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Roadblocks for Efficient E-Waste Management in Asian Countries: A Fuzzy TOPSIS Approach

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Abstract: - The management of electronic waste (e-waste) poses a significant challenge in Asian countries, necessitating a nuanced understanding of the multifaceted issues involved. This study employs a Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS) approach to comprehensively evaluate and prioritize the roadblocks impeding efficient e-waste management in the Asian context. The research identifies and assesses various dimensions of roadblocks, encompassing regulatory, technological, economic, and social aspects. In this study, nine roadblocks have been identified through expert opinion and literature survey, the study aims to provide insights into the complex interplay of obstacles hindering optimal e-waste management practices. The Fuzzy TOPSIS model facilitates a nuanced comparison of these impediments, enabling policymakers and practitioners to prioritize interventions based on their relative significance. The findings hold the potential to inform targeted strategies, policies, and collaborative efforts aimed at mitigating the identified roadblocks, fostering a more effective and environmentally conscious approach to handling electronic waste in the diverse and dynamic context of Asian nations.

Keywords: *E-waste Management, Fuzzy TOPSIS, Asian Countries*.

1. Introduction

In the rapidly advancing era of technology, the proliferation of electronic devices has become an integral part of modern life. However, the exponential growth in the production and consumption of electronic gadgets has given rise to a critical environmental challenge – electronic waste, or e-waste. E-waste comprises discarded electronic devices, ranging from smartphones and laptops to larger appliances like refrigerators and televisions, which contain hazardous materials and pose a significant threat to both human health and the environment. As the global digital landscape continues to evolve, the need for effective e-waste management has become more pressing than ever. Improper disposal of electronic waste not only contributes to environmental degradation but also results in the loss of valuable resources embedded in these devices. To address these concerns, countries around the world are increasingly recognizing the importance of implementing comprehensive e-waste management strategies.

E-waste management involves the collection, recycling, and safe disposal of electronic devices at the end of their life cycle. This multifaceted approach aims to mitigate the environmental impact of electronic waste, minimize the release of hazardous substances into ecosystems, and recover valuable materials for reuse[1]. Additionally, responsible e-waste management practices contribute to the conservation of natural resources, reduction of greenhouse gas emissions, and the promotion of a circular economy.

In this context, stakeholders such as governments, businesses, and consumers play crucial roles in fostering sustainable e-waste management practices. Legislative measures, awareness campaigns, and technological innovations are essential components of a holistic approach to address the challenges posed by the escalating volumes of electronic waste[2]. By embracing responsible e-waste management, societies can not only protect the environment and human health but also pave the way for a more sustainable and technologically advanced future.

E-waste management in Asian countries presents a unique set of challenges and opportunities, shaped by the region's rapid economic development, urbanization, and the increasing adoption of electronic devices. Some Asian countries may have limited or inadequately enforced regulations regarding e-waste management. Strengthening legislative frameworks and improving enforcement mechanisms are crucial steps to address the challenges of improper disposal and handling of electronic waste. Despite the growing recognition of the critical need for effective e-waste management in Asian countries, there exist significant research gaps that impede a comprehensive understanding of the roadblocks hindering progress in this area. Firstly, little research has been conducted to systematically identify the diverse roadblocks affecting e-waste management across Asian countries. While certain challenges, such as informal sector involvement and inadequate legislation, are acknowledged, a nuanced exploration of the specific barriers within each country and their variations is lacking. Bridging this gap is crucial for tailoring interventions that address the unique challenges faced by individual nations. Research objectives of the study are as follow:

1. To identify the roadblocks affecting effective e-waste management in Asian countries.
2. To determine the interrelationship among the identified roadblocks in Asian countries.
3. To priories the roadblocks of e-waste management in Asian countries.

2. Literature Review

E-waste management is a global concern due to the rapid growth of electronic waste and its harmful effects on human health and the environment. Effective e-waste management involves recycling hazardous e-wastes into reusable products, creating e-waste management systems, and implementing policies and regulations[3]. However, there are challenges in implementing e-waste management systems, such as low awareness and lack of recycling practices. To address these challenges, it is important to increase awareness, improve regulations, enhance collection methods, and focus on formal recycling[4].

Developing countries, including India, need strategic frameworks for collection, transportation, recycling, disposal, and monitoring of e-waste. By adopting safety measures, increasing awareness, and implementing strict monitoring and policies, e-waste management can be improved[5]. Overall, effective e-waste management is crucial to mitigate the environmental and health hazards associated with electronic waste[6].

Lack of e-waste management in India and the dangers it poses to the environment and personal health. It mentions the introduction of Extended Producer Responsibility certificates and the requirement for producers to set up e-waste exchange facilities for collection and recycling[7]. However, it does not provide specific details on how e-waste is managed in India. challenges and importance of e-waste management, emphasizing the responsibility of producers and consumers to take adequate steps for its management. However, it does not provide specific details on how to manage e-waste.

Challenges faced by Asian countries in managing e-waste, including weak regulatory frameworks, lack of specific regulations, and the presence of informal recycling sectors[8]. It also mentions the highest e-waste generators in the region, such as China, India, Japan, and Indonesia. However, it does not provide specific details on how e-waste is managed in Asian countries. e-waste management in Singapore, Malaysia, and Indonesia, highlighting the inadequate governmental policies, lack of e-waste laws, and lack of public awareness in these countries[4]. However, it does not provide a specific answer to the question about e-waste management in Asian countries as a whole.

E-waste scenario in South-Asia, particularly in India, Bangladesh, and Pakistan. It mentions the need for more studies on environmental and human health effects, legal implementations, awareness, and managerial strategies. However, it does not provide specific information on e-waste management in other Asian countries[9].

Table 1 Roadblocks of e-waste management in Asian countries

S. No	Roadblocks	Description	Source
1.	Lack of holistic e-waste legislation	The lack of holistic e-waste legislation refers to the absence or inadequacy of comprehensive legal frameworks designed to regulate the entire life cycle of electronic products, from manufacturing and consumption to disposal and recycling.	[10], [11]
2.	Illegal import of e-waste	The illegal trade exacerbates the global e-waste problem by distributing environmental burdens. The improper disposal and processing of e-waste in one region can contribute to pollution that transcends borders, affecting ecosystems, wildlife, and even entering the global food chain.	[12], [13], [14]
3.	Lack of infrastructure and finances for formal e-waste recycling	One major aspect of infrastructure deficiency is the lack of organized and widespread collection systems for e-waste. Many regions, particularly in developing countries, lack the necessary infrastructure to collect electronic devices at the end of their life cycle.	[15], [16], [17]
4.	Non-uniformity for illicit trade	Lack of standardized regulations, procedures, or enforcement mechanisms across different jurisdictions or regions, creating inconsistencies and disparities that may be exploited by those engaged in illegal activities, such as smuggling, trafficking, or trade in prohibited goods.	[18], [19], [20]
5.	Lack of public awareness	Significant portion of the population is uninformed or has limited knowledge about a particular issue, topic, or cause. In the context of various societal challenges, such as environmental issues, health concerns, or social problems, the lack of public awareness can impede the adoption of positive behaviors, hinder community engagement, and limit the effectiveness of initiatives aimed at addressing these issues.	[21], [22], [23]
6.	Lack of incentive schemes from governing bodies to regulate e-waste disposal	Absence or insufficient implementation of reward-based programs or policies that encourage individuals, businesses, and other stakeholders to adhere to proper and environmentally friendly electronic waste management practices	[24], [25], [26]
7.	Lacks auditing, reporting, and compliance	Deficiency or inadequacy in the processes of systematically examining, documenting, and ensuring adherence to established standards, regulations, or guidelines. This deficiency is often observed in various contexts, such as corporate governance, environmental management, or regulatory compliance.	[27], [28], [29]
8.	Limited human resources	Organization or a particular context faces constraints in terms of the quantity or quality of its workforce. This limitation can have significant implications for the organization's ability to carry out its functions, meet its objectives, and respond to challenges effectively.	[30], [12]
9.	Lack of corporate social responsibility (CSR) initiatives	Without CSR initiatives, businesses may miss opportunities to positively impact the communities in which they operate and contribute to environmental sustainability. CSR initiatives can include charitable donations, community development projects, and environmental conservation efforts.	[31], [23], [32]

3. Research Methodology

The first step involves a comprehensive examination of the literature review in selecting the criteria for the study. In this case, nine critical roadblocks as shown in table 1, were identified through reviewing prior studies on e-waste management practices. These roadblocks were then sent to e-waste experts for deliberation to ascertain whether these criteria are significant in addressing e-waste formalization challenges through consensus building. Then, fuzzy TOPSIS questionnaires were designed for data collection. Steps of the study id shown in figure 1.

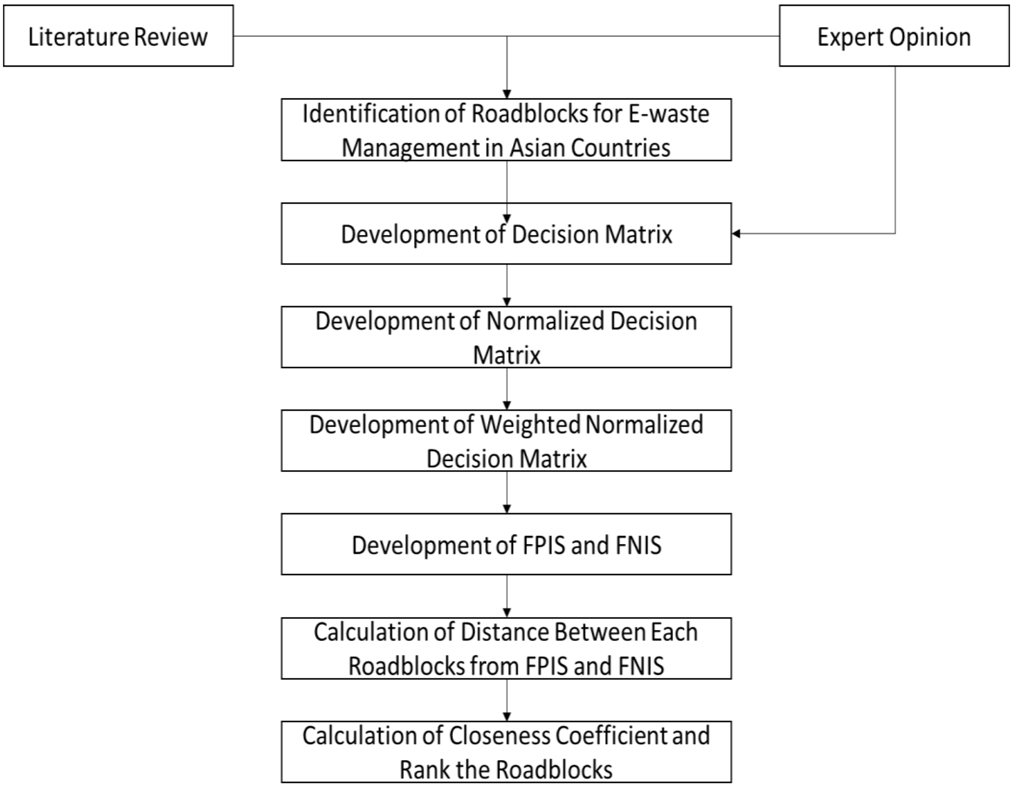

Figure 1 Flow chart for fuzzy TOPSIS

Identification of roadblocks affecting e-waste management in Asian countries

Firstly, author searched different websites like science direct, google scholar and Scopus with a keywords like e-waste, circular economy, circular economy of e-waste, recycling of e-waste, formal and informal recycling of e-waste. Finally, using previous literature and expert opinion nine roadblocks have been identified viz, lack of holistic e-waste legislation (I 1), illegal import of e-waste (I 2), lack of infrastructure and finances for formal e-waste recycling (I 3), non-uniformity for illicit trade (I 4), lack of public awareness (I 5), lack of incentive schemes from governing bodies to regulate e-waste disposal (I 6), lacks auditing, reporting, and compliance (I 7), limited human resources (I 8) and lack of corporate social responsibility (CSR) initiatives (I 9) which affect the e-waste management in Asian countries.

Fuzzy TOPSIS

The Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method integrates fuzzy logic with TOPSIS to address uncertainties and imprecisions in the evaluation process. It offers a systematic process for assessing and selecting options based on how well they meet a set of requirements. The first step in the procedure is to translate the decision-makers' subjective assessments and linguistic uncertainty into fuzzy numerical values as shown in table 2. The closeness coefficients concept is then used to calculate the relative distances between each option and the ideal solution, which is the alternative that performs best according to the evaluated criteria. Fuzzy numbers and proximity are used to establish each option's overall acceptability as well as ranking.

Table 2 Fuzzy Code for TOPSIS

S. No	Response	Code
1	Very Low	1,1,3
2	Low	1,3,5
3	Average	3,5,7
4	High	5,7,9
5	Very High	7,9,9

Here, the fuzzy number applied is defined by the triangular fuzzy numbers (TFN), which describe the linguistic scale of the roadblocks. The linguistic scale and fuzzy numbers are presented in table 2. The scale was used to set up the comparison matrix x_{ij}, between the roadblocks where i is the number of roadblocks affecting e-waste management and j is the number of experts who has given the response. After the construction of the comparison matrix table, the next step is to calculate the weighted normalized decision matrix. The weighted, normalized decision matrix which is r_{ij} calculated by using the following equation:

$$x_{ij} = (a_{ij}, b_{ij}, c_{ij}) \tag{1}$$

$$r_{ij} = [a_{ij}/c_j^*, b_{ij}/c_j^*, c_{ij}/ c_j^*] \quad c_j^* = \max[c_{ij}] \tag{2}$$

$$r_{ij} = [a_j^-/ a_{ij}, a_j^-/ b_{ij}, a_j^-/ c_{ij}] \quad a_j^- = \min[a_{ij}] \tag{3}$$

Weighted normalized matrix is shown in below equation which is denoted by v_{ij}.

$$v_{ij} = r_{ij} \times w_j \tag{4}$$

Fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) are calculated using weighted normalized matrix.

$$\text{FPIS } (A^+) = [v_1^+, v_2^+ \ldots\ldots v_n^+], v_j^+ = \max[v_{ij}], \tag{5}$$

$$\text{similarly FNIS } (A^-) = [v_1^-, v_2^- \ldots\ldots v_n^-], v_j^- = \min[v_{ij}] \tag{6}$$

Distance between two fuzzy values can be calculated through vortex method as shown in table 6 and table 7.

After that, closeness coefficient (CC) is calculated by using the values of table 6 and table 7 with the equation shown below.

$$CC_i = d_i^-/ (d_i^- + d_i^+) \tag{7}$$

4. Result and Discussion

The article depicts the roadblocks affecting e-waste management in Asian countries. In this regard, nine roadblocks have been identified from experts' opinions and validated through previously published reputed articles. After identification of the roadblocks, it has been ranked through fuzzy TOPSIS technique which is a well-known MCDM technique used to determine the most influential or critical criteria. In fuzzy TOPSIS technique first step is the development of decision matrix through expert opinion, in this study a total of twelve expert are taken having more than 15 years of experience, in recycling and academic field. Decision matrix is shown in table 3. After that, normalization matrix is developed by using equation 1, 2 and 3 through decision matrix. The normalization decision matrix is shown in table 4. Next step is the development of weighted normalized matrix. For weighted normalized matrix equation 4 is used. In this matrix some preference is given to response of reviewers according to their experience in respective field. In weighted normalized matrix the values are calculated by using the response of decision matrix which is multiplied with respective weight given to reviewers as shown in table 5. Next fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) which is calculated by equation 5 and 6. The positive ideal solution represents the best values for each criterion, while the negative ideal solution represents the worst values. The FPIS serves as a reference point in fuzzy TOPSIS, against which the alternatives are evaluated. The distance of each alternative from the FPIS and the

Fuzzy Negative Ideal Solution (FNIS) is calculated, and the relative closeness to the ideal solution is used to rank the alternatives.

The Closeness Coefficient (CC) is calculated which is a measure used to assess the proximity of each alternative to the ideal solution. It is a crucial step in the decision-making process where alternatives are ranked based on their relative closeness to the positive ideal solution and the negative ideal solution. The Closeness Coefficient is calculated by considering the distances of an alternative to both the positive ideal solution (denoted as D^{+}) and the negative ideal solution (denoted as D^{-}) as shown in equation 7 and table 6,7. According to the value of closeness coefficient rank would be assigned to roadblocks.

The first ranked roadblocks are lack of holistic e-waste legislation which is the most influential roadblock, without comprehensive legislation, there may be gaps in the regulation of e-waste management, leading to informal or improper disposal methods, such as dumping or illegal export. Holistic e-waste legislation is crucial for creating a structured and sustainable approach to managing electronic waste, ensuring environmental protection, resource recovery, and the promotion of a circular economy. Illegal import of e-waste is the next most influential roadblocks which affect the effective e-waste management to Asian countries. Countries typically have regulations in place to control the import, export, and management of electronic waste. Illegal importation bypasses these regulations, contributing to environmental degradation and health hazards. The least influential roadblocks are limited human resources. Hence, the rankings of the roadblocks are as follows: I1> I2> I3> I6> I5> I4>I7> I9 and I8 in descending order of their CC values as shown in table 8.

Table 3 Response from Experts

Issues/ Response	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12
I 1	5,7,9	5,7,9	7,9,9	5,7,9	7,9,9	5,7,9	3,5,7	5,7,9	7,9,9	5,7,9	7,9,9	7,9,9
I 2	3,5,7	1,3,5	3,5,7	5,7,9	5,7,9	5,7,9	3,5,7	7,9,9	5,7,9	7,9,9	7,9,9	5,7,9
I 3	5,7,9	3,5,7	3,5,7	3,5,7	5,7,9	3,5,7	7,9,9	3,5,7	1,3,5	5,7,9	5,7,9	5,7,9
I 4	1,3,5	3,5,7	3,5,7	3,5,7	1,3,5	3,5,7	3,5,7	1,3,5	3,5,7	3,5,7	3,5,7	5,7,9
I 5	1,3,5	1,3,5	3,5,7	1,3,5	1,3,5	1,3,5	5,7,9	5,7,9	3,5,7	3,5,7	5,7,9	3,5,7
I 6	3,5,7	3,5,7	5,7,9	7,9,9	5,7,9	7,9,9	1,3,5	1,3,5	1,3,5	5,7,9	5,7,9	1,3,5
I 7	1,1,3	1,3,5	1,3,5	1,1,3	1,1,3	1,3,5	5,7,9	3,5,7	5,7,9	3,5,7	3,5,7	5,7,9
I 8	3,5,7	1,3,5	3,5,7	3,5,7	1,3,5	3,5,7	3,5,7	1,3,5	1,3,5	3,5,7	1,3,5	1,1,3
I 9	5,7,9	5,7,9	1,3,5	5,7,9	1,3,5	3,5,7	1,3,5	1,3,5	1,3,5	3,5,7	1,3,5	1,1,3

Table 4 Normalized Decision Matrix

Issues/ Response	R1			R2			R3			R4			R5			R6			R7			R8			R9			R10			R11			R12		
I1	0.6	0.8	1.0	0.6	0.8	1.0	0.8	1.0	1.0	0.6	0.8	1.0	0.8	1.0	1.0	0.6	0.8	1.0	0.3	0.6	0.8	0.6	0.8	1.0	0.8	1.0	1.0	0.6	0.8	1.0	0.8	1.0	1.0	0.8	1.0	1.0
I2	0.3	0.6	0.8	0.1	0.3	0.6	0.3	0.6	0.8	0.6	0.8	1.0	0.6	0.8	1.0	0.6	0.8	1.0	0.3	0.6	0.8	0.8	1.0	1.0	0.6	0.8	1.0	0.8	0.8	1.0	0.8	1.0	1.0	0.6	0.8	1.0
I3	0.6	0.8	1.0	0.3	0.6	0.8	0.3	0.6	0.8	0.3	0.6	0.8	0.6	0.8	1.0	0.3	0.6	0.8	0.8	1.0	1.0	0.3	0.6	0.8	0.1	0.3	0.6	0.6	0.8	1.0	0.6	0.8	1.0	0.6	0.8	1.0
I4	0.1	0.3	0.6	0.3	0.6	0.8	0.3	0.6	0.8	0.3	0.6	0.8	0.1	0.3	0.6	0.3	0.6	0.8	0.3	0.6	0.8	0.1	0.3	0.6	0.3	0.6	0.8	0.3	0.6	0.8	0.3	0.6	0.8	0.6	0.8	1.0
I5	0.1	0.3	0.6	0.1	0.3	0.6	0.3	0.6	0.8	0.1	0.3	0.6	0.1	0.3	0.6	0.1	0.3	0.6	0.6	0.8	1.0	0.6	0.8	1.0	0.3	0.6	0.8	0.3	0.6	0.8	0.6	0.8	1.0	0.3	0.6	0.8
I6	0.3	0.6	0.8	0.3	0.6	0.8	0.6	0.8	1.0	0.8	1.0	1.0	0.6	0.8	1.0	0.8	1.0	1.0	0.1	0.3	0.6	0.1	0.3	0.6	0.1	0.3	0.6	0.6	0.8	1.0	0.6	0.8	1.0	0.1	0.3	0.6
I7	0.1	0.3	0.6	0.1	0.3	0.6	0.1	0.3	0.6	0.1	0.1	0.3	0.1	0.1	0.3	0.1	0.3	0.6	0.6	0.8	1.0	0.3	0.6	0.8	0.6	0.8	1.0	0.3	0.6	0.8	0.3	0.6	0.8	0.6	0.8	1.0
I8	0.3	0.6	0.8	0.1	0.3	0.6	0.3	0.6	0.8	0.3	0.6	0.8	0.1	0.3	0.6	0.3	0.6	0.8	0.3	0.6	0.8	0.1	0.3	0.6	0.1	0.3	0.6	0.3	0.6	0.8	0.1	0.3	0.6	0.1	0.1	0.3
I9	0.6	0.8	1.0	0.6	0.8	1.0	0.1	0.3	0.6	0.6	0.8	1.0	0.1	0.3	0.6	0.3	0.6	0.8	0.1	0.3	0.6	0.1	0.3	0.6	0.1	0.3	0.6	0.3	0.6	0.8	0.1	0.3	0.6	0.1	0.1	0.3
Weights	5	7	9	7	9	9	5	7	9	1	3	5	3	5	7	5	7	9	3	5	7	7	9	9	7	9	9	5	7	9	7	9	9	5	7	9

Table 5 Weighted Decision Matrix with FPIS & FNIS

	Issues	R1			R2			R3			R4			R5			R6			R7			R8			R9			R10			R11			R12		
	I1	2.8	5.4	9.0	3.9	7.0	9.0	3.9	7.0	9.0	0.6	2.3	5.0	2.3	5.0	7.0	2.8	5.4	9.0	1.0	2.8	5.4	3.9	7.0	9.0	5.4	9.0	9.0	2.8	5.4	9.0	5.4	9.0	9.0	3.9	7.0	9.0
	I2	1.7	3.9	7.0	0.8	3.0	5.0	1.7	3.9	7.0	0.6	2.3	5.0	1.7	3.9	7.0	2.8	5.4	9.0	1.0	2.8	5.4	5.4	9.0	9.0	3.9	7.0	9.0	3.9	5.4	9.0	5.4	9.0	9.0	2.8	5.4	9.0
	I3	2.8	5.4	9.0	2.3	5.0	7.0	1.7	3.9	7.0	0.3	1.7	3.9	1.7	3.9	7.0	1.7	3.9	7.0	2.3	5.0	7.0	2.3	5.0	7.0	0.8	3.0	5.0	2.8	5.4	9.0	3.9	7.0	9.0	2.8	5.4	9.0
	I4	0.6	2.3	5.0	2.3	5.0	7.0	1.7	3.9	7.0	0.3	1.7	3.9	0.3	1.7	3.9	1.7	3.9	7.0	1.0	2.8	5.4	0.8	3.0	5.0	2.3	5.0	7.0	1.7	3.9	7.0	2.3	5.0	7.0	2.8	5.4	9.0
	I5	0.6	2.3	5.0	0.8	3.0	5.0	1.7	3.9	7.0	0.1	1.0	2.8	0.3	1.7	3.9	0.6	2.3	5.0	1.7	3.9	7.0	3.9	7.0	9.0	2.3	5.0	7.0	1.7	3.9	7.0	3.9	7.0	9.0	1.7	3.9	7.0
	I6	1.7	3.9	7.0	2.3	5.0	7.0	2.8	5.4	9.0	0.8	3.0	5.0	1.7	3.9	7.0	3.9	7.0	9.0	0.3	1.7	3.9	0.8	3.0	5.0	0.8	3.0	5.0	2.8	5.4	9.0	3.9	7.0	9.0	0.6	2.3	5.0
	I7	0.6	2.3	5.0	0.8	3.0	5.0	0.6	2.3	5.0	0.1	0.3	1.7	0.3	0.6	2.3	0.6	2.3	5.0	1.7	3.9	7.0	2.3	5.0	7.0	3.9	7.0	9.0	1.7	3.9	7.0	2.3	5.0	7.0	2.8	5.4	9.0
	I8	1.7	3.9	7.0	0.8	3.0	5.0	1.7	3.9	7.0	0.3	1.7	3.9	0.3	1.7	3.9	1.7	3.9	7.0	1.0	2.8	5.4	0.8	3.0	5.0	0.8	3.0	5.0	1.7	3.9	7.0	0.8	3.0	5.0	0.6	0.8	3.0
	I9	2.8	5.4	9.0	3.9	7.0	9.0	0.6	2.3	5.0	0.6	2.3	5.0	0.3	1.7	3.9	1.7	3.9	7.0	0.3	1.7	3.9	0.8	3.0	5.0	0.8	3.0	5.0	1.7	3.9	7.0	0.8	3.0	5.0	0.6	0.8	3.0
FPIS	A+	2.8	5.4	9.0	3.9	7.0	9.0	3.9	7.0	9.0	0.8	3.0	5.0	2.3	5.0	7.0	3.9	7.0	9.0	2.3	5.0	7.0	5.4	9.0	9.0	5.4	9.0	9.0	3.9	5.4	9.0	5.4	9.0	9.0	3.9	7.0	9.0
FNIS	A-	0.6	2.3	5.0	0.8	3.0	5.0	0.6	2.3	5.0	0.1	0.3	1.7	0.3	0.6	2.3	0.6	2.3	5.0	0.3	1.7	3.9	0.8	3.0	5.0	0.8	3.0	5.0	1.7	3.9	7.0	0.8	3.0	5.0	0.6	1	3.0

Table 6 Distance Between Each Roadblocks from FPIS

Issues	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	D+
I 1	0.0	0.0	0.0	0.4	0.0	1.1	1.7	1.5	0.0	0.6	0.0	0.0	5
I 2	1.6	3.7	2.5	0.4	0.7	1.1	1.7	0.0	1.5	0.0	0.0	1.1	14
I 3	0.0	1.9	2.5	1.0	0.7	2.5	0.0	3.1	5.0	0.6	1.5	1.1	20
I 4	3.2	1.9	2.5	1.0	2.9	2.5	1.7	5.0	3.1	1.9	3.1	1.1	30
I 5	3.2	3.7	2.5	1.8	2.9	4.0	0.7	1.5	3.1	1.9	1.5	2.5	29
I 6	1.6	1.9	1.1	0.0	0.7	0.0	2.9	5.0	5.0	0.6	1.5	4.0	24
I 7	3.2	3.7	4.0	2.5	3.9	4.0	0.7	3.1	1.5	1.9	3.1	1.1	33
I 8	1.6	3.7	2.5	1.0	2.9	2.5	1.7	5.0	5.0	1.9	5.0	5.3	38
I 9	0.0	0.0	4.0	0.4	2.9	2.5	2.9	5.0	5.0	1.9	5.0	5.3	35

Table 7 Distance Between Each Roadblocks from FNIS

Issues	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	D-
I 1	3.2	3.7	4.0	3.9	3.9	3.2	1.2	3.7	5.0	1.6	5.0	5.3	43.7
I 2	1.6	0.0	1.6	3.4	3.4	3.2	1.2	5.0	3.7	1.9	5.0	4.6	34.5
I 3	3.2	1.9	1.6	3.4	3.4	1.6	2.9	1.9	0.0	1.6	3.7	4.6	29.7
I 4	0.0	1.9	1.6	1.1	1.1	1.6	1.2	0.0	1.9	0.0	1.9	4.6	16.7
I 5	0.0	0.0	1.6	1.1	1.1	0.0	2.3	3.7	1.9	0.0	3.7	3.0	18.5
I 6	1.6	1.9	3.2	3.4	3.4	4.0	0.0	0.0	0.0	1.6	3.7	1.5	24.3
I 7	0.0	0.0	0.0	0.0	0.0	0.0	2.3	1.9	3.7	0.0	1.9	4.6	14.4
I 8	1.6	0.0	1.6	1.1	1.1	1.6	1.2	0.0	0.0	0.0	0.0	0.0	8.2
I 9	3.2	3.7	0.0	1.1	1.1	1.6	0.0	0.0	0.0	0.0	0.0	0.0	10.7

Table 8 Ranking with Reference to Closeness Coefficient

Issues/ Response	D+	D-	CC	Rank
I 1	5	43.7	0.891	1
I 2	14	34.5	0.706	2
I 3	20	29.7	0.598	3
I 4	30	16.7	0.358	6
I 5	29	18.5	0.386	5
I 6	24	24.3	0.5	4
I 7	33	14.4	0.304	7
I 8	38	8.2	0.176	9
I 9	35	10.7	0.235	8

5. Conclusion

The findings of this study highlight critical roadblocks in the effective management of e-waste in Asian countries, assessed through the Fuzzy TOPSIS technique. The identification and ranking of these roadblocks were based on the input from twelve experts with substantial experience in recycling and academia. The results shed light on the relative importance of each roadblock, offering insights that can inform targeted interventions and policy-making in the region.

The primary roadblock identified as the most influential is the "lack of holistic e-waste legislation." The absence or inadequacy of comprehensive legal frameworks poses a significant challenge to e-waste management. This roadblock encompasses gaps in regulation that may lead to informal and improper disposal practices, such as dumping or illegal export. The study underscores the importance of enacting and enforcing robust e-waste legislation to establish a structured and sustainable approach to managing electronic waste.

The second most influential roadblock is the "illegal import of e-waste." The study emphasizes that despite existing regulations designed to control the import, export, and management of electronic waste, illegal importation remains a substantial challenge. This practice not only contributes to environmental degradation but also poses health hazards, emphasizing the need for strengthened border controls and international collaboration.

Interestingly, the roadblock identified as the least influential is "limited human resources." While this roadblock is recognized as a challenge, its lower rank suggests that, relative to other factors, it may be addressed more feasibly through capacity-building initiatives and strategic workforce planning.

The study provides a comprehensive assessment of the roadblocks affecting e-waste management in Asian countries, offering a valuable foundation for policymakers, environmental agencies, and stakeholders. The prioritization of roadblocks based on the Fuzzy TOPSIS technique provides a roadmap for focusing efforts on the most critical issues, ultimately contributing to the development of effective strategies for sustainable e-waste management in the region.

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