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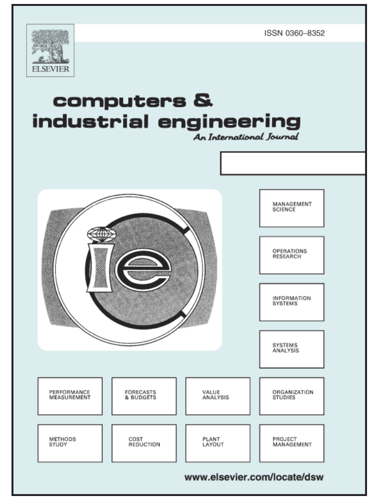

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CLUS-MCDA: A Novel Framework based on Cluster Analysis and Multiple Criteria Decision Theory in a Supplier Selection Problem

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Abstract. In past recent years, by increasing in the considerations on the significance of data science many studies have been developed concerning the big data structured problems. Along with the information science, in the field of decision science, multi-attribute decision-making (MADM) approaches have been considerably applied in research studies. One of the most important procedures in supply chain management is selecting the optimal supplier to maintain the long-term productivity of the supply chain. There has been a vast amount of research which utilized MADM approaches to tackle the supplier selection problems, but only a few of these research considered big data structured problems. The current study presents a comprehensive novel approach for improving Multiple Criteria Decision Analysis (MCDA) based on cluster analysis considering crisp big data structure input which is called CLUS-MCDA (Cluster analysis for improving Multiple Criteria Decision Analysis) algorithm. The proposed method is based on consolidating a data mining technique i.e. k-means clustering method and a MADM approach which is MULTIMOORA method. CLUS-MCDA method is a fast and practical approach which has been developed in this research which is implied in a supplier selection problem considering crisp big data structured input. A real-world case study in MAMUT multi-national corporation has been presented to show the validity and practicality of the CLUS-MCDA approach which calculated considering the business areas and criteria based on expert comments of mentioned organizations and previuos literature on supplier selection problem.

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CLUS-MCDA: A Novel Framework based on Cluster Analysis and Multiple Criteria Decision Theory in a Supplier Selection Problem

Abstract

In past recent years, by increasing in the considerations on the significance of data science many studies have been developed concerning the big data structured problems. Along with the information science, in the field of decision science, multi-attribute decision-making (MADM) approaches have been considerably applied in research studies. One of the most important procedures in supply chain management is selecting the optimal supplier to maintain the long-term productivity of the supply chain. There has been a vast amount of research which utilized MADM approaches to tackle the supplier selection problems, but only a few of these research considered big data structured problems. The current study presents a comprehensive novel approach for improving Multiple Criteria Decision Analysis (MCDA) based on cluster analysis considering crisp big data structure input which is called CLUS-MCDA (Cluster analysis for improving Multiple Criteria Decision Analysis) algorithm. The proposed method is based on consolidating a data mining technique i.e. k-means clustering method and a MADM approach which is MULTIMOORA method. CLUS-MCDA method is a fast and practical approach which has been developed in this research which is implied in a supplier selection problem considering crisp big data structured input. A real-world case study in MAMUT multi-national corporation has been presented to show the validity and practicality of the CLUS-MCDA approach which calculated considering the business areas and criteria based on expert comments of mentioned organizations and previuos literature on supplier selection problem.

Keywords

Supplier Selection Problem (SSP), Cluster Analysis, Data Mining, Multiple Criteria Decision Analysis (MCDM), MULTIMOORA method, Cluster analysis for improving Multiple Criteria Decision Analysis (CLUS-MCDA).

1. Introduction

In today's rapidly growing economies and fast changing environments, outsourcing has encountered a considerable amount of attention in numerous industries (Aksoy et al., 2014; Wetzstein et al., 2016). The selection of the right vendors (or suppliers) has become a tremendous challenge for a firm's business success. With the appearance of globalization, in today's competitive market, companies are under extreme force to have high-quality products (or services) (Chan and Kumar, 2007). Thus, business firms' try to reduce their costs to conserve and maintain their competitive status. Since the costs of raw materials and parts represent the main cost of a product (or service), and most organizations need to spend a vast amount of their revenues on purchasing.

Supplier Selection (SS) problems have become a very critical issue which is described as one of the most important functions in the purchasing and supply chains (Armaghan Heidarzade et al., 2016; Lima Junior et al., 2014; Scott et al., 2015; Wetzstein et al., 2016).

Supplier selection (SS) is a typical multi-criteria decision problem, and it is a decision process with the aim of reducing the numbers of potential vendors (or suppliers) to the final choices (Liao and Rittscher, 2007). supplier selection problem is a crucial subject which has a significant impact on the overall imposed expenses to the companies (Azadeh et al., 2016). Decisions are based on an evaluation of suppliers on multiple quantitative as well as qualitative criteria (Azadeh et al., 2016). Depending on the situation at hand, selecting suppliers may require searching for new suppliers or choosing suppliers from the existing pool of vendors (Lima Junior et al., 2014).

One of the main challenges for large industrial companies and manufacturers is dealing with the vast amount of data. Fortunately, there is a comprehensive solution for analyzing massive scale data flows and data generations; Data mining is an interdisciplinary subfield of computer science, overall target of the data mining methods and procedures are to reproduce information from data sets and transform them into an understandable structure for further use (Friedman et al., 2009). The significance of data mining emerges from the fact that the modern world is a data-driven world. Data is surrounding us, for example, numerical information and other type of unstructured data, which must be analyzed and processed to convert them into information that informs, instructs, answers, or else aids understanding and decision making (Kantardzic, 2011).

Statistical learning is one the subfields of data mining that plays a vital role in many areas of science, finance and industry (Friedman et al., 2009). Cluster analysis or clustering is a set of methodologies for automatic classification of large samples into some groups using a measure of association and organized criteria so that the samples in one group are similar and samples which belong to different groups are not similar (Barros et al., 2011). It is the primary task of exploratory data mining, and a common technique for statistical data analysis, used in many fields, including machine learning, pattern recognition, image analysis, information retrieval, bioinformatics, data compression, and computer graphics (Kantardzic, 2011) and It has been extensively studied and employed in intelligent decision-making (Barros et al., 2011). The input information for a system of cluster analysis is a set of samples (data) and a measure of similarity (or dissimilarity) between two samples (data). The output from cluster analysis is some groups (clusters) that form a partition or a structure of partitions, of the data set (Kantardzic, 2011). One additional result of cluster analysis is a generalized description of every cluster, and this is especially crucial for a deeper analysis of the data set's characteristics (Friedman et al., 2009).

The focus of this paper is to provide a comprehensive decision-making framework for outranking the optimal supplier among others in data structures which have an enormous amount of information. To achieve this target, after determination of cluster analysis criteria with expert opinions and library research, a proposition of clustering is conducted for the preprocessing procedure after this process, computing of the clusters with the application of the MULTIMOORA method obtained, then the optimal ranking will be determined. After repeating this procedure in several stages and determining the optimal supplier ranks, selecting the best supplier becomes facile. There has been a majority of developments, and research in supplier selection problems in the past decade, most of these developments focused on ranking and analyzing of small amount of data and these research mostly concentrated on Multiple Criteria Decision Analysis (MCDA) solutions i.e. multiple attribute decision making (MADM) methods, The new classification algorithm based on clustering, named CLUS-MCDA (Cluster analysis for improving Multiple Criteria Decision Analysis), which is an operational solution for MCDA problems considering big data structures.

This paper is structured as follow; Section 2.1 reviews a short survey on applications of MADM methods in supplier selection problems; Section 2.2 a survey on data mining and cluster analysis in supply chain managements; Section 2.3 reviews applications and developments on MULTIMOORA technique; Section 3.1 and 3.2 gives a short explanation about cluster analysis method and MULTIMOORA approach respectively; then a comprehensive description of CLUS-MCDA algorithm has been defined in section 3.3; Section 4 presents the applications of CLUS-MCDA approach in a real-world case study for a supplier selection problem in MAMUT multi-national corporation in Iran; while Section 5 offers conclusions and recommendations for the future researchers.

2. Literature review

2.1. Survey on applications of MADM methods in supplier selection problem

One of the main goals in supply chain analytics is to maintain long term partnership with a supplier, therefore, selection of the reliable and right suppliers involves a huge range of elements which could affect the decision process. In past five decades there are at least ten journal articles reviewing the applications and developments in supplier selection and evaluation (Chai et al., 2013; de Boer et al., 1998; De Boer et al., 2001; Edwards, 1967; Fahimnia et al., 2015; Farahani et al., 2014; Ho et al., 2010; Keshavarz Ghorabaee et al., 2017; Narasimhan, 1983; Olson, 2015; Spekman, 1988; Wetzstein et al., 2016; Wu and Barnes, 2011). There are many factors involved in evaluation and selection of the optimal supplier, because of this reason supplier selection problem is usually considered as a multiple attribute decision-making problem (Partovi, 2013; Sevkli et al., 2010a).

There has been a huge amount of research in MADM methods which implied either as a single approach or hybrid MADM approach. For example application of techniques such as; Analytic hierarchy process (AHP) (Kumar and Roy, 2011; Wang, 2015; Zeydan et al., 2011; Zhang et al., 2012), Analytic network process (ANP) (Bayazit, 2006; Dargi et al., 2014; Tavana et al., 2016), Complex proportional assessment (COPRAS) (Keshavarz Ghorabaee et al., 2014; Mobin et al., 2015; Nourianfar and Montazer, 2013; Zolfani et al., 2012), Data envelopment analysis (DEA) (Ahmady et al., 2013; Wu et al., 2007; Wu and Blackhurst, 2009), Evaluation based on distance from average solution (EDAS) (Ghorabaee et al., 2016), Elimination et Choix Traduisant la Realité (ELECTRE) (Liu and Zhang, 2011; Sevkli et al., 2010b; Wan et al., 2017), Multi-objective optimisation by ratio analysis (MOORA) and MULTIMOORA (Dey et al., 2012; Farzamnia and Babolghani, 2014; Karande and Chakraborty, 2012a; Pascual Serrano et al., 2016), Preference ranking organisation method for enrichment of evaluations (PROMETHEE) (Alencar and Almeida, 2011; Behzadian et al., 2010; Dulmin and Mininno, 2003; Safari et al., 2012), Technique for order of preference by similarity to ideal solution (TOPSIS) (Banaeian et al., 2016; Chen et al., 2006; Deng and Chan, 2011; Ghorbani et al., 2013), Visekriterijumska Optimizacija I kompromisno resenje (VIKOR) (Alguliyev et al., 2015; Kaya and Kahraman, 2010; Sahu et al., 2016a; Shemshadi et al., 2011; Wu et al., 2016), Decision-making trial and evaluation laboratory (DEMATEL) (Chang et al., 2011; Hsu et al., 2013; Wang, 2015), Axiomatic Design (AD) (Beng and Omar, 2014; Büyüközkan, 2012; Buyukozkan and Arsenyan, 2009; Kannan et al., 2015; Lee and Omar, 2016), Best-Worst method (BWM) (Rezaei et al., 2016, 2015).

Dobos and Vörösmarty (2014) proposed a DEA method considering composite indicator (CI) and the common weights analysis (CWA) method approach to add environmental factors to traditional supplier selection methods. You et al. (2015) suggested an extended VIKOR method i.e. interval 2-tuple linguistic VIKOR (ITL-VIKOR) method in a group multiple criteria supplier selection problem. Also, a comparison of proposed method to other approaches obtained which methods showed its efficiency and confirmed the appropriateness of the technique for supplier selection considering ambiguity, uncertainty, and incomplete information. Ayhan and Kilic (2015) proposed a hybrid AHP and fuzzy mixed integer linear programming approach to a supplier selection problem considering constraint as multi-product suppliers where suppliers are not able to provide all items. Wood (2016) used multiple MCDM methods i.e. linear, nonlinear, TOPSIS, Fuzzy TOPSIS methods for supplier selection in the gas industry.

Jain et al. (2016) presented a supplier assessment by implying Fuzzy AHP and TOPSIS to tackle a supplier selection problem in Indian automotive industry, the evaluation of the criteria is obtained by AHP computations and obtained from previous studies. Chang et al. (2016) suggested an AHP approach considering soft set data structure to solve a general supplier selection problem concerning the tourism factory, and then compared the results to traditional AHP method. Keshavarz Ghorabaee et al. (2016) proposed an extended WASPAS considering interval type-2 fuzzy sets (IT2FS) in a green group supplier selection problem.

2.2. Survey on applications and developments on data mining in supply chain managements

From three decades ago data mining has become the most valuable tool for knowledge discovery from a large database and large data structures (Khademolqorani and Hamadani, 2013). Data mining is a set of procedures based on semi-automaticall analysis of large databases to find useful and understandable patterns. In recent years, application of data mining method expanded extensively which also covers supply chain management. There has been a vast amount of research in data mining applications and developments in the past few decades. By consolidating data analysis procedures and quantitative tools and techniques, it can be a great help in different fields of management and performance improvement such as supplier management. Azadnia et al. (2011) proposed a Fuzzy C-Means (FCM) and a hybrid FAHP and ELECTERE method to rank the optimal supplier considering big data structure in two large size car manufacturers in Iran i.e. SAIPA and IRANKHODRO. Zhao and Yu (2011) proposed a case-based reasoning considering data mining and clustering for attribute weight calculation in entropy with back-propagation neural networks for the petroleum industry in China. Zou et al. (2011) proposed an empirical study based on rough set theory to derive decision rules to select the optimal distributor.

Masciari (2012) suggested a system based an outlier template definition for monitoring anomalies in RFID data streams in supply chains. Ghadge et al. (2012) examine the supply chain risk management (SCRM) with an unbiased and holistic perspective of advances within SCRM based on the text mining of the proposed literature. Le et al. (2013) proposed association rules to remove sensitive knowledge from released databases in a retail supply chain. Ji et al. (2013) presented a gathering data system based on Internet-of- things technology which is processed by data mining algorithms to control supply chain inventory. Faezy Razi (2014) consolidated grey relational analysis and an artificial bee colony heuristic algorithm in a supplier selection under conditions of multiple criteria. Bhattacharya et al. (2014) suggested an application of support vector machines (SVM) and mixed integer programming for intermodal transportation support of traffic flow in an existing Fast Moving Consumer Goods (FMCG) distribution network in India. Olson (2015) presented an overview of supply chain data mining publications based on 97 journal articles concerning of data mining applications in supply chain analytics.

Kuo et al. (2015) presented an integration of an association rule algorithm (TD-FP-growth algorithm) with a hybrid artificial immune network (Opt-aiNet) and particle swarm optimization (PSO) which is called aiNet-PSO in a supplier selection and order quantity allocation. Kar (2015) proposed a hybrid group decision support system based on analytic hierarchy process, fuzzy set theory and neural network in two supplier selection case studies. He et al. (2016) proposed a data mining application on agricultural products supply chain for selecting the optimal partner. Heidarzade et al. (2016) conducted an experimental analysis using clustering method based on a new distance for interval type-2 Fuzzy sets (IT2FS) in a supplier selection problem. He and Jiang (2017) suggested an evidential supplier selection based on a basic probability assignment(BPA) determined by the distance among the evidence. Trautrims et al. (2017) proposed an innovation-based concerning patent analysis in strategic supplier selection in the US automotive sector. Roehrich et al. (2017) applied self-determination theory (SDT) to green supply chain management (GSCM) through a supplier selection and value internalization in the aerospace industry.

2.3. Survey on applications and developments on MULTIMOORA approach

The multi-objective optimization on the basis of ratio analysis (MOORA) method has been proposed by Brauers and Zavadskas (2006) which has been further developed to the extended version of MOORA approach which is MULTIMOORA method (Willem Karel M Brauers and Zavadskas, 2010). MULTIMOORA method is one of the most straightforward and efficient multiple attribute decision-making methods (MADM) which is a comprehensive form of the MOORA technique. The MULTIMOORA approach which integrates three subordinate ranks results in more robust and accurate rankings than the traditional MADM methods and its previous form MOORA method (Brauers and Ginevičius, 2010; Hafezalkotob and Hafezalkotob, 2016). Brauers and Zavadskas (2010) proposed a test for the robustness of the MULTIMOORA approach by applying the MULTIMOORA approach in project management which was computed from the MOORA method into the standard form of MULTIMOORA. The robustness of MULTIMOORA method utilized by an application to the economy of the Belgian regions has been examined by Brauers and Ginevičius (2010) which was one of the first applications of MULTIMOORA method. Since the introduction of MULTIMOORA method in 2006, there has been various research conducted on the MULTIMOORA applications in diverse areas.
Application of MULTIMOORA method in technology selection (Altuntas et al., 2015; Balezentiene et al., 2013; Liu et al., 2014; Streimikiene et al., 2012; Zavadskas et al., 2013), Enterprise Resource Planning (ERP) system selection (Karande and Chakraborty, 2012b), machine selection (Datta et al., 2013; Kracka et al., 2010; Mandal and Sarkar, 2012; Sahu et al., 2016b), personnel selection (Akkaya et al., 2015; Baležentis et al., 2012; Karabasevic et al., 2015), project selection (Willem Karel M Brauers and Zavadskas, 2010; El-Santawy and Ahmed, 2012), Supplier Selection Problem (SSP) (Baležentis and Baležentis, 2011a; Çebi and Otay, 2016; Dey et al., 2012; Farzamnia and Babolghani, 2014; Karande and Chakraborty, 2012a; Mishra et al., 2015; Sahu et al., 2014) material selection problem (Hafezalkotob et al., 2016; Hafezalkotob and Hafezalkotob, 2016, 2015a).
Zavadskas et al. (2015) suggested an interval-valued intuitionistic Fuzzy MULTIMOORA for group decision making in real-world civil engineering problems. Stanujkic et al. (2015) developed an extension of the MULTIMOORA method considering the triangular Fuzzy data structure to resolve communication circuits design selection problem. Ceballos et al. (2016) compared rankings obtained by Fuzzy MULTIMOORA, Fuzzy TOPSIS, Fuzzy VIKOR, and Fuzzy WASPAS To answer the question in every MCDM problem that is Which method should be used to solve the ranking problem which results in the answer that the question is still open. Zhao et al. (2016) suggested a novel approach toward Failure mode and effect analysis (FMEA) based on interval-valued intuitionistic Fuzzy sets (IVIFSs) and MULTIMOORA approach For handling the uncertainty and vagueness in FMEA process and to achieve a more accurate ranking of failure modes which identified in FMEA

Gou et al (2017) applied an extended development on MULTIMOORA approach by developing Hesitant Fuzzy linguistic term set (HFLTS) to novel concepts named double hierarchy linguistic term set (DHLTS) and double hierarchy hesitant Fuzzy linguistic term set (DHHFLTS) and integrating these new concepts with MULTIMOORA method, which results in DHHFL-MULTIMOORA method to select the optimal city in China by evaluating the implementation status of haze controlling measurements. Awasthi and Baležentis (2017) A hybrid approach utilizing BOCR and fuzzy MULTIMOORA based on a Monte Carlo simulation based sensitivity analysis is conducted to determine the robustness of MULTIMOORA to variation in criterion and decision maker weights for logistics service provider selection. Stanujkic et al. (2017) proposed a new extension to the MULTIMOORA approach by using single-valued neutrosophic sets which result in more efficiency in the case of solving complex problems where solving requires assessment and prediction.

3. Methodology of the CLUS-MCDA algorithm

This section presents a comprehensive overview through the core procedures of CLUS-MCDA algorithm considering k-means clustering technique and MULTIMOORA approach which provides a hybrid multiple attribute decision making (MADM) and data mining (DM) method considering crisp big data structure. To the best of authors' knowledge, there is not a single study considering an algorithm based on cluster analysis and MULTIMOORA method combined. There has been various studies considering MULTIMOORA algorithm for supplier selection problem (Baležentis and Baležentis, 2011b; Çebi and Otay, 2016; Farzamnia and Babolghani, 2014; Mishra et al., 2015; Pascual Serrano et al., 2016). Also, there are few studies which considers clustering methods in pre-processing procedure based on big data structure (Azadnia et al., 2011; Camus et al., 2011; Faezy Razi, 2014; A. Heidarzade et al., 2016; Malakooti and Raman, 2000). Furthermore, no study has considered the mentioned approaches i.e. clustering algorithm and MULTIMOORA method in a consolidated procedure. Also, there is not a single study that applied algorithms such as CLUS-MCDA in a supplier selection problem. The main difference of the CLUS-MCDA algorithm is that the proposed algorithm could analyze and evaluate a decision based big data structured input. Additionally, in current research an application of the proposed algorithm CLUS-MCDA in a real-world supplier selection problem is presented which is comprehensively demonstrated in Section 4.

3.1. Clustering Algorithm

The k-means algorithm is one of the most well-known partitioning approaches based on iterative distance-based technique in data mining algorithms (Peng et al., 2012a). k predefines the number of the clusters which is the input parameter. The first step in k-means clustering algorithm is calculated by choosing the k objects randomly to be the centres of the clusters. Every k object is then partitioned into k clusters based on the minimum squared error criterion, which measures the distance between an object and the cluster centre (Peng et al., 2012a).
The new mean of each cluster is computed and the complete procedure iterates until the cluster centers remain the same (Peng et al., 2012b; Witten et al., 2011). The squared-error between μ_i and the objects in cluster C_i is defined as follows (Witten et al., 2011):

$$WCSS(C_i) = \sum_{x_j \in c_i} \|x_j - \mu_i\|, \quad (1)$$

in which $X = \{x_i\}, i = 1,2, \dots, n$ be the n objects to be clustered, $C_i = \{C_1, C_2, \dots, C_k\}$ is the set of clusters. μ_i is the mean of the cluster C_i WCSS denotes the sum of the squared error in the inner-cluster. The main goal of k-means algorithm is to minimize the sum of the squared error overall k clusters, which is computed as:

$$\min\,(WCSS(C_i)) = arg\ min_c \sum_{i=1}^{k} \sum_{x_j \in c_i} \|x_j - \mu_i\|^2, \quad (2)$$

to generate a new partition by assigning each observed point to its closest cluster center which is one of the essential steps of k-means algorithm where have a huge impact on the sum of squared error is obtained from Eq.(3):

$$C_i^{(t)} = \left\{x_j : \left\|x_j - m_i^{(t)}\right\| \leq \left\|x_j - m_{i^*}^{(t)}\right\| \; for\ all\ i^* = 1,2,\ldots,k\right\}, \tag{3}$$

where $m_i^{(t)}$ defines mean of the ith cluster in tth times clustering, while $C_i^{(t)}$ represents all sets contained in the ith cluster in tth times clustering.
New cluster mean centers which are another critical aspect where effects on the sum of squared error are calculated as follows:

$$m_i^{(t+1)} = \frac{1}{\left|C_i^{(t+1)}\right|} \sum_{x_j \in C_i^{(t)}} x_j, \tag{4}$$

where $m_i^{(t+1)}$ presents the mean of the ith cluster in $(t+1)$th times clustering while $C_i^{(t+1)}$ represents all sets contained in the ith cluster in $(t+1)$th times clustering.

3.2. MULTIMOORA method

The MULTIMOORA method is composed of three parts which the ratio system and the reference point approaches defined in multi-objective optimization by ratio analysis (MOORA) developed by Brauers and Zavadskas (Brauers and Zavadskas, 2006). Later on, the full multiplicative form added to the MOORA procedure which results in the extended version of MOORA method proposed by Brauers and Zavadskas (Brauers and Zavadskas, 2010) which is called MULTIMOORA approach to achieve a more robust method.
The first step in MULTIMOORA method is forming the decision matrix **X** which x_{ij} presents the performance index of ***i***th alternative respecting ***j***th attribute $i = 1,2, \ldots m$ and $j = 1,2, \ldots n$, and w_j^s denotes the subjective significance coefficients of ***j***th attribute $j = 1,2, \ldots n$:

$$\boldsymbol{X} = [x_{ij}]_{m \times n}\,, \tag{5}$$

$$\boldsymbol{w_j^s} = [w_j]_n\,, \sum w_j = 1\,. \tag{6}$$

In MULTIMOORA approach, these parameters should be dimensionless in order to make performance indices comparable. Therefore, the decision matrix is a normalization ratio of caparison between each response of an alternative to a criterion as a numerator, and a denominator that is a representative for all alternative performances on that attribute.
The dimension dominator is calculated as the square root of the sum of squares of performance indices per attribute as shown in Equation (7):

$$X_{ij}^* = \frac{x_{ij}}{\sqrt[2]{\sum_{i=1}^{m} x_{ij}^2}}\,, \tag{7}$$

in which, X_{ij}^* denotes the normalized performance index of ***i***th alternative respecting ***j***th attribute $i = 1,2, \ldots m$ and $j = 1,2, \ldots n$ and x_{ij} presents the performance index of ***i***th alternative respecting ***j***th attribute $i = 1,2, \ldots m$ and $j = 1,2, \ldots n$. This normalization method is the most robust selection among various normalization approaches towards the MULTIMOORA method (Brauers and Zavadskas, 2006).

3.2.1. The ratio system

The normalization equation i.e. Equation (7) justifies foundations of this approach as the ratio system (Hafezalkotob and Hafezalkotob, 2016). In the current approach for optimization, the normalized performance indices are added for beneficial attributes or deducted for non-beneficial attributes which mean these responses are added in case of maximization and subtracted in the event of minimization (Brauers and Zavadskas, 2011):

$$y_i^* = \sum_{j=1}^{g} w_j^s X_{ij}^* - \sum_{j=g+1}^{n} w_j^s X_{ij}^* , \tag{8}$$

in which, g indicates as the objectives to be maximized and $(n-g)$ indicates the objectives being minimized, y_i^* denotes the total assessment of alternative j with respect to subjective significance coefficients of all attributes w_j^s which can be positive or negative based on the totals of calculations. The optimal alternative based on ratio system A_{RS}^* is an ordinal ranking of the y_i^* which has the highest assessment value A_i (Datta et al., 2013; Hafezalkotob and Hafezalkotob, 2016):

$$A_{RS}^* = \{A_i | max_i\ y_i^*\} . \tag{9}$$

3.2.2. The reference point approach

The second part of the proposed approach starting based on foundations of ratio system which is Eq. (7). A maximal objective reference point is also concluded in the method which obtained by Eq. (10) (Brauers and Zavadskas, 2006; Hafezalkotob and Hafezalkotob, 2015a):

$$r_j = \begin{cases} max_i\, X_{ij}^* & in\ case\ of\ maximization \\ min_i X_{ij}^* & in\ case\ of\ minimization \end{cases}, \tag{10}$$

where r_j denotes the ***i***th co-ordinate of the maximal objective reference point vector.
Deviation of a performance index from the reference point r_j can be obtained as $(r_j - X_{ij}^*)$. Subsequently, the maximum value of the deviation for each alternative z_i^* respecting subjective significance coefficients of all criteria w_j^s can be calculated as Eq. (11) (Hafezalkotob and Hafezalkotob, 2016):

$$z_i^* = max_j \left| (w_j^s r_j - w_j^s X_{ij}^*) \right|, \tag{11}$$

in the reference point approach calculation of optimal alternative A_{RP}^* is calculated by computing the minimum value of Eq. (11) which demonstrated in Eq. (12) (Datta et al., 2013):

$$A_{RP}^* = \{A_i | min_i\ z_i^*\} . \tag{12}$$

Additionally, for the second part of the MULTIMOORA method which is the reference point theory is chosen with the Min-Max Metric of Tchebycheff as given by the Eq. (13) where the basic form reference point is calculated (Brauers et al., 2014).

$$min_j \{max_j \left| (r_j - X_{ij}^*) \right| \}. \tag{13}$$

With $\left|(r_j - X_{ij}^*)\right|$ the absolute value if X_{ij}^* is larger than r_j for instance by minimization.

3.2.3. The full multiplicative form

The third part of the MULTIMOORA method developed by Brauers and Zavadskas is based on an idea in economic mathematics (Brauers and Zavadskas, 2010). The formula of the full multiplicative form can be determined as demonstrated in Eq. (14) where g denotes as the objectives to be maximized and $(n-g)$ indicates as the objectives to be minimized. The numerator of Eq. (14) indicates the product of performance indices of ***i***th alternative relating to beneficial attributes. The denominator of Eq. (14) i.e. U_i' represents the product of performance indices of ***i***th alternative relating to non-beneficial attributes respecting subjective significance coefficients of each attribute w_j^s (Hafezalkotob et al., 2016; Hafezalkotob and Hafezalkotob, 2015a).

$$U_i' = \frac{\prod_{j=1}^{g} (x_{ij})^{w_j^s}}{\prod_{j=g+1}^{n} (x_{ij})^{w_j^s}} , \tag{14}$$

by using normalized decision matrix an equivalent equation form of U_i' can be demonstrated as Eq. (15):

$$U_i^* = \frac{\prod_{j=1}^{g} (X_{ij}^*)^{w_j^s}}{\prod_{j=g+1}^{n} (X_{ij}^*)^{w_j^s}}, \tag{15}$$

to maintain a harmony among all parts of calculations in MULTIMOORA approach, Eq. (15) which is the normalized form of the full multiplicative form i.e. U_i^* is used. Similar to the ratio system computation of the optimal alternative A_{MF}^* is based on the search for maximum evaluation measurement A_i among all assessment values of U_i^* as demonstrated in Eq. (16):

$$A_{MF}^* = \{A_i | max_i \, U_i^*\}. \tag{16}$$

3.2.4. The dominance theory: The final ranking of the MULTIMOORA method

The dominance theory was proposed as a tool for ranking subordinate alternatives in MULTIMOORA method (Brauers et al., 2011; Brauers and Zavadskas, 2012, 2011; Hafezalkotob and Hafezalkotob, 2015b). After the calculation of the subordinate ranks, they can be integrated into a final ranking, which is the final MULTIMOORA rank based on the dominance theory that is obtained.
In dominance theory, a summary of the classification of the three MULTIMOORA methods is made based on cardinal and ordinal scales which in rankings rules should be applied (i.e. dominated, transitivity and equability.) (Brauers and Zavadskas, 2012). Theory of dominance can be discussed as the: "(a) the plurality rule assisted with a kind of lexicographic method, (b) the method of correlation of ranks." which has been demonstrated by Brauers and Zavadskas (2012). For more detailed explanation of the dominance theory, readers can refer to the study of Brauers and Zavadskas (2012).

3.3. CLUS-MCDA method

Cluster Analysis for improving Multiple Criteria Decision Analysis which is called CLUS-MCDA; is an approach based on k-means clustering method and MULTIMOORA technique. In Section 3.1 and 3.2, the procedure of k-means clustering technique and the MULTIMOORA method is provided respectively. CLUS-MCDA algorithm is an iterating based approach which is concerns on the main loop which repeats the core procedure of the algorithm which is k-means clustering and MULTIMOORA method till the algorithm allows to stop and present a final rank. Figure (1) illustrates the flow diagram of the CLUS-MCDA algorithm applied to a supplier selection problem as demonstrated in Section 4.

Figure (1): Flow diagram of CLUS-MCDA algorithm which implied in the case-study.

As aforementioned, CLUS-MCDA approach is a repetitive algorithm which considers loops of a decision making algorithm and a data mining technique. The proposed pre-processing algorithm consists of straightforward procedure which is the clustering method, and the ranking process consists of a valid and fast MADM method i.e. MULTIMOORA technique.

4. Finding and results

In the current research study in terms of research type is practical regarding its purpose, considering presenting a novel framework i.e. CLUS-MCDA, but the proposed algorithm could also expand and extend regarding the input data structure in terms of mathematical calculations. Regarding the content and data collection, this study is descriptive and quantitative, and the type of the review is a case study. Given that the success of selecting the optimal supplier in an organization is considered from the perspective of procurement manager and high-level managers, the study population includes the specialists, experts, and officials which concerned by selecting the optimal supplier of ICT sector in MAMUT corporations. A set of criteria for proposing the clustering algorithm based on expert comments has been collected. Furthermore, there are other criteria for selecting the optimal supplier which has been identified and collected from the previous research and expert comments which

classified in Table (1) where the description of each criterion is available. Table (2) shows the business areas which have been selected to include in the ranking procedure after the clustering process. These business areas of suppliers collected and classified from supplier directory of organization and expert comments which are directly dealing with the case study's ranking and selecting the optimal vendor.
In the current study, the input data i.e. supplier options and alternatives are imported from the MAMUT Corporation's supplier database measured by the procurement management of ICT sector in the mentioned organization. As to select the optimal supplier in ICT sector of MAMUTs Company aforementioned the measurement criteria identified by experts and previous research. In this section, the CLUS-MCDA algorithm is utilized based on the vendor's database which is considered as a big data structure. This study is based on one case study i.e. MAMUT corporation in Iran. MAMUT multi-national corporation is recognized as the largest industrial contracting company and manufacturer of Trailers in the Middle East. Additionally, the MAMUT corporation plays a critical role in the information and communications technology (ICT) industry in Iran such as telecommunication infrastructures, organizational ICT solutions, etc. The CLUS-MCDA method has been implemented in MAMUT's ICT sector for a supplier selection problem considering the huge amount of data.
As explained by Easton (2010), focusing on one case study leads to a better understanding of existing data and a robust exploration and reflection of data examination obtained by researchers. Flyvbjerg (2006) clarified that to employ in-depth research on any topic, "one can study only one case, and the result can be generalized." Consequently, the mentioned case-study in this research was not chosen randomly. It intended and targeted to select a specific organization to be able to obtain certain understandings that other organizations would not be able to offer which in this case study is collecting a huge amount of data (or a big data structure) from suppliers for selecting the optimum. As a result, this practical example has been chosen to gain a thorough knowledge of the selection of the optimal supplier in MAMUT corporations in Iran. As aforementioned, the criteria for selecting a supplier is extracted from the literature review (library research) and expert comments. Also, the supplier record considered as alternatives, are extracted from the expert comments and the organization supplier database.
The necessary research data for current research in this case-study collected through interview. Characteristics of the respondents regarding their education, occupation, and experience are high-level managers (i.e. two managers; one in ICT sector and one in project management office), one procurements manager and two manager assistants who are directly dealing with the procedure of selecting the optimal supplier. In the current study, weights of the respondents i.e. experts are considered as the same which is assumed as $w_j^s = 1$. The method of interview was question and answer (Q&A) which was based on linguistic terms of Table (3). The fundamental purpose of Q&A was to complete the decision matrix which builds on the linguistic terms and the corresponding numbers of Table (3).
Additionally, the calculation process of the big structured data which is imported from the SQL Server database in the ICT sector of mentioned company is computed by Microsoft Excel and Microsoft SQL Server SP1 Data Mining Add-ins for Microsoft Office. For validating the results of the CLUS-MCDA algorithm calculation of the proposed method has been coded and computed using Python language.
For the sake of open-science considerations the coding procedure of the CLUS-MCDA algorithm applied in the current real-world case study, has been demonstrated in an uploaded Mendeley dataset*. Furthermore, the detailed procedure of the CLUS-MCDA algorithm which contains process details in every business area considering every iteration and plots of the procedure result is also available in the mentioned open data-set.

Table (1): Criteria definition for selection of the optimal supplier.

Table (2): candidate alternatives as groups i.e. business areas.

*Ijadi Maghsoodi, Abteen; Kavian, Azad (2017), "A big data structured dataset of suppliers for a multi-national company analyzed by CLUS-MCDA", Mendeley Data, v3 http://dx.doi.org/10.17632/y3wv3gf28n.3

Table (3): Linguistic terms and the corresponding numbers.

As described in Table (2), in total, there are 479 suppliers and 20 business areas which the CLUS-MCDA algorithm computed the data and selected the optimal supplier in every mentioned criterion. Figure (2) illustrates a scatter graph based on the total amount of data i.e. 479 suppliers and the total cost of each supplier considering the product or the service provided. The y-axis in Figure (2) is based on total cost per unit of the supplier's product or service. Consequently, as aforementioned the gathered data are from the MAMUT Corporation which is based in Iran. The monetary unit is US Dollar ($).

Figure (2): Scatter Graph of the big structured input data based on supplier information.

Additionally, Figure (3) illustrates a scatter plot based on the clusters of business areas in which X-axis is the number of suppliers and Y-axis is total cost per unit of the supplier's product or service.

Figure (3): Scatter diagram of the input data based on business area clusters.

Based on the procedure's flow-diagram which is illustrated in Figure (1), the first step after clustering based on business areas is to apply the k-means clustering algorithm based on financial elements. In order to truncate the result process in current study an example of data from the whole population of suppliers' data has been processed by the CLUS-MCDA approach. Subsequently, in the final result the complete numbers of data i.e. 479 suppliers has been shown in the resultant rankings.
Figure (4) shows the first step of the CLUS-MCDA algorithm after determination of the business areas clusters for an example which is Contractors suppliers. In which, the k-means clustering technique with $k = 5$ implied, the X symbols in Figure (4) shows the centroid or geometric center of clustering which means; the arithmetic mean or average position of all the points in the clusters.

Figure (4): k-means clustering concerning $k = 5$ in the first iteration for Contractors as an example.

Table (4) indicates the rankings of the clusters calculated from the k-means approach considering example of Contractors which has been computed by applying the MULTIMOORA method. In the first iteration the total data of the clusters contains a total of 109 contractors.

Table (4): Rankings of the first iteration clusters based on MULTIMOORA approach concerning Contractors.

Furthermore, Figure (5) illustrates the clusters after four iterations based on the k-means algorithm considering $k = 5$ based on final rankings of the previous state of the algorithm which is the MULTIMOORA technique rankings for the clusters of Contractors business area as an example. Table (5) indicates the rankings of the clusters after four iterations based on $k = 5$ in the k-means clustering process based on the proposed MADM technique i.e. MULTIMOORA approach considering the fourth iteration in which the total data in the clusters contains 19 contractors.

Figure (5): k-means clustering concerning $k = 5$ in the fourth iteration for Contractors as an example.

Table (5): Rankings of the fourth iteration clusters based on MULTIMOORA approach concerning Contractors.

Consequently, Figure (6) shows the clusters of the final iteration based on the k-means algorithm considering $k = 5$ considering the final rankings of the previous iteration which was calculated from MULTIMOORA approach for the clusters of Contractors business area as an example. Table (6) indicates the rankings of the clusters of the final iteration based on $k = 5$ in the k-means clustering process based on the aforementioned technique which is the MULTIMOORA method concerning on the final iteration in which the total data in the clusters contains 5 contractors.

Figure (6): k-means clustering concerning $k = 5$ in the iteration X for Contractors as an example.

Table (6): Rankings of the final iteration clusters based on MULTIMOORA approach concerning Contractors.

Consequently, Table (7) demonstrates the final results of the CLUS-MCDA algorithm based on an example of suppliers i.e. Contractors which contains 109 suppliers where has been calculated by computing the k-means clustering approach and ranked with MULTIMOORA method.

Table (7): Final ranking for the example suppliers i.e. Contractors with the CLUS-MCDA algorithm.

Ultimately, Table (8) demonstrates the final detailed ranking result of the CLUS-MCDA algorithm based on the total amount of data which are 479 suppliers and 20 business areas. As mentioned previously in the aforementioned open data-set[†], the detailed process of every business area has been demonstrated.

Table (8): Final rankings of complete input data based on CLUS-MCDA algorithm.

In order to evaluate the similarity of rankings considering CLUS-MCDA approach and the rankings based on expert judgments in the case-study, final ranks of both methods of assessment have been compared by utilizing the Spearman rank correlation coefficient. A coefficient is a real number in the range of -1 and 1, which the coefficient equal to 1 denotes identical rankings and -1 indicates opposite rankings (Sedgwick, 2014). Figure (7) illustrates the correlation between mentioned ranking lists by utilizing Spearman rank correlation coefficient. In which, Figure (7) shows that the rankings in the business areas are based on expert judgments compared to rankings of the CLUS-MCDA algorithm accordingly have high correlations and based on the expert comments on the ranking of the CLUS-MCDA approach and based on the expert experiences the proposed assessment of the CLUS-MCDA results in the optimal rankings. Consequently, the final results of the proposition of the CLUS-MCDA approach in the case study concerning on big data structure input show that the CLUS-MCDA approach is a valid and fast technique to preprocess the big data input, and it helps decision-makers to achieve the optimal ranking with the proposed method.

Figure (7): Correlation between the rankings of business areas based on Spearman coefficient.

As mentioned in the previous sections, processing big data structures is one of the challenging problems of organizations considering century of data. There are many methods which could process the big data structure based on data mining techniques. But, from the perspective of organization management team the best calculation process is the fastest and most accurate technique. CLUS-MCDA method is a hybrid approach towards decision making considering big data structures which allow decision makers to obtain fast and accurate results in order to solve the decision making problem. As reviewed in this paper CLUS-MCDA algorithm has proved that the proposed technique is an accurate and practical method. Based on the correlation between ranking lists considering the fact that expert judgments were compared to the rankings of the CLUS-MCDA algorithm, the results showed high correlations. Which means, the computed results of the CLUS-MCDA approach is close to expert judgements. Ultimately, there are 8 business areas which indicate lower correlation values. In this case, based on the case-study experts' predictions and calculations, the results of the CLUS-MCDA approach could be more beneficial to the selection process. For an example; the correlation between ranking lists of expert judgments and CLUS-MCDA approach in the "Electrical Panels" are calculated as 0.5. The decision making process consists of expert judgements in comparison to CLUS-MCDA approach impose over-head costs approximately 400$ to the selection process. Additionally, to decrease the unreasonable costs in the supplier selection problem the managerial team in the MAMUT organization utilizes the CLUS-MCDA approach. Ultimately, as a practical matter of concern, there is far more available data in the organization which produces in a big data structure format such as hiring and talent management data, risk analysis data, human interaction data, and etc. CLUS-MCDA method could be an accurate and fast technique in order to tackle the processing and calculating challenge of the mentioned big data structure problems.

[†]Ijadi Maghsoodi, Abteen; Kavian, Azad (2017), "A big data structured dataset of suppliers for a multi-national company analyzed by CLUS-MCDA", Mendeley Data, v3 http://dx.doi.org/10.17632/y3wv3gf28n.3

5. Conclusion

Dynamic and competitive environments of organizations in recent years results in an enormous attention to continuous improvement of the organization itself. One of the main discussable fields in any supply chain is selecting the optimal supplier which could improve the procedure of the supply chain. Therefore, selecting the optimal supplier is substantial. The 21st century is called the century of Information and Communication Technology (ICT) developments where data is more valuable than gold. Accordingly, data analysis for the purpose of finding the meaningful answers become critical and necessary. The shifted paradigm in valuable matters in organizations results in applying state-of-the-art and update methods of knowledge discovery in data bases such as data mining. Consolidation of data mining methods with MCDM techniques gives decision makers in an organization such as high-level managers, easy and user-friendly tools to tackle the managerial problems such as supplier selection.

The current study presented a novel and comprehensive method to address the decision-making problems considering crisp, big data structures. The CLUS-MCDA approach is based on k-means clustering technique and MULTIMOORA method which results in a fast and logical decision-making tool. To examine the proposed algorithm i.e. CLUS-MCDA a case study is provided which is the application of CLUS-MCDA method in a supplier selection problem in ICT sector of MAMUT's Corporation. Implementation of the CLUS-MCDA algorithm in the case study shows that the proposed algorithm can be an effective decision-making tool considering crisp, big data structure in a supplier selection problem.

Suggestions for future developments of this study may be as the following. First, the input data of the CLUS-MCDA algorithm can be extended to the cases in which the data of the problem has different mathematical forms such as extensions of Fuzzy sets, e.g., L-Fuzzy sets, flou sets, Fuzzy multi-sets, Fuzzy bipolar sets, and interval data structure. Second, significance coefficients of attributes may be achieved using various techniques. In the present study, subjective significance coefficients were considered while in a future study objective significance coefficients can be calculated using methods such as Shannon's entropy. Additionally, Subjective significance coefficients may be computed by applying various methods like the analytic network process, analytic hierarchy process, and Best-Worst-Method.

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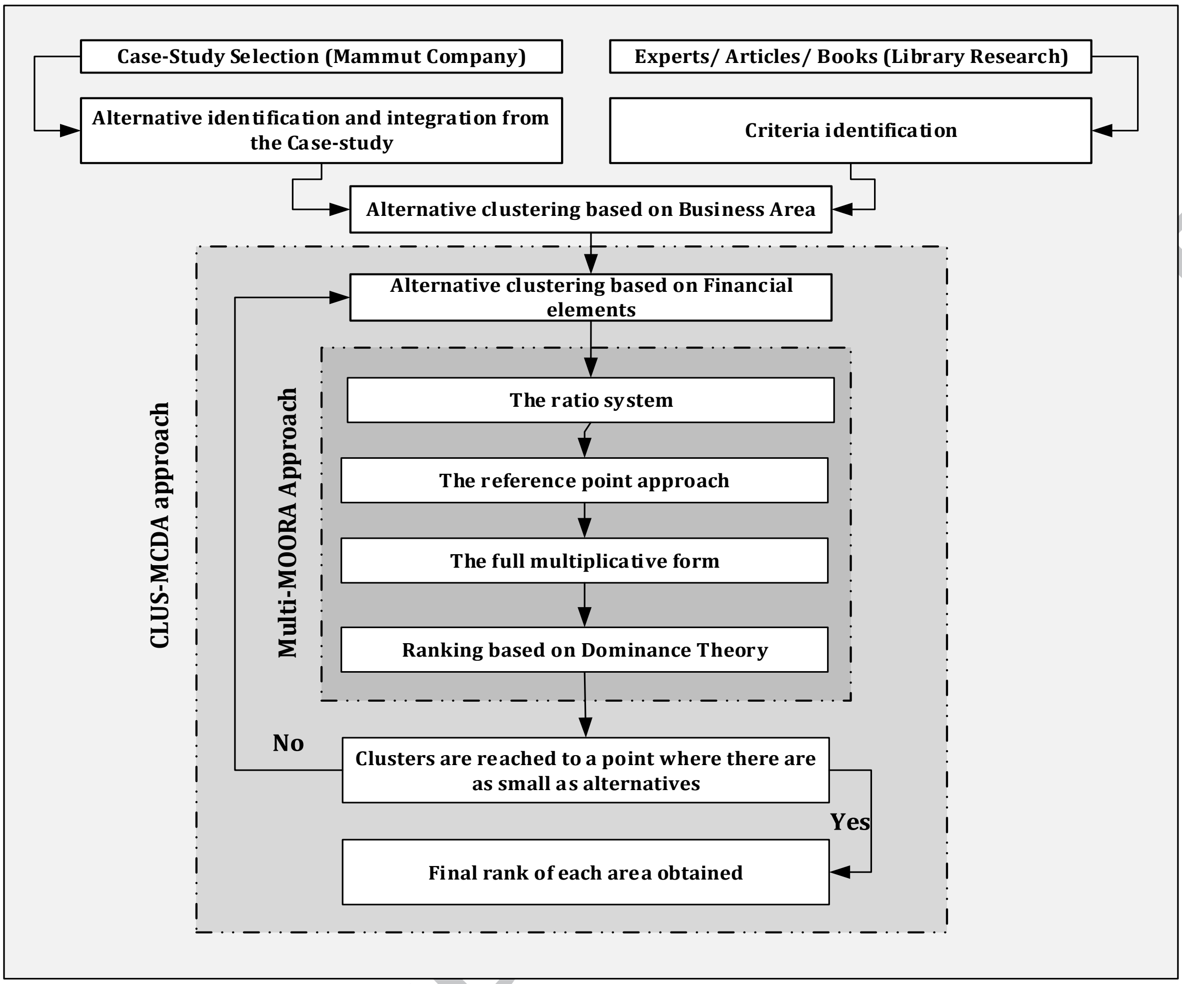


Figure (1): Flow diagram of CLUS-MCDA algorithm which implied in the case-study.

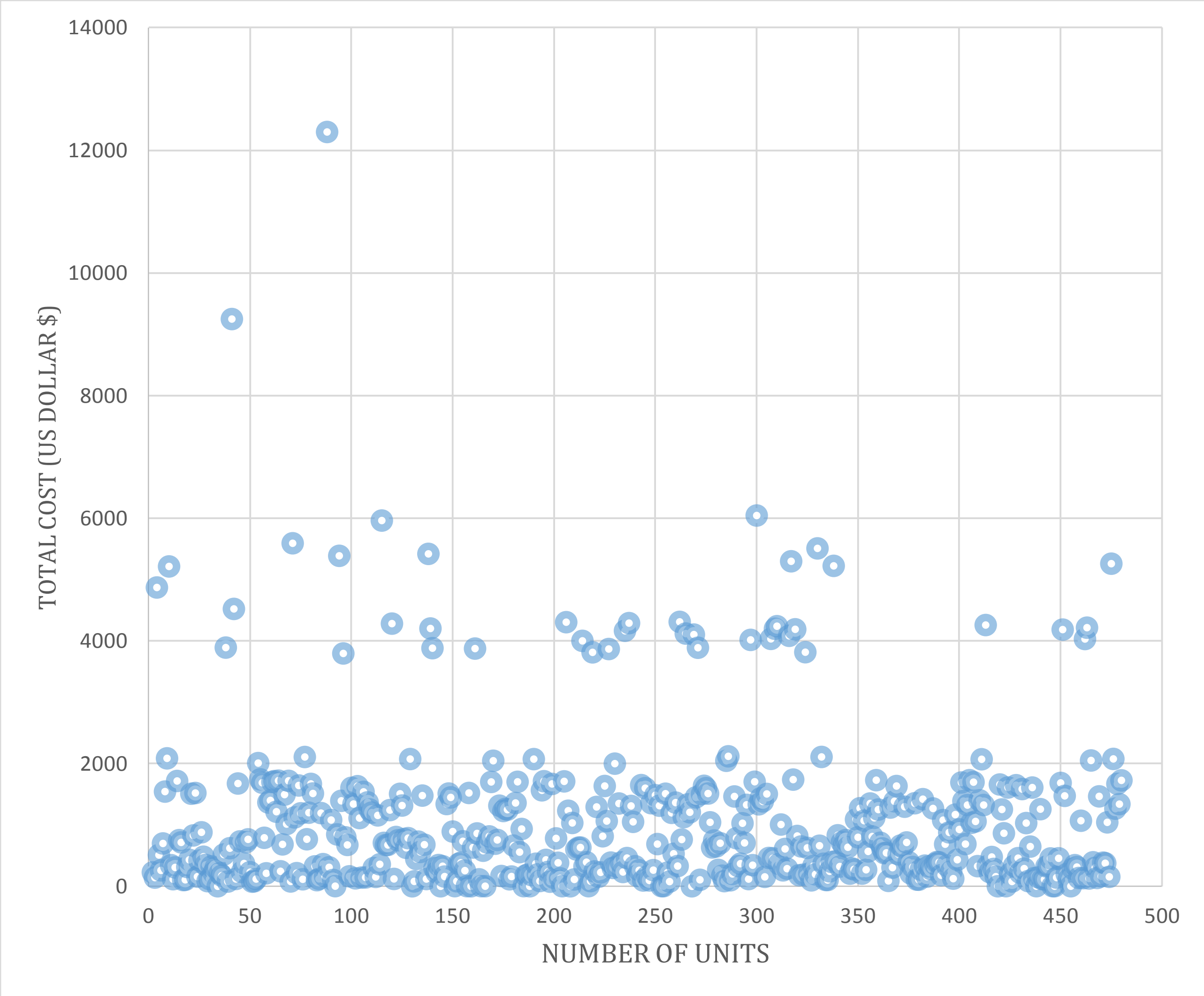


Figure (2): Scatter Graph of the big structured input data based on supplier information.

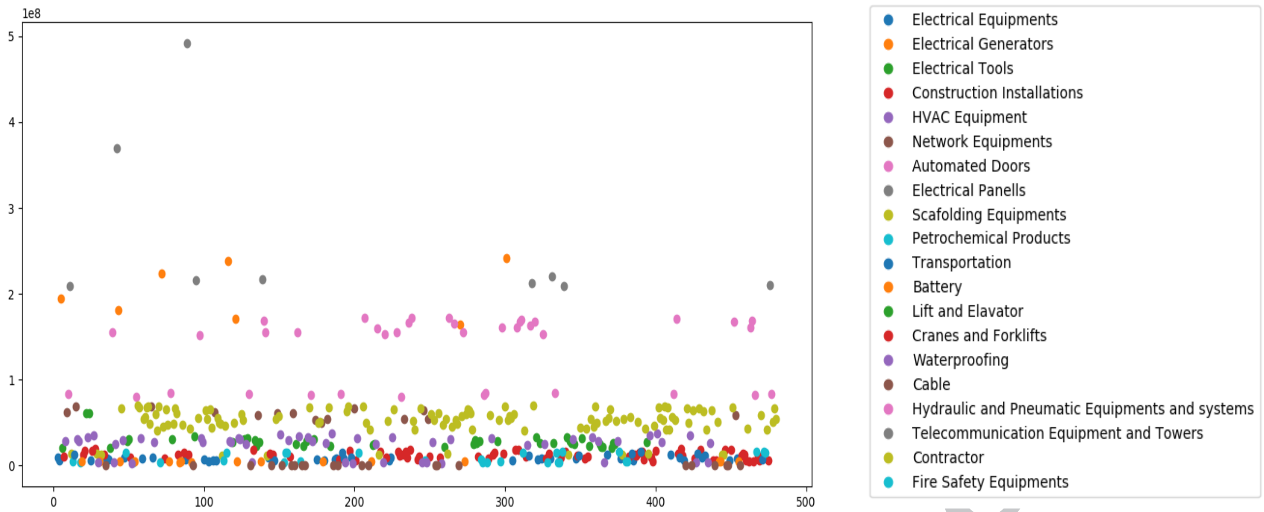


Figure (3): Scatter diagram of the input data based on business area clusters.

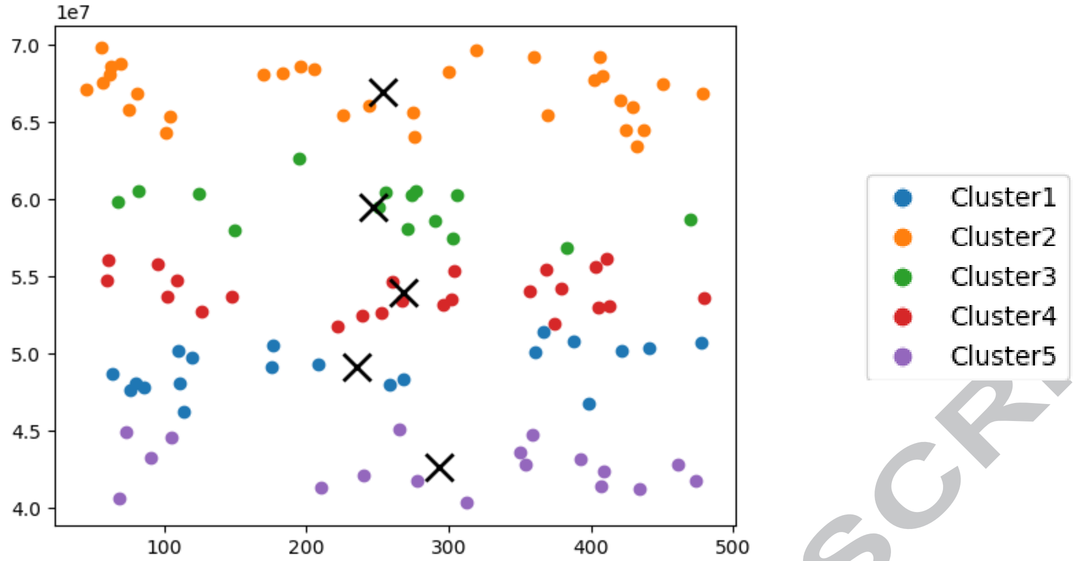


Figure (4): k-means clustering concerning $k = 5$ in the first iteration for Contractors as an example.

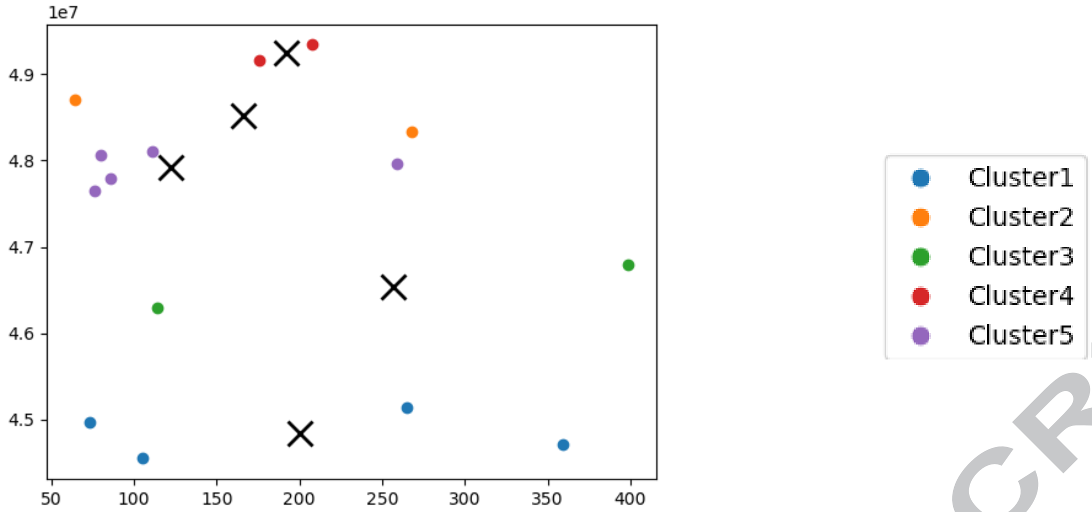


Figure (5): k-means clustering concerning $k = 5$ in the fourth iteration for Contractors as an example.

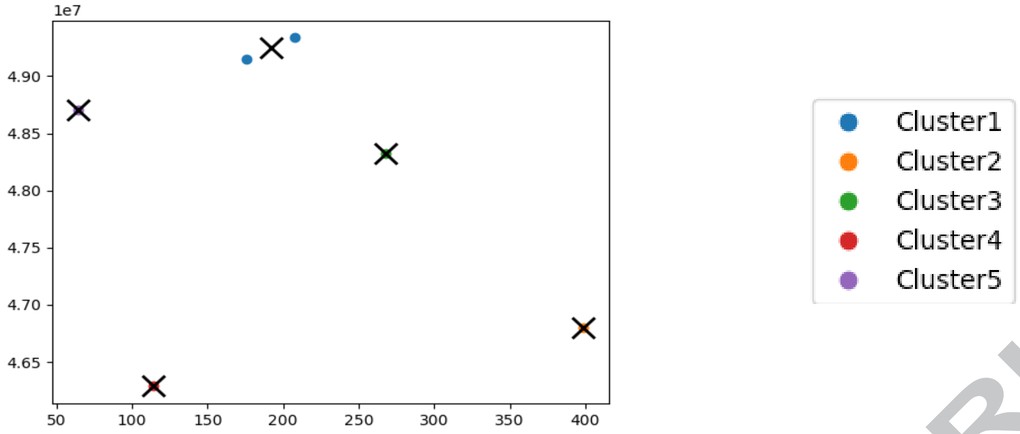


Figure (6): k-means clustering concerning $k = 5$ in the iteration X for Contractors as an example.

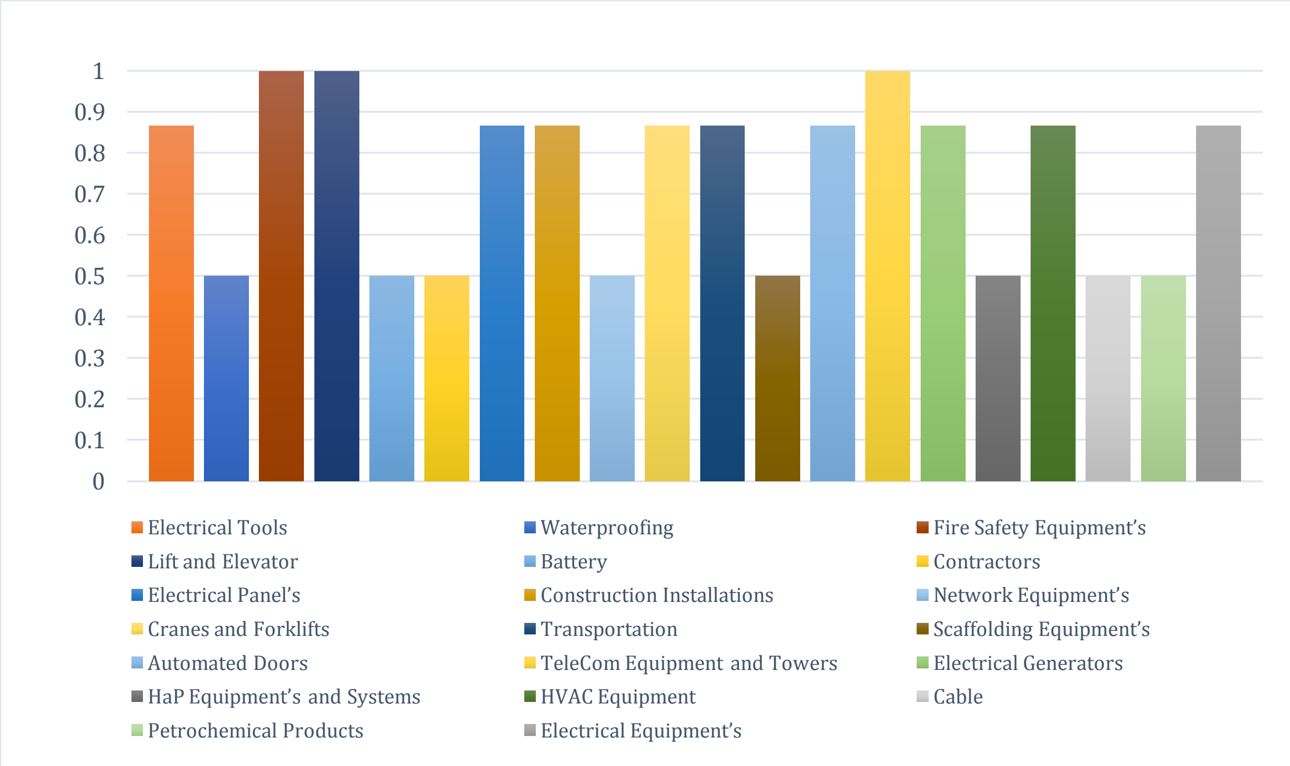


Figure (7): Correlation between the rankings of business areas based on Spearman coefficient.

Table (1): Criteria definition for selection of the optimal supplier.

ID	Criteria	Functional Requirement	Description
C1	Financial Elements (Price/Cost)	Minimum	One of the most important factors for selecting the optimal supplier is concerns on financial elements for purchasing the product which suppliers present such as services or goods. In customers' perspective, financial elements such as the price of the product, the cost of the maintenance, transportation costs, etc. are one of the discriminant factors for selecting the supplier.
C2	Service cooperation	Maximum	Cooperating with the terms and conditions of the customers based on the presented products of vendors (i.e. services or goods) results in more satisfying environments.
C3	Conforming service	Maximum	In customer's perspective achieving quality perceptions of the presented products in the form of service or goods concerns on multiple matters (Mauri et al., 2013; Yu, 2005). Therefore, increase in conformity of the products based on the customers' expectations results in higher satisfaction.
C4	Flexibility	Maximum	Supplier's flexibility concerning multiple elements such as costs, time, etc. is an important criterion to contract long-time partnerships with customers.
C5	After sale services	Maximum	One of the crucial elements for selecting the desired supplier is the after sale services. To maintain the high quality of the purchased service or products, it is important for customers to have the assurance of receiving the guaranty/warranty services in the future to maintain the optimal quality of the products (services/goods).
C6	Compliant management	Minimum	Considering the complaints of the customers and handling the specified problems based on customer feedbacks increases the satisfaction of the clients and users of specified service or products.
C7	Waiting Time	Minimum	Since there is a specific time to present a decent service or product by suppliers, the waiting time and the waiting period for offering the product (service/goods) matters. Furthermore, one of the important criteria to select a supplier is waiting period and existence of such issue.

Table (2): candidate alternatives as groups i.e. business areas.

ID	Business Area/ Activity List	Quantity of suppliers
BA1	Electrical Tools	41
BA2	Waterproofing	13
BA3	Fire Safety Equipment	12
BA4	Lift and Elevator	2
BA5	Battery	16
BA6	Contractors	113
BA7	Electrical Panel	7
BA8	Construction Installations	64
BA9	Network Equipment	15
BA10	Cranes and Forklifts	8
BA11	Transportation	17
BA12	Scaffolding Equipment	13
BA13	Automated Doors	13
BA14	Telecommunication (TeleCom) Equipment and Towers	2
BA15	Electrical Generators	7
BA16	Hydraulic and Pneumatic (HaP) Equipment and systems	25
BA17	Heating, Ventilation, and Air-Conditioning (HVAC) Equipment	40
BA18	Cable	23
BA19	Petrochemical Products	17
BA20	Electrical Equipment	31
	Total	**479**

Table (3): Linguistic terms and the corresponding numbers.

Linguistic term	Alphabetical Value of Verbal Comments	Numerical Value of Verbal Comments
Very Poor	A	0
Poor	B	40
Moderate	C	60
Good	D	80
Very Good	E	100

Table (4): Rankings of the first iteration clusters based on MULTIMOORA approach concerning Contractors.

Clusters (Contractors)	Assessment Values			Rankings			Final Rank
	y_i^*	z_i^*	U_i^*	y_i^*	z_i^*	U_i^*	
Cluster 1	0.0026	0.1767	0.7896	5	1	5	5
Cluster 2	0.0037	0.2355	0.8202	2	4	2	2
Cluster 3	0.0034	0.2040	0.8006	3	2	4	3
Cluster 4	0.0041	0.2235	0.8157	1	3	3	1
Cluster 5	0.0029	0.2581	0.8330	4	5	1	4

Table (5): Rankings of the fourth iteration clusters based on MULTIMOORA approach concerning Contractors.

Clusters (Contractors)	Assessment Values			Rankings			Final Rank
	y_i^*	z_i^*	U_i^*	y_i^*	z_i^*	U_i^*	
Cluster 1	0.0111	0.5773	0.9276	3	3	2	2
Cluster 2	0.0172	0.7070	0.9545	1	5	1	1
Cluster 3	0.0080	0.3779	0.8776	5	1	5	5
Cluster 4	0.0111	0.4999	0.9100	4	2	4	4
Cluster 5	0.0141	0.5773	0.9148	2	4	3	3

Table (6): Rankings of the final iteration clusters based on MULTIMOORA approach concerning Contractors.

Clusters (Contractors)	Assessment Values			Rankings			Final Rank
	y_i^*	z_i^*	U_i^*	y_i^*	z_i^*	U_i^*	
Cluster 1	0.0141	0.5773	0.9148	4	1	5	4
Cluster 2	0.0243	1.0000	1.0000	1	3	1	1
Cluster 3	0.0119	0.7071	0.9545	5	2	4	5
Cluster 4	0.0243	1.0000	1.0000	1	3	1	2
Cluster 5	0.0243	1.0000	1.0000	1	3	1	3

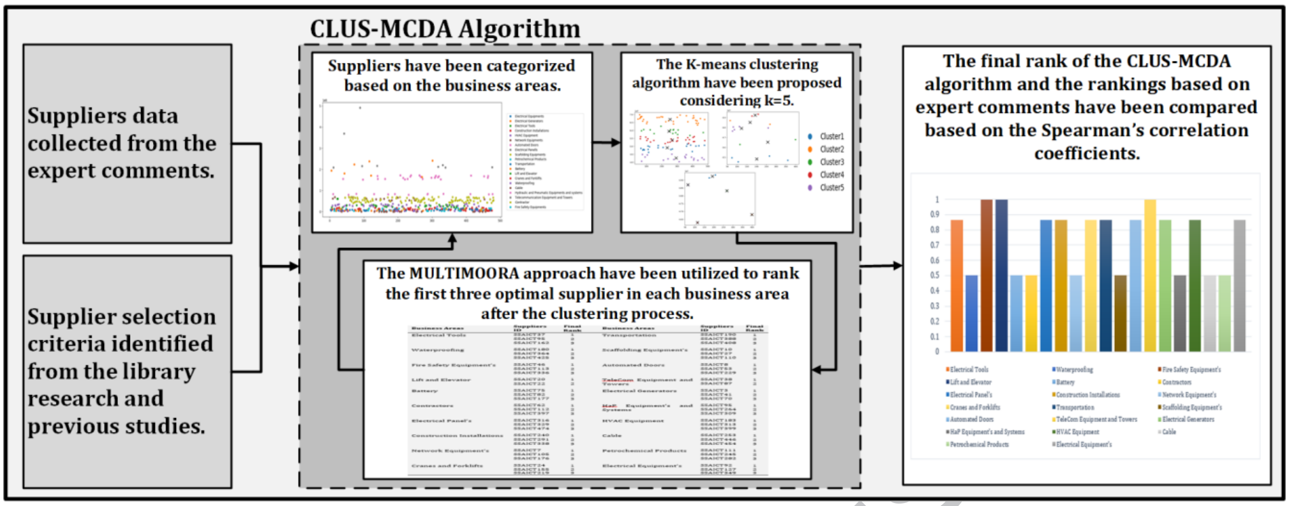
Table (7): Final ranking for the example suppliers i.e. Contractors with the CLUS-MCDA algorithm.

Supplier's Business Area	Supplier Code	Final Rank
Contractor	SSAICT112	1
	SSAICT397	2
	SSAICT62	3

Table (8): Final rankings of complete input data based on CLUS-MCDA algorithm.

Business Areas	Suppliers ID	Final Rank	Business Areas	Suppliers ID	Final Rank
Electrical Tools	SSAICT37	1	Transportation	SSAICT190	1
	SSAICT95	2		SSAICT388	2
	SSAICT162	3		SSAICT408	3
Waterproofing	SSAICT180	1	Scaffolding Equipment	SSAICT10	1
	SSAICT364	2		SSAICT27	2
	SSAICT425	3		SSAICT110	3
Fire Safety Equipment	SSAICT46	1	Automated Doors	SSAICT8	1
	SSAICT113	2		SSAICT53	2
	SSAICT336	3		SSAICT229	3
Lift and Elevator	SSAICT20	1	TeleCom Equipment and Towers	SSAICT38	1
	SSAICT22	2		SSAICT87	2
Battery	SSAICT75	1	Electrical Generators	SSAICT3	1
	SSAICT82	2		SSAICT41	2
	SSAICT177	3		SSAICT70	3
Contractors	SSAICT62	1	HaP Equipment and Systems	SSAICT95	1
	SSAICT112	2		SSAICT264	2
	SSAICT397	3		SSAICT309	3
Electrical Panel	SSAICT316	1	HVAC Equipment	SSAICT183	1
	SSAICT329	2		SSAICT313	2
	SSAICT474	3		SSAICT399	3
Construction Installations	SSAICT240	1	Cable	SSAICT253	1
	SSAICT291	2		SSAICT446	2
	SSAICT338	3		SSAICT454	3
Network Equipment	SSAICT7	1	Petrochemical Products	SSAICT111	1
	SSAICT105	2		SSAICT245	2
	SSAICT176	3		SSAICT282	3
Cranes and Forklifts	SSAICT24	1	Electrical Equipment	SSAICT92	1
	SSAICT155	2		SSAICT127	2
	SSAICT219	3		SSAICT349	3

Graphical abstract



Highlights

- We suggest a hybrid MCDM approach considering big data structure.
- CLUS-MCDA: Cluster analysis for improving Multiple Criteria Decision Analysis.
- CLUS-MCDA method is combination of k-means technique and MULTIMOORA method.
- We present an example concerning the supplier selection problem.
- The input data of the case-study is big data structured.