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Research Paper

Uncovering Obstacles to Household Waste Recycling in Seremban, Malaysia through Decision-Making Trial and Evaluation Laboratory (DEMATEL) Analysis

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Abstract
This study investigates the barriers to household waste recycling in Seremban, Malaysia, using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) analysis. The research questions aimed to identify and rank the most significant barriers to recycling and understand the causal relationships between them. The study found that limited access to recycling facilities and services and lack of motivation or incentive to recycle were the most significant causes of household waste recycling barriers in Seremban. On the other hand, lack of motivation or incentive to recycle and negative attitudes towards recycling, were identified as the most significant effects. The study's findings have theoretical implications for waste management and sustainable development and offer practical implications for policymakers and waste management practitioners in developing effective waste management strategies and policies that can address these barriers. Furthermore, the study's insights into the most significant barriers to household waste recycling can inform the design of recycling campaigns and educational programs to increase awareness and promote household waste recycling in Seremban. Overall, this study provides a valuable contribution to the field of waste management and sustainable development and offers insights into the challenges of promoting household waste recycling in urban areas.

Keywords
Waste Management, Recycling, Household Waste, Barriers, Decision-making, DEMATEL, Seremban, Malaysia

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1. INTRODUCTION

Waste recycling has emerged as a crucial tactic in sustainable waste management, aiming to reduce landfill waste, conserve natural resources, and foster environmental preservation (Ayeleru et al., 2023). The aim of this research is to examine the barriers to waste recycling by means of a comprehensive review of literature and expert insights, followed by an assessment of the Decision-Making Trial and Evaluation Laboratory (DEMATEL) methodology in appraising these obstacles in the context of Seremban, Malaysia. The present investigation aims to address two distinct research inquiries:

RQ1: What are the key factors that influence household waste recycling in Seremban, Malaysia, and how do they relate to each other?

RQ2: What are the most significant barriers that prevent households in Seremban, Malaysia from engaging in waste recycling, and how do these barriers interrelate?

The present study aims to attain its research objectives by utilizing the DEMATEL method to scrutinize and determine the crucial factors and impediments associated with waste recycling in Seremban, Malaysia. The utilization of DEMATEL analysis presents a thorough and methodical methodology for comprehending the intricate interconnections between the various factors and hindrances (Garg, 2021). This approach offers valuable discernment into prospective policies and practical solutions that can effectively surmount these obstacles and promote household waste recycling (Favot et al., 2022).

According to statistics provided by the Department of National Solid Waste Management (JPSPN), Malaysia's recycling rate for the year 2020 was documented at 31.52%, which fell short of the government's target of attaining a recycling rate of 40% by 2025. In contrast, a significant proportion of developed countries have attained a recycling rate of at least 60%. The imperative to surmount barriers that impede recycling endeavors in Malaysia and enhance communal engagement in

recycling programs is of utmost significance. The findings of a research study that elucidate the barriers to waste recycling are presented in Table 1.

Despite the challenges, Malaysia has implemented various measures aimed at promoting recycling and reducing waste. The government at the national level launched a program called "Kampungku Bersih" (My Clean Village) to promote communal responsibility for waste management and encourage the adoption of recycling practices.

Private sector initiatives, such as the take-back program for pre-owned furniture by IKEA Malaysia and the Tzu Chi Foundation's dispersed recycling centers that cater to a wide range of recyclable materials, are aimed at promoting recycling practices and reducing waste. The iCycle platform has been implemented in Malaysia as a supplementary initiative to promote the recycling of domestic waste. The government of Malaysia has initiated a campaign aimed at promoting sustainable practices and addressing the issue of waste management, which is referred to as the "zero waste" campaign. Table 2 provides a comprehensive summary of recycling activities in Seremban, focusing on the quantity of recycling materials collected in different sectors such as schools, kindergartens, communities, government offices, universities, and industries. The table includes the weight of the recycled materials measured in kilograms (KG) as well as their corresponding monetary value in Ringgit Malaysia (RM).

Over the course of five years, from 2017 to 2021, a significant amount of recycling materials was collected. The recycling bank in schools yielded a total of 313,180 kilograms, with a corresponding value of RM 68,185. Similarly, the recycling bank in kindergartens contributed 20,768 kilograms of recyclables, amounting to RM 4,998. The community recycling bank collected a total of 59,297 kilograms of materials, valued at RM 17,100. Government offices in Seremban also actively participated in recycling, resulting in the collection of 124,109 kilograms of recyclables, with a value of RM 24,339. Furthermore, universities in the area contributed 13,137 kilograms of recycling materials, which were valued at RM 2,049. The recycling efforts in industries were notable as well, with a total collection of 249,398 kilograms, amounting to RM 24,212.

2. EXPERIMENTAL SECTION

The study's first stage involved a research methodology that encompassed a thorough examination of published articles and reports related to household waste recycling. The aim of the literature review was to determine the previously identified and researched barriers to household waste recycling. In addition to performing a comprehensive literature review, the researchers engaged in discussions with experts in the fields of waste management and recycling to gather their insights on the barriers to household waste recycling in Seremban.

The second phase of the study involves gathering data from experts who have at least a decade of experience in waste management within the Seremban region of Malaysia. The expert panel was composed of an academic, a government official,

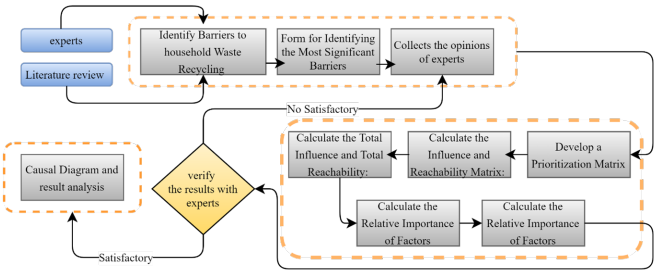

Figure 1. Research Methodology Framework

a representative from the waste management industry, and a member of a non-governmental organization specializing in household waste recycling. Semi-structured interviews were conducted with the experts.

The interview questions were designed to elicit expert opinions on the barriers that impede household waste recycling in Seremban. The evaluators were tasked with assessing the degree of correlation between each obstacle, utilizing a Likert scale that ranged from 1 to 5. The scale's values ranged from "not related" at 1 to "highly related" at 5.

The study utilized the Decision-Making Trial and Evaluation Laboratory (DEMATEL) methodology to analyse the data. This technique enables the investigation of causal relationships among variables. The experts' ratings on the barriers were employed in the development of a DEMATEL matrix. The matrix enabled the discernment of the causal connections that exist among the hindrances. The study employed the DEMATEL software to conduct a matrix analysis and identify the main barriers to household waste recycling in Seremban. The findings were then validated by experts. If the experts are content with the causal diagram and result analysis, they will be presented. However, if they are dissatisfied, the data collection process will be repeated. The Figure 1 shows the Research methodology framework for this study. Figure 1 depicts the research methodology framework employed in this study.

The steps involved in the DEMATEL method are as follows:

Step 1. Creating the matrix of direct influence

The first step involves the creation of a Direct Relationship Matrix, where x_{ij}^{k} represents an integer score k assigned by an expert. This metric indicates the degree of impact that criterion i has on criterion j. The matrix A of dimension $n \times n$, as presented in Equation (1), the computation of household waste recycling scores involves the utilisation of an averaging process that incorporates the individual evaluations of three distinct experts, namely an academician, an industry specialist, and a government representative. Table 3 presents the DEMATEL binary comparison scale that was utilised.

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

Table 1. The Barriers to Waste Recycling

Barriers	References
B1-Negative attitudes towards recycling	Almasi et al., 2019; Ayeleru et al., 2023; Babaei et al., 2015; Byrne and O'Regan, 2014; Corrado et al., 2022; Gilli et al., 2018; Padilla and Trujillo, 2018; Karaktekin et al., 2023; King et al., 2023; Lau et al., 2021; Malibari et al., 2023; Vijayan et al., 2023; Wu et al., 2021; Yadav et al., 2022
B2-Limited storage space for recyclable materials at home	Li et al., 2020a; Lu et al., 2022; Luthra et al., 2023; Matsumoto, 2011; Nguyen et al., 2022
B3-Inconvenient or inconsistent recycling collection schedules	de Moraes et al., 2022; Dias et al., 2022; Shuvo, 2023; Tsimnadis et al., 2023
B4-Lack of awareness and understanding of the benefits of recycling	Almulhim, 2022; Chengqin et al., 2022; Jacobsen et al., 2022; Ghaedrahmati et al., 2023; Helmefalk et al., 2023; Mousa, 2020; Nguyen et al., 2022; Azme et al., 2023; Reijonen et al., 2021; Shah and Rezai, 2023; Shaikh et al., 2020; Tian et al., 2022; Vijayan et al., 2023; Zhong et al., 2022
B5-Limited access to recycling facilities and services	Dutta and Goel, 2021; Gu et al., 2022; Maiurova et al., 2022; Wang et al., 2021b; Zaharudin et al., 2022; Zhang et al., 2016
B6-Lack of motivation or incentive to recycle	Cheng et al., 2022; Chengqin et al., 2022; Li et al., 2020b; Li et al., 2022; Wang et al., 2021a; Xu et al., 2023; Yang and Thøgersen, 2022; Zhong et al., 2022; Zhou et al., 2021
B7-Lack of enforcement or penalties for non-compliance with recycling regulations	Ayeleru et al., 2023; Favot et al., 2022; Li et al., 2022; Ma et al., 2020; Woodard, 2020

H: number of experts.

Step 2. Normalising of the matrix of direct influence Formulas (2) and (3) are used to get the normalised direct-relation matrix S from matrix A.

$$S = k.A \tag{2}$$

$$k = \min\left(\frac{1}{\max_{1\le i\le n}\sum_{j=1}^{n}[a_{ij}]'}\frac{1}{\max_{1\le j\le n}\sum_{i=1}^{n}[a_{ij}]}\right) \tag{3}$$

$$i, j \in (1, 2, \ldots, n)$$

Step 3. Constructing the matrix of complete relations After normalising the direct-relation matrix S, the total-relation matrix M is computed using the Formula (4), where I denote the Identity Matrix:

$$M = S(I - S)^{-1} \tag{4}$$

Step 4. The development of a cause-and-effect diagram The utilisation of $C + R$ and $R - C$ is demonstrated in Formula (5) to (7) for matrix M, where R represents the sum of columns and C represents the sum of rows. Criteria that exhibit positive $R-C$ values exert a stronger influence on the remaining criteria. The term "dispatchers" is commonly used to refer to these individuals. Individuals with lower $R-C$ levels tend to be more susceptible to external influences. The entities are commonly denoted as "receivers." Conversely, the summation of R and C denotes the extent of correlation between one criterion and the rest.

$$M = [m_{ij}]_{n\times n}\ i, j \in (1, 2, \ldots, n) \tag{5}$$

$$R_i = \sum_{j=1}^{n}[m_{ij}]_{n\times 1} = [m_i]_{n\times 1} \tag{6}$$

$$C_i = \sum_{i=1}^{n}[m_{ij}]_{1\times n} = [m_j]_{1\times n} \tag{7}$$

Step 5. Obtaining the matrix of internal dependencies and the map of effect relationships The dataset was mapped utilising the $(R + C, R - C)$. The parameter known as the threshold value is employed to denote the degree of influence present between a set of criteria.

Table 2. Summary of Recycling Activities in Seremban

Year	Recycling Bank in School		Recycling Bank in Kindergarden		Recycling Bank in Community		Recycling Bank in Government Office		Recycling Bank in University		Recycling Bank Industry	
	KG	RM	KG	RM	KG	RM	KG	RM	KG	RM	KG	RM
2017	45,608	9,488	8,803	2,213	2,522	576	41,127	12,899	6,262	1,249	224,767	17,647
2018	45,226	9,389	4,092	898	5,547	845	11,069	1,391	2,458	34	3,345	14
2019	74,048	16,154	4,042	1,015	7,001	1,306	5,385	1,455	1,171	144	2,417	5,123
2020	96,018	20,181	2,590	551	6,227	1,066	26,677	4,974	1,018	185	14,596	860
2021	52,279	12,974	1,242	320	38,001	13,307	39,851	3,620	2,229	437	4,272	568
Total	313,180	68,185	20,768	4,998	59,297	17,100	124,109	24,339	13,137	2,049	249,398	24,212

Table 3. Linguistic Term

Linguistic Terms	Influence Score
Unrelated	1
Slightly Unrelated	2
Moderately Related	3
Related	4
Very Related	5

3. RESULTS AND DISCUSSION

This section presents the findings of the DEMATEL analysis, which provided significant insights into the main barriers to household waste recycling in Seremban and their underlying root causes. The study proposed effective interventions for mitigating barriers through recognizing causal relationships among them. The objective of this research is to elucidate the key outcomes of the DEMATEL analysis and their significance in advancing the practice of household waste recycling in Seremban. Table 4 displays the prominence and net cause/effects of this study.

The variable exhibiting the greatest $R+C$ value of 10.9256 within the table pertains to "Limited access to recycling facilities and services", indicating a noteworthy impact on recycling behavior. The recycling behavior of individuals can be influenced by various factors. Among these factors, insufficient awareness and comprehension of the benefits of recycling, with a $R+C$ value of 10.3973, inconvenient or irregular recycling collection timetables, with a $R+C$ value of 10.0067, and inadequate motivation or incentive to recycle, with a $R+C$ value of 10.6433, are noteworthy. The variables that demonstrate a lower $R+C$ score, specifically "Negative attitudes towards recycling" with a $R+C$ score of 9.2361 and "Lack of enforcement or penalties for non-compliance with recycling regulations" with a $R+C$ score of 9.2680, exhibit a noticeable impact, albeit to a relatively lesser extent. Mitigating these factors can generally aid in overcoming obstacles to recycling and promoting the adoption of environmentally responsible waste management practises.

This Influence Diagram aids in Figure 2 visualizing the cause-and-effect relationship among barriers to waste recycling in Seremban. Insufficient availability of recycling infrastructure and services, coupled with inadequate knowledge and comprehension of the advantages of recycling, are significant contributing factors that can impact the recycling conduct of individuals. The restricted availability of recycling facilities and services may potentially lead to a decrease in recycling behavior among individuals, as the inconvenience and difficulty in locating a nearby recycling centre can act as a deterrent. This phenomenon may result in the disposal of recyclable materials in the conventional waste stream.

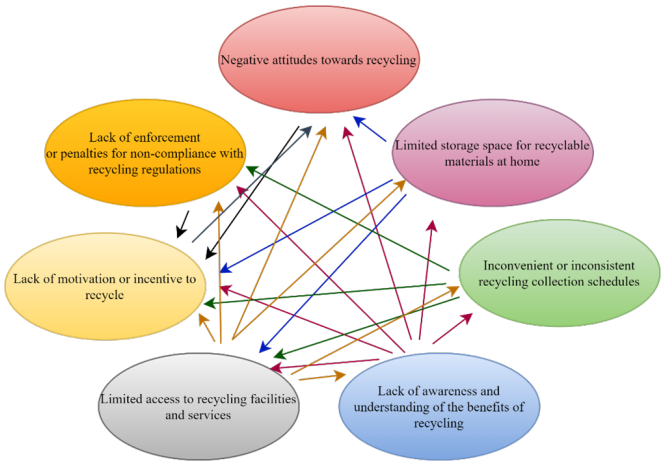

Figure 2. Waste Recycling Barrier's Criteria Influence Diagram

The deficiency in knowledge and comprehension regarding the advantages of recycling can potentially result in a decreased inclination among individuals to engage in recycling practices. Insufficient understanding of the advantages of recycling could lead to a decreased recognition of the significance of participating in recycling activities, ultimately lowering the probability of individuals taking the extra step to recycle their materials. Inadequate understanding may lead to uncertainty regarding the categorization of recyclable and non-recyclable materials, which can further contribute to individuals' hesitancy to engage in recycling.

The interdependence between these two factors may potentially impact the remaining obstacles outlined in the table. The lack of access to recycling facilities and services may poten-

Table 4. Prominence and Net Cause/Effects

Barriers	R	C	R+C	R-C	Identify
B1-Negative attitudes towards recycling	4.2517	4.9844	9.2361	-0.7327	Effect
B2-Limited storage space for recyclable materials at home	4.7308	4.6358	9.3666	0.095	Cause
B3-Inconvenient or inconsistent recycling collection schedules	5.0172	4.9894	10.0067	0.0278	Cause
B4-Lack of awareness and understanding of the benefits of recycling	5.8796	4.5177	10.3973	1.3619	Cause
B5-Limited access to recycling facilities and services	5.7631	5.1625	10.9256	0.6006	Cause
B6-Lack of motivation or incentive to recycle	4.8764	5.7669	10.6433	-0.8906	Effect
B7-Lack of enforcement or penalties for non-compliance with recycling regulations	4.403	4.865	9.268	-0.4619	Effect

tially decrease individuals' motivation and incentives to engage in recycling practices. Furthermore, irregular recycling collection timetables could potentially worsen the issue, thereby increasing the challenge of recycling for individuals.

Hence, tackling these two underlying factors could potentially play a pivotal role in enhancing recycling conduct and augmenting the overall recycling percentages. The initiatives may encompass endeavors aimed at enhancing the availability of recycling facilities and services, alongside educational endeavors designed to augment comprehension and recognition of the advantages associated with recycling.

The absence of strict implementation or sanctions for non-adherence to recycling policies may result in diminished impetus or inducement to engage in recycling activities. This is because individuals may perceive little value in expending additional effort towards recycling when there are no repercussions for non-compliance. If individuals do not observe a substantial influence of their actions or the lack of repercussions for abstaining from recycling practices, they may develop a belief that the activity lacks value and is not worth their time and energy. A decrease in recycling rates due to a lack of motivation can have negative consequences on the environment. Thus, the implementation of recycling regulations and the imposition of penalties for non-compliance can serve as effective measures to encourage individuals to engage in recycling practices and foster favorable recycling conduct.

4. CONCLUSION

To summarize, the present study utilized the DEMATEL analysis methodology to identify the hindrances to household waste recycling in Seremban, Malaysia. This research undertaking conducted a comprehensive analysis of academic literature, consulted with experts, and scrutinized the causal relationships among the identified obstacles. The results underscore the significant obstacles that impede household waste recycling in the region, such as insufficient recycling infrastructure, absence of motivation, and restricted incentives.

This study has noteworthy practical implications for waste management professionals and policymakers. The promotion of a recycling culture in Seremban can be facilitated by policymakers through the identification and addressing of barriers, including the enhancement of recycling infrastructure and the implementation of incentive programmers. Furthermore, promoting consciousness and cultivating favorable dispositions towards recycling can potentially enhance engagement in domestic waste recycling. The endeavors are of paramount importance in attaining sustainable waste management targets and conforming to the recycling rate objectives set forth by the government.

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