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A New Application of Coordination Contracts for Supplier Selection in a Cloud Environment

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Abstract. Cloud manufacturing (CMfg) is considered to be a facilitator for mass manufacturing resources. It is a paradigm of intelligent systems, which makes the manufacturing procedures easier. In this regard, the most important issues of the manufacturing environment are discussed in the literature. Supplier selection and order allocation have been great concerns for researchers in all manufacturing systems, even in a cyber-physical environment allocating orders to the best supplier is of great importance. Hence, this research highlights one of the most challenging issues in a cloud environment which is related to supplier selection in CMfg. A hybrid multi-criteria decision-making framework (i.e., fuzzy DEMATEL-VIKOR) considering sustainable criteria is proposed to help the decision-makers for better dealing with supplier selection in a cloud environment. Selecting the best supplier is not the only issue discussed in this paper. Coordinating the suppliers is also taken into account because a better partnership supplier and the client need to work in a coordinated structure. In the second stage of this paper, the best coordination contract is proposed based on the client's given score on some predetermined criteria. The results indicate that a revenue-sharing contract is an ideal coordination framework, which will satisfy the client and supplier and help them to work in a coordinated environment.

Keywords: Cloud manufacturing, Coordination contract, Supplier and contract selection, Multi-criteria decision-making, Uncertainty.

1 Introduction and literature review

With the existing change in a manufacturing system toward intelligent manufacturing technologies, new manufacturing modes have been presented; global manufacturing, manufacturing grid, cloud manufacturing (CMfg) are great examples in this regard. It is worthy to note that the complexity of manufacturing systems and the importance of resource sharing highlight the importance of distributed intelligent manufacturing. CMfg is a service-oriented manufacturing system that can be considered a distributed intelligent manufacturing system, which seeks to transform today's manufacturing industry toward the collaborative and innovative manufacturing system [1]. In a CMfg environment, manufacturing resources support costumers in a form of service. A ser-

vice platform is used as a determiner in a CMfg system. A cloud manufacturing platform can provide manufacturing services by manufacturing resource access from different suppliers. A service-oriented architecture is of high prominence in the scope of developed technologies in the integration of distributed systems and software [2].

Centralized and decentralized operating modes are two main methods in a cloud environment, in which CMfg can be operated. To the best of our knowledge, in a centralized operating mode, the platform investigates the services to fulfill the clients' requirements. In this case, clients do not choose their providers (suppliers) by themselves. In general, centralized networking has had problems regarding flexibility, efficiency, availability, and security [3]. On the other hand, decentralized operating mode gives the clients the volition to make decisions regarding service and provider selection. Each client can choose the desired services based on his requirements. But, there is a point that can't be neglected in this scope, owing to the selfish behavior of clients the overall productivity of the system can be decreased [4]. A CMfg system is a new manufacturing system that emerged based on Industry 4.0 guidelines. Also, the critical role of contracts for supply chain coordination is not covered for anyone.

Wang et al. [5] asserted as logistics-based industries and information technology developed manufacturing models to get more innovative. Thus, manufacturing enterprises became eager to outsourcing different parts of their manufacturing process to contractors, who were more proficient so the enterprises could reach their goals for their main occupation core. They presented a manufacturing resource selection strategy based on a distributed genetic algorithm (DGA) to optimize the combination of manufacturing resources in CMfg. Raj et al. [6] studied coordination issues of a supply chain that formed due to concurrent consideration of green supply chain (GSC) and corporate responsibility on social issues that are done by supply chain agents. They considered the situation that responsibility of greening is on suppliers or supply agents and so on, in which the vendee is responsible for social responsibility. With this regard, Lu et al. [7] proposed some beneficial approaches to make improvements in this field and proposed a cloud model for optimal green supplier selection considering the fuzziness of evaluation information. In their research, a fuzzy analytic hierarchy process (AHP) was applied to determine the index weight. In the case of CMfg and supplier selection, an online evaluation of the supplier's service capability was proposed by Jain et al. [8].

To the best of our knowledge, online evaluation of the supplier's service capability is the key to efficient service matching. It is worthy to note that we gather the related data for the performance test of the supplier's machine tools, which are taken from the cloud platform [8]. In the second stage, supplier's machine tools are evaluated and then their processing stability is evaluated. Simeone et al. [9] presented a framework, in which CMfg enables the resource sharing. To increase the resource efficiency in a manufacturing network, an intelligent CMfg platform is proposed through dynamic sharing of manufacturing services that can be offered on demands according to a service-oriented paradigm. In the scope of supplier selection, on the other hand, Luthra et al. [10] proposed a framework for evaluating sustainable supplier selection by using AHP and VIKOR methods. They considered three criteria (i.e., economic, environmental, and social). In the scope of coordination contract selection, Zhou et al. [11] investigated

three contracts for a monopoly firm, which acts as a transaction platform between clients and providers. The mentioned platform can charge different rates of commissions and select the optimal contract. Zhen et al. [12] developed a model, in which a retailer sells products through offline, online, and third party platform channels, and then the best contract is considered in the proposed platform. Su et al. [13] proposed a framework for Cloud Service Selection in which they applied a fuzzy measure to measure and aggregate non-linear relations between criteria. They introduced a non-linear constraint optimization model to determine criteria interaction indices.

As investigated in the reviewed articles, researchers in recent years have paid much attention to CMfg systems. This issue has been welcomed by researchers in particular with the advent of the 4th Industrial Revolution (i.e., Industry 4.0). According to the reviewed articles, the following research gaps are identified by:

We found no article in the CMfg field examined the importance of contract selection. However, there are a few articles used a multi-criteria decision-making (MCDM) method in the process of contract selection [14, 15]. Supplier selection is neglected in the research agenda in cyber-physical systems, such as a CMfg system. There are a few real-life cases used CMfg principles, especially in Iran.

In this paper, we propose a new methodology for CMfg systems that considers a variety of coordination contracts from different providers. Then, based on client criteria, it chooses the best provider and after that, the best coordination contract is chosen.

MCDM techniques are applied based on the expert's opinion and the reviewed articles in the proposed framework (as it has been reviewed through articles by [16, 17]). We apply from a fuzzy DEMATEL method to allocate weights to criteria and the VIKOR method for ranking the alternatives. At the end of this stage, the best provider is chosen. Like Stage I, in Stage II, client criteria are defined based on the expert's opinion and the literature review of this field. The first step after the identification of criteria is to determine the proper weight of each coordination contract, so we use the best-worst method (BWM). A TOPSIS method is applied for ranking the options in the second step. For illuminating this concept, it is worth to say that the options are the different coordination contracts of different providers.

The objective of this paper is to help the managers in CMfg systems to choose the best providers and select the best coordination contracts.

2 Problem Description and Methodology

This paper examines the application of the supply chain coordination contract advanced by Industry 4.0 principles in the CMfg platform. The proposed methodology considers a data-based agent, whose duty in the proposed cyber-physical system (CPS) of CMfg is to connect the best provider to the client under the best coordination contract. These data-based agents are connected to a variety of different providers and clients, which are acting in the manufacturing of a specific product. When a client ordering on a system, he/she is asked about his/her criteria for selecting a supplier, in which the Likert's program for converting expressions into triangular fuzzy numbers is used. We develop a two-stage method, which in the first stage, the best supplier (i.e., provider) is selected

based on the clients' criteria and in the second stage, the selected supplier proposed its coordination contract and the client according to the criteria that identified based on reviewed articles and experts' opinion, select the optimal coordination contract.

Owing to the fact that selecting the best supplier for cloud manufacturing (CMfg) is momentous; by reviewing the articles in this case, the hybrid fuzzy DEMATEL-VIKOR method is found applicable. In the process of data gathering, some questionnaires have been filled with the help of experts, who utilize CMfg to help us identify the criteria that influence on the supplier selection procedure profoundly. These questionnaires have been filled using the 5-point Likert scale. By identifying the criteria and their weights with the help of the above-mentioned questionnaires and fuzzy-DEMATEL, it is worthy to find the best supplier based on the predetermined criteria. In this case, the VIKOR method is of great help, due to the fact that we need to apply a compromising method among MCDM methods. In this case, it is found the most applicable one.

By identifying the best supplier, selecting the coordination contract for suppliers is the next decision problem, in which managers face with. In this step, the best-worst method is applied to determine the criteria, which affect that contract selection. It is worthy to note that the best-worst method is a novel outstanding method introduced in 2015 with so many applications in various decision problems. As a compromising method needed to be implemented for best contract selection, the TOPSIS method is found exemplary. Fig. 1 shows the summary of this two-stage methodology.

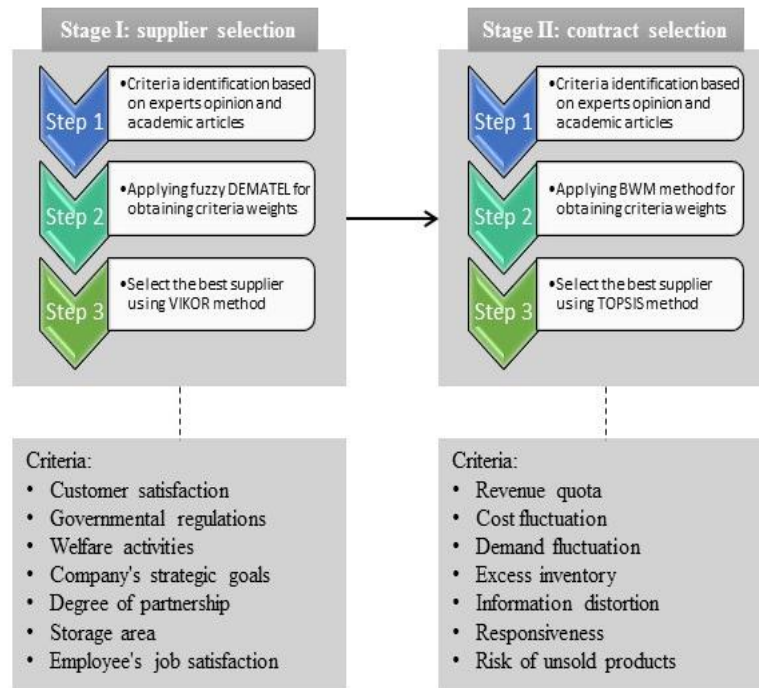


Fig. 1. A proposed two-stage methodology

3 Case Study and Results

To better understanding, the subject here is one of the projects that took place based on this articles' method in Iran. An "Indamin Saipa" company located in Iran is one of the "Saipa Group" companies that is responsible for manufacturing the shock absorbers for Saipa cars. One of the components designed for shock absorbers production is cylinders' tubes that are made in such a way that there is no seam or in other words, they have to be en bloc. Since these monolith cylinders' tubes had a 3-micrometers surface smoothness in the design process and no machinery is available to produce such a product in Iran, we should replace the product and produce the alternative product with innovative processes (the alternate production) method is out of this paper scope so no further explanation is proposed. Due to internal policies and existing conditions, senior management decided to use CMfg techniques for alternative manufacturing steps. For each step, numbers of providers, candidate, and each of them proposed a variety of coordination contracts.

Stage I:

In this section, the information of the providers and the reports of this paper's method for supplier selection and contract selection is provided. In the first step, the criteria for the first stage of supplier selection based on a sustainable triple bottom line are identified. The predetermined criteria in this part and their discription are shown in Table 1.

In this stage, the obtained weights of each criterion are obtained by using the fuzzy DEMATEL technique. This technique will not provide us with the weights; however, the weights of criteria are found by using this technique. Table 2 shows the obtained weights using the fuzzy DEMATEL technique.

Table 1. First stage criteria for supplier selection

Notation	Criteria	Description
C1	Customer satisfaction	In every organization and company, customers play a decisive role
C2	Governmental regulations	Government as another stakeholder in a project supply chain is a key element
C3	Welfare activities	Company must consider its visions to assign expenses to the activities
C4	Company's strategic goals	Branding and the company's competitive advantage
C5	Degree of partnership impact on objectives fulfillment	Supply chain partnership is also an important factor that can enhance the satisfaction of final customers
C6	Storage area	Storage area is the other criterion considered to be a constraint for suppliers
C7	Employee's job satisfaction	Employee's satisfaction is the final criterion, which influences the process of decision making.

Table 2. Obtained weights of each criteria using the fuzzy DEMATEL technique

Criteria	C1	C2	C3	C4	C5	C6	C7
Weights	0.1470	0.1522	0.0863	0.1653	0.1474	0.1481	0.1532

In the following procedure of supplier selection in a CMfg environment, the VIKOR method is applied to help the client choose the ideal supplier. The obtained results of the VIKOR method indicates that among 5 suppliers, which are compared, supplier 2 is superior to suppliers 4 and 5. And supplier 3 has shown a better performance based on the mentioned criteria; however, the superiority of suppliers 2 and 3 over each other is not identified as they have the same performance in most of the criteria.

Stage II:

In the second stage by identifying the best supplier with the help of the fuzzy DEMATEL-VIKOR method, the best contract is chosen by using the BWM-TOPSIS method. In the following paragraph, the criteria used for the process of the cloud supplier selection based on coordination contracts are identified. Table 3 asserts the criteria of the contract selection in this methodology.

Table 3. Second stage criteria for contract selection

Notation	Criteria	Description
A1	Revenue quota	As supply chains are becoming more global worldwide, in the competitive market of which depends heavily on the application of internet and smart manufacturing, the global supply chains investigate to find the best suppliers based on the gained revenues of their partnership.
A2	Cost fluctuation	Because we are living in the world, in which the uncertainty and cost inflation are an undetached part of it, and considering cost fluctuations is momentous.
A3	Demand fluctuation	Uncertainty in demand and demand fluctuations is influencing the process of selecting the most appropriate contract.
A4	Excess inventory	Suppliers need to vigilant regarding the inventory that they hold, because the excess inventory can impose costs to the suppliers
A5	Information distortion	information distortion is a great concern in the process of exchanging the information.
A6	Responsiveness	Responsiveness of the service provider and the predetermined lead time of each supplier must be taken in to account as a factor for contract selection.
A7	Risk of unsold products	The last factor, which influences the contract selection, is the risk of unsold inventory because unsold inventory needs to be brought back or to be sold to the client.

By considering the above-mentioned factors and by using the experts' ideas, we find that the revenue quota (A1) is the most important criterion, besides, the information exchange is the worst one. By using the best-worst method (BWM), the weights are obtained as shown in Table 4.

Criterion 1 as the most important one has a higher weight. In Table 5, the ranking of criteria is obtained by using the TOPSIS method, in which the BWM weights are taken into account as inputs for the TOPSIS method.

Table 4. Obtained weights for each criterion

Criteria	A1	A2	A3	A4	A5	A6	A7
Weights	0.379	0.166	0.100	0.125	0.032	0.125	0.079

Table 5. Ranking of criterion

Revenue sharing	0.701	Option contract	0.336
Buyback	0.256	Quality flexibility	0.372

The results of the supplier selection procedure show the significant role of the company's strategic goals in decision making. In this process, the welfare activities are considered a factor because the client cares about the supportive role of his supplier in nonprofit organizations. Governmental rules and regulations and the hindrance that the government causes for the supplier during the production is taken into account for a supplier selection process. Among the mentioned factors for the first stage, the obtained results indicate that the employee's job satisfaction is in the second rank for the decision-maker (i.e., client). In the second stage, the desired contract is selected based on the determined criteria. The obtained results indicate the fact that the revenue sharing contract is the most applicable one. This is mostly because of the importance of the first criterion (i.e., revenue quota). In the other mentioned contracts (e.g., buyback, option contract, and quantity flexibility), the excess inventory and unsold products play a decisive role. In the quantity flexibility contract, the fluctuation in demand is the pivotal factor for the selection procedure of the contract. Since the experts' interviews do not show the superiority of demand fluctuation over gained revenue the quantity flexibility contract is in the last rank.

4 Conclusions

This paper proposed a framework for cloud manufacturing (CMfg) supplier selection, in which the last step was the determination of the best contract for the selected supplier. The proposed framework consisted of two stages. In the first stage, the best supplier was identified by using the fuzzy DEMATEL-VIKOR method. The predetermined criteria in this step were based on experts' interviews. In the second stage, as the beginning of the partnership period, the coordination contracts were the alternatives. The best coordination contract was presented by using the BWM-TOPSIS method. By using the BWM method, the criteria's weights were determined and the TOPSIS method helped the decision-makers to rank the contracts. To the best of our knowledge, this study was the first research, which was conducted in the field of supplier selection in CMfg by using MCDM methods. Furthermore, the application of contract selection improved the partnership, which was the main objective in SCM.

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