BEST-WORST METHOD

A MULTI-CRITERIA DECISION-MAKING METHOD

THE FIRST INTERNATIONAL WORKSHOP ON BEST-WORST METHOD

BOOK OF ABSTRACTS 2020

11-12 June 2020

Delft, The Netherlands

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PROGRAM

Thursday, June 11th, 2020

08:00-08:15	**Welcome and opening** | Jafar Rezaei	
08:15-09:15	Lecture 1: Foundations of BWM	Jafar Rezaei
09:15-09:30	*Break*	
09:30-10:15	Lecture 2: Multiplicative BWM	Matteo Brunelli
10-15-10:30	*Break*	
10:30-11:15	Lecture 3: Bayesian BWM	Majid Mohammadi
11:15-12:30	*Break*	
Session 1 (presentations) | Chair: Himanshu Gupta		
12:30-14:00	A weight determination tool for Food Supply chain practices	Morteza Yazdani, Ali Ebadi Torkayesh, Prasenjit Chatterjee
	A novel group multi-criteria decision-making approach for establishing users' technology acceptance in the context of apparel e-commerce	Ruchika Kalpoe, Jafar Rezaei, Hadi Asghari
	Evaluating Strategies for Implementing Industry 4.0: A Hybrid Expert Oriented Approach of BWM and Interval Valued Intuitionistic Fuzzy TODIM	Hannan Amoozad Mahdiraji, Edmundas Kazimieras Zavadskas, Marinko Skare, Fatemeh Zahra Rajabi Kafshgar, Alireza Arab
14:00-14:30	*Break*	
Session 2 (presentations) | Chair: Jingzheng Ren		
14:30-16:00	Prioritizing the broader dimensions of Service Supply Chain Performance: A Case of Majan Electricity Company	Haidar Abbas, Sanyo Moosa
	Social sustainable supplier evaluation and selection: A Group Decision Support Approach	Chunguang Bai, Simonov Kusi-Sarpong, Hadi Badri Ahmadi, Joseph Sarkis
	Inland terminal location selection: Developing and applying a consensus model for BWM group decision-making	Fuqi Liang, Kyle Verhoeven, Matteo Brunelli, Jafar Rezaei

Friday, June 12th 2020

Session 3 (presentations) | Chair: Matteo Brunelli		
08:00-09:30	Best-Worst Method (BWM), its Family and Applications: Quo Vadis?	Ruojue Lin, Yue Liu, Jingzheng Ren
	A Comparison Between AHP and BWM Models to Analyze Travel Mode Choice	Sarbast Moslem
	A Hybrid Spanning Trees Enumeration and BWM (STE-BWM) for Decision Making under Uncertainty: An application in the UK Energy Supply Chain	Amin Vafadarnikjoo
09:30-10:00	*Break*	
Session 4 (presentations) | Chair: Majid Mohammadi		
10:00-11:30	Multi-criteria competence analysis (MCCA): A case study on crowdsourcing delivery personnel on takeaway platform	Longxiao Li, Xu Wang, Jafar Rezaei
	A hybrid failure assessment approach by an FMEA using fuzzy Bayesian network and fuzzy best-worst method	Muhammet Gul, Melih Yucesan, Erkan Celik
	Using Bayesian Best Worst Method to Assess the Airport Resilience	Huai-Wei Lo, James J.H. Liou, Chun-Nen Huang
11:30-12:30	*Break*	
Session 5 (presentations) | Chair: Fuqi Liang		
12:30-14:00	Identifying and ranking the barriers to organizational productivity of the railway industry - using the Best-Worst Method	Mahdie Hamedi, Mohamad Sadeq Abolhasani, Hamidreza Fallah Lajimi, Zahra Jafari Soruni
	Identifying and Prioritizing Competency Factors for Platforms Managing Service Providers in Knowledge-Intensive Crowdsourcing Context	Biyu Yang, Xu Wang, Zhoufei Ding
	An analysis of sustainable business practices: An emerging economy perspective	Himanshu Gupta, Ashwani Kumar
14:00-14:30	Closing the workshop | Jafar Rezaei	

1ST INTERNATIONAL WORKSHOP ON BEST-WORST METHOD

11-12 June 2020, Delft, The Netherlands

Lecture 1: Foundations of Best-Worst Method

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In this lecture, we first discuss the philosophy behind the best-worst method (BWM). Then, we will discuss how an MCDM problem can be formulated and solved by BWM. More specifically the non-linear and linear models of BWM are discussed with some examples. We then discuss the way we can check the consistency and concentration of the findings (weights of the criteria or overall value of alternatives).

We will also discuss some salient features of the method and explain some practical considerations when using the method.

The lecture is designed mainly for those with limited knowledge about the BWM. However, we will also discuss some topics which are not discussed in the existing literature.

Lecture 2: The multiplicative Best-Worst Method

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In this presentation, we shall consider the best-worst method from a more algebraic point of view and inquiry into the metric used to find the weights. By means of abstract algebra, we shall consider and justify an alternate metric. In particular, we will see that this new metric can lead to a simple optimization problem and is supported by a more general concept of distance. In fact, albeit seemingly more complex the new optimization problem (i) can be equivalently formulated as a linear optimization problem, and (ii) is a special case of the notion of distance for continuous Abelian linearly ordered groups.

While having these attractive features, the new (multiplicative) formulation of the best-worst method retains the characteristics that made the original best-worst method appealing: the logic of using the best and the worst criteria as pivots for the comparisons, the minimization of the maximum discrepancy, the ability of providing an intrinsic measure of inconsistency, the possibility of estimating interval-valued weights.

The presentation will be self-contained and no preliminary notion of abstract algebra is necessary and it hopefully will raise some questions and sparkle a discussion, besides showing a variant of the best-worst method.

Lecture 3: The Bayesian Best-Worst Method

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In this presentation, a probabilistic extension of the best-worst method (BWM) is presented, where the inputs and the outputs of the original method are modeled by using probability distributions. The new modeling, though seemingly different, would preserve the underlying ideas of the original best-worst method. As such, the problem of identifying the weights of criteria in the BWM is translated into a statistical inference problem, and a Bayesian model is especially-tailored accordingly. We further introduce a new ranking scheme for decision criteria, called credal ranking, where a confidence level is assigned to measure the extent to which a group of DMs prefers one criterion over one another.

The presentation is primarily focused on the group decision-making problem within the framework of the BWM, but other types of decision-making problems are discussed. Also, different ways for extending the current model are put forward for further discussions.

A weight determination tool for Food Supply chain practices

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Keywords: Food supply chain, weighting tools, Best-Worst Method, Supply chain practices, MCDM

Abstract

Food supply chain (FSC) is one of the globally important and critical supply chain networks which is designed for perishable edible products. It is defined as series of operations from production farms to manufacturers to distribution centres that deliver agricultural products to the final consumers. Identification of food supply chain practices (FSCP) is an important process where decision makers should select most effective technological, economic, environmental, and social factors that contribute to FSC management. Unlike other applications of supply chain management, FSC is always under surveillance of different environmental, social and economic circumstances. FSC management and its corresponding operations should be deliberately addressed in order to maximize the satisfaction of final consumers and profit of food companies. However, determination of importance of each factor is a complicated task where decision makers can become unable to do so based on the biasedness of their decisions. Multi Criteria Decision Making models provide decision makers with reliable weight determination methods in order to obtain the optimal weight of each factors. Best-Worst Method (BWM) is one of the promising Multiple Criteria Decision Making models that is frequently used to determine weight of decision factors for MCDM problems. A hierarchical weight determination is developed based on BWM model. The proposed model can be applied to assign the relevant weights for MCDM problems such as food logistic provider selection, and so on.

A novel group multi-criteria decision-making approach for establishing users' technology acceptance in the context of apparel e-commerce

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Keywords: Returns management, Apparel e-commerce, Customer-based information technologies, Multi-Criteria Decision-Making, Bayesian Best-Worst Method

1.Introduction

Although e-commerce has its benefits, it also imposes societal implications. With the increase of online purchases, the number of order returns also increases (Minnema, Bijmolt, & Gensler, 2017). According to Minnema et al. (2017), approximately 30% of all online purchases in the Netherlands are returned to the sender, which imposes structural problems for online retailers. Of all returned products, apparel is the biggest part. According to Wiese, Toporowski, & Zielke (2012), returns for apparel items are more common than for most other products, due to the many apparel attributes. Of all the returned products bought online, 40% are apparel items (Edwards, McKinnon, & Cullinane, 2010). For apparel e-commerce retailers, the increase of apparel returns has implications such as extra quality checks, extra administrative work, re-packaging and storing of apparel, which furthermore results in an increase of logistic costs (Kennisinstituut voor Mobiliteitsbeleid, 2017). Due to the increase in order returns, the number of transport van-movements in residential areas has also increased, which imposes consequences for the air quality, traffic safety, the overall living environment of cities and the congestion problem the Netherlands is currently confronted with (Kennisinstituut voor Mobiliteitsbeleid, 2017).

Whilst most research so far has been conducted about monetary instruments and efficient transport routing and handling of returns of online purchased apparel items, not much empirical research is conducted so far about customer-based instruments that can be used during the customers' online screening process of apparel, in order to prevent unnecessary apparel returns. Consequently, so far empirical studies which 1) examine/compare the perceived effectiveness of various customer-based technological concepts in addressing online purchased apparel return reasons and 2) assess the users' technology preference, are sparse. Therefore, this research aims to establish what the customers' preference is regarding technological alternatives which can be used during the online screening process of apparel items, in order to increase customers' online apparel purchase successes and reduce unnecessary returns. Since the technologies are designed to be used by customers, its success relies greatly on the customers usage. Therefore, the research is mainly approached from the users (customers) perspective.

2. Method and Data

In order to eventually understand the users preference of technologies, the Technology Acceptance Model (TAM) was used, developed by Davis (Davis, 1986). In literature, TAM is mostly operationalized using Structural Equation Modelling (SEM), which requires a

large sample size to produce reliable results. Since due to time and budget constraints it was not viable to acquire a large sample size, a less data extensive, simpler and reliable approach to predict the customers' acceptance regarding various technological alternatives was needed. As a result, a Multi-Criteria Decision-Analysis (MCDA) approach is applied, wherein the novel Bayesian BWM developed by Mohammadi & Rezaei (2019) is applied to operationalize TAM. This approach involved identifying various indicators, quantifying the importance of each indicator through the assigned preference and determining which indicator has the highest impact on technology acceptance through the assigned weight. The influence on technology acceptance is quantified through the computed weights of each indicator (i.e. criteria). Criteria with high optimal group weights are considered to have a significant impact on technology acceptance, suggesting that a high level of users' (customers') acceptance can be realized when scoring well on each criterion.

Following the MCDA approach, first a set of alternatives needed to be established. For this, a literature study was conducted through which various apparel return reasons were established, followed by various customers-based instruments. Based on this, the required apparel attribute information customers need to have upfront were identified and technological alternatives were composed. Afterwards, a set of decision-criteria used to evaluate the technological alternatives was established through a thorough literate study regarding TAM. The set was finalized with the opinion of online apparel experts. Through an online BWM survey, the users' (online apparel shoppers') optimal group weights per criterion was acquired. The scores of each technological concept was acquired through six apparel e-commerce expert interviews stemming from four apparel e-commerce retailers in the Netherlands. To obtain the scores per technological alternative with respect to each criterion, the Bayesian BWM was again applied. As a result, the interview was constructed using the imposed structure of the BWM.

3. Results and main conclusion

The results have shown that predicting the technology acceptance by operationalizing TAM can be done using the aforementioned MCDA approach as well. The novel Bayesian BWM, developed by Mohammadi & Rezaei (2019), is applied to a real-life problem (apparel e-commerce) to check its robustness. The result show that the technological alternative which has the highest probability of achieving customers' acceptance is also the one which is currently the most employed by online apparel retailers in the Netherlands. This shows that the novel Bayesian BWM method is indeed a successful method which can predict technology acceptance and preference.

All the results will be presented in the conference.

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Evaluating Strategies for Implementing Industry 4.0: A Hybrid Expert Oriented Approach of BWM and Interval Valued Intuitionistic Fuzzy TODIM

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***Keywords*:** Industry 4.0; BWM; IVIF; Multi-Criteria Decision Making; TODIM; Information Systems.

Abstract

Developing and accepting industry 4.0 influences the industry structure and customer willingness. To a successful transition to industry 4.0, implementation strategies should be selected with a systematic and comprehensive view to responding to the changes flexibly. This research aims to identify and prioritize the strategies for implementing industry 4.0. For this purpose, at first, evaluation attributes of strategies and also strategies to put industry 4.0 in practice are recognized. Then, the attributes are weighted to the experts' opinion by using the Best Worst Method (BWM). Subsequently, the strategies for implementing industry 4.0 in Fara-Sanat Company, as a case study, have been ranked based on the Interval-Valued Intuitionistic Fuzzy (IVIF) of the TODIM method. The results indicated that the attributes of "Technology", "Quality", and "Operation" have respectively the highest importance. Furthermore, the strategies for "new business models development", "Improving information systems" and "Human resource management" received a higher rank. Eventually, some research and executive recommendations are provided. Having strategies for implementing industry 4.0 is a very important solution. Accordingly, MCDM methods are a useful tool for adopting and selecting appropriate strategies. In this research, a novel and Hybrid combination of BWM-TODIM is presented under IVIF information.

Abstract review

Developing in information and communication technology leads to form new facts in many fields such as manufacturing, resulting in a new concept as the 4th industrial revolution (intelligent manufacturing and continuous manufactory). Developing and accepting industry 4.0 influences the industry structure and customer willingness. countries that implement the Industry 4.0 applications effectively can improve competitive advantages, labor market, and operational processes. These developments in manufacturing will lead to an increase in economic growth as well as European commission reported in 2017 about Key lessons from national industry 4.0 policy initiatives in Europe.

To a successful transition to industry 4.0, implementation strategies should be selected with a systematic and comprehensive view to responding to the changes flexibly. Because in the real world, organizations and companies face limited resources, including financial, human, technological, and so on. if they want to get into the Implementing Industry 4.0 without a strategy, they will fail. Therefore, the purpose of the present study is to identify and prioritize strategies for implementing industry 4.0, thus this research enabling companies to move further in this direction by focusing more on the specific conditions governing their proprietary business environment. In this regard, the objectives of the present study are to identify the attributes for evaluating strategies for implementing industry 4.0, weighting and determining the relative importance of these attributes, identifying strategies for implementing industry 4.0, prioritizing these strategies according to the identified attributes and finally introducing the most optimal ones. Accordingly, MCDM methods are a useful tool for adopting and selecting appropriate strategies. In this research, a novel and Hybrid combination of BWM-TODIM is presented under IVIF information.

For this purpose, at first, evaluation attributes of strategies and also strategies to put industry 4.0 in practice are recognized. Six strategies “Human resource management”, “Improving information systems”, “Work organization and design-oriented”, “Resources and standardization related”, “New business models development”, “Operation optimization”, recognized in the literature.

Then, the attributes for evaluating these strategies extracted from literature as “Leadership”, “Customer”, “Product”, “Operation”, “Culture”, “Staffs”, “Technology”, “Organization”, “Quality”. Then this attribute weighted by using the Best Worst Method (BWM).

Subsequently, the strategies for implementing industry 4.0 in Iranian auto part manufacture Company, as a case study, have been ranked based on the Interval-Valued Intuitionistic Fuzzy (IVIF) of the TODIM method. The results indicated that the attributes of "Technology", "Quality", and "Operation" have respectively the highest importance. Furthermore, the strategies for "new business models development", "Improving information systems" and "Human resource management" received a higher rank. Eventually, some research and executive recommendations are provided. Having strategies for implementing industry 4.0 is a very important solution. Accordingly, MCDM methods are a useful tool for adopting and selecting appropriate strategies. In this research, a novel and Hybrid combination of BWM-TODIM is presented under IVIF information.

The advantages of the BWM, which convinced the authors to use it, are:

- It is compatible with many other existing MCDM methods.
- It can be applied to different MCDM problems with qualitative and quantitative criteria.
- It is proper for group decision-making.
- It leads to more consistent comparisons, hence more reliable weights/rankings.
- It makes the comparisons in a structured way.
- It is an easy-to-understand and easy-to-apply method.
- It has the debiasing strategy “consider-the-opposite”.

Finally, based on my experience in publishing various domestic and international papers using BWM method, as well as my research field, which is multi-criteria decision making, I came to the conclusion and can say that in most research works after finishing work and obtaining feedback from decision makers, this method reflects their views exactly, and this satisfaction with the results showed the high effectiveness of this method, which along with its high efficiency, which was mentioned in the advantages section of this method, makes

this method one of the most widely used and most cited MCDM weighting method. Certainly, Dr. Rezaei's efforts have opened a new chapter in this field to all the researchers. Thank you for your efforts, Dr. Rezaei.

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Prioritizing the broader dimensions of Service Supply Chain Performance: A Case of Majan Electricity Company

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1. Introduction and Review of Previous Studies

Most of the research attempts in supply chain discipline are made around the manufacturing (physical goods) supply chains, leaving the service sector scarcely attended till 1990s (Sengupta, Heiser and Cook, 2006; Zhou, Park, and Yi, 2009; Zhang & Chen, 2015). Ellram, Tate, and Billington (2004) defined a service supply chain (SSC) as "an integrated management of service information, service processes, service capacity, service performance and service funds from the earliest suppliers to the ultimate customers".

For sustenance as well as excellence, the performance measurement system matters for service supply chains as much as for the manufacturing supply chains. Among many, the Supply Chain Operations Reference (SCOR) model (plan, source, make, deliver and return) and the Balance Score Card (financial, customer, internal business process and innovation and learning) are two frequently used approaches (Taticchi, Tonelli, and Cagnazzo, 2010). Cho, Lee, Ahn, & Hwang, (2012) considered service supply chain operations (responsiveness, flexibility and reliability), customer service (tangibles, assurance and empathy) and corporate management (profitability, cost, and asset and resource utilization) with a total of twenty-nine (29) sub-parameters while proposing their performance measurement model for hoteling sector.

This research aims to prioritize performance parameters of the service supply chain at Majan Electricity Company (MJEC). For the purpose of bringing a more substantiated and comparative outcomes, it uses the Analytical Hierarchy Process (AHP) and the Best-Worst Method (BWM). Majan Electricity Company (MJEC) is a closely held Omani Joint Stock company which was registered under the Commercial Companies Law of Oman. It began its operations on May 1st, 2005. It bears a license issued by the Authority for Electricity Regulation, Oman to deal in the regulated distribution and supply of electricity in the North Batinah Governorate, Al Dhahirah Governorate and the Buraimi Governorate of the Sultanate of Oman.

A SLR of the performance management for humanitarian supply chains (Abidi,, de Leeuw, & Klumpp, 2014), an analytical framework for the sustainability performance of supply chains management (Schaltegger & Burritt, 2014), critical determinants of the supply chain performance (Ab Talib, Hamid, & Thoo, 2015), performance measures related to supply chain and knowledge management (Ramish & Aslam, 2016), and performance measurement for reverse supply chains (Butzer, Schötz, Petroschke, & Steinhilper, 2017) are some recent and relevant studies.

2. Objectives & Research Methodology

The researchers aimed to prioritize the selected measures of service supply chain performance (satisfaction, empathy, reliability, profitability, responsiveness and efficiency) in the context of Majan Electricity Company. The researchers have used the Analytical Hierarchy Process (AHP)

(Saaty and Kirti, 2008) and the Best-Worst Method (BWM) (Rezaei, 2015) to accomplish the study objectives. The structured questionnaire meant for Analytical Hierarchy Process (AHP) was administered on a total of eight (08) respondents whereas the other questionnaire for the Best-Worst Method (BWM) was administered on a number of six (06) respondents holding some managerial positions in their respective branches.

3. Results and Discussion

The performance dimensions are listed in order of their reported importance by the two different groups of respondents which were analyzed using different methods.
4.1) *Analytical Hierarchy Process (AHP):* satisfaction, profitability, responsiveness, efficiency, empathy, and reliability.
4.2) *Best-Worst Method (BWM):* profitability, satisfaction, responsiveness, efficiency, empathy, and reliability.
All the results will be presented in the conference.

4. Limitations and directions for the future research

Given the limited number of respondents and a single entity & sector focussed study, the future researchers may take a larger sample as well as conduct a comparative study by taking one service supply chain(s) and one or more manufacturing supply chain(s).

Note: This research paper was submitted to a journal which expressed certain reservations. The authors withdrew it and developed it in the light of the inputs. The authors expect to learn and incorporate certain latest developments in this method, if recommended by the conference session chair and the peer researchers.

Acknowledgement: The authors are grateful to one of their students, Ms. Khadija Al-Maktoumi (Majan Electricity Company) for the support extended by her in the data collection phase. We are equally grateful to our respondents who spared time to provide their valuable inputs.

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Social sustainable supplier evaluation and selection: A Group Decision Support Approach

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Keywords: Sustainability; social sustainability; sustainable supply chains; BWM; TODIM

Abstract

Organizational and managerial decisions are becoming influenced corporate sustainability pressures. Organizations need to consider economic, environmental, and social dimensions of sustainability in their decisions if their goal is to become sustainable. Supply chain decisions play a distinct and critical role in overall sustainability of organizational good and service outputs. Regulatory demands, stakeholder awareness and increasing pressures, have forced the hand of organizations to take into consideration sustainability in their decisions. These suppliers' serious social consequences range from strike actions due to poor work health and safety reasons, to employee rights related to poor employment practices. resulting in production losses and the inability to meet buying firms' deadlines. Since suppliers provide raw materials, services, and finished products as inputs to organizational supply chains, their activities play a critical role in helping firms achieve sustainable and collaborative competitive edge and increasing performance. A few studies have recently attempted to focus and utilize the social sustainability dimension separately or in combination with environmental and economic dimensions in the supplier selection process. To address these issues, this work adopts and integrates a previously proposed social sustainability attribute framework into the supplier selection decision problem, with a hybrid of two complementary tools, BWM and TODIM methodologies under a grey number environment. The specific objectives of this work are as follows: 1. Introduce a multiple attribute approach that integrates the "Best Worst Method" (BWM) and TODIM in a grey number environment for the supplier selection decision; 2. To investigate a multiple attribute social sustainable supplier evaluation and selection process from a manufacturing sector context; 3. Provide insights in the application of this model to an emerging economy context (Iran). This study makes the following academic and managerial contributions: (1) identifies and introduces a proposed social sustainability attributes framework for guiding general social sustainability decision making; (2) Introduces and applies a multi- criteria decision-making (MCDM) model that integrates interval grey number based BWM and TODIM. These analytical tools provide complementary avenues to rank or select preferred socially sustainable suppliers using expert judgments. In order to directly obtain relative weights, BWM has been reformulated, a modelling contribution; (3) BWM and interval grey number are jointly used to overcome the limitations of the TODIM method to solve the MCDM problem under experts' uncertain judgments. The interval grey number is more appropriate to model decision maker judgments extending BWM and TODIM methods to effectively deal with decision making problems under uncertain and grey environments. Grey-

BWM is used to develop the relative weight of attributes to overcome TODIM method limitations that require additional information about the variable weights.

Methods and Data

To advance the field methodologically, this work introduces the Grey-BWM and Grey-TODIM methodology to evaluate and select the best social sustainable supplier based on decision-maker opinions and behavioral characteristics. Interval grey number is applied to numerically model decision makers' judgments within the BWM and TODIM methods. Grey-BWM complements the TODIM method by identifying the social sustainability attribute relative weights. These combined capabilities make the methodology more realistic and flexible. The biggest Iranian multinational automobile manufacturing company, employing more than 10% of the automotive workforce, in the sector intends to take a leading step in improving its social sustainability performance by selecting a socially conscious supplier for parts. 5 suppliers were shortlisted by the management. A ten-member (10) team of decision-makers (managers) that influence the supplier selection decision was involved in the selection process. This team included a supply manager, assistant supply chain manager, purchasing manager, finance manager, research and development manager, IT manager, production manager, general manager, logistics manager and maintenance manager.

Results and Conclusion

In this study, we utilized a novel integrated MCDM tool composed of grey numbers, BWM and TODIM to investigate social sustainability supplier evaluation and selection. Overall, this work introduced a comprehensive framework for investigating and supporting social sustainability supplier evaluation and selection. The framework consists of eight social sustainability attributes including: 'Work health and safety' (WSLH/SSA1); 'Training education and community influence' (TECI/SSA2); 'Contractual stakeholders' influence' (CSI/SSA3); 'Occupational health and safety management system' (OHSMS/SSA4); 'The interests and rights of employees' (IRE/SSA5); 'The rights of stakeholders' (RS/SSA6); 'Information disclosure' (ID/SSA7); and 'Employment practices' (EP/SSA8). The social sustainability framework was then applied to an Iranian manufacturing company with inputs from ten of their industrial experts using a novel decision support tool that integrates for the first time grey system theory, BWM and TODIM approaches for assessing and ranking five suppliers in terms of their social sustainability performance.

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Inland terminal location selection: Developing and applying a consensus model for BWM group decision-making

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***Keywords*:** Inland terminal location selection; Shipping line; Group BWM; Consensus

Abstract

The purpose of this paper is to develop an inland terminal location selection methodology, viewed from the perspective of the shipping line designing the inland transport chain, while also taking into account the objectives of the terminal operator and terminal user stakeholders. To that end, we develop a consensus model for a group Best-Worst Method (BWM) to aggregate the evaluations of the various stakeholders. Firstly, potential alternatives and a group of relative stakeholders are identified by the shipping line, after which each stakeholder evaluates the location selection problem and identifies its own set of criteria. Next, BWM is used to prioritize the importance of the criteria identified by the various stakeholders, and alternatives are evaluated based on the different sets of criteria, in which the value of each alternative is obtained based on an additive value function for each stakeholder. Using the proposed consensus model makes it possible to identify the aggregated values of the alternatives and then selected the desired location. The proposed method is applied to a real-life case study involving shipping line Maersk, which considered six locations and nine experts representing three different types of stakeholders. After data collection and calculation, container volume potential is identified as one of the most important criteria. Using a sensitivity analysis, we find that a varying influx of container volume has no impact on the most desirable location.

Best-Worst Method (BWM), its Family and Applications: Quo Vadis?

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***Keywords*:** Best-Worst Method; multi-criteria decision making; interval number; group decision-making

Abstract

Best-worst method (BWM) is a new efficient multi-criteria decision-making (MCDM) tool developed by Razeai (2015). Compared with the classical MCDM methods (especially the Analytic Hierarchy Process), BWM provides more consistent weighting results based on only two vectors of pairwise comparisons, and it requires less times of comparisons and has relatively higher consistency. With the features of high efficiency and accuracy, BWM has been widely applied in various disciplines for solving different types of decision-making problems. This study aims to have a comprehensive literature review on the applications of BWM through bibliometric analysis; subsequently investigate the BWM family; then predict the future research trend of BWM; finally, we present and compare the fuzzy BWM and the interval BWM.

Specially, firstly, the applications of BWM in different fields, such as energy supply (van de Kaa et al., 2017; Wan Ahmad et al., 2017), supply chain (Palanisamy et al., 2020), and transportation (Shojaei et al., 2018), are reviewed, and the bibliometric analysis has been carried out. Secondly, the extended BWM models are investigated. The BWM has been improved and combined with fuzzy sets (Moslem et al., 2020), interval numbers (Hafezalkotob et al., 2020), rough-fuzzy sets (Chen et al., 2020), and other mathematical theories in order to solve more complex decision-making problems. Thirdly, the potential development directions of BWM in the future are analyzed according to current research trends. For example, the group decision-making and the combination of BWM and artificial intelligence (AI) could be considered as research topics in the future. Finally, the procedures of fuzzy BWM and interval BWM have been specified and illustrated. In order to promote the development of BWM and its modified versions, we proposed some effective methods such as establishing a journal for BWM and developing a convenient computing software for BWM.

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A Comparison Between AHP and BWM Models to Analyze Travel Mode Choice

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***Keywords*:** Travel mode choice; Analytic Hierarchy Process (AHP); Best-Worst Method (BWM); Pairwise comparison

Abstract

Evaluating commuting trip patterns plays essential role in urban planning and improvement. Passenger travels cover the majority of all travels in the urban transportation system and the mode choice in these type of travels makes severe impact on the sustainability of system operations. In this work, we endeavor to extend the methodological family of direct mode choice determination and forecast. The objective is deriving their attitude by stated comparisons of travel modes. For this objective, two well-proven and widely applied techniques: the Analytic Hierarchy Process (AHP) and the Best-Worst Method (BWM) have been selected. Compared to AHP, the Best-Worst Method has significant practical advantages in user surveys; it needs less time and effort to complete the questionnaire, the responses are generally more consistent and the response rate is much higher than in an AHP survey. Two passenger surveys conducted in a Turkish big city, Mersin in 2020. The conducted results indicate that Public Transport is the most used mobility type. BWM survey was easier and shorter than AHP survey, moreover, the final scores derived from BWM are highly reliable as it generates more consistent comparisons compared to AHP.

A Hybrid Spanning Trees Enumeration and BWM (STE-BWM) for Decision Making under Uncertainty: An application in the UK Energy Supply Chain

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Abstract

In the original Best-Worst Method (BWM), a Decision Maker (DM) (i.e. expert) must provide with certainty one decision-making criterion as the best and another decision-making criterion as the worst criterion. In the real-world decision-making process applying the original BWM dealing with subjective judgements of human beings, it is not always straightforward for DMs to choose only one criterion as either the best or the worst without any level of hesitancy. In other words, there might be a set of best and a set of worst criteria instead of just one single best or worst criterion. In this study, a hybrid application of Spanning Trees Enumeration (STE) and the BWM as a solution is suggested in order to deal with this type of uncertainty and capture the hesitancy of DMs. This method by applying STE offers an opportunity for DMs to suggest more than one best or worst criteria. The reason is that in many cases DMs are unable to choose only one criterion due to uncertainty, hesitancy or lack of information. The proposed method is capable to calculate which criteria are actually the best and worst ones based on already provided pair-wise comparisons by DMs.

In the UK energy supply chain, it has been identified that Natural Disasters (ND), Climate Change (CC), Industrial Action (IA), Affordability (AF), Political Instability (PI), and Sabotage/Terrorism (ST) are the most crucial risks. In this study, the objectives are twofold: (1) to theoretically enhance the BWM, and (2) to practically apply it in the UK energy supply chain risks prioritisation in order to show the applicability of methodological extension of the BWM as well as verifying the most critical risk dimensions in the UK energy supply chain.

Multi-criteria competence analysis (MCCA): A case study on crowdsourcing delivery personnel on takeaway platform

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***Keywords*:** Multi-criteria competence analysis; Multi-criteria decision analysis; Crowdsourcing delivery; Bayesian Best-Worst Method

Abstract

Competence analysis provides a way to determine whether individuals meet the specified performance criteria, and there are several frameworks in existing literature: Knowledge, Skills, Experience and Qualifications (KSEQ) (Kurz & Bartram, 2002), Knowledge, Skills, Abilities and Other characteristics (KSAOs) (Maurer & Lippstreu, 2008), Knowledge, Skills and Attitudes (KSA) (Mulder, 2014). Although the proposed frameworks are very well-grounded in theory, they are more difficult to put into practice. For instance, it is not evident what a company can do when managers have different views regarding the importance of different dimensions. Therefore, we develop a multi-criteria competence analysis (MCCA) as a novel approach to evaluating the competence of personnel. Using the dimensions as criteria and personnel as alternatives, the competence analysis is formulated as an MCCA. As a generic framework for evaluating the competence of personnel, the steps of MCCA are described as follows: (i) Determine the objective of the competence analysis and define the scope of the problem; (ii) Determine the evaluation criteria for competence analysis of the personnel through competence analysis frameworks and experts' opinions; (iii) Collect competence scores of each individual for all criteria from various data sources; (iv) Find the optimal weights of all criteria that have been identified for the competence analysis; (v) Find an overall level of the personnel competence with aggregating the scores.

To illustrate the MCCA approach, a real-world case study is carried out involving a Chinese takeaway delivery platform. Following the above MCCA steps, we use BWM (Rezaei, 2015) in the case study because of its several attractive features such as providing more reliable pairwise comparisons, while mitigating possible anchoring bias, most data (and time) efficient, and also providing a consistency check. There are several extended versions of BWM and in this paper, we use the Bayesian BWM (Mohammadi & Rezaei, 2019), to determine the weights of the criteria in MCCA based on the data collected from managers of the platform company. The Bayesian BWM introduces the concept of credal ranking. In the proposed main criteria as shown in Figure 1, Skills is the most important competence of all the main criteria with the confidence level value 1, 1, 0.71 compared with the Traits, Knowledge and Abilities. Also, it is not surprising to see that "Knowledge" is considered to be the least important criterion, with even "Traits" ranking higher with a confidence of 0.94. This is in line with the actual situation involving crowdsourcing delivery personnel in China because, to attract more people to the crowdsourcing delivery platform, the entry barrier is kept relatively low.

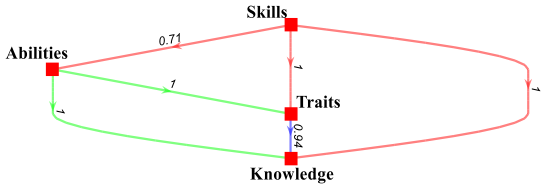

Figure 1. Credal ranking for the main criteria

Given the weights and the competence scores for a sample of crowdsourcing delivery personnel, we use additive value function to identify the overall competence scores, which reflects the level of competence for their job. On this basis, some statistic results can be derived, as shown in Table 1.

Table 1. Statistical results for overall competence scores

Personnel	N	Mean	Max	Min	S.D.
Overall	81	0.575	0.733	0.314	0.089

Table 1 shows that, among all the crowdsourcing delivery personnel, there is a significant difference between the highest competence score and the lowest score. The same situation is also reflected in the standard deviation, which is relatively high. It also clearly illustrates the fact that the competence of 81 crowdsourcing delivery personnel varies significantly. In addition, we discuss the relationship between the competence level and registration time. A comparison of four groups' crowdsourcing delivery personnel shows that their competence levels improve over time, while more pronounced fluctuations reflect a shorter time on the job. In our case study, the MCCA approach developed in this paper is validated in the context of crowdsourcing delivery, it also can be extended and applied to analyze the competence of personnel in many other industries as well.

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A hybrid failure assessment approach by an FMEA using fuzzy Bayesian network and fuzzy best-worst method

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***Keywords*:** Failure assessment; FMEA; Fuzzy set; Bayesian network; Best-worst method

Abstract

To assess failures, a number of methods are developed and applied. One of these methods is failure modes and effects analysis (FMEA). It is a well-known and broadly applied failure assessment tool. Researchers applied FMEA to various fields, from manufacturing to the service industry. Since the classical FMEA contains some deficiencies, numerous improvement FMEAs are performed over the originally recommended version. While in the one hand, it has merged with some multi-attribute decision-making methods and their fuzzy versions, on the other hand, it is combined with probabilistic (e.g., Bayesian network), machine learning (e.g. artificial neural network), and sophisticated methods (e.g., Petri net). In this study, an FMEA approach using fuzzy Bayesian network (FBN) and fuzzy best-worst method (FBWM) is proposed and applied to assess failures in plastic production. Parameters of classical FMEA are modified by adding three sub-parameters under the consequence parameter, which are entirely specific for the plastic production failure assessment. The main parameters used under FMEA are named as consequence, detection, and occurrence likelihood. Under the consequence parameter, three sub-parameters are suggested as follows: (1) The flexibility of the product is not at the desired level, (2) Product color is not in desired standard, and (3) The strength of the product is not at the desired level. Weights of these parameters and sub-parameters are determined by FBWM. FBWM has many pluses against similar methods, like the fuzzy analytic hierarchy process. The classical BWM method was created by Rezaei (2015) to derive the weights of the criteria with the smaller number of comparisons and more consistent comparisons. The best criterion is the one which has the most vital role in making the decision, while the worst criterion has the opposite role. Furthermore, the BWM does not only derive the weights independently, but it can be also integrated with other methods. We have combined it with FMEA in this study. Then a fuzzy rule-based system is constructed by incorporating Bayesian network, as stated by Wan et al. (2019). Bayesian network determination is modeled by GeNle 2.4 software. Flow chart of the proposed hybrid approach is given in Figure 1.

The results of the study are strengthened with the experts' opinions regarding the importance of failure modes for the final product and the whole system and supported them by experience feedback in the observed facility. Final risk priority numbers (RPNs) are obtained as in Table 1. On conclusion of the results from Table 8, the failure prioritization of five failure modes is $FM2 \succ FM3 \succ FM1 \succ FM4 \succ FM5$. So, the failure mode of FM2 with its highest final RPN score should be taken the great attention. The control measures should be initially taken for this failure mode. On the other hand, the lowest attention should be provided to the failure mode of FM5 as it has the lowest final RPN value.

Finally, a comparative analysis with two approaches of traditional FMEA and FBWM-based FMEA (without a fuzzy rule-based system incorporating Bayesian network) is fulfilled.

Also, a sensitivity analysis is performed to observe the final FMEA score changes in accordance with the change of subjective probability values.

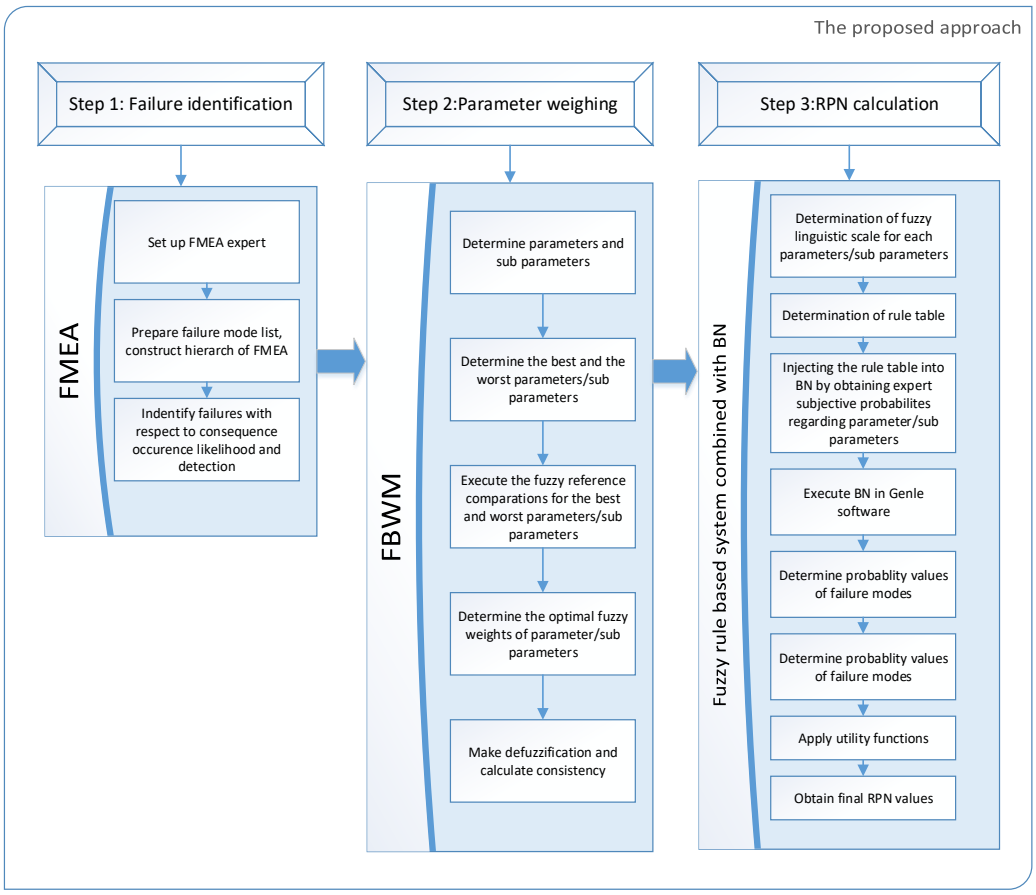

Figure 1. Flow chart of the proposed hybrid approach.

Table 1. Final RPN values of failure modes.

Failure mode	Final RPN
Failure to send the appropriate quality of raw materials to the Shredder (FM1)	85.07
The raw material in the extruder cannot be adjusted to the appropriate melting temperature (FM2)	92.89
Failure to adjust the temperature in the second extruder to an appropriate value (FM3)	92.02
Awaiting cooling time of the product in the press (FM4)	55.6
Deformation of press molds (FM5)	17.44

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Using Bayesian Best Worst Method to Assess the Airport Resilience

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Keywords: Disaster, Critical Infrastructure, Airport Resilience, Bayesian Best Worst Method

Abstract

International airport is one of the most important critical infrastructures for transportation. Facing unpredictable natural disasters and man-made threats, whether the airport has sufficient response and resilience has attracted much attention. This study proposes an airport resilience assessment framework to examine the proactive planning of airport while facing disaster or threats. Bayesian Best Worst Method (Bayesian BWM), an effective method to determine the importance weights of the criteria, is applied to evaluate the priorities of the proposed indicators. The proposed assessment framework is demonstrated by conducting a case study involving in Taiwan. The results indicate that adequate disaster response plans, proper airside isolation measures, and sufficient security personnel are the most critical factors for airport risk management. Some management implications are provided.

Identifying and ranking the barriers to organizational productivity of the railway industry - using the Best-Worst Method

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***Keywords*:** Productivity, Productivity Barriers, Railway Industry, Best-Worst Method

Abstract

Productivity is a concept looking for the improvement of the status quo continuously. The public service sector provides people with numerous sensory services. Hence, the productivity of service provider organizations, such as the railway industry, is of paramount importance. The aim of the current study is to provide a complete and systematic structure of the barriers to improvement of organizational productivity in the railway industry. For this purpose, the required criteria have been extracted from previous researches done in the railway industry. In order to weighting and determination of the identified criteria, after holding interview sessions with the railway industry experts, the multi criteria decision making method called best-worst technique (BWM) has been used to rank the criteria. The acquired result indicates that systematic, legal and political, environmental, occupational, organizational and individual obstacles respectively are the most influencing barriers to productivity. The present study is functional in terms of purpose and descriptive-survey in terms of data gathering.

Abstract review

Productivity is a mindset that seeks continuous amelioration of the status-quo. Since the public service sector provides the majority of people with abundant services, productivity in service organizations such as the railway is of paramount importance. The aim of this paper is to provide a comprehensive framework for identifying crucial barriers to organizational productivity improvement in the railway industry.

In order to identify and determine the importance of barriers to improving organizational productivity in the railway industry, required criteria have been extracted from the literature review. Afterwards, to calculate the weight and determine the importance of identified criteria, after interviewing the railway industry experts, using the best - worst method the criteria were ranked. Afterwards, optima and local weights of barriers calculated using equation 1(Rezaei, 2016).

$$
\begin{aligned}
&\min \xi \\
&\text{s.t.} \\
&\left|w_B - a_{Bj} w_j\right| \le \xi, \text{ for all } j \\
&\left|w_j - a_{jw} w_w\right| \le \xi, \text{ for all } j \\
&\sum_j w_j = 1 \\
&w_j \ge 0, \text{ for all } j
\end{aligned} \tag{1}
$$

Due to the information depicted in table 1, the acquired results indicate that level of facilities and equipment, workplace environment conditions, organizational and industrial infrastructure, and economic status in railway service organizations are the most serious barriers affecting improvement of productivity.

Table 1. Optimal weight of dimensions and criteria

Criteria total rank	Criteria total weight	Criteria local rank	Criteria local weight	Criteria	Dimension weight	Barrier dimension
22	0.0099	2	0.2222	Individual mobility	0.0446	Individual barriers
23	0.0074	3	0.1667	Knowledge level		
12	0.0242	1	0.5417	Experience		
26	0.0031	4	0.0694	Physical status		
15	0.0168	2	0.1565	Workload	0.1071	Occupational barriers
18	0.0134	4	0.1252	Working time		
15	0.0168	2	0.1565	Complexity of work		
5	0.0543	1	0.5064	Work structure		
24	0.0059	5	0.0552	Work uniformity		
6	0.0467	3	0.1045	Design of railway system	0.4464	Systematic barriers
14	0.0218	5	0.0488	Human-machine relationships		
1	0.2147	1	0.4808	Level of facilities and equipment		
2	0.1167	2	0.2613	workplace environment conditions		
6	0.0467	3	0.1045	Financial resources		
21	0.0112	4	0.1250	Job security	0.0893	Organizational barriers
8	0.0372	1	0.4167	Leadership		
17	0.0149	3	0.1667	Level of trust within the organization		
13	0.0223	2	0.2500	Training programs		
25	0.0037	5	0.0417	Changes in organizational patterns		
11	0.0265	3	0.1485	Policies and strategies	0.1786	Legal and political barriers
3	0.1072	1	0.6004	Infrastructures		
20	0.0117	4	0.0655	pace of industry growth		
10	0.0331	2	0.1856	Sanctions		
4	0.0857	1	0.6400	Economic status	0.1339	Environmental barriers
9	0.0348	2	0.2600	Social conditions		
19	0.0134	3	0.1000	Physical conditions of the workplace		

Due to the results of this study, to overcome the barriers, providing required facilities and equipment, and preparing appropriate infrastructure must be taken into consideration by the railway industry so as to improve employee's performance that will ultimately result in organizational productivity amelioration. To conclude, it is highly recommended that special attention should be paid to fast-paced changes in technology and railroad transportation management in order to achieve Iran’s 20-year vision goals.

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Identifying and Prioritizing Competency Factors for Platforms Managing Service Providers in Knowledge-Intensive Crowdsourcing Context

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Abstract

Knowledge-intensive crowdsourcing platforms (KICPs) operate as two- or multi-sided markets, meaning that each side of the market derives externalities from participation of the respective other side, which is called network effects (Thies et al., 2018). In KIC context, SPs, usually recognized as an important source of innovation, are varied in backgrounds, skills, and abilities, making different levels of contributions to crowdsourcing activities. As more and more service providers (SPs) joining the platform, it is of great challenge for KICPs to manage and align SPs' diverse intentions, interests and performance (Boudreau, 2012).

Existing research suggests quality assessment approaches, such as qualification test, gold-injected method, and iterative quality computation methods, to estimate SPs' quality and performance (Dang et al., 2016; Stouthuysen et al., 2018). However, these quality assessment methods either are task-oriented, or have simple outputs that convey little insightful information to platforms for management improvement (Li et al., 2019). The competency theory suggests that competency analysis is an effective approach to differentiate high from average and low performance based on differences in knowledge, skills, abilities, or other characteristics (Mirabile, 1997). To address the limitations of current research, in our research, we introduce competency theory into SPs management in KIC context, and aim to answer the following questions: (i) what are the competency factors that can differentiate high-performance SPs from average- and low-performance SPs in KIC context? (ii) What are the relative importance associated with each of these competency factors?

To identify and recognize effective competency factors that can differentiate SPs in terms of their performance, we leveraged quantities of interview records posted online, in which includes the experiences by successful SPs about what qualities and capabilities SPs should possess to perform KIC tasks well. We first crawled these online interview posts and extracted 18 effective competency factors leveraging Latent Dirichlet Allocation (LDA). Then we mapped the 18 competency factors to and constructed a KSAOs competency model in KIC environment. To answer the second question, questionnaires were used to collect experts' opinion and the Best-Worst Method (BWM) (Rezaei, J., 2015) were applied to prioritize the competency factors. The global weights of competency factors are presented in Table 1. According to our results, skill is the most important competency cluster among the four clusters and communication ability has the highest influence on SPs' performance.

Table 1 Global weights of Sub-competency

Main competency	Weight	Rank	Main competency	Weight	Rank
Communication ability	0.088	1	Branding	0.028	10
Profession experience	0.065	2	Trustworthiness	0.028	11
Entrepreneurial experience	0.050	3	Online and offline coordination	0.025	12
Customer relationship management	0.040	4	Professional dedication	0.023	13
Customer acceptance	0.040	5	Reasonable suggestion	0.020	14
Modification and after-sales service	0.037	6	Team composition	0.018	15
Demand understanding	0.036	7	Competitive spirit	0.014	16
Customers' industry background	0.032	8	Achievement orientation	0.012	17
Innovation ability	0.032	9	Team environment	0.011	18

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An analysis of sustainable business practices: An emerging economy perspective

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Abstract

In the era of industrial digitalization, the linkage between Industry 4.0 (I4.0) and the circular economy (CE) persistently emerge more clearly to explore various paths through which the objectives of ecological sustainability can achieved (Tseng et al. 2018). Circular economy implies an alternate way to deal with cleaner production strategies. In other words, it goes from a linear procedure that sees the utilization of raw or virgin materials and the generation of production waste that is discarded by the companies, to a model that recovers itself, changing what is normally viewed as waste into an asset (Lieder and Rashid 2016). A recent study by Ellen MacArther Foundation and the Mckinsey Center for Business and Environment estimate that consumption of new or virgin material could be reduced by as much as 32% within 15 years and 53% by the end of 2050. New or raw material can be replaced with recovered and repurposed materials in cascaded use, in circular business model (Lakatos et al., 2018). Industry 4.0 also plays equally critical role to achieve sustainability of the organizations through its various tools and practices. Industry 4.0 including such a concept like cloud manufacturing (CM), additive manufacturing (AM) and disruptive technologies such as Big data and analytics (BDA), cloud computing, artificial intelligence (AI), and internet of things (IoT) are playing a pivotal role in circular business model (CBM) (Bocken et al., 2016). Considering the importance of adopting circular business model and achieving sustainability in the organizations, this study focuses on analyzing the sustainable business practices in Indian organizations. A total of eighteen sustainable business practices were identified through literature review and discussion with experts. These were further categorized into three main categories. Best Worst Method (BWM) developed by Rezaei (2015) is applied on the responses obtained from ten different experts. The practices and their obtained ranks are depicted in Table 1.

Circular economy related practices emerged are the most important one for achieving circular business model and sustainability at the organization. Managers should focus on enhancing supply chain traceability, Supply chain traceability practices helps in sharing of real time information of about waste generated at each stage of the supply chain and thus helps in waste minimization and optimum utilization of the resources. Reuse and recycling infrastructure also needs to be developed, once the useful life of products is over, they are often discarded and are many times kept in stock yards without any processing on them. Recycling and reuse infrastructure and facilities if present can help in extraction of useful components and resources from these products, which can be reused in some other products, thus greatly reducing the resource burden of organizations and sustainable development of the businesses.

Table 1 Criteria weights and rankings for Industry 4.0, SCP and Circular Economy practices

Main Category Practices	Main Category Practices Weights	Sub Category Practices Criteria	Sub Category Practices Weights	Global Weights	Global Ranking
Industry 4.0 (IDY)	0.159	IoT (Internet of Things) (IDY1)	0.155	0.025	16
		Big data technologies (IDY2)	0.259	0.041	12
		Smart factory and Cloud manufacturing (IDY3)	0.154	0.025	17
		Additive manufacturing and 3-D printing technologies (IDY4)	0.356	0.057	6
		Robotic systems (IDY5)	0.075	0.012	18
Sustainable and Cleaner Production (SCP)	0.337	Top management commitment (SCP1)	0.109	0.037	15
		Energy and material use (SCP2)	0.110	0.037	14
		Natural and clean environment (SCP3)	0.266	0.090	3
		Packaging and design (SCP4)	0.134	0.045	11
		Competency and skillset building of workforce (SCP5)	0.159	0.054	8
		Supply chain collaboration and integration (SCP6)	0.221	0.075	5
Circular Economy (CEY)	0.504	Reuse and recycling infrastructure (CEY1)	0.215	0.108	2
		End of life determination (CEY2)	0.079	0.040	13
		Supply chain traceability/information (CEY3)	0.227	0.114	1
		Reduction is supply related risks (CEY4)	0.104	0.052	10
		Legal compliance (CEY5)	0.162	0.081	4
		Investment recovery and long-term profits (CEY6)	0.104	0.052	9
		Global standards and sustainability goals (CEY7)	0.110	0.055	7

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