Identify and ranking green manufacturing barriers by using MCDM methods

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Abstract: Green manufacturing operations create the base for building environmentally friendly goods. Especially, manufacturing industries face different barriers and serious problems in the implementation of manufacturing processes. In this article 32 barriers are identified by reviewing the literature review which classified into three perspectives of knowledge, organisational and environmental. 20 experts were asked to rate the dimensions and the barriers by a questionnaire review on the findings of which best worst (BWM) and fuzzy TOPSIS methods are utilised to rank the barriers. The results reveal that the most critical barriers are lack of special policy, support from the government and lack of top management support respectively. The study findings, which provide helpful insight for managers of Iranian manufacturing, can be utilised to form suitable strategies to overcome the barriers.

Keywords: green manufacturing; GM; barriers; best worst method; BWM; fuzzy TOPSIS.

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1 Introduction

Due to fast industrialisation, the consumption of natural resources in the universe is getting consumed rapidly. As a consequence, the world is in a crucial position of facing a critical resource deficiency (Kothawade, 2017). In some situations, environmental difficulties have impacted societies and human health (Tol, 2018). Also, green subject is one of the most controversial and significance issues in the globalisation era. Meanwhile, different aspects of green manufacturing (GM) includes manufacturing processes that concentrate on the minimisation of waste generation and natural resource consumption, warrant the removal of waste entering landfill (Agarwal et al., 2020). Generally, GM is a

conscious process environmentally that diminishes the adverse environmental influence (Paul et al., 2014). In association with this issue, numerous manufacturing industries of different countries have implemented their interest in utilising GM strategies (Alam et al., 2016). GM manners have been utilised as GM strategies through numerous manufacturing industries.

Besides, many of green strategies were developed and combined within the managerial decisions (Soosay et al., 2016; Mittal and Sangwan, 2014). These strategic decisions are crucial actions to protect our planet (Hillary, 2004; Yao et al., 2019; Guyenne et al., 2009). Therefore, GM brings ecological awareness and consciousness in production processes and decisions (Xia et al., 2015; Singh et al., 2018).

Moreover, an important strategy of GM includes obtaining energy from renewable sources, removal and reduction of pollution, recycling, decrement of greenhouse gas and protection of natural resources (Malek and Desai, 2019). Generally, GM includes all different steps of production including research, design and development, logistics, production, sales and distribution and services (Xia et al., 2015; Dornfeld, 2014). This systematic view to GM assists manufacturing industries to economically reduces harmful environmental effects, saves energy, natural assets and develops economics for securing and retain societies, humans (Roscoe et al., 2016; Rehman et al., 2016).

Investigations indicated that most of the manufacturing industries don't have sufficient consciousness on GM issue (Wilman, 2015). A common reason in most cases is lack of prohibiting laws and governmental sensitivity. As a systematic global approach, countries can start with setting strict laws and policies. In developing countries, like Iran, a deeper lack of laws and sensitivity exist. Furthermore, negligible environmental worries of these countries affect the entire world. The context for this article is exactly manufacturing industries in a developing country like Iran. In the Iranian context, the role of manufacturing industries is important in terms of the development of economic. However, to take full benefit of such opportunities, manufacturing industries are forced to meet the stringent environmental laws and implement GM processes. In general, it is deemed that the identification of barriers to GM implementation is a prerequisite for forming suitable strategies for improving GM operations (Ghosh et al., 2018; Kurdve et al., 2014).

Therefore, this article can help manufacturing managers as it identifies the barriers of GM, shows their relationships, classifies and ranks them. It also determines the priority of the barriers by multi-criteria decision making (MCDM) tools (Mittal and Sangwan, 2015). As various barriers limit the implementation of GM processes, a novel integrated MCDM framework mixing best worst method (BWM) and fuzzy TOPSIS methods are utilised to decrease the uncertainty of results (Rezaei, 2016; Chen, 2000). In this study, the BWM and fuzzy TOPSIS methods were used to prioritise the barriers and their classes. Moreover, the sensitivity analysis is conducted to estimate the reasons for the results provides utilising the selected technique. Also, the findings of this article can help manufacturing industries to improve the execution of GM processes. In so doing, the findings of this investigation promoted and comprehend the GM barriers in several manners.

At first, they increase the knowledge of GM in manufacturing industries (Digalwar et al., 2017). Though, concentrated on Iranian manufacturing industries, the conclusions of this investigation can be studied as a reference for different industries in all developing nations as they have similar properties. Secondly, the research provides the literature on GM implementation (Karuppiah et al., 2020). Thirdly, the investigation combines two MCDM methods to identify and analyse the GM barriers. To our information, no prior study has analysed GM barriers through mixing BWM and fuzzy TOPSIS method. It is a novel contribution of this study. More particularly, the research aims to respond to the following investigation questions:

Q1 What are the different barriers to the implementation of GM processes in Iranian manufacturing industries?

Q2 What are the most important barriers in implementing GM processes?

The rest of this study is organised as follows. Section 2 investigates the literature review that plays a major role in data collection. Section 3 describes ranking methods. Section 4 provides the application of the offered framework including identifying and ranking methods. Sections 5 follows by results and discussion. Finally, Section 6 offers managerial implications and concludes the paper.

2 Literature review

The literature review is separate into three sector\s. Firstly, an overview and details of the present endeavour create through scholars in GM of the field. Secondly, this section investigates the barriers to GM in the existing literature. Thirdly, this part presented the gaps and presents the highlights of this paper.

2.1 GM

The energy request increasing and fast consumption of natural resources have enhanced scientist and even consumer consciousness and worries on ecological issues. Meanwhile, GM attitude is vital to reduce the negative effect of human behaviour on environment and to guarantee pollution controlling. In the literature of the GM, Hillary (2004) suggested that existing environmental activities have changed the living and planet. Perron and Duffy (2006) provided an overview of green subjects and attributes involved to remove waste and pollution. Luken and Rompaey (2008) mentioned that these factors such as environmental policies and high production cost are thoroughly significant factors of ecological manufacturing. Moreover, Guyenne et al. (2009) believe that industry must be responsible on ecological aware strategies and policies for activities like manufacturing, environmental services and end-of-life functions.

Sangwan (2011) has investigated the advantages and benefits of GM qualitatively and quantitatively. Singh et al. (2012) studied the barriers of GM activities and created a framework to help the efficient manufacturing process in industries. Mittal et al. (2012) comprehended that stimulants, competitiveness and organisational management are high

ranked criteria rather than other GM criteria. Mittal and Sangwan (2014) discussed the environmental consciousness in terms of the development of barriers and key factors in this field. Mittal and Sangwan (2015) revealed that GM is a global rising issue with the aim of reducing the detrimental impact on the environment and increasing world resource productivity.

Ghazilla et al. (2015) defined GM as the utilisation of ecological and social principles to diminish the negative effect of manufacturing operations. Singh et al. (2015) researched on endeavours to accept GM in India (Singh et al., 2015). Rehman et al. (2016) presented that GM practices have a higher financial impact on organisational performance. Yao et al. (2019) explained GM as a business strategy that emphasis on profitableness by ecologically friendly operating activities to reduce emissions and wastage which leads to decreasing of environmental effect and increasing of resources efficiency.

2.2 Barriers of GM

In the literature, few researchers have focused their consideration to the barriers and stresses of GM. This study emphasise chiefly on organisational, knowledge and environmental barriers. It searched the implementation of the GM process with the providing of important barriers that display them in Table 1.

Figure 1 The framework of barriers for GM

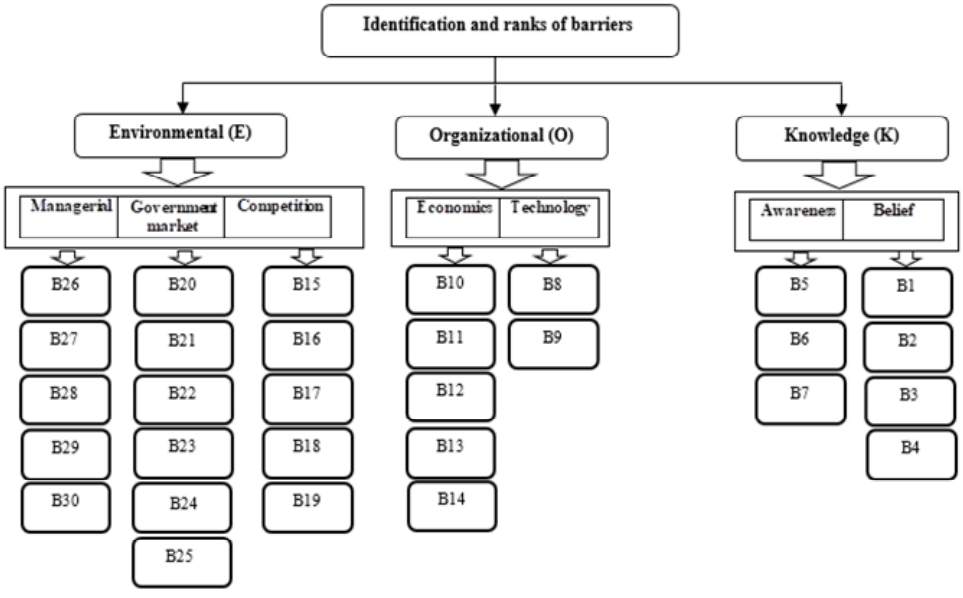


Table 1 Barriers to implement GM

Criteria	*Dimensions*	*Sub-dimensions*	*Explanations*	*References*
Knowledge barriers (IB)	Belief (IBB)	Low belief in environmental benefits of producers, suppliers, consumers, shareholders (IBB1)	It means to difficulties in obtaining GM data and benefits.	Hillary (2004) and Walker et al. (2008)
		Doubts and concerns to become new systems (fears of industry accepting new systems) (IBB2)	It refers to no arising from keeping awareness about modern systems.	Hillary (2004), Walker et al. (2008) and Lai and Wong (2012)
		Absence of responsibility and culture in the organisation (IBB3)	It expresses poor commitment and culture of firms towards GM	Hillary (2004), Walker et al. (2008) and Lai and Wong (2012)
		Lack of awareness of supply chain members use reverse logistics (IBB4)	It donates that no increase information of reverse logistics	Simpson et al. (2004), Geng and Doberstein (2008) and Guyenne et al. (2009)
	Awareness (IBA)	Lack of awareness manufacturers, consumers, suppliers, advisers, counsellors, shareholders of GM (IBA1)	It refers to raise of awareness in this area such as interests and extend sustainability	Geng and Doberstein (2008), Guyenne et al. (2009), Mathiyazhagan (2013), Dube and Gawande (2016) and Sangwan et al. (2014)
		Lack of training courses and consulting services (IBA2)	It shows that no training of courses provided by the firms relate to GM	Ghazilla et al. (2015), Karuppiah et al. (2020) and Sarkis et al. (2010)
		Lack of awareness of the laws and environmental impacts of the organisation's activities (IBA3)	It indicates that no environmental press , protect and guidance in terms of regulatory, financial motivations and policies	Geng and Doberstein (2008) and Guyenne et al. (2009)
Organisational barriers (OB)	Technology (OBT)	Lack of technology, new materials ,and processes (OBT1)	It means no execution technology such as carbon sinks, efficient fuels, consumer, transportation green, industry efficiency, innovation, R&D, etc.	Quayle (2003), Singh et al. (2012) and Mittal and Sangwan (2015)
		Fear of failures and lack of systems infrastructure and scheme is reused or recycled (OBT2)	It refers to inadequate designing and testing within the company to protect GM, additional infrastructure, complexity of design to support GM.	Mittal and Sangwan (2015), Dornfeld et al. (2013), Wong et al. (2016), Hofer et al. (2012) and Ghazilla et al. (2015)
	Economics (OBE)	High investment and low return on investment on GM (OBE1)	It indicates that difficulties in providing financial capital.	Luo et al. (2018), Zhang et al. (2017) and Wakeford et al. (2017)
		High costs for implement GM process and projects (OBE2)	It shows that absences of finance and asset for GM's process and projects.	Luthra et al. (2016), Mangla et al. (2017) and Skjøndal bar (2015) and Neto et al. (2017)
		Concerned about the high cost of packaging environmentally friendly (OBE3)	There is not protect and control the cost of packaging of goods	Govindan et al. (2014), Skjøndal bar (2015) and Mangla et al. (2017)
		Concerned about rising costs of replacing new systems to implement GM processes (OBE4)	It refers to no government not replace new systems for industry-friendly policies toward GM.	Hillary (2004), Diaz et al. (2010) and Fernandez et al. (2003)
		Lack of human resources (OBE5)	It shows lack of well qualified and skillful employees.	Fernandez et al. (2003), Ghazilla et al. (2015), Mittal and Sangwan (2014) and Govindan et al. (2014)

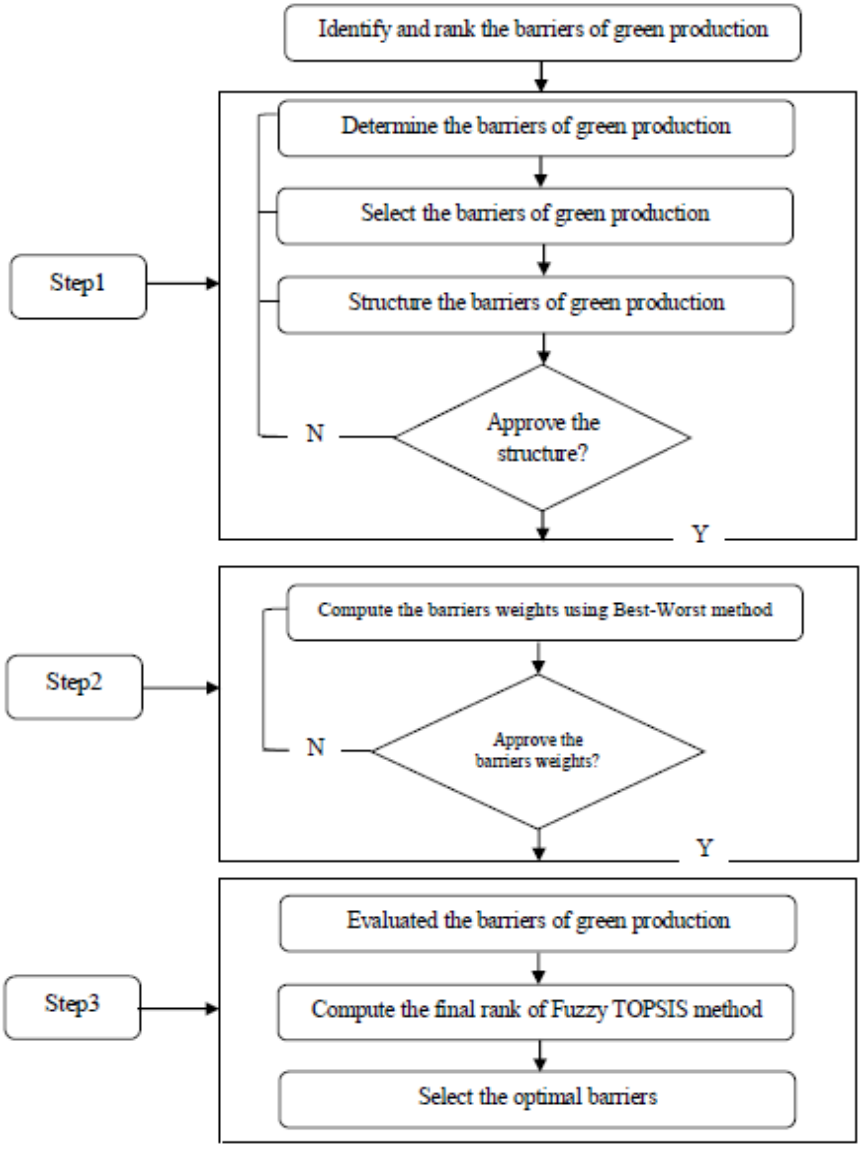
Table 1 Barriers to implement GM (continued)

Criteria	*Dimensions*	*Sub-dimensions*	*Explanations*	*References*
Environmental barriers (EB)		Lack of top management support from adopting GM management (EBM1)	It means that top management not indicating benefits in GM	Hosseini (2007), Hsu and Hu (2008), Srivastva (2007) and Singh et al. (2012)
		Instability in management and internal organisation (EBM2)	It expresses to no plans and polices for manage firm.	Chen et al. (2012) and Joung et al. (2013)
		Lack of corporate social responsibility (EBM3)	It shows to no exist green attitudes and public force and pressure.	Simpson et al. (2004) and Jayant and Azhar (2014)
		Lack of communication and cooperation considering the process of monitoring the product and not paying back to the GM (EBM4)	It means that weak organisational cooperation to support the GM	Carter and Rogers (2008)
		The unwillingness of the stakeholders to exchange information about the organisation and to resist it (EBM5)	The stakeholders are not support via the firm that can interchange data.	Del Brío (2003)
		Non-commitment and desire of environmental stakeholders in the organisation, including strategic environmental (EBM6)	There are not policy, policy that can make strategic plan among stakeholders.	Del Brío (2003) and Mathiyazhagan (2013)
		Lack of goals and plans environmental in the organisation (EBM7)	It means that limited firm policies and aims towards products/process control for GM.	Rao Pa (2005) and Singh et al. (2016)
		Difficulty in identifying environmental opportunities (EBG1)	It expresses to no survey and analysis for reaching environmental opportunity	Revell and Rutherfoord (2003)
		Uncertainty in the market(EBG2)	It shows that market uncertainties and customer's different lead to make competition	Dornfeld et al. (2013) and Deif (2011)
		Absence of industry information of customer requests for eco-friendly goods (EBG3)	It said that no knowledge and information about eco-friendly goods	Bhanot et al. (2017) and Govindan et al. (2014)
		Absence of competition in global markets (EBG4)	It means to no support and plans by government and organisations.	Dube and Gawande (2016) and Govindan et al. (2014)
		Non-membership in conventional and international protocols (EBG5)	It refers to no activates organisations in international events.	Carter and Rogers (2008) and Luthra et al. (2016)
		Absence of educational courses and rewards for suppliers to respect environmental subjects (EBG6)	It means to no support by suppliers because of training system and rewards.	Xia et al. (2015) and Malek and Desai (2019)
		Absence of financial advantages and interests (EBC1)	It means there are economic pressures and critical condition related to GM activities to rises financial interests of the organisation.	Dornfeld et al. (2013) and Govindan et al. (2014)
		Lack of support and guidance for audio and visual media for environmental protection (EBC2)	It indicates that high advertising cost of audio and visual media.	Perron and Duffy (2006), Geng and Doberstein (2008) and Carter and Rogers (2008)
		Lack of legal levers to implement environmental laws (EBC3)	It includes a set of rules and regulations to protect the environment from harmful operations.	Simpson et al. (2004)
		The rare presence of government and organisation in programs, meetings, conferences and environmental seminars (EBC4)	It refers to the systematic meetings and programs aimed at developing professional activities in order to increase the information by held governments / organisation.	Luthra et al. (2016) and Govindan et al. (2014)
		Lack of special policy and support for the government to move towards GM (EBC5)	The governments pass laws and policies that require the industries to implement new operations for decreasing the levels of pollution and improving environmental performance.	Bhanot et al. (2017), Dube and Gawande (2016) and Mangla et al. (2017)

2.3 Research gap and highlights

According to the mentioned investigation there few studies analysing the barriers to GM. According to our best of knowledge, most of these studies only recognise the barriers and not ranking and compare them. Furthermore, they are not based on Iranian industries and experts. Moreover, in this research, MCDM methods are applied for ranking of barriers GM for Iran automotive industries with knowledge, organisational, environmental perspectives.

Figure 2 The diagram of GM for steps of methodology



3 Research methodology

In general, MCDM is related to decisions problems including multiple criteria. The goal is to protect decision-makers facing conflicting challenges and problems (Hojjati and Anvary, 2013). In this paper, the implemented methods are TOPSIS and BWM. The objective of this research is to provide a framework for identifying barriers of GM and ranking them. Different steps of the methodology are presented in Figure 2. Through a detailed literature review, a total of 32 barriers are identified and classified into three main categories (knowledge, organisational, environmental) the base on Table 1. Our research population contained the automobile industry experts familiar with GM concepts (Bhanot et al., 2017). The procedure for this methodology is explained the blow part.

3.2.1 The BWM

BWM is a potent MCDM method and is extensively applied in different researches (Rezaei, 2016; Rezaei, 2015). It includes five following stages.

Phase 1 Recognise the barriers from literature review and experts or managers' ideas. These barriers are the alternatives of the analysis and prepare decision matrix $\{c_1, c_2, \ldots, c_n\}$.

Phase 2 Worst and the best variable is finalised by each expert to show the original class and subclass variables.

Phase 3 Each expert is inquired to present preference ranking for the finest property chosen in respect to alternative properties applying a measure of 1 to 9. The best measure over other measure vector can be written as $A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn})$,where a_{Bj} demonstrates the ranking of best chosen measure B over any other measure j and set $a_{BB} = 1$. Agreements of different specialist is consensus of various experts is selected for finalisation of priority ranks.

Phase 4 Priority ranking of every properties with the worst property is accepted by experts.

Phase 5 The whole properties are computed for optimising the obstacles weights $\left(W_1^*, W_2^*, \ldots, W_n^*\right)$. Then, display the utmost perfect varieties for i that make smaller $\left\{\left|W_B - a_{Bj}W_j\right|, \left|W_j - a_{jw}W_w\right|\right\}$.

The minimax model will be provided: minimax $\left\{w_B - a_{BJ}w_j\right\}, \left\{w_j - a_{jw}w_w\right\}$.

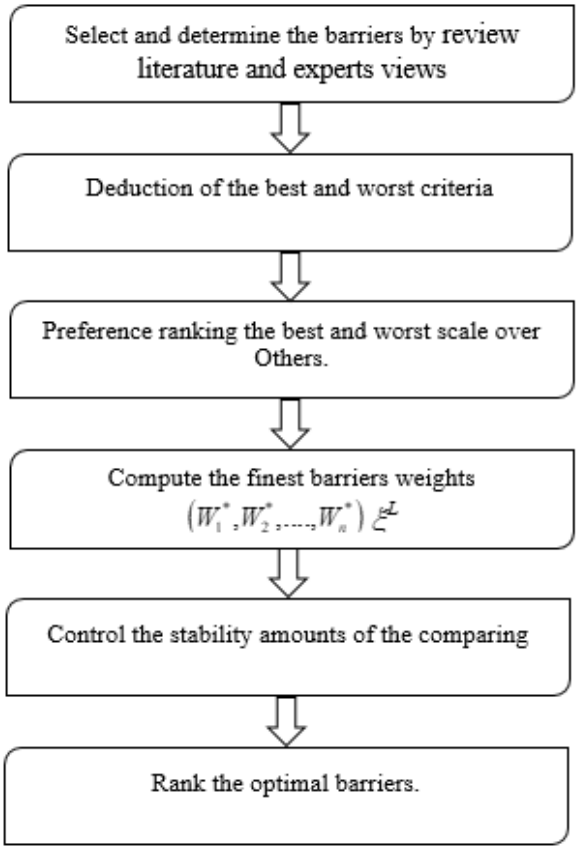
$$S.T. \sum_j w_j = 1$$
$$W_j \geq 0, \text{ for all } j \tag{1}$$

Pattern (1) whereas converted into a lineal sample present superior findings, a pattern displayed under: ξ^L (low)

$$
\begin{aligned}
&s.t.\\
&\left|W_B - a_{Bj}W_j\right| \le \xi^L, \text{ for all } j\\
&\left|W_j - a_{jw}W_w\right| \le \xi^L, \text{ for all } j\\
&\sum_j Wj = 1\\
&W_j \ge 0, \text{ for all } j
\end{aligned}
\tag{2}
$$

Model (2) can be solved to provide suitable weights $\left(W_1^*, W_2^*, \ldots, W_n^*\right)$ and the appropriate amount ξ^L included $\left(\xi^L\right)$ priority measurement near to zero is favourable.

Figure 3 The diagram for phases of BWM methodology



3.2.2 The fuzzy TOPSIS method

Nowadays, this method has been beneficially apply for rating obstacles to GM (Rouhani et al., 2012). The triangular fuzzy figure for this technique is favourable because it is a useful manner that can delete or improve difficulties data present uncompleted (Wang

and Lee, 2009; Awasthi et al., 2011). The triple fuzzy figures $\alpha^{\sim}$ shown via a threefold $(\alpha_1, \alpha_2, \alpha_3)^{57}$. According to the blow equation (3):

$$\mu_{\alpha^{\sim}}(x) = \begin{cases} \dfrac{x-\alpha_1}{\alpha_2-\alpha_1}, \alpha_1 \le x \le \alpha_2, \\ \dfrac{\alpha_3-x}{\alpha_3-\alpha_2}, \alpha_2 \le x \le \alpha_3, \\ 0 \ eles \end{cases} \tag{3}$$

The fuzzy TOPSIS is included six stages that they are introduced below:

Phase 1 Allocation of rankings to the obstacles and options
D = according to this method J choices $D = \{D_1, D_2, \ldots, D_J\}$,which are to be computed to oppose to M measure $C = \{C_1, C_2, \ldots, C_M\}$.
$W_i = (J = 1, 2, \ldots, m)$, are defined the index weights.
Also, each option $D_j = (j = 1, 2, \ldots, n)$ for index $C = \{C_1, C_2, \ldots, C_M\}$ carry out the ranking of the determiner $D_K = \{K = 1, 2, \ldots, K\}$ via $R_k^{\sim} = x_{ijk}^{\sim}(i = 1, 2, \ldots, m; j = 1, 2, \ldots, n; k = 1, 2, \ldots, K)$ on base $\mu_{R_K}(x) \cdot s$.

Phase 2 Then it is transformed into the weighted normalised $R^{\sim}$ matrix as displayed below:

$$R^{\sim} = \left[r_{ij}^{\sim} \right]_{m \times n,} \ i = 1, 2, \ldots, m : j = 1, 2, \ldots, n. \tag{4}$$

$$r_{ij}^{\sim} = \left(\frac{a_{ij}, b_{ij}, c_{ij}}{c_j^*, c_j^*, c_j^*} \right) \text{ and } c_j^* = \max\left\{ c_{ij} \right\} \qquad \text{(chief measure)} \tag{5}$$

$$r_{ij}^{\sim} = \left(\frac{a_{ij}, b_{ij}, c_{ij}}{c_j^*, c_j^*, c_j^*} \right) \text{ and } \alpha_j^{-} = \min_j \left\{ a_{ij} \right\} \qquad \text{(cost measure)} \tag{6}$$

Phase 3 Calculated the fuzzy + FPIS and – FNIS

$$\begin{aligned} A^+ &= (v_1^{\sim +}, v_2^{\sim +}, \ldots, v_n^{\sim +}), v_j^{\sim +} = \max_i \left\{ v_{ij3} \right\}, m : j = 1, 2, \ldots, n. \\ A^- &= (v_1^{\sim -}, v_2^{\sim -}, \ldots, v_n^{\sim -}), v_j^{\sim -} = \min_i \left\{ v_{ij3} \right\}, m : j = 1, 2, \ldots, n. \end{aligned} \tag{7}$$

Phase 4 Calculated interval from FNIS and FPIS:

$$d_i^+ = \left\{ \sum_{j=1}^{n} \left(v_{ij}^{\sim} - v_{ij}^{\sim +} \right)^2 \right\}^{1/2}, i = 1 \ldots\ldots m \tag{8}$$

$$d_i^- = \left\{ \sum_{j=1}^{n} \left(v_{ij}^{\sim} - v_{ij}^{\sim -} \right)^2 \right\}^{1/2}, i = 1 \ldots\ldots m \tag{9}$$

Phase 5 Nearest to coefficient for each answer is provided by applying the equation below:

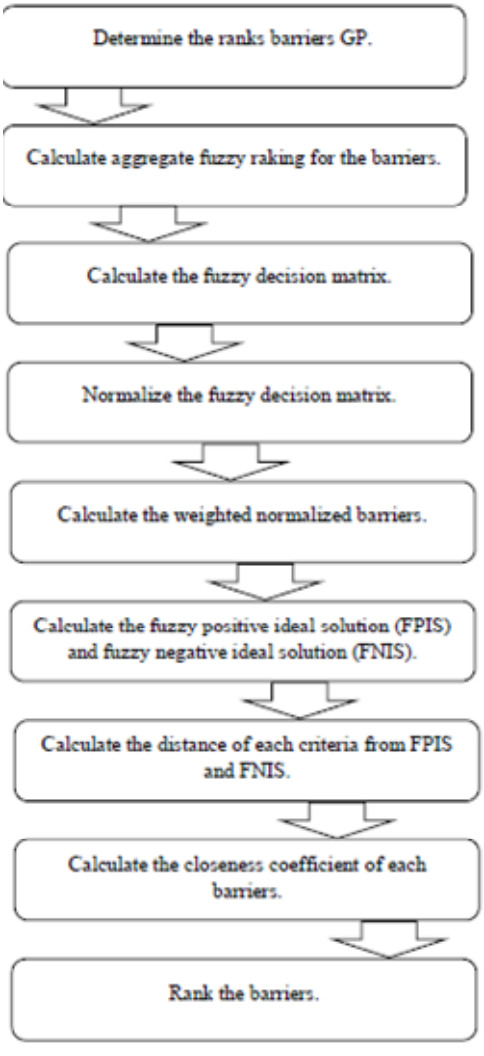
$$cc_i = \frac{d_i^-}{d_i^- + d_i^+}, i = 1 \ldots\ldots m \ cc_{i\varepsilon} (0, 1) \tag{10}$$

Table 2 Linguistic scale for alternatives selection

Linguistic variables	*Corresponding fuzzy numbers*
Very low (VL)	(0.0, 0.0, 0.2)
Low (L)	(0.0, 0.2, 0.4)
Medium (M)	(0.2, 0.4, 0.6)
High (H)	(0.4, 0.6, 0.8)
Very high (VH)	(0.6, 0.8, 1.0)
Excellent (E)	(0.8, 1.0, 1.0)

Phase 6 Lastly answer are ranked on the base of CC_i amounts provided (Awasthi et al., 2011).

Figure 4 The diagram for phases of fuzzy TOPSIS methodology



4 Application of offered framework

The offered framework is confirmed by a two-step procedure. Firstly, this step is to determine and identify the key barriers of GM. Secondly, this sector is to rank and priority these barriers by applying BWM and fuzzy TOPSIS. Both steps are described below.

4.1 Determine and identification of key barriers

Firstly, this step is to determine and identify the key barriers of GM. This part is conducted based on the manufacturing experts and literature. The first step reviewed literature and studies in the fields of GM with ecologically awareness. Then, this research leads shortlisted. In addition, the barriers were gathered and analysed according to several rounds of arguments. The second part invited the 115 industrial production managers and experts. This meeting prepared the matters and concepts that need for this paper, particularly in Iran. As the output, thirty-two key barriers of GM are determined by blending of industrial managers and experts insights and the literature reviews.

4.2 Rank and priority among key barriers

This sector is to rank and priority among these barriers of GM by applying BWM and fuzzy TOPSIS.

4.3 Evaluation and identification of key barriers of GM implementation

In the first step of the study, a questionnaire that included 32 barriers, reviewed in Table 1, was built to gather the data from the experts to finalise the list of barriers to implementing GM processes in the automotive industries of Iran. The questionnaire was sent to 16 experts to study the barriers in GM implementation. Among the ten experts who responded to the questionnaire by Delphi analysis. In a Delphi study, there is no clear-cut law about the size of the expert panel (Keeney et al, 2001). Because, it often depends on the aim of the article; therefore, a comparison was done with the related kinds of articles. The panel size of DM was considered acceptable rather than the prior investigations, i.e., Rezaei (2016) (six experts), Karuppiah et al. (2020) (eight experts) and Hussein et al. (2019) (eight experts). Furthermore, the total among the experts was kept to assure that each respondent obtains data completely and without any type of pressure from other experts (Keeney et al., 2001). Additionally, the expert panel comprises people from different backgrounds like the academic, industrial sections to get different inputs and to ensure group dynamics. The basic profile of the experts who responded is presented in Table 3.

According to the experts' answers, 32 key barriers in GM implementation in manufacturing industries in Iran were separated and are listed in Table 1. Barriers that gained maximum repeated answers from the experts were chosen and barriers with the least repetition were refused (Abdullah et al., 2016).

Table 3 Profile of the responders

Designation	*Experts*	*Experience (years)*	*Department/area of expertise*
Industrial engineer	3	12	Production department
Industrial management	2	10	Management
Managers	3	20	Management
Academician	4	25	GM
Product managers	2	8	Production unit
Environmental manager	1	15	Production department
Safety engineer	1	10	Production department

5 Results and discussion

According to Table 6 and Table 8, lack of special policy and support from the government to move towards GM by 1.674, from fuzzy TOPSIS and lack of top management protect from adopting GM management by 0.192, from BWM, are the important barriers among barriers of GM. The barriers are assisting criteria in the implementation of GM. Moreover, lack of special policy and support from the government to move towards GM. Therefore, governments must pass laws to support society's health and ecology and makes rulers enforce those laws. Also, they should increase tax and give subsidies as punishing and supporting policy.

5.1 Results of the BWM method

The variables weights of GM activates are provided by BWM and are shown in Table 6 and Table 8.

Table 4 The priority of the best criterion over all criteria by experts

	DM1	*DM2*	*DM3*	*DM4*	*DM5*	*DM6*
	Best criterion: C23	*Best criterion: C28*	*Best criterion: C8*	*Best criterion: C5*	*Best criterion: C32*	*Best criterion: C20*
C1	3	2	7	9	3	7
C2	2	3	3	2	2	5
C3	9	7	2	3	9	3
C4	7	9	5	4	7	5
C5	5	4	4	1	4	4
C6	4	5	9	7	5	9
C7	8	6	3	4	2	3
C8	6	8	1	6	8	8
C9	4	3	8	8	6	9
C10	3	4	5	2	4	8
C11	5	2	4	5	3	5

Table 4 The priority of the best criterion over all criteria by experts (continued)

	DM1	*DM2*	*DM3*	*DM4*	*DM5*	*DM6*
	Best criterion: C23	*Best criterion: C28*	*Best criterion: C8*	*Best criterion: C5*	*Best criterion: C32*	*Best criterion: C20*
C12	2	5	2	3	5	2
C13	7	8	5	4	7	4
C14	8	7	8	8	8	5
C15	4	5	7	5	4	7
C16	5	4	6	5	5	6
C17	6	8	8	4	6	8
C18	8	6	4	7	8	4
C19	9	7	6	9	9	9
C20	7	9	9	8	3	1
C21	5	6	7	5	5	5
C22	6	5	2	6	6	2
C23	1	4	4	5	8	4
C24	5	2	5	7	5	5
C25	2	5	7	2	2	3
C26	7	9	9	5	7	9
C27	9	7	5	7	4	7
C28	4	1	3	3	3	4
C29	3	8	8	4	7	3
C30	7	3	6	8	6	8
C31	8	7	3	9	9	2
C32	5	4	2	6	1	7

Table 5 The priority of all criteria over the worst criterion by experts

	DM1	*DM2*	*DM3*	*DM4*	*DM5*	*DM6*
	Worst criterion: C3	*Worst criterion: C6*	*Worst criterion: C20*	*Worst criterion: C25*	*Worst criterion: C5*	*Worst criterion: C30*
C1	3	6	4	6	4	3
C2	4	3	3	3	6	4
C3	1	4	6	4	3	6
C4	8	5	3	5	8	2
C5	5	8	2	2	1	2
C6	6	1	8	8	2	8
C7	7	4	5	4	5	5
C8	5	9	7	3	9	3
C9	9	7	2	4	3	5
C10	4	3	9	8	4	4

Table 5 The priority of all criteria over the worst criterion by experts (continued)

	DM1	*DM2*	*DM3*	*DM4*	*DM5*	*DM6*
	Worst criterion: C3	*Worst criterion: C6*	*Worst criterion: C20*	*Worst criterion: C25*	*Worst criterion: C5*	*Worst criterion: C30*
C11	3	5	5	4	6	2
C12	8	8	3	7	4	5
C13	5	3	4	6	7	3
C14	7	7	7	3	6	5
C15	3	6	8	2	3	6
C16	7	5	3	6	2	8
C17	4	2	2	3	8	2
C18	4	4	4	2	5	3
C19	2	4	6	8	6	4
C20	8	2	1	4	2	5
C21	6	6	2	3	4	7
C22	2	8	3	3	8	6
C23	2	6	3	5	7	7
C24	3	2	6	1	2	3
C25	6	3	8	5	6	5
C26	9	4	7	2	3	2
C27	5	5	5	7	7	4
C28	4	9	4	3	2	6
C29	3	7	3	2	3	3
C30	5	6	2	5	4	1
C31	2	2	7	9	6	8
C32	6	5	5	2	4	9

So, the respect with the equations (1)–(2), the optimal weight vectors of the evaluation index system for the experts can be provided as Table 6.

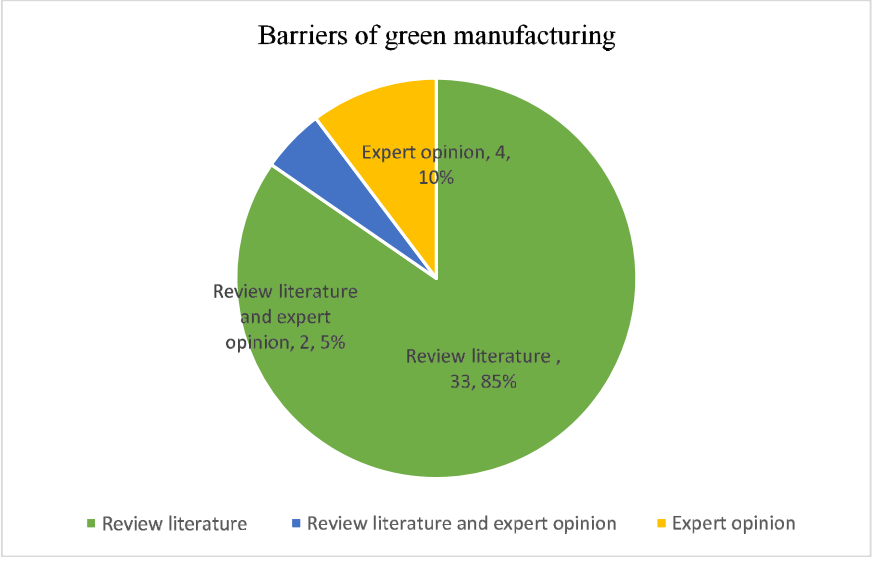
Table 6 Weights of barriers

	The barriers code	*Weights*	*Global weights*	*Ranking*	*Obtain of sources*
IBB		0.072	3		Review literature
C1	IBB1	0.408	0.029	8	Review literature and expert opinions
C2	IBB2	0. 129	0.010	22	Review literature
C3	IBB3	0.072	0.011	21	Review literature
C4	IBB4	0.053	0.015	18	Review literature

Table 6 Weights of barriers (continued)

	The barriers code	*Weights*	*Global weights*	*Ranking*	*Obtain of sources*
IBA		0.377		6	Review literature
C5	IBA1	0.390	0.034	6	Review literature
C6	IBA2	0.145	0.013	18	Review literature and expert opinions
C7	IBA3	0.039	0.008	24	Review literature
OBT		0.086		1	Review literature
C8	OBT1	0.221	0.020	14	Review literature
C9	OBT2	0.127	0.022	13	Review literature
OBE		0.130		7	Review literature
C10	OBE1	0.051	0.014	19	Review literature
C11	OBE2	0.087	0.012	14	Review literature
C12	OBE3	0.488	0.064	4	Review literature
C13	OBE4	0.174	0.023	12	Review literature
C14	OBE5	0.129	0.018	15	Review literature
EBM		0.488		5	Review literature
C15	EBM1	0.393	0.192	1	Review literature
C16	EBM2	0.041	0.021	12	Review literature
C17	EBM3	0.054	0.026	10	Review literature
C18	EBM4	0.061	0.030	7	Expert opinions
C19	EBM5	0.105	0.052	5	Review literature
C20	EBM6	0.211	0.103	2	Expert opinions
C21	EBM7	0.141	0.069	3	Review literature
MBG		0.075		2	Review literature
C22	MBG1	0.221	0.017	16	Expert opinions
C23	MBG2	0.399	0.028	9	Review literature
C24	MBG3	0.148	0.012	19	Review literature
C25	MBG4	0.052	0.016	17	Review literature
C26	MBG5	0.111	0.009	23	Review literature
C27	MBG6	0.074	0.006	25	Review literature
EBC		0.052		4	Review literature
C28	EBC1	0.437	0.024	11	Review literature
C29	EBC2	0.236	0.014	17	Review literature
C30	EBC3	0.118	0.013	20	Expert opinions
C31	EBC4	0.095	0.005	26	Review literature
C32	EBC5	0.051	0.003	27	Review literature

Figure 5 The barriers of GM (see online version for colours)



5.2 Results of the fuzzy TOPSIS method

Then, by implementing a fuzzy TOPSIS method, the ranking of the barriers is determined.

Table 7 Weighted fuzzy assessment matrix for the automobile industries

	C1			*C2*			*C3*			*C4*		
DM1	0.000	0.080	0.312	0.204	0.456	0.098	0.072	0.272	0.660	0.192	0.570	0.780
DM2	0.000	0.000	0.156	0.068	0.228	0.588	0.024	0.136	0.396	0.000	0.000	0.156
DM3	0.000	0.000	0.156	0.068	0.228	0.588	0.048	0.204	0.528	0.096	0.000	0.156
DM4	0.160	0.400	0.780	0.204	0.456	0.980	0.048	0.204	0.528	0.192	0.570	0.780
DM5	0.040	0.160	0.468	0.068	0.228	0.588	0.000	0.068	0.264	0.048	0.228	0.468
DM6	0.000	0.080	0.312	0.204	0.456	0.980	0.072	0.272	0.660	0.000	0.114	0.312
I+	0.160	0.400	0.780	0.204	0.456	0.980	0.072	0.272	0.660	0.192	0.570	0.780
I–	0.000	0.000	0.156	0.068	0.228	0.098	0.000	0.068	0.264	0.000	0.000	0.156
	C5			*C6*			*C7*			*C8*		
DM1	0.00	0.08	0.312	0.136	0.342	0.784	0.024	0.136	0.396	0.192	0.57	0.78
DM2	0.16	0.4	0.78	0.068	0.228	0.588	0.000	0.000	0.132	0.192	0.57	0.78
DM3	0.04	0.16	0.468	0.000	0.000	0.196	0.048	0.204	0.528	0.192	0.57	0.78
DM4	0.12	0.32	0.78	0.272	0.57	0.98	0.048	0.204	0.528	0.192	0.57	0.78
DM5	0.12	0.32	0.78	0.136	0.342	0.784	0.024	0.136	0.396	0.144	0.456	0.78
DM6	0.00	0.08	0.312	0.136	0.342	0.784	0.024	0.136	0.396	0.144	0.456	0.78
I+	0.160	0.400	0.780	0.272	0.570	0.980	0.048	0.204	0.528	0.192	0.570	0.780
I–	0.000	0.080	0.312	0.000	0.000	0.196	0.000	0.000	0.132	0.144	0.456	0.780

Table 7 Weighted fuzzy assessment matrix for the automobile industries (continued)

	C9			*C10*			*C11*			*C12*		
DM1	0.16	0.4	0.78	0.000	0.000	0.196	0.000	0.068	0.264	0.000	0.114	0.312
DM2	0.08	0.24	0.624	0.000	0.114	0.392	0.024	0.136	0.396	0.096	0.342	0.624
DM3	0.12	0.32	0.78	0.000	0.114	0.392	0.000	0.068	0.264	0.144	0.456	0.78
DM4	0.12	0.32	0.78	0.204	0.456	0.98	0.072	0.272	0.66	0.192	0.57	0.78
DM5	0.08	0.24	0.624	0.068	0.228	0.588	0.024	0.136	0.396	0.000	0.000	0.156
DM6	0.08	0.24	0.624	0.068	0.228	0.588	0.000	0.068	0.396	0.000	0.000	0.156
I+	0.160	0.400	0.780	0.204	0.456	0.980	0.072	0.272	0.660	0.192	0.570	0.780
I–	0.080	0.240	0.624	0.000	0.000	0.196	0.000	0.068	0.264	0.000	0.000	0.156
	C13			*C14*			*C15*			*C16*		
DM1	0.12	0.32	0.78	0.000	0.000	0.196	0.072	0.272	0.66	0.000	0.114	0.312
DM2	0.12	0.32	0.78	0.136	0.342	0.784	0.024	0.136	0.396	0.144	0.456	0.78
DM3	0.16	0.4	0.78	0.000	0.000	0.196	0.072	0.272	0.66	0.192	0.57	0.78
DM4	0.16	0.4	0.78	0.204	0.456	0.98	0.072	0.272	0.66	0.144	0.456	0.78
DM5	0.12	0.32	0.78	0.000	0.114	0.392	0.072	0.272	0.66	0.096	0.342	0.624
DM6	0.12	0.32	0.78	0.000	0.114	0.392	0.024	0.136	0.396	0.000	0.114	0.312
I+	0.160	0.400	0.780	0.204	0.456	0.980	0.072	0.272	0.660	0.192	0.570	0.780
I–	0.120	0.320	0.780	0.000	0.000	0.196	0.024	0.136	0.396	0.000	0.114	0.312
	C17			*C18*			*C19*			*C20*		
DM1	0.08	0.24	0.624	0.000	0.114	0.392	0.000	0.068	0.264	0.000	0.114	0.312
DM2	0.000	0.000	0.156	0.000	0.000	0.196	0.072	0.272	0.66	1.92	0.57	0.78
DM3	0.000	0.08	0.312	0.136	0.342	0.784	0.024	0.136	0.396	0.000	0.114	0.312
DM4	0.08	0.24	0.624	0.136	0.342	0.784	0.072	0.272	0.66	0.144	0.456	0.78
DM5	0.12	0.32	0.78	0.136	0.342	0.784	0.024	0.136	0.396	0.048	0.228	0.468
DM6	0.000	0.000	0.156	0.000	0.114	0.392	0.024	0.068	0.264	0.000	0.114	0.312
I+	0.120	0.320	0.780	0.136	0.342	0.784	0.072	0.272	0.660	1.920	0.570	0.780
I–	0.000	0.000	0.156	0.000	0.000	0.196	0.000	0.068	0.264	0.000	0.114	0.312
	C21			*C22*			*C23*			*C24*		
DM1	0.00	0.08	0.312	0.000	0.114	0.392	0.096	0.34	0.66	0.000	0.000	0.156
DM2	0.16	0.4	0.78	0.000	0.114	0.392	0.096	0.34	0.66	0.096	0.342	0.624
DM3	0.12	0.32	0.78	0.000	0.00	0.196	0.048	0.204	0.528	0.048	0.228	0.468
DM4	0.12	0.32	0.78	0.272	0.57	0.98	0.048	0.204	0.528	0.048	0.228	0.468
DM5	0.16	0.4	0.78	0.272	0.57	0.98	0.072	0.272	0.66	0.048	0.228	0.468
DM6	0.000	0.08	0.312	0.000	0.000	0.196	0.096	0.34	0.66	0.000	0.114	0.312
I+	0.160	0.400	0.780	0.272	0.570	0.980	0.096	0.340	0.660	0.096	0.342	0.624
I–	0.000	0.080	0.312	0.000	0.000	0.196	0.048	0.204	0.528	0.000	0.000	0.156

Table 7 Weighted fuzzy assessment matrix for the automobile industries (continued)

	C25			*C26*			*C27*			*C28*		
DM1	0.00	0.08	0.312	0.204	0.456	0.98	0.000	0.000	0.132	0.000	0.114	0.312
DM2	0.08	0.24	0.624	0.136	0.342	0.784	0.000	0.068	0.264	0.096	0.342	0.624
DM3	0.12	0.32	0.78	0.068	0.228	0.588	0.000	0	0.132	0.000	0.114	0.312
DM4	0.04	0.16	0.468	0.000	0.114	0.392	0.000	0.068	0.264	0.048	0.228	0.468
DM5	0.04	0.16	0.468	0.000	0.114	0.392	0.072	0.272	0.66	0.000	0.000	0.156
DM6	0.16	0.4	0.78	0.000	0.114	0.392	0.000	0.068	0.264	0.000	0.114	0.312
I+	0.160	0.400	0.780	0.204	0.456	0.980	0.072	0.272	0.660	0.096	0.342	0.624
I–	0.000	0.080	0.312	0.000	0.114	0.392	0.000	0.000	0.132	0.000	0.000	0.156
	C29			*C30*			*C31*			*C32*		
DM1	0.00	0.08	0.312	0.000	0.000	0.196	0.024	0.136	0.396	0.000	0.114	0.312
DM2	0.00	0.08	0.312	0.000	0.114	0.392	0.000	0.068	0.264	0.000	0.000	0.156
DM3	0.12	0.32	0.78	0.000	0.000	0.196	0.000	0.068	0.264	0.096	0.342	0.624
DM4	0.08	0.24	0.624	0.000	0.000	0.196	0.000	0.068	0.264	0.144	0.456	0.78
DM5	0.00	0.08	0.312	0.000	0.114	0.392	0.048	0.204	0.528	0.192	0.57	0.78
DM6	0.00	0.000	0.156	0.204	0.456	0.98	0.024	0.136	0.396	0.000	0.000	0.156
I+	0.120	0.320	0.780	0.204	0.456	0.980	0.048	0.204	0.528	0.192	0.570	0.780
I–	0.000	0.000	0.156	0.000	0.000	0.196	0.000	0.068	0.264	0.000	0.000	0.156

Table 8 presents the final ranking of the barriers and the analysis findings of fuzzy TOPSIS displayed and ranked the GM attributes.

Table 8 The ranking barriers

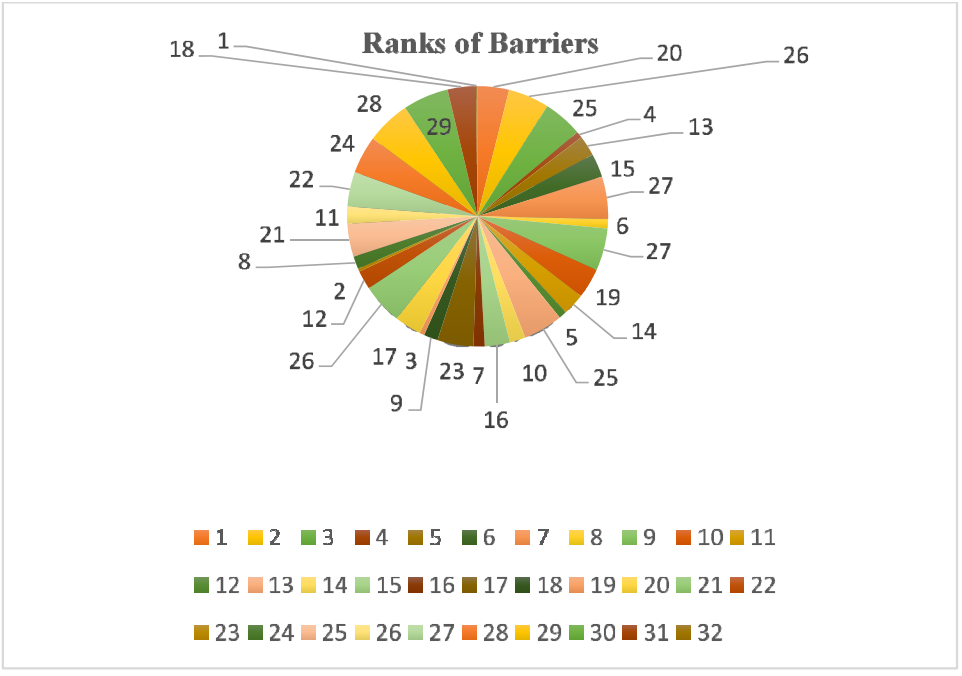
The all barriers		*D+*	*D–*	CC_i	*Ranks*
Low belief in environmental benefits in producers, suppliers, consumers, shareholders, stakeholders (IBB1)	C1	0.963	0.831	0.463	20
Doubts and concerns to become new systems (fears of industry accepting new systems) (IBB2)	C2	0.932	0.501	0.350	26
Absence of responsibility culture in the organisation(IBB3)	C3	0.958	0.540	0.361	25
Lack of Awareness of supply chain members use Reverse logistics (IBB4)	C4	0.103	1.101	0.914	4
Lack of awareness manufacturers, consumers, suppliers, advisers, counsellors, shareholders of GM (IBA1)	C5	0.471	0.551	0.539	13
Lack of training courses and consulting services (IBA2)	C6	0.491	0.515	0.512	15
Lack of awareness of the laws and environmental impacts of the organisation's activities (IBA3)	C7	0.733	0.390	0.347	27
Lack of technology, new materials ,and processes (OBT1)	C8	0.120	0.842	0.875	6
Fear of failures and lack of systems infrastructure and scheme reuse or recycling (OBT2)	C9	0.868	0.281	0.245	27

Table 8 The ranking barriers (continued)

The all barriers		*D+*	*D–*	CC_i	*Ranks*
High investment and low return on investment in implement GM (OBE1)	C10	1.587	0.493	1.587	3
High costs for implement GM process and projects (OBE2)	C11	0.581	0.636	0.523	14
Concerned about the high cost of packaging environmentally friendly (OBE3)	C12	0.120	0.992	0.892	5
Concerned about rising costs of replacing new systems to implement GM process (OBE4)	C13	0.819	0.287	0.260	25
Lack of human resources (OBE5)	C14	0.330	0.657	0.665	10
Lack of top management protect from adopting GM management (EBM1)	C15	1.596	0.377	1.596	2
Instability in management, internal organisation (EBM2)	C16	0.174	0.804	0.822	7
Lack of corporate social responsibility (EBM3)	C17	0.721	0.455	0.387	23
Lack of communication and cooperation considering the process of monitoring the product and not paying back to the GM (EBM4)	C18	0.674	1.564	0.674	9
The unwillingness of the stakeholders to exchange information about the organisation and to resist it (EBM5)	C19	0.588	0.512	0.466	19
Non-commitment and desire of environmental stakeholders in the organisation, including strategic environmental (EBM6)	C20	0.682	0.666	0.494	17
Lack of goals and plans environmental in the organisation (EBM7)	C21	0.776	0.256	0.248	26
Difficulty in identifying environmental opportunities (EBG1)	C22	0.509	0.619	0.549	12
Uncertainty in the market (EBG2)	C23	0.616	0.611	0.498	16
Absence of industry information of customer requests for eco-friendly goods (EBG3)	C24	0.244	0.817	0.770	8
Absence and competition in global markets (EBG4)	C25	0.637	0.480	0.430	21
Non-membership in conventions and protocols international (EBG5)	C26	0.387	0.591	0.604	11
Absence of education courses and rewards for suppliers to respect environmental subjects (EBG6)	C27	0.598	0.407	0.405	22
Absence of financial advantages and interests (EBC1)	C28	0.623	0.351	0.360	24
Lack of support and guidance for audio and visual media for environmental protection (EBC2)	C29	0.890	0.225	0.202	28
Lack of legal levers to implement environmental laws (EBC3)	C30	0.913	0.212	0.188	29
The fair presence of government and organisation in programs, meetings, conferences and environmental seminars (EBC4)	C31	0.704	0.623	0.469	18
Lack of special policy and support from the government to move towards GM (EBC5)	C32	1.674	0.773	1.674	1

Hence, this article emphasises that the identified barriers and ranking are only confined to Iranian manufacturing industries.

Figure 6 Ranking for barriers by analysis (see online version for colours)



6 Managerial implications

This study investigates some managerial suggestions. They assist the industrial managers to manifest the significance of GM to all staff in different parts of the factory and persuade their companies to carry out greening activates. They aid increment the facility of GM by motivating the key barriers which are evaluated in the current article. The following information provided from search findings are also considerable.

6.1 Lack of special policy and support from governments

Lack of special policy and support from governments has a high priority in green production. This factor emphasis the tactics and policies create in this structure used to the readiness of governments' plans and to decide connection with applied policies. Governments must pass laws to support society's health and ecology and makes rulers to enforce those laws. Also, they should increase tax as a punishing strategy or give subsidies as a supporting tactic.

6.2 Lack of top management protect

Lack of top management protection plays the main role in the performance of green activities. Top management will be to support GM processes. When the manufacturing processes implement standards such as ISO1400 certifications, in the time of auditing or inspections they are forced to follow their claimed GM goals.

6.3 Non-commitment and desire of environmental stakeholders

Commitment from stakeholders is evaluated as a significant criteria in the performance of GM. Building, exploring and maintaining commitments is to identify as one of the most noteworthy dimensions of stakeholder connection environment regulatory and compliance. Finally, stakeholder pressure can move towards improved regulations and implementation of GM shown in this study.

7 Conclusions

In general, GM has been viewed as a sustainable solution as they make numerous benefits for all kinds of manufacturing industries (Digalwar et al., 2017). Therefore, this research work identifies and ranks the barriers in implementing GM processes in Iran. According to the literature review and experts' view, the current study identified 32 barriers to GM implementation which were then broadly categorised knowledge, organisational, environmental perspectives. Next, utilising a novel combined MCDM framework and a blending of BWM and TOPSIS methods, this research ranked the classes and barriers. The outcomes present that among the barriers of implementing GM processes in Iran manufacturing industries, the five most important barriers are Lack of special policy and support from the government to move towards GM (EBC5), instability in management, internal organisation (EBM2), high investment and low return on investment in implement GM (OBE1), lack of awareness of supply chain members use reverse logistics (IBB4) and concerned about the high cost of packaging environmentally friendly (OBE3).

This study offers unique contributions. This research enhances the consciousness of green actions in the manufacturing industries and developing countries. It is very little investigation in operations management in manufacturing industries in developing countries. This article connected DM with a novel integrated MCDM framework utilising BWM and fuzzy TOPSIS. Such integration of DM with several MCDM methods have not been applied before and present a comprehensive comprehension of the subject of the investigation. This article has studied and assessed the role of the production sections in implementing GM processes through analysing the barriers coming under production class, a subject not discussed in earlier investigations.

Also, this research provides considerably to the literature, it additionally has some restrictions. For instance, the investigation is limited to Iranian manufacturing industries in the automobile industry. Hence, attention should be used in utilising the findings to other Iranian manufacturing industries and in other developing countries. Future research could be offered to compare the conclusions in the setting of other industries and countries with different conditions to that in Iran. Furthermore, the cause-effect

relationship among barriers was only studied utilising the answers of 16 experts and fuzzy MCDM techniques.

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