OPENACCESS Freely available online

ISSN: 2252-5211
International Journal of Waste Resources

Research Article

Identification and Modeling of Challenges to E-Waste Management for Policy Analysis Using TISM Technique

Eeshika Madaan[1], Urfi Khan[2]

Department of Mechanical and Automation Engineering, Indira Gandhi Delhi Technical University for Women, New Delhi, India

ABSTRACT

Electronic waste abbreviated as E-waste refers to electronic products that are no longer useful due to redundancy or breakage. E-waste management through rudimentary and risky methods has a hazardous effect on human health and the environment. Therefore, responsive legislative measures and cost-effective and environment-friendly technological solutions are required to address the barriers to efficiency in E-waste management. This paper helps in addressing these barriers by identifying and establishing relationships among the major challenges to the process of E-waste management. An analytical model is constructed by using Total Interpretive Structural Modeling (TISM) method to obtain the hierarchy of the identified challenges. The hierarchy is based on their interdependence and driving strength. The resulting model may serve as a framework for planning and analyzing policies of E-waste systems.

Keywords: E-waste management; TISM method; Policy planning

INTRODUCTION

The digital age has enhanced the methods of connectivity and associations across the world. This has resulted in the growth of the digital market enhancing the sales of electronic gadgets like laptops, computers, televisions, smart watches, smart phones, washing machines, refrigerators, microwave, ovens, etc., which are now a necessary part of human lives. The technological advancements have led to a boost in business activities and job opportunities but the industry's quick growth brought with it the high rate of obsolescence which has resulted in unrestrained resource consumption and accumulation of electronic waste. Electronic waste or E-waste has become a worldwide issue in the last two decades. Unwanted electronic goods are referred to as “Electronic garbage” or “Electronic waste”. Metals, polymers, and glass are among the key components found in E-waste. Poly- and Perfluorinated Alkyl Substances (PFAS) are used in electronic products for improving the performance and quality but its decomposition is very harmful [1 . Heavy metals like copper, iron, aluminum and gold account for over 60% of the total [2]. Globally, around 50 million tonnes of E-waste are created, with this figure expected to rise. The recent Covid-19 pandemic has further increased people's reliance on electronic gadgets resulting in a surge in E-waste production [3].

Electronic devices that are no longer economically useful are frequently dumped in landfills and waterways or are treated through practices like acid leaching and open incineration. As the formal sector is burdened with bureaucratic inefficiencies, and lacks infrastructure as well as financial capacity to carry out the decomposition of E-waste at large scale, the informal sector plays significant contribution in the E-waste management cycle. The recycling process carried out in the informal sector uses primitive methods for metals and plastics in E-waste are potentially toxic and hazardous to the environment with negative consequences on the soil due to hazardous contents leaching from landfills and on water due to contamination of water bodies such as ground water, rivers, and wells amongst other water sources [4]. It has adverse effect on the atmosphere due to toxic emissions from E-waste burning [5] Inhalation of toxic gases during recycling, physical contact with potentially hazardous compounds, and lack of safety measures for the workers during the chemical treatments employed in the recovery process poses harm to humans. Hence, there is an urgent need to undertake proper measures for effective performance and recycling of E-waste to dissipate its negative impacts [6]. Various conferences like the basel convention, E-waste world conference and expo, E-waste management and sustainability conferences etc. on waste management have resulted in formulation of laws. Although current E-waste legislation has been embraced by 71% of the world's population, there is still a need to build a worldwide regulatory framework for overseeing E-waste disposal in order

Correspondence to: Eeshika Madaan, Department of Mechanical and Automation Engineering, Indira Gandhi Delhi Technical University for Women, New Delhi, India, E-mail: eeshikamadaan11@gmail.com

Received: 28-Nov-2022, Manuscript No. IJWR-22-17936; **Editor assigned:** 02-Dec-2022, PreQC No. IJWR-22-17936 (PQ); **Reviewed:** 22-Dec-2022, QC No. IJWR-22-17936; **Revised:** 29-Dec-2023, Manuscript No. IJWR-22-17936 (R); **Published:** 05-Jan-2023, DOI: 10.35248/2252-5211.23.13.507.

Citation: Madaan E, Khan U (2023) Identification and Modeling of Challenges to E-Waste Management for Policy Analysis Using TISM Technique. Int J Waste Resour. 13:507.

to bind the other 29% [7]. The policies made for regulating and governing the process of E-waste management have not been implemented properly posing one of the major challenges to the issue. Hence, the need to generate a framework to study the inappropriate disposal of E-waste has necessitated research into the elements influencing E- waste management (Figure 1).

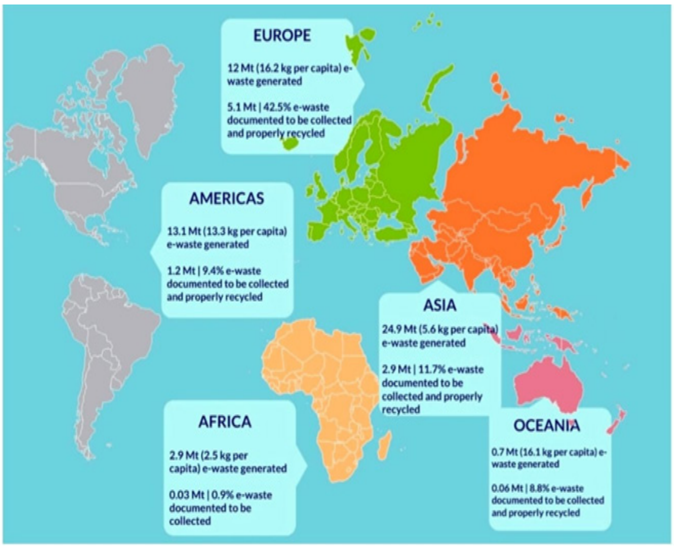

Figure 1: Current E-waste and formal recycling statistics..

This paper is a comprehensive study of the challenges associated with E-waste disposal and management. The methodology of the study involves identification of the major challenges to E-waste management and utilization of Total Interpretive Structural Modeling (TISM) method to assist us level the challenges on the basis of their relevance. The analysis of the obtained model suggests a need for an increased role of government and relevant authorities in convening and developing appropriate legislative framework for the better management of the E-waste. They must also ensure that the implementation is carried out appropriately within the countries and beyond borders since e-waste management is a massive issue that must be handled before it becomes a significant concern for humanity.

Problem identification

The issues of E-waste management have been recognized, modeled, and discussed in this work. As a result, we've designated this issue as, "E-Waste Management: Modeling of Challenges" (Table 1).

Table 1: Challenges to E-waste.

Code	Challenges to E-waste	References
C1	Short life-span of IT products as compared to the rate of urbanization	
C2	Lack of trained, literate and skilled workforce	(Kumar Adhana, 2019)
C3	Limited government intervention, improper regulations and implementation of policies	
C4	Inadequate logistical, infrastructural and resource distribution systems	(Tihomir Tomic Daniel, et al, 2020)(Kumar Adhana, 2019)(Wang, et al, 2017)(Chowdhury and Jitendra, 2017)
C5	Import of E-waste from developed countries to developing countries	(E-Waste In India Research Unit (Larrdis) Rajya Sabha Secretariat New Delhi, 2011)(Wang, et al, 2017)
C6	Involvement of unorganized sector in E-waste management	(Electronic Waste and India, n.d.)
C7	Low environmental consciousness about disposal of E-waste, and absence of effective programmes for monitoring the E-waste process	(Md TasbirulIslam, et al, 2020) (Carisma, 2009) (Osibanjo & Nnorom, 2007) (Wong, et al, n.d.)
C8	Use of toxic chemical materials for manufacturing	(Daniel Oteng, et al, 2022) (Sabino De Gisi, et al, 2022) (Prakash Pokhrel, et al, 2020) (Chowdhury & Jitendra, 2017)(Wang, et al, 2017) (Needhidasan, et al, 2014)
C9	Lack of reliable data on electronic appliances sold and managed annually	(Srimathi H, et al., 2019)
C10	Lack of government investment, tax relaxation and funds to support enterprises collecting E-waste	(Wang, et al., 2017)
C11	High running costs for registered E-waste treatment plants	

OBJECTIVES OF THE STUDY

Brief description of challenges

Short life span of IT products as compared to the rate of urbanization collection: With the advent of new technologies and advancements entering the digital market, people prefer to replace their electronic devices in a short period of time. IT companies incorporate the market strategy of enhancing their sales by shortening the product life span so that the customers frequently buy them. The current generation has the mindset that buying a new model is more convenient than wasting money on the older one. Hence, the older versions become antiquated and are sold or dumped as scrap. Moreover, the movement of masses from rural areas to urban areas for better opportunities, better living standards, and availability of choices has led to increased rate of urbanization in metropolitan cities. As the purchasing capacity of people improves, the amount of E-waste generated has also increased causing adverse effects on health and environment [8].

Lack of trained, literate and skilled workforce: The discarded E-waste is generally collected by rag pickers, migrated laborers, women and children who are not integrated in the cycle of E-waste management. They form a part of the informal and unorganized sector [9]. These unskilled laborers lack training for the proper waste collection, processing and disposal of E-waste. They face occupational hazards with the job they do as they have no social security for them [10]. The valuable parts which can be reused and serve as secondary raw materials are also dismantled in pieces due to lack of knowledge and training of the workers [11].

Limited government intervention, improper regulations and Implementation of Policies: The inefficiency of the formal sector in the installation of E-waste collection mechanisms for disintegration of electronic products in developing countries like India, Sri Lanka, Bangladesh has paved the way for the informal sector to be included, which uses conventional methods such as landfills and dumping grounds for the decomposition of electronic waste. The existing policies for solid waste management as well as E-waste management are primitive and ineffective in the contemporary socio-economic setting. The E-waste dealers and people refrain from obeying the existing policies and paying the principle of processing and administrative cost because of a lack of implementation of the current schemes and programmes in this regard. Extremely limited involvement of governments in the E-waste management cycle and lack of coordination among various local authorities in the segregation, collection, monitoring, and disposal of E-waste decreases accountability of government as well as bureaucratic authorities. Hence, efficient waste management regulations are required to be updated to meet the current needs and demands [12].

Inadequate logistical, infrastructural and resource distribution systems: Since organizational authorities do not prioritize E-waste management, there is a complete absence of resource distribution methods as well as budgetary limits in this area [13]. Due to poor selection of technology for the E-waste disposal system, there is a significant gap in the processing capacity of current collecting and recycling facilities to the volume of E-waste generated. The lack of effective recycling facilities is evident from the poorly managed logistics in waste collection procedures, absence of effective and acceptable collection models, and non-economical techniques for segregating E-waste material [14].

Import of E-waste from developed countries to developing countries: Globalization has expanded the flow of trade across the globe and has opened the gates for import and export of raw materials and finished goods. With this incident of trafficking of waste have escalated and the incentives earned upon selling it have also up surged. Countries across the globe tend to find safer, easier and economical means for discarding E-waste. Hence, rich countries like the US, Japan, and Switzerland segregate the beneficial constituents and export the leftover toxic scrap to the impoverished South Asian countries like India, China, Pakistan, etc. that have neither basic knowledge nor the ability to safely dispose of garbage [15].The developed countries earn profit due to the cost effectiveness in availing cheap labor and also a relief from the ultimate problem of destroying E-waste by legally evading it. On the other hand, junk dealers and e-waste brokers in developing countries import them as fresh goods, earning the financial benefit due to non-existent and unregulated policies for E-waste [16] . Due to this intercontinental and unauthorized trans boundary movement of E-wastes, they face the strenuous trouble of destruction and pose a mammoth danger to nature (E-Waste in India Research Unit (Larrdis) Rajya Sabha Secretariat New Delhi, 2011) [17] .

Involvement of unorganized sector in E-waste management: Unorganized sector involves junk dealers, rag pickers, scavengers, dismantlers, women and children who play a significant contribution in the collection, processing and disposal of electronic scrap [18]. Improper methods of recycling or destroying the toxic materials in the E-waste are employed in this sector which results in the reduction of life of the products and has negative effect on the health of living beings and environment due to their activities. It is run by scrap dealers in workshops, backyards or open barren grounds with a business motive and the people engaged earn their livelihood through this work. The process followed here involves separating, dismantling segregation, and incineration of materials by categorizing the products as usable and waste [19]. The various industrial procedures of recycling E-waste and circuit boards are as listed: pyrolysis, mechanical milling, hydrometallurgical, air classification, bio-metallurgical, electrostatic and magnetic separation. It has also been brought to notice that the E-waste collected by government recognized retailers and offices are sent to scrap dealers which at the end become a part of the informal sector. The reason is that waste collection and disposal services by the formal sector in developing countries are costlier than the developed countries thus the role of the informal sector is significant [20-25]. Although the network in this sector is well established, it is not bound by laws therefore making most of its operations illegal.

Low environmental consciousness about disposal of e-waste, and absence of effective programmes for monitoring the e-waste process

Although technology is progressing day by day, most people do not know what exactly is electronic waste or E-waste. Today's youth are updated about the latest technologies in the market but have no idea about what happens to the obsolete ones and how they have an unpropitious effect on the environment and health [26-30]. Even the ethnic groups and households prefer to sell their rejected electronic devices instead of paying for waste recycling and disposal services as they can make some money by selling it to "kabadiwalas". This implies a clear lack of schemes and programmes concentrating on the problem of E- waste generation and awareness of E-waste management [31]. There are no proper operational government authorities, local civic bodies or residential associations to oversee and supervise the E-waste recycling and waste step-down procedures. There is a lack of training of the stakeholders involved in this business. These are the main reasons for the low percentage of recycled and reused scrap. These phenomena clearly show a lack of awareness and environmental consciousness [32].

Use of toxic chemical materials in electronic appliances: The use of petro-chemical products like plastics (Sabino De Gisi et. al, 2022), and metals like aluminum (Al), lead (Pb), gold (Au), tin (Sn), iron (Fe), and zinc (Zn) used for manufacturing of electronic products including PCB's, switches, motherboard, photovoltaic cells etc., [33-37]. The emission of gases on decomposition endangers the environment and human health [38]. Also, when dumped and incinerated in open areas, the fumes generated ads to the menaces caused [39]. In addition, petrol and other such raw products are non- renewable natural resources which are likely to be extinct soon due to over consumption [40] (Figure 2).

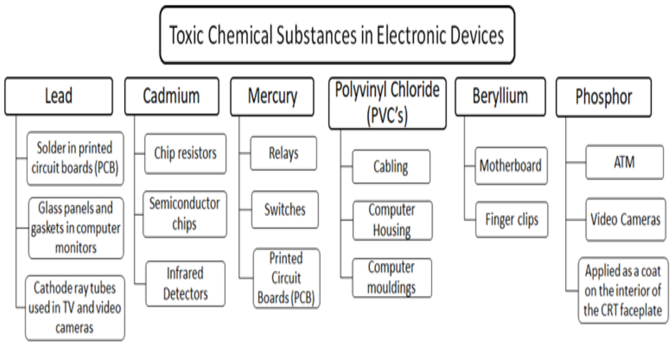

Figure 2: Harmful chemicals used in manufacturing of electronics.

Lack of reliable data on electronic appliances sold and managed annually: Across the globe, there is a lack of techniques for accurate data collection on the numbers or percentage of electronic devices dumped annually and the end outcome of the dumped devices. 90-95% of the discarded electronic devices are processed by the unorganized sector through methods like open burning, dismantling, breaking, incineration, and dumping [41]. Are no suitable rules governing the disposal of electronic trash, the illegal trading of E-waste across the globe, especially from rich countries to impoverishing countries, becomes easier. This results in enhanced disturbance in maintaining the counting leading to deficiency of lethal statistics which further escalate the difficulty level. Also, there are insufficient methods and no proper technique for collection and analysis of data of E-waste [42-45].

Lack of government investment, tax relaxation and funds to support E-waste collecting enterprises

Most governments ignore the quantity of harmful E-waste produced and do not invest in E-waste management, preferring instead to use illicit methods to solve the problem. We do not see substantial alternatives to handle this gigantic issue since a lot of money has to be spent following the right method of recycling and decomposition of E-waste, and no tax relief or financial help is offered to the formal sector or recognized factories run by private enterprises [46].

High running costs for registered E-waste treatment plants: E-waste treatment plants are the sites where the end-of-life electrical products are transported for recycling through proper scientific techniques so that they can be further used. The main processes performed involve collection of electronic scrap, segregation, transportation to the plant, mechanical shredding of items, sorting with advanced separation technologies, and treatment for further use. This requires a significant amount of investment for the establishment, working and tackling the operation of the treatment plan. Moreover, skilled employees are needed to run such heavy machinery and it costs the employer a good decent amount to have such people on ground. Yet, a low amount is offered in turn for the E-waste that is processed and disposed through the formal sector [47].

MODELING OF CHALLENGES TO E-WASTE MANAGEMENT

An appropriate analytical model of the pivotal challenges to e-waste is obtained by using the TISM method.

Total interpretive structural modeling-A brief review: Interpretive Structural Modeling (ISM) is described as a method for helping the people in better understanding and recognizing what they are unable to analyze [48]. The ISM method converts hazy, poorly phrased representations of systems into observable, well-defined models. The existence of a high number of components and their interactions add to the complexity [49]. The inclusion of elements that are directly or indirectly connected makes the structure of the system complex, which may or may not be stated clearly. As a result, it is necessary to design a technique that assists in the identification of a structure inside a system. Interpretive Structural Modeling (ISM) is an example of such a technique [50]. A patriarchal sequence is obtained on arranging the system components of ISM. Based on the correlations, a structural model for the factors connected with the system is constructed [51]. ISM investigates the dynamic interaction of several elements that are connected directly or indirectly.

The Interpretive Matrix can be used in modal analysis to assess directed and undirected binary or fuzzy relations: The interpretation of the relation can be indicated by the side of the network connecting the pair of elements that share the connection. A Total Interpretive Structural Model (TISM) may be enhanced from an interpretive structural model, giving it more relevance in real-world settings. This not only helps to develop a completely interpretive structural model, but it also tends to make a knowledge base of all the relations' interpretative logic. Specialists are included in such studies to build a descriptive logic of the directional connection shown for comparison of each pair. The entire interpretative structural models are supposed to be backed by in-depth information about the system. The dimension interpretive is determined by a group of specialists in the subject. To assess if and how the variables are connected, a group of expert opinions were gathered (Figure 3).

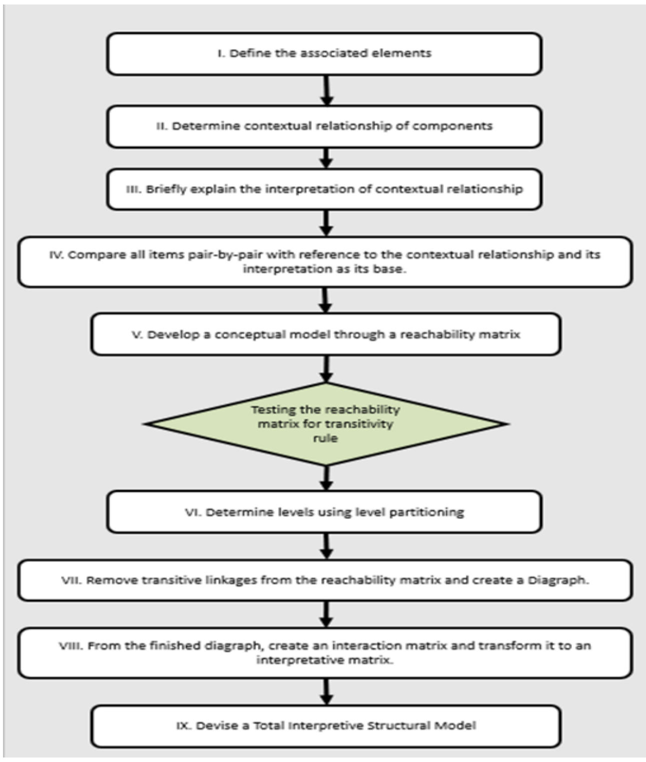

Figure 3: Flowchart indicating the steps of TISM.

The significant steps of TISM methodology

Define the Associated elements:
The first stage in the structural modelling method is to specify the linked elements whose interactions will be represented. This can be accomplished through the use of any idea creation

approach as a small group activity or through the use of grounded theory. Adequate results available from previous research can also be used to link the detected elements.

Determination of contextual relationship of components: It is critical to determine and establish a contextual link between the elements to construct the structure of the model relating the components.

Briefly expalin the Understanding of the relevant connections:

This is a significant improvement over the conventional ISM. Despite the relevant connection analyses the significance of the relation according to the structure, it is practically quiet when it comes to interpreting how the relationship really functions. To generate TISM from ISM, it is necessary to expalin the perception of the association. In TISM, connection for each combination of objectives would be interpreted differently and explicitly, with knowledge being the base.

Comparing all items pair-by-pair with reference to the relevant connection and its interpretation as its base: In TISM, the elements are compared to create TISM. The linkage among the challenges might be one of different forms: whether one enables the other or conversally, whether they facilitate each other, or whether they are unconnected. The connection between the two barriers, let p and q, is represented by the symbols given below:

1. V: p elevates q
2. A: p gets elevated by q
3. X: p and q elevate each other
4. O: p and q are unrelated

The Interpretative Matrix concept is now utilized to thoroughly interpret each challenge paired for comparison in terms of how that directional link operates in the system under investigation by answering the interpretative query specified in step. The ith element is compared to each element from each element (i-1)th to nth in paired comparison. There will be in all n (n-1)/2 paired comparisons if there are n items. The knowledge base will have n (n-1) rows. Each pair of items (i, j) might have two potential directed links (i–j) or (j-i). The item for each connection might be 'Yes (Y)' or 'No (N),' and if it is 'Yes,' it must be processed further. The interpretive logic of the paired links will be provided in the form 'Interpretive Logic-Knowledge Base' (Table 2).

Develop a conceptual model through a reachability matrix: The interpretive logic—knowledge base paired comparisons are translated into a reachability matrix by inserting 1 in the i-j cell if the corresponding item in the knowledge base is 'Y,' or 0 if the corresponding entry in the knowledge base is 'N.' This matrix is tested for the transitivity rule and adjusted until full transitivity is established, as shown in Tables 4(a) and 4(b). The Knowledge Base is updated with each new transitive link. The 'No' value should be updated to 'Yes,' and 'Transitive' should be typed in the interpretation column. If the transitive connection can be described concisely, the reasoning is placed beside the 'Transitive' item; otherwise, it is left alone. The transitivity of a connection is predicated on the assumption that if C1 drives C2 and C2 drives C3, then C1 must drive C3. Table 4(a) shows the original reachability matrix, and Table 4(b) shows the final reachability matrix, post-transitivity check. Driving strength of the challenges is given by summation of row values, whereas summations of column values quantify challenge's reliance (Table 3).

Determine levels using level partitioning: The levels are partitioned based on the final reachability matrix inputs. In this case, initially, the reachability and predicate sets for each challenge is discovered. A challenge's reachability set includes the challenge itself as well as all challenges that are driven by it. The preceding set of a challenge, on the other hand, includes both the challenge and all the challenge that operate it. A challenge's intersection set consists of the common challenges in its reachability and antecedent sets. Challenges with equal intersection and reachability sets are placed in Level 1 and eliminated from the table [52]. The technique is continued until the challenges are matched to the next level. The method is repeated until each challenge's level is reached are shown (Tables 4(a)-4(b)).

Removing transitive linkages from the reachability matrix and create a digraph: The elements are classified into levels; the guided linkages are created and illustrated based on the associations displayed in the reachability matrix. By evaluating the relevance of the transitive linkages in the knowledge base, a simplified version of the initial digraph is produced by deleting them one at a time. Only transitive relations with important interpretations are maintained (Table 5).

Table 2: Structural Self-Interaction Matrix (SSIM).

S. No.	Challenges Code	Challenges to e-waste management in India	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2
1	C1	Short life span of IT products as compared to the rate of urbanization	O	O	O	A	O	O	V	O	O	O
2	C2	Lack of trained, literate and skilled workforce	V	O	O	O	A	O	O	O	A	-
3	C3	Limited government intervention, improper regulations and implementation of policies	O	V	O	V	V	V	V	O	-	-
4	C4	Inadequate logistical, infrastructural and resource distribution systems	V	A	A	O	O	V	O	-	-	-
5	C5	Import of E-waste from developed countries to developing countries	O	O	V	O	A	A	-	-	-	-
6	C6	Involvement of unorganized sector in E- waste management	V	A	V	O	A	-	-	-	-	-

7	C7	Low environmental consciousness about disposal of E-waste, and absence of effective programmes for monitoring the E-waste process	O	O	O	V	-	-	-	-	-	-
8	C8	Use of toxic chemical materials for manufacturing	V	O	O	-	-	-	-	-	-	-
9	C9	Lack of reliable data on electronic appliances sold and managed annually	O	O	-	-	-	-	-	-	-	-
10	C10	Lack of government investment, tax relaxation and funds to support E-waste collecting enterprises	V	-	-	-	-	-	-	-	-	-
11	C11	High running costs for registered E-waste treatment plants	-	-	-	-	-	-	-	-	-	-

Table3: Knowledge base showing interpretive logic.

S.No.	Challenge no.	Comparison of challenges (in pairs)	Y/N	What effect will a challenge have on other challenges?
1.	C1–C5	Short life span of IT products as compared to the rate of urbanization will enhance or influence import of E-waste from developed countries to developing countries.	Y	Electronic gadgets are replaced in a short amount of time, as technology advances. The E-waste created is transported throughout the world so that land in developed countries is not squandered.
2	C8–C1	Use of toxic chemical materials for manufacturing will enhance or influence short life span of IT products as compared to the rate of urbanization.	Y	Toxic chemicals like lead, mercury, phosphor used in electronic devices cannot be reused again as the treatment used for the extraction of these chemicals degrade their efficiency leading to a limited shelf life.
3.	C3–C2	Limited government intervention, improper regulations and implementation of policies will enhance or influence lack of trained, literate and skilled workforce.	Y	Unprivileged people get involved in waste collection risking their lives and health without any proper measures and knowledge on the management of such hazardous materials for earning a livelihood.
4.	C7–C2	Low environmental consciousness about disposal of E-waste, and absence of effective programmes for monitoring the E-waste process will enhance or influence lack of trained, literate and skilled workforce.	Y	Lack of understanding about the handling of toxic materials draws the marginalized people into the garbage collection industry, putting their lives and health at risk.
5.	C2–C11	Lack of trained, literate and skilled workforce will enhance or influence high running costs for registered e-waste treatment plants.	Y	Limited number of literate individuals with appropriate understanding of e-waste management makes their demand high, and hence they are paid a reasonable wage.
6.	C3–C5	Limited government intervention, improper regulations and implementation of policies will enhance or influence import of e-waste from developed countries to developing countries.	Y	Lack of restrictions and regulation by the concerned authorities on the movement of waste in the developing nations fosters unlawful cross-border trading.
7.	C3–C6	Limited government intervention, improper regulations and implementation of policies will enhance or influence involvement of unorganized sector in E- waste management.	Y	Lack of government engagement in the e-waste management cycle to separate authorized dealers, and insufficient cooperation among federal entities for e-waste supervision and disposal leads to inclusion of the informal sector which is exposed to toxic materials.
8.	C3–C7	Limited government intervention, improper regulations and implementation of policies will enhance or influence low environmental consciousness about disposal of E-waste, and absence of effective programmes for monitoring the E-waste process.	Y	No intervention of the regulatory stakeholders in the process of e-waste collection and treatment results in a complete lack of awareness campaigns and environmental conscience.
9.	C3–C8	Limited government intervention, improper regulations and implementation of policies will enhance or influence use of toxic chemical materials for manufacturing.	Y	Absence of coordination among various federal agencies for e-waste supervision and disposal implies the inclusion of toxic and non-biodegradable chemicals in manufacturing of electronic devices.
10.	C3–C10	Limited government intervention, improper regulations and implementation of policies will enhance or influence lack of government investment, tax relaxation and funds to support e-waste collecting enterprises.	Y	There is truancy of E-waste treatment since no tax incentives or financial help are available to the formal sector by legislators.

11.	C4–C6	Inadequate logistical, infrastructural and resource distribution systems will enhance or influence involvement of unorganized sector in E-waste management.	Y	The constraints of logistics, distribution networks and infrastructure have resulted in the inclusion of the unorganized sector as it does not require many inputs.
12.	C9–C4	Lack of reliable data on electronic appliances sold and managed annually will enhance or influence Inadequate logistical, infrastructural and resource distribution systems.	Y	The absence of critical information and appropriate data leads to ineffective logistical and resource distribution networks. Limited supply due to the government's lack of financial or philanthropic assistance in E-waste dumping procedure.
14.	C4–C11	Inadequate logistical, infrastructural and resource distribution systems will enhance or influence high running costs for registered E-waste treatment plants.	Y	Inadequate machinery, resources, and Expertise led to greater operating costs for E-waste treatment operations.
15.	C6–C5	Involvement of unorganized sector in E- waste management will enhance or influence import of E-waste from developed countries to developing countries.	Y	The transportation of collected E-scrap
16.	C7–C5	Low environmental consciousness about disposal of E-waste and absence of effective programmes for monitoring the E-waste process will enhance or influence import of e-waste from developed countries to developing countries.	Y	Pollution from the developed world might have been avoided if there had been adequate awareness and information about the negative repercussions.
17.	C5–C9	Import of E-waste from developed countries to developing countries will enhance or influence lack of reliable data on electronic appliances sold and managed annually.	Y	Since the transportation of collected waste to growing economies is unrestricted by law, there is no accurate count or data on the overall number of electronic gadgets in the country.
18.	C7–C6	Low environmental consciousness about disposal of E-waste and absence of effective programmes for monitoring the E-waste process will enhance or influence involvement of unorganized sector in E- waste management.	Y	Dearth of information about E-waste and its correct treatment engages the unorganized sector that functions in an inefficient manner. Devices or components of electronic gadgets. Purchased and as the sector comprises benighted. Individuals, there is no formal documentation. Accountability, transparency and traceability in the E-waste recycling chain.
20.	C10–C6	Lack of government investment, tax relaxation and funds to support e-waste collecting enterprises will enhance or influence involvement of unorganized sector in E- waste management.	Y	Lack of financial support from the government for e-waste management, the high cost of maintaining treatment plants, the informal sector gets engaged because the investment is small and the returns are comparatively greater.
21.	C6–C11	Involvement of unorganized sector in E- waste management will enhance or influence high running costs for registered e-waste treatment plants.	Y	The unorganized sector takes precedence over e-waste treatment plants as the former gives better cost returns on electronic scrap by reselling the devices second hand or selling the parts separately.
22.	C7–C8	Low environmental consciousness about disposal of E-waste and absence of effective programmes for monitoring the E-waste process will enhance or influence use of toxic chemical materials for manufacturing.	Y	Non-renewable toxic chemicals are employed in electronics due to a lack of information about the harm caused to health and the environment.
23.	C8–C11	Use of toxic chemical materials for manufacturing will enhance or influence high running costs for registered e-waste treatment plants.	Y	Since specific processes must be utilized to treat or recycle non-renewable resources, the cost of employing the necessary technology is considerable.
24.	C10–C11	Lack of government investment, tax relaxation and funds to support e-waste collecting enterprises will enhance or influence high running costs for registered e-waste treatment plants.	Y	As the government does not reimburse or subsidize e-waste management, the cost of running treatment plants is quite expensive.

Table 4(a): Initial reachability matrix.

S.No.	Challenges code	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
1	C1	1	0	0	0	1	0	0	0	0	0	0
2	C2	0	1	0	0	0	0	0	0	0	0	1
3	C3	0	1	1	0	1	1	1	1	0	1	0
4	C4	0	0	0	1	0	1	0	0	0	0	1
5	C5	0	0	0	0	1	0	0	0	1	0	0
6	C6	0	0	0	0	1	1	0	0	1	0	1
7	C7	0	1	0	0	1	1	1	1	0	0	0
8	C8	1	0	0	0	0	0	0	1	0	0	1
9	C9	0	0	0	1	0	0	0	0	1	0	0
10	C10	0	0	0	1	0	1	0	0	0	1	1
11	C11	0	0	0	0	0	0	0	0	0	0	1

Table 4(b): Final reachability matrix.

S.No.	Challenges code	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	Driving power
1	C1	1	0	0	0	1	0	0	0	1*	0	0	3
2	C2	0	1	0	0	0	0	0	0	0	0	1	2
3	C3	1*	1	1	1*	1	1	1	1	1*	1	1*	11
4	C4	0	0	0	1	1*	1	0	0	1*	0	1	5
5	C5	0	0	0	1*	1	0	0	0	1	0	0	3
6	C6	0	0	0	1*	1	1	0	0	1	0	1	5
7	C7	1*	1	0	0	1	1	1	1	1*	0	1*	9
8	C8	1	0	0	0	1*	0	0	1	0	0	1	4
9	C9	0	0	0	1	0	1*	0	0	1	0	1*	3
10	C10	0	0	0	1	1*	1	0	0	1*	1	1	5
11	C11	0	0	0	0	0	0	0	0	0	0	1	1
Dependence power	4	3	1	6	8	6	2	3	8	2	9	-	

Table 5: Level partitioning.

Variables	Reachability set	Antecedent set	Intersection set	Level
		Iteration 1		
C1	1,5,9	1,3,7,8	1	
C2	2,11	2,3,7	2	
C3	1,2,3,4,5,6,7,8,9,10,11	3	3	
C4	4,5,6,9,11	3,4,5,6,9,10	4,5,6,9	
C5	4,5,9	1,3,4,5,6,7,8,10	4,5	
C6	4,5,6,9,11	3,4,6,7,9,10	4,6,9	
C7	1,2,5,6,7,8,9,11	3,7	7	

C8	1,5,8,11	3,7,8	8	
C9	4,6,9,11	1,3,4,5,6,7,9,10	4,6,9	
C10	4,5,6,9,10,11	3,10	10	
C11	11	2,3,4,6,7,8,9,10,11	11	I
		Iteration 2		
C1	1,5,9	1,3,7,8	1	
C2	2	2,3,7	2	II
C3	1,2,3,4,5,6,7,8,9,10	3	3	
C4	4,5,6,9	3,4,5,6,9,10	4,5,6,9	II
C5	4,5,9	1,3,4,5,6,7,8,10	4,5	
C6	4,5,6,9	3,4,6,7,9,10	4,6,9	
C7	1,2,5,6,7,8,9	3,7	7	
C8	1,5,8	3,7,8	8	
C9	4,6,9	1,3,4,5,6,7,9,10	4,6,9	II
C10	4,5,6,9,10	3,10	10	
		Iteration – 3		
C1	1,5	1,3,7,8	1	
C3	1,3,5,6,7,8,10	3	3	
C5	5	1,3,5,6,7,8,10	5	III
C6	5,6	3,6,7,10	6	
C7	1,5,6,7,8	3,7	7	
C8	1,5,8	3,7,8	8	
C10	5,6,10	3,10	10	
		Iteration – 4		
C1	1	1,3,7,8	1	IV
C3	1,3,6,7,8,10	3	3	
C6	6	3,6,7,10	6	IV
C7	1,6,7,8	3,7	7	
C8	1,8	3,7,8	8	
C10	6,10	3,10	10	
		Iteration – 5		
C3	3,7,8,10	3	3	
C7	7,8	3,7	7	
C8	8	3,7,8	8	V
C10	10	3,10	10	V
		Iteration – 6		
C3	3,7	3	3	
C7	7	3,7	7	VI
		Iteration – 7		
C3	3	3	3	VII

From the Finished digraph, by creating an interaction matrix and transform into an interpretative matrix: A binary interaction matrix with 1 entry for each interaction is generated. Cells with a single element are inferred by using an interpretive matrix to pick suitable knowledge base interpretation [53].

Devise a total interpretive structural model: The TISM is generated from the interpretive direct interaction matrix and digraph's connective and interpretative information. The interpretation of components included in boxes replaces the nodes in the digraph. The interpretation is displayed in the boxes of the interpretative direct interaction matrix on the structural model's appropriate linkages. This results in a thorough description of the structural model in terms of node and linkage interpretation, as shown (Figure 4).

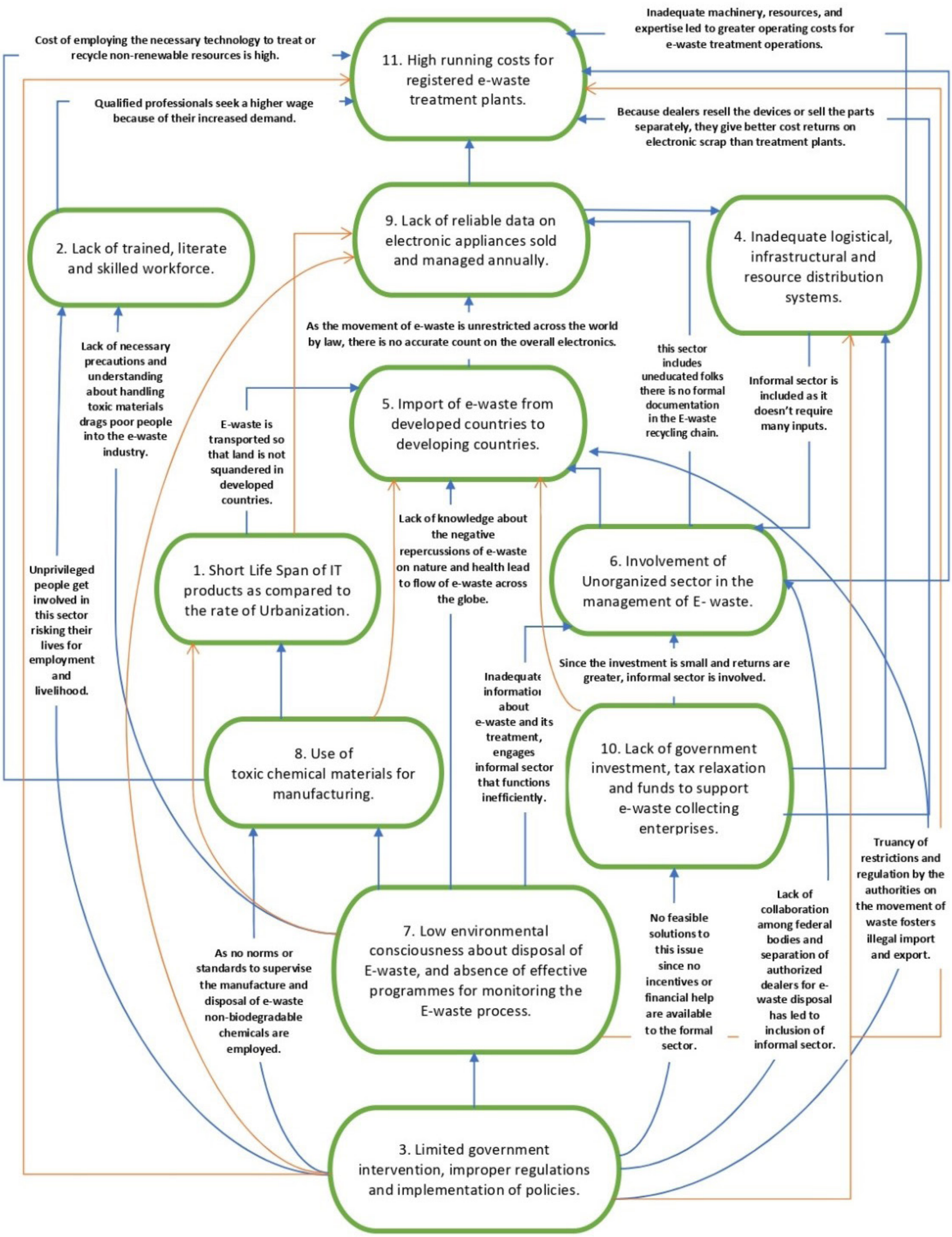

Figure 5: Total interpretive structural model.

RESULT

Insights from TISM model

Using Figure 4, it is found that the challenges such as limited government intervention, improper regulations and implementation of policies and absence of effective monitoring programmes, low environmental consciousness and lack of awareness on disposal of E-waste are independent challenges. They drive the other challenges with their strong driving power. They are at the bottom of the TISM model's hierarchy. A high running cost for registered E-waste treatment plants are a dependent challenge and is driven by other challenges. It is ranked first in the TISM model. The remaining challenges are linkages positioned at intermediate hierarchy in the TISM model. Challenges like short life span of IT products as compared to the rate of urbanization and involvement of the unorganized sector in the management of E-waste are placed at the intermediate position between dependent and independent challenges [54]. These challenges have a considerable reliance and driving force, therefore they greatly impact and are influenced by other challenges. This study has created a methodology for determining the root cause of problems in policy implementation of 'E-waste management' and feeding the root cause as an input during the policy design stage to be worked upon on priority basis. This framework can be used as an input by concerned authorities in better policy formulation, implementation and evaluation across any vertical of policy-making in politico-administrative context.

CONCLUSION

A descriptive picture was drawn for the challenges on mammoth issue of electronic waste management. Literature review was done for identifying the challenges to E-waste management. The TISM method was used for developing a model (Figure 4) and arranging the identified challenges based on their dependency. The challenges of E-waste management were classified as dependent and independent according to their dependence power and driving power. The most important challenge with high driving power and less dependence placed down in the flowchart is limited government intervention, improper regulations and implementation of policies. This factor drives all other challenges and therefore must be addressed on priority in order to lessen its impact. The basic premise is that if adequate observation is paid to eradicate it, other obstacles are less likely to occur. Subsequently, the responsible authorities associated with other/derived challenges will improve their functioning by taking appropriate actions for overcoming these challenges. Hence, the results obtained from this model can be useful for the governments, especially in developing countries, in formulation, legislation and adoption of suitable policies for E- waste management. This paper can facilitate the policy-makers to understand the inter-relationships of the challenges to E-waste management and to work upon them with extensive focus.

REFERENCES

1. ATansel B. PFAS use in electronic products and exposure risks during handling and processing of e-waste: A review. J Environ Manage. 2022;316:115291.
2. Chen Z, Ren Z, Zheng R, Gao H, Ni BJ. Migration behavior of impurities during the purification of waste graphite powders. J Environ Manage. 2022;315:115150.
3. Oteng D, Zuo J, Sharifi E. Environmental emissions influencing solar photovoltaic waste management in Australia: An optimised system network of waste collection facilities. J Environ Manage. 2022;314:115007.
4. De Gisi S, Gadaleta G, Gorrasi G, La Mantia FP, Notarnicola M, Sorrentino A. The role of (bio) degradability on the management of petrochemical and bio-based plastic waste. J Environ Manage. 2022;310:114769.
5. Ajay SV, Kirankumar PS, Sanath K, Prathish KP, Haridas A. An experimental simulation study of conventional waste burning practices in India for the assessment and inventorisation of PCDD/F/dl-PCB emissions. J Environ Manage. 2022;303:114109.
6. Putra PH, Rozali S, Patah MF, Idris A. A review of microwave pyrolysis as a sustainable plastic waste management technique. J Environ Manage. 2022;303:114240.
7. Hantoko D, Li X, Pariatamby A, Yoshikawa K, Horttanainen M, Yan M. Challenges and practices on waste management and disposal during COVID-19 pandemic. J Environ Manage. 2021;286:112140.
8. Pokhrel P, Lin SL, Tsai CT. Environmental and economic performance analysis of recycling waste printed circuit boards using life cycle assessment. J Environ Manage. 2020;276:111276.
9. Islam MT, Dias P, Huda N. Waste mobile phones: A survey and analysis of the awareness, consumption and disposal behavior of consumers in Australia. J Environ Manage. 2020;275:111111.
10. Tomic T, Schneider DR. Circular economy in waste management–Socio-economic effect of changes in waste management system structure. J Environ Manage. 2020;267:110564.
11. Ismail H, Hanafiah MM. A review of sustainable e-waste generation and management: Present and future perspectives. J Environ Manage. 2020;264:110495.
12. Tangaran J, Patimo DM, Dollado RF. Disposal Management Practices of Unserviceable Electronic Resources. Sri J Env. 2021;6(1):8-12.
13. Borthakur A, Singh P. Electronic waste in India: Problems and policies. Int J Environ Sci. 2012;3(1):353-362.
14. Bhutta MK, Omar A, Yang X. Electronic waste: a growing concern in today's environment. Econ Res Int. 2011;2011.
15. Brown J. Assessment of domestic solid waste management practices at household level Nyamagana municipality in Mwanza city northern Tanzania (Doctoral dissertation, Masters Thesis. Catholic University).
16. Carisma B. Drivers of and barriers to E-waste management in the Philippines.
17. Chowdhury A, Jitendra P. E-Waste Management and its Consequences: A Literature Review. J Manag Res. 2017;4(1).
18. David A, Thangavel YD, Sankriti R. Recover, recycle and reuse: An efficient way to reduce the waste. Int J Mech Prod Eng Res Dev. 2019;9:31-42.
19. Dewi SR. Different Approach of Policies in E-Waste Management System: A Case Study of India in Comparison to Germany.
20. Sabha R. E-waste in India, research unit (Larrdis), Rajya Sabha secretariat, New Delhi.
21. Banini DKS. Thesis on The Hazards of Electronic Waste (E-Waste). 2018.
22. Havinal R. Electronic Waste: Growing issues Practices and strategies.
23. Hilty LM. Electronic waste-an emerging risk? Environ Impact Assess Rev. 2005;5(25):431-435.
24. Joseph K. Electronic waste management in India–issues and strategies. InEleventh Int Waste Manage and landfill symposium, Sardinia 2007.
25. Karuppannan S. E Waste: Challenge and Impacts on Environment and Health. Waste Manage Conference at MDHS. 2019.
26. Khan MI, Khan S, Khan U, Haleem A. Modeling the Big Data challenges in context of smart cities–An integrated fuzzy ISM-DEMATEL approach. Int J Build Pathol Adapt. 2021.
27. Khan U, Haleem A. Production Planning and Control. Int J Electron Gov, Glob J Flex Syst Manag. 2012.
28. Khan U, Haleem A. Improving to smart organization: an integrated ISM and fuzzy-MICMAC modelling of barriers. J Manuf Technol Manag. 2015.

29. Khan I, Khan U, Haleem A. Corporate social responsibility: Modelling of critical factors using an integrated ISM and Fuzzy-Micmac approach. Int J Glob Bus Compet. 2014;9(1):1-3.

30. Khatwani G, Singh SP, Trivedi A, Chauhan A. Fuzzy-TISM: A fuzzy extension of TISM for group decision making. Glob J Flex Syst Manag. 2015;16:97-112.

31. Kiddee P, Naidu R, Wong MH. Electronic waste management approaches: An overview. Waste Manag. 2013;33(5):1237-1250.

32. Garg N, Adhana D. E-waste management in India: A study of current scenario. Int J Manag Technol eng. 2019;9.

33. Kumar P, Haleem A, Qamar F, Khan U. Modelling inland waterborne transport for supply chain policy planning: An Indian perspective. Glob J Flex Syst Manag. 2017;18:353-366.

34. Kumar S, Singh R, Singh D, Prasad R, Yadav T. Electronics-waste Management Solar energy based Closed loop SEPIC Converter with Inverter for Efficient DC-AC Conversion System View project Electronics-waste Management. Int J Environ Eng Manag. 2013;4:4.

35. Kumar U, Singh D. Electronic waste: concerns of lighting lamps in Jharkhand. Int J Electron Electr Eng Res (IJEEER). 2014;4:103-20.

36. Liu X, Tanaka M, Matsui Y. Electrical and electronic waste management in China: progress and the barriers to overcome. Waste Manag Res. 2006;24(1):92-101.

37. Mirgerami SM, Yaftian MR, Parizanganeh AH, Zamani AA. The status of electronic waste in Iran. J Hum Environ Health Promot. 2018;4(2):55.

38. Mohd S, Kaushal VK. E-waste management in India: current practices and challenges. ResearchGate A Comprehensive Study on Electrical. 2018;355.

39. Murthy V, Ramakrishna S. A review on global e-waste management: urban mining towards a sustainable future and circular economy. Sustainability. 2022;14(2):647.

40. Nautiyal NS, Agarwal S. E-waste management: an empirical study on retiring and disposal of retiring gadgets. Int J Manag. 2020;11(12).

41. Needhidasan S, Samuel M, Chidambaram R. Electronic waste–an emerging threat to the environment of urban India. J Environ Health Sci Eng. 2014;12:1-9.

42. Ninan J B. Electronic waste and management. In Texila Int J Acad Res. 2016;3:2.

43. Osibanjo O, Nnorom IC. The challenge of electronic waste (e-waste) management in developing countries. Waste Manag Res. 2007;25(6):489-501.

44. Purushothaman M, Inamdar MG, Muthunarayanan V. Socio-economic impact of the e-waste pollution in India. Mater Today: Proc. 2021;37:280-283.

45. Saheed Olanrewaju Y. Rethinking Approach to the Control of Illegal Transboundary Waste Trading, Transfer and Diplomacy in Developing Countries. Acad Lett. 2021. [Cross Ref

46. Sainy M, Vidhyapeeth V, Khasgiwala V. E-waste Management & Swachh Bharat Abhiyan. Int. J. Eng. Res. Technol. 2017;6. [Cross Ref

47. Singh P, Thomas S. E-waste management and environment protection: A critical legal analysis. Bharti Law Review. 2016:27-35.

48. Srimathi H, Krishnamoorthy A, Dharshini S. E-Waste management and awareness. Int J Sci Technol Res. 2019;8:11.

49. Sushil S. Interpreting the interpretive structural model. Glob J Flex Syst Manag. 2012;13(2):87-106.

50. Thanavathi C. E-waste management among prospective teachers.

51. Turaga RM, Bhaskar K, Sinha S, Hinchliffe D, Hemkhaus M, Arora R, et al. E-waste management in India: Issues and strategies. Vikalpa. 2019;44(3):127-162.

52. Wang W, Tian Y, Zhu Q, Zhong Y. Barriers for household e-waste collection in China: Perspectives from formal collecting enterprises in Liaoning Province. J Clean Prod. 2017;153:299-308.

53. Yuan PW, Mun NK, Rajendran SD. A Study on Barriers to Implement E-Waste Management. InE3S Web of Conferences. 2019;136:02026.

54. Zulfequar S, Singh J. E-Waste: An Environmental And Economic Overview On Generation And Recycling For Different Indian States. JETIR.