Journal of Modelling in Manag

Modeling and analysing the barriers to the acceptance of energy-efficient appliances using an ISM-DEMATEL approach

Journal:	*Journal of Modelling in Management*
Manuscript ID	JM2-02-2022-0064.R1
Manuscript Type:	Original Article
Keywords:	Modelling, Decision making, Management, Energy

Modeling and analysing the barriers to the acceptance of energy-efficient appliances using an ISM-DEMATEL approach

Abstract

Purpose – Electricity savings from energy-efficient appliances (EEAs) may have a significant impact on reducing global warming. There are several barriers confronted by EEAs, which have lowered their acceptance rate. The current study identifies and highlights key barriers to strengthening domestic sector adoption of EEAs in developing countries.

Design/methodology/approach - In the current study, thirteen barriers were discovered by an in-depth literature review and the judgement of experts as well. Further, integrated "Interpretive Structural Modeling" (ISM) and "Decision Making Trial and Evaluation Laboratory" (DEMATEL) approaches are utilized to evaluate barriers. The ISM technique is implemented to categorize barriers into distinct hierarchy levels, and "Cross-Impact Matrix Multiplication Applied to Classification" (MICMAC) analysis to divide barriers among four clusters "independent, linkage, dependent, and autonomous". Moreover, the DEMATEL methodology is applied to classify the barriers among cause and effect clusters.

Findings – The integrated ISM and DEMATEL approach suggests that the topmost influencing barriers to the acceptance of EEAs are the lack of Government policies and initiatives, lack of attractive loan financing, and subsidized energy prices.

Practical Implications – This study would help researchers, regulators, producers, policymakers, and consumers to comprehend the need for additional developments and understand that the adoption of EEAs is a current need. Overall, the results of this study expedite stakeholders with the key barriers that may assist to enhance the acceptance of EEAs within the domestic sector.

Originality/Value - An extensive literature survey showed a dearth of studies for the identification, modeling, and analysis of barriers collectively. Therefore, the current work utilized the ISM and DEMATEL approaches to fill the gap and to provide more comprehensive knowledge on barriers related to the acceptance of EEA.

Keywords: Energy-efficient appliances; Barriers; Modeling; ISM; and DEMATEL.

Paper Type - Research paper

1. Introduction

In the current scenario, electrical appliances have become an integral part of human life. The increased usage of appliances has made life easier and more comfortable, but on the other hand, they are responsible for the higher consumption of non-renewable resources. Also, their increased usage is accountable for global warming, which ultimately affects nature and the health of human beings. As per the prediction of Fawzy *et al.* (2020) the earth's climate is likely to rise about 1.5 degrees Celsius between the years 2030 and 2052 if companies and societies, in general, continue to use the same business models and practices. Furthermore, if the global average temperature increases by more than 2°C, people may suffer irreversible or permanent effects. The usage of electrical appliances is not only limited to the industrial segment but also the domestic sector is a big contributor. Due to the continuous increase in global population and energy demand, the domestic sector is considered a key area through which reduction in global warming can be attained with Energy-efficient appliances (EEAs).

With modernization, it is difficult to conceive households without appliances like refrigerators and air conditioners. It is evident that these two devices utilize a major portion of energy in households (Mahlia and Saidur, 2010). Therefore, enhancing the efficiency of energy-intensive appliances and their usage in the domestic market can be a major step toward decreasing energy consumption and avoiding global warming. Also, this will help nations in meeting their ever-growing energy demands owing to rapid economic growth.

Various countries have already started to follow the energy labels and the usage of EEAs, but in developing countries, consumers are not appreciating the context (UNIDO, 2020). It may be due to unawareness, unavailability or high cost of EEAs and unwillingness to accept changes in already used appliances. The adoption and consumption of EEAs in underdeveloped countries are surrounded by a large number of barriers. In this situation, regulators, policymakers, and producers need to develop and implement programmes that will allow the household sector to embrace energy-efficient products by removing these barriers.

In order to remove the barriers to the adoption of EEAs, it is necessary to explore them and arrange them in a hierarchical structure to understand which barriers have the strongest impact and/or dependence on other barriers. The present research work aims to understand and prioritize the barriers to help industrialists and policymakers in recognizing the interaction and main effects of barriers on the acceptance of EEAs. Thus, the study addresses the following research questions:

i. To identify the key barriers in the path to the acceptance of EEAs?
ii. To evaluate the mutual relationships among these barriers by using the Interpretive Structural Modelling technique.
iii. To classify the barriers in cause and effect groups by using the DEMATEL approach.

The interlinkage between the impediments makes the study more intricate and challenging unless impediments have not been organized hierarchically, which is an uphill act (Kumar and Dixit, 2018). Numerous strategies have been developed to address the inequality that occurs when the interrelationships between the barriers are not considered during the judgement process. In this regard, the techniques adopted are “Interpretive Structural Modeling” (ISM), “Decision Making Trial and Evaluation Laboratory” (DEMATEL) along with “Analytical Network Process” (ANP). Though ANP is applied successfully in various researches, however, the interlinkages in those researches are not flawless owing to the complexity of eliminating the possibilities of interconnection inside the criteria (Wu, 2008). Hence, the selection of a suitable technique is very critical in determining the solution to the present problem. In this context, ISM and DEMATEL approaches have been selected to determine interrelationships and hierarchical structure among the identified barriers (Chauhan *et al.*, 2016, dos Muchangos *et al.*, 2015, Raeesi *et al.*, 2013, Wang *et al.*, 2018). The ISM approach is used for determining contextual relationships and hierarchal order amongst impediments. Moreover, the “Cross-Impact Matrix Multiplication Applied to Classification” (MICMAC) approach is used for dividing the impediments among “independent, linkage, dependent, and autonomous” clusters. The DEMATEL approach divides the impediments among “cause and effect categories”. By using these techniques, a more determined approach to enhance the penetration of energy-saving devices in developing economies may be developed. The present study will provide constructive suggestions for future work by evolving efficient tactics for effective evaluation of the constraints in the acceptance of EEAs in the domestic sector.

The current research is organized into six segments, the first of which is the introduction. The second section is an overview of literature pertaining to EEAs, followed by a discussion of the research gap. The study's methodologies are discussed in section 3. The application of techniques employed in this work is elaborated in section 4. Additionally, section 5 of the paper explains the results of the current study along with their implications. The study's conclusions, shortcomings, and future scope are discussed in the sixth section of the article.

2. Literature review

Any country's economic progress is built on a number of pillars, one of which is energy. Rapid economic development and growing energy demand in developing nations such as India have resulted in families consuming the second biggest amount of energy after industry (Singh *et al.*, 2019). With increasing energy usage, there will be energy scarcity and global warming. As a result, developing economies must emphasize energy efficiency to ensure their prosperity and social/economic development. The discussion of the relevant literature and the articulation of the research gap addressed through the present research is introduced in the following sections:

2.1. Energy Efficient Appliances (EEAs)

EEAs are energy-efficient devices that require less energy to do the same task as traditional devices. Although EEAs have existed in developing countries for a long period, their market share remains minimal owing to many impediments (UNIDO, 2020). The impediments identified in earlier research to the acceptance of EEAs were social, economic, structural, and institutional behavior (Hesselink and Chappin, 2019, Alyousef and Varnham, 2010, Baldini *et al.*, 2018). Energy audits, subsidies, feedback, etc. can remove the barriers to the adoption of energy-efficient equipment (Cattaneo, 2019). Harun *et al.* (2022) studied the buying of energy-efficient appliances by consumers (EEAs). From the standpoint of consumer behaviour, the implementation of EEA would lessen the negative effects on the environment. Parveen and Chaudhary (2022) influenced customer purchasing intentions for energy-efficient items as consumer buying patterns for energy-efficient products have a significant role in environmental protection. Mahlia and Saidur (2010) discussed measures, testing, and labels of energy-efficient devices adopted by various developed countries and how these standards can be useful for developing countries. The main factors identified for promoting EEAs were market transformation price reduction and increasing market volume (Birner and Martinot, 2005). The barriers found in past studies for effective implementation of energy-efficient technology in various sectors of India were the uncertainty of savings, non-availability, high initial cost, and lack of awareness. The least awareness of energy labeling was for refrigerators, air conditioners, and electric motors (Reddy and Shrestha, 1998). Park *et al.* (2019) found that energy-efficient technology available in the market for refrigerators of small sizes 50-100 L (although it is costly) may reduce the amount of electricity consumption by 50 to 70%. This reduction in electricity consumption can provide a solution for off-grid using the solar home system as it requires small capacity batteries and panels.

From the manufacturer's perspective, high technical costs and a lack of local availability were noted as significant factors in EEAs. Government incentives and legislation, combined with technical study and extensive testing, may result in benefits for increasing the share of these appliances in the Indian market (Dianshu *et al.*, 2010). There is a high correlation between the barriers to energy adoption in the house (such as belief, family cost, landlord-tenant relationship, etc.) and demographic characteristics (such as martial, sex education, location, etc.). These relationships can be used by policymakers, members, and local governments to eliminate barriers (Pelenur and Cruickshank, 2012). The barriers for energy service companies (ESCos) vary from country to country as we cannot implement the concept and model of developed countries in developing countries (Simsek and Urmee, 2020). Bhadbhade *et al.* (2020) analyzed the ODYSSEE energy efficiency index (ODEX) in every sector of Switzerland and found a 1.4% per annum improvement in energy efficiency for the year between 2000-2016 with households showing the fastest (1.7% per annum) and industry showing the slowest (1.0% per annum). Through life-cycle cost analysis, an improvement of 12 to 60 % in efficiency was observed as a result of EEAs usage in "window air conditioners, freezes, transformers, and motors" (McNeil *et al.*, 2008). In Europe, the expected reduction of residential electricity consumption after mandatory energy labels is up to 0.24% (Aydin and Brounen, 2019).

The increase in energy price and Government incentives prominently affect energy-efficient technology acceptance (Radpour *et al.*, 2017). Wada *et al.* (2012) concluded that a larger rebate is required for the adoption of EEAs, especially in developing countries. The policy change and implementation of minimum efficiency performance standards (MEPS) may accelerate the growth of efficient appliances in the domestic market. The energy labeling of appliances and removing the subsidy from fossil fuels will help in the adoption of EEAs (Kelly, 2012). Through the theory of planned behavior (TPB), it was observed that knowledge of the environment, environmental concern, and subjective norms did not affect purchasers' buying intent for EEAs as compared to perceived behavioral control, moral norm, and attitude (Tan *et al.*, 2017). Multiple price list (MPL) experiments coined that there is a requirement of reducing the household risk burdened (Qiu *et al.*, 2014). It was predicted for India that the use of refrigerators and AC will be increased by 7 and 17 times whereas the population will increase by 22% up to 2030 as compared to stock in 2009. Hence, the use of energy-efficient technologies must be increased as it reduces electricity consumption which in turn lowers the effect of global warming (Parikh and Parikh, 2016). The forthcoming growth of equipment ownership and population housing, proprietorship of buildings versus leases, and the development of awareness movements are the three key points to be considered when making energy-saving policies (Baldini *et al.*, 2018). It was depicted that the provision of subsidy in the domestic sector for the difference in the amount of conventional and EEAs along with an increase in a carbon tax will result in the reduction of CO_2 emissions at a domestic level (Ashina and Nakata, 2008).

2.2.Research gap and objective

Globally, researchers and stakeholders have adopted multiple methods and doing their efforts to reduce global warming, from which promoting the use of EEAs in the residential sector is proven to be an effective method (Parikh and Parikh, 2016). But, the usage of EEAs in the domestic sector is lesser than required for effective results (Hesselink and Chappin, 2019). It may be possible due to the presence of certain dominating factors that are restricting the adoption of EEAs by common people. Considering this fact, various studies related to the benefits of using EEAs, consumer propensities toward EEAs, and the relation of EEAs barriers with demographic characteristics have been conducted (McNeil *et al.*, 2008, Baldini *et al.*, 2018, Pelenur and Cruickshank, 2012). Earlier studies adopted distinct approaches like agent-based modeling, chi-square test, and theory of planned behavior (Hesselink and Chappin, 2019, Tan *et al.*, 2017). We have not yet attained the required results that would aid in effective policymaking and would drive consumers to use EEAs more frequently in the residential sector. Through an exhaustive literature survey, it is found that there is a paucity of collective study for identification, modeling, and analysis of barriers by utilizing approaches like ISM and DEMATEL. Therefore, the discussed research gaps have been utilized as a base for the present work.

3. Research methodology

To achieve the goals, the Delphi method was used to ascertain the barriers. Following, the Delphi method, the ISM and DEMATEL approaches were utilized to establish the connection among barriers. Although less work on integrated ISM and DEMATEL approaches was available, these techniques were chosen because they offer the benefit of effectively helping policymakers in their decision-making (Kumar and Dixit, 2018). Fig. 1 depicts the research framework adopted in the present study. The adopted methodologies are defined in the following sections.

3.1. Exploration of barriers through the Delphi method

For effective use of EEAs in the domestic sector, many vital barriers need to be eliminated. Through an exhaustive literature survey, identification of barriers was accomplished for effective diffusion of EEAs. Alongside, screening of barriers was carried out using the Delphi method.

Delphi is an orderly and qualitative technique of predicting by gathering views from a panel of experts through multiple sessions of questionnaires. It was found through prior research work (Murry Jr and Hammons, 1995) that a panel of ten to thirteen experts is sufficient for applying the Delphi technique. Therefore, a panel of twelve experts, six from academia and six from the energy sector, was selected for conducting the Delphi analysis. After performing multiple rounds of the Delphi technique, thirteen barriers were selected as shown in Table 1. The identified barriers were cost barrier for consumer, lack of consumer awareness, lack of appliance recycling program, lack of reliability, higher maintenance cost, lack of government policies and initiatives, lack of attractive loan financing, subsidized energy price, lack of minimum energy performance standard (MEPS), lack of research and development (R&D), lack of local availability of energy-efficient components, cost barrier for manufacturer and dealer reluctance.

[Insert Table 1 here]

3.2. ISM methodology

In 1973, Warfield (1973) suggested the ISM method to determine the interrelation between factors affecting a given system. These interrelations between factors may elucidate complex problems more appropriately and precisely than when considering factors individually. The ISM method is preferred over other methods as it not only provides the interrelationship among elements but also arranges the elements in a hierarchical manner (Janes, 1988). Therefore, ISM was considered an ideal technique to achieve the goals of the current study. The utilization of the ISM methodology by various researchers is shown in Table 2.

[Insert Table 2 here]

The ISM approach is applied by utilizing the following steps (Jain and Raj, 2015a):

i. List the different barriers influencing the adoption of EEAs.
ii. The relationship between different barriers in four notations is determined through the expert's opinion and this serves as a basis for constructing a "self-interaction matrix" (SSIM).
iii. The "initial reachability matrix" (RM) is established from SSIM. The transitivity criteria are applied to the initial RM to create a final RM.
iv. Different levels of barriers are obtained through partitioning the final RM.
v. A digraph is drawn from different levels and afterwards, transitivity links are removed. Further, the ISM model is created by changing nodes of a digraph to statements.
vi. At last, the conceptual discrepancy in the developed model is examined followed by essential improvements.

3.3.DEMATEL methodology

DEMATEL technique determines the interaction between the barriers through classification in "cause and effect groups" (Farooque *et al.*, 2020). Researchers across a wide range of disciplines have employed the DEMATEL technique (refer to Table 3).

[Insert Table 3 here]

Detailed instructions for the DEMATEL method are provided below.

i. Create "Average Initial Direct Influence Matrix (X)"

DEMATEL technique begins with determining the pair-wise relation between barriers on a scale of 0 to 4 from expert advice. The value 0 indicates no effect, 1 and 2 suggest a very weak and a very weak effect, respectively, while 3 and 4 indicate a strong and a very strong effect. The pair-wise relation among barriers from k^{th} expert advice is represented by the matrix $H^k = [H^k_{ij}]_{n \times n}$ in which the effect of barrier i on barrier j is computed the each matrix's diagonal elements diagonal H^k are assigned 0 value. The matrix X for n number of barriers is a n x n matrix (non–

negative) which is created by equating the pairs and incorporating advice from all experts (E) as shown below:

$$X = [x_{ij}]_{n \times n} = \frac{1}{E}\sum_{k=1}^{E}[H_{ij}^{k}]_{n \times n} \qquad (1)$$

ii. Generate "Normalized Initial Direct Influence Matrix (N)"

The mathematical expression of 'N' is

$$N = X \times f \qquad (2)$$

Where f >0,

$$f = \min_{i,j}\left(\frac{1}{\max_i \sum_{j=1}^{n} x_{ij}}, \frac{1}{\max_j \sum_{i=1}^{n} x_{ij}}\right) \qquad (3)$$

iii. Compute "Total Influence Matrix (T)"

The mathematical expression of 'T' with identity matrix (I) is as follows:

$$T = N(I - N)^{-1} \qquad (4)$$

iv. Develop the casual diagram

The vectors D and R are determined by the addition of rows and columns for each barrier respectively within the total influence matrix and these values are calculated using equations 5, 6, and 7.

$$T = [t_{ij}]_{n \times n} \quad i,j = 1, 2, \ldots\ldots\ldots n \qquad (5)$$

$$D = \left[\sum_{j=1}^{n} t_{ij}\right]_{n \times 1} \qquad (6)$$

$$R = \left[\sum_{i=1}^{n} t_{ij}\right]_{1 \times n} \qquad (7)$$

The horizontal axis vector (D+R) is termed as 'Prominence', which is developed with a summation of D and R. This describes the significance of the criteria. Similarly, the vertical axis (D-R) is called 'Relation' which is developed with subtraction between D and R. The barriers having a positive value of D-R are categorized as cause cluster and negative value of D-R as effect cluster.

4. Results

The primary goal of this research is to investigate the usage of energy-efficient devices in households by analyzing the barriers to their implementation. The following sections present the models and their respective results.

4.1.ISM analysis

The model is evaluated using different steps as indicated below.

i. Creation of self-interaction matrix (SSIM)

Thirteen barriers have been listed through expert opinions in addition to a detailed literature survey. The symbols representing interrelationships among barriers are depicted in Table 4.

[Insert Table 4 here]

The SSIM (refer to Table 5) is created by following the interrelation between barriers shown in Table 4. To develop the significant contextual relationship between barriers, expert advice from the field of the energy sector and academia has been taken. The meaning of the symbols used in Table 5 is indicated below:

- Symbol V indicates that in cell (1, 5), the CB1 barrier influences the CB5 barrier.
- Symbol A indicates that in cell (2, 3), the CB3 barrier influences the CB2 barrier.
- Symbol X indicates that in cell (2, 9), the CB2 and CB9 barriers influence each other.
- Symbol O indicates that in cell (4, 6), the CB4 and CB6 barriers are unrelated.

[Insert Table 5 here]

ii. Development of "reachability matrix (RM)"

Initially, RM has been created by converting symbols used in SSIM to binary digits as shown in Table 6. The rules followed during the conversion are explained below:

- Cell (i, j) having symbol V within SSIM is represented by '1' whereas the corresponding cell (j, i) by '0'.
- Cell (i, j) having symbol A within SSIM is represented by '0' whereas corresponding cell (j, i) by '1'.

- Cell (i, j) having symbol X within SSIM along with corresponding cell (j, i) are represented by '1'.
- Cell (i, j) having symbol O within SSIM along with corresponding cell (j, i) are represented by '0'.

[Insert Table 6 here]

The initially generated RM is transformed into the final RM (refer to Table 7) using the transitivity rule. For instance, barrier (CB3) has a relationship with the barrier (CB2), and barrier (CB2) has a relationship with the barrier (CB4). Then, barriers (CB3) and (CB4) have a relationship too. The symbol used for transitivity is 1*. The driving, as well as dependency power of individual barriers, can be observed in the final RM.

[Insert Table 7 here]

iii. Reachability matrix (RM) partitioning

The "reachability set" (RS) and "antecedent set" (AS) are obtained from the final RM (Warfield, 1974b, Warfield, 1974a, Farris and Sage, 1975). The RS of a given barrier is made up of the barrier itself as well as additional barriers to whom it affects whereas AS of a specified barrier is made up of a selected barrier along with others which are affecting it. The intersection set (IS) is made of those barriers which are found similar in RS and AS. The barriers selected for level I are those whose RS and IS are alike and this formed iteration 1. Similar iterations are performed by removing the barriers obtained at the same level in the previous iteration. The iterations will continue until all barriers are assigned a level number. Table 8 depicts the level of barriers after performing five iterations.

[Insert Table 8 here]

v. ISM model development

A digraph is generated from RM partitioning followed by the removal of transitivity. The nodes of the digraph are changed with element statements to develop a model of ISM. This is depicted in Fig. 2.

[Insert Fig. 2 here]

4.2.MICMAC analysis

The MICMAC technique had been discovered in 1973, and it is applied in union with the ISM methodology (Xu and Zou, 2020). It is comprised of the following steps:

i. For each barrier, driving as well as dependency power are found by summation of binary digits (1 and 1*) of rows and columns respectively (refer to Table 7).

ii. Each barrier is classified into distinct clusters based on "driving and dependence power" (refer to Fig. 3). These distinct clusters are: a dependent cluster indicates a strong dependency but weak driving capability, an autonomous cluster suggests a poor driving as well as dependence capability, a linkage cluster indicates a strong driving and dependency capability, and an independent cluster represents a strong driving and poor dependency capability so barriers in this cluster are termed as 'key barriers' (Mandal and Deshmukh, 1994).

[Insert Fig. 3 here]

4.3 DEMATEL analysis

This methodology has divided barriers among "cause and effect clusters" by DEMATEL methodology which is obtained through the following steps:

i. Matrix 'A' represented by Table 7 is obtained from equation 1.

ii. Equation 2 and 3 along with Table 7 is used to generate Matrix 'N' and it is shown in Table 9.

[Insert Table 9 here]

iii. Equation 4 is used to generate Matrix 'T' and it is shown in Table 10.

[Insert Table 10 here]

iv. The barriers have been placed in "cause and effect clusters" by determining D+R and D-R using equations 5, 6, and 7. Depending upon positive and negative D-R values, the barriers have been listed in the cause and effect cluster respectively, as illustrated in Table 11.

[Insert Table 11 here]

v. Based on prominence and relation, a "cause-effect diagram" is drawn which is depicted in Fig. 4.

[Insert Fig. 4 here]

5. Discussions

The present research conducted a modeling and analysis of the barriers to the acceptance of energy-saving devices in the domestic sector. Thirteen barriers were identified in this context by a comprehensive review of the literature and experts' opinion from industry and academia. Simply identifying the barriers is not enough for business success; their impact and interrelationships must also be studied (Yadav and Desai, 2017). Hence, the ISM and DEMATEL techniques were applied in the present research. A model based on the ISM technique that established the contextual relationships (refer to Table 4) and prioritization among the barriers was developed. The model can aid government and industry officials to take steps in a hierarchical form that may expedite the usage of energy-efficient products. The lack of Government policies and initiatives (CB6) has been considered a key barrier as it appears at the lowermost level in the model as shown in Fig. 2. This key barrier highly influences other barriers, although it is the least affected. Thus, Government policies and initiatives must be closely monitored, analyzed, and revised regularly. Likewise, Dianshu *et al.* (2010) mentioned the dearth of Government policies as well as initiatives as a major impediment to the acceptance of EEAs. The current study further reveals the lack of attractive loan financing (CB7) and subsidized energy price (CB8) as the second most influencing driving barrier in the hierarchy structure of ISM. Similarly, these barriers were also cited as significant roadblocks in the report published by (UNIDO, 2020). After that, the lack of an appliance recycling program (CB3), lack of R&D (CB10), and lack of local availability of energy-efficient components (CB11) need more attention. Barriers such as lack of consumer awareness (CB2) and lack of MEPS (CB9) were found to be at the middle level, possessing a higher driving power than upstream barriers like cost barrier for the manufacturer (CB12), lack of reliability (CB4), and higher maintenance cost (CB5). Therefore, middle-level barriers require more attention than upstream barriers. The influence of middle and upstream barriers will be reduced if the downstream barriers are also diminished. The cost barrier for consumer (CB1) and dealer reluctance (CB13) were positioned, in the model, at the very top. This suggests that they require least attention as these will itself get eliminated if we remove the other barriers.

Through the MICMAC study, the barriers were divided into four clusters: "independent, linked, dependent, and autonomous". Fig. 3 reveals that barriers that lie in the independent cluster are lack of Government policies and initiatives (CB6), lack of attractive loan financing (CB7), subsidized energy price (CB8), lack of R&D (CB10), lack of local availability of energy-efficient components (CB11), and lack of an appliance recycling program (CB3). These barriers, found in the independent cluster, signify a "maximum driving power and minimum dependency". Therefore, these barriers are identified as the most influential among the determined barriers (Raghuvanshi *et al.*, 2017). Lack of consumer awareness (CB2) lies in the linkage cluster, hence it has a "strong driving as well as dependence power". Dependent barriers were lack of MEPS (CB9)**,** cost barrier for the manufacturer (CB12), cost barrier for consumers (CB1), lack of reliability (CB4), dealer reluctance (CB13), and higher maintenance cost (CB5)**.** Dependent barriers strongly depend on each other and also on other barriers due to their weak driving power. It can be deduced from Fig. 3 that no barrier was present in the autonomous category, which implies that all considered barriers are important (Muruganantham *et al.*, 2018).

The DEMATEL analysis contributed to classifying the barriers in cause and effect clusters. The barriers in the cause cluster (refer to Fig. 4) were lack of Government policies (CB6), lack of attractive loan financing (CB7), subsidized energy price (CB8), lack of local availability of energy-efficient components (CB11), lack of R&D (CB10), and lack of appliance recycling program (CB3). These barriers require more attention than other barriers since they have an impact on others. As a result, to implement EEAs successfully, the barriers involved with the cause cluster should be addressed first. Moreover, these barriers were also prominent in the ISM approach. Thus, the findings obtained using the ISM and DEMATEL techniques are reasonably consistent. The barriers in the effect cluster (refer to Fig. 4) were lack of consumer awareness (CB2), lack of MEPS (CB9), higher maintenance cost (CB5), lack of reliability (CB4), cost barrier for the manufacturer (CB12) cost barrier for consumers (CB1), and dealer reluctance (CB13). These barriers require less comparatively attention, as these are influenced by other barriers (Tseng and Lin, 2009).

However, most of the ISM and DEMATEL findings were indistinguishable, there are a few notable differences in this section. For instance, the linkage barrier lack of consumer awareness (CB2) in the MICMAC analysis was categorized under the cause cluster in the DEMATEL analysis. Likewise, the barriers observed at the middle-level in the ISM approach were categorized under the effect cluster in the DEMATEL approach. As suggested earlier, the cause cluster barriers must be given high significance for the successful adoption of EEAs in the domestic sector. Moreover, no barrier was determined as an autonomous barrier in the MICMAC analysis.

6. Implications of the research

The increased adoption of EEAs has a significant impact on the environment and the economy. Environmentally, their use can reduce pollutants in the air while economically they can help in reducing electricity charges and improve energy efficiency. These two factors are critical for the economic and health aspects of a nation. However, EEAs have attained a better penetration in the domestic sector of developed in comparison to developing countries. The main reason behind this is the unwillingness to buy as well as the unawareness of customers of these higher star rating appliances. The research findings can be regarded as a fundamental guideline for stakeholders to enhance the acceptance of EEAs in the domestic sector of developing countries. The barriers to the acceptance of EEAs can be well understood as per their "driving and dependence power". Research scholars can utilize the findings of this study to understand the effect of barriers on the acceptance of EEAs. Policy and decision-makers may utilize the findings to formulate and deploy effective policies and strategies to eliminate the barriers. Policymakers can also encourage consumers to buy more EEAs by implementing policies in the relevant field, giving incentives or subsidies, spreading awareness, and making them understand the benefits of EEAs.

7. Conclusions

The current research paves the way for the successful implementation of EEAs in the domestic sector to attain the goals of reducing global warming and minimising the utilization of natural resources. For the effective acceptance of EEAs, policy and decision-makers need to comprehend the characteristics and interrelationships of barriers associated with it. Thirteen barriers were identified in this context after a thorough analysis of the literature and consultation with experts. The integrated approach of ISM and DEMATEL was critical in determining the influence and structures of barriers. The ISM methodology was a useful technique for determining the relationship between distinct barriers of EEAs. The cost barrier for consumers and dealer reluctance were found at the top level of the developed ISM model, whereas the Government policies and initiatives barrier was found at the lowest level. The barrier identified at the lowermost level of the model was given higher priority due to its more driving and weakest dependence capabilities, which was hierarchically followed by the barriers at other levels. The ISM modeling of barriers contributed to practitioners in better comprehending the leveling and relationships among barriers so that it will enhance the diffusion of EEAs. Furthermore, the MICMAC analysis classified six barriers as independent barriers, one barrier as a linkage barrier, six barriers as dependent barriers, and no barrier as an autonomous barrier. The barriers found as independent barriers influence the whole system so these require more focus in comparison to other barriers. The barriers were also categorized into "cause and effect groups" using the DEMATEL approach. Out of thirteen barriers, six barriers were observed in the cause cluster and remaining in the effect cluster. The barriers observed in the cause group need more attention as compared to other barriers as these are the root causes of the problem. The combined ISM and DEMATEL approach showed that for the effective implementation of EEAs in the residential sector of developing economies like India, the key priority barrier that needs to be addressed first is the lack of Government policies and initiatives, followed by the lack of attractive loan financing and subsidized energy price. These are the most important barriers, as recognized in the literature. Thus, they require more attention from policy and decision-makers as well as researchers.

The rigidity towards the unacceptability of EEAs is not limited to the thirteen barriers included in this study only. Depending on a specific geographical location, the count of barriers may vary. This study can be considered as a basis to work more on the same area to improve the adoption rate of EEAs in domestic sectors of developing countries. The identified barriers can provide a link to finding further barriers and simultaneously the findings can be assessed by a real-world case study. In this study, only the mathematical modeling of barriers has been performed. To validate the model, "structural equation modeling" (SEM) can be used. Also, the modeling is only focused on a qualitative approach. To obtain a deeper insight, a quantitative analysis using graph theory may also be conducted. Research scholars can further work in the field to provide facts and logic to remove the existing barriers.

References

Ajmera, P. and Jain, V. (2019a), "A fuzzy interpretive structural modeling approach for evaluating the factors affecting lean implementation in Indian healthcare industry". *International Journal of Lean Six Sigma*, Vol. 11 No. 2, pp. 376–397.

Ajmera, P. and Jain, V. (2019b), "Modeling the factors affecting the quality of life in diabetic patients in India using total interpretive structural modeling". *Benchmarking: An International Journal*, Vol. 26 No. 3, pp. 951-970.

Ajmera, P. and Jain, V. (2019c), "Modelling the barriers of Health 4.0–the fourth healthcare industrial revolution in India by TISM". *Operations Management Research*, Vol. 12 No. 3, pp. 129–145.

Alyousef, Y. and Varnham, A. (2010), "Saudi Arabia's National Energy Efficiency Programme: description, achievements and way forward". *International journal of low-carbon technologies*, Vol. 5 No. 4, pp. 291-297.

Ashina, S. and Nakata, T. (2008), "Energy-efficiency strategy for CO2 emissions in a residential sector in Japan". *Applied Energy*, Vol. 85 No. 2-3, pp. 101-114.

Aydin, E. and Brounen, D. (2019), "The impact of policy on residential energy consumption". *Energy*, Vol. 169, pp. 115-129.

Baldini, M., Trivella, A. and Wente, J. W. (2018), "The impact of socioeconomic and behavioural factors for purchasing energy efficient household appliances: A case study for Denmark". *Energy Policy*, Vol. 120, pp. 503-513.

Bhadbhade, N., Yilmaz, S., Zuberi, J. S., Eichhammer, W. and Patel, M. K. (2020), "The evolution of energy efficiency in Switzerland in the period 2000–2016". *Energy*, Vol. 191, pp. 116526.

Birner, S. and Martinot, E. (2005), "Promoting energy-efficient products: GEF experience and lessons for market transformation in developing countries". *Energy Policy*, Vol. 33 No. 14, pp. 1765-1779.

Bruegge, C., Carrión-Flores, C. and Pope, J. C. (2016), "Does the housing market value energy efficient homes? Evidence from the energy star program". *Regional Science and Urban Economics*, Vol. 57, pp. 63-76.

Büyüközkan, G. and Güleryüz, S. (2016), "An integrated DEMATEL-ANP approach for renewable energy resources selection in Turkey". *International Journal of Production Economics*, Vol. 182, pp. 435-448.

Cattaneo, C. (2019), "Internal and external barriers to energy efficiency: which role for policy interventions?". *Energy efficiency*, Vol. 12 No. 5, pp. 1293-1311.

Chauhan, R., Singh, T., Thakur, N. and Patnaik, A. (2016), "Optimization of parameters in solar thermal collector provided with impinging air jets based upon preference selection index method". *Renewable Energy*, Vol. 99, pp. 118-126.

Deng, Q., Liu, X. and Liao, H. (2015), "Identifying critical factors in the eco-efficiency of remanufacturing based on the fuzzy DEMATEL method". *Sustainability*, Vol. 7 No. 11, pp. 15527-15547.

Dianshu, F., Sovacool, B. K. and Vu, K. M. (2010), "The barriers to energy efficiency in China: Assessing household electricity savings and consumer behavior in Liaoning Province". *Energy Policy*, Vol. 38 No. 2, pp. 1202-1209.

Dos Muchangos, L. S., Tokai, A. and Hanashima, A. (2015), "Analyzing the structure of barriers to municipal solid waste management policy planning in Maputo city, Mozambique". *Environmental Development*, Vol. 16, pp. 76-89.

Farooque, M., Jain, V., Zhang, A. and Li, Z. (2020), "Fuzzy DEMATEL analysis of barriers to Blockchain-based life cycle assessment in China". *Computers & Industrial Engineering*, Vol. 147, pp. 106684.

Farris, D. and Sage, A. P. (1975), "On the use of interpretive structural modeling for worth assessment". *Computers & Electrical Engineering*, Vol. 2 No. 2, pp. 149-174.

Fawzy, S., Osman, A. I., Doran, J. and Rooney, D. W. (2020), "Strategies for mitigation of climate change: a review". *Environmental Chemistry Letters*, Vol. 18, pp. 2069–2094.

Garg, C. P. (2021), "Modeling the e-waste mitigation strategies using Grey-theory and DEMATEL framework". *Journal of Cleaner Production*, Vol. 281, pp. 124035.

Guan, L., Abbasi, A. and Ryan, M. J. (2020), "Analyzing green building project risk interdependencies using Interpretive Structural Modeling". *Journal of Cleaner Production*, Vol. 256, pp. 120372.

Harun, S. A., Fauzi, M. A. and Sulaiman, N. S. (2022), "Examining consumer's purchasing behavior of energy-efficient appliance through the lenses of theory of planned behavior and environmental factors". *Management of Environmental Quality: An International Journal*, Vol. ahead-of-print No. ahead-of-print.

Hesselink, L. X. and Chappin, E. J. (2019), "Adoption of energy efficient technologies by households–Barriers, policies and agent-based modelling studies". *Renewable and Sustainable Energy Reviews*, Vol. 99, pp. 29-41.

Jain, V. and Ajmera, P. (2018), "Modelling the factors affecting Indian Medical Tourism Sector using Interpretive Structural Modeling". *Benchmarking: An International Journal*, Vol. 25 No. 5, pp. 1461-79.

Jain, V. and Ajmera, P. (2020), "Modelling the enablers of industry 4.0 in the Indian manufacturing industry". *International Journal of Productivity and Performance Management*, Vol. 70 No. 6, pp. 1233-1262.

Jain, V. and Ajmera, P. (2021a), "DEMATEL method for evaluating FMS variables in the Indian manufacturing industry". *International Journal of Process Management and Benchmarking*, Vol. 11 No. 6, pp. 822-838.

Jain, V. and Ajmera, P. (2021b), "Modelling the barriers of Industry 4.0 in India using Fuzzy TISM". *International Journal of Business Performance Management* Vol. ahead-of-print No. ahead-of-print, pp. 1-43.

Jain, V. and Ajmera, P. (2022), "Fuzzy TISM and DEMATEL approach to analyze Lean variables in Indian Healthcare Industry ". *International Journal of Process Management and Benchmarking*, Vol. 12 No. 2, pp. 233-275.

Jain, V. and Raj, T. (2014), "Modelling and analysis of FMS productivity variables by ISM, SEM and GTMA approach". *Frontiers of Mechanical Engineering*, Vol. 9 No. 3, pp. 218-232.

Jain, V. and Raj, T. (2015a), "A hybrid approach using ISM and modified TOPSIS for the evaluation of flexibility in FMS". *International Journal of Industrial and Systems Engineering*, Vol. 19 No. 3, pp. 389–406.

Jain, V. and Raj, T. (2015b), "Modeling and analysis of FMS flexibility factors by TISM and fuzzy MICMAC". *International Journal of System Assurance Engineering and Management*, Vol. 6 No. 3, pp. 350-371.

Jain, V. and Raj, T. (2016), "Modeling and analysis of FMS performance variables by ISM, SEM and GTMA approach". *International Journal of Production Economics*, Vol. 171 No. 1, pp. 84-96.

Jain, V. and Raj, T. (2021), "Study of issues related to constraints in FMS by ISM, fuzzy ISM and TISM". *International Journal of Industrial and Systems Engineering*, Vol. 37 No. 2, pp. 197-221.

Jain, V. and Soni, V. K. (2019), "Modeling and analysis of FMS performance variables by fuzzy TISM". *Journal of Modelling in Management*, Vol. 14 No. 1, pp. 2-30.

Janes, F. (1988), "Interpretive structural modelling: a methodology for structuring complex issues". *Transactions of the Institute of Measurement and Control*, Vol. 10 No. 3, pp. 145-154.

Kaswan, M. S. and Rathi, R. (2019), "Analysis and modeling the enablers of green lean six sigma implementation using interpretive structural modeling". *Journal of cleaner production*, Vol. 231, pp. 1182-1191.

Kelly, G. (2012), "Sustainability at home: Policy measures for energy-efficient appliances". *Renewable and Sustainable Energy Reviews*, Vol. 16 No. 9, pp. 6851-6860.

Khaba, S., Bhar, C. and Ray, A. (2021), "A study on key lean enablers of the coal mining sector using ISM, MICMAC and SEM". *The TQM Journal*, Vol. 33 No. 6, pp. 1281-1305.

Kumar, A. and Dixit, G. (2018), "An analysis of barriers affecting the implementation of e-waste management practices in India: A novel ISM-DEMATEL approach". *Sustainable Production and Consumption*, Vol. 14, pp. 36-52.

Liu, T., Deng, Y. and Chan, F. (2018), "Evidential supplier selection based on DEMATEL and game theory". *International Journal of Fuzzy Systems*, Vol. 20 No. 4, pp. 1321-1333.

Mahlia, T. M. I. and Saidur, R. (2010), "A review on test procedure, energy efficiency standards and energy labels for room air conditioners and refrigerator–freezers". *Renewable and Sustainable Energy Reviews*, Vol. 14 No. 7, pp. 1888-1900.

Mandal, A. and Deshmukh, S. (1994), "Vendor selection using interpretive structural modelling (ISM)". *International Journal of Operations & Production Management*, Vol. 14 No. 6, pp. 52-59.

Mavi, R. K. and Standing, C. (2018), "Critical success factors of sustainable project management in construction: A fuzzy DEMATEL-ANP approach". *Journal of Cleaner Production*, Vol. 194, pp. 751-765.

Mcneil, M. A., Iyer, M., Meyers, S., Letschert, V. E. and Mcmahon, J. E. (2008), "Potential benefits from improved energy efficiency of key electrical products: The case of India". *Energy Policy*, Vol. 36 No. 9, pp. 3467-3476.

Mittal, P., Ajmera, P., Jain, V. and Aggarwal, G. (2021), "Modeling and analysis of barriers in controlling TB: developing countries' perspective". *International Journal of Health Governance*, Vol. 26 No. 4, pp. 362-383.

Murry Jr, J. W. and Hammons, J. O. (1995), "Delphi: A versatile methodology for conducting qualitative research". *The review of higher education*, Vol. 18 No. 4, pp. 423-436.

Muruganantham, G., Vinodh, S., Arun, C. and Ramesh, K. (2018), "Application of interpretive structural modelling for analysing barriers to total quality management practices implementation in the automotive sector". *Total Quality Management & Business Excellence*, Vol. 29 No. 5-6, pp. 524-545.

Nilashi, M., Samad, S., Manaf, A. A., Ahmadi, H., Rashid, T. A., Munshi, A., Almukadi, W., Ibrahim, O. and Ahmed, O. H. (2019), "Factors influencing medical tourism adoption in Malaysia: A DEMATEL-Fuzzy TOPSIS approach". *Computers & Industrial Engineering*, Vol. 137, pp. 106005.

Parikh, K. S. and Parikh, J. K. (2016), "Realizing potential savings of energy and emissions from efficient household appliances in India". *Energy Policy*, Vol. 97, pp. 102-111.

Park, W. Y., Shah, N. and Phadke, A. (2019), "Enabling access to household refrigeration services through cost reductions from energy efficiency improvements". *Energy Efficiency*, Vol. 12 No. 7, pp. 1795-1819.

Parveen, A. and Chaudhary, R. (2022), "Investigating the Purchase Intention Determinants of Energy Efficient Products Using Structural Equation Modelling Analysis". *Vision*, Vol. 0 No. 0, pp. 09722629221101160.

Pelenur, M. J. and Cruickshank, H. J. (2012), "Closing the energy efficiency gap: a study linking demographics with barriers to adopting energy efficiency measures in the home". *Energy*, Vol. 47 No. 1, pp. 348-357.

Potdar, P. K., Routroy, S. and Behera, A. (2017), "Analyzing the agile manufacturing barriers using fuzzy DEMATEL". *Benchmarking: An International Journal*, Vol. 24 No. 7, pp. 1912-1936.

Priya, M. S., Jain, V., Kabiraj, S. and Priya, S. S. (2021), "Modelling the factors affecting global economy during COVID-19 using ISM approach". *International Journal of Services, Economics and Management*, Vol. 12 No. 3, pp. 294–316.

Priya, S. S., Priya, M. S., Jain, V. and Dixit, S. K. (2022), "An assessment of government measures in combatting COVID-19 using ISM and DEMATEL modelling". *Benchmarking: An International Journal*, Vol. 29 No. 5, pp. 1429-1451.

Qiu, Y., Colson, G. and Grebitus, C. (2014), "Risk preferences and purchase of energy-efficient technologies in the residential sector". *Ecological Economics*, Vol. 107, pp. 216-229.

Radpour, S., Mondal, M. a. H. and Kumar, A. (2017), "Market penetration modeling of high energy efficiency appliances in the residential sector". *Energy*, Vol. 134, pp. 951-961.

Raeesi, R., Dastranj, M., Mohammadi, S. and Rasouli, E. (2013), "Understanding the interactions among the barriers to entrepreneurship using interpretive structural modeling". *international Journal of Business and Management*, Vol. 8 No. 13, pp. 56.

Raghuvanshi, J., Ghosh, P., Agrawal, R. and Gupta, H. (2017), "Hierarchical structure for enhancing the innovation in the MSME sector of India". *International Journal of Business Excellence*, Vol. 13 No. 2, pp. 181-199.

Reddy, B. S. and Shrestha, R. M. (1998), "Barriers to the adoption of efficient electricity technologies: a case study of India". *International Journal of Energy Research*, Vol. 22 No. 3, pp. 257-270.

Simsek, Y. and Urmee, T. (2020), "Opportunities and challenges of energy service companies to promote energy efficiency programs in Indonesia". *Energy*, Vol. 205, pp. 117603.

Singh, V. K., Henriques, C. O. and Martins, A. G. (2019), "Assessment of energy-efficient appliances: A review of the technologies and policies in India's residential sector". *Wiley Interdisciplinary Reviews: Energy and Environment*, Vol. 8 No. 3, pp. e330.

Su, C.-M., Horng, D.-J., Tseng, M.-L., Chiu, A. S., Wu, K.-J. and Chen, H.-P. (2016), "Improving sustainable supply chain management using a novel hierarchical grey-DEMATEL approach". *Journal of Cleaner Production*, Vol. 134, pp. 469-481.

Supeekit, T., Somboonwiwat, T. and Kritchanchai, D. (2016), "DEMATEL-modified ANP to evaluate internal hospital supply chain performance". *Computers & Industrial Engineering*, Vol. 102, pp. 318-330.

Tan, C.-S., Ooi, H.-Y. and Goh, Y.-N. (2017), "A moral extension of the theory of planned behavior to predict consumers' purchase intention for energy-efficient household appliances in Malaysia". *Energy Policy*, Vol. 107, pp. 459-471.

Tseng, M.-L. and Lin, Y. H. (2009), "Application of fuzzy DEMATEL to develop a cause and effect model of municipal solid waste management in Metro Manila". *Environmental monitoring and assessment*, Vol. 158 No. 1, pp. 519-533.

Unido 2020. Assessment of incremental capital and operating costs for improved energy efficiency in domestic, commercial and retail refrigeration. https://www.unido.org/sites/default/files/files/2020-07/Guidance%20Report%20on%20net%20benefits%20and%20cost%20for%20different%20energy%20efficient%20refrigeration%20design%20options%20Final%20200720.pdf. Accessed November 5th, 2020.

Wada, K., Akimoto, K., Sano, F., Oda, J. and Homma, T. (2012), "Energy efficiency opportunities in the residential sector and their feasibility". *Energy*, Vol. 48 No. 1, pp. 5-10.

Wang, L., Cao, Q. and Zhou, L. (2018), "Research on the influencing factors in coal mine production safety based on the combination of DEMATEL and ISM". *Safety science*, Vol. 103, pp. 51-61.

Warfield, J. N. (1973), "On arranging elements of a hierarchy in graphic form". *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. No. 2, pp. 121-132.

Warfield, J. N. (1974a), "Developing interconnection matrices in structural modeling". *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. No. 1, pp. 81-87.

Warfield, J. N. (1974b), "Developing subsystem matrices in structural modeling". *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. No. 1, pp. 74-80.

Wu, W.-W. (2008), "Choosing knowledge management strategies by using a combined ANP and DEMATEL approach". *Expert Systems with Applications*, Vol. 35 No. 3, pp. 828-835.

Wu, Y., Liao, M., Hu, M., Lin, J., Zhou, J., Zhang, B. and Xu, C. (2020), "A decision framework of low-speed wind farm projects in hilly areas based on DEMATEL-entropy-TODIM method from the sustainability perspective: A case in China". *Energy*, Vol. 213, pp. 119014.

Xia, X., Govindan, K. and Zhu, Q. (2015), "Analyzing internal barriers for automotive parts remanufacturers in China using grey-DEMATEL approach". *Journal of Cleaner Production*, Vol. 87, pp. 811-825.

Xu, X. and Zou, P. X. (2020), "Analysis of factors and their hierarchical relationships influencing building energy performance using interpretive structural modelling (ISM) approach". *Journal of Cleaner Production*, Vol. 272, pp. 122650.

Yadav, G. and Desai, T. N. (2017), "Analyzing lean six sigma enablers: a hybrid ISM-fuzzy MICMAC approach". *The TQM Journal*, Vol. 29 No. 3, pp. 488-511.

Yang, Z. and Lin, Y. (2020), "The effects of supply chain collaboration on green innovation performance: An interpretive structural modeling analysis". *Sustainable Production and Consumption*, Vol. 23, pp. 1-10.

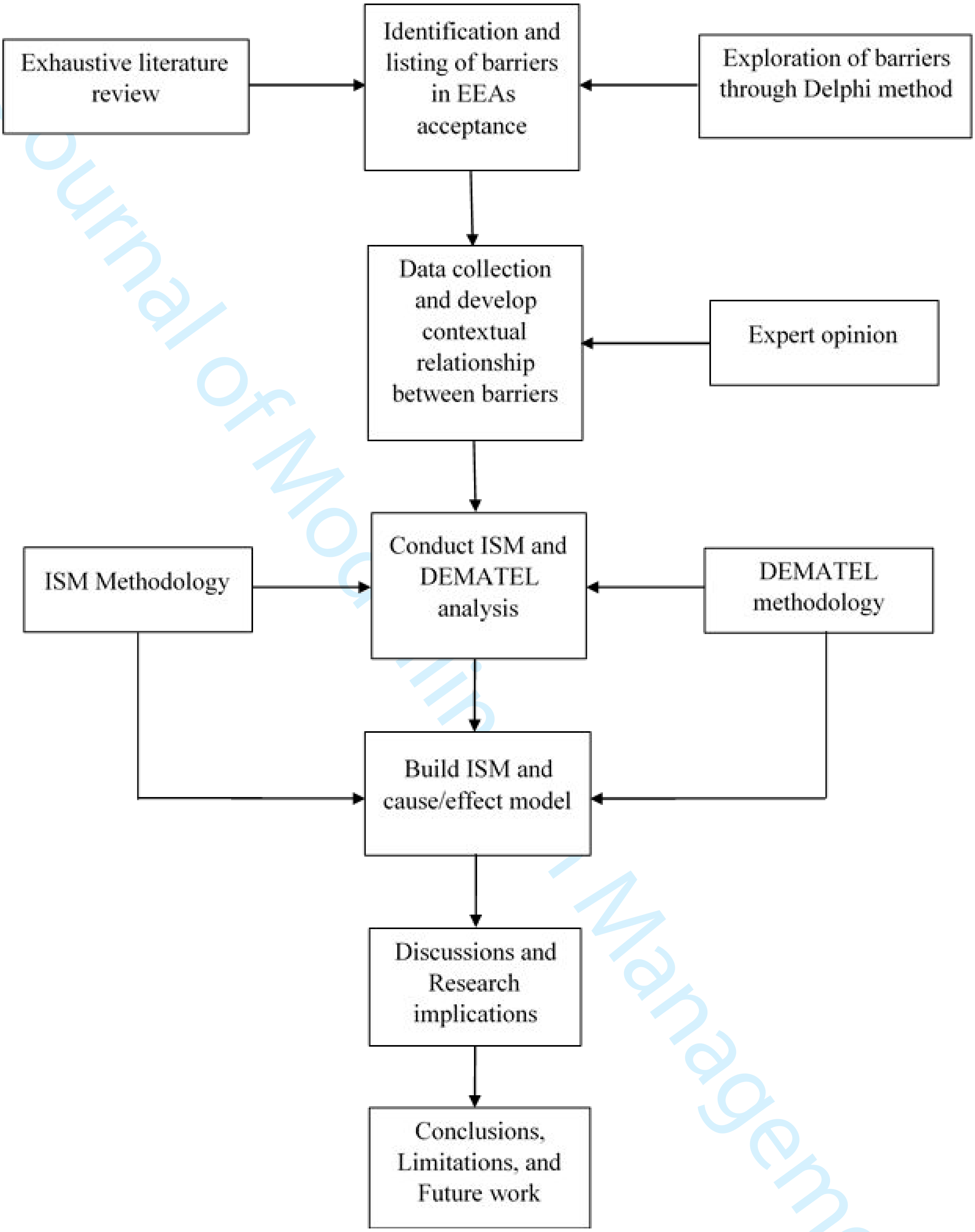

Fig. 1. Proposed research framework

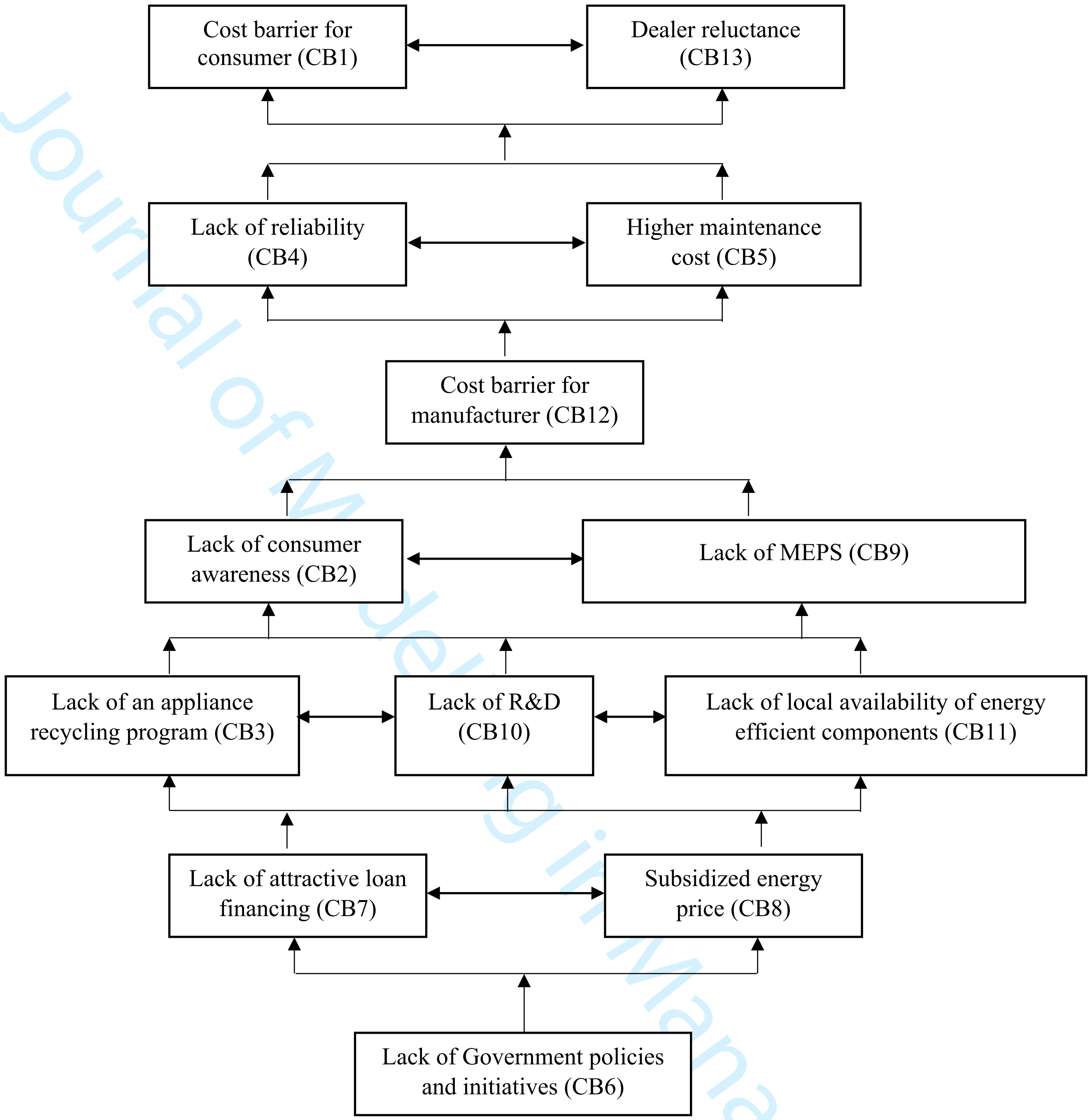

Fig. 2. Barriers influencing the acceptance of energy-efficient appliances (ISM model)

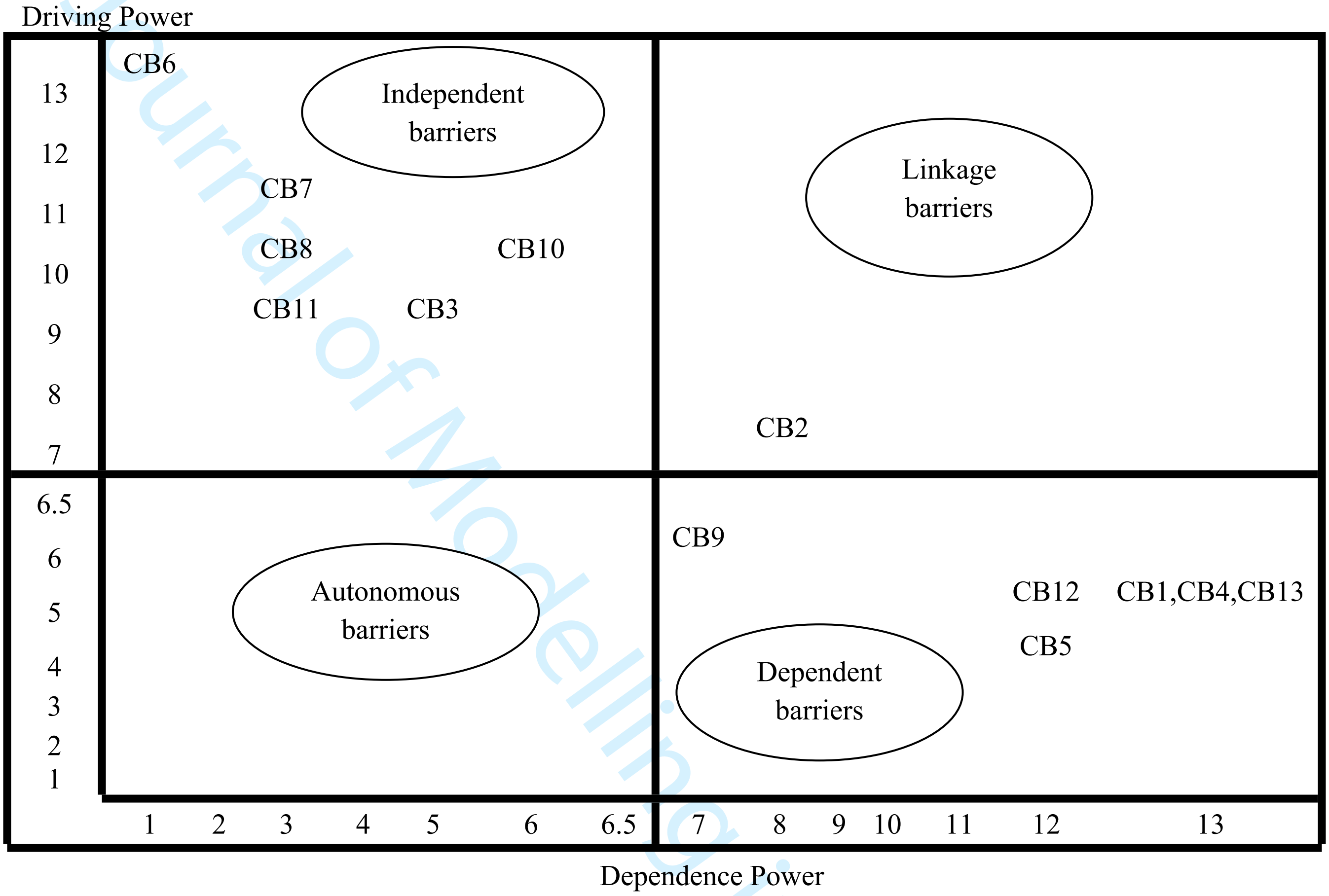

Fig. 3. MICMAC analysis of barriers inflencing the acceptance of energy- efficient appliances.

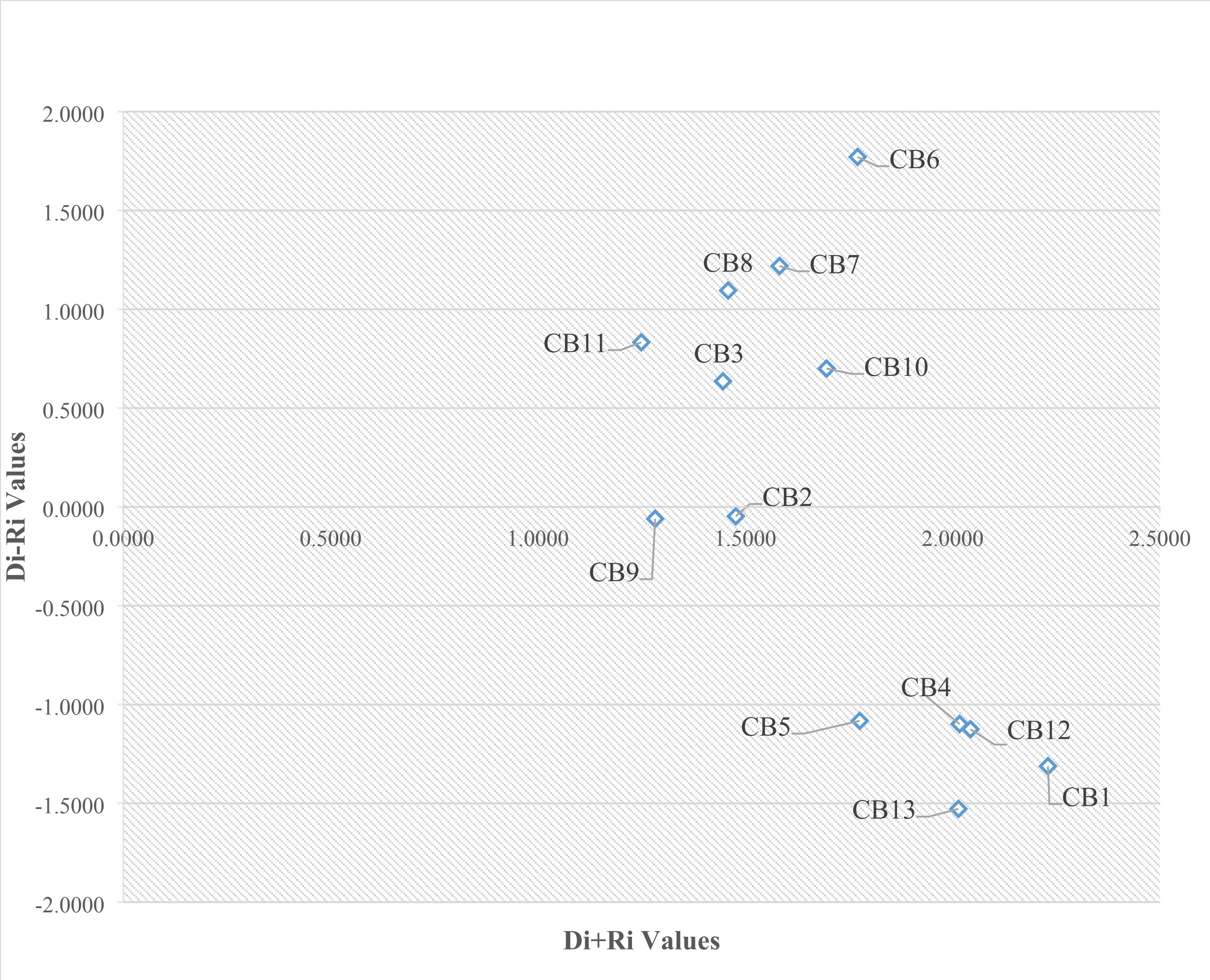

Fig. 4. "Cause and Effect diagram".

Table 1 Barriers to acceptance of EEAs

Barriers Code	Barriers	Barriers Explanation	Source
CB1	Cost barrier for consumer	Many customers are ready to pay a slight premium for energy-efficient appliances in comparison to the market price of similar goods.	UNIDO, 2020; Singh et al. (2019); Hesselink and Chappin (2019); Cattaneo (2019)
CB2	Lack of consumer awareness	Consumers are unaware of the lifecycle economic advantages of energy-efficient appliances, which include environmental benefits and a shorter payback period for the additional cost of the energy-efficient equipment.	UNIDO, 2020; Singh et al. (2019); Hesselink and Chappin (2019); Cattaneo (2019)
CB3	Lack of appliance recycling program	Unlike many developed countries in which older appliances are scrapped or recycled, market research suggests that due to the absence of an appliance recycling scheme, many new buyers in developing countries such as India retained their old appliances.	Hesselink and Chappin (2019); Cattaneo (2019)
CB4	Lack of reliability	Lack of confidence that the appliance will live up to its energy performance/payback promises over time. Certain markets are characterised by an unreliable electric grid or a low penetration of electricity. Consumers in these areas are searching for more dependable refrigerators that can withstand lengthy power outages and/or are unaffected by low power quality.	UNIDO, 2020;Singh et al. (2019); Hesselink and Chappin (2019); Cattaneo (2019)
CB5	Higher maintenance cost	Energy-efficient appliances require higher maintenance costs as they required a trained technician and also, parts are costly.	Bruegge et al. (2016); UNIDO, 2020
CB6	Lack of Government policies and initiatives	Inadequate Government policies and initiatives to spur local production and to create a well-developed eco-system for super-efficient technologies that will help bring down the price of super-efficient technologies	UNIDO, 2020; Singh et al. (2019)
CB7	Lack of attractive loan financing	Non-availability of loan financing with lower interest rates for energy-efficient appliances.	UNIDO, 2020; Singh et al. (2019); Cattaneo

			(2019)
CB8	Subsidized energy price	Due to government subsidies and decreased power costs, consumers have no motivation to save energy. This results in longer payback periods, which is detrimental to the adoption of energy-efficient products.	UNIDO, 2020; Singh et al. (2019)
CB9	Lack of MEPS	In developing countries, there is either an absence or poor implementation of MEPS.	UNIDO, 2020; Hesselink and Chappin (2019)
CB10	Lack of R&D	Inadequate R&D facilities for the development of super-efficient technologies. Most of the local manufacturers lack in R&D required for cost-effective and efficiency improvement in appliances.	UNIDO, 2020; Singh et al. (2019)
CB11	Lack of local availability of energy-efficient components	Non-availability of components that are energy-efficient appliances such as highly efficient compressors and the latest insulation technology is a barrier to widely deploying the best available energy-efficient technologies at a competitive price. The majority, if not all, of the components required to build higher-energy-efficiency goods are imported.	UNIDO, 2020; Singh et al. (2019)
CB12	Cost barrier for manufacturer	Manufacturer's reluctance to produce energy-efficient appliances owing to additional investments required and lower return on investment from the market on these appliances.	Singh et al. (2019); Cattaneo (2019)
CB13	Dealer reluctance	Dealer unwillingness to stock or promote energy-efficient appliances because of market uncertainty for energy-efficient appliances.	UNIDO, 2020

Table 2 ISM applications found in literature

S. No.	Authors	Application
1	Priya et al. (2021)	Government measures
2	Jain and Ajmera (2021)	Barriers of I4.0
3	Jain and Raj (2021)	Constraints of FMS
4	Priya et al. (2021)	Global economy
5	Jain and Ajmera (2020)	Industry 4.0
6	Yang and Lin (2020)	Supply chain Performance
7	Guan et al. (2020)	Green building project risk
8	Khaba et al. (2020)	Coal mining
9	Xu and Zou (2020)	Building energy performance
10	Ajmera and Jain (2019a)	Lean implementation
11	Kaswan and Rathi (2019)	Green lean six sigma
12	Ajmera and Jain (2019b)	Quality of life
13	Jain and Soni (2019)	FMS performance
14	Ajmera and Jain (2019c)	Health 4.0
15	Jain and Ajmera (2018)	Medical Tourism
16	Jain and Raj (2016)	FMS performance
17	Jain and Raj (2015b)	FMS flexibility
18	Jain and Raj (2014)	FMS productivity

Table 3 DEMATEL methodology applications found in literature

S. No.	Authors	Application
1	Mittal et al. (2021)	TB Barriers
2	Jain and Ajmera (2021a)	FMS variables
3	Garg (2021)	E-waste mitigation
4	Jain and Ajmera (2021b)	Lean variables
5	Farooque et al. (2020)	Life cycle assessment
6	Wu et al. (2020)	Wind farm projects
7	Nilashi et al. (2019)	Medical tourism
8	Liu et al. (2018)	Supplier selection
9	Kumar and Dixit (2018)	E-waste management
10	Mavi and Standing (2018)	Project management
11	Potdar et al. (2017)	Agile manufacturing
12	Büyüközkan and Güleryüz (2016)	Renewable energy
13	Supeekit and Somboonwiwat (2016)	Hospital supply chain
14	Su et al. (2016)	Supply chain management
15	Xia et al.(2015)	Automotive parts remanufacturers
16	Deng (2015)	Eco-efficiency of remanufacturing

Table 4 Symbol representation

Symbol	Representation
V	"barrier i" affects to "barrier j"
A	"barrier j" affects to "barrier i"
X	"barriers i and j" affects one other
O	"barriers i and j" are not affected

Table 5 SSIM of barriers

Barriers Code	CB 1	CB 2	CB 3	CB 4	CB 5	CB 6	CB 7	CB 8	CB 9	CB 10	CB 11	CB 12	CB 13
CB 1		A	O	X	V	A	A	A	O	A	A	X	X
CB 2			A	V	O	A	A	O	X	O	O	O	O
CB 3				O	O	A	A	A	O	X	O	O	V
CB 4					A	O	O	O	A	O	A	O	V
CB 5						A	O	O	O	A	A	O	O
CB 6							V	V	V	V	V	V	V
CB 7								X	O	O	O	V	V
CB 8									O	O	O	O	O
CB 9										A	A	V	O
CB 10											X	V	O
CB 11												V	O
CB 12													A
CB 13													

Table 6 Initial RM of barriers

Barriers Code	CB 1	CB 2	CB 3	CB 4	CB 5	CB 6	CB 7	CB 8	CB 9	CB 10	CB 11	CB 12	CB 13
CB 1	1	0	0	1	1	0	0	0	0	0	0	1	1
CB 2	1	1	0	1	0	0	0	0	1	0	0	0	0
CB 3	0	1	1	0	0	0	0	0	0	1	0	0	1
CB 4	1	0	0	1	0	0	0	0	0	0	0	0	1
CB 5	0	0	0	1	1	0	0	0	0	0	0	0	0
CB 6	1	1	1	0	1	1	1	1	1	1	1	1	1
CB 7	1	1	1	0	0	0	1	1	0	0	0	1	1
CB 8	1	0	1	0	0	0	1	1	0	0	0	0	0
CB 9	0	1	0	1	0	0	0	0	1	0	0	1	0
CB 10	1	0	1	0	1	0	0	0	1	1	1	1	0
CB 11	1	0	0	1	1	0	0	0	1	1	1	1	0
CB 12	1	0	0	0	0	0	0	0	0	0	0	1	0
CB 13	1	0	0	0	0	0	0	0	0	0	0	1	1

Table 7 Final RM of barriers

Barriers	CB 1	CB 2	CB 3	CB 4	CB 5	CB 6	CB 7	CB 8	CB 9	CB 10	CB 11	CB 12	CB 13	Driving Power
CB 1	1	0	0	1	1	0	0	0	0	0	0	1	1	5
CB 2	1	1	0	1	1*	0	0	0	1	0	0	1*	1*	7
CB 3	1*	1	1	1*	1*	0	0	0	1*	1	0	1*	1	9
CB 4	1	0	0	1	1*	0	0	0	0	0	0	1*	1	5
CB 5	1*	0	0	1	1	0	0	0	0	0	0	0	1*	4
CB 6	1	1	1	1*	1	1	1	1	1	1	1	1	1	13
CB 7	1	1	1	1*	1*	0	1	1	1*	1*	0	1	1	11
CB 8	1	1*	1	1*	1*	0	1	1	0	1*	0	1*	1*	10
CB 9	1*	1	0	1	0	0	0	0	1	0	0	1	1*	6
CB 10	1	1*	1	1*	1	0	0	0	1	1	1	1	1*	10
CB 11	1	1*	0	1	1	0	0	0	1	1	1	1	1*	9
CB 12	1	0	0	1*	1*	0	0	0	0	0	0	1	1*	5
CB 13	1	0	0	1*	1*	0	0	0	0	0	0	1	1	5
Dependence Power	13	8	5	13	12	1	3	3	7	6	3	12	13	

Table 8 Barriers Level

Barriers Code	Barriers	"Reachability Set"	"Antecedent Set"	"Intersection Set"	"Level"
CB1	Cost barrier for consumer	1,4,5,12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	1,4,5,12,13	I
CB13	Dealer reluctance	1,4,5,12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	1,4,5,12,13	I
CB4	Lack of reliability	4,5,12	2,3,4,5,6,7,8,9,10,11,12	4,5,12	II
CB5	Higher maintenance cost	4,5	2,4,5,6,7,8,9,10,11,12	4,5	II
CB12	Cost barrier for manufacturer	12	2,3,6,7,8,9,10,11,12	12	III
CB2	Lack of consumer awareness	2,9	2,3,6,7,8,9,10,11	2,9	IV
CB9	Lack of MEPS	2,9	2,3,6,7,9,10,11	2,9	IV
CB3	Lack of an appliance recycling program	3,10	3,6,7,8,10	3,10	V
CB10	Lack of R&D	3,10,11	3,6,7,8,10,11	3,10,11	V
CB11	Lack of local Availability of energy-efficient components	10,11	6,10,11	10,11	V
CB7	Lack of attractive loan financing	7,8	6,7,8	7,8	VI
CB8	Subsidized energy price	7,8	6,7,8	7,8	VI
CB6	Lack of Government policies and initiatives	6	6	6	VII

Table 9 Normalized comparison matrix (N)

Barriers Code	CB 1	CB 2	CB 3	CB 4	CB 5	CB 6	CB 7	CB 8	CB 9	CB 10	CB 11	CB 12	CB 13
CB 1	0.00000	0.00000	0.00000	0.08333	0.08333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08333	0.08333
CB 2	0.08333	0.00000	0.00000	0.08333	0.08333	0.00000	0.00000	0.00000	0.08333	0.00000	0.00000	0.08333	0.08333
CB 3	0.08333	0.08333	0.00000	0.08333	0.08333	0.00000	0.00000	0.00000	0.08333	0.08333	0.00000	0.08333	0.08333
CB 4	0.08333	0.00000	0.00000	0.00000	0.08333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08333	0.08333
CB 5	0.08333	0.00000	0.00000	0.08333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08333
CB 6	0.08333	0.08333	0.08333	0.08333	0.08333	0.00000	0.08333	0.08333	0.08333	0.08333	0.08333	0.08333	0.08333
CB 7	0.08333	0.08333	0.08333	0.08333	0.08333	0.00000	0.00000	0.08333	0.08333	0.08333	0.00000	0.08333	0.08333
CB 8	0.08333	0.08333	0.08333	0.08333	0.08333	0.00000	0.08333	0.00000	0.00000	0.08333	0.00000	0.08333	0.08333
CB 9	0.08333	0.08333	0.00000	0.08333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08333	0.08333
CB 10	0.08333	0.08333	0.08333	0.08333	0.08333	0.00000	0.00000	0.00000	0.08333	0.00000	0.08333	0.08333	0.08333
CB 11	0.08333	0.08333	0.00000	0.08333	0.08333	0.00000	0.00000	0.00000	0.08333	0.08333	0.00000	0.08333	0.08333
CB 12	0.08333	0.00000	0.00000	0.08333	0.08333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08333
CB 13	0.08333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08333	0.00000

Table 10 Total influence matrix (T)

Barriers Code	CB 1	CB 2	CB 3	CB 4	CB 5	CB 6	CB 7	CB 8	CB 9	CB 10	CB 11	CB 12	CB 13	Sum
CB 1	0.0353	0.0000	0.0000	0.1036	0.1036	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1043	0.1122	0.4590
CB 2	0.1319	0.0070	0.0000	0.1218	0.1153	0.0000	0.0000	0.0000	0.0839	0.0000	0.0000	0.1230	0.1319	0.7148
CB 3	0.1570	0.0999	0.0070	0.1449	0.1372	0.0000	0.0000	0.0000	0.0999	0.0845	0.0070	0.1464	0.1570	1.0409
CB 4	0.1122	0.0000	0.0000	0.0267	0.1036	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1043	0.1122	0.4590
CB 5	0.1036	0.0000	0.0000	0.0956	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0252	0.1036	0.3468
CB 6	0.2131	0.1356	0.1081	0.1967	0.1869	0.0000	0.0909	0.0909	0.1286	0.1152	0.0929	0.1988	0.2131	1.7709
CB 7	0.1847	0.1174	0.0992	0.1705	0.1619	0.0000	0.0070	0.0839	0.1110	0.0999	0.0083	0.1722	0.1847	1.4007
CB 8	0.1751	0.1110	0.0992	0.1617	0.1591	0.0000	0.0839	0.0070	0.0335	0.0999	0.0083	0.1629	0.1751	1.2768
CB 9	0.1239	0.0839	0.0000	0.1144	0.0369	0.0000	0.0000	0.0000	0.0070	0.0000	0.0000	0.1211	0.1239	0.6112
CB 10	0.1691	0.1076	0.0845	0.1561	0.1478	0.0000	0.0000	0.0000	0.1076	0.0141	0.0845	0.1577	0.1691	1.1979
CB 11	0.1570	0.0999	0.0070	0.1449	0.1372	0.0000	0.0000	0.0000	0.0999	0.0845	0.0070	0.1464	0.1570	1.0409
CB 12	0.1122	0.0000	0.0000	0.1036	0.1036	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0273	0.1122	0.4590
CB 13	0.0956	0.0000	0.0000	0.0173	0.0173	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0943	0.0187	0.2432
Sum	1.7709	0.7622	0.4051	1.5577	1.4291	0.0000	0.1818	0.1818	0.6713	0.4981	0.2082	1.5840	1.7709	

Table 11 Effect and Cause analysis

Barriers Code	Horizontal Axis	Vertical Axis	Effect/Cause
	Di+Ri	Di-Ri	
CB 1	2.2298	-1.3119	Effect
CB 2	1.4770	-0.0473	Effect
CB 3	1.4461	0.6358	Cause
CB 4	2.0167	-1.0987	Effect
CB 5	1.7759	-1.0824	Effect
CB 6	1.7709	1.7709	Cause
CB 7	1.5825	1.2189	Cause
CB 8	1.4586	1.0950	Cause
CB 9	1.2825	-0.0600	Effect
CB 10	1.6960	0.6998	Cause
CB 11	1.2491	0.8327	Cause
CB 12	2.0430	-1.1250	Effect
CB 13	2.0140	-1.5277	Effect