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A framework to overcome sustainable supply chain challenges through solution measures of industry 4.0 and circular economy: An automotive case

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A B S T R A C T

Adoption of sustainability has become extremely essential aspect over the last decade for the industries to sustain in the global market. However, the adoption of sustainability in supply chain is more concern for the manufacturing organisations. Constantly, changing market has insisted these organisations to revisit their supply chain activities in order to penetrate sustainability effectively through various practices such as lean, green, circular, and industry 4.0 etc. But, the lack of verified Sustainable Supply Chain Management (SSCM) frameworks has become a concern for the practitioners. Similarly, solutions required to overcome the SSCM adoption issues also need to be updated accordingly to changing business environments. So, the present study aims to develop a framework to overcome SSCM challenges through industry 4.0 and circular economy based solution measures. This study identifies a unique set of 28 SSCM challenges and 22 solution measures. Further, an automotive case organisation is used to test the applicability of the developed framework through hybrid Best Worst Method (BWM)- ELimination and Choice Expressing REality (ELECTRE) approach. The inputs for BWM-ELECTRE approach is obtained by constructing an expert panel within the case organisation. Initial inputs are taken for BWM comparisons to compute the weight of SSCM challenges; whereas, further a comparison of challenges and solution measures is also obtained for ELECTRE approach to compute the final ranking of the solution measures to overcome SSCM challenges. The case findings reveal that managerial and organisational challenges and economic challenges emerge as most critical to SSCM adoption. The present study outcomes will be beneficial for researchers working in SSCM industry 4.0 and circular economy domain; whereas, the practitioners can use the prioritised solution measures to formulate effective strategies to overcome SSCM adoption failures.

1. Introduction

The concept of sustainability has gained its importance in supply chain over last couple of decades (Pieroni et al., 2019). The constant increase in competition among the organisations at global level has insisted them to switch over the sustainability practices to remain stable (Shibin et al., 2018). Sustainability has its roots from idea generation till delivering final product to the end user (Bastas and Liyanage, 2018). To support it, various researchers (Beske and Seuring, 2014; Khalid et al., 2015) working on Sustainable Supply Chain Management (SSCM) have proposed the frameworks for improving SSCM adoption rate. However, it is significant to notice that present industry era is switching quickly towards digitisation and hence it has become difficult for the organisations to adopt

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SSCM effectively using traditional supply chain and sustainability practices (Bocken et al., 2019). Similarly, the industry 4.0 and circular economy has gained their importance in recent times by delivering sustainable outputs and reducing man-machine interaction (van Loon and Van Wassenhove, 2018). Industry 4.0 specifically focuses on cyber physical systems to build smart factories for sustainable future; while, circular economy mainly emphasises over the adoption of 6 R's among the organisations (Merli et al., 2018).

Silvestre et al. (2018) discussed several challenges faced by the organisations recently; but the decision makers and practitioners in the organisations are constantly facing issues in overcoming these challenges. Similarly, the enhanced automation and usage of advanced technological setups has made it really difficult for the practitioners to develop strategies for elimination of these challenges so that sustainability can be achieved effectively in their existing supply chain system (Irani et al., 2017). Ghadimi et al. (2019) highlighted in their study that the literature strongly demands for innovative solution measures such that the organisations can easily adoption SSCM according to changing industry environment. Hence, it becomes essential to note that the solution measures required to overcome the SSCM adoption challenges must include the essence of present industry environment that includes industry 4.0 as well as circular economy (Gopal and Thakkar, 2016).

Fatorachian and Kazemi (2018) indicated various facilitators of industry 4.0 that possess direct co-relation with the supply chain. They further highlighted the key issues insisting the requirement of sustainability adoption among existing system to achieve desired organisational performances. Similarly, Kirchherr et al. (2017) also pointed several enablers of circular economy and explained their importance in achieving sustainability in supply chain and also proposed its benefits among the reverse logistics. Hence, it can be noted that the solution measures based on industry 4.0 and circular economy has its strong influence on tackling the challenges of SSCM adoption (Liao et al., 2017). Various studies in literature (Oesterreich and Teuteberg, 2016; Gobbo et al., 2018; Luthra and Mangla, 2018) reported that the success factors of industry 4.0 and circular economy will key requirement for successful execution of quality and supplier management practices in near future.

On the other hand, the supply chain performance strongly affects the organisational performance whether it belongs to manufacturing, service or healthcare sector etc. (Walker et al., 2008) So, it is extremely critical to assess the present state of SSCM challenges and accordingly explore the solution measures based on industry 4.0 and circular economy to overcome the said challenges. However, the frameworks available for SSCM adoption in literature either focuses on the challenges or the facilitators, but none of them links the challenges and their solution measures in the form of framework (José et al., 2017). Similarly, inclusion of industry 4.0 and circular economy practices in manufacturing organisations has become necessary if the organisation wants to compete at global level. So, the solution measures based on industry 4.0 and circular economy will help the organisations to remain update with the advanced technologies and penetrate the sustainability in the existing supply chain. The Indian automotive industry has been one of the largest producers of automotive parts. Many countries (developed) consider India for offshore outsourcing of automotive products, instead of manufacturing in their own country (Yadav et al., 2019). The reason behind this is availability of cheap labour, low capital on lands, and low supply chain and logistics costs etc. This also attracts the foreign direct investments in the country. Many researchers in literature also claimed that automotive industry in India has a strong contribution to the nation's economy (Gopal and Thakkar, 2016; Luthra et al., 2016). Hence, the availability of such framework will not only help the practitioners in successfully adopting SSCM in Indian automobile industry but also assist them in improving the organisational performance and strengthening the organisation's sustainable future. Based on the above discussed issues, following objectives are defined for the present research work:

- To identify and compute the weights of key challenges that obstructs the adoption of sustainable supply chain in automobile industry;
- To rank the solution measures of industry 4.0 and circular economy for effective sustainable supply chain adoption chain in automobile industry

In order to achieve above defined objectives, a case organisation is selected to test the developed framework. Initially, the Best Worst Method (BWM) is adopted to compute the weights of key sustainable supply chain adoption challenges and later ELimination and Choice Expressing REality (ELECTRE) approach is utilised for ranking the industry 4.0 and circular economy based solution measures for enhancing it adoption rate.

The present article is organised in eight sections including introduction. Section 2 presents the literature review carried out to explore the sustainable supply chain adoption challenges and industry 4.0 and circular economy based solution measures followed by the literature gaps. Section 3 defines the research methodology adopted for present research work. The details of framework development and case description are shown in Section 4. Section 5 represents the analysis of developed framework in case organisation. Section 6 highlights the case discussion along with the study findings along with the study implications, whereas; the conclusion and future scope are presented in Section 7.

2. Literature review

The literature review is considered as the backbone of any research work (Tranfield et al., 2003). So, it is critical to observe the quality and quantity of data. It is preferred to use systematic literature review approach for the purpose (Yadav and Desai, 2016). To ensure the comprehensiveness and quality issues, present study utilises Web of Science, Scopus, and Google scholar as the search databases. Following keywords are used to extract the required articles- "Sustainable supply chain challenges", "Sustainable supply chain barriers", "Industry 4.0 solutions", "Industry 4.0 enablers", "Circular economy solutions", "Circular economy enablers". The methodology of literature review adopted by (Tranfield et al., 2003; Yadav et al., 2018b) is utilised for present research work. Hence, following filter criteria are used.

1) The initial search includes only journal articles. However, all other types of articles including conference papers, book chapters, editorial notes etc. are excluded.
2) The concept of sustainability in supply chain came into existence during early 2000s (Silvestre, 2015). Hence, time horizon for present research is taken from 2000 to December 2018.
3) Inclusion of article focussing on SSCM challenges and industry 4.0 and circular economy based facilitators and solution measures are included.

Using the above filter criteria, the authors collected journal articles and finally the forward snowball and backward snowball technique (Yadav et al., 2018a) is applied to obtain the final set of articles for review purpose. Accordingly, the detailed literature review carried out of the shortlisted articles is portrayed in subsequent sub-sections.

2.1. Sustainable supply chain challenges

The sustainability in supply chain is an essential component for organisations to sustain the global competition (Mollenkopf et al., 2010). However, if adopted in a faulty manner than the organisation need to face the loss of high investment cost (Shibin et al., 2018). Hence, it becomes necessary to identify the crucial factors that obstruct the successful adoption of sustainable supply chain (Koberg and Longoni, 2019). Several studies in literature have reported them in the form of barriers, failure factors and challenges. Many studies (Walker et al., 2008; Sarkis and Sarkis, 2012; Tseng et al., 2019) reported the downfall of organisational performance while executing the traditional supply chain practices, and insisted the immediate switch over to the sustainable supply chain environments. Neumüller et al. (2015) justified the need of sustainability in supply chain by conducting a case study and later compared the before and after organisational performance. However, Sajjad et al. (2015) and Batista et al. (2018) argued that unawareness of SSCM challenges proves to be a difficult task for practitioners for SSCM adoption.

Eltayeb et al. (2011) pointed out that high initial cost for environmental friendly packaging restricts the organisations to adopt sustainability practices. Specially, in developing economies where the profit margins for organisations are very low, so it becomes really difficult for them to execute green packaging systems (Walker et al., 2008). Similarly, Tseng et al. (2019) highlighted that ineffective linkage of sustainability with existing process structure and conflict of interest between the product sustainability policies and free trade provisions are the prime reasons for SSCM failures. Whereas, from the management perspective; “Poor management commitment for adoption of sustainability”, “Strong perceptions towards low economic returns” and “Non-uniform alignment of sustainability, organisation goal and customer expectation” are the most significant challenges that obstructs SSCM adoption.

Chiarini (2017) indicated in their study that the supplier oriented challenges possess strong influence on SSCM adoption. Suppliers play a very significant role in SSCM process and can be considered primary input parameter for effective SSCM execution, hence; it is essential that suppliers should closely observe sustainability parameters and helps in executing them smoothly (Jin et al., 2017). Batista et al. (2018) discussed various such challenges that includes “Lack of effective communication with suppliers”, “Lack of awareness of sustainable standards for raw materials”, “Inappropriate system of reverse logistics”, “Ineffective supplier selection strategies” to be responsible to SSCM adoption failures. Hence, it becomes critical for the supply chain managers to keep a constant track of the supplier related activities for an uninterrupted sustainable supply chain system (Gopal and Thakkar, 2016).

It is further noticed that many researchers (Carter and Liane Easton, 2011; Singh, 2016; Ansari and Kant, 2017) conducted literature review on SSCM and explained different set of SSCM challenges faced by the manufacturing, service, healthcare and other industry sectors. It is observed that majority of them reported “Unavailability of effective framework for SSCM adoption”, “Inappropriate execution of sustainability practices”, and “High cost of sustainability adoption” as the primary responsible challenges that influences SSCM adoption (Irani et al., 2017). Similarly (Beske et al., 2014; Beske and Seuring, 2014; Schrettle et al., 2014), also argued that it is extremely essential to have a framework that could guide the path for successful SSCM adoption. Macchion et al. (2018) supported the above raised issue, and pointed out that the effective SSCM framework can be formed by linking the SSCM challenges and solution measures which could overcome them.

Winter and Knemeyer (2013) highlighted “Resistance of culture change”, “Lack of effective employee engagement and empowerment”, “Ineffective employee training for sustainability”, “Non-consideration of human factors”, “Lack of effective inter-departmental communication” as some of the socio-cultural factors holding strong intensity to restrict sustainability adoption. However, in context to the organisation; “Replicating sustainability adoption strategies of other organisations”, “Unavailability of sustainability standard and regulations”, “High disposal costs” emerges as critical concerns for sustainability aspects (Beske and Seuring, 2014). Sajjad et al. (2015) also indicated in their study that various organisations have failed to adopt SSCM due replication of other organisations sustainability adoption strategies. Hence, it should be understood that every organisation has different environment and mode of process execution which makes them unique and the adoption strategies should be formulated accordingly (Ozturk et al., 2016). Also, the awareness of sustainability standards and regulations builds a platform for executing sustainability practices (Meckenstock et al., 2016).

Hence, after reviewing these SSCM challenges specific articles, all the identified challenges are tabulated as shown in Table 1.

2.2. Solution measures of industry 4.0 and circular economy

Many studies (Zhong et al., 2017; Fatorachian and Kazemi, 2018) in literature pointed out industry 4.0 and circular economy as future of organisations. Due to rise in automation and reverse logistics practices, the above mentioned concepts are rapidly adopted by various organisations to achieve global sustainability (Hofmann and Rüsch, 2017). Bibby and Dehe (2018) also argued that the facilitating factors of industry 4.0 and circular economy has strong influence on supply chain related activities. Hence, the industry 4.0 and circular economy based facilitating factors can be considered as solution measures of SSCM adoption (Wang et al., 2016). Various researchers in literature termed these facilitating factors as enablers, drivers, critical success factors and indicators (Lee et al., 2015). Hence, the authors reviewed the articles that explored the solution measures based on industry 4.0 and circular economy.

Oliveira et al. (2017) identified several industry 4.0 based indicators such as “Adoption of smart factory components”, “Integration of digital and physical systems”, “Environmental Product Design and life cycle analysis”, and “Adoption of advanced machine learning algorithms”. The main aim of industry 4.0 is to promote digitisation and develop a smart system that could utilise sustainable resources for obtaining green future (Fatorachian and Kazemi, 2018). According to Moeuf et al. (2018), “the industry 4.0 adoption promotes the adoption green practices so as to achieve produce sustainable products that could not harm the environment”. Oesterreich and Teuteberg (2016) conducted a case study on industry 4.0 adoption and listed out industry 4.0 indicators that helped in improving the organisational performance. Various researchers reported that strong inter-departmental IT linkage system assist in tracking the supply chain activities more precisely and any unusual behaviour within the supply chain could be tracked and improved immediately.

Suppliers are considered as an essential component in supply chain and hence the activity related with them has direct effect on sustainable performance of supply chain (Moktadir et al., 2018b). So, it is desired to have positive commitment from suppliers for delivering recyclable materials (Silvestre et al., 2018). Further, there should be an effective co-ordination and collaboration among the supply chain members. Similarly, digitisation of supply activities will result in obtaining the optimised outputs by removing various types of wastes and non-value added activities (Bibby and Dehe, 2018). In addition to suppliers, it is expected to educate the customers for recycling practices so that the manufactured product does not harm the environment and gets recycled (Liao et al., 2017). However, from the employee perspective it is suggested to develop a rewards and recognition system for executing the greener activities that will further promote green purchasing and green packaging (Zhong et al., 2017).

On the other hand (Ghisellini et al., 2016), conducted a literature review on circular economy and pointed out that adoption of 6 R's (recycle, reuse, reduce, refuse, rethink and repair) in the organisation directly correlates to sustainability. According to the automotive context, the recycle refers to consider an existing product that has become waste and re-process the material for use in a new product. Reuse refers to consider an existing product that has become waste and use the material or parts for another purpose, without processing it. Reduce refers to minimise the amount of material and energy used during the entire product life cycle. Refuse refers to rejection of the product if it is not required or it is environmentally or socially unsustainable. Rethink refers to assess the current process of design and finding the alternative ways for optimisation. Repair refers to find the immediate measures to fix any breakdown occur with the entire process structure. They emphasised on executing the circular economy oriented framework such as RESOLVE (Regenerate, Share, Optimise, Loop, Virtualise and Exchange), to optimise the entire organisational process structure in order to gain environmental and societal benefits. Whereas, adopting industrial ecology initiatives synchronises the material and energy flow through industrial systems (Oliveira et al., 2017).

Table 1
SSCM adoption challenges identified through literature.

S. No.	SSCM adoption challenges	Description	Literature support
1	High initial cost for environmental friendly packaging	The high cost for packaging of products restricts its adoption among the organisation	(Silvestre et al., 2018; Tseng et al., 2019)
2	Poor management commitment for adoption of sustainability	The minimal involvement of top management authorities towards sustainability adoption leads to SSCM implementation failures	(Irani et al., 2017; Ghadimi et al., 2019)
3	Ineffective linkage of sustainability with existing process structure	In many cases, the management is unable to link sustainability within the existing supply chain process structure	(Irani et al., 2017; Ghadimi et al., 2019)
4	Conflict among product sustainability policy and free trade provisions	There exists conflict of interest between the product sustainability policy and free trade provisions which influences sustainability adoption	(Walker et al., 2008; Gopal and Thakkar, 2016)
5	Unavailability of effective framework for SSCM adoption	Lack of availability of appropriate SSCM framework deviates the organisation from achieving sustainability in supply chain	(Sarkis and Sarkis, 2012; José et al., 2017; Batista et al., 2018)
6	Lack of awareness of sustainable standards for raw materials	It is extremely critical to be aware of existing sustainable standards of raw material in context to the suppliers	(Macchion et al., 2018; Ghadimi et al., 2019)
7	Strong perception towards low economic returns	The decision making authorities have perception of low economic returns through adoption of SSCM	(Irani et al., 2017; Silvestre et al., 2018)
8	High cost of sustainability adoption	The adoption of SSCM requires high initial investment and this again acts as a drawback that resists the management through adoption process	(Walker et al., 2008; Silvestre et al., 2018)
9	Ineffective employee training for sustainability	The employees need to be trained regarding adoption strategies for sustainability in order to enhance supply chain performance	(Moktadir et al., 2018b; Shibin et al., 2018)
10	Non-consideration of human factors	Many organisations ignore the human factors that eventually affects the organisational performance and misaligns the supply chain activities	(Walker and Jones, 2012; Koberg and Longoni, 2019)
11	Non-uniform alignment of sustainability, organisation goal and customer expectation	It is significant to make a perfect mix of sustainability, organisation goals and customer expectations to sustain in the global competition	(Bastas and Liyanage, 2018; Majumdar and Sinha, 2019)
12	High disposal costs	The high disposal costs restricts the organisation from adopting sustainability in supply chain	(Mollenkopf et al., 2010; Jia et al., 2018)
13	Lack of effective communication with suppliers	It is important to have strong and real time communication with the supplier by tracking organisational activities to eliminate the production delay	(Walker et al., 2008; Batista et al., 2018; Jia et al., 2018)
14	Replicating sustainability adoption strategies of other organisations	To gain quick success in SSCM adoption, many organisation attempts to replicate other organisations' strategies that often lead to adoption failures	(Sarkis and Sarkis, 2012; José et al., 2017; Silvestre et al., 2018)
15	Design complexity for energy consumption reduction	To produce sustainable products and reducing energy consumption several organisations switches to alters design procedures which leads to complexity	(Walker et al., 2008; Batista et al., 2018; Tseng et al., 2019)
16	Inappropriate execution of sustainability practices	Ineffective utilisation of sustainability practices makes it difficult to adopt SSCM	(Walker and Jones, 2012; Koberg and Longoni, 2019)
17	Lack of effective employee engagement and empowerment	Defined involvement of employee in managerial activities and offering empowerment improves their efficiency and supports SSCM adoption	(Gopal and Thakkar, 2016; Moktadir et al., 2018b; Shibin et al., 2018)
18	Inappropriate estimation of SSCM adoption cost	Lack of effective estimation of SSCM adoption is extremely necessary for its successful execution	(Mollenkopf et al., 2010; Jia et al., 2018)
19	Lack of availability of resources (financial, technical, human, etc.)	Unavailability of financial, technical and human resources makes it critical for the organisation to adopt sustainability	(Batista et al., 2018; Ghadimi et al., 2019)
20	Ineffective supplier selection strategies	Selection of appropriate supplier is necessary to produce desired sustainable products	(Moktadir et al., 2018b; Shibin et al., 2018)
21	Ineffective performance measurement system	Lack of appropriate performance measurement system results in ineffective mapping of performance and tracking of supply chain activities	(Giunipero et al., 2012; Moktadir et al., 2018b; Shibin et al., 2018)
22	Inappropriate system of reverse logistics	Lack of effective reverse logistics system makes it difficult to recycle the products and the path towards sustainability achievement gets deviated	(Silvestre et al., 2018; Ghadimi et al., 2019)
23	Unavailability of sustainability standard and regulations	It is essential to have exposure towards sustainability standards and regulations because it ensures the benchmarking of the produced products	(Jia et al., 2018; Shibin et al., 2018; Ghadimi et al., 2019)
24	Lack of effective inter-departmental communication	Poor communication within the departments delays the monitoring of activities and though the adoption process	(Koberg and Longoni, 2019; Majumdar and Sinha, 2019)
25	Loss of return material in transit	Return material loss in transit strongly affects the reverse logistics activities	(Irani et al., 2017; Ghadimi et al., 2019)
26	Resistance of culture change	During sustainability adoption, the employees portrays resistance to culture change which makes SSCM adoption difficult	(Luthra et al., 2019; Mangla et al., 2019)
27	Usage of outdated auditing standards	Unavailability of advanced data auditing standards affects SSCM adoption	(Irani et al., 2017; Ghadimi et al., 2019)
28	Complexity within supply chain configuration	Existence of complexity within the supply chain restricts in adopting sustainability among traditional SC	(Sarkis and Sarkis, 2012; José et al., 2017; Silvestre et al., 2018)

This initiative promotes the sustainability and helps the organisation in developing a circular economy based system. It also helps the managers to track the supply chain activities effectively (Ghisellini et al., 2016). Similarly, the effective facility planning also assists in planning the strategies for SSCM adoption.

Wang et al. (2018) and Kirchherr et al. (2017) noticed that building a brand image based on industry 4.0 and circular economy not only ensures the sustainability within the organisation but also helps in educating the internal and external customers towards green culture. It further assists in understanding the economic and societal benefits (Yadav et al., 2017). Several organisations include the adoption of safety standards to overcome any unexpected incidents in their supply chain (Oliveira et al., 2017). It boosts the sustainability among the final products. Kirchherr, Reike, and Hekkert (2017) indicated that adoption of advanced predictive maintenance system supports the execution of safety standards within the organisation. Hence, after reviewing specified articles, all the industry 4.0 and circular economy based solution measures reported by various researchers in literature are shown in Table 2.

2.3. Gaps observed in literature

After conducting the above discussed literature review, following gap areas are observed.

- A large number of studies (Tonelli, 2013; Rehman et al., 2016; Gold et al., 2017) are available in literature that addresses the challenges observed by practitioners while adopting sustainability in supply chain. However, very limited articles could compute the intensity of identified challenges by adopting any decision making approach.
- There are various SSCM frameworks (Siong Kuik et al., 2011; Beske et al., 2014; Bhattacharya et al., 2014) available in literature. However, it is interesting to note that none of them could establish a linkage between the challenges and solution measures.
- Majority of available frameworks are non-verified, which raise a serious question on their applicability.
- Most of the verified SSCM frameworks adopted case study approach as their mode of verification, while none of them used the multi-criteria decision making approach for the same to strengthen its applicability.
- Several articles (Diabat et al., 2014; Dubey et al., 2015; Hussain et al., 2015) in literature reports the solution measures based on industry 4.0 and circular economy. But, these articles failed to shed light on the intensity of these solution measures.
- There are various studies (Kang et al., 2016; Caldera et al., 2019) reporting industry 4.0 and circular economy based facilitators but very few articles could portray their inter-relation with SSCM.

The above addressed gaps clearly indicate a strong need of SSCM framework that could link its challenges with industry 4.0 and circular economy based solution measures. It further demands the application of Multi-Criteria Decision-Making (MCDM) approach for computing the intensity of challenges and prioritisation of solution measures. This clearly justifies the objectives defined for present research work.

3. Research methodology

The overall flow of present research work is shown in Fig. 1.

Initially, an exhaustive literature review is carried out to identify the key SSCM challenges and the solution measures required to overcome them through industry 4.0 and circular facilitators. Later, these factors are tabulated and presented before the decision panel of the case organisation for finalisation. Based on the experts' feedback, a framework is developed and tested across the case organisation by application of hybrid BWM-ELECTRE approach. BWM approach is utilised for computing the weight of SSCM challenges. The outputs are tested primarily for consistency, and if the Consistency Ratio (CR) is observed more than 0.1 than the comparison is sent back to the decision panel for providing inputs again, else; it is forwarded to the next stage.

Accordingly, the results though obtained are taken as inputs for ELECTRE approach along with the expert inputs for paired comparison of challenges and solution measures. By following standard procedure of ELECTRE, the solution approaches are ranked so as to identify the high priority solution measures. The study further discusses the relationship of SSCM challenges and its solution measures by describing how these top priority solutions will assist in overcoming the SSCM challenges. Finally, the case study findings are discussed and the implications of present study for researchers and practitioners are presented.

4. Case description and framework development

It is extremely important to notice how the essential components are linked together to form an execution framework. Similarly, it is equally important to test the developed framework across the case organisation to strengthen its applicability. It becomes an additional advantage when the developed framework utilises MCDM approach for its testing in case organisation. The subsequent sub-sections portray the description of case organisation, problem definition and framework development.

4.1. Case organisation and problem definition

The adoption of sustainability in supply chain in manufacturing organisations is difficult as compare to other industry sectors (Kleindorfer et al., 2009). Majumdar and Sinha (2019) indicated in their study that the supply chain performance of service and healthcare industries is much higher than manufacturing industries. While due to existence of hard and tangible goods in automotive sector, it becomes extremely tough for the practitioners to adopt sustainability in their existing supply chain structure effectively (Gimenez et al., 2012). Hence, an automotive organisation located in central India is selected for the present study. The case organisation came into existence in 1982 and deals in manufacturing of gear boxes. It holds 1200 employees and has an annual turnover of $ 45 million. The organisation is planning to expand their business over the international platform and hence plan to adopt sustainability in their existing supply chain. The management of the case organisation wants to ensure the successful adoption of SSCM and hence they decided to test the framework developed by authors prior to their actual adoption. For the purpose, a decision panel of six experts is formed within the case organisation which includes two project managers, two assistant managers from sales and distribution, one supervisor from production department, and one senior manager from purchase department. All the experts have exposure to supply chain activities for more than 20 years. However, four experts have the experience of handling international supply chain activities for 10 years.

4.2. Data collection and framework development

Prior to the data collection procedure an approval is taken from the university ethics committee as well as the case organisation that data collected during the study will be utilised to framework development process. Further, the study outcomes will be shared with the case organisation to facilitate SSCM adoption.

Table 2
Industry 4.0 and CE based solution measures identified through literature.

S. No.	Solution measures	Description	Literature support
1	Supplier commitment for recyclable materials	Assurance of supply of recyclable raw materials uplifts the probability sustainability adoption in existing supply chain	(Batista et al., 2018; Tseng et al., 2019)
2	Adoption of 6 R's within the organisation	By adopting 6 R's in the organisation, the sustainability level can be enhanced	(Batista et al., 2018; Shibin et al., 2018)
3	Green Purchasing and packaging	Green purchasing and packaging ensures minimal harm to the environment and society	(Moktadir et al., 2018b; Tseng et al., 2019)
4	Rewards and incentives for greener activities	Planned rewards for execution of greener activities promotes sustainability	(Lee et al., 2015; Ivanov et al., 2016)
5	Co-ordination and collaboration among SC members	Effective co-ordination among supply chain members leads to develop smart information and communication system	(Zhong et al., 2017; Fatorachian and Kazemi, 2018)
6	Supplier Commitment and involvement for sustainability adoption	Suppliers need to be educated for sustainability benefits to strengthen their commitment	(Wang et al., 2016; Lu, 2017b)
7	Adoption of advanced machine learning algorithms	Usage of advanced machine learning algorithms will develop flexibility among the existing supply chain	(Hofmann and Rüsch, 2017; Bibby and Dehe, 2018)
8	Adoption of smart factory components	Employing smart factory components will boosts the success possibility of SSCM	(Hofmann and Rüsch, 2017; Zhong et al., 2017)
9	Availability of CE oriented framework (Resolve)	Adopting CE specific framework will help in enhancing reverse logistics activities	(Wang et al., 2016; Liao et al., 2017)
10	Strong interdepartmental IT linkage system	Effective interdepartmental IT linkage system results in uninterrupted monitoring of SSCM activities	(Lu, 2017; Fatorachian and Kazemi, 2018)
11	Environmental Product Design and life cycle analysis	Designing of product considering environmental aspects and effective life cycle analysis smoothens SSCM adoption	(Liao et al., 2017; Fatorachian and Kazemi, 2018)
12	Adoption of advanced quality improvement techniques	Practicing advanced quality improvement techniques will assist in removing non-value added activities in existing SC results continuous improvement	(Zhong et al., 2017; Fatorachian and Kazemi, 2018)
13	Digitisation of supply chain activities	Digitising supply chain activities will help in optimising the entire supply chain	(Batista et al., 2018; Tseng et al., 2019)
14	Sustainable resource management	Sustainable resource management will help in reducing the energy consumption leading sustainability achievement	(Zhong et al., 2017; Fatorachian and Kazemi, 2018)
15	Adopting Industrial ecology initiatives	Industrial ecology initiatives helps in implementing circular economy practices for better sustainability	(Hofmann and Rüsch, 2017; Bibby and Dehe, 2018)
16	Adoption of advanced predictive maintenance system	Execution of advanced predictive maintenance helps to prevent system shutdown and break in supply chain	Oliveira et al. (2017)
17	Effective facility planning	Better facility planning helps in executing supply chain practices optimally	(Hofmann and Rüsch, 2017; Zhong et al., 2017)
18	Adoption of safety standards	Existence of safety standards in the system ensures employee safety from accidents during supply chain	Ghisellini et al. (2016)
19	Understanding economic and social benefits	Realising economic and social benefits of sustainability enhances its adoption possibilities	(Batista et al., 2018; Shibin et al., 2018)
20	Building brand image based on CE and I 4.0	Developing a brand image on CE and I 4.0 helps in global acceptability of produced product	(Wang et al., 2016; Lu, 2017b)
21	Educating customers for recycling practices	Regular education for customers to execute recycling practices assist in improving sustainability adoption	(Batista et al., 2018; Tseng et al., 2019)
22	Integration of digital and physical systems	Linking digital and physical systems facilitates the supply chain tracking system for quick responses	(Hofmann and Rüsch, 2017; Zhong et al., 2017)

The decision panel formed in case organisation is utilised in three different phases by conducting brainstorming sessions. The tabulated list of challenges and solution measures extracted through literature review is presented before the expert panel. The first phase includes finalisation of SSCM challenges and their performance measures required to develop the framework for SSCM adoption and later the challenges identified through literature review are categorised among five major groups namely; economic challenges, managerial and organisational challenges, supplier challenges, socio-cultural challenges, and process challenges.

A framework is developed accordingly by linking the major and sub-group challenges with its solution measures. Further, a questionnaire is developed to obtain the inputs for hybrid BWM-ELECTRE approach. During the second phase, the input judgements are obtained from questionnaire that includes pairwise comparison of major group challenges as well as subgroup challenges; which are utilised for computing the weights of challenges through BWM approach. Finally, in the third phase, the inputs for ELECTRE approach are obtained by comparison of challenges with solution measures made by the expert panel to compute the final rankings of solution measures. The framework developed in present research work is shown in Fig. 2.

5. Analysis

The developed framework to enhance sustainable supply chain management adoption is tested in the case organisation across two stages. First stage computes the weights of SSCM challenges, whereas; second stage identifies the rank of solution measures adopted to improve its adoption rate. The details are shown in subsequent sections.

5.1. Computation of weights of SSCM challenges

The MCDM literature offers a number of methods for computation of weights such as analytical hierarchy process, simple multi attribute rating technique, weighted sum method and many more (Yadav and Desai, 2017). The applicability of each method strongly depends on the nature of the problem. However, these methods require large number of judgements of decision maker which may lead to biasness and scattered decisions. Every method has its unique feature; but, it also important to notice the number judgements

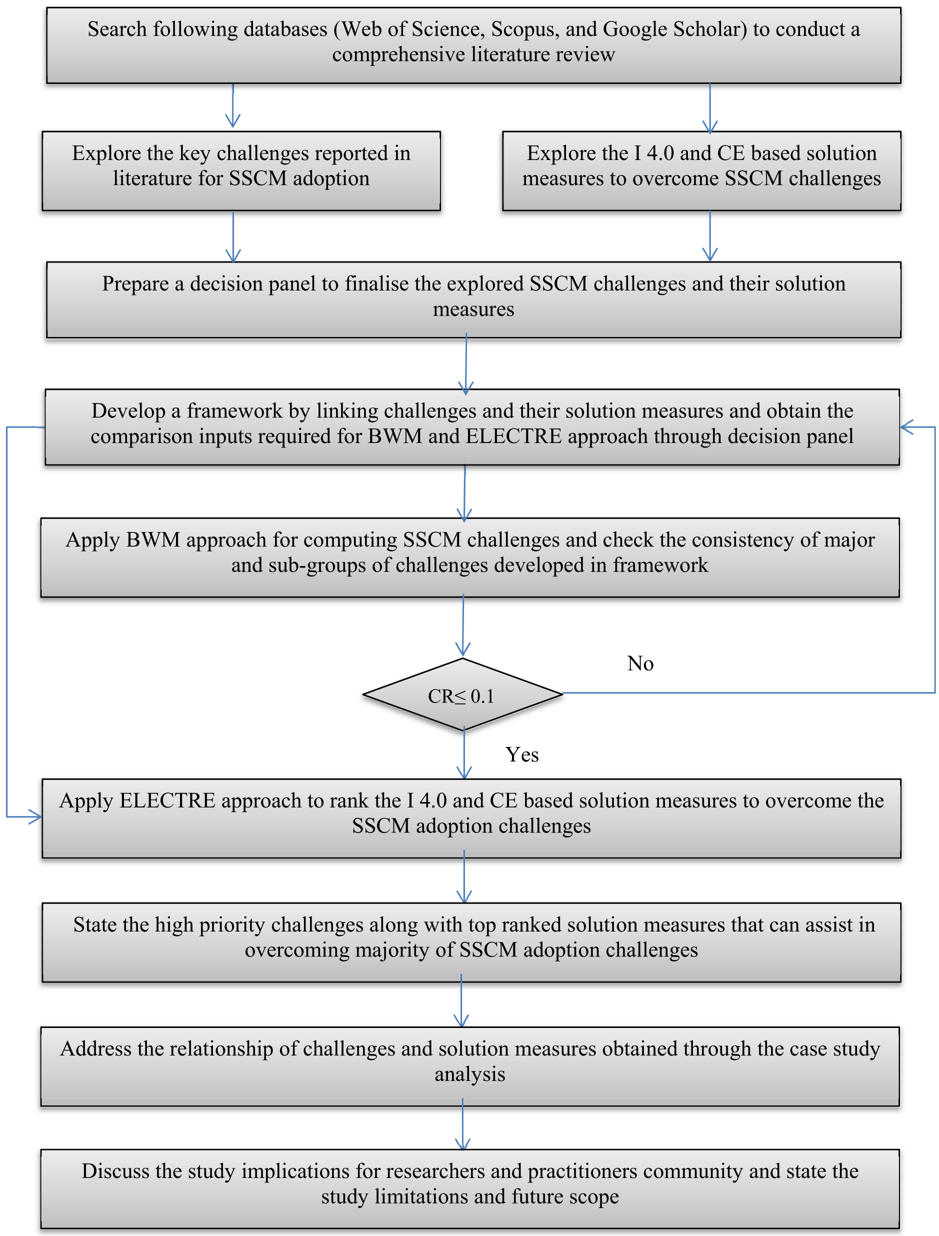

Fig. 1. The overall flow of present research work.

required to arrive at a particular decision. While, on the other hand when comparing attribute A to B, and then B to C, there are chances that it does not satisfy the corresponding relation of A to C.

Hence, to overcome such situations, Rezaei (2015) proposed best worst method to fill the above discussed gap. Many researchers (Ghasemian Sahebi et al., 2017; Moktadir et al., 2018a; Yadav et al., 2018a) have recently utilised this approach to compute attribute weights. So, the weights of SSCM challenges in the present study are computed by employing best worst method. The detailed execution of BWM is explained below:

1) Based on the developed framework, prepare the different comparison table for major groups and sub-groups. Let us say the considered challenges be c_1, c_2, c_3, c_4…….. c_n.
2) Using judgments of decision panel, best and the worst challenges criteria are defined: This step individually helps in identifying the most preferred and least preferred challenge among each group.
3) Assign the intensity of preference within 1–9 for the most preferred challenge over the other challenges of the group. This step indicates the best to other vectors.

$$A_B = (a_{1B}, a_{2B}, a_{3B}, \ldots. a_{nB}) \quad \text{(i)}$$

4) Assign the intensity of preference within 1–9 for the least preferred challenge over the other challenges of the group. This step indicates the worst to other vectors.

$$A_w = (a_{1w}, a_{2w}, a_{3w}, \ldots. a_{nw}) \quad \text{(ii)}$$

5) Compute the local weights for each sub-group (w_1^*, w_2^*, w_3^*,…. w_n^*). The systematic procedure for local weight computation is

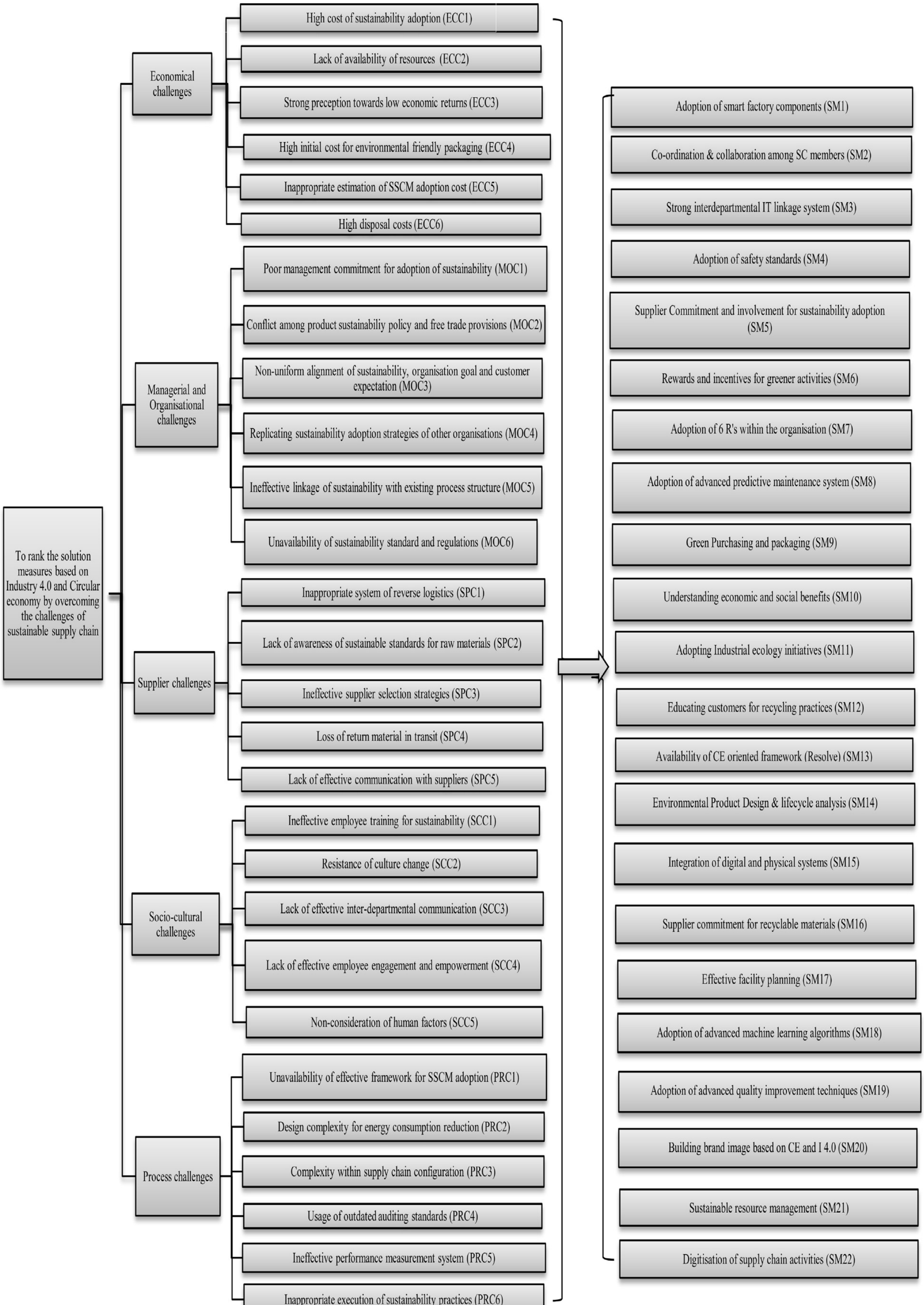

Fig. 2. Framework to overcome sustainable supply chain challenges.

shown below. The defined LP problem is solved to compute the SSCM challenges weights.

Min ξ - Subject to

$$\left|\frac{wB}{wj} - a_{Bj}\right| \le \xi, \text{ for all values of j} \tag{iii}$$

$$\left|\frac{wj}{ww} - a_{jw}\right| \le \xi, \text{ for all values of j} \tag{iv}$$

$\sum wj = 1$, $w_j \ge 0$, for all values of j.

Merely, computation of weights is not sufficient; as it is essential to check whether the obtained weights are consistent or not. Accordingly, $\xi^{\#}$ values are calculated in order to ensure that the judgements made by the decision panel are consistent. If not found so, the experts need to be recalled to revision of comparison of challenges.

In BWM, the primary requirement is to identify the best and worst criterion from each group and later two categories of comparisons are made. Firstly, the best criterion is compared with all other criteria of the same group. Secondly, the worst criterion is compared with all other criteria of the same group. Such comparison ensures the least possibility of the judgements made by the decision makers to be inconsistent. Whereas, ξ indicates the level of consistency; hence, its closeness to 0 indicates that the judgements are strongly consistent. While the increase in the value of ξ from 0 to 1 reduces the consistency level of the judgements made by the decision makers. By using the above two mentioned categories for comparison, the decision makers' confidence in making appropriate judgements strongly increases and accordingly it is more likely to have the consistent comparisons when compared to different variants of analytical hierarchy process where λ values are chosen as basis for computing the consistency of input paired comparisons.

Following the above procedure, the comparisons for the major group and all the sub-groups are done separately. However, due to limitation of space only the major group comparison is shown. Table 3 represents the best to others and others to worst comparisons done for major group of SSCM challenges. It further indicates the final weights obtained for major group challenges. It is found that $\xi^{\#}$ values for all the comparisons made by different experts are found to be consistent.

After obtaining the major group weights, the subsequent local weights for each group is computed and later multiplied to its corresponding major group weight. It results in obtaining the global weight of each SSCM challenge. Each sub-group is further checked for consistency to ensure that the global weights are optimum. Table 4 represents the global weights finally obtained for SSCM challenges.

Table 3
Best to others comparison of major group challenges.

Expert No.	Best/Worst		ECC	MOC	SPC	SCC	PRC	$\xi^{\#}$
1	Best	MOC	2	1	4	3	8	0.0109
	Worst	PRC	4	8	2	3	1	
	Weights obtained		0.2295	0.4481	0.1148	0.1530	0.0546	
2	Best	SPC	5	2	1	3	3	0.0552
	Worst	ECC	1	3	5	2	3	
	Weights obtained		0.0690	0.2276	0.4000	0.1517	0.1517	
3	Best	ECC	1	4	6	2	5	0.0880
	Worst	SPC	7	3	1	6	3	
	Weights obtained		0.4399	0.1320	0.0587	0.2639	0.1056	
4	Best	PRC	7	5	3	4	1	0.0910
	Worst	ECC	1	3	5	4	7	
	Weights obtained		0.0569	0.1160	0.1933	0.1450	0.4889	
5	Best	ECC	1	5	2	6	4	0.0641
	Worst	SCC	6	2	4	1	3	
	Weights obtained		0.4487	0.1026	0.2564	0.0641	0.1282	
6	Best	MOC	4	1	6	2	3	0.0390
	Worst	SPC	2	6	1	4	3	
	Weights obtained		0.1169	0.4286	0.0649	0.2338	0.1558	
Mean Weights [a]			**0.2268**	**0.2425**	**0.1813**	**0.1686**	**0.1808**	**0.0580**

[a] indicates mean weight obtained through judgements made by decision panel.

5.2. Ranking of solution measures

Similar to the weight computation methods, the MCDM literature also offers a variety of methods to rank the alternatives based on the availability of attribute weights such as Technique for Order Preference and Similarity to Ideal Solution (TOPSIS), VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), Grey Relational Analysis (GRA), Step-wise Weight Assessment Ratio Analysis (SWARA), Weighted Aggregated Sum Product ASsessment (WASPAS), Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) and many more (Yadav et al., 2018). However, the applicability of each MCDM approach depends on the nature of chosen problem. For the present case, there exists large number of challenges (attributes) as well as solution measures (alternatives); hence, for the purpose ELECTRE appears to be most appropriate method. Many researchers argued regarding the relevancy of PROMETHEE approach instead of ELECTRE approach. But, it is observed that in PROMETHEE approach, relation between two variables is either 0 or 1; however, in actual practice it is not possible to have such relations. Hence, the ELECTRE approach utilises the percentage of relation between the two variables in order to have more optimised results. The ability to compare available set of alternatives separately with respect to each attribute gives ELECTRE as an edge over other outranking methods. So, the weights of SSCM challenges calculated in previous stage are considered as input for this stage. The standard procedure for executing ELECTRE approach is defined as follows (Rao, 2007):

a) **Construct the decision table:** It includes paired comparison of all the alternatives (solution measures) with the available attributes (challenges). It assists in developing the hierarchical structure of the chosen problem.
b) **Assign weights:** This step includes extraction of weights of challenges obtained through application of BWM in previous stage. It is utilised as initial inputs for ELECTRE approach.

Appendix A1 represents the initial paired comparison of SSCM challenges with their solution measures.

c) **Compute the concordance matrix:** After grouping of challenges, it is important to distinguish the beneficial and non-beneficial factors. For every beneficial attribute, the highest value is desired; while, for every non-beneficial attribute the lowest value is desired. For the present problem, all the challenges are non-beneficial and hence need to be minimised. For every function $f(b_1)$, b_1 describes the alternative score, whereas w_j indicates the weight of attribute j, accordingly the concordance index $C(b_1,b_2)$ may be defined as:

$$C(b_1, b_2) = \sum_{j=1}^{M} wj{*}cj(b_1, b_2) \tag{v}$$

The $c_j(b_1,b_2)$ can be computed by:

Table 4
Global weights of SSCM challenges.

Major group	Major group weight	Sub-challenge	ξ^L	Local weight	Global weight	Final Rank
Economic challenges	0.2268	ECC1	0.0561	0.1838	0.0417	7
		ECC2		0.2672	0.0606	1
		ECC3		0.1483	0.0336	13
		ECC4		0.1340	0.0304	20
		ECC5		0.1481	0.0336	15
		ECC6		0.1187	0.0269	23
Managerial and organisational challenges	0.2425	MOC1	0.0626	0.2236	0.0542	3
		MOC2		0.2451	0.0594	2
		MOC3		0.1256	0.0304	19
		MOC4		0.1376	0.0334	16
		MOC5		0.1439	0.0349	12
		MOC6		0.1243	0.0301	21
Supplier challenges	0.1813	SPC1	0.0584	0.2350	0.0426	5
		SPC2		0.2440	0.0442	4
		SPC3		0.1266	0.0230	28
		SPC4		0.1696	0.0308	18
		SPC5		0.2248	0.0408	9
Socio- cultural challenges	0.1686	SCC1	0.0763	0.2481	0.0418	6
		SCC2		0.2429	0.0409	8
		SCC3		0.1538	0.0259	24
		SCC4		0.1438	0.0243	26
		SCC5		0.2114	0.0356	11
Process challenges	0.1808	PRC1	0.0600	0.2187	0.0395	10
		PRC2		0.1857	0.0336	14
		PRC3		0.1331	0.0241	27
		PRC4		0.1767	0.0319	17
		PRC5		0.1353	0.0245	25
		PRC6		0.1505	0.0272	22

$$C_j(b_1, b_2) = \left\{ \begin{array}{lll} 1, & if & fj(b1) + qj \geq fj(b2) \\ 0, & if & fj(b1) + pj \leq fj(b2) \\ \dfrac{fj(b1) + pj - fj(b2)}{pj - qj} & if & else \end{array} \right\} \tag{vi}$$

It is important to note that $C(b_1,b_2)$ portrays the relative importance of one solution measure over the other.

d) **Compute the discordance index:** Initially, veto threshold (v_j) is computed. It indicates that influence intensity of a_1 over a_2 can be ignored in the case where the second solution measure reflects greater value than the sum of first solution measure and veto threshold. The discordance index of every solution measure $d_j(b_1,b_2)$ may be computed as:

$$D_j(b_1, b_2) = \begin{array}{lll} 0, & if & fj(b1) + pj \geq fj(b2) \\ 1, & if & fj(b1) + vj \leq fj(b2) \\ \dfrac{fj(b2) - pj - fj(b1)}{vj - pj} & if & else \end{array} \tag{vii}$$

e) **Compute the credibility index:** Credibility index indicates the influence intensity such that the “first solution measure is at least as good as solution measure 2”. It can be computed as:

Table 5
Ranking of solution measures to overcome SSCM challenges.

Solution Measures	Concordance credibility	Discordance credibility	Superiority ratio	Final Rank
SM1	18.2265	19.0903	0.9548	13
SM2	18.3602	20.4114	0.8995	19
SM3	18.6214	20.2318	0.9204	17
SM4	16.4405	20.7969	0.7905	22
SM5	21.4041	18.624	1.1493	5
SM6	19.9644	19.3636	1.031	9
SM7	20.6214	17.1078	1.2054	1
SM8	17.439	20.8024	0.8383	21
SM9	20.5497	19.2455	1.0678	8
SM10	18.2503	19.7955	0.9219	16
SM11	19.1431	19.2286	0.9956	12
SM12	19.7354	18.2281	1.0827	7
SM13	19.3802	19.0866	1.0154	11
SM14	19.6485	16.6679	1.1788	2
SM15	19.5819	19.1633	1.0218	10
SM16	20.0814	17.2994	1.1608	4
SM17	18.0763	19.9697	0.9052	18
SM18	18.6726	19.5669	0.9543	14
SM19	17.8227	20.3977	0.8738	20
SM20	18.7583	20.2697	0.9254	15
SM21	20.1774	18.493	1.0911	6
SM22	19.1235	16.2385	1.1777	3

$$S(b_1, b_2) = \begin{cases} C(b1, b2), & if \quad C(b1, b2) \geq dj(b1, b2)\ \forall j \\ C(b1, b2)^* \prod_{j \in J(b1, b2)} \frac{1 - dj(b1, b2)}{1 - C(b1, b2)} & else \end{cases} \tag{viii}$$

f) **Compute the superiority ratio:** The ratio of concordance credibility to discordance credibility is known as superiority ratio. The higher value of superiority ratio denotes the most preferred solution measure. Hence, based on the decreasing values of superiority ratio, all the solution measures are ranked. The final rankings of solution measures required to overcome SSCM challenges are shown in Table 5.

6. Case discussion

The application of BWM approach is utilised to for calculating SSCM challenges weights. The results obtained after analysis reveals that among the major groups, managerial and organisational challenges (0.2425) holds the highest weight, followed by economic challenges (0.2268), supplier challenges (0.1813), process challenges (0.1808), and socio-cultural challenges (0.1686). Walker and Jones (2012) also indicated in their study that improper execution of managerial and organisational activities strongly obstructs sustainability adoption in supply chain. Similarly, Silvestre et al. (2018) suggested that supplier oriented activities are majorly responsible for SSCM adoption failures. Whereas, among the overall sub-groups; lack of availability of resources including financial, technical and human [ECC2] (0.0605), Conflict among product sustainability policy and free trade provisions [MOC2] (0.0594), and Poor management commitment for adoption of sustainability [MOC1] (0.0542) are observed as the most critical challenges that restricts SSCM adoption.

Among the economic challenges, lack of availability of resources [ECC2], high cost of sustainability adoption [ECC1] (0.0416), and strong perception towards low economic returns [ECC3] (0.0336) are the most crucial challenges. According to Irani et al. (2017), many organisations hold a strong belief that adoption of sustainability requires high cost and eventually it will degrade their organisational performance. Such myth makes it extremely difficult to execute sustainability in existing supply chain. Among the managerial and organisational challenges, Conflict among product sustainability policy and free trade provisions [MOC2], Poor management commitment for adoption of sustainability [MOC1], and Ineffective linkage of sustainability with existing process structure [MOC5] (0.0348) are strong intensity challenges.

Among the supplier challenges, Lack of awareness of sustainable standards for raw materials [SPC2] (0.0442), Inappropriate system of reverse logistics [SPC1] (0.0426), and Lack of effective communication with suppliers [SPC5] (0.0407) emerged as most important challenges. Majumdar and Sinha (2019) also reported that suppliers play a very critical role in achieving sustainability in supply chain. Gopal and Thakkar (2016) also highlighted the inappropriate system of reverse logistics can lead to SSCM adoption success. Among the socio-cultural challenges, Ineffective employee training for sustainability [SCC1] (0.0418), Resistance of culture change [SCC2] (0.0409), and Non-consideration of human factors [SCC5] (0.0356)

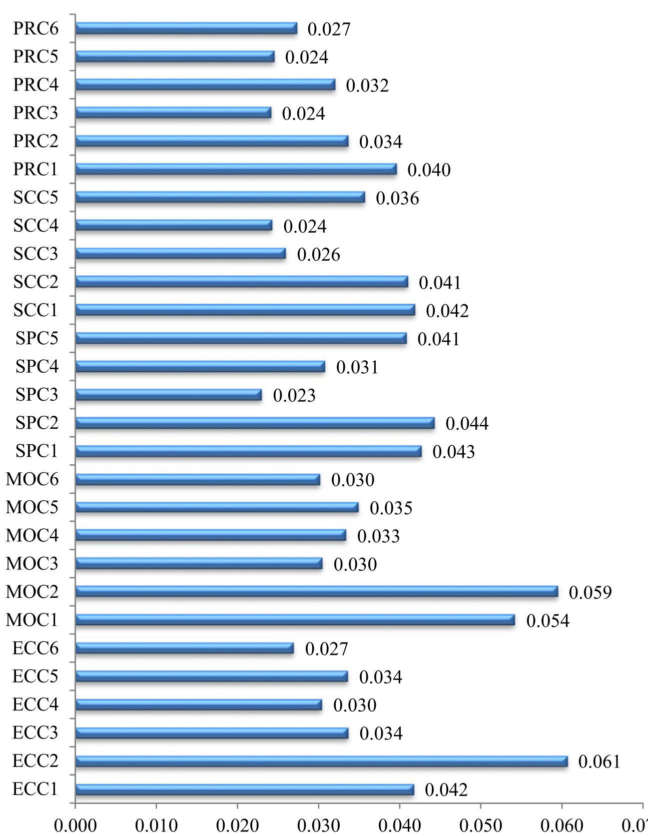

Fig. 3. Weights of SSCM challenges obtained through BWM.

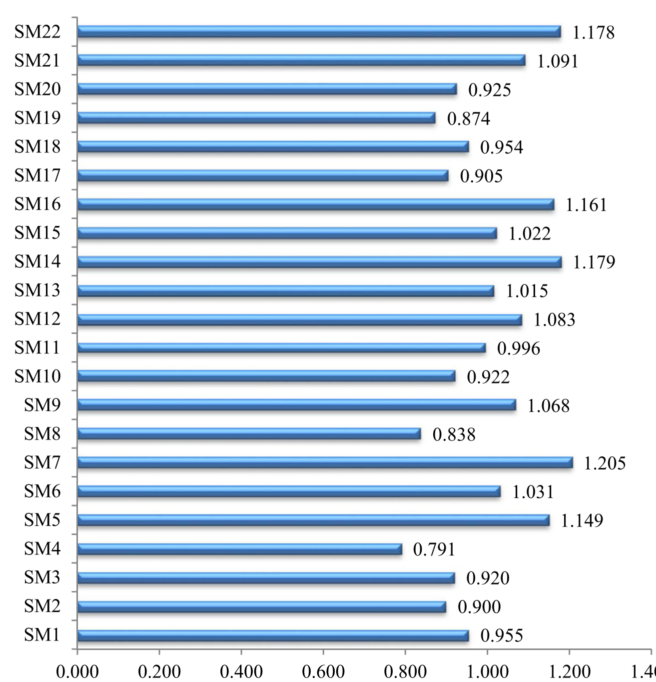

Fig. 4. Superiority ratio values of solution measures obtained through ELECTRE approach.

are the top priority challenges. It is observed in various studies (José et al., 2017; Tseng et al., 2019) that the lack of training of employees towards sustainability has been one of the root causes for SSCM failures. Giunipero, Hooker, and Denslow (2012) also indicated that in majority of organisations, the employee possess resistance to change which restricts the penetration of sustainability in existing supply chain. Among the process challenges, Unavailability of effective framework for SSCM adoption [PRC1] (0.0395), Design complexity for energy consumption reduction [PRC2] (0.0335), and Usage of outdated auditing standards [PRC4] (0.0319) are majorly responsible for ineffective SSCM adoption. Fig. 3 indicates the weight of SSCM challenges obtained through BWM to identify the intensity of selected challenges influencing SSCM adoption.

The weights obtained for SSCM challenges are treated as input for ELECTRE approach to compute the ranking of solution measures required to overcome SSCM challenges. The result reveals that adoption of 6 R's within the organisation (SM7), environmental Product Design and life cycle analysis (SM14), and digitisation of supply chain activities (SM22) are most essential solution measures that can help to cure majority of the challenges.

Further, supplier commitment for recyclable materials (SM16), supplier Commitment and involvement for sustainability adoption (SM5), and sustainable resource management (SM21) also holds high importance and facilitates the adoption of sustainability. Macchion et al. (2018) discussed the role of industry 4.0 and circular economy in achieving sustainability, and pointed out that sustainable resource management should be strongly focussed as it has direct impact over the supply chain sustainability. Similarly, educating customers for recycling practices (SM12), green purchasing and packaging (SM9), and rewards and incentives for greener activities (SM6) are the subsequent significant solution measures that enhance SSCM adoption. The ranks of solution measures will assist the practitioners to formulate the strategies for successful SSCM adoption. Fig. 4 indicates the final superiority ratio values of solution measures for prioritisation through ELECTRE approach.

6.1. Implications for researchers and practitioners

The present study possesses strong theoretical as well as practical contribution towards the domain of supply chain, industry 4.0 and circular economy. The implications of this study for researchers and practitioners are discussed below.

- The constantly changing market needs have demanded the business professionals to identify the key challenges in adoption SSCM effectively. The present study provides an exhaustive list of SSCM challenges faced by the organisations reported by various researchers in literature.
- The practitioners across the manufacturing industries are constantly looking forward for innovative industry practitioners to improve their existing supply chain performance. For the purpose, the concept of industry 4.0 and circular economy has gained their importance over the last decade. Still, the literature lacks studies presenting the facilitators that could lead them to achieve sustainability with the organisation. The list of industry 4.0 and circular economy based solution measures will assist the researchers working in similar domain to develop new frameworks and ultimately improve the adoption rate of SSCM.
- The existing literature portrays several frameworks for enhancing the adoption of SSCM. However, from the framework perspective, many studies in literature have proposed barriers/challenges specific frameworks but a framework linking SSCM challenges with its solution measures in rarely observed. So, the framework developed in this study will strongly assist the practitioners to improve SSCM adoption rate.
- The study outcomes will provide the supply chain managers an in-depth assessment of challenges and solution measures based on their ranking obtained through the application of hybrid BWM-ELECTRE approach.
- Majority of the frameworks reported in literature are verified by using case study approach. However, the present research work utilises case study approach with the treatment of MCDM to boost the applicability of the developed framework.
- In practical industry environment, it is extremely difficult for the practitioners to execute all the solution measures simultaneously. Hence, the prioritisation of solution measures computed in this study will assist them in focussing towards high intensity solutions primarily and subsequently others can be executed.

6.2. Recommendations for policy makers

The adoption of sustainability in supply chain will be the future of industries. Industry 4.0 and circular economy have been supportive to the organisation in providing sustainable products to the customers with high priority to environmental considerations. It is therefore expected that the government should develop policies favouring the adoption of industry 4.0 and circular economy. The policy makers must come up with subsidies to the organisations adopting sustainability practices in their process structure. Such initiatives will boost the organisations interest towards green culture and motivate them to build their brand image reflecting industry 4.0 and circular economy as key components. The policy makers are though advised to conduct sustainability awareness campaigns to educate the organisations as well as their customers who can strongly contribute in improving the performance of recyclability practices. The final rankings of solution measures obtained in this study can be utilised by the government officials for developing effective strategies favouring the organisations and the end users that could assist in enhancing nation's economy.

7. Conclusions

In line with the research objective, the present study initially conducts an exhaustive literature review to explore the key SSCM challenges and industry 4.0 and circular economy based solution measures to improve SSCM adoption. A unique set of 28 SSCM challenges and 22 solution measures is obtained through literature. A framework linking the SSCM challenges and its solution measures is developed and tested case organisation with the help of experts. A hybrid BWM-ELECTRE approach is utilised for framework testing. The case analysis outcome shows that managerial and organisational challenges are primarily responsible for SSCM adoption failures. However, among the sub-group challenges lack of financial, technical and human resources restricts the adoption of sustainability. Various researchers (Koberg and Longoni, 2019; Shibin et al., 2018) have argued that linking the free trade provisions and sustainability policies are debatable issues for the management which further leads to poor commitment of management for sustainability adoption. The ranking of solution measures indicates that adoption of 6 R's within the organisation and environmental product design and life cycle analysis are the top rank solutions that can overcome the SSCM challenges effectively. Hong et al. (2018) and Das (2017) also indicated the importance of 6 R's within the organisation and emphasised the adoption of environmental product design to enhance the sustainability aspects. While, Mani et al. (2018) considered the case of emerging economies and reported life cycle analysis as one of the essential element that help in enhancing the rate of SSCM adoption. These ranking appears to be more meaningful because from the perspective of practitioners, it will be convenient for them to focus on high ranked solutions initially and observe the amount of challenges being removed.

The present study prepares the list of SSCM challenges and their solution measures by exploring literature review and seeking expert opinion. However, it is suggested for the researchers to conduct a large scale survey to enrich the list developed in present study. It is further expected to employ any structural modelling technique such as interpretive structural modelling, decision making trial and evaluation laboratory, or analytical network process to portray the structural relationship among the included factors. The developed framework can be applied to other sub-domains of manufacturing to enhance its applicability. The findings of the present study are also supported by various literature studies related to challenges of SSCM adoption. But, the unique feature of this study is that it establishes a linkage between the SSCM challenges and corresponding solutions that can help to overcome the challenges that obstructs smooth adoption of SSCM. Many studies in literature reported that achieving sustainability across service industries is much easier as compared to manufacturing industries. This also portrays strong need for developing the studies that could handle the challenges and solutions together in a single framework and identifies the intensity of challenges and prioritise the solutions.

The framework developed in this study is tested for its applicability across an Indian organisation. Hence, it won't be wrong if author claim its applicability across developing economies. But, considering its applicability across the developed economies would require certain modifications before its actual implementation. The challenges and the solution measures included in this study are especially in context to developing economies. However, it is suggested that the practitioners should consult the experts of respective developed country to finalise the country specific challenges and also explore the possible solution measures required. It is well known fact that due to availability of advanced technological setups and concerns for sustainability, the developed countries outperform the developing ones. While many challenges and their solution measures identified in this study might be similar when applied across different countries. It is expected that the present research attempt can be considered as a strong contribution to the sustainability adoption and it will be equally beneficial for researchers, practitioners and policy makers.

Declaration of competing interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2020.120112.

Appendix A

Table A1
Initial comparison of SSCM challenges with their solution measures

	ECC1	ECC2	ECC3	ECC4	ECC5	ECC6	MOC1	MOC2	MOC3	MOC4	MOC5	MOC6	SPC1	SPC2	SPC3	SPC4	SPC5	SCC1	SCC2	SCC3	SCC4	SCC5	PRC1	PRC2	PRC3	PRC4	PRC5	PRC6
SM1	5.97	4.67	6.92	4.69	4.67	4.97	7.11	5.64	5.64	6.28	6.31	3.36	2.39	7.25	6.28	6.31	3.36	2.39	5.64	5.64	6.28	6.31	3.36	2.39	4.97	7.11	5.64	5.64
SM2	8.25	4.69	8.39	4.69	7.42	4.69	5.64	4.36	5.31	4.36	3.69	6.94	4.97	6.94	4.36	3.69	6.94	4.97	4.36	5.31	4.36	3.69	6.94	4.97	4.69	5.64	4.36	5.31
SM3	8.08	4.69	8.22	4.69	7.25	5.97	7.08	5.64	5.31	4.00	3.36	5.33	4.69	4.36	4.00	3.36	5.33	4.69	5.64	5.31	4.00	3.36	5.33	4.69	5.97	7.08	5.64	5.31
SM4	6.94	5.03	8.06	5.33	6.94	5.00	7.58	5.36	3.69	3.36	6.94	6.28	5.97	5.00	3.36	6.94	6.28	5.97	5.33	5.00	3.36	6.94	6.28	5.97	6.31	6.75	5.33	5.00
SM5	5.00	4.36	6.28	3.69	4.36	4.67	5.33	3.08	3.36	4.97	4.36	5.64	3.69	4.67	3.36	4.36	3.69	5.00	3.39	4.03	4.69	5.33	4.69	4.36	3.69	5.00	3.39	4.03
SM6	5.31	5.33	7.25	5.03	5.00	4.00	3.36	4.67	5.33	4.69	4.97	7.11	5.64	5.64	5.33	4.00	3.36	4.67	3.06	4.33	4.69	6.28	5.97	4.00	3.36	4.67	3.06	4.33
SM7	4.69	4.36	5.64	3.69	4.67	3.36	2.39	3.69	6.28	5.97	4.69	5.64	4.36	5.31	4.69	3.36	2.39	3.69	2.11	2.72	5.03	6.28	6.31	3.36	2.39	3.69	2.11	2.72
SM8	6.94	4.97	7.11	5.64	5.64	5.33	4.36	6.92	6.28	6.31	5.97	7.08	5.64	5.31	5.97	4.69	5.03	8.06	5.33	6.94	4.36	4.36	3.69	6.94	4.97	7.11	5.64	5.64
SM9	5.33	4.69	5.64	4.36	5.31	4.69	3.69	5.31	4.36	3.69	5.00	7.58	5.36	3.69	5.00	3.39	4.36	6.28	3.69	4.36	5.33	4.00	3.36	5.33	4.69	5.64	4.36	5.31
SM10	6.28	5.97	7.08	5.64	5.31	5.97	5.31	7.42	4.00	3.36	4.67	5.33	3.08	3.36	4.67	3.06	5.33	7.25	5.03	5.00	4.36	3.36	6.94	6.28	5.97	7.08	5.64	5.31
SM11	6.28	6.31	6.75	5.33	5.00	4.69	4.00	3.36	4.67	8.25	4.69	8.39	4.69	2.39	3.69	2.11	4.36	5.64	5.33	3.69	5.31	3.69	4.69	4.69	6.31	6.75	5.33	5.00
SM12	4.36	3.69	5.00	3.39	4.03	5.64	3.36	2.39	3.69	8.08	4.69	8.22	4.69	4.36	6.92	4.06	4.97	4.69	8.39	4.69	2.39	3.69	6.28	4.36	3.69	5.00	3.39	4.03
SM13	4.00	3.36	4.67	3.06	4.33	5.31	3.69	4.36	6.92	6.94	5.03	8.06	5.33	3.69	5.31	3.69	4.69	4.69	8.22	4.69	4.36	6.92	6.28	4.00	3.36	4.67	3.06	4.33
SM14	3.36	2.39	3.69	2.11	2.72	7.42	6.31	3.69	5.31	5.31	3.69	4.33	3.69	5.31	7.42	6.31	5.97	5.03	8.06	5.33	3.69	5.31	4.36	3.36	2.39	3.69	2.11	2.72
SM15	5.33	4.36	6.92	4.06	5.00	5.31	3.69	5.31	7.42	7.42	6.31	5.97	3.36	4.67	3.06	4.33	5.31	3.69	6.28	3.69	5.31	7.42	4.00	3.36	4.67	3.06	4.33	4.69
SM16	4.69	3.69	5.31	3.69	4.33	7.42	6.31	4.03	4.97	5.31	3.69	4.33	2.39	3.69	2.11	2.72	7.42	6.31	7.25	3.36	4.67	3.06	3.36	2.39	3.69	2.11	2.72	5.97
SM17	5.97	5.31	7.42	6.31	5.97	4.69	8.22	4.69	7.25	7.42	6.31	5.97	4.36	6.92	4.06	4.00	5.31	3.69	3.06	4.33	3.69	2.11	4.06	7.58	4.69	4.69	7.11	4.36
SM18	4.69	4.03	4.97	3.39	4.97	5.03	8.06	5.33	6.94	4.97	3.39	4.97	3.69	5.31	3.69	4.33	7.42	6.31	2.11	2.72	6.92	6.94	4.97	7.11	5.64	5.64	5.64	4.00
SM19	5.64	4.36	7.25	4.39	5.00	4.36	6.28	3.69	4.36	7.25	4.39	5.00	5.31	7.42	6.31	5.97	3.69	8.08	4.69	8.22	4.69	4.36	6.92	5.64	4.36	5.31	7.08	3.36
SM20	5.64	4.36	7.58	5.36	5.33	5.33	7.25	5.03	5.00	7.58	5.36	5.33	3.08	3.36	4.67	3.06	5.33	5.64	5.33	3.69	5.31	3.69	5.97	7.08	5.64	5.31	7.58	6.94
SM21	4.69	3.36	5.33	3.08	4.33	4.36	5.64	3.69	4.67	5.33	3.08	4.33	4.69	2.39	3.69	2.11	4.36	4.69	8.39	4.69	2.39	3.69	6.31	6.75	5.33	5.00	5.33	5.33
SM22	2.69	2.08	3.03	2.42	2.72	4.97	7.11	5.64	5.64	3.03	2.42	2.72	4.69	4.36	6.92	4.06	4.97	4.69	2.72	8.22	7.42	6.31	3.69	5.00	3.39	4.03	8.39	6.28

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