Journal of Cleaner Production 362 (2022) 132282

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Barriers to organic waste management in a circular economy

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A R T I C L E I N F O

Handling Editor: Kathleen Aviso

Keywords:
Barriers
Organic waste management
Sustainability
Fuzzy theory
Decision making trial and evaluation laboratory
Circular economy

A B S T R A C T

Organic waste disposal methods, notably landfilling, not only deplete resources but also contribute to environmental challenges. This research looks at potential barriers to organic waste management solutions. The objective of this study is to identify the barriers to organic waste management solutions from an actor's perspective, and to explore their causal relationships to overcome the organic waste management problem from a system perspective. Several key challenges were identified regarding organic waste management solution, the current intervention overview indicates that promoting and tracking attention towards "value to waste" would be an effective solution approach. Waste collection fees, unethical behavior, and a lack of engagement and commitment in activities show a subsequent effect on consumer-household solutions, which are currently acting as priority barriers in this research. In order to have a better understanding of this complex issue, a detailed knowledge of barriers (leading to organic waste) is discovered and evaluated with the application of fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL). The data for this research has been taken in the context of a developing economy like India. This work can provide structural support to the managers by knowing the cause (influencing) and effect-group (influencing) barriers to the effective implementation of an organic waste management system in a circular economy context.

1. Introduction

The percentage of organic solid waste generated each year is increasing rapidly. Middle- and low-income countries generate 53% and 57% of food and green waste, respectively, with the proportion of organic waste increasing as economic development levels decrease. Except for Europe, Central Asia, and North America, which produce more dry trash, every region produces around 50% or more dry waste on average. (The World Bank/IBRD.IDA, 2022)

According to current research, organic materials account for more than half of mixed Municipal Solid Waste (MSW) in India, with percentages ranging from 30 to 70% percent. India has a low overall share of organic waste in total MSW as compared to other recently industrialised Asian nations (e.g., Indonesia, China) (Speier et al., 2018).

People may not have full control over the non-organic waste that is recycled or dumped every day. However, if one discusses organic waste and studies the process of managing it, one may also take over organic waste recycling at its own level. This contribution can very much affect our waste supply chains (post-consumer waste, collection of waste, and separation of waste, recycling, landfill) and can make it much easier to deal with the already collected mixed waste, which is a major global concern. It is more cost-effective and environmentally beneficial to deal with separated organic and non-organic waste rather than processed mixed waste and subsequently be unable to recover both. Undeniably, the vision of the complete elimination of waste is highly unrealistic. Hence, the ideal strategy is to regulate and manage the generated waste

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https://doi.org/10.1016/j.jclepro.2022.132282
Received 30 November 2021; Received in revised form 27 April 2022; Accepted 15 May 2022
Available online 19 May 2022
0959-6526/

in a way that is ecologically friendly, economically feasible, and socially acceptable. (Edwards et al., 2017).

Our everyday garbage generates primarily two types of waste. The first type of waste is non-biodegradable waste like plastics, metals, glass, and other home goods. The second type of waste is biodegradable waste, which includes leftover food, fruit and vegetable peels, dried leaves, etc. Garden waste, food waste, degradable carbon, and other animal and plant-based products are all examples of biodegradable organic waste. Organic waste disposal done correctly can have a positive impact on the environment. Recycling organic waste by methods such as anaerobic digestion can provide energy in the form of biogas. Separation of organic and non-organic wastes also improves non-organic recycling efficiency (Aini et al., 2002). One of the most significant benefits of organic waste recycling is that it minimizes pollution in the air, water, and land by reducing issues such as odour creation and gas emissions. Organic waste recycling also minimizes the amount of garbage left over for less efficient procedures like disposal and incineration. Organic waste stabilization offers value by increasing nutrient content and availability for use as fertilizer in agriculture. Soil bio-fertilizers made through a recycling process improve soil quality, which boosts soil fertility and plant growth. Organic waste recycling also uplifts popular concepts such as cleaner production, zero-waste policies, sustainability and bio-based circular economy (CE) (Sharma et al., 2019; Kumar et al., 2022).

However, poor organic waste disposal practices in developing countries cause a slew of environmental issues. Organic waste decomposes anaerobically when dumped in landfills (in the absence of oxygen). Green waste decomposition under anaerobic conditions produces harmful greenhouse gases such as methane, which are a major contributor to global warming (El-Fadel and Massoud, 2000). Another issue with direct landfill is the rapidly depleting landfill space. Giving that organic waste accounts for half of all domestic garbage, putting it in landfills doubles landfill use. Furthermore, landfills have a finite lifespan, and we simply cannot afford to continue wasting valuable land by building new landfills. Unfortunately, there are numerous significant barriers to proper Organic Waste Management (OWM). In impoverished countries, properly built landfills are rare, and contemporary incineration is too expensive. As a result, landfills are the most frequent method of trash disposal, with variations including uncontrolled dumping in undefined areas, collection and disposal in unmanaged open dumps, and collection and disposal in controlled dumpsites. The lack of a shared vision of the governments, private sectors, and citizens in managing organic wastes is also a barrier that prevents this potential for handling organic wastes separately. Inertia, a lack of understanding, and a lack of infrastructure are all key roadblocks. Inadequate infrastructure, poor strategic planning, registration, staff capacity, information systems, programme engagement, and disorganised waste management and fee collection processes make the task even more difficult. There is also a lack of involvement in garbage separation initiatives and insufficient communication between the municipality and homeowners (Kumar et al., 2017).

Solid waste is usually handled effectively in developed countries. Often, highly advanced and complicated waste management technologies that have shown to be beneficial in developed countries are imported to developing countries. However, due to a lack of capacity and the incongruity of attempting to construct systems in varied contexts, these solutions are frequently not sustainable. Various authors have focused on the solutions of separating and recycling organic waste from complete solid waste in developing countries (Hettiarachchi et al., 2018; Buratti et al., 2015; Lin et al., 2018; Ng et al., 2019). Westerman and Bicudo (2005) reviewed the many aspects and challenges associated with the use of organic wastes in agriculture. Dhar et al. (2017) explored organic waste to energy (WtE) potentials, technologies, and constraints in an Indian context in order to achieve sustainable energy production while minimizing environmental impact. Demirbas (2008) and Odlare et al. (2011) investigated the biological uses of organic waste for reducing organic waste. However, despite a promising future (Ak and Demirbas, 2016) and past advantages (Ju et al., 2005) OWM solutions have lacked consistency due to different barriers in varied economies (Colombo et al., 2017). Thus, in order to successfully perceive solutions for efficiently managing organic waste, it is necessary to first successfully recognize the intermediary barriers that prevent solutions from being implemented.

To fill the gap, this study aims to analyze and classify some prominent barriers in context of developing economies such as India that hinder the implementation of proper OWM. This research becomes highly significant as it is timely in advancing the field of OWM solutions more explicitly. It also supports the 2030 Agenda of the United Nations (UN), by making specific contributions to the Sustainable Development Goals (SDGs) such as zero hunger (SDG 2), affordable and clean energy (SDG 7), climate action (SDG 13), clean water and sanitation (SDG 6), and sustainable cities and communities (SDG 11).

Hence, the study proposes the following two key research questions:

1. What are the major barriers to OWM solutions?
2. How these barriers are inter-related?

Therefore, the objectives of this study are given as follows:

1. To identify the major barriers to OWM solutions in context of a developing nation.
2. To present an importance order and a causal relationship between the barriers by using one of the multi-criteria decision techniques, DEMATEL (Decision Making Trial and Evaluation Laboratory) under a fuzzy environment.

Mostly, barriers to OWM solutions were discovered through a literature analysis, and subsequently the listed barriers were grouped into four primary dimensions. These barriers were also validated using expert feedback collected using a questionnaire. Additionally, these barriers were studied under a decision-making technique, the fuzzy DEMATEL method. The fuzzy-DEMATEL model combines the fuzzy linguistic aspect of fuzzy theory with the DEMATEL. Applying the DEMATEL in a fuzzy context enables researchers to analyze the causal relationships of fuzzy variables and determine the level of interactive influence between 'variables' (in this case 'barriers') (Deng et al., 2015).

This research activity is divided into two parts in order to fulfil the aforementioned goal and address the asked problems. The primary barriers to OWM solutions in the context of developing country India were identified in the first phase of the study through a literature review. A questionnaire was delivered to around fifty professionals at random through email. However, five of them answered favourably and volunteered to join the decision-making body. The size of the decision-making body can certainly impact the outcome, but (Gumus, 2009) suggests that it should be between 5 and 50 individuals. Four of the experts are from renowned Indian universities, while one is from a Greek university. The experts are highly competent in terms of their qualification, knowledge, and decision-making in their respective fields as high-ranking academicians and professionals in managerial positions. All the experts have over ten years of experience and a depth of expertize in waste management, circular economy, and related topics. The experts were contacted via phone and email to explain the questionnaire's objective in the context of developing nations. In addition, a discussion was carried out to finalize the primary barriers described in Table 1. The second portion of the study evaluates these barriers using the fuzzy-DEMATEL technique, which aids in the recognition of causal relationships and provides a holistic view of the barriers. It also aids in the classification of the barriers under investigation into cause and effect groups. According to the findings of this study, ten barriers are classified as cause-groups, while the remaining ten barriers are classified as effect-groups.

The remainder of the paper is structured as follows. The review of the literature on OWM and barriers respectively are presented in Section 2.

Table 1
Key barriers to OWM solutions.

Barriers to OWM Solutions	Details	Sources
Physical Barriers		
Inconsistency and lack in waste collection infrastructure and technology (B_1)	Lack of waste collecting points; Irregularity in waste collection; Inadequate waste collection vehicles; Inadequate access to waste bins.	Booker et al. (2004)
Inconsistency and lack in waste separation infrastructure and technology (B_2)	Improper waste separation facilities; Irregularity of waste separation; Inadequate waste separation technologies.	Kumar et al. (2017)
Incorrect waste disposal alternatives (B_3)	Unnecessary burning of waste; Uncontrolled dumping of waste; Lack of properly engineered landfills.	Abdel-Shafy and Mansour (2018)
Untimely collection and quantity of waste (B_4)	No fixed volume of collected waste; Untimely generation and collection of waste from households, public organizations etc.	Idris et al. (2004)
Site location and land space (B_5)	Limited space; Un-appropriate landfilling sites; Lack of significant dumping area.	De Feo and De Gisi (2014)
Strategical Barriers		
Poor and limited planning (B_6)	Poor planning and implementation; No separate OWM; No clear visions; The local government's inability to manage MSW.	Rouse (2008)
Limitation and flaws in policies (B_7)	No immediate policies, No clear and earnest policies, Policies are made according to financial benefits and not environmental benefits.	Hettiarachchi et al. (2018)
Lack of communication and coordination (B_8)	Lack of staff capacity; Lack of communication between OW producers and users; Out-dated ways for inviting people to public meetings or broadcasting messages by megaphone from a moving vehicle.	Buenrostro and Bocco (2003)
Lack of information, media and training (B_9)	There is no information on how to dispose of waste or manage waste; Inefficient techniques of disseminating information were found to be ineffective. There aren't enough public awareness campaigns.	Bui et al. (2020)
Educational/Social barriers		
Lack of awareness among people (B_{10})	Lack of awareness of waste collection and separation activities; Lack of attendance at community meetings; Failing to observe waste management signs.	Kala and Bolia (2020)
Lack of engagement and commitment in activities (B_{11})	No time to dispose waste properly; 'Take it easy' attitude; No concern about environment; Lack of Co-Operation.	Veleva et al. (2017)
Negative attitude for system (B_{12})	Impossible to change the behaviour of people; Failing to separate waste even after information; Not following suggestions and authority orders.	Tucker and Speirs (2003)
Unwillingness to cooperate (B_{13})	Lack of concern for waste management; Lack of Participation; Non-cooperative municipalities.	Vego et al. (2008)
Un-ethical behaviour (B_{14})	Negative Attitudes; Blaming others; Ignoring instructing signs; Unethical scattering of waste at public areas.	Mu'azu et al. (2019)
Monetary/Legal Barriers		
Inadequate financial resources (B_{15})	No clear fee system for waste handling services; Insufficient funding. For waste trucks, maintenance, fuel, collection, and waste to energy techniques.	Kumar et al. (2009)
No value of waste (B_{16})	Negative Public attitude to the little or no value of waste; Waste separation consumes time; No time to collect waste or sell recyclable waste.	Yukalang et al. (2017)
Waste collection fee (B_{17})	Unwillingness to pay for the collection of fees by the Municipality; People willing to dispose waste unethically rather than disposing it to disposal vehicles.	Troschinetz and Mihelcic (2009)
Increasing population (B_{18})	Increasing population is directly proportional to increasing waste; Limited budget.	Pai et al. (2014)
Conflict of interest (B_{19})	Problems and conflicts among political parties; Social conflicts on waste disposal sites.	Wiedemann and Femers (1993)
Weak legislation system (B_{20})	Inadequate legislation; No rules for waste management; Continued unethical behaviour because of no strict actions taken.	Kumar and Pandit (2013)

The solution methodology is proposed in Section 3. Calculations are presented in Section 4. Section 5 describes the results and application of this study. Sensitivity analysis is conducted in Section 6. Section 7 summarizes the implications, and finally, Section 8, the conclusion, discusses possible future research directions.

2. Literature review

2.1. Organic waste

The organic portion of solid waste has been identified as a potential resource that may be transformed into useable substances through microbial mediated transformations. Agriculture, home activities, and industrial goods are the most frequent sources of organic waste. Food waste, food-soiled paper, non-hazardous wood waste, landscaping waste, and pruning waste are examples of organic waste. Despite the fact that most organic wastes in the soil provide nutrients and minerals to soil fertility and plant development, improper disposal techniques such as landfilling, may cause significant environmental harm (Kharola et al., 2022). Landfills and hazardous waste dumps are more likely to be found in minority and low-income areas. These areas have fewer resources to fight the construction of these facilities. As a consequence, they are a straightforward target for landfill placement than higher-income areas. Unfortunately, multiple studies have demonstrated that disposing of organic waste in landfills has detrimental environmental implications (Manfredi et al., 2009). The health of people who live and work near landfills is impacted by waste emissions.

The challenge of OWM is the conversion of organic matter/trash into useful products using various recycling processes. Over time, the demand for organic waste recycling has become more prevalent, particularly in urban areas. These wastes have a direct impact on urban living systems due to the high moisture content. The excess moisture proportion increases the volume, resulting in overload of waste material (Lay et al., 1997). To deal with the issues in OWM various treatment methods have been proposed and implemented throughout the world.

2.2. Organic waste recovery and waste-to-energy features and techniques

In light of the ever-increasing load of energy demand countries around the world have turned their attention to renewable energy options in recent years. There are several techniques for recycling organic waste, each of which may be utilized for a specific type of waste to generate useable organic matter (Woon and Lo, 2016). The production of organic waste begins at home, in restaurants, in organizations, and in other places. Organic waste may be dealt with as organically on a small scale as it can be on a big scale in order to reduce its growth.

There are a number of techniques to keep organic and non-organic waste separate. Organic waste is easily recycled by feeding it to animals and is one of the most common and efficient way of recycling it. People can contact farms and contribute their kitchen waste for animals to consume. However, feeding organic waste directly to animals may cause health problems in such animals. As a result, several nations, such as the United States, have enacted rules governing the amount and type of food supplied to animals. Food recycling through animal feed offers a number of benefits, including reduced landfill pressure, reduced methane generation from fruits and vegetables, and the elimination of the need to transform organic waste into other forms. This also benefits farmers since they do not have to purchase additional animal feed, which benefits the economy in the long run (Salemdeeb et al., 2017).

Another form of organic waste is that which is typically thrown away by customers due to excess or expiration. Food waste is increasing as a result of over production, mismanagement, and wasteful behaviour, posing a serious obstacle to attaining sustainability and resource efficiency (Kazancoglu et al., 2018). Before dumping or discarding garbage to add to landfill, it is preferable to consider the redistribution approach to decrease wastages at all levels, whether at home or at larger scales. Redistributing non-marketable food goods is a frequent waste reduction strategy at the retail level. First and foremost, retailers who donate items to charity groups such as food banks and social supermarkets should be preferred (Michelini et al., 2018).

Composting is an aerobic process in which organic materials decay organically, yielding compost, carbon dioxide, water, and heat. Compost has long been utilized as a soil conditioner and fertilizer. Compost can help to prevent land deterioration and soil erosion. Additionally, by promoting helpful microorganisms and suppressing detrimental microorganisms, composting can help achieve adequate hygienization of organic wastes and prevent soil borne and airborne infections. As a result, it is proposed that the heat created during the composting process be utilized as a source of renewable energy (Omer, 2007). Vegetables, fruits, and flowers are sold in huge numbers at markets, and their wastes are disposed of in landfills or dumpsites alongside MSW, providing a breeding ground for vectors, pests, odours, and Greenhouse Gas (GHG) emissions into the environment. Waste-to-energy methods transform renewable waste materials from agricultural, industry, and household sources into useable energy forms including biohydrogen, biogas, and bioalcohols for worldwide sustainable growth. Kumar et al. (2015) discusses the various category of biomass in India. The research reveals that India has large potential for bio mass feed stock from different sources. Government of India deployed different policies and executed strategies for biomass power generation. Such approaches have included the whole biomass energy sector which incorporates bio gas, bio diesel etc. in the policies.

There are a variety of ways for treating organic waste, but anaerobic digestion appears to be one of the most promising. The metabolic processes of anaerobic digestion include hydrolysis, acidogensis, and methanogensis under absence of oxygen. Methane and carbon dioxide that are released in anaerobic digestion of organic waste in landfills has the ability to produce valuable products like biofuel and organic supplement (soil conditioner) under specified conditions. Furthermore, as potential fuels, methane and hydrogen are regarded to be cleaner than fossil fuels. Moreover, this has the advantage of not requiring the use of fossil fuels for energy consumption (Khalid et al., 2011; Cesaro et al., 2019).

Rendering is the conversion of leftover animal tissues into stable, useful forms, such as feed protein. Fatty tissues, bones, and animal carcasses are heated to around 130 °C and then pressed to kill germs during the rendering process. Rendering may be done on a small scale as well as on a large scale. Non-animal products can also be reduced down to create pulps in some situations. Rendering outputs can be used in a variety of ways, with solid particles being used in pet food and fat added to soap-making processes. Esterase enzymes can be used to esterify oils and produce biodiesel. Sugars, too, can be esterified and used as surfactants (Bayr et al., 2012). Beyond all these solutions, the primary goal of recycling organic waste is to maintain a sustainable cycle, constituting a CE in waste management systems (Borrello et al., 2017).

2.3. Barriers to OWM solutions

Still, the quest for adequate solutions for the collection, treatment and disposal of organic waste is a serious challenge for stakeholders, engineers and scientists in developing countries (Chongrak, 1996). Waste disposal procedures that are uncontrolled and dangerous are still a major public health and environmental concern. In India, the current state of OWM is bad since the most appropriate waste collection and disposal procedures are not being implemented. There is a scarcity of trained waste management specialists and there is a dearth of training. In India's current structures, there is also a lack of accountability. Municipal governments in India are in charge of handling MSW, but their budgets are insufficient to pay the costs of constructing proper garbage collection, storage, treatment, and disposal systems. In India, successful Solid Waste Management (SWM) is hampered by a lack of strategic MSW plans, waste collection/segregation, and a government financially regulatory framework. Low motivation and a lack of environmental knowledge have stifled innovation and the adoption of innovative technology that could improve garbage management in India. Negative public attitude towards waste handling is also a major barrier to attaining a successful SWM in India (Thi et al., 2015).

Chauhan et al. (2018) and Satapathy et al. (2018) carried out studies on how to address the issue of waste management in India. With the use of Multi-Criteria Decision-Making (MCDM) techniques such as Interpretive Structural Modelling(ISM), DEMATEL, Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE II), and the VIekriterijumsko KOmpromisno Rangiranje (VIKOR) method, the barriers to this challenge have been identified and their importance has been established. Hung et al. (2007) investigated decision making in support of MSW management using an MCDM technique combined with a Consensus Analysis Model (CAM) using a case study in Taiwan. Mir et al. (2016) provided a systematic and logical way for SWM, using the MCDM techniques such as Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and VIKOR to investigate and rate the treatment methods for environmental and economic advantages. Shahnazari et al. (2020), in their study analyzed and evaluated the thermochemical strategies utilized to burn MSW. They employed Analytic Hierarchy Process (AHP) and TOPSIS to determine which technique is best based on technical, economic and environmental parameters. Shukor et al. (2018) synthesized the use of decision-making to overcome the complexity of deciding on the optimum composing technique for organic waste disposal. Tseng (2009) evaluated different MSW management solutions using a combined effort that includes Analytic Network Process (ANP) and DEMATEL decision-making approaches. Coban et al. (2018) evaluated various waste disposal techniques that are used globally in different situations relevant in the context of developing countries, using TOPSIS, PROMETHEE I, and PROMETHEE II. The findings highlight the importance of recycling and landfilling for developing countries using all tree methods. Sharma et al. (2020) presented adoption problems for the Internet of Things (IOT) in smart city waste management systems in developing economies like India. Various MCDM approaches were investigated at the same time to determine significant barriers. Using a fuzzy MCDM method, Ali et al. (2021) evaluated the adoption barriers of CE in food waste management in underdeveloped countries. The report offers policy suggestions to public and private sector officials to help the food industry transition to a CE model.

The present study has identified 20 key barriers that prevent the development and implementation of the necessary solutions for an effective and sustainable OWM. The identified barriers were classified into 4 dimensions such as physical barriers, strategical barriers, educational/social barriers and some monetary/legal barriers. Table 1 provides a detailed description of identified barriers along their corresponding dimension.

The next section describes the solution methodology of this research.

3. Solution methodology

The major barriers of OWM solutions have been identified through the literature review. The present study categorised these solutions into 4 major dimensions and 20 associated barriers, as shown in Table 1. Further, these barriers were assessed based on expert opinions retrieved though a questionnaire. Fig. 1 shows the implementation of the proposed research framework by fuzzy-DEMATEL approach for OWM solutions.

3.1. The questionnaire design

The crisp (non-fuzzy) questionnaire design comprised 20 dimensions of barriers (B_1, B_2 ⋯ B_{20}) (please see Appendix). The questionnaires were mostly administered by a group of professionals who shared their personal perspectives on the barriers and their interactions with each other. The uncertainty of the experts' subjective assessments was taken into account during the survey. As a result, a linguistic description method was used to verify that the experts' subjective assessments' evaluation values were accurately stated. Following that, each judgement value was converted to a triangular fuzzy number, which was then used to determine the degree of effect on a 5-point scale. The influence was ranked as No influence (NO), Very Low influence (VL), Low influence (L), High influence (H), and Very High influence (VH).

The recipients of the questionnaire were experts from research and academic fields both from national and international universities serving in distinct departments. The linkages among the 20 barriers were analyzed after the questionnaires were completed, particularly pairwise assessments of the degree of causal and interaction relationships among the barriers. Prior to the survey's administration, the researchers personally contacted each expert to clarify the questionnaire's substance. A total of 5 valid questionnaires were recovered, resulting in a positive effective recovery rate.

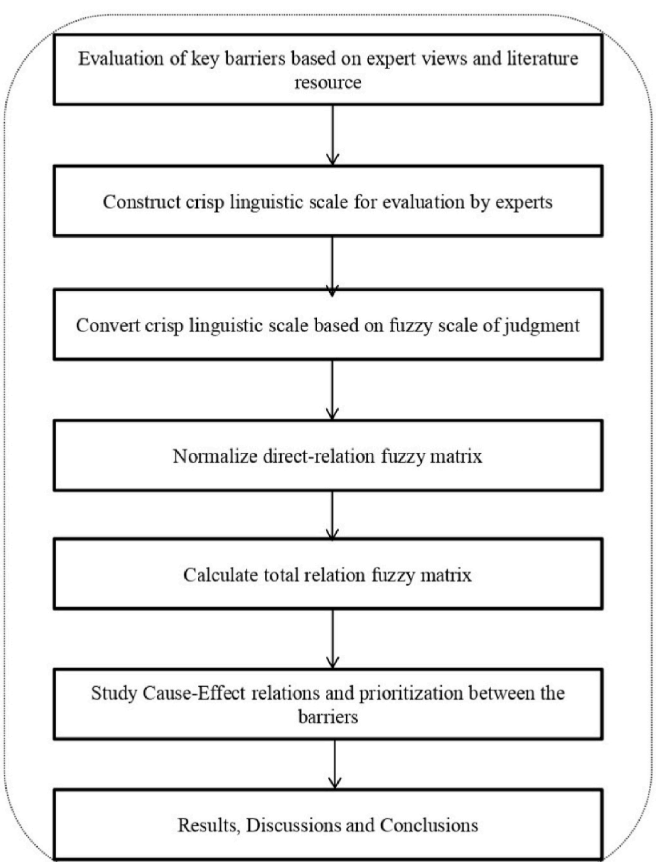

Fig. 1. Proposed research framework implementing fuzzy-DEMATEL.

3.2. The fuzzy DEMATEL method

The DEMATEL has been widely used to solve difficulties in a variety of fields in recent years (Gandhi et al., 2015; Mangla et al., 2021). The DEMATEL approach is a well-known and thorough method for constructing a structural model that shows informal links between complex real-world variables. The DEMATEL method outperforms other techniques like AHP, because it uses a causal diagram to account for the interdependence between system elements (Kiani Mavi and Standing, 2018). Traditional quantification methodologies, although providing accurate answers, are unsuccessful in resolving people-centred problems because of the difficulties caused by human factors. As a result (Zadeh, 1978),'s fuzzy set theory principles are extensively used in real-world situations including uncertainty and fuzziness in the environment. The fuzziness and unpredictability of realistic situations need the use of fuzzy set theory techniques. This method permits research outcomes to mimic human cognitive patterns as nearly as possible.

The fuzzy-DEMATEL model combines fuzzy linguistic aspect with the DEMATEL (Deng et al., 2015). The fuzzy DEMATEL approach is utilized in this work to evaluate causal relationships of the barriers. The proposed method is useful for revealing links between barriers and ranking barriers based on the type of relationship and the severity of the relationship's impact on each criterion.

4. Case study

The computation procedures of the fuzzy-DEMATEL model consist of the following steps:

Step 1 Generate the fuzzy direct-relation matrix.

An $n \times n$ matrix is first produced in order to identify the model of the relations among the n criteria. A fuzzy number can be used to express the influence of each row's element on each column's element in this matrix. If more than one expert's opinion is sought, the matrix must be completed by all experts. The direct relation matrix z is created by taking the arithmetic mean of all of the experts' judgments.

$$z = \begin{bmatrix} 0 & \cdots & \tilde{z}_{n1} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{1n} & \cdots & 0 \end{bmatrix}$$

The direct relation matrix, which is the same as the experts' pairwise comparison matrix, is shown in Table 2 below.

A set of triangular fuzzy number is a set as A (l, m, u) in which l and u respectively denote the lower and upper limits of fuzzy value and m is the most possible value. The membership function $\mu_A(x)$ is defined as follows,

$$\mu_A(x) = \begin{cases} \dfrac{x-l}{m-l}, & (l < x < m) \\ \dfrac{x-u}{m-u}, & (m < x < u) \\ 0 : \textit{the rest} \end{cases} \tag{6}$$

Where

$0 \leq \mu_A(x) \leq 1,\ and 1, m, u \in R$

Table 3 shows the fuzzy-scale used in the model (Deng et al., 2015).

Step 2 Normalize the fuzzy direct-relation matrix.

The following formula can be used to calculate the normalized fuzzy direct-relation matrix as shown in Table 4.

Table 2
The direct-relation matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20
B1	(0.000,0.000,0.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.100,0.300,0.500)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.100,0.300,0.500)	(0.000,0.100,0.300)	(0.300,0.500,0.700)	(0.100,0.300,0.500)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.000,0.100,0.300)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.000,0.100,0.300)	(0.500,0.700,0.900)	(0.100,0.300,0.500)
B2	(0.100,0.300,0.500)	(0.000,0.000,0.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.100,0.300,0.500)	(0.500,0.700,0.900)	(0.100,0.300,0.500)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.000,0.100,0.300)	(0.300,0.500,0.700)	(0.100,0.300,0.500)
B3	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.000,0.000,0.000)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.100,0.300,0.500)	(0.500,0.700,0.900)	(0.100,0.300,0.500)	(0.100,0.300,0.500)	(0.100,0.300,0.500)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.000,0.100,0.300)	(0.100,0.300,0.500)	(0.000,0.100,0.300)
B4	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.000,0.000,0.000)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.000,0.100,0.300)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.000,0.100,0.300)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.000,0.100,0.300)	(0.300,0.500,0.700)	(0.000,0.100,0.300)
B5	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.000,0.000,0.000)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.100,0.300,0.500)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.100,0.300,0.500)	(0.300,0.500,0.700)	(0.000,0.100,0.300)	(0.100,0.300,0.500)	(0.700,0.900,1.000)	(0.000,0.100,0.300)	(0.000,0.100,0.300)	(0.000,0.100,0.300)
B6	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.000,0.000,0.000)	(0.100,0.300,0.500)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.000,0.100,0.300)	(0.700,0.900,1.000)	(0.000,0.100,0.300)
B7	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.000,0.000,0.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.000,0.100,0.300)	(0.500,0.700,0.900)	(0.500,0.700,0.900)
B8	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.100,0.300,0.500)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.000,0.000,0.000)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.000,0.100,0.300)	(0.700,0.900,1.000)	(0.000,0.100,0.300)
B9	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.000,0.100,0.300)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.000,0.000,0.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.100,0.300,0.500)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.000,0.100,0.300)	(0.500,0.700,0.900)	(0.300,0.500,0.700)
B10	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.100,0.300,0.500)	(0.100,0.300,0.500)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.000,0.000,0.000)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.100,0.300,0.500)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.000,0.100,0.300)	(0.300,0.500,0.700)	(0.300,0.500,0.700)
B11	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.000,0.100,0.300)	(0.500,0.700,0.900)	(0.000,0.100,0.300)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.000,0.000,0.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.000,0.100,0.300)	(0.500,0.700,0.900)	(0.300,0.500,0.700)
B12	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.000,0.100,0.300)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.000,0.000,0.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.000,0.100,0.300)	(0.700,0.900,1.000)	(0.100,0.300,0.500)
B13	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.000,0.000,0.000)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.000,0.100,0.300)	(0.700,0.900,1.000)	(0.100,0.300,0.500)
B14	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.100,0.300,0.500)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.000,0.000,0.000)	(0.100,0.300,0.500)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.300,0.500,0.700)
B15	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.000,0.000,0.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.100,0.300,0.500)
B16	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.000,0.000,0.000)	(0.700,0.900,1.000)	(0.100,0.300,0.500)	(0.700,0.900,1.000)	(0.300,0.500,0.700)
B17	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.100,0.300,0.500)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.000,0.000,0.000)	(0.100,0.300,0.500)	(0.500,0.700,0.900)	(0.300,0.500,0.700)
B18	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.100,0.300,0.500)	(0.100,0.300,0.500)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.100,0.300,0.500)	(0.100,0.300,0.500)	(0.100,0.300,0.500)	(0.100,0.300,0.500)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.300,0.500,0.700)	(0.000,0.000,0.000)	(0.300,0.500,0.700)	(0.100,0.300,0.500)
B19	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.300,0.500,0.700)	(0.000,0.100,0.300)	(0.000,0.000,0.000)	(0.000,0.100,0.300)
B20	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.700,0.900,1.000)	(0.300,0.500,0.700)	(0.500,0.700,0.900)	(0.000,0.100,0.300)	(0.700,0.900,1.000)	(0.000,0.000,0.000)

Table 3
Fuzzy scale.

Code	Linguistic terms	L	M	U
1	No Influence	0	0.1	0.3
2	Very Low Influence	0.1	0.3	0.5
3	Low Influence	0.3	0.5	0.7
4	High Influence	0.5	0.7	0.9
5	Very High Influence	0.7	0.9	1

$$\widetilde{x}_{ij} = \frac{\widetilde{z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right)$$

Where

$$r = \max_{i,j}\left\{\max_i \sum_{j=1}^{n} u_{ij}, \max_j \sum_{i=1}^{n} u_{ij}\right\} \quad i,j \in \{1,2,3,\ldots,n\} \tag{7}$$

Step 3 Calculate the fuzzy total-relation matrix.

The fuzzy total-relation matrix can be calculated in step 3 using the formula:

$$\widetilde{T} = \lim_{k\to+\infty}\left(\widetilde{x}^1 \oplus \widetilde{x}^2 \oplus \ldots \oplus \widetilde{x}^k\right) \tag{8}$$

If each element of the fuzzy total-relation matrix is expressed as $\widetilde{t}_{ij} = (l''_{ij}, m''_{ij}, u''_{ij})$, it can be calculated as follows:

$$\left[l''_{ij}\right] = x_l \times (I - x_l)^{-1}$$

$$\left[m''_{ij}\right] = x_m \times (I - x_m)^{-1}$$

$$\left[u''_{ij}\right] = x_u \times (I - x_u)^{-1}$$

The inverse of the normalized matrix is calculated first, and then subtracted from matrix I, and finally the normalized matrix is multiplied by the resulting matrix. The fuzzy total-relation matrix is shown in Table 5.

Step 4 Defuzzify into crisp values.

To acquire a crisp value of the total-relation matrix, the CFCS (converting fuzzy data into crisp scores) approach proposed by (Opricovic and Tzeng, 2003) was applied. The following are the steps in the CFCS method:

$$l^n_{ij} = \frac{\left(l^t_{ij} - \min l^t_{ij}\right)}{\Delta^{max}_{min}}$$

$$m^n_{ij} = \frac{\left(m^t_{ij} - \min l^t_{ij}\right)}{\Delta^{max}_{min}}$$

$$u^n_{ij} = \frac{\left(u^t_{ij} - \min l^t_{ij}\right)}{\Delta^{max}_{min}}$$

So that

$$\Delta^{max}_{min} = \max u^t_{ij} - \min l^t_{ij} \tag{9}$$

Calculating the upper and lower bounds of normalized values:

$$l^s_{ij} = m^n_{ij} \Big/ \left(1 + m^n_{ij} - l^n_{ij}\right)$$

$$u^s_{ij} = u^n_{ij} \Big/ \left(1 + u^n_{ij} - l^n_{ij}\right)$$

The output of the CFCS algorithm is crisp values.

On calculating total normalized crisp values, the matrix is represented as shown in Table 6.

$$x_{ij} = \frac{\left[l^s_{ij}\left(1 - l^s_{ij}\right) + u^s_{ij} \times u^s_{ij}\right]}{\left[1 - l^s_{ij} + u^s_{ij}\right]} \tag{10}$$

Step 5 Set the threshold value.

In order to calculate the internal relations matrix, the threshold value must be obtained. As a result, incomplete relationships are ignored, and a Network Relationship Map (NRM) is drawn. In the NRM, only relations with values in matrix T greater than the threshold value are shown. Calculating the average values of the matrix T is enough to compute the threshold value for relations. After determining the threshold intensity, all values in matrix T that are smaller than the threshold value are set to zero, ignoring the causal relationship described before.

In this study, the threshold value is equal to 0.101. All the values in matrix T which are smaller than 0.101 are set to zero, that is, the causal relation mentioned above is not considered. The model of significant relations is presented in Table 7.

Step 6 Final output and create a causal relation diagram.

The next step is to find out the sum of each row and each column of T (in step 4). The sum of rows (D) and columns (R) can be calculated as follows:

$$D = \sum_{j=1}^{n} T_{ij} \tag{11}$$

$$R = \sum_{i=1}^{n} T_{ij} \tag{12}$$

Then, the values of (D + R) and (D-R) can be calculated by D and R, where (D + R) represent the degree of importance of factor *i* in the entire system and (D-R) represent net effects that factor *i* contributes to the system. Table 8 shows the final output.

5. Results and discussions

Fig. 2 shows the model of significant relations. This model can be represented as a diagram in which the values of (D + R) are placed on the horizontal axis and the values of (D-R) on the vertical axis. The position and interaction of each factor with a point in the coordinates (D + R, D-R) are determined by coordinate system.

According to Fig. 2 and Table 8 above, each factor can be assessed based on the following aspects:

Horizontal vector (D + R) represents the degree of importance between each factor played in the entire system. In other words, (D + R) indicates both factor *i*'s impact on the whole system and other system factors' impact on the factor in terms of degree of importance. The vertical vector (D-R) represents the degree of a factor's influence on system. In general, the positive value of (D-R) represents a causal variable, and the negative value of (D-R) represents an effect in terms of degree of importance.

No value of waste (B_{16})is ranked in first place and Negative attitude for system (B_{12}), Waste collection fee (B_{17}), Un-ethical behaviour (B_{14}), Lack of engagement and commitment in activities (B_{11}), Conflict of interest (B_{19}), Unwillingness to cooperate (B_{13}), Untimely collection and quantity of waste (B_4), Lack of communication and coordination (B_8), Poor and limited planning (B_6), Inadequate financial resources (B_{15}), Incorrect waste disposal alternatives (B_3), Inconsistency and lack in waste collection infrastructure and technology (B_1), Inconsistency and lack in waste separation infrastructure and technology (B_2), Lack of

Table 4
The normalized fuzzy direct-relation matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20
B1	(0.000,0.000,0.000)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.005,0.016,0.027)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.005,0.016,0.027)	(0.000,0.005,0.016)	(0.016,0.027,0.038)	(0.005,0.016,0.027)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.000,0.005,0.016)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.000,0.005,0.016)	(0.027,0.038,0.048)	(0.005,0.016,0.027)
B2	(0.005,0.016,0.027)	(0.000,0.000,0.000)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.005,0.016,0.027)	(0.027,0.038,0.048)	(0.005,0.016,0.027)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.000,0.005,0.016)	(0.016,0.027,0.038)	(0.005,0.016,0.027)
B3	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.000,0.000,0.000)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.005,0.016,0.027)	(0.027,0.038,0.048)	(0.005,0.016,0.027)	(0.005,0.016,0.027)	(0.005,0.016,0.027)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.000,0.005,0.016)	(0.005,0.016,0.027)	(0.000,0.005,0.016)
B4	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.000,0.000,0.000)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.000,0.005,0.016)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.000,0.005,0.016)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.000,0.005,0.016)	(0.016,0.027,0.038)	(0.000,0.005,0.016)
B5	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.000,0.000,0.000)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.005,0.016,0.027)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.005,0.016,0.027)	(0.016,0.027,0.038)	(0.000,0.005,0.016)	(0.005,0.016,0.027)	(0.038,0.048,0.054)	(0.000,0.005,0.016)	(0.000,0.005,0.016)	(0.000,0.005,0.016)
B6	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.000,0.000,0.000)	(0.005,0.016,0.027)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.000,0.005,0.016)	(0.038,0.048,0.054)	(0.000,0.005,0.016)
B7	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.000,0.000,0.000)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.000,0.005,0.016)	(0.027,0.038,0.048)	(0.027,0.038,0.048)
B8	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.005,0.016,0.027)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.000,0.000,0.000)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.000,0.005,0.016)	(0.038,0.048,0.054)	(0.000,0.005,0.016)
B9	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.000,0.005,0.016)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.000,0.000,0.000)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.005,0.016,0.027)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.000,0.005,0.016)	(0.027,0.038,0.048)	(0.016,0.027,0.038)
B10	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.005,0.016,0.027)	(0.005,0.016,0.027)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.000,0.000,0.000)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.005,0.016,0.027)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.000,0.005,0.016)	(0.016,0.027,0.038)	(0.016,0.027,0.038)
B11	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.000,0.005,0.016)	(0.027,0.038,0.048)	(0.000,0.005,0.016)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.000,0.000,0.000)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.000,0.005,0.016)	(0.027,0.038,0.048)	(0.016,0.027,0.038)
B12	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.000,0.005,0.016)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.000,0.000,0.000)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.000,0.005,0.016)	(0.038,0.048,0.054)	(0.005,0.016,0.027)
B13	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.000,0.000,0.000)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.000,0.005,0.016)	(0.038,0.048,0.054)	(0.005,0.016,0.027)
B14	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.005,0.016,0.027)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.000,0.000,0.000)	(0.005,0.016,0.027)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.016,0.027,0.038)
B15	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.000,0.000,0.000)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.005,0.016,0.027)
B16	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.000,0.000,0.000)	(0.038,0.048,0.054)	(0.005,0.016,0.027)	(0.038,0.048,0.054)	(0.016,0.027,0.038)
B17	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.005,0.016,0.027)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.000,0.000,0.000)	(0.005,0.016,0.027)	(0.027,0.038,0.048)	(0.016,0.027,0.038)
B18	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.005,0.016,0.027)	(0.005,0.016,0.027)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.005,0.016,0.027)	(0.005,0.016,0.027)	(0.005,0.016,0.027)	(0.005,0.016,0.027)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.016,0.027,0.038)	(0.000,0.000,0.000)	(0.016,0.027,0.038)	(0.005,0.016,0.027)
B19	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.016,0.027,0.038)	(0.000,0.005,0.016)	(0.000,0.000,0.000)	(0.000,0.005,0.016)
B20	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.038,0.048,0.054)	(0.016,0.027,0.038)	(0.027,0.038,0.048)	(0.000,0.005,0.016)	(0.038,0.048,0.054)	(0.000,0.000,0.000)

Table 5
The fuzzy total-relation matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20
B1	(0.014,0.049,0.150)	(0.051,0.095,0.202)	(0.044,0.091,0.208)	(0.050,0.094,0.198)	(0.014,0.048,0.141)	(0.010,0.042,0.139)	(0.008,0.036,0.125)	(0.011,0.044,0.145)	(0.016,0.055,0.156)	(0.010,0.042,0.140)	(0.027,0.068,0.173)	(0.021,0.065,0.176)	(0.027,0.066,0.169)	(0.052,0.097,0.205)	(0.008,0.036,0.126)	(0.050,0.091,0.194)	(0.041,0.084,0.193)	(0.002,0.017,0.079)	(0.038,0.078,0.183)	(0.009,0.037,0.114)
B2	(0.021,0.066,0.178)	(0.015,0.049,0.151)	(0.054,0.102,0.213)	(0.050,0.094,0.199)	(0.035,0.069,0.162)	(0.010,0.043,0.140)	(0.009,0.037,0.126)	(0.011,0.045,0.146)	(0.011,0.046,0.147)	(0.010,0.043,0.141)	(0.017,0.059,0.164)	(0.041,0.086,0.197)	(0.016,0.056,0.160)	(0.041,0.087,0.201)	(0.024,0.057,0.146)	(0.049,0.091,0.194)	(0.052,0.095,0.199)	(0.002,0.018,0.080)	(0.027,0.068,0.173)	(0.009,0.036,0.114)
B3	(0.038,0.078,0.182)	(0.028,0.069,0.173)	(0.013,0.047,0.146)	(0.012,0.047,0.150)	(0.007,0.034,0.120)	(0.024,0.057,0.148)	(0.023,0.053,0.135)	(0.008,0.038,0.133)	(0.009,0.040,0.135)	(0.009,0.039,0.130)	(0.015,0.053,0.150)	(0.037,0.077,0.181)	(0.014,0.050,0.147)	(0.018,0.060,0.166)	(0.012,0.042,0.125)	(0.047,0.085,0.180)	(0.048,0.087,0.184)	(0.001,0.015,0.073)	(0.015,0.053,0.151)	(0.004,0.024,0.096)
B4	(0.056,0.106,0.224)	(0.045,0.095,0.219)	(0.059,0.112,0.236)	(0.019,0.058,0.169)	(0.026,0.064,0.167)	(0.029,0.070,0.177)	(0.010,0.042,0.140)	(0.040,0.082,0.194)	(0.030,0.073,0.186)	(0.014,0.051,0.159)	(0.042,0.088,0.203)	(0.055,0.105,0.223)	(0.031,0.075,0.189)	(0.057,0.108,0.228)	(0.025,0.062,0.161)	(0.034,0.081,0.200)	(0.045,0.093,0.215)	(0.002,0.019,0.089)	(0.032,0.077,0.194)	(0.005,0.030,0.116)
B5	(0.050,0.093,0.199)	(0.030,0.073,0.184)	(0.042,0.088,0.204)	(0.050,0.092,0.196)	(0.007,0.029,0.111)	(0.009,0.039,0.136)	(0.006,0.033,0.122)	(0.035,0.072,0.172)	(0.025,0.063,0.164)	(0.014,0.050,0.148)	(0.026,0.066,0.170)	(0.039,0.082,0.193)	(0.016,0.054,0.157)	(0.031,0.076,0.188)	(0.007,0.034,0.123)	(0.018,0.059,0.166)	(0.050,0.091,0.196)	(0.001,0.016,0.078)	(0.011,0.046,0.151)	(0.004,0.025,0.102)
B6	(0.065,0.126,0.258)	(0.064,0.125,0.257)	(0.070,0.135,0.272)	(0.064,0.124,0.254)	(0.052,0.098,0.208)	(0.019,0.058,0.168)	(0.019,0.063,0.174)	(0.057,0.109,0.229)	(0.058,0.110,0.231)	(0.057,0.107,0.222)	(0.060,0.116,0.240)	(0.054,0.115,0.251)	(0.048,0.101,0.229)	(0.067,0.129,0.263)	(0.029,0.073,0.185)	(0.051,0.108,0.242)	(0.063,0.122,0.253)	(0.002,0.024,0.103)	(0.059,0.114,0.239)	(0.008,0.039,0.136)
B7	(0.066,0.128,0.265)	(0.065,0.127,0.265)	(0.070,0.137,0.280)	(0.065,0.126,0.261)	(0.053,0.100,0.214)	(0.045,0.096,0.221)	(0.014,0.049,0.154)	(0.048,0.101,0.230)	(0.058,0.112,0.237)	(0.047,0.098,0.224)	(0.061,0.118,0.247)	(0.065,0.127,0.264)	(0.038,0.093,0.226)	(0.068,0.131,0.271)	(0.029,0.075,0.191)	(0.052,0.110,0.249)	(0.054,0.114,0.255)	(0.002,0.024,0.106)	(0.050,0.106,0.241)	(0.034,0.071,0.170)
B8	(0.063,0.122,0.253)	(0.053,0.112,0.248)	(0.057,0.120,0.262)	(0.063,0.120,0.249)	(0.020,0.065,0.179)	(0.055,0.103,0.216)	(0.029,0.071,0.181)	(0.020,0.060,0.173)	(0.047,0.098,0.222)	(0.046,0.095,0.214)	(0.060,0.114,0.236)	(0.063,0.121,0.251)	(0.057,0.109,0.230)	(0.065,0.126,0.258)	(0.028,0.071,0.182)	(0.050,0.105,0.237)	(0.051,0.108,0.242)	(0.002,0.023,0.100)	(0.059,0.112,0.235)	(0.007,0.038,0.133)
B9	(0.036,0.090,0.220)	(0.047,0.100,0.229)	(0.061,0.118,0.248)	(0.036,0.088,0.216)	(0.012,0.048,0.156)	(0.030,0.074,0.187)	(0.027,0.065,0.169)	(0.042,0.087,0.204)	(0.016,0.052,0.160)	(0.052,0.096,0.204)	(0.044,0.094,0.215)	(0.047,0.100,0.229)	(0.032,0.080,0.199)	(0.059,0.114,0.240)	(0.015,0.055,0.159)	(0.045,0.095,0.220)	(0.035,0.087,0.215)	(0.002,0.020,0.093)	(0.044,0.092,0.214)	(0.022,0.054,0.143)
B10	(0.046,0.098,0.225)	(0.035,0.087,0.215)	(0.059,0.115,0.242)	(0.045,0.096,0.221)	(0.036,0.076,0.181)	(0.018,0.062,0.172)	(0.015,0.053,0.155)	(0.030,0.075,0.190)	(0.040,0.086,0.201)	(0.014,0.047,0.148)	(0.052,0.101,0.215)	(0.035,0.087,0.214)	(0.041,0.087,0.204)	(0.057,0.111,0.234)	(0.014,0.053,0.155)	(0.033,0.082,0.205)	(0.034,0.085,0.211)	(0.002,0.019,0.091)	(0.032,0.079,0.199)	(0.021,0.052,0.140)
B11	(0.064,0.123,0.254)	(0.064,0.123,0.254)	(0.069,0.133,0.268)	(0.063,0.122,0.250)	(0.016,0.056,0.170)	(0.045,0.094,0.212)	(0.015,0.053,0.163)	(0.057,0.107,0.225)	(0.057,0.109,0.227)	(0.057,0.106,0.220)	(0.024,0.069,0.186)	(0.064,0.123,0.252)	(0.058,0.111,0.231)	(0.067,0.128,0.259)	(0.029,0.073,0.183)	(0.061,0.117,0.243)	(0.052,0.110,0.244)	(0.002,0.023,0.101)	(0.050,0.104,0.232)	(0.023,0.059,0.154)
B12	(0.063,0.123,0.254)	(0.064,0.123,0.254)	(0.068,0.132,0.268)	(0.063,0.121,0.250)	(0.015,0.056,0.171)	(0.035,0.084,0.203)	(0.040,0.083,0.192)	(0.056,0.106,0.225)	(0.047,0.098,0.223)	(0.046,0.095,0.215)	(0.059,0.114,0.237)	(0.027,0.076,0.202)	(0.057,0.110,0.231)	(0.066,0.127,0.260)	(0.029,0.072,0.183)	(0.051,0.106,0.239)	(0.051,0.109,0.244)	(0.002,0.023,0.101)	(0.059,0.113,0.237)	(0.013,0.048,0.144)
B13	(0.065,0.127,0.261)	(0.065,0.126,0.260)	(0.070,0.136,0.275)	(0.065,0.125,0.256)	(0.032,0.079,0.195)	(0.056,0.106,0.222)	(0.040,0.084,0.196)	(0.058,0.110,0.231)	(0.048,0.102,0.228)	(0.057,0.108,0.225)	(0.061,0.118,0.243)	(0.065,0.126,0.259)	(0.022,0.067,0.185)	(0.067,0.131,0.266)	(0.029,0.074,0.187)	(0.052,0.110,0.245)	(0.043,0.103,0.241)	(0.002,0.024,0.104)	(0.060,0.116,0.242)	(0.013,0.050,0.148)
B14	(0.037,0.091,0.220)	(0.036,0.090,0.219)	(0.060,0.117,0.247)	(0.036,0.088,0.216)	(0.028,0.069,0.176)	(0.030,0.074,0.186)	(0.027,0.066,0.169)	(0.031,0.077,0.194)	(0.021,0.068,0.186)	(0.031,0.076,0.189)	(0.033,0.083,0.204)	(0.056,0.109,0.233)	(0.042,0.089,0.208)	(0.021,0.067,0.188)	(0.016,0.055,0.159)	(0.044,0.094,0.219)	(0.055,0.107,0.230)	(0.017,0.041,0.113)	(0.043,0.091,0.213)	(0.021,0.053,0.142)
B15	(0.069,0.135,0.275)	(0.069,0.135,0.275)	(0.074,0.145,0.291)	(0.068,0.133,0.271)	(0.055,0.105,0.222)	(0.057,0.111,0.233)	(0.052,0.099,0.212)	(0.050,0.106,0.239)	(0.061,0.118,0.246)	(0.060,0.114,0.237)	(0.063,0.124,0.256)	(0.068,0.133,0.273)	(0.050,0.108,0.244)	(0.071,0.139,0.281)	(0.015,0.053,0.162)	(0.065,0.126,0.263)	(0.067,0.131,0.270)	(0.029,0.057,0.140)	(0.042,0.102,0.240)	(0.015,0.054,0.156)
B16	(0.057,0.122,0.266)	(0.068,0.132,0.271)	(0.073,0.142,0.286)	(0.057,0.120,0.262)	(0.034,0.083,0.204)	(0.058,0.110,0.231)	(0.053,0.098,0.210)	(0.050,0.105,0.236)	(0.061,0.117,0.243)	(0.060,0.113,0.235)	(0.063,0.123,0.253)	(0.067,0.131,0.270)	(0.050,0.107,0.241)	(0.070,0.136,0.277)	(0.041,0.088,0.205)	(0.028,0.078,0.208)	(0.065,0.128,0.266)	(0.008,0.035,0.118)	(0.062,0.120,0.252)	(0.025,0.063,0.164)
B17	(0.063,0.124,0.258)	(0.063,0.123,0.258)	(0.068,0.132,0.273)	(0.053,0.112,0.249)	(0.053,0.099,0.210)	(0.044,0.093,0.215)	(0.040,0.083,0.195)	(0.035,0.087,0.214)	(0.056,0.109,0.231)	(0.055,0.105,0.223)	(0.028,0.085,0.216)	(0.052,0.112,0.252)	(0.046,0.099,0.229)	(0.065,0.127,0.263)	(0.049,0.092,0.200)	(0.040,0.096,0.232)	(0.026,0.074,0.202)	(0.008,0.034,0.113)	(0.047,0.102,0.234)	(0.023,0.059,0.156)
B18	(0.040,0.087,0.205)	(0.040,0.087,0.205)	(0.042,0.093,0.217)	(0.029,0.076,0.192)	(0.024,0.060,0.158)	(0.014,0.053,0.156)	(0.012,0.047,0.141)	(0.025,0.065,0.172)	(0.025,0.067,0.174)	(0.014,0.054,0.158)	(0.016,0.060,0.171)	(0.019,0.066,0.184)	(0.015,0.057,0.167)	(0.041,0.089,0.210)	(0.022,0.057,0.151)	(0.028,0.073,0.187)	(0.029,0.075,0.192)	(0.002,0.012,0.067)	(0.027,0.069,0.181)	(0.009,0.037,0.119)
B19	(0.065,0.125,0.259)	(0.065,0.125,0.258)	(0.069,0.134,0.273)	(0.065,0.124,0.255)	(0.041,0.087,0.203)	(0.055,0.104,0.220)	(0.040,0.083,0.195)	(0.058,0.109,0.230)	(0.058,0.110,0.231)	(0.047,0.097,0.218)	(0.061,0.117,0.241)	(0.065,0.124,0.257)	(0.058,0.111,0.234)	(0.057,0.119,0.259)	(0.029,0.073,0.185)	(0.052,0.108,0.243)	(0.043,0.101,0.239)	(0.002,0.023,0.103)	(0.023,0.068,0.189)	(0.008,0.039,0.136)
B20	(0.071,0.138,0.277)	(0.070,0.137,0.277)	(0.076,0.148,0.293)	(0.071,0.136,0.273)	(0.057,0.107,0.223)	(0.060,0.114,0.236)	(0.054,0.101,0.214)	(0.062,0.119,0.246)	(0.063,0.121,0.248)	(0.062,0.117,0.239)	(0.066,0.128,0.258)	(0.070,0.137,0.276)	(0.063,0.121,0.251)	(0.073,0.142,0.283)	(0.052,0.101,0.214)	(0.046,0.109,0.250)	(0.058,0.123,0.266)	(0.003,0.026,0.111)	(0.064,0.124,0.257)	(0.009,0.038,0.131)

information, media and training (B_9), Limitation and flaws in policies (B_7), Lack of awareness among people (B_{10}), Weak legislation system (B_{20}), Site location and land space (B_5)and Increasing population (B_{18}), are ranked in the next places. In this study, Poor and limited planning (B_6), Limitation and flaws in policies (B_7), Lack of communication and coordination (B_8), Lack of engagement and commitment in activities (B_{11}), Unwillingness to cooperate (B_{13}), Inadequate financial resources (B_{15}), No value of waste (B_{16}), Increasing population (B_{18}), Conflict of interest (B_{19}), Weak legislation system (B_{20}) are considered to be as causal (cause group/influencing) variables. Inconsistency and lack in waste collection infrastructure and technology (B_1), Inconsistency and lack in waste separation infrastructure and technology (B_2), Incorrect waste disposal alternatives (B_3), Untimely collection and quantity of waste (B_4), Site location and land space (B_5), Lack of information, media and training (B_9), Lack of awareness among people (B_{10}), Negative attitude for system (B_{12}), Un-ethical behaviour (B_{14}), Waste collection fee (B_{17})are regarded as effect (effect group/influenced) variables. The causal effect illustration enables an analysis of the barriers for the successful adoption of solutions to OWM. Managers can distinguish the significant barriers and their position in the system and can plan their decision policies accordingly. Hence, this work can provide a structural support to the managers by knowing the cause (influencing) and effect group (influenced) barriers to OWM implementation.

6. Sensitivity analysis

Sensitivity analysis is used to test the robustness of an expert's decision. It is used to analyze the effects of applying various combinations of decision criteria weights. A sensitivity analysis is given in this study to validate the results. Here, weight scores out of 1 (most) to 5 (least) for each expert is calculated according to their years of experience and job responsibilities to analyze how much the cause–effect relationships vary (Luthra et al., 2018). Experts 2, 1, and 4 are assigned higher weights than the other experts. As mentioned above, the higher the expert's qualifications and experience, the higher the weight score. Expert 2 has the highest weight score of one, indicating that he is highly qualified and has more professional experience compared to other experts. Similarly, expert 1 is ranked second, expert 4 is ranked third, expert 3 is ranked fourth, and expert 5 is ranked fifth. Hence, the weight score (λ_{max}) of each expert is calculated by dividing the individual weight score by the total average of five experts (Seker and Zavadskas, 2017). In the sensitivity analysis, expert 2 has the highest weight score of 0.33. Expert 1 has the second highest weight score of 0.26. Experts 4, 3, and 5, have a weight score of 0.2, 0.13, and 0.06 respectively, as shown in Appendix C. According to weight scores of experts, sensitivity run 1 to 5 are implemented and values of D + R and D-R are calculated. The results of sensitivity analysis are shown in Appendix B. For each sensitivity analysis run, Figs. 3–7 clearly illustrates the causal relationships among the barriers.

According to the sensitivity analysis results, the cause and effect variables are virtually in the same order with minor order deviations. However, the barriers B4 (untimely collection and quantity of waste), B5 (site location and landscape), B9 (lack of information, media, and training), B10 (lack of awareness among people) and B11 (lack of engagement and commitment in activities) tend to shift from cause to effect variables or vice-versa in different sensitivity runs. All the other cause and effect barriers are consistent in each sensitivity run. In terms of degree of importance, B16 (no value of waste), B12 (negative attitude towards the system) and B17 (waste collection fee) are the three most important barriers identified overall in the entire analysis. Barriers B4 (untimely collection and quantity of waste), B5 (site location and landscape), B10 (lack of awareness among people), B18 (increasing population) and B20 (weak legislation system) have been identified as the least important barriers in terms of degree of importance among all the sensitivity runs.

Table 6
The crisp total-relation matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20
B1	0.065	0.11	0.108	0.108	0.063	0.058	0.05	0.06	0.07	0.058	0.084	0.082	0.082	0.112	0.051	0.105	0.1	0.027	0.093	0.049
B2	0.083	0.065	0.116	0.108	0.083	0.058	0.051	0.061	0.062	0.059	0.075	0.102	0.072	0.104	0.07	0.105	0.109	0.028	0.083	0.048
B3	0.094	0.084	0.062	0.063	0.048	0.071	0.065	0.054	0.056	0.053	0.068	0.093	0.065	0.076	0.055	0.098	0.101	0.025	0.068	0.036
B4	0.121	0.112	0.128	0.075	0.079	0.085	0.057	0.098	0.089	0.068	0.104	0.12	0.091	0.123	0.076	0.098	0.11	0.031	0.094	0.044
B5	0.108	0.089	0.105	0.106	0.043	0.055	0.047	0.087	0.078	0.065	0.082	0.098	0.07	0.092	0.048	0.075	0.106	0.026	0.063	0.038
B6	0.139	0.139	0.148	0.137	0.11	0.075	0.078	0.122	0.123	0.119	0.129	0.13	0.117	0.143	0.088	0.124	0.136	0.037	0.128	0.054
B7	0.142	0.141	0.151	0.14	0.112	0.111	0.065	0.116	0.126	0.113	0.132	0.141	0.11	0.146	0.09	0.126	0.13	0.037	0.122	0.082
B8	0.136	0.128	0.137	0.134	0.081	0.115	0.086	0.077	0.113	0.109	0.127	0.135	0.123	0.14	0.086	0.121	0.124	0.036	0.126	0.052
B9	0.108	0.117	0.133	0.106	0.065	0.09	0.08	0.102	0.069	0.109	0.109	0.117	0.096	0.129	0.07	0.111	0.105	0.032	0.108	0.066
B10	0.115	0.105	0.13	0.113	0.09	0.078	0.068	0.091	0.101	0.063	0.115	0.105	0.103	0.126	0.068	0.1	0.103	0.031	0.096	0.06
B11	0.137	0.137	0.147	0.135	0.073	0.108	0.07	0.12	0.122	0.119	0.086	0.137	0.124	0.142	0.087	0.131	0.126	0.036	0.119	0.071
B12	0.137	0.137	0.146	0.135	0.073	0.099	0.096	0.12	0.113	0.11	0.128	0.095	0.123	0.141	0.087	0.122	0.125	0.036	0.126	0.062
B13	0.141	0.14	0.15	0.139	0.094	0.118	0.098	0.123	0.116	0.121	0.131	0.14	0.084	0.145	0.089	0.125	0.12	0.037	0.129	0.063
B14	0.108	0.108	0.133	0.106	0.084	0.09	0.08	0.093	0.085	0.091	0.099	0.125	0.105	0.085	0.071	0.111	0.123	0.051	0.107	0.066
B15	0.148	0.148	0.158	0.146	0.117	0.123	0.111	0.121	0.131	0.126	0.137	0.147	0.123	0.152	0.069	0.14	0.145	0.067	0.118	0.067
B16	0.137	0.145	0.155	0.135	0.098	0.123	0.11	0.119	0.129	0.125	0.135	0.145	0.122	0.15	0.102	0.097	0.142	0.048	0.134	0.075
B17	0.138	0.138	0.147	0.128	0.111	0.107	0.097	0.103	0.122	0.118	0.102	0.129	0.115	0.142	0.105	0.114	0.093	0.046	0.118	0.072
B18	0.104	0.104	0.11	0.092	0.075	0.069	0.061	0.081	0.082	0.07	0.077	0.084	0.074	0.106	0.071	0.09	0.093	0.021	0.086	0.05
B19	0.139	0.139	0.148	0.137	0.102	0.117	0.097	0.122	0.123	0.111	0.13	0.139	0.125	0.135	0.088	0.124	0.119	0.036	0.086	0.054
B20	0.15	0.15	0.16	0.148	0.119	0.126	0.113	0.131	0.133	0.128	0.14	0.149	0.134	0.154	0.112	0.125	0.138	0.04	0.137	0.053

Table 7
The crisp total-relationships matrix by considering the threshold value.

B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	
B1	0	0.11	0.108	0.108	0	0	0	0	0	0	0	0	0	0.112	0	0.105	0	0	0	0
B2	0	0	0.116	0.108	0	0	0	0	0	0	0	0.102	0	0.104	0	0.105	0.109	0	0	0
B3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B4	0.121	0.112	0.128	0	0	0	0	0	0	0	0.104	0.12	0	0.123	0	0	0.11	0	0	0
B5	0.108	0	0.105	0.106	0	0	0	0	0	0	0	0	0	0	0	0	0.106	0	0	0
B6	0.139	0.139	0.148	0.137	0.11	0	0	0.122	0.123	0.119	0.129	0.13	0.117	0.143	0	0.124	0.136	0	0.128	0
B7	0.142	0.141	0.151	0.14	0.112	0.111	0	0.116	0.126	0.113	0.132	0.141	0.11	0.146	0	0.126	0.13	0	0.122	0
B8	0.136	0.128	0.137	0.134	0	0.115	0	0	0.113	0.109	0.127	0.135	0.123	0.14	0	0.121	0.124	0	0.126	0
B9	0.108	0.117	0.133	0.106	0	0	0	0.102	0	0.109	0.109	0.117	0	0.129	0	0.111	0.105	0	0.108	0
B10	0.115	0.105	0.13	0.113	0	0	0	0	0	0	0.115	0.105	0.103	0.126	0	0	0.103	0	0	0
B11	0.137	0.137	0.147	0.135	0	0.108	0	0.12	0.122	0.119	0	0.137	0.124	0.142	0	0.131	0.126	0	0.119	0
B12	0.137	0.137	0.146	0.135	0	0	0	0.12	0.113	0.11	0.128	0	0.123	0.141	0	0.122	0.125	0	0.126	0
B13	0.141	0.14	0.15	0.139	0	0.118	0	0.123	0.116	0.121	0.131	0.14	0	0.145	0	0.125	0.12	0	0.129	0
B14	0.108	0.108	0.133	0.106	0	0	0	0	0	0	0	0.125	0.105	0	0	0.111	0.123	0	0.107	0
B15	0.148	0.148	0.158	0.146	0.117	0.123	0.111	0.121	0.131	0.126	0.137	0.147	0.123	0.152	0	0.14	0.145	0	0.118	0
B16	0.137	0.145	0.155	0.135	0	0.123	0.11	0.119	0.129	0.125	0.135	0.145	0.122	0.15	0.102	0	0.142	0	0.134	0
B17	0.138	0.138	0.147	0.128	0.111	0.107	0	0.103	0.122	0.118	0.102	0.129	0.115	0.142	0.105	0.114	0	0	0.118	0
B18	0.104	0.104	0.11	0	0	0	0	0	0	0	0	0	0	0.106	0	0	0	0	0	0
B19	0.139	0.139	0.148	0.137	0.102	0.117	0	0.122	0.123	0.111	0.13	0.139	0.125	0.135	0	0.124	0.119	0	0	0
B20	0.15	0.15	0.16	0.148	0.119	0.126	0.113	0.131	0.133	0.128	0.14	0.149	0.134	0.154	0.112	0.125	0.138	0	0.137	0

Table 8
The final output Table.

Barriers	R	D	D + R	D-R	Cause/Effect
B1	2.449	1.534	3.983	−0.915	Effect
B2	2.435	1.542	3.977	−0.893	Effect
B3	2.671	1.335	4.006	−1.336	Effect
B4	2.392	1.804	4.195	−0.588	Effect
B5	1.718	1.483	3.201	−0.236	Effect
B6	1.876	2.277	4.153	0.402	Cause
B7	1.582	2.332	3.914	0.75	Cause
B8	2.002	2.188	4.19	0.186	Cause
B9	2.045	1.924	3.968	−0.121	Effect
B10	1.937	1.865	3.802	−0.072	Effect
B11	2.189	2.228	4.418	0.039	Cause
B12	2.411	2.21	4.622	−0.201	Effect
B13	2.058	2.302	4.36	0.245	Cause
B14	2.544	1.92	4.463	−0.624	Effect
B15	1.582	2.494	4.075	0.912	Cause
B16	2.243	2.427	4.67	0.185	Cause
B17	2.348	2.243	4.591	−0.105	Effect
B18	0.729	1.598	2.327	0.869	Cause
B19	2.14	2.271	4.412	0.131	Cause
B20	1.166	2.539	3.706	1.373	Cause

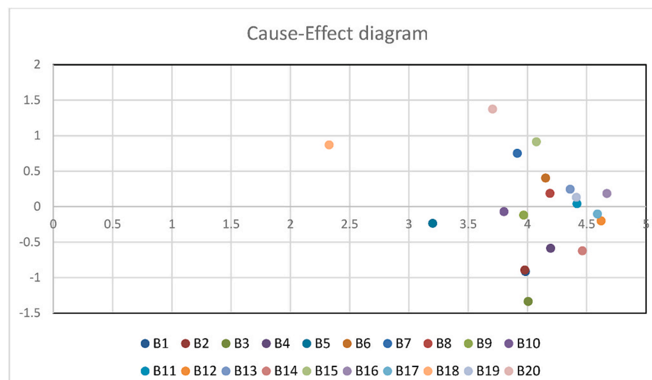

Fig. 2. Cause-Effect diagram.

7. Research implications

According to the findings, the management procedure for an organic waste recycling programme should include as many options as possible to allow for a more effective decision-making process. The planning and implementation of a waste-recycling programme are critical to its overall success (Pickering et al., 2020). Many countries have been using waste recycling programmes for decades, but proper planning procedures and institutional setup have yet to be developed.

Household, industrial, and public-sector wastes are the components of a waste recycling programme, which can be reproduced into valuable goods as well as achieve additional advantages such as improved public health and pollution reduction (Karnchanawong and Suriyanon, 2011). Over the planning period, the programme must consider waste quality and quantity limitations (Villalba et al., 2020). The current and future workforce requirements must be estimated, and future manpower growth must be planned. A programme or project for waste recycling must be financially sustainable. Local governments or international organizations may be required to fund the programmes at first (Agranoff and McGuire, 2003). Later on, fees for garbage collection and treatment, as well as the sale of recycled products, must be implemented, and the public must accept them adequately. To maximize the advantages while minimizing environmental pollution, effective techniques for collecting, handling, processing, and final disposal/reuse of waste and by-products are required (Singh and Ordoñez, 2016). If there is no market for recovered products, all of the resources and work put into recovering and recycling garbage will be wasted. Waste recycling technologies and facilities must be able to consistently meet the user's requirements for quality, quantity, and on-time delivery. It is necessary to continue to educate people at all levels in order to raise public awareness and recognize the necessity of waste recycling (Desa et al., 2012). Uncertainties and falsehoods must be debunked, such as the effects of garbage recycling programmes on public health and the environment.

Circular supply chain models in application of reuse, recycling and remanufacturing should be promoted (Mangla et al., 2018). The technology should be economically and culturally compatible with the local environment. Local workforce should be able to easily operate and maintain the system, and the technology should employ local materials and energy sources whenever possible. The technology should be basic and easy to understand for the locals, as well as flexible enough to accommodate future developments. Through the application of new organizational types and technical equipment, technology should be innovative in order to improve the human and material situations of the local people (Bányai et al., 2019). When practicable, the technology could be installed in existing high-density regions. Technology should not contribute to the contamination and destruction of the current ecology, either directly or indirectly. A preliminary site screening should be carried out to acquire critical information such as soil qualities, depth to ground water, site grades, current and prospective land use patterns, and organic waste transport distance from the community to the possible site (Ekmekçioğlu et al., 2010). The organic waste-recycling site should be positioned downwind and away from community centres to reduce health risks and gain public support. The land area need, which is usually dependent on the required degree of waste treatment and the technique of organic waste recycling to be used, is critical information for site selection. In addition, there are financial benefits to be acquired from organic waste recycling by-products such as compost fertilizer, biofuels, and protein biomass, among others (Eden et al., 2017). An institutional arrangement between government agencies, municipalities, private enterprises, and non-government groups is a vital component in the success of waste recovery and recycling programmes (Taylor, 2000). To avoid disputes and duplication of work and responsibilities, all of these entities must work together and coordinate all actions. Institutional arrangements for financing, administering, and operating recovery and recycling programmes may be considered. Without government leadership, it appears unlikely that other institutions in developing nations will be able to handle waste materials efficiently and optimally. To ensure success in pursuing the programme, some government control, guidance, and incentive are required. To establish the groundwork, a strategy or approach must be devised, either regionally or at the grassroots level. For financial or technical assistance, private enterprises and non-governmental organizations, such as international agencies and foundations, should be engaged. The municipality and the government must work together to promote and implement planning plans (Xiao et al., 2018). If there are any recycling facilities, cooperatives or districts should be formed to be directly involved in the building, operation, and upkeep of those facilities. On the basis of these agencies' comprehensive policies, the development and use of science and technology should be beneficial to waste recycling. Furthermore, if implemented correctly, a policy that considers the ecological, economic,

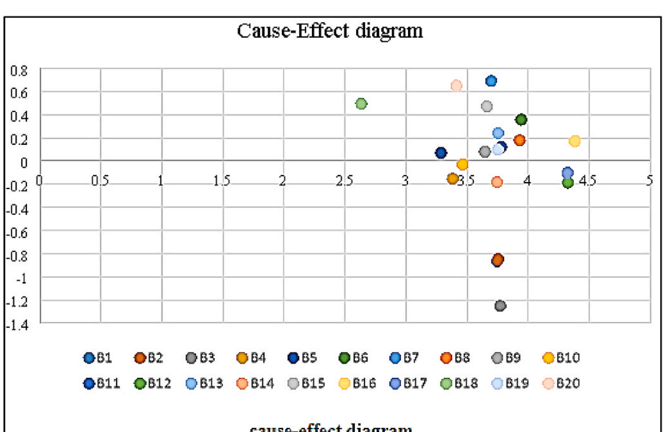

Fig. 3. Sensitivity run 1.

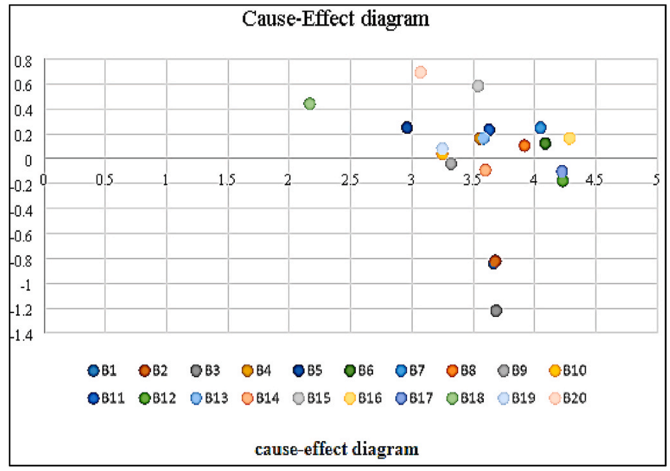

Fig. 4. Sensitivity run 2.

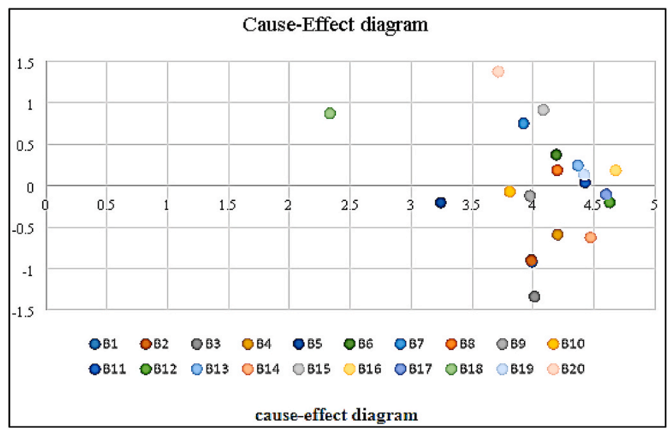

Fig. 5. Sensitivity run 3.

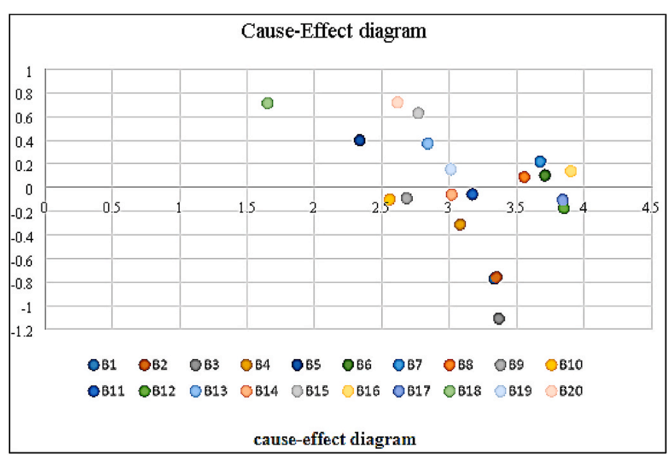

Fig. 6. Sensitivity run 4.

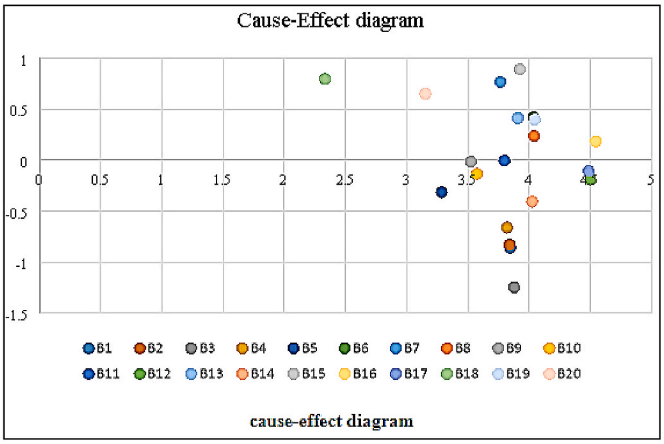

Fig. 7. Sensitivity run 5.

and social aspects of each region or municipality will result in greater cooperation in the development of recycling policies. To make steady progress in waste recycling policy and achieve more satisfactory results in this direction, all parties involved in recycling issues (such as government agencies, municipalities, non-profit corporations, entrepreneurs, and residents) must be aware of their respective roles and make continuous efforts commensurate with their positions. Government agencies are responsible for creating trash recovery and recycling policies, guidelines, and planning programmes. All programme participants should get technical, financial, and management support. The municipality's duty is to help government agencies in choosing which recovery and recycling programmes in the community should be undertaken. Also, assist in the continual flow of information between government agencies and the community, which is necessary for the recovery and recycling programme to succeed and recommend corrective actions to prevent the program's failure. The role of a private corporation is to provide financial and possibly technical assistance to government agencies and municipalities in waste recovery and recycling programmes (Joseph, 2006). Invest in projects that will turn their waste into useful products (this is possible for private companies dealing with agro-based industries that generate large amounts of agro-industrial waste). Conduct some research in order to develop sound technology for the recovery and recycling of waste. Appropriate legislation creates institutions to implement policies and enforce rules by establishing binding policies and standards, laying the groundwork for substantive and procedural regulations. Legislation reflects public acceptance of the importance of waste recycling and enhancement via institutions. It is also a measure of how well waste recycling institutions are entrusted with political clout and legal justification, allowing for better enforcement of environmental regulations. Legislation on waste recycling and waste recycling administration reinforce each other, making them more effective in practise.

The most important aspect to be valued in this research is the 'value of waste' or 'value-added waste'. According to Tuck et al. (2012), nearly all waste currently have some value. This means, nearly all low-value or no-value recyclables can be transformed into higher-value profitable products through certain activities and processes. This research characterizes 'no value of waste' as the strongest barrier in dealing with the organic waste and pulls attention of every sector involved, towards considering it at the first priority among all other barriers.

8. Conclusion and future work

This paper establishes a barrier set to the OWM on the basis of current development and expert opinions in order to achieve the potential economic, social and environmental benefits. Also the paper provides decision-making basis for managers to achieve the sustainable business development. The authors use the fuzzy DEMATEL approach to identify critical barriers impacting OWM solutions, taking into account interconnections among barriers and subjective fuzziness in the expert review process. Results show that the main barrier with the highest ranking is 'No value of waste'. Further, Poor and limited planning (B_6), Limitation and flaws in policies (B_7), Lack of communication and coordination (B_8), Lack of engagement and commitment in activities (B_{11}), Unwillingness to cooperate (B_{13}), Inadequate financial resources (B_{15}), No value of waste (B_{16}), Increasing population (B_{18}), Conflict of interest (B_{19}), and Weak legislation system (B_{20}) are considered to be as causal (cause group/influencing) variables. Inconsistency and lack in waste collection infrastructure and technology (B_1), Inconsistency and lack in waste separation infrastructure and technology (B_2), Incorrect waste disposal alternatives (B_3), Untimely collection and quantity of waste (B_4), Site location and land space (B_5), Lack of information, media and training (B_9), Lack of awareness among people (B_{10}), Negative attitude for system (B_{12}), Un-ethical behaviour (B_{14}), and Waste collection fee (B_{17})are regarded as effect (effect group/influenced) variables. 'No value of waste' is the most significant barrier to consider in this study. Most importantly the research lays stress on the creation of 'value from waste' as 'no value of waste' is evaluated as the most effective barrier in OWM solutions.

Despite significant contributions, this research also contains limitations. The results of a small number of experienced evaluators were used to create the analysis reported in this study. Future study may examine a bigger sample size in terms of respondents, as well as research that includes other internal (e.g., suppliers) and external (e.g., government/regulatory agencies) stakeholders. Future research may look at diverse contexts to uncover new insights that will help us better understand the dynamics of organic waste solutions and treatments.

CRediT authorship contribution statement

Shristi Kharola: Formal analysis, Conceptualization, Methodology, Data, Formal analysis. **Mangey Ram:** Project administration, Methodology, Formal analysis. **Nupur Goyal:** Conceptualization, Methodology, Formal analysis. **Sachin Kumar Mangla:** Supervision, Ideas, Conceptualization, Methodology, Writing – original draft, Preparation, Writing – Review and Editing. **O.P. Nautiyal:** Ideas, Conceptualization, Formal analysis. **Anita Rawat:** Data Collection, Conceptualization. **Yigit Kazancoglu:** Supervision, Conceptualization, Writing – original draft, Preparation. **Durgesh Pant:** Data Collection, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

This work was supported and funded by Uttarakhand Science Education and Research Centre (USERC), Dehra Dun, India, (USERC/2019-20/602). The authors are grateful and acknowledge the assistance of USERC in implementing this joint research in collaboration with Graphic Era Deemed to be University, Dehradun, India; Yasar University, Izmir, Turkey; and O P Jindal Global University, India and University of Plymouth, Plymouth, United Kingdom.

Appendix

A. The DEMATEL Questionnaire

For a Project- Kindly fill the below sheet as per the instructions.
Personal Details:

1. Name* -
2. Designation* -
3. Organization* -
4. Department*-
5. Email ID* -

Step 1 Kindly study the barriers to organic waste management listed below.

B1	Inconsistency and lack in waste collection infrastructure and technology	**B11**	Lack of engagement and commitment in activities
B2	Inconsistency and lack in waste separation infrastructure and technology	**B12**	Negative attitude for the system
B3	Incorrect waste disposal alternatives (Eg: burning, dumping)	**B13**	Unwillingness to cooperate
B4	Untimely collection and quantity of waste	**B14**	Unethical behaviour (Throwing waste in public areas)
B5	Site location and landscape	**B15**	Inadequate financial resources
B6	Poor and limited planning	**B16**	No value of waste
B7	Limitiations and flaws in policies	**B17**	Waste collection fee
B8	Lack of communication and coordination	**B18**	Increasing population
B9	Lack of information, media and training	**B19**	Conflict of interest
B10	lack of awareness among people	**B20**	Weak legislation system

Step 2 Kindly fill the below matrix as per the five options:

5-Very high influence.
4-High Influence.
3-Low influence.
2-Very low influence.
1-No influence.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20
B1	1																			
B2		1																		
B3			1																	
B4				1																
B5					1															
B6						1														
B7							1													
B8								1												
B9									1											
B10										1										
B11											1									
B12												1								
B13													1							
B14														1						
B15															1					
B16																1				
B17																	1			
B18																		1		
B19																			1	
B20																				1

B. Values of D + R and D-R for each Sensitivity Run

Barriers	Sensitivity Run 1		R	Sensitivity Run 2		R	Sensitivity Run 3		R
	D + R	D-R		D + R	D-R		D + R	D-R	
B1	3.746	−0.865	11	3.667	−0.838	9	3.991	−0.917	13
B2	3.753	−0.848	10	3.683	−0.821	8	3.985	−0.895	14
B3	3.771	−1.252	7	3.686	−1.22	7	4.014	−1.339	12
B4	3.381	−0.155	18	3.554	0.164	13	4.203	−0.589	8
B5	3.286	0.069	19	2.96	0.249	19	3.241	−0.204	19
B6	3.942	0.357	4	4.086	0.123	4	4.19	0.374	10
B7	3.697	0.69	13	4.049	0.248	5	3.922	0.752	16
B8	3.93	0.178	5	3.919	0.106	6	4.198	0.185	9
B9	3.646	0.079	15	3.319	−0.04	15	3.976	−0.122	15
B10	3.464	−0.03	16	3.247	0.039	17	3.81	−0.072	17
B11	3.779	0.121	6	3.63	0.232	10	4.426	0.038	5
B12	**4.327**	**−0.188**	**2**	**4.23**	**−0.177**	**2**	**4.63**	**−0.202**	**2**
B13	3.754	0.241	9	3.587	0.165	12	4.368	0.245	7
B14	3.745	−0.183	12	3.599	−0.09	11	4.472	−0.626	4
B15	3.663	0.471	14	3.54	0.584	14	4.084	0.914	11
B16	**4.384**	**0.172**	**1**	**4.286**	**0.164**	**1**	**4.679**	**0.184**	**1**
B17	**4.323**	**−0.102**	**3**	**4.224**	**−0.102**	**3**	**4.6**	**−0.105**	**3**
B18	2.632	0.495	20	2.166	0.44	20	2.331	0.871	20
B19	3.754	0.099	8	3.248	0.081	16	4.421	0.131	6
B20	3.411	0.65	17	3.07	0.693	18	3.713	1.376	18

Barriers	Sensitivity Run 4		R	Sensitivity Run 5		R
	D + R	D-R		D + R	D-R	
B1	3.333	−0.771	9	3.846	−0.856	11
B2	3.35	−0.757	8	3.842	−0.824	12
B3	3.366	−1.108	7	3.878	−1.245	10
B4	3.079	−0.313	11	3.82	−0.659	13
B5	2.336	0.398	19	3.286	−0.315	18
B6	3.707	0.103	4	4.036	0.42	6
B7	3.673	0.22	5	3.766	0.766	15
B8	3.555	0.089	6	4.041	0.237	5
B9	2.683	−0.091	16	3.525	−0.014	17
B10	2.557	−0.102	18	3.576	−0.133	16
B11	3.168	−0.057	10	3.799	−0.004	14
B12	**3.849**	**−0.175**	**2**	**4.5**	**−0.19**	**2**
B13	2.84	0.373	14	3.909	0.413	9
B14	3.016	−0.059	12	4.026	−0.406	7
B15	2.768	0.628	15	3.925	0.891	8
B16	**3.9**	**0.139**	**1**	**4.546**	**0.185**	**1**
B17	**3.841**	**−0.105**	**3**	**4.488**	**−0.107**	**3**
B18	1.652	0.713	20	2.333	0.795	20
B19	3.011	0.155	13	4.046	0.397	4
B20	2.615	0.72	17	3.153	0.65	19

C. Expert weightages

Experts	Experts weight score	Expert weight, λ_{max}
Expert 1	2	0.26
Expert 2	1	0.33
Expert 3	4	0.13
Expert 4	3	0.2
Expert 5	5	0.06

References

Aini, M.S., Fakhru'l-Razi, A., Lad, S.M., Hashim, A.H., 2002. Practices, attitudes and motives for domestic waste recycling. Int. J. Sustain. Dev. World Ecol. 9 (3), 232–238.

Agranoff, R., McGuire, M., 2003. Collaborative Public Management: New Strategies for Local Governments. Georgetown University Press.

Ak, N., Demirbas, A., 2016. Promising sources of energy in the near future. Energy Sources, Part A Recovery, Util. Environ. Eff. 38 (12), 1730–1738.

Abdel-Shafy, H.I., Mansour, M.S., 2018. Solid waste issue: sources, composition, disposal, recycling, and valorization. Egypt J. Petrol. 27 (4), 1275–1290.

Ali, Y., Jokhio, D.H., Dojki, A.A., Rehman, O.U., Khan, F., Salman, A., 2021. Adoption of Circular Economy for Food Waste Management in the Context of a Developing Country. Waste Management and Research, 0734242X211038198.

Buenrostro, O., Bocco, G., 2003. Solid waste management in municipalities in Mexico: goals and perspectives. Resour. Conserv. Recycl. 39 (3), 251–263.

Booker, J.R., Brachman, R., Quigley, R.M., Rowe, R.K., 2004. Barrier Systems for Waste Disposal Facilities. Crc Press.

Bayr, S., Rantanen, M., Kaparaju, P., Rintala, J., 2012. Mesophilic and thermophilic anaerobic co-digestion of rendering plant and slaughterhouse wastes. Bioresour. Technol. 104, 28–36.

Buratti, C., Barbanera, M., Testarmata, F., Fantozzi, F., 2015. Life Cycle Assessment of organic waste management strategies: an Italian case study. J. Clean. Prod. 89, 125–136.
Borrello, M., Caracciolo, F., Lombardi, A., Pascucci, S., Cembalo, L., 2017. Consumers' perspective on circular economy strategy for reducing food waste. Sustainability 9 (1), 141.
Bányai, T., Tamás, P., Illés, B., Stankevičiūtė, Ž., Bányai, Á., 2019. Optimization of municipal waste collection routing: impact of industry 4.0 technologies on environmental awareness and sustainability. Int. J. Environ. Res. Publ. Health 16 (4), 634.
Bui, T.D., Tsai, F.M., Tseng, M.L., Ali, M.H., 2020. Identifying sustainable solid waste management barriers in practice using the fuzzy Delphi method. Resour. Conserv. Recycl. 154, 104625.
Chongrak, P., 1996. Organic Waste Recycling: Technology and Management. Environmental Engineering and Management Field Asian Institute of Technology Bangkok Thailand. *Published by* IWA Publishing, Alliance House, p. 12.
Colombo, B., Favini, F., Scaglia, B., Sciarria, T.P., D'Imporzano, G., Pognani, M., Adani, F., 2017. Enhanced polyhydroxyalkanoate (PHA) production from the organic fraction of municipal solid waste by using mixed microbial culture. Biotechnol. Biofuels 10 (1), 1–15.
Chauhan, A., Singh, A., Jharkharia, S., 2018. An interpretive structural modeling (ISM) and decision-making trail and evaluation laboratory (DEMATEL) method approach for the analysis of barriers of waste recycling in India. J. Air Waste Manag. Assoc. 68 (2), 100–110.
Coban, A., Ertis, I.F., Cavdaroglu, N.A., 2018. Municipal solid waste management via multi-criteria decision making methods: a case study in Istanbul, Turkey. J. Clean. Prod. 180, 159–167.
Cesaro, A., Belgiorno, V., Siciliano, A., Guida, M., 2019. The sustainable recovery of the organic fraction of municipal solid waste by integrated ozonation and anaerobic digestion. Resour. Conserv. Recycl. 141, 390–397.
Demirbas, A., 2008. Biomethanol production from organic waste materials. *Energy Sources* Part A 30 (6), 565–572.
Desa, A., Ba'yah Abd Kadir, N., Yusooff, F., 2012. Waste education and awareness strategy: towards solid waste management (SWM) program at UKM. Proc. Social Behave. Sci. 59, 47–50.
De Feo, G., De Gisi, S., 2014. Using MCDA and GIS for hazardous waste landfill siting considering land scarcity for waste disposal. Waste Manag. 34 (11), 2225–2238.
Deng, Q., Liu, X., Liao, H., 2015. Identifying critical factors in the eco-efficiency of remanufacturing based on the fuzzy DEMATEL method. Sustainability 7 (11), 15527–15547.
Dhar, H., Kumar, S., Kumar, R., 2017. A review on organic waste to energy systems in India. Bioresour. Technol. 245, 1229–1237.
El-Fadel, M., Massoud, M., 2000. Emissions from landfills: a methodology comparative assessment. Environ. Technol. 21 (9), 965–978.
Ekmekçioğlu, M., Kaya, T., Kahraman, C., 2010. Fuzzy multicriteria disposal method and site selection for municipal solid waste. Waste Manag. 30 (8–9), 1729–1736.
Edwards, J., Othman, M., Crossin, E., Burn, S., 2017. Life cycle inventory and mass-balance of municipal food waste management systems: decision support methods beyond the waste hierarchy. Waste Manag. 69, 577–591.
Eden, M., Gerke, H.H., Houot, S., 2017. Organic waste recycling in agriculture and related effects on soil water retention and plant available water: a review. Agron. Sustain. Dev. 37 (2), 11.
Gumus, A.T., 2009. Evaluation of hazardous waste transportation firms by using a two-step fuzzy-AHP and TOPSIS methodology. Expert Syst. Appl. 36 (2), 4067–4074.
Gandhi, S., Mangla, S.K., Kumar, P., Kumar, D., 2015. Evaluating factors in implementation of successful green supply chain management using DEMATEL: a case study. Int. Strat. Manage. Rev. 3 (1–2), 96–109.
Hung, M.L., Ma, H.W., Yang, W.F., 2007. A novel sustainable decision making model for municipal solid waste management. Waste Manag. 27 (2), 209–219.
Hettiarachchi, H., Meegoda, J.N., Ryu, S., 2018. Organic waste buyback as a viable method to enhance sustainable municipal solid waste management in developing countries. Int. J. Environ. Res. Publ. Health 15 (11), 2483.
Idris, A., Inanc, B., Hassan, M.N., 2004. Overview of waste disposal and landfills/dumps in Asian countries. J. Mater. Cycles Waste Manag. 6 (2), 104–110.
Ju, X., Zhang, F., Bao, X., Römheld, V., Roelcke, M., 2005. Utilization and management of organic wastes in Chinese agriculture: past, present and perspectives. Sci. China C Life Sci. 48 (2), 965–979.
Joseph, K., 2006. Stakeholder participation for sustainable waste management. Habitat Int. 30 (4), 863–871.
Kumar, S., Bhattacharyya, J.K., Vaidya, A.N., Chakrabarti, T., Devotta, S., Akolkar, A.B., 2009. Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: an insight. Waste Manag. 29 (2), 883–895.
Karnchanawong, S., Suriyanon, N., 2011. Household organic waste composting using bins with different types of passive aeration. Resour. Conserv. Recycl. 55 (5), 548–553.
Khalid, A., Arshad, M., Anjum, M., Mahmood, T., Dawson, L., 2011. The anaerobic digestion of solid organic waste. Waste Manag. 31 (8), 1737–1744.
Kumar, V., Pandit, R.K., 2013. Problems of solid waste management in Indian cities. Int. J. Sci. Res. Pub. 3 (3), 1–9.
Kumar, A., Kumar, N., Baredar, P., Shukla, A., 2015. A review on biomass energy resources, potential, conversion and policy in India. Renew. Sustain. Energy Rev. 45, 530–539.
Kumar, S., Smith, S.R., Fowler, G., Velis, C., Kumar, S.J., Arya, S., Cheeseman, C., 2017. Challenges and opportunities associated with waste management in India. R. Soc. Open Sci. 4 (3), 160764.
Kiani Mavi, R., Standing, C., 2018. Cause and effect analysis of business intelligence (BI) benefits with fuzzy DEMATEL. Knowl. Manag. Res. Pract. 16 (2), 245–257.
Kazancoglu, Y., Ozkan-Ozen, Y.D., Ozbiltekin, M., 2018. Minimizing losses in milk supply chain with sustainability: an example from an emerging economy. Resour. Conserv. Recycl. 139, 270–279.
Kala, K., Bolia, N.B., 2020. Waste management communication policy for effective citizen awareness. J. Pol. Model. 42 (3), 661–678.
Kumar, A., Mangla, S.K., Kumar, P., 2022. An Integrated Literature Review on Sustainable Food Supply Chains: Exploring Research Themes and Future Directions. Science of the Total Environment, 153411.
Kharola, S., Ram, M., Mangla, S.K., Goyal, N., Nautiyal, O.P., Pant, D., Kazancoglu, Y., 2022. Exploring the green waste management problem in food supply chains: a circular economy context. J. Clean. Prod., 131355
Lay, J.J., Li, Y.Y., Noike, T., Endo, J., Ishimoto, S., 1997. Analysis of environmental factors affecting methane production from high-solids organic waste. Water Sci. Technol. 36 (6–7), 493–500.
Lin, L., Xu, F., Ge, X., Li, Y., 2018. Improving the sustainability of organic waste management practices in the food-energy-water nexus: a comparative review of anaerobic digestion and composting. Renew. Sustain. Energy Rev. 89, 151–167.
Luthra, S., Mangla, S.K., Shankar, R., Prakash Garg, C., Jakhar, S., 2018. Modelling critical success factors for sustainability initiatives in supply chains in Indian context using Grey-DEMATEL. Prod. Plann. Control 29 (9), 705–728.
Manfredi, S., Tonini, D., Christensen, T.H., Scharff, H., 2009. Landfilling of waste: accounting of greenhouse gases and global warming contributions. Waste Manag. Res. 27 (8), 825–836.
Mir, M.A., Ghazvinei, P.T., Sulaiman, N.M.N., Basri, N.E.A., Saheri, S., Mahmood, N.Z., Aghamohammadi, N., 2016. Application of TOPSIS and VIKOR improved versions in a multi criteria decision analysis to develop an optimized municipal solid waste management model. J. Environ. Manag. 166, 109–115.
Mangla, S.K., Luthra, S., Mishra, N., Singh, A., Rana, N.P., Dora, M., Dwivedi, Y., 2018. Barriers to effective circular supply chain management in a developing country context. Prod. Plann. Control 29 (6), 551–569.
Michelini, L., Principato, L., Iasevoli, G., 2018. Understanding food sharing models to tackle sustainability challenges. Ecol. Econ. 145, 205–217.
Mu'azu, N.D., Blaisi, N.I., Naji, A.A., Abdel-Magid, I.M., AlQahtany, A., 2019. Food waste management current practices and sustainable future approaches: a Saudi Arabian perspectives. J. Mater. Cycles Waste Manag. 21 (3), 678–690.
Mangla, S.K., Bhattacharya, A., Yadav, A.K., Sharma, Y.K., Ishizaka, A., Luthra, S., Chakraborty, R., 2021. A framework to assess the challenges to food safety initiatives in an emerging economy. J. Clean. Prod. 284, 124709.
Ng, K.S., Yang, A., Yakovleva, N., 2019. Sustainable waste management through synergistic utilisation of commercial and domestic organic waste for efficient resource recovery and valorisation in the UK. J. Clean. Prod. 227, 248–262.
Opricovic, S., Tzeng, G.H., 2003. Defuzzification within a multicriteria decision model. Int. J. Uncertain. Fuzziness Knowledge-Based Syst. 11, 635–652, 05.
Omer, A.M., 2007. Organic waste treatment for power production and energy supply. J. Cell Anim. Biol. 1 (3), 034-047.
Odlare, M., Arthurson, V., Pell, M., Svensson, K., Nehrenheim, E., Abubaker, J., 2011. Land application of organic waste–effects on the soil ecosystem. Appl. Energy 88 (6), 2210–2218.
Pai, R.R., Rodrigues, L.L., Mathew, A.O., Hebbar, S., 2014. Impact of urbanization on municipal solid waste management: a system dynamics approach. Int. J. Renewable Energy Environ. Eng. 2 (1), 31–37.
Pickering, G.J., Pickering, H.M., Northcotte, A., Habermebl, C., 2020. Participation in residential organic waste diversion programs: motivators and optimizing educational messaging. Resour. Conserv. Recycl. 158, 104807.
Rouse, C.J., 2008. Planning for sustainable municipal solid waste management. Appropr. Technol. 35 (3), 65.
Singh, J., Ordoñez, I., 2016. Resource recovery from post-consumer waste: important lessons for the upcoming circular economy. J. Clean. Prod. 134, 342–353.
Salemdeeb, R., Zu Ermgassen, E.K., Kim, M.H., Balmford, A., Al-Tabbaa, A., 2017. Environmental and health impacts of using food waste as animal feed: a comparative analysis of food waste management options. J. Clean. Prod. 140, 871–880.
Seker, S., Zavadskas, E.K., 2017. Application of fuzzy DEMATEL method for analyzing occupational risks on construction sites. Sustainability 9 (11), 2083.
Shukor, J.A., Omar, M.F., Kasim, M.M., Jamaludin, M.H., Naim, M.A., 2018. Assessment of composting technologies for organic waste management. J. *Assessment.* 9 (8).
Speier, C.J., Mondal, M.M., Weichgrebe, D., 2018. Evaluation of compositional characteristics of organic waste shares in municipal solid waste in fast-growing metropolitan cities of India. J. Mater. Cycles Waste Manag. 20 (4), 2150–2162.
Satapathy, S., Garanaik, A., Kumar, S., 2018. Prioritising the barriers of waste management as per Indian perspective by PROMETHEE II and VIKOR methods. Int. J. Serv. Oper. Manag. 29 (4), 462–486.
Sharma, B., Vaish, B., Singh, U.K., Singh, P., Singh, R.P., 2019. Recycling of organic wastes in agriculture: an environmental perspective. Int. J. Environ. Res. 13 (2), 409–429.
Shahnazari, A., Rafiee, M., Rohani, A., Nagar, B.B., Ebrahiminik, M.A., Aghkhani, M.H., 2020. Identification of effective factors to select energy recovery technologies from municipal solid waste using multi-criteria decision making (MCDM): a review of thermochemical technologies. Sustain. Energy Technol. Assessments 40, 100737.
Sharma, M., Joshi, S., Kannan, D., Govindan, K., Singh, R., Purohit, H.C., 2020. Internet of Things (IoT) adoption barriers of smart cities' waste management: an Indian context. J. Clean. Prod. 270, 122047.
Taylor, D.C., 2000. Policy incentives to minimize generation of municipal solid waste. Waste Manag. Res. 18 (5), 406–419.

The World Bank/IBRD.IDA. 2022. What a waste 2.0. https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html (accessed 10 March 2022).

Tucker, P., Speirs, D., 2003. Attitudes and behavioural change in household waste management behaviours. J. Environ. Plann. Manag. 46 (2), 289–307.

Tseng, M.L., 2009. Application of ANP and DEMATEL to evaluate the decision-making of municipal solid waste management in Metro Manila. Environ. Monit. Assess. 156 (1), 181–197.

Troschinetz, A.M., Mihelcic, J.R., 2009. Sustainable recycling of municipal solid waste in developing countries. Waste Manag. 29 (2), 915–923.

Tuck, C.O., Pérez, E., Horváth, I.T., Sheldon, R.A., Poliakoff, M., 2012. Valorization of biomass: deriving more value from waste. Science 337 (6095), 695–699.

Thi, N.B.D., Kumar, G., Lin, C.Y., 2015. An overview of food waste management in developing countries: current status and future perspective. J. Environ. Manag. 157, 220–229.

Vego, G., Kučar-Dragičević, S., Koprivanac, N., 2008. Application of multi-criteria decision-making on strategic municipal solid waste management in Dalmatia, Croatia. Waste Manag. 28 (11), 2192–2201.

Veleva, V., Bodkin, G., Todorova, S., 2017. The need for better measurement and employee engagement to advance a circular economy: lessons from Biogen's "zero waste" journey. J. Clean. Prod. 154, 517–529.

Villalba, L., Donalisio, R.S., Basualdo, N.E.C., Noriega, R.B., 2020. Household solid waste characterization in Tandil (Argentina): socioeconomic, institutional, temporal and cultural aspects influencing waste quantity and composition. Resour. Conserv. Recycl. 152, 104530.

Wiedemann, P.M., Femers, S., 1993. Public participation in waste management decision making: analysis and management of conflicts. J. Hazard Mater. 33 (3), 355–368.

Westerman, P.W., Bicudo, J.R., 2005. Management considerations for organic waste use in agriculture. Bioresour. Technol. 96 (2), 215–221.

Woon, K.S., Lo, I.M., 2016. A proposed framework of food waste collection and recycling for renewable biogas fuel production in Hong Kong. Waste Manag. 47, 3–10.

Xiao, S., Dong, H., Geng, Y., Brander, M., 2018. An overview of China's recyclable waste recycling and recommendations for integrated solutions. Resour. Conserv. Recycl. 134, 112–120.

Yukalang, N., Clarke, B., Ross, K., 2017. Barriers to effective municipal solid waste management in a rapidly urbanizing area in Thailand. Int. J. Environ. Res. Publ. Health 14 (9), 1013.

Zadeh, L.A., 1978. Fuzzy sets as a basis for a theory of possibility. Fuzzy Set Syst. 1 (1), 3–28.