 8,10,12	1,2,3,5,8,9,10, 11,12,13	2,5,8,10,12	
6.	1,2,4,5,6,7, 8,9,10,11,1 2	1,2,3,5,8,10,11 ,12,13	2,5,8,10,11 ,12	**I**
7.	1,2,4,5,6,7, 8,9,10,11,1 2,13	2,5,8,10,11,12, 13	2,5,8,10,11 ,12,13	

Table 4.3.2: Iteration II

S.No.	Reachability set	Antecedent set	Intersection set	Level
2.	**4**	1,2,3,4,5,7,8,9, 10,11,12,13	4	
3.	1,4,10,5,7, 12	1,2,3,5,7,8,9,1 0,11,12,13	1,10,5,7,12	
4.	1,4,5,7,8,1 0,12	1,2,3,5,8,9,10, 11,12,13	5,8,10,12	
5.	1,2,4,5,7,8, 10,12	1,2,3,5,8,9,10, 11,12,13	2,5,8,10,12	
6.	1,2,4,5,7,8, 9,10,11,12	1,2,3,5,8,10,11 ,12,13	2,5,8,10,11 ,12	
7.	1,2,4,5,7,8, 9,10,11,12, 13	2,5,8,10,11,12, 13	2,5,8,10,11 ,12,13	**II**

Table 4.3.3: Iteration III

S.No.	Reachability set	Antecedent set	Intersection set	Level
3.	**1,10,5,7, 12**	1,2,3,5,7,8,9,1 0,11,12,13	1,10,5,7, 12	
4.	1,5,7,8,10, 12	1,2,3,5,8,9,10, 11,12,13	5,8,10,12	
5.	1,2,5,7,8, 10,12	1,2,3,5,8,9,10, 11,12,13	2,5,8,10, 12	
6.	1,2,5,7,8,9, 10,11,12	1,2,3,5,8,10,11 ,12,13	2,5,8,10, 11,12	**III**
7.	1,2,5,7,8,9, 10,11,12,1 3	2,5,8,10,11,12, 13	2,5,8,10, 11,12,13	

Table 4.3.4: Iteration IV

S.No.	Reachability set	Antecedent set	Intersection set	Level
4.	**8**	2,3,8,9,11,13	8	
5.	2,8	2,3,8,9,11,13	2,8	
6.	2,8,9,11	2,3,8,9,11,12, 13	2,8,9,11	**IV**
7.	2,8,9,11, 13	2,8,11,13	2,8,11,13	

Table 4.3.5: Iteration V

S.No.	Reachability set	Antecedent set	Intersection set	Level
5.	2	2,3,9,11,13	2	
6.	**2,9,11**	2,3,9,11,13	2,9,11	**V**
7.	2,9,11,13	2,11,13	2,11,13	

Table 4.3.6: Iteration VI

S.No.	Reachability set	Antecedent set	Intersection set	Level
7.	**13**	13	13	**VI**

4.4 Classification of factors

The critical success factors described earlier are classified in to four clusters *viz.* autonomous factor, dependent factors, linkage factors and independent / Driving factors are mentioned below.

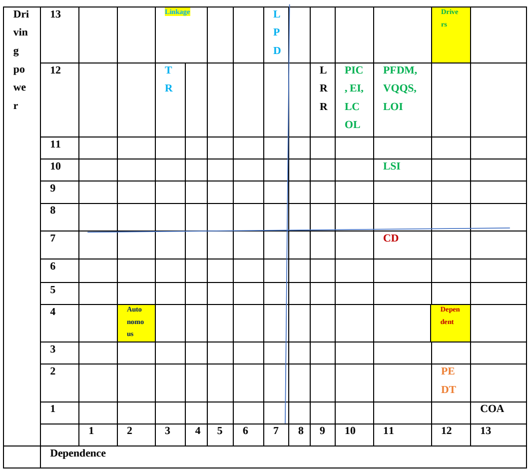

Fig. 4.Driving Power and Dependence Diagram

4.5 ISM model

An ISM model is developed (as shown in fig. 5 below) after arranging the elements as per their interaction or dependence relationships.

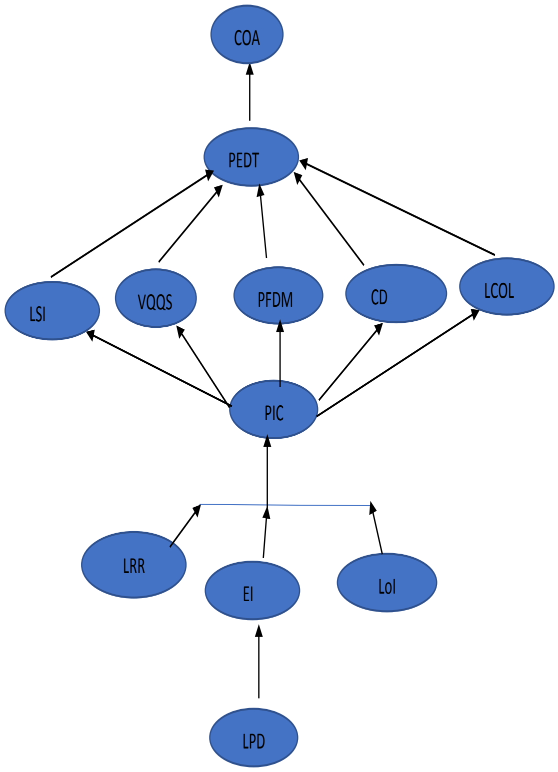

Fig 5 : ISM Model

5. CHALLENGES AND OPPORTUNITIES FOR IMPROVING PLASTIC RECYCLING

- Effective recycling of mixed plastics waste is the next major challenge for the plastics recycling sector. The advantage is the ability to recycle a larger proportion of the plastic waste stream by expanding post-consumer collection of plastic packaging to cover a wider variety of materials and pack types.

- Product design for recycling has strong potential to assist in such recycling efforts. Most post-consumer collection schemes are for rigid packaging as flexible packaging tends to be problematic during the collection and sorting stages.

- Most current material recovery facilities have difficulty handling flexible plastic packaging because of the different handling characteristics of rigid packaging. The low weight-to-volume ratio of films and plastic bags also makes it less economically viable to invest in the necessary collection and sorting facilities.

- However, plastic films are currently recycled from sources including secondary packaging such as shrink-wrap of pallets and boxes and some agricultural films, so this is feasible under the right conditions. In order to have successful recycling of mixed plastics, high-performance sorting of the input materials needs to be performed to ensure that plastic types are separated to high levels of purity; there is, however, a need for the further development of end markets for each polymer re-cyclate stream.

6. FUTURE DIRECTIONS

6.1 Bioplastics — the new wonder material?

Bioplastics is a term that broadly includes bio (mass)-derived plastics and biodegradable plastics. Being sourced from carbohydrate rich biomass, they align with sustainable development and provide the option of quick-fixing our waste problem. Thus, these plastics are projected as a good alternative to indestructible, fossil derived plastics.

- The biodegradability of a polymer is dependent on its chemical structure, not on its source of origin — all biodegradable plastics are bioplastics, but all bioplastics are not biodegradable. Then there are categories such as "oxo-biodegradable" or "biodegradable" or "compostable". Oxo-biodegradables, a greenwashed alternative to plastics, are essentially oil-derived plastics containing additives that accelerate their degradation on exposure to ultraviolet, heat, oxygen, etc.

- **Compostable bioplastics** require controlled conditions (pH, temperature, humidity, etc.) that can only be found in industrial composting facilities. Moreover, these materials take longer to break down as compared to the preferred compost feed (organic waste) and may add toxicity to the resulting compost. High rate of contamination of these compostable plastic waste streams by conventional plastics further diminish their credibility.

- Biodegradable plastics have the potential to solve a number of waste-management issues, especially for disposable packaging that cannot be easily separated from organic waste in catering or from agricultural applications.

- It is possible to include biodegradable plastics in aerobic composting, or by anaerobic digestion with methane capture for energy use. However, biodegradable plastics also have the potential to complicate waste management when introduced without appropriate technical attributes, handling systems and consumer education.

6.2. Extended Producer Responsibility (EPR) : Responsibility falls on the shoulders of the government to adopt a comprehensive strategy that can prevent the excessive generation of disposable plastics and then ascertain techniques to sustainably manage end-of-life of their products. This includes paving a smooth legal roadmap for **Extended Producers Responsibility (EPR)**, co-processing and incineration in the nation. Certain countries have taken distinctive measures like supporting recycling and recovery structures by indicating role of EPR and PROs etc.

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