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A service decomposition and definition model in cloud manufacturing systems using game theory focusing on cost accounting perspectives

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Abstract

Cloud manufacturing is a new paradigm which has been under study since 2010 and a vast body of research has been conducted on this topic. Among them, service composition problems are of utmost importance. However, most studies only focused on private clouds meaning the objective function is defined for just one component of the supply chain. This paper attempts to consider service composition problem by using the concept of game theory in cloud manufacturing which is the main contribution. This issue is investigated by introducing a bi-level mathematical model with emphasizing on the realization of public clouds, in which the preferences of all stakeholders in the cloud manufacturing system have been taken into consideration. Concretely, the first level is defined based on manufacturer company's perspective while the second level is a game designed to obtain a feasible solution by making trade-offs among costs and revenues of service providers. Manufacturer tends to optimize the quality of service metrics by producing a package of operations inside the company's environment or assigning a combination of service providers with considering clustering. Results show the model will be able to enable the trade-off mechanism among the compositions of all stakeholders' preferences in cloud manufacturing system with focusing on cost accounting.

Keywords: Cloud manufacturing, service decomposition, game theory, public manufacturing cloud

1-Introduction

Cloud manufacturing is a new manufacturing paradigm which is a combination of new technologies such as Internet of Things, cloud computing, semantic web services, virtualization technologies. It is also developed from advanced manufacturing models such as computer integrated manufacturing, agile manufacturing, network manufacturing, virtual manufacturing, lean manufacturing and manufacturing grid, share resources and capabilities as a service (Stachtiari et al, 2012), (Aghamohammadzadeh and Valilai, 2020) and (Assari et al, 2018).

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The first attempt to explain and describe the concept of cloud manufacturing was made by Li *et al.* (2010). Cloud manufacturing is a new platform which shifts from the product-oriented approach to the service-oriented approach, covering the whole life cycle of a product. In comparison with cloud computing, cloud manufacturing expands the philosophy of "everything as a service" based on new concepts of "resources as a service" and "manufacturing capabilities as a service" (Delaram and Valilai , 2018), (Houshmand and Valilai , 2013), (Valilai and Houshmand , 2013) and (Valizadeh et al., 2019).

Concepts and architecture of cloud manufacturing (Martin et al., 2004), (Oh et al., 2008), (Li et al., 2017), (Rao et al., 2006), (Delaram and Valilai, 2017), (Delaram and Valilai, 2018a) and (Delaram, and Valilai, 2018b), business models (Gutierrez-Garcia and Sim, 2013), (Singh et al., 2017) and (Liu et al., 2013), service composition and optimal selection, service discovery and matching (Tao et al., 2013), (Xiang et al., 2014) and (Chen et al., 2016), and service scheduling (Zheng et al.,2016), (Liu et al., 2017), (Osborne , 2004) and (Myerson , 2013), are among the subjects extensively studied in the field of cloud manufacturing.

Service composition is among the most challenging topics in cloud manufacturing. This paper attempts to consider the service composition problem by using the concept of game theory in cloud manufacturing. This issue is investigated by introducing a bi-level mathematical model with emphasizing on the realization of public clouds, in which the preferences of all stakeholders in the cloud manufacturing system have been taken into consideration. Concretely, the first level is defined based on manufacturer company's perspective while the second level is a game designed to obtain a feasible solution by making trade-offs among costs and revenues of service providers. Manufacturer tends to optimize the quality of service metrics by producing a package of operations inside the company's environment or assigning a combination of service providers with considering clustering. Since there is no article which investigates service composition with considering game theory in the literature reviews, the literature of service composition and game theory in cloud manufacturing are reviewed separately.

1-1-Service composition in cloud manufacturing

The aim of cloud manufacturing is sharing resources and distributed companies' capabilities across the world and creates collaboration among them, and the optimal selection and composition services are implemented to meet the requirements and needs of users. On the cloud manufacturing platform, a single service is not usually capable to fulfil a user's order, so it is necessary to combine different services to complete the customer's order in a collaborative manner. To achieve this goal, a set of activities including service decomposition, service discovery, service matching, and service combination and optimal selection are done respectively.

Studies in the field of service compositions have mostly focused on service composition structure, service composition validation, and service composition methods. The latter can be summarized into the following 5 categories:

1- Service composition based on platforms and languages including:
    - Workflow based service composition (Stachtiari et al., 2012)
    - XML-based service composition (e.g. BPEL4WS) (Li et al., 2010)
    - Ontology-based service composition (e.g. OWL-S) (Martin et al., 2004)

2- Artificial intelligence-based service composition (Oh et al., 2008)

3- Graph-based and network-based service composition (Delaram and Valilai, 2018) and (Houshmand and Valilai, 2013)

4- Agent-based service composition (Gutierrez-Garcia and Sim, 2013) and (Singh et al., 2017)

5- Quality of service (QoS)-service composition (Delaram and Valilai, 2018), (Houshmand and Valilai, 2013), (Valilai and Houshmand, 2013) and (Valizadeh, et al., 2019)

Most of the researchers have been emphasized on service composition problem based on QoS in cloud manufacturing platform for instance: Liu et al. (2013) proposed a new pattern for service composition and optimization named Multi-Composition Every Task (MCET). This pattern combines services that are not properly composed, in a way that ensures the realization of service composition requirements (success rate) and service quality. Local, global, and hybrid approaches are usually used in multitask-oriented services composition and optimization (MTO-SCO), the second one was used in their study. For this purpose, several compositions for each task, formulas, and external aggregation patterns were proposed for the problem modelling, which describe structural modes in the aggregation of multitasking composite services. MTO-SCO is carried out in two stages; first, each MFMT divides into several subtasks and then eligible services in accordance with applicable requirements for each subtask are searched for to be transferred to the candidate's pool. The MCET model permits the formation of groups from composite services for the implementation of each MFTM. Tao et al. (2013) developed a new intelligent algorithm titled full connection-based parallel adaptive chaos optimization with reflex migration (FC-PACO-RM). This algorithm deals with the composition of rotatory selection and adaptive chaos optimization with the dynamics of chaotic sequences. The aim is the reduction of service composition time. The criteria used in this study to evaluate service quality in the service composition problem included time, cost, energy, reliability, trust, and function similarity. The fitting value obtained for FC-PACO-RM in their study was higher than that of the genetic algorithm, chaos genetic algorithm, and chaos optimization. The innovative point in their work was the use of connection and migration in order to raise efficiency in solving the service composition problem. Considering the two-objective function of service quality and energy consumption, Xiang et al. (2014) formulated the problem of optimal selection and service composition. They solved the problem by combining the group leader algorithm with the Pareto algorithm. They used time, cost, and reliability as the criteria for evaluating service quality. They also employed the structure of the sequential service composition. Chen et al. (2016) modelled the service composition problem in order to provide users with multiple and alternative choices when there is no appropriate service composition. They modelled the problem through the Multi-objective function independent of service quality optimization and service quality risk. They also employed variables such as response time (runtime + delay time), cost, reliability, and availability to optimize service quality performance. In addition, the problem was solved using the efficient ε-dominance multi-objective evolutionary algorithm. Zheng et al. (2016) modelled the problem of fuzzy service quality measurement and best service selection by considering the design preferences. They proposed an approach to the selection of integrated resource services in order to help the users to achieve an optimal service. They employed the particle swarm optimization algorithm to solve the problem and a simple additive weighting approach to decide on the service quality problem. Liu et al. (2017) proposed an approach to multiple compositions of cloud manufacturing services based on dynamism. To effectively solve the problem and prevent too many constraints on the process of service composition in this problem, the modified constraints hierarchy approach for service composition was used. The problem was solved using the culture genetic max-min ant system (CGMMS) and then the results were compared with the ant colony algorithm and the max-min ant system. The comparison indicated that the CGMMS provided a higher search power and faster convergence.

1-2-Game theory in cloud manufacturing

Game theory is a mathematical-economic discipline analysing certain conditions in which multiple independent agents make decisions and try to maximize their returns (Osborne, 2004). Social psychology has offered many theories surrounding collective decision-making and cooperation, all of which help develop effective business models. There are two theories of social psychology for the future cloud manufacturing environments: game theory and equity theory. Game theory discusses how logical players make decisions in mutual roles. It can be either non-cooperative, where players are able to work together but they are not limited to official contracts, or cooperative, in which official contracts are employed. Game theory identifies incentives in cooperative environments and promotes teamwork to help create specific environments (Myerson, 2013).

The behaviours of entities have significant effects on the development of cloud manufacturing. Therefore, Chen et al. (2014) employed game theory to analyse the interactions of cloud manufacturing participants, i.e. users, application providers (APs), and physical resource providers (PRPs). In their study, they analysed the interaction between users and APs in line with the pricing policy of APs. Then the fairness or unfairness of the cloud environment and the effects of innovation were dealt with to continue analysing the relationship between APs and PRPs. Su et al. (2015)

proposed a non-cooperative game to solve the problem of manufacturing resources allocation without considering the demand priority in cloud manufacturing. In their game, the interests of demanders and service providers are taken into account. In this article a multi-objective optimization problem was turned into a non-cooperative game. The objective function of this problem was regarded as the quality of service. In another study, Wang and Peng (2016) analysed the problem of cloud manufacturing market evolution based on game theory and the Nash equilibrium. They discussed the Nash equilibrium in static and dynamic games. It is expected that the cloud manufacturing market evolution should experience three major stages of development: emergence, growth, and maturity. In this paper, the classic economy models were employed to analyse the behaviour of every cloud manufacturing player in each stage. Song (2016) proposed a two-level game model for cloud manufacturing to maximize the mutual profits of service providers. At the first level, the competition of service providers is analysed. In the game model, strategies are based on customer requirements in the long term. At the second level, the mutual effects of the game are considered. For this purpose, it is necessary to analyse the effects of service providers on each other. Then the decisions affected by the first level should be analysed. The important point is that players should participate in a manufacturing union to obtain more profit. Zhang et al. (2016) analysed a scheduling problem in a real-time cloud manufacturing space by employing the game theory tools. For this purpose, they used a non-cooperative N-player game with full information to make decisions and solve problems. Wang et al. (2018) analysed the cloud service rescheduling (CSRS) problem, regarded as a hybrid optimization problem with multiple participators. The CSRS problem differs from the traditional flow shop scheduling problems. Since it is difficult to coordinate the communications among service providers and develop an encouraging mechanism to motivate them to participate in the rescheduling process, they thought of a static non-cooperative game with full information, the rescheduling reward and scheme of each provider can be seen by others.

2-Methodology

2-1-Problem definition

The problem assumes a manufacturer company that aims to produce a product with specified operations and fulfil customer’s need. For this, there are different strategies.

In the first strategy, the company performs all operations in the company environment without assigning any of them to other physical service providers. In other strategies, the company should not perform any of the operations in company environment and must assign the complete operations to service providers. There are two possible approaches. In the first approach, the company can decompose each operation phase into first level service providers. In the second approach, each activity can be decomposed into second level service providers. First Level operations are performed by first level service providers while second level operations are performed by second level service providers. First level service providers are concentrated in a specific geographical location and possess high technical knowledge about the operations, on the other hand, second level service providers have less technical knowledge, are geographically distributed, and can collaborate via predefined protocols to complete the operations.

From the above, the company has to choose the optimal strategy in order to optimize Overall costs. The following are some of the important modelling assumptions:

- A specific product has limited operation phases and specified time period;
- First level service providers are concentrated in a single location while second level providers are distributed and form a geographic clusters according to the distance between close urban areas;
- The manufacturer company has a limited budget of money for perform operations or assigning the operations to first or second level service providers;
- Cloud manufacturing costs are broken down into the following:
    - Total costs of performing the operation package in the manufacturer company;
    - The cost of assigning each level of operation to service providers from various levels;
    - Transportation costs from the manufacturer company to geographic clusters.

- If multiple service providers are at the same geographic cluster, transportation costs will be shared among them;
- Each operation performed by first level service providers will be performed centralized (only at a single location) , however second level service providers can collaborate via predefined protocols to complete the operation;
- If the manufacturer company participates in the manufacturing process, it can only be as performing the total production process which leads to the final product, otherwise it has to assign all production phases to a combination of first or second level and service providers or only one of them;
- The (producing) manufacturer company has to transfer specific transport vehicles (trucks) to specified areas for collection parts of product and this assumed for first and second level service providers;
- From second level service providers at each geographic cluster, only one of them can act as the administrator;
- In the designed game between second level service provider, the administrator service provider in the cluster is remunerated for this responsibility as a revenue but in return must visits other cluster points and collect product parts, thus incurring collection expenses.

In this article, proposed model is a bi-level model in the form of leader-follower models. In the leader model, the purpose of the manufacturer company is to minimize overall costs and the company's approach to the production process is investigated thereafter and the final decision as to perform all operations in company environment or assigning them to a combination of first and second level service providers .The other output will be activation of geographic clusters and share cost between cluster's members.

In the follower model, the optimization will be based on the view of the second level service providers, focusing on maximizing their profit. The profit obtained by each second level service provider in a specified period. At the first step, the second level service provider is remunerated by the producing company for taking the task of producing parts of the final product as well as incurring the costs for producing and processing the parts at its own firm. To this, income and expenses depend on the model output. In the second step, each second level service provider must participate in the game among all second level service providers in each cluster and Trade-Off between its total income and total cost according to the model assumptions. Therefore in the second step the profit of each second level service provider is determined for each cluster at each period by participating in the game.

2-2-Mathematical modelling

This section introduces the sets, parameters, decision variables, objective functions, and constraints.

2-2-1-Sets

i: Set of Operations (i ∈ I)
j: Type of Service Providers (j ∈ J = {1,2})
u: Set of Cluster (u ∈ U)

2-2-2-Parameters

C': The cost of performing the total production package in a manufacturer company;
C_{ij}: The fee paid to jth-type service provider for operation i of the product;
P_{ij}^{u}: If the operation i performed by jth-type service provider which is located in cluster u, will be valued 1 otherwise 0;
T_u: Cost of transform vehicle to cluster u for collecting parts of the product.
rev_{iju}^{1}: The second-type service provider's revenue (part of the cluster u) generated by performing operation i of the product in $j = 2$.
rev_{iju}^{2}: The total revenue the second-type service provider (part of cluster u, who performs activity i in $j = 2$) receives from other cluster members for taking the role of administrator.

CA_{ij}^{u}: The total cost incurred due to gathering and dispatching the required parts of product from other cluster members by the admin of cluster u, performing operation i in $j = 2$.
CC_{ij}^{u}: The cost incurred due to performing operation i by the second-type service provider. The cost consists of human resources, operation processing, and other operations performed at the service provider's location.
B: Maximum budget the manufacturer company can allocate to the production process in a specified period.
BB_{ij}^{u}: Maximum budget the service provider (part of cluster u, performing activity i in $j = 2$) can allocate to producing the parts and participating in the second-type service providers' game;
M: A very big number;
x'_{ij}: Optimal value of X_{ij} variable obtained from the leader problem.

2-2-3-Decision variables

Y: A binary variable which is equal to 1 if the manufacturer company performs the full production package in company environment otherwise is equal 0;
X_{ij}: A binary variable which is equal to 1 if the manufacturer company assigns operation i to jth-type service providers and is 0 otherwise;
d_u: A binary variable which is equal to 1 if the manufacturer company transfers a transport vehicle (truck) to cluster u and is 0 otherwise. That is, if at least one of the second-type service providers in cluster u does at least one of the production operations, the value will be 1 and otherwise it will be 0;
θ_{ij}^{u}: A binary variable which is equal to 1 If a service provider in cluster u who performs operation i in $j = 2$ is assigned as the administrator of cluster u otherwise it will be 0;
a_u: Auxiliary binary variable for linearization;
A_u: Auxiliary positive variable for linearization;
b_{i}^{u}: Auxiliary binary variable for linearization;

2-2-4-Mathematical model of the leader problem

$$Min\ Z_{leader} = \sum_{i \in I} x_{ij} C_{ij} \sum_{j \in J} C'Y + \frac{\sum_{u \in U} T_u d_u}{\sum_{i \in I} \sum_{j \in J} \sum_{u \in U} x_{ij} P_{ij}^{u} + Y} \qquad (1)$$

In equation (1), an objective function for leader problem to minimize total cost, $\frac{\sum_{u \in U} T_u d_u}{\sum_{i \in I} \sum_{j \in J} \sum_{u \in U} X_{ij} P_{ij}^{u} + Y}$ is nonlinear. Before describing the problem constraints, some definitions will mention about the linearization of that term.
As $d_u$is divided by$\sum_{i \in I} \sum_{j \in J} \sum_{u \in U} x_{ij} P_{ij}^{u} + Y$, $\frac{\sum_{u \in U} T_u d_u}{\sum_{i \in I} \sum_{j \in J} \sum_{u \in U} X_{ij} P_{ij}^{u} + Y}$is nonlinear. Moreover, according to the problem assumptions, the product of the denominator term is always larger than 1, therefore it can be turned into a linear format. For this purpose, $\frac{\sum_{u \in U} T_u d_u}{\sum_{i \in I} \sum_{j \in J} \sum_{u \in U} X_{ij} P_{ij}^{u} + Y}$ is assumed equal to the positive variable A_u, producing the nonlinear form below:

$$Min\ Z_{leader} = \sum_{i \in I} \sum_{j \in J} x_{ij} C_{ij} + C'Y + \sum_{u \in U} T_u A_u \qquad (2)$$

St:

$$\sum_{j \in J} X_{ij} \leq 1 - Y \qquad \forall i \qquad (3)$$

$$\sum_{i \in I} \sum_{j \in J} X_{ij} C_{ij} + Y \times C' + \sum_{u \in U} A_u \times T_u \leq B \qquad (4)$$

$$X_{ij} \times P_{ij}^{u} \leq d_u \qquad \forall i, j, u \qquad (5)$$

$$\sum_{i \in I} \sum_{j \in J} X_{ij} \times P_{ij}^{u} + Y \geq 1 \qquad \forall u \qquad (6)$$

$$\sum_{i \in I} \sum_{j \in J} X_{ij} \times P_{ij}^{u} + Y = \sum_{i} i \times b_{i}^{u} \qquad \forall u \qquad (7)$$

$$a_u = \sum_{i \in I} \frac{b_{i}^{u}}{i} \qquad \forall u \qquad (8)$$

$$\sum_{i} b_{i}^{u} = 1 \qquad \forall u \qquad (9)$$

$$A_u \leq M \times d_u \qquad \forall u \qquad (10)$$

$$A_u \geq a_u - M \times (1 - d_u) \quad \forall u \tag{11}$$
$$A_u \geq a_u \quad \forall u \tag{12}$$

According to (3), if operation i is part of the production package performed by the company, it will not be assigned to service providers. Equation (4) shows the budget of money constraint for Manufacturer Company. Equation (5) guarantees that cluster u will activate first and then service providers performing activity i in type j will perform the service. Equation (6) guarantees that at least one type of operations will be performed in each activated cluster. Equations (7) to (12) show the linearization process of expression $\frac{\sum_{u\in U} T_u d_u}{\sum_{i\in I}\sum_{j\in J}\sum_{u\in U} X_{ij} P_{ij}^u + Y}$.

2-2-5-Mathematical model of the follower problem:

$$Max\ Z_{follower} = \sum_{i\in I}\sum_{j\in J}\sum_{u\in U} rev^1 \times (x'_{ij} \times P_{ij}^u) + \sum_{i\in I}\sum_{j\in J}\sum_{u\in U} rev^2 \times \theta_{ij}^u \times P_{ij}^u$$
$$- \sum_{i\in I}\sum_{j\in J}\sum_{u\in U} CC_{ij}^u \times x'_{ij} - \sum_{i\in I}\sum_{j\in J}\sum_{u\in U} CA_{ij}^u \times \theta_{ij}^u \times P_{ij}^u \tag{13}$$

St:

$$\sum_{i\in I}\sum_{j\in J} \theta_{ij}^u \times P_{ij}^u = 1 \quad \forall u \tag{14}$$
$$CA_{ij}^u \times \theta_{ij}^u \times P_{ij}^u + CC_{ij}^u \times x'_{ij} \leq BB_{ij}^u \quad \forall i, j, u \tag{15}$$

Equation (13) denotes profit maximization in the view of a second-type service provider. Equation (14) guarantees that in the cluster u only a single second-type service provider can act as administrator. Equation (15) denotes budget constraint for the second-type service provider.

3-Numerical example

For implementation our model, one of the important companies in Iran automotive industry has been selected which is located in Tehran and is shown with green colour in figure 1, in this company one of the products with five main operations has been chosen, these five operations should be done in the company environment or should be assigned to first-type service providers, these five operations decomposed to sub-operations which should be done by second-type service providers.

In considered problem, clustering of service providers has been done, as the figure below:

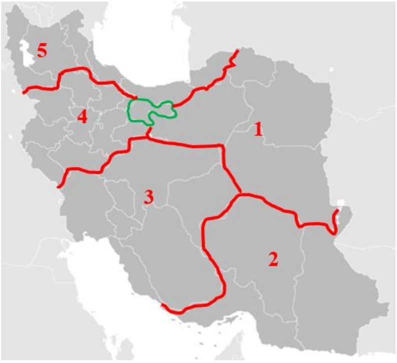

Fig 1. Clustering of service providers

The country of Iran has been divided into five clusters, assigning each first-type service providers to each cluster is as below:

1. Tehran (4)
2. Esfahan (3)
3. Mashhad (1)
4. Bandarabbas (2)
5. Babolsar (5)

And for second level service providers is like below:

1. Ghazvin (4), Esfahan (3), Mashhad (1), Karaj (4)

2. Bijar (4), Babol (5), Fooladshahr (3)
3. Saveh (4), Shiraz (3), Varamin (4)
4. Sabzevar (1), Tabriz (5), Naein (3)
5. Qom (4), Khoramshar (3), Amol (5)

$$P_{ij}^{u} = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 \\ 1.1 & 0 & 0 & 0 & 1 & 0 \\ 1.2 & 1 & 0 & 1 & 1 & 0 \\ 2.1 & 0 & 0 & 1 & 0 & 0 \\ 2.2 & 0 & 0 & 1 & 1 & 1 \\ 3.1 & 1 & 0 & 0 & 0 & 0 \\ 3.2 & 0 & 0 & 1 & 1 & 0 \\ 4.1 & 0 & 1 & 0 & 0 & 0 \\ 4.2 & 1 & 0 & 1 & 0 & 1 \\ 5.1 & 0 & 0 & 0 & 0 & 1 \\ 5.2 & 0 & 0 & 1 & 1 & 1 \end{bmatrix}$$

In this problem, cost of transportation to each cluster is considered as below:

1: 2,000,000, 2: 2,500,000, 3: 1,000,000, 4: 500,000, 5: 1,200,000

For numerical analysis because of existence certain data for leader problem, crisp data has been used meanwhile for follower problem lack of certain data obliged us to use uniform distribution finally after solving the problem the value of objective function for leader problem has been achieved 4.44E+07 and the value of objective function for follower problem has been achieved 1.97E+07.
For showing results we can demonstrate two issues at first by increasing the cost of each service provider (first-type) the overall cost of the manufacturer will increase an assigning of operations depend on the value of increase and the optimum solution will change by this.

The second issue is adding or reducing a member to each cluster for example if we add a member like blow matrix:

$$P_{ij}^{u} = \begin{bmatrix} & 1 & 2 & 3 & 4 & 5 \\ 1.1 & 0 & 0 & 0 & 1 & 0 \\ 1.2 & 1 & 0 & 1 & 1 & 0 \\ 2.1 & 0 & 0 & 1 & 0 & 0 \\ 2.2 & 0 & 0 & 1 & 1 & 1 \\ 3.1 & 1 & 0 & 0 & 0 & 0 \\ 3.2 & 0 & 0 & 1 & 1 & 0 \\ 4.1 & 0 & 0 & 0 & 1 & 0 \\ 4.2 & 1 & 0 & 1 & 0 & 1 \\ 5.1 & 0 & 0 & 0 & 0 & 1 \\ 5.2 & 0 & 0 & 1 & 1 & 1 \end{bmatrix}$$

The optimal solution will change like this:

$$\Delta Z = Zleader^{2} - Zleader^{1} = -8.60E + 06$$

The percentage of cost change will be:

$$\%D = -19\%$$

Every other composition for changing in members of the cluster can be assumed and the impact of that on the value of the objective function can be calculated.

4- Conclusion

In this paper a bi-level model has defined for a cloud manufacturing problem, the modelling of the problem is emphasized on the concept of public cloud, at the first level of problem a manufacturer company is supposed and an optimization process designed for this company in this process a single product with five specified operations is supposed the management of company has some strategies for producing this product in first strategy company can do all of the operations in the own environment and in other strategies company must assign these operations to one or a group of service providers due to these strategies company intends to minimize its total costs. Service providers are divided into two types: first-type service providers are centralized and are experienced for performing operations on the other hand second–type service providers are decentralized and have less experienced in comparison with first-type service providers.

The problem of this paper has been implemented in one of the companies in Iran car industry In the first level after solving the decision was assigning all operations to service providers and in this level the value of objective function was 4.44E+07 which is called the total profit of manufacturer company, in the second level of model among second-type service providers a game was designed and in this game a service provider in each cluster selected as administrator of cluster and in this level the value of objective function was 1.97E+07 which is called as total profit of second-type service providers.

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