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RESEARCH ARTICLE

Assessing enablers of e-waste management in circular economy using DEMATEL method: An Indian perspective

Manu Sharma[1] · Sudhanshu Joshi[2] · Ashwani Kumar[3]

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Abstract

With increasing population, excessive use of electrical and electronic products and extreme demand of resources have compelled the linear economy to transform into Circular Economy (CE). In the current scenario, e-waste management has become the top priority of all the developed and developing nations especially those in the transition phase. The generation of e-waste has increased proportionally across the world and created an intense pressure on the firms to implement sustainable practices to redesign and recycle the products. The current status of the developing countries like India confronts number of challenges to manage e-waste produced, and the only possible solution is to minimize the waste generation and practicing recycling processes. For transforming into CEs, there is a need to identify the most influencing key enablers through which an effective and robust e-waste management (e-WM) system can be developed. An extensive literature review and expert judgments are expended to identify the most influencing key enablers of e-WM in circular economies, and, being the highest producer of e-waste, Mumbai (Maharashtra) has been chosen as the case location. To explore the strength of causal and effect enablers, the DEMATEL method is applied. This study has shown that 'Environmental management system' (EMS) is the most significant and important driving enabler to influence all the other existing enablers. This study has also highlighted that e-WM can be efficient if it focuses on producing eco-friendly products, developing strict legislations, building green image and supporting the producers to implement CE practices. This study helps stakeholders and policy makers to reduce the burden from the environment and focus on developing an efficient e-WM system on the basis of identified key enablers like EMS and collaboration with environmental partners to contribute towards CE transition.

Keywords E-waste management (e-WM) · End-of-life (EoL) · Circular economy (CE) · Developing countries · MCDM

Introduction

The hasty consumption of electronic innovative products has created many challenges in linear economy to manage electronic waste (e-waste). The lifestyle and technological changes are increasing the usage of electrical and electronic appliances in our lives everyday. The presence of harmful metals in the electrical and electronic appliance is adversely affecting human's health and enormously deteriorating the environment (Babu et al. 2007; Heeks et al. 2015; Garlapati 2016). The term 'e-waste' is explained as any waste generated from appliances that uses electric power and is reach to End-of-Life (EoL) (Bain et al. 2010; OECD 2016; Mane et al. 2019). The e-waste has lifted the concerns regarding its disposal and recycling all over the world and considered as an emerging challenge by policy makers, practitioners and academic researchers (Babu et al. 2007; Akram et al. 2019; Mihai et al. 2019) and has crossed 48.5 Million Tones (MT) mark in 2018,

Responsible editor: Philippe Loubet

✉ Manu Sharma
manusharma@doonuniversity.ac.in

Sudhanshu Joshi
sudhanshujoshi@doonuniversity.ac.in

Ashwani Kumar
ashwani.983@gmail.com

[1] Marketing and Advertising Area, School of Management, Doon University, Dehradun, Uttarakhand, India

[2] Operations and Supply chain Area, School of Management, Doon University, Dehradun, Uttarakhand, India

[3] Jaipuria Institute of Management, Noida, India

which is projected to get double in next 5 years. However, only 20% out of it is recyclable (Balde et al. 2017; Mihai et al. 2019; WEF 2019).

With the increasing pace of urbanization, e-waste is among the topmost issues in the modernized world and constantly generating several hazardous and toxic elements like calcium, lead, mercury, chromium and polybrominated biphenyls to the environment (Zeng 2018). On the other side, it is the main source of iron, copper, and many other metals (Borthakur and Govind 2018a, b; Awasthi et al. 2019; Ravindra and Mor 2019; Zhang et al. 2019). As the demand for advanced electronic products increases the resource required for production become scarce, and thus managing e-waste is the best solution for reverse supply of the resources. To fulfill the desire of bringing precious back, there is a need to develop an effective and efficient system e-WM, which may be considered as the only possible solution to overcome this problem faced by the developing nations (Pérez-Martínez et al. 2019). The problems like lack of services and legislations towards e-waste in the developing nations have severe concerns, leads to mishandling and malpractices (viz. open-burning and open dumping practices), and causing pollution at different levels (Herat and Agamuthu 2012; Alghazo et al. 2019). It also affects the public health and environmental ecosystem (Liu et al. 2012; Awasthi et al. 2016). Many researchers have conducted studies in the last decade to address this serious issue (Borthakur et al. 2019), and few of them addressed the challenges of e-waste in developing and developed nations (Sthiannopkao and Wong 2013), but still the research is very scarce on enablers or causal and effect group variables of e-WM in developing countries (Duan et al. 2016; Pradhan and Kumar 2014; Ackah 2017; Andrade et al. 2019; Dias et al. 2019; Liu et al. 2009). Thus, limited research on e-WM needs to be extended and analyzed by a conceptual framework of enablers to understand the interrelationships among them and influencing the environment ecosystem.

Due to the incessant emphasis on the recycling issue, Circular Economy (CE) is acknowledged as a strategic approach for reducing the stress from the environment and an effort to balance the economies (Akram et al. 2019; Blomsma and Brennan 2017; Ramzan et al. 2019). The CE concept has been highlighted due to high increase in the usage of electronic products and rising volumes as well as confronts in the recycling of EoL products (Parajuly 2017). The recycling of EoL products in developing nations will bring sustainable development (Hischier and Wäger 2015; Marra et al. 2019; Slaveykova et al. 2019), and thus all the developing nations need to transform CEs. Among the CEs, India shows tremendous potential as a new economic system (Krishnamurthy et al. 2019; Symeonides et al. 2019), which is constantly taking initiatives to control the issues like waste management including pollution, e-WM, environmental security and protection. In India, e-waste in various denominations will substantially rise to 18 times by 2020 (UNDP 2007; Awasthi et al. 2018; Akram et al. 2019; Andrade et al. 2019; Gao et al. 2019; Masud et al. 2019).

As e-WM aims to integrate processes for designing green products, multi-agency collaboration, e-waste collection, community participation, disposal and recycling (Zeng 2017b), it is becoming the first priority of the policy makers and stakeholders nowadays to perform as an integrated system to bring sustainable development and jointly solve the e-waste issue (Awasthi and Li 2018; Korhonen et al. 2018; Ramzan et al. 2019). e-WM becomes very challenging due to the absence of environmental and regulatory framework, lack of operational awareness related to asset recovery from used products and lack of integrated supply chain planning and design (Kim et al. 2013; Ismail and Hanafiah 2019a, b; Ramzan et al. 2019; Masud et al. 2019). Therefore, the execution of e-WM practices needs to be designed from environmental and economic perspective (Alghazo et al. 2019; Kumar and Dixit 2018a; Ramzan et al. 2019).

In the recent studies, researchers argue that in e-WM, critical factors are more concentrated to developed nations, whereas the developing countries are still struggling with policy and structural framework (Al-Anzi et al. 2017; Arya et al. 2019; Dias et al. 2019; Akram et al. 2019; Khoshand et al. 2019). Thus, in order to bridge this research gap and to accelerate CE activities in context to e-waste, the present study is an attempt to identify and assess set of enablers related to e-WM in India. This study showcases a well-structured case organization. Considering the above critical research gaps, the research study contributes effective and efficient execution of e-WM to solve the critical issue of developing countries like India. From this perspective, the study is broadly focusing on various dimensions, including the following: Firstly, identification and finalization of key enablers those are responsible for efficient e-WM system, based on systematic literature review and experts opinion. Further, based on selected set of enablers, causal relationship has been established using DEMATEL approach. In the presence of substantial growth of the subject on e-WM, the study has following research objectives, including

- Finalizing and listing set of enablers for execution of e-WM through a literature review and experts input.
- Investigating and establishing a cause–effect relationship among the enablers of e-WM using a DEMATEL approach

To achieve the above objectives, MCDM approach has been applied for e-WM in Indian context. The enablers are identified from the existing literature and validated by experts. Further, the interrelationship among the enablers and the intensity of influencing each other are examined by DEMATEL method. DEMATEL is the best method to explore interrelationships, and this method is applied in this study to measure the mutual effects of the enablers (Kamble et al. 2019). The decision makers may decide to implement and practice the e-WM framework on the basis of dominant enablers influencing other enablers. This paper is organized into 6 sections. “Literature review” elaborates the review on e-WM, circular economies and enablers. “Research methodology” presents the methods implemented to conduct the study. “Model application” illustrates the step by step process of DEMATEL model application. The findings and results are discussed in “Results and “Discussion.” Moreover, contribution to literature and implications are also presented followed by the conclusion.”

The research framework for the study is presented in Fig. 1.

Literature review

It is a must to have a systematic review of e-WM in CE like India, reported by the researchers to develop a conceptual framework. It has three sub-sections: (a) e-WM in circular economy; (b) e-WM in Indian context; and (c) enablers of e-WM in circular economies.

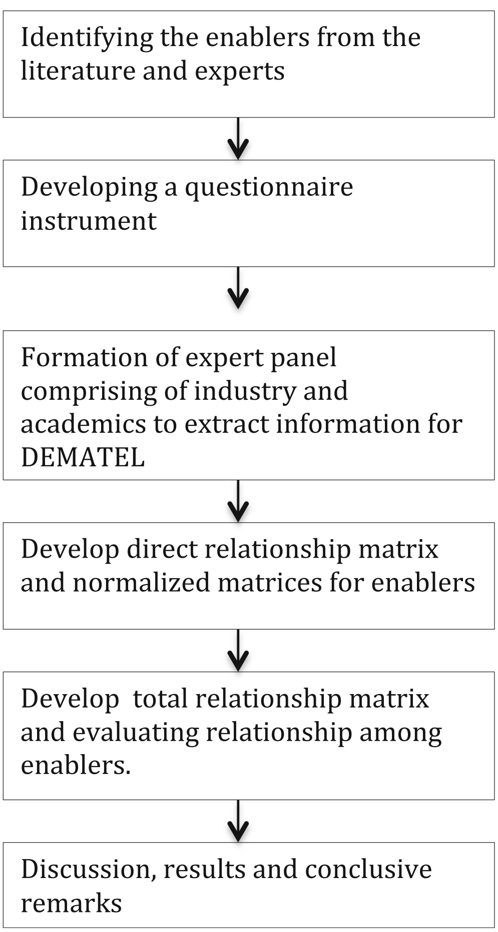

Fig. 1 Research framework

Electronic waste management and circular economy

In the last two decades, e-waste has emerged as a worldwide apprehension to bring environmental improvement and recycling (Akram et al. 2019) with a huge figure of 49.8 million tons in 2018 (Balde et al. 2017). The rising e-waste and environmental issues have made the world to transit from linear economy to CE model by means of global research, communication and efficient practices in different forms (Goyal et al. 2018; Slaveykova et al. 2019). CE is considered as an umbrella concept to minimize the waste generation process (Cullen 2017;Homrich et al. 2018;Korhonen et al. 2018; Pauliuk 2018), which involves creation of closed-loop ecosystem for efficient consumption and utilization of resources aims to waste free owing to reduce, reuse and recycle waste (Esposito et al. 2016; Slaveykova et al. 2019; Symeonides et al. 2019). The focus of CE model is to efficiently manage the resources by means of reverse logistics, innovation, redesigned and collaborative ecosystems. But this concept is still in nascent phase (Rosa et al. 2019). There is a need to substitute the linear model into CE to develop a sustainable ecosystem for future generations (MacArthur et al. 2016; Parajuly 2017; Cobo-Ceacero et al. 2019). Currently, managing e-waste is confronted by advance technological up gradation with increasing number of electrical and electronics products day by day (Akram et al. 2019; Andrade et al. 2019; Zhang et al. 2019). Moreover, low rate of collection and recycling creates a significant loss of resources, which may be derived by the e-products. Today, managing e-waste is not limited to recycling, rather initiatives are required to reshape and redesign the product manufacturing processes that create a need to develop a closed loop system of CE (Pauliuk 2018). Additionally, integrating the concept of sustainable or green practices into e-WM system such as eco-design, green packaging and cleaner technologies help to provide an edge in improving both environmental as well economic performance of electronic industry (Somsuk and Laosirihongthong 2017; Andrade et al. 2019; Akram et al. 2019; Masud et al. 2019; Zhang et al. 2019). However, some other sustainable factors such as economic, social, environmental, technological and policy formulation may influence the e-WM (Abdulrahman et al. 2014; Jadhao et al. 2016; Shaharudin et al. 2017; Kumar and Dixit 2018a; Xu et al. 2018). These extended sustainable dimensions play critical role during adoption of e-WM in the CE (Garlapati 2016; Awasthi and Li 2018; Awasthi et al. 2019). The existing literature also depicts the majority of developing countries that show the trends of CE, lack in infrastructure and information systems to establish and maintain e-WM systems.

Electronic waste management in Indian context

Electronic waste addressed CAGR about 30% in India alone (BS 2013; Priya and Hait 2017; Joon et al. 2017; UNEP 2019). With the large population base, India becomes a key attraction from leading electronic goods manufacturers for market expansion (Awasthi and Li 2018; Borthakur and Govind 2018a, b). However, India has become fastest emerging economies of the world and ranked fifth in the e-waste generation considering tag-line of favorable e-waste dumpyard for several developed nations due to the availability of cheap labor for recycling (Manomaivibool 2009). India is about to generate 2 million metric tons per annum (Garg and Adhana 2019). Besides, electronic import coupled with domestic waste and it is likely to reach 3 million metric tons by the end of 2020. Still, an alarming 95% of waste is managed by informal sector for recovery activities. Currently, besides to domestic generation, e-waste is transfered from developed nations to CEs like India, and China remains relatively high (Li et al. 2017a, b; Dias et al. 2019;Masud et al. 2019; Schroeder et al. 2019). 65–70% of e-waste gathered from European and other developed is directly or indirectly sent to these countries for recycling purpose (Azevedo et al. 2017; Dias et al. 2019; Sajid et al. 2019). In India, only 5% of total waste is recyclable, which occurs due to lack of good infrastructure, weak policy instruments and an institutional framework, which leads to natural resource shortage and environmental degradation and causes adverse effect to people engaged in recycling industry (Kumar and Dixit 2018a, b).

In developing nations, economic growth has enhanced the living standards and helps in lowering down the poverty rate (Widmer et al. 2005; Kvint 2010; Al-Anzi et al. 2017; UN 2018). These economies have started taking e-waste as an important environmental and health issue (Shinkuma and Managi 2010; Abdelbasir et al. 2018; Matarazo et al. 2019) and started encountering e-WM challenges, either generated domestically or imported illegally, and disposed in unsanitary landfill sites (Nnorom and Osibanjo 2008; Ackah 2017; Araujo et al. 2017; Ikhlayel 2017, 2018; Zhang et al. 2019). Considering the severity of the e-waste issue in India, there is a need to take immediate action to manage waste efficiently (Dhull and Narwal 2018).

Proposed enablers for e-WM in circular economies

To build the theoretical framework of e-WM in circular economies, it is mandatory to conduct literature review to identify enablers reported by various researchers. Several studies conducted on drifts of e-waste and its effects on environment were analyzed. Particularly, the reviews conducted by Liu et al. (2009), Ryen et al. (2018), Akram et al. (2019), Andrade et al. (2019) and Pires et al. (2019) are undertaken for the present research work. The enablers of e-WM in circular economies are undertaken in context to economic, social, environmental and technological aspects. Economic instrument has vital role in e-WM system implementation (Cucchiella et al. 2015; Singh 2017). To manage the quantum rise of e-waste, a huge amount of investment and skilled workforce is required to run the management effectively (Zaman 2013, 2015; Ahmed et al. 2015). For environmental sound management of e-waste, deposit refund scheme provides an incentive plan for pre-paid consumers if they returned the obsolete product to the formal recycler (Wath et al. 2010; Tansel 2017; Zhou et al. 2017; Ikhlayel 2018; Vanegas 2018). One of the main aims of sustainable e-WM is to recover the rare earth metal and the commercialization of recovered precious material. This precious material consists of gold, palladium, silver, copper, aluminum, zinc, lead, titanium and so on (Pan et al. 2015; Azevedo et al. 2017; Ackah 2017). The recovery of precious material can minimize the use of the virgin material in production, which may lead to resource conservation and economic benefits (Zhu et al. 2013; Pan et al. 2015; Ackah 2017). Subsidies benefits payback to the consumers who returned their waste to formal recyclers for recycling, which acts as a motivating factor for the consumer, thus increasing the recycling rate of e-waste treated by formal sector (Wath et al. 2010; Ikhlayel 2017; Shevchenko et al. 2019; Yunita et al. 2019). Due to climate change, ozone depletion and greenhouse gas emissions (GHG-Es), consumers are more aware of environmental protection, green purchasing and e-waste recycling and disposal (Vachon and Klassen 2008; Lee and Lam 2012; Borthakur 2017; Echegaray 2017). A study by Gupta and Barua (2016) suggested that the concept of green collaboration focused on waste minimization by setting a common environmental goal and provides all the required assistance in terms of technology sharing, information sharing and providing training to the recycling workers to minimize toxic waste and thus contributing to social dimension (Agamuthu et al. 2011; An et al. 2015; Awasthi et al. 2016; Liu 2017). As per United Nations 2030, sustainable development goals (SDGs), enhancing the quality of workplace safety is another important strategy to ensure that the workers can deliver their best for the nation (Gupta and Barua 2017). Finally, a study by An et al. (2015) suggested that green training program fosters worker skills and encourages them to adopt environmentally sound or cleaner technologies, which can protect workers' health as well as the ecosystem (Awasthi et al. 2016; An et al. 2015; Bhatia 2018; Xu et al. 2018; Khoshand et al. 2019). Heras and Arana (2010) stated that Environment Management System (EMS) works as an environmental policy tool that supports electronic manufacturers for setting up environmental goals, planning, execution and constant monitoring of its supply chain components. EMS certification such as ISO 14000 enhances the firm green image in the global market (Manomaivibool 2009; Diabat and Govindan

2011; Pathak 2017; Shaharudin et al. 2017; Zeng 2017a, b; Bakhiyi 2018; Lee et al. 2018; Xu et al. 2018). Rousis et al. (2008) stated that the emission of hazardous and toxic substances originated from the e-waste treatment plants should be taken into prior consideration while implementing the e-WM system. Hence, reducing resources utilization and harmful emissions is a primary concern for waste management (Yang et al. 2011). The enablers identified are listed in Table 1.

Research gaps

Developing countries are limited to research in e-waste generations (Wath et al. 2010; Saidan and Tarawneh 2015; Hira et al. 2018; Ismail and Hanafiah 2019b), e-waste estimations (Zeng et al. 2017; Heeks et al. 2015; Liu et al. 2009; Supian et al. 2015; Yedla 2016; Bogar et al. 2019), recycling (Chen et al. 2011; Awasthi et al. 2016; Tiwari et al. 2019), life cycle assessment (Ikhlayel 2017) and legislations (Nnorom and Osibanjo 2008; Wath et al. 2010; Kumar et al. 2017; Pathak and Srivastava 2017; Mehta 2019). Many researchers have discussed the emerging e-WM–related issues, and studies increased gradually since last decade, but still the literature on conceptual framework of enablers by which the stakeholders may take necessary actions and developing strategies to overcome this problem is still missing. Past researchers have discussed the e-WM in respect to TBL, but, till date, no research is conducted to identify the most critical dimension, which needs to be considered immediately. The transition to CEs is dependent completely on the e-WM implementation, and few researchers have discussed the challenges of e-WM in Indian perspective, but still causal and effect group factors' relationship among the enablers has not been discussed yet. Thus, this study aims to address these gaps to help stakeholders and policy makers to identify the causing factors, which are influencing the e-waste ecosystem adversely.

Table 1 Key enablers of e-WM

Enablers	Brief description	References
Collaboration with environmental partners (EN1)	Providing assistance in terms of technology, information sharing, providing training to the recycling workers in order to minimize toxic waste	Vachon and Klassen (2008); Borthakur (2017); Echegaray (2017); Andrade et al. 2019); Zhang et al. (2019).
Subsidies benefits (EN2)	It's a motivating factor for the consumers who returned their waste to formal recyclers for recycling	Macauley et al. (2003); Awasthi (2017); Zhu et al. (2017); Kumar and Dixit (2018a); Islam (2018), Lee (2018); Ramzan et al. (2019)
Recovery of precious material (EN3)	The recovery of precious material can minimize the use of the virgin material in production, which may lead to resource conservation and economic benefits	Pan et al. (2015); Daso et al. (2016). Parajuly (2017); Xu (2017); Xu et al. 2017); Coban et al. (2018); Andrade et al. (2019).
Deposit refund scheme (EN4)	An incentive plan for pre-paid consumers, if they return the obsolete product to the formal recycler	Wath et al. (2010); Duan et al. (2016); Afroz et al. (2017); Zhou et al. (2017); Ikhlayel (2017, 2018); Tansel (2017); Vanegas (2018); Shevchenko et al. (2019) and Yunita et al. (2019)
Employee health schemes, Training programs for environmental consciousness (EN5)	These schemes aim to ensure safety for the workers and maintain their health so that they can deliver their best for the nation. Green training program foster worker skills and encourage them to adopt environmentally sound or cleaner technologies	Agamuthu et al. (2011); An et al. (2015); Awasthi et al. (2016); Liu (2017); Bhatia (2018); Xu et al. (2018); Haibo et al. (2019)
Green image (EN6)	Practices to be followed to be perceives as 'green' product	Pathak (2017); Bakhiyi (2018); Xu et al. (2018); Ramzan et al. (2019)
Reduction in landfill practices (EN7)	Reducing the landfill practices to control e-waste	Babu et al. (2007); Wibowo and Deng (2015); Zeng (2017a, b, 2018)
Environmental management systems (EMS) (EN8)	An environmental policy tool that supports electronic manufacturers for setting up environmental goals, planning, execution, and constant monitoring of its supply chain	Manomaivibool (2009); Shaharudin et al. (2017); Zeng 2017a, b; Lee et al. (2018); Akram et al. (2019)
Environmental legislation (EN9)	The regulatory framework to follow environmental friendly practices	Heeks et al. (2015)
Reduction of hazardous and toxic substances in environment (EN10)	To reduce toxic substances while treatment of the e-waste components.	Grant and Marshburn (2014); Xu (2017a); Nagaraju et al. (2018); Xu et al. (2018); Alghazo et al. (2019)

Research methodology

The present study aims to build novel research framework for enablers of e-WM in CEs on the basis of experts' knowledge and previous studies undertaken. The study has undertaken semi-structured interviews of experts and comprehensive reviews of e-WM reports and databases. Several researchers have applied MCDM approaches in past to solve the issues of waste management in CE. Wibowo and Deng (2015) used multi-criteria group decision making to evaluate performance of e-waste recycling programs. Kumar and Dixit (2018a, b) employed ISM and DEMATEL approach to develop interrelationships among barriers of e-WM in India. Bhatia and Srivastava (2018) employed Gray-DEMATEL for analyzing external barriers in re-manufacturing in Indian e-WM sector. Stefanovic et al. (2016) used AHP to analyze the best waste scenarios. The current study has applied DEMATEL approach to identify the interrelationships among the enablers of e-WM.

The selection of MCDM approach is dependent on the nature of the problem and the outcome anticipated. MCDM approaches are useful in assessing the best alternatives, weight measurement, ranking and developing multi-level structure (Sharma et al. 2019; Sharma and Joshi 2019; Sharma and Joshi 2020). The present study needs two objectives to be fulfilled by employing MCDM approach. Firstly, the enablers influencing the e-WM system the most are need to be identified and, secondly, the intensity of enablers to be examined. The use of DEMATEL will be providing evaluation of enablers of e-WM in Indian perspective and also explore the causal and effect relationship among enablers. The enablers are identified from the secondary data and for this; the pool of journals is extracted from the databases like Web of science, Scopus, Emerald insight and Google scholar. Further, the enablers are analyzed by DEMATEL method to explore the interrelationships among enablers.

DEMATEL method

DEMATEL method is applied to explore the causal factor group. The relationship is quantified on the scale of 0 to 4 where 0 indicates that variable '*x*' does not have any influence on '*y*' and 4 indicates that '*x*' influences '*y*' significantly. This method is used to reveal the interdependency of one variable on other. The interdependence among the variables is shown with the help of causal diagram called as diagraph (Wu 2008). The steps for the method are as follows:

Step 1: From critical literature review, the enablers for e-WM are identified. The potential enablers need to be evaluated are listed in Table 1.

Step 2: Establish a Direct-Relation Matrix (DRM).

The experts were requested to quantify the enablers on the scale of 0 to 4 where 0 indicated 'no influence', 1 indicates 'very low influence', 2 indicates 'low influence', 3 indicates 'high influence' and 4 indicates 'very high influence'. On the basis of responses, the $n\ x\ n$ matrix is developed as $X^k = [x_{ij}^k]$. The responses are incorporated from h respondents, direct relation matric 'a_{ij}' is formed though Equation 1. For n, number of variables, the matrix will be in the form shown below (Singh 2017).

$$a_{ij} = \frac{1}{H}\sum_{K=1}^{H} x_{ij}^{k} \quad (1)$$

Where, K = number of respondent with $1 \leq ik \leq H$ and N = number of criteria.

Step 3: Normalizing the DRM

The normalized matrix is developed from DRM as per following eq.

$$D = M\ X\ B$$

$$B = \text{Min}\left[\frac{1}{Max\sum_{j=1}^{n} a_{ij}}, \frac{1}{Max\sum_{i=1}^{n} a_{ij}}\right] \quad (2)$$

Step 4: Obtaining the total relation matrix (T)

By the following equation, T is calculated as

$$T = N(I-N)^{-1} \quad (3)$$

I denotes the identity matrix.

Step 5: Developing diagraph

Sum of rows $[R_i]_{n\ x}$ and columns $[C_j]_{1\ x}\ n$ denotes the vectors of the table T. Values of $(R_i + C_j)$ and $(R_i - C_j)$ are calculated. If the value of $(R_i - Cc_j)$ is positive then the enabler is classified into causal group, whereas, if the value of $(R_i - C_j)$ is negative, then the enablers are classified into effect group.

Data collection and expert selection

The top three states of India producing the highest e-waste are Maharashtra, Tamil Nadu and Andhra Pradesh. Moreover, 65 cities in India are generating more than 60% of India's total e-waste, and Mumbai is on the top e-waste generation. This research study has undertaken Bhiwandi and Navi Mumbai as the case locations from Mumbai Metropolitan region. These two regions are the major source of collected e-waste from manufacturing units, service centres, banking and financial institutions, government offices and imports. The fully computerized banking solutions have made the banking and financial sector as the main source of e-waste since last decade. Almost all the computer hardware and peripherals are from Wipro, HCL, HP and IBM. There are several manufacturing and assembling units for all types of electronics and electrical products in these locations. Exclusive authorized service centers of big manufacturers are returning their waste generated through spare and service functions to their central warehouses located in main areas of the Mumbai City, and the biggest challenge is that none of the vendors is practicing formalized recycling of their equipment and thus increasing e-waste everyday. Additionally, The Nhava port in Navi Mumbai is the most important gateway for the import of e-waste in the city. The government offices under the Ministry of Information Technology such as CDAC also generate e-waste to the maximum. All the above organizations engaged in generating e-waste do not have any policy for e-waste disposal. This study will help the policy makers to develop and implement e-WM efficiently to lower down the percentage of e-waste.

This region is the best suitable case location to understand the e-WM issue and to identify the best possible solution. The executives, officers and manufacturers of these areas are required to provide their insights to analyze the e-WM scenario and thus are chosen as experts in this study. The 15 experts including two experts each from the manufacturing units, services centers, banks, imports and government institutions, and five experts are taken from the e-waste recycling units. The executives, heading maintenance department of the organization, are chosen as the experts. A questionnaire is constructed and distributed among the experts to gather data needed for research work. To obtain the inclusive dataset, 12 organizations in Mumbai were contacted. Out of which, 7 organizations agreed to be the part of the research. The agreed organizations include manufacturing units, services centers, banks, imports and government institutions, educational institution and e-waste recycling. Out of these 7 organizations, a total of 21 experts were contacted through phone, email and personal interaction. Twelve industrial professional and three academicians agreed to contribute for the research study. In this way, a group of fifteen experts was made to identify the key enablers of e-waste management in Indian context. The selected decision group is well versed with organizational planning, research and consultancy in production activities. All the experts are having a working experience of more than eight years, highly qualified and respected in their area. The data collection was done in one-day session consisting of discussions on e-WM in circular economies. The literature review and experts' responses were integrated and assessed on the five-point Likert scale. The ten enablers were finalized from the session and further assessed by the experts using DEMATEL.

Model application

DEMATEL approach is applied to analyze the listed enablers. This approach helps to scrutinize the interrelationship among the enablers to explore cause and effects relationship. The steps of the DEMATEL process discussed in "Research methodology" are followed and following tables are developed. From the steps 1,2,3,4 and 5 in previous section of DEMATEL methodology, the DRM, normalized DRM, TRM and degree of influences are developed and exhibited in Tables 2, 3, 4 and 5.

Results

In this study, enablers of e-WM were ranked on the prominence value and then visualized the causal relationship among the enablers on the basis of responses of the experts. For the deeper understanding of critical enablers, the focus should be on the causal factors with high values. In other words, it can be implied that these causal group factors are autonomous and will drive the other factors. On the basis of R + C values the order of the enablers is EN10 > EN1 > EN2 > EN5 > EN4 > EN9 > EN7 > EN6 > EN3 > EN8. On the basis of R − C values, the enablers are grouped into two groups (causal and effect). The diagram of the enablers is shown in (Fig. 2). The causal group factors includes enablers EN8, EN4, EN9, EN1, EN5 and EN2, which show that Environmental management system (EMS) (EN8) is the utmost crucial and foremost enabler, which is driving all the other enablers. The influence of enabler (EN8) is shown in Fig. 3. The receiver group factors includes the order—EN10 > EN7 > EN6 > EN3, which shows that reduction of hazardous and toxic substance in environment is the most influenced dependent variable shown in Fig. 4.

From Table 5 and Fig. 2, it is visible that Environmental management system (EMS) (EN8) has the highest driving

Table 2 Direct relation matrix

	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10
EN1	0	4	4	3	4	3	0	1	4	3
EN2	3	0	2	2	2	2	3	1	3	3
EN3	3	1	0	1	1	1	3	0	0	3
EN4	3	3	2	0	3	3	3	2	2	4
EN5	3	3	2	1	0	3	3	2	1	4
EN6	1	0	1	1	2	0	3	0	1	3
EN7	2	2	1	2	1	1	0	1	1	3
EN8	1	2	3	3	3	1	2	0	1	3
EN9	4	4	3	2	2	3	2	1	0	3
EN10	3	3	3	2	3	3	1	2	4	0

Table 3 Normalized matrix

0.000	0.138	0.133	0.103	0.138	0.103	0.000	0.034	0.138	0.103
0.103	0.000	0.067	0.069	0.069	0.069	0.103	0.034	0.103	0.103
0.103	0.034	0.000	0.034	0.034	0.034	0.103	0.000	0.000	0.103
0.103	0.103	0.067	0.000	0.103	0.103	0.103	0.069	0.069	0.138
0.103	0.103	0.067	0.034	0.000	0.103	0.103	0.069	0.034	0.138
0.034	0.000	0.033	0.034	0.069	0.000	0.103	0.000	0.034	0.103
0.069	0.069	0.033	0.069	0.034	0.034	0.000	0.034	0.034	0.103
0.034	0.069	0.100	0.103	0.103	0.034	0.069	0.000	0.034	0.103
0.138	0.138	0.100	0.069	0.069	0.103	0.069	0.034	0.000	0.103
0.103	0.103	0.100	0.069	0.103	0.103	0.034	0.069	0.138	0.000

power (1.119) and acting as the causal factor to influence all the other enablers, whereas reduction of hazardous and toxic substances in environment (EN10) has the least value (− .0233) and the most influenced enabler in the receiver group factor shown in Fig. 4.

Discussion

The R + C and R − C values elucidate the cause and effect relationships among the enablers, respectively. The causal group factors drive the effect group variables, which implies that these factors are independent whereas the effect group factors are driven and influenced by them. From Table 5, Environmental management system (EN8) is considered to be the most significant enabler as per the (R − C) values and falls under causal group factors, which requires to be implemented for e-WM in Indian context (Shaharudin et al. 2017). Emission of hazardous and toxic substances originated from the e-waste treatment plants is considered to be the most dependent enabler based on prominence value and falls under effect category as per relation value. Deposit refund scheme (EN4) ranked second, based on the prominence value and comes under causal group as per relation value.

Table 5 Total relation matrix

Enablers	R	C	R + C	R − C
EN1	2.8980	2.2833	5.1812	0.6146
EN2	2.3708	2.1677	4.5386	0.2030
EN3	1.5038	1.993	3.4961	− 0.4892
EN4	2.7674	1.6708	4.4318	1.0966
EN5	2.4174	2.0555	4.4728	0.3619
EN6	1.3648	2.0067	3.3715	− 0.6418
EN7	1.6583	1.9679	3.6261	− 0.3095
EN8	2.1318	1.0127	3.1444	1.1190
EN9	2.6644	1.7423	4.4067	.9221
EN10	2.6734	2.8768	5.5501	− 0.2033

Based on (R − C) values, six enablers are prioritized according their relative positive relation score are as follows: EN8 > EN4 > EN9 > EN1 > EN5 > EN2. These causal enablers act as drivers that can act as a significantly to influence the overall system. The causal group enabler should be given utmost attention and controlled accordingly because they can easily influence the enablers that fall under effect group. In the cause group enablers, EN8, EN4 and EN9, EN1 are identified as the top four key enablers for implementation of e-WM. From visual representation it is observed that Environmental management system (EN8) have strong impact on effect enablers (refer to Fig. 2). EMS works as an environmental policy tool that supports electronic manufacturers for setting up environmental goals, planning and responsibilities as well as regular monitoring of the EoL products by downstream activities such as recycling, resource recovery and disposal in an environmentally sound manner (Zhu et al. 2013; Xu et al. 2018). Similarly, the investigation can be done for effect enablers, which are dependent or easily influenced by other enablers. These effected enablers can be prioritized according to their (R − C) values (Table 5). According to Fig. 2, reduction in hazardous and toxic substance in environment is found to be the most effected enablers followed by and reduction in

Table 4 Total influence matrix

EN1	0.2466	0.3533	0.3315	0.2645	0.3399	0.3117	0.2103	0.1415	0.3143	0.3843
EN2	0.2932	0.1902	0.2355	0.2077	0.2418	0.2404	0.2562	0.1225	0.2531	0.3301
EN3	0.2193	0.1541	0.1099	0.1253	0.1474	0.1448	0.1938	0.0588	0.1072	0.2433
EN4	0.3228	0.3124	0.2629	0.1665	0.3022	0.2986	0.2849	0.1691	0.2487	0.3991
EN5	0.2918	0.2825	0.2376	0.1804	0.1813	0.2708	0.2594	0.1545	0.1963	0.3629
EN6	0.1474	0.1113	0.1295	0.1141	0.1647	0.1012	0.1879	0.0548	0.1235	0.2304
EN7	0.2031	0.1979	0.1549	0.1659	0.1606	0.1577	0.1125	0.0977	0.1484	0.2594
EN8	0.2127	0.2319	0.2452	0.2216	0.2529	0.1899	0.2152	0.0827	0.1712	0.3084
EN9	0.3462	0.3342	0.2860	0.2247	0.2646	0.2915	0.2477	0.1312	0.1796	0.3588
EN10	0.3184	0.3063	0.2875	0.2243	0.2945	0.2929	0.2209	0.1626	0.2993	0.2668

Alpha = .2456

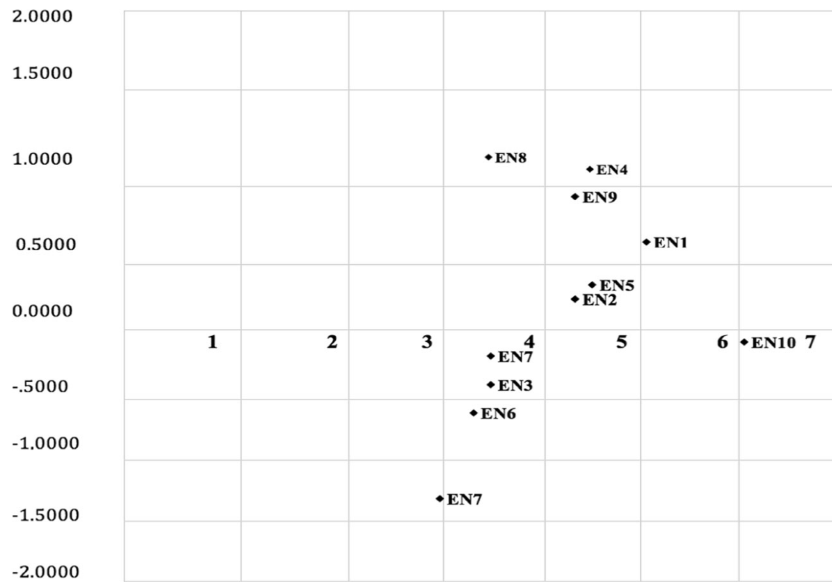

Fig. 2 Casual effect relationship among enablers

landfill practices (EN7), green image (EN6) and recovery of precious material (EN3).

Contribution to literature

Managing e-waste is a major challenge for the developing economies like India. The mountains of e-waste produced are supported by land-filling method in developing countries like India without knowing the main causing variables as well as existing associations among the causal factors. The gap of lack of studies on the prominent enablers of e-WM is addressed by this research work. This study is a first attempt to explore the intensity/strength of the enablers influencing the e-WM in India. The other developing countries targeting to shift towards CEs may also conduct the similar studies to manage their waste efficiently. The growing e-waste issue has been discussed by the researchers but limited to the general understanding and future estimations only which does not resolve the real issue of e-WM. Researchers have applied TBL concept for developing the framework on the basis of economic, social and environmental dimensions, but rare studies are found on the affecting dimension, which is critical and need to be addressed immediately. This study is imperative to compare the enablers exist among the TBL dimensions and reveal the most critical enabler as well as dimensions in context to Indian perspective. This study develops a framework, which supports the stakeholders and decision makers to understand the key enablers for the efficient e-WM in India.

EMS is the found to be the most critical enabler for the e-WM issue from this study, which indicates the electric and electronics manufacturing organizations need to strictly follow and implement a comprehensive, systematic organization environmental program. Currently, the electronics industry is the one of the fastest growing industry, and, due to excessive e-products consumption, disposal and recycling issues, the

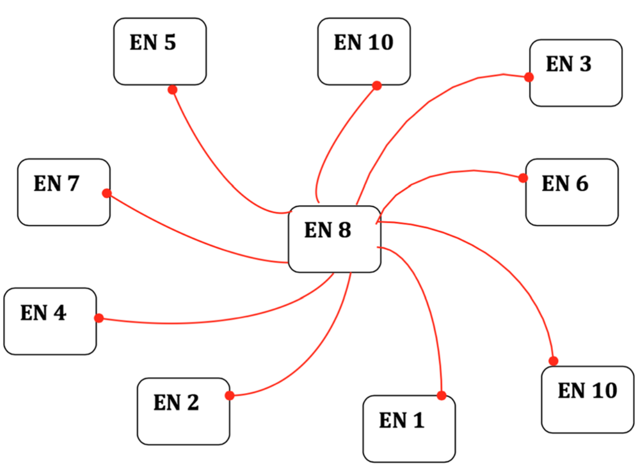

Fig. 3 Influence diagram of EN8

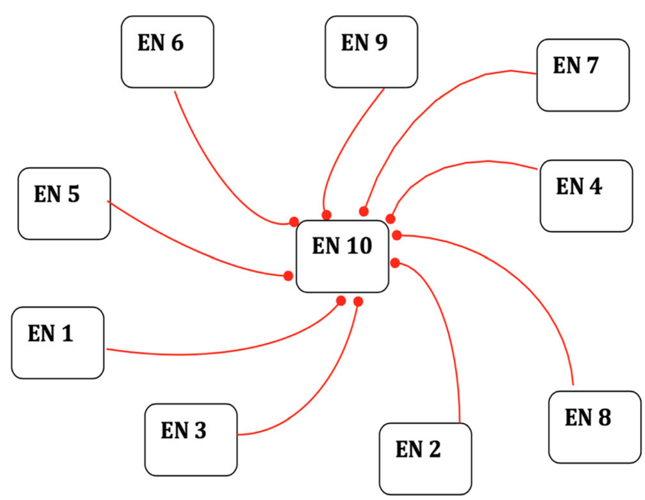

Fig. 4 Influence diagram of EN10

developing countries like India are struggling to deal with the increasing waste generation (Wath et al. 2010). The conventional methods for waste management are removing the waste from living environment and processing it through landfill treatments. But, today, the need of the developing nation is to implement advance waste management techniques like EMS, sustainable innovations, green image, consumers' participation, environmental friendly products and zero waste.

A recent study by Garlapati (2016) suggested that deposit refund system provides an incentive plan for consumers who pay at the time of purchase, which is reimbursed when they returned the obsolete product to the formal recycler, which helps to achieve zero waste and minimize environmental degradation. This indicates that the consumers need to be more targeted to participate in the e-WM practices in India. Furthermore, electronics industry needs to design and manufacture eco-friendly products to become more sustainable and contribute towards 'zero waste' objective.

Numerous developed nations have realized the significance of the regulations (legislations) and formulated policies to manage e-waste and maximize recycling process, but, in developing countries, informal recycling of the e-waste is one of the major challenges. In India, Ministry of Environment and Forest (MoEF) has issued e-waste rules in 2012, based on concept of Extended Producer Responsibility (EPR), which targets to recycle the e-waste formally. This needs to be followed strictly to enhance recycling or e-waste in India. The triple bottom line concept is the key to attain sustainability and therefore e-waste in any CE can be reduced to minimum with its dimensions. The various enablers across Triple Bottom Line (TBL), ranging from economic, social to environmental aspects, are applied to evaluate the sustainability of e-waste. Successful implementation of these enablers ensures the sustainable development of the circular economies.

Implications

This study has explored the interrelationships among the enablers, which could support decision and policy makers in reducing the e-waste from India. The e-waste is the emerging policy concern among CEs to ensure sustainable ecosystems, but, currently, there is lack of infrastructure, planning, participation, regulations and collaboration for conducting e-WM practices in India. There is also a need to establish short and long-term understanding of e-WM when most of the CEs are in transition stage of development. Currently, the e-products users do not actively participate in recycling processes through authorized recycler, and, moreover, recycling process is dominated by the informal agencies. Thus, the decision and policy makers need to develop a strict regulatory environment. The structural framework of the e-WM derived from this paper develops a basis for the decision makers to engage the end users, policy makers and manufacturers to perform e-WM practices by considering key enablers like environmental management system, reduction in hazardous waste from products, legislations and others to develop a sustainable CE. It also has direct policy implications for stakeholders who have responsibility to reduce e-waste from manufacturing to recycling. The policy makers should emphasis on incorporation of key enablers during the strategy formulation for developing an efficient e-WM system. The prominent enablers that can extent the quality of waste management policies are required to be considered as foremost to control e-waste and helps policy makers and practitioners to reduce the harmful effects of e-waste on humans. This paper addresses the economic and social needs of the society showcasing the producers' responsibility to manufacture environment friendly products, developing a green image and many job opportunities for skilled labor to be the part of e-WM.

It is visible from this study that implementation of EMS, manufacturing eco-friendly products, strict legislations to recycle of e-waste separately and enhancing community participation are the main enablers to develop e-waste management. In India, currently, e-waste demands a behavioral change among people to consider waste as product and contribute towards becoming a sustainable circular economy. The collaboration is required among the policy makers and stakeholders such as manufacturers, recyclers, government officials and e-product users to bring the behavioral change towards e-waste management practices in India. For an efficient e-WM system in India, there is need of robust legislation framework to smoothly conduct the e-WM practices from manufacturing to recycling with more scientific and environmental friendly manner.

Conclusion

In India, e-waste management lacks in infrastructural and environmental legislations. The results display the need of integration among manufacturers, communities' participation and technological innovations in collection, disposal and recycling to develop an effective and efficient e-WM. From the current study, it is proposed that the enablers such as EMS, legislation and reduction of hazardous metal need to be considered by the manufacturers, stakeholders and policy makers in developing an e-WM ecosystem. This study is one such attempt to determine and analyze the set of enablers influencing e-WM in Indian context. The present study utilized DEMATEL methodology for evaluating the enablers to build the strategic planning to configure e-waste efficiently, by targeting both short and long term flexible verdict making strategies to handle this issue. The research findings of the study also highlight that stakeholders should emphasize strategically to the causal group enablers, which significantly influence the effect enablers in the implementation process. Finally, this proposed approach helps stakeholders to save their time and resources by prioritizing the enablers of high dominance, which have significant relevance in the context of the electronic industry. The outcome of the research verified that DEMATEL is a sustainable tool to assist the waste management practitioners and policy makers in order to formulate reliable and consistent decisions.

The initiatives taken by the other nations to open e-waste disposal and dumping points with latest technologies to minimize the hazardous environmental consequences of backyard operations of recycling are to be replicated in India. Apart from the manufacturers' contribution, the consumers may also be targeted to be the part of recycling process at these centers by e-waste financial inclusions.

However, the research has few limitations including non-unified judgment scale and biased inputs from the experts while using DEMATEL Technique. Although making the research more comprehensive, a larger sample base could be covered (including experts at regional and international level). The model derived from this study may be tested further in real world for different economies confirming whether the results match with the previous literature. The DEMATEL model can be validated, and more advanced statistical techniques can be used (viz. PLS-SEM). Finally, this study may extend the insights explored from India perspective. This study may be further replicated in other developing nations like China, Brazil and other Asian countries.

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