cogent
engineering

COMPUTER SCIENCE | RESEARCH ARTICLE

Optimal allocation of human resources based on operational performance of organizational units using fuzzy game theory

Rahim Khanizad[1]* and Gholamali Montazer[2]

*Corresponding author: Rahim Khanizad, Faculty of Management and Economics, ITM Department, Tarbiat Modares University, Jalal e Ale Ahmad, Tehran, Iran
E-mail: Rahim.Khanizad@modares.ac.ir

Reviewing editor:
Saurabh Pratap, Indian Institute of Information Technology Design and Manufacturing, India

Additional information is available at the end of the article

Abstract: The allocation of human resources is considered as one of daily challenges of many organizations to achieve optimal efficiency. After investigating this challenge, in this research, a multi-agent system is used to make a cooperative game between organizational units for allocation of tasks and human resources in an organization. In the game, every unit provides a proposal for promoting his and other unit's performance. Our model uses fuzzification to facilitate game process and increase probability of reaching an agreement in the game. Meanwhile it helps for simulation of real conditions in organizations. Results of the fuzzy game have shown that for special allocations of human resources and tasks, organizational performance is more desirable, and its productivity will be higher. We used an example to apply the model and show the results. The model can improve the human resources and task allocation in organizations by using a fuzzy game theory.

ABOUT THE AUTHORS

Rahim Khanizad, PhD student, Information Technology (Business Intelligence), University of Tarbiat Modares, Tehran, Iran. I received my BSc and his MSc degrees in Information Technology Management (E-Commerce) from the Shahid Beheshti University, Tehran, Iran in 2006 and 2009, respectively. My special areas of research include: business intelligence, E-commerce, data mining, knowledge management, Technology management, multiagent systems and game theory.

Gholam Ali Montazer received his BSc degree in Electrical Engineering from the Kh. N. Toosi University of Technology, Tehran, Iran in 1993 and his MSc and PhD degrees in Electrical Engineering from the Tarbiat Modares University, Tehran, Iran in 1995 and 1999, respectively. Currently, he is an associate professor in the Department of Information Technology at Tarbiat Modares University (TMU). His areas of research include, soft computing approaches such as artificial neural network (ANN), fuzzy set theory (FST) and rough set theory (RST), Evolutionary computation and their applications in pattern recognition, e-learning systems, and e-commerce environment.

PUBLIC INTEREST STATEMENT

The allocation of human resources is considered as one of daily challenges of many organizations to achieve optimal efficiency. This article uses a multi-agent system and game theory to make a coalition between organizational units for allocation of human resources and task in the organization, based on historical operational performance data and data gathered from the experts of Milad hospital, which was used to implement and evaluate the model. It was found that for special allocations of human resources and tasks, organizational performance is more desirable, and its productivity will be higher. We used an example to apply the model and show the results. Our model can help organizations to improve productivity by effective allocation of the human resources, tasks and other resources in the future.

Rahim Khanizad

cogent oa

1. Introduction

Human resource allocation in an organization is one of the most difficult and day to day problems of managers, as it is a combination of scheduling and staffing decision-making problems. The decision-making environment getting more complex and dynamic when different parameters comes to account in organization environment. In this dynamic condition, planners must take to account human resource preferences, organizational constraints, time periods, different tasks and skills, etc. Meanwhile distributing human resources in an optimum way in the organization and take advantage of their various skills in doing organizational duties in the desirable way is one of the main organizational issues and this issue had been considered as one of the main challenge for organizations (Cheang, Li, Lim, & Rodrigues, 2003). On the other hand, human resource allocation is raised at different levels of the organization and different factors are effective in how to distribute the human resource at each level and this leads to increase the complexity of the issue. Many organizations have had difficulty in dealing with this challenge and in addition to wasting their resources, have failed to use the existing human resource in the organization to achieve the optimal efficiency.

Recently, many researchers have focused on applying different methods to human resource allocation. In the early researches, in the optimization of the human resources allocation, exact mathematical methods (Azimi, Beheshti, Imanzadeh, & Nazari, 2013; Borba & Ritt, 2014; Burke, Curtois, Post, Qu, & Veltman, 2007; Güler, Keskin, Döyen, & Akyer, 2015; Oussedik, 2007; Vilà & Pereira, 2014), heuristic and meta-heuristic methods (Aickelin & Li, 2007; Ammar, Elkosantini, & Pierreval, 2012; Burke et al., 2007; Costa Filho, Rocha, Costa, & de Albuquerque Pereira, 2012; Dowsland, 1998; Gunawan & Ng, 2011; Moreira, Miralles, & Costa, 2015; Mutlu, Polat, & Supciller, 2013; Ornek & Ozturk, 2016; Özcan, 2005; Wang & Liu, 2010; Wang, Wang, Li, & Sun, 2012) and multi-agent-based systems (e Silva & Costa, 2013; González, Espín, & Fernández, 2015; Lucas & Huzita, 2014) has been used previously. However, they rarely take to account the information of current and previous state of the operational performance of the organizational units, the knowledge of experts and the interactions in the dynamic environment of organization. The dynamic environment of the organizations needs to be simulated to benefit from interactions between the units and to avoid big changes in the problem state from small changes in the effective parameters in the allocation process.

Simulation, genetic algorithms and other heuristic and meta-heuristic methods had been used for the human resources allocation optimization (Barreto, Barros, & Werner, 2008; Daher & Almeida, 2010; Gerogiannis, Rapti, Karageorgos, & Fitsilis, 2015; Kang, Jung, & Bae, 2011; Korhonen & Syrjänen, 2004; Mota, Almeida, & Alencar, 2009; Otero, Centeno, Ruiz-Torres, & Otero, 2008; Santos, Lima, Reis, & Reis, 2014), however the productivity of units beside the productivity of the whole organization had not been considered in these researches.

Also, it was previously used the fuzzy theory to optimize the allocation of human resources and maximize the productivity (Barreto et al., 2008; Daher & Almeida, 2010), Our model uses the fuzzy theory to simulate more the organization dynamic environment and to translate imprecise cases to precise numbers and vice versa and to increase the possibility of reaching agreement in the negotiation process.

Our model uses the previous operational information of units as a criterion in the negotiation and allocation process to guaranty the high level of performance in all units beside the whole of organization. We try to optimize the performance of any units in the distribution process to find the maximum productivity points for the whole organization that can be calculated from the best total of optimal performance of the units.

We believe that experts and their information from previous performance of the units beside the interaction between the organizational units is an important element in the allocation process that can be achieved by using of a cooperative game in the allocation process.

One of the objectives in this research is to develop a model based on fuzzy game theory to provide a flexible solution to optimize the productivity of organization. Our proposed fuzzy game theory based model has several advantages:

(1) Taking to account the experts and their information from the current and the previous state of the operational performance beside the interaction between the organizational units in the game as an important element in the allocation process.

(2) The productivity of units beside the productivity of the whole organization had been considered in the negotiation and allocation process to guaranty the high level of performance in all units beside the whole of organization.

(3) Using the fuzzy theory to simulate more the organization dynamic environment and to translate imprecise cases to precise numbers and vice versa and to increase the possibility of reaching agreement in the negotiation process.

(4) Using game theory to simulate interactions between the units and to create the possibility for more units to participate in the allocation process.

(5) Using fuzzy game theory creates the possibility of taking more elements to account at the same time such as tasks, number of workforce and time shifts in the organization units as effective factors in an optimal human resource allocation.

In the present study, we work on an organization with many units each of which work with different personnel skills and types and different work shifts. The aim of the present study is to develop a model based on fuzzy game theory for optimal allocation of human resources based on the operational performance of organizational units by using multi-agent systems.

2. Background of research

Three main challenges are raised in the allocation of resources (Endriss, Maudet, Sadri, & Toni, 2006). First, what kind of resources can be distributed? Second, how can be the mechanism of this allocation? And finally, why the special mechanism is used to the allocation of resources?

The human resource allocation as a subproblem in many real-life problems, such as in health care systems (Lanzarone & Matta, 2014), production systems (Nembhard & Bentefouet, 2015), timetabling problem (Güler et al., 2015), tourism and hotel management (Murakami, Tasan, Gen, & Oyabu, 2011), project management (Kyriklidis, Vassiliadis, Kirytopoulos, & Dounias, 2014), maintenance management (Bennour, Addouche, & El Mhamedi, 2012), and too many others, considered by many scholars (Bouajaja & Dridi, 2017).

Since the human resource allocation is known to be a NP-hard combinatorial optimization problem, different approaches are proposed as a solution mechanism for different conditions. Some used approaches in the state of the art are exact mathematical based solution methods (Azimi et al., 2013; Borba & Ritt, 2014; Burke et al., 2007; Güler et al., 2015; Oussedik, 2007; Vilà & Pereira, 2014), heuristic algorithms (Moreira et al., 2015; Ornek & Ozturk, 2016), and metaheuristics (Aickelin & Li, 2007; Burke, 2004; Burke et al., 2007; Dowsland, 1998; Osman, Abo-Sinna, & Mousa, 2005; Ornek & Ozturk, 2016; Özcan, 2005; Wang, Gong, & Yan, 2009; Wang & Liu, 2010) such as tabu search (Ammar et al., 2012), generic algorithm (Mutlu et al., 2013), simulated annealing (Gunawan & Ng, 2011) and ant colony optimization (Wang et al., 2012). Combined heuristic and metaheuristic approaches (Costa Filho et al., 2012; Lukas, Aribowo, & Muchri, 2013) also has been used to benefit advantage of both methods. Mathematical or accurate methods related to human resource allocation are somewhat disabling to solve large problems with multiple variables in a reasonable time. Evolutionary algorithms such as genetic algorithm (Barreto et al., 2008; Daher & Almeida, 2010; Kang et al., 2011;

Korhonen & Syrjänen, 2004; Mutlu et al., 2013; Osman et al., 2005), particle swarm optimization algorithm (Wang et al., 2009) and ant colony optimization algorithm (Wang & Liu, 2010) are used mostly in heuristic and meta-heuristic researches. A detailed listing of research work using mathematical and heuristics and meta Heuristics is compiled by De Bruecker, Van den Bergh, Beliën, and Demeule-meester (2015).

In the field of mechanism and allocation methods, the heuristics and meta-heuristics methods, mathematical methods, use of multi agent systems and methods based on game theory have been used more than other methods (Endriss et al., 2006).

As a computer science field approach, fuzzy theory also, has been used for human resource allocation (Mota et al., 2009; Otero et al., 2008). Also, in Gerogiannis et al. (2015), a fuzzy approach used for human resource evaluation and selection in software projects based on their skills and the required skills for each project task.

Multi-agent system has been used to human resources allocation in information system projects in e Silva and Costa (2013) and in Lucas and Huzita (2014) multi-agent system has been used to allocation of human resources in a distributed software development environment.

In Santos et al. (2014), Roque, Araújo, Dantas, Saraiva, and Souza (2016) authors described an allocation process in the software project management process based on the analysis of organizational repositories as a mean to take empirical evidence to support dynamic decision-making.

Considering the mentioned researches, the organizations need to consider some other criteria such as the current and previous performance rate of the units, the whole organizational performance beside the unit's performance, dynamic and vagueness in some conditions and capability to consider the changes in organizational environment in the allocation process. Using simple models and algorithms could not consider all these criteria's in the allocation process. According to researches, interaction between the organizational units has a key role in the optimal allocation process. Meanwhile considering expert's opinions about performance of the units as a historical input is necessary in the allocation process.

In this research, a model will be presented to distribution of the human resources and sharing the work in a dynamic and complex environment in the organization level and units level to optimize efficiency of human resources. For tackling with the complex and dynamic environment of the organization, we use the fuzzy game theory; the use of game theory makes this possibility that we model the organizational interactions of units properly and the use of fuzzy game can make the model closer more to the existing real space in organizations and helps to simulate the existing conditions in organizations more and better.

In this regard, the game theory will be used to design the mechanism of this interaction and the agents (in behalf of organization units) interact with each other to obtain the certain amount of human resources and the amount of work using the fuzzy values to define the human resources, the amount of work of the organization and the performance rate of organizational units in the game process.

In this work, an organization is considered to have several organizational units. There are several human resources with different skills are working in each of these units and different working shifts also have been defined in the organization. A game has been created and each organizational unit is represented by an agent. The agents in behalf of units are negotiating for a higher utility to distribute the human resources and the amount of work. Any agent has detail information and the utility preferences of its own unit and as a self-interesting agent, try to maximize the utility of its represented unit. The agents use the Fuzzy Inference System in negotiation process.

The purpose of this research is to find optimal allocation of the human resources required for each of the organizational units so that each unit can operate at its best performance level (Table 1).

The rest of the paper is organized as follows. The next section provides the theoretical background which this work intends to address. It is followed by present of our human resource allocation model. The developed model for human resource allocation is then discussed and a case study is utilized to demonstrate the capabilities of the model. The result of the game is then presented and evaluated and Finally, conclusions and recommendations for future work are discussed.

3. Theoretical background

Economists study how the consumer chooses the product, and they elaborate the theory of consumer behavior. The theory in microeconomics, is based on the study of selection between two important issues of succession and its impact on demand. Consumer behavior theory is investigated in two ways, utility-based method and indifference curves method.

In the Organizations each unit has different performance levels and uses different number of human resources accordingly. Thus, there is different utility levels for having different number of human resources for a unit (Haspeslagh, De Causmaecker, & Berghe, 2012). Here, first, we determine the utility of every organizational unit (consumer) and the utility of human resources and the tasks (product). Then we continue to make use of indifference curves and different levels of utility in different using level of human resources.

Game theory is a branch of economy that deals with studying the interaction between self-interested agents. The main and primary question that is asked in the game theory is that what is the best and most rational thing that an agent can do? In many cases, the answer is that what an agent obtains, depends on the choices that have been done by other agents. As a result, if an agent tries to optimize his/her revenue, conditions must be imagined in which all agents seek to optimize their own results. The game theory provides us with analysis and formulation of these conditions (Parsons & Wooldridge, 2000). The field of negotiation is the most important and most widely used part of the game theory around interaction of agents (Wooldridge, 2012).

Bargaining and negotiation are raised in many activities related to the organization as well as various businesses. Different negotiations are classified through their complexity rate in obtaining an agreement in a dynamic environment, with several agents and unformed environment (González et al., 2015). Some researchers have used "Principled Bargaining" method of Fisher and Ury (Fisher & Ury, 1981; Fitzgerald & Ross, 2015; Korobkin, 2008; Lewicki, Weiss, & Lewin, 1992; Menkel-Meadow, 1993; Mircica, 2014) that according to it any kind of negotiation can be judged by considering the following three conditions (González et al., 2015):

(1) Negotiation must create an intelligent agreement (if the agreement is available). Intelligent agreement is an agreement that meets legitimate demands of the parties and solve disputed demands in fair, in addition to be sustainable and consider the interests of the parties of negotiation.

(2) Performed agreement must have the necessary efficacy. This means that meets the consent of the parties and the parties do not feel to change of their condition.

(3) The agreement must improve the relationships of parties or at least does not harm their relationships.

On the other hand, the game theory is the study of the contradictory situations among a group of agents, where the decision of each of them, affects the decision-making of others (Wooldridge, 2012). In fact, to decide, the agent chooses an option among available options (strategies) for doing but what should be decided in encountering with other parties at time of negotiation is not very clear (Wooldridge, 2012).

Game theory uses different methods to model the interactions and solves the problems based on the kind of interactions, the number of agents as well as the cooperation or the lack of cooperation among agents. Cooperative Games are used to model and solve the problem according to the kind of issue here that we will be explained in following.

Cooperative Games are the games in which there is a possibility to form the coalition for agents that the game is done so that the maximum revenue of all participants in game to be achieved. In this case, the final revenue will be achieved from combination of strategies of agents and result of the game should achieve the purposes of agents (Huang & Wang, 2010).

The purpose of each agent in cooperative games is to maximize the revenue of other parties in addition to maximize his own revenue of the game. Formation of the coalition has importance in political and international ties (Turocy & von Stengel, 2001).

In this research, since the organizational units try to maximize the revenue (Performance) of each other, we model them by using of a Cooperative Finitely-Repeated Games model. The game is played among the agents in limited numbers and Information of agents will be updated according to the space of game in each-iteration of the game.

This conditions in the organization can create an ideal condition for the cooperative game model in the organization, because organizational units can maximize either their revenue of the game or revenue of other units by forming the coalition and due to the game conditions and finally maximize also the revenue of whole organization. By this assumption, the success conditions of the game are when the total revenue of agents to be maximized in the game.

Inputs and revenue of the agents in this model are expressed using the fuzzy theory. Fuzzy theory is a method that models the uncertain and inaccurate environment that was proposed by Lotfi Zadeh for the first time. Fuzzy set is a set of elements that has different degrees of membership in set. Fuzzy set of *A* is introduced in Equation (1):

$$A = \{(x, \mu_A(x)) | x \in X, \mu_A(x) \in [0, 1]\} \tag{1}$$

In this equation the reference set, *x* is each of the elements and $\mu_A(x)$ is function (degree) of membership of element of x in set of *A* (De Wilde, 2010). Fuzzy Decision-Making System uses a set of functions of fuzzy membership to decide in special issue. The degree of membership of members also has been adopted from experts in related field. The components of Fuzzy Decision-Making System include Fuzzification Section, Fuzzy Rule Base, Fuzzy Decision Logic and Defuzzification part (Famuyiwa, Monplaisir, & Nepal, 2008). This system has been shown in Figure 1.

Figure 1. Implementation the fuzzy decision-making system.
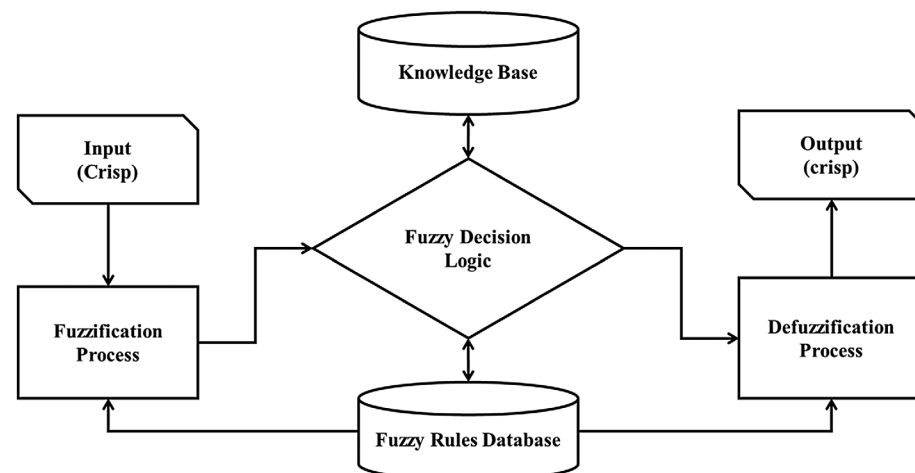
(1) Fuzzification Section: This section shapes the inputs of system to fuzzy qualities (fuzzy set). Many of numbers that are used in daily issues are inaccurate and in fact are fuzzy and they can be shown in the form of fuzzy set.

(2) Fuzzy Rule Base: Rules are stated in the form of Conditional statement "If … Then …". The set of these rules of Fuzzy Rule Base shape the fuzzy logic. There is an abbreviated form for fuzzy rule base for a number of certain inputs that is called Fuzzy Associative Memory. Fuzzy tool box also will be used to deduction and reasoning the rules in Matlab software.

(3) Decision Making Logic: Fuzzy Decision Logic is like the classical logic in reasoning. In fact, reasoning rules in fuzzy logic stimulate the manner of decision-making of human in the inaccurate activities (Ross, 2005). There are several methods for Fuzzy to inference that here Mamdani model has been used among three Mamdani, Sugeno, and Tsukamot models.

(4) Defuzzification process: This stage includes converting the fuzzy results to accurate inputs. There are various methods for this that Centroid Defuzzification Method is used here. This method is the most common method for Defuzzification that is used to calculate the accurate amount of output from the point of gravity of output set. The combination of game theory and fuzzy logic has been used in the process of decision-making in some researches (Braathen & Sendstad, 2004; Costantino & Gravio, 2009).

Organizational units developed to the type of uncertainty in perception in complete recognition of the rate of its performance in exchange for the productivity of resources and the amount of work. That is due to the inherent complexity and the effect of different factors in the rate of their performance. That makes it difficult to clearly define the boundaries between different level of performance and create a kind of vagueness. General framework for dealing with these conditions and inaccurate and ambiguous information is use of the concepts and theories such as fuzzy theory and Grey Systems Theory to explain the incomplete qualitative information conditions. Fuzzy sets are used to explain and model the conditions for this purpose in this research.

Organizational units need information of internal condition of each other to interact with each other. The units do not have complete information about each other that it is due to a shortage of their knowledge of each other. Game theory has been used to deal with these conditions as well as model the interaction between organizational units in this research to create an appropriate mechanism for modeling with insufficient information of units about parties and provide the possibility of interaction.

The combination of fuzzy logic and game theory is used to explain the performance status of units as well as the study of the interaction of organizational units to human resource allocation and share the work.

By employing fuzzy logic, the organizational units use their internal information in the negotiation process that includes functional status of them. The information that each agent uses it includes information related to the human resources, work environment and the information of optimal performance of the unit.

4. Human resources allocation model

The organizations are consisted of various business units that each of them uses the human resource of organization to do their duties. If the organizational units can achieve an interaction between themselves that improves the performance of each of the units, it can be said that this interaction will ultimately lead to improve the performance and efficiency of the whole organization.

The Game theory can model the existing conditions and status of each of the agents and revenue of them. The mode of utility corresponding to the amount of their revenue of the game can be shown

for each agent. On the other hand, performance framework of each organizational unit is defined as "the capability of the organizational unit to do the certain number of organizational tasks using the certain number of the human resources" (Haspeslagh et al., 2012). So, it can be imagined that each organizational unit will have different performance for using certain number of human resources. Different performances create different utility for the organizational units. The more performance (efficiency), the more utility will be created for the organizational unit. Regarding the human resources, the rate of having a number of human resources by organizational unit, can create separate utility (revenue) for that organizational unit.

Thus, it can be imagined that for each certain strategy (having a number of resources and the amount of works) that one agent uses in the game, there will be a separate utility (revenue) given that each organizational unit has different utility due to their utility for different conditions.

A model can be presented to the organizational units using the game theory in which the agents (organizational units) try to reach to their maximum utility, namely having appropriate human resources to achieve their own highest performance. If we show the rate of utility with the numbers between 0 and 1, the highest utility is showed with 1 and the lowest utility with zero. If the organizational unit has enough and ideal conditions, it will have the high level of performance and utility of 1, and whatever the more or less number of human resources, performance and consequently the utility will be reduced for the organizational unit. This issue has been shown in Table 2.

The opinions of experts have been used to measure the rate of utilities. So that, 10 experts of each organizational unit were selected with a history of activity for more than 5 years in the field of planning for the distribution of the human resource, and then the performance of unit was asked them in the form of questionnaire in terms of having human resources (qualitatively) as well as the rate of utility in terms of different numbers of human resources (quantitatively). Its results have been shown in Tables 2 and 3.

Table 1. Excellence of present study			
Research field	**Research carried out**	**The using mechanism**	**Excellence of present study**
Shortage of specialized human resources	Bard and Purnomo (2006)	Heuristic and Meta-heuristic methods	Use advantage of the units operating performance and the distribution of specialized human resources based on performance of units
			Considering optimization of the allocation performed
Allocation of human resources	Barreto et al. (2008), Daher and Almeida (2010), Kang et al. (2011), Korhonen and Syrjänen (2004), Mota et al. (2009), Otero et al. (2008), Santos et al. (2014), Gerogiannis et al. (2015)	Simulation, use of Genetic Algorithms and Fuzzy theory	Optimize the allocation of human resources and maximizing
			Productivity of units besides the optimizing organizational performance
Optimize the allocation of human resources	Burke (2004), Osman et al. (2005), Wang et al. (2009), Wang and Liu (2010), Aickelin and Li (2007), Özcan (2005), Dowsland (1998), Burke et al. (2007)	Heuristic and Meta-heuristic methods	Implementation of the operational performance of organizational units as a criterion for allocation
	Burke et al. (2007), Oussedik (2007)	Mathematical methods	The use of fuzzy theory to simulate more the organization dynamic environment
			Take advantage of game theory and create the possibility for more units in the allocation process
	e Silva and Costa (2013), Lucas and Huzita (2014)	Multi-agent systems	Considering organizational performance optimization, while paying attention to optimum allocation of human resources and at the same time distribution of tasks and number of workforce

cogent ·· engineering

Table 2. Level of utility in terms of having human resources			
Level	**Level of utilization**	**Unit performance**	**Utility**
1	Enough force and full utilization of human resources	Full	1
2	Medium utilization of human resources	Medium	0.8
3	Utilization, a little over human resources needs	Medium	0.6
4	Very low utilization of human resources	Low	0.4
5	Excessive utilization of human resources	Low	0.2
6	Utilization much more or much less than the human resource	Unacceptable	0

Table 3. The amount of utility in terms of different numbers of human resource for the assumed unit			
Number of human resources	**Amount of works assigned to the unit**		
	High	**Medium**	**Low**
1	0.1	0.15	0.1
2	0.15	0.2	0.15
3	0.2	0.25	0.2
4	0.25	0.3	0.25
5	0.3	0.35	0.3
6	0.35	0.4	0.35
7	0.4	0.45	0.4
8	0.45	0.5	0.45
9	0.5	0.55	0.5
10	0.55	0.6	0.55
11	0.6	0.65	0.6
12	0.65	0.7	0.65
13	0.7	0.75	0.7
14	0.75	0.8	0.75
15	0.8	0.85	0.8
16	0.85	0.9	0.85
17	0.9	0.95	0.9
18	0.95	1	0.95
19	1	0.95	1
20	0.85	0.9	0.85
21	0.8	0.85	0.8
22	0.75	0.8	0.75
23	0.7	0.75	0.7
24	0.65	0.7	0.65
25	0.6	0.65	0.6
26	0.55	0.6	0.55
27	0.5	0.55	0.5
28	0.45	0.5	0.45
29	0.4	0.45	0.4
30	0.35	0.4	0.35

Different strategies can be presented in terms of the number of human resources for each unit corresponding the utilities that each unit has. In designing strategies of each unit, the amount of work imagined for each unit has been presented in three modes of high, average and low, and the utilities are also measured based on the certain amount of human resources. For example, the amount of performance and revenue of each unit for each strategy for assumed unit in terms of the certain number of human resources have been presented in Table 3. To measure and the awareness of the utility, the opinions of experts have also been used in the order that is mentioned. In this table for any composition of the number of human resources (1, 2, 3, … 30) and the amount of works assigned to the unit (High, Medium, Low), we have different rate for the utility. For instance, if a unit uses "3" person and amount of work assigned to it was "Medium", so the utility rate for the unit is "0.25". For any composition (number of human resource and the amount of works assigned to the unit) we asked from experts to rate of utility. Experts Rated equal utility amounts for "High" and "Low". For any composition of the number of human resources and the amount of works assigned to a unit, there is a utility amount for the unit and any increase (High) or decrease (Low) in the amounts of the works assigned to it can decrease the amount of utility because the number of human resources is not changed, and this cause a performance decline in the unit.

The more corresponding the number of human resources of unit to the unit duty, the amount of efficiency (performance) of unit will be more, and thus, it will create more utility for the unit.

In the game theory, a strategy is a way to making decision which determines the way of action of an agent in every possible situation in the game space (Banerjee, Biswas, & Chintada, 2006). Choosing any strategy can affect the game space and future movements of the agents. In this research, each unit must adopt the necessary strategy about how many human resources as well as how much of the work to be done by them.

In the model, the human resource is shown with the letter (H) and the amount of work with the letter (W). In this case, the amount of allocation will be shown with the ordinal pair of (W, H) which indicates the selective strategy of each agent. For example, if an agent decides to have 5 units of human resources against 10 work units, the strategy of this agent will be shown as (5, 10).

If a unit selects more human resources against the amount of work of the organization, it will affect the strategy of other unit and the second unit should select the appropriate strategy. The appropriate strategy is used by each unit to select which amount of work and human resources by each unit.

Two fuzzy agents are used as two assumed units to model this fuzzy game where units adopt mutual decisions. In this model, each unit knows the previous movements of each other, but it is not clear for parties that which strategy will be used in the future. To design and implement the fuzzy game as a decision-making system, let to explain the following cases (these are not the process of the fuzzy game, but the cases that we need to know in the game process):

(1) Fuzzy variables and factors: Inaccurate factors that have been used in the model include the rate of demand for the human resources in the organizational units (D) the amount of work (W) and the amount of Utility (U) of units. Also, the number of available human resources (by observing the minimum and maximum necessary number of human resources) is shown with (E).

(2) Strategies of each agent: some strategies are specified for each agent that are the number of human resource and the amount of work (H, W).

(3) Inputs and outputs of the model: inputs of the model include the rate of demand (D) and the number of available human resources (E) and its outputs will be the expected human resources (H_E) the expected amount of work (W_E) and the rate of utility (U) for each agent. Obviously,

the total expected human resources that is for each agent will be equal to the total number of available human resource.

(4) Create the sets of fuzzy membership functions: The opinions of experts can be used for phasing the inputs and outputs (Dweiri & Kablan, 2006) or uses the existing data in the research source (Negnevitsky, 2005). Triangular function has been used for the membership function in this research because it can be shown with 3 variables and if it is necessary, it will facilitate the learning process (Oderanti & De Wilde, 2009).

(5) Formulation the decision-making rules for rules base: The opinions of experts also will be used in this section.

(6) Implementation the game: Two fuzzy agents are used as two assumed units. The process of the game is so that first an initial mode will be created for the game of agents and then each agent can select his/her strategy. Initial mode for the game is defined in vector form in the form of $[A_H, B_H, U_A, U_B, R]$. In which A_H is the initial number of human resource in unit of A and B_H is the initial number of human resources in unit of B and U_A, U_B are respectively the rate of utility in units A and B and R is the rounds that game has been played. The strategy of agent A and B will be shown as $[A_H, A_W]$ and $[B_H, B_W]$ respectively and since the total human resources and the amount of work is fixed, the whole rules of game will be as follows:

F-1. Initial mode of game is in vector form as [0, 0, 0, 0, 100].

F-2. By observing the limitations in equation (2) and (3);

$$A_H + B_H \leq E \tag{2}$$

$$A_W + B_W \leq D \tag{3}$$

F-3. The first agent starts his/her movement with going to the mode $[A_H, A_W]$ in any case and the second agent goes to the mode $[B_H, B_W]$. Limitations should be observed in strategies of agents.

F-4. Due to the type of game, in each mode and at any stage of the game, what an agent obtains is added or subtracted from his/her previous assets and then new mode is calculated.

(7) Fuzzy Inference System and its output: As was mentioned, the method of Mamdani has been used for Fuzzy Inference System.

(8) End of game: if $R = 0$ (a game is done on the number of predicted rounds) the game ends.

(9) Performance evaluation: the agents can act to evaluate their performance of the rate of revenue of the game for the utility variable (U). The utility of each agent will be between 0 and 1, more tendency towards 1, the performance will be better.

5. Developed model validation and case study application

We consider data of two organizational units in Milad hospital of Tehran as an example. Tehran's Milad hospitals has various department and it is considered as one of the biggest hospitals of Iran. Allocation of the tasks and human resources in different departments and units of this hospital is done by experts who are engaged in task allocation and scheduling of each unit for more than 5 years. Data related to the number of human resources and expected work in each unit have been fuzzy by the experts of that department and through the table that they have had, and different utilities have been listed for them. For define the Fuzzy Membership Functions, we fuzzified all values, the number of human resources (very low, low, medium, high, very high) and the amount of works assigned to the units (very low, low, medium, high) and all combinations of the number of human resources and the amount of assigned work (very low, low, medium, high, very high). Table 4 shows the fuzzy membership function for the expected output of human resource number and Tables 5 and 6 show the fuzzy membership function for the expected output of assigned works and

cogent ·· engineering

Table 4. Fuzzy membership function for the expected output of human resources

Number of human resources		Amount of work assigned to the unit			
		Very low	**Low**	**Medium**	**High**
1–50	Very low	Very low	Low	Medium	Very high
30–90	Low	Low	Medium	High	High
70–190	Medium	Low	Low	Medium	High
170–250	High	Very low	Low	Medium	High
Over 250	Very high	Very low	Very low	Low	Medium

Table 5. Fuzzy membership function for the expected output of the amount of work

Number of human resources		Amount of work assigned to the unit			
		Very low	**Low**	**Medium**	**High**
1–50	Very low	Very low	Low	Low	Low
30–90	Low	Low	Low	Low	Low
70–190	Medium	Medium	Medium	High	Medium
170–250	High	High	Medium	Medium	High
Over 250	Very high	Very high	High	Medium	Medium

Table 6. Fuzzy membership function for the expected output of utility

Number of human resources		Amount of work assigned to the unit			
		Very low	**Low**	**Medium**	**High**
1–50	Very low	High	Medium	Low	Very Low
30–90	Low	Medium	High	Medium	Low
70–190	Medium	Low	Medium	High	Medium
170–250	High	Low	Low	Medium	High
Over 250	Very high	Very low	Low	Low	Medium

the fuzzy membership function for the expected output of utility, respectively. For example, in Table 4, if a unit uses "Very low" numbers (1 to 50) of the human resources and have "High" level of the assigned work, then it has a "Very high" level of the expected output of number of human resources. Also, in Table 6, if a unit uses "High" numbers (170 to 250) of the human resources and have "Medium" level of the assigned work, then it has a "Medium" level of the expected output utility for that combination of the number of human resources and the assigned work.

Thus, each organizational unit has a table of revenue that can use it in process of the game. Each unit tries to achieve the most appropriate combination of the number of human resources and the amount of work and at the same time cooperates with other units to achieve the highest level of performance of their own department. As it is difficult to reach an agreement by using the accurate number of human resources, the amount of the work and the rate of utility, data have been fuzzy to increase the possibility of agreement in terms of multiple variables.

Fuzzy membership functions related to each of the variables in terms of their inputs and outputs have been shown in Figure 2.

Initial inputs for the number of human resources and the amount of work in the organization is 250 people and 500 working shifts, respectively. According to fuzzy membership functions, Inputs and outputs in MATLAB software environment have been shown in Figure 3.

Figure 2. The fuzzy membership functions for output and input variables.
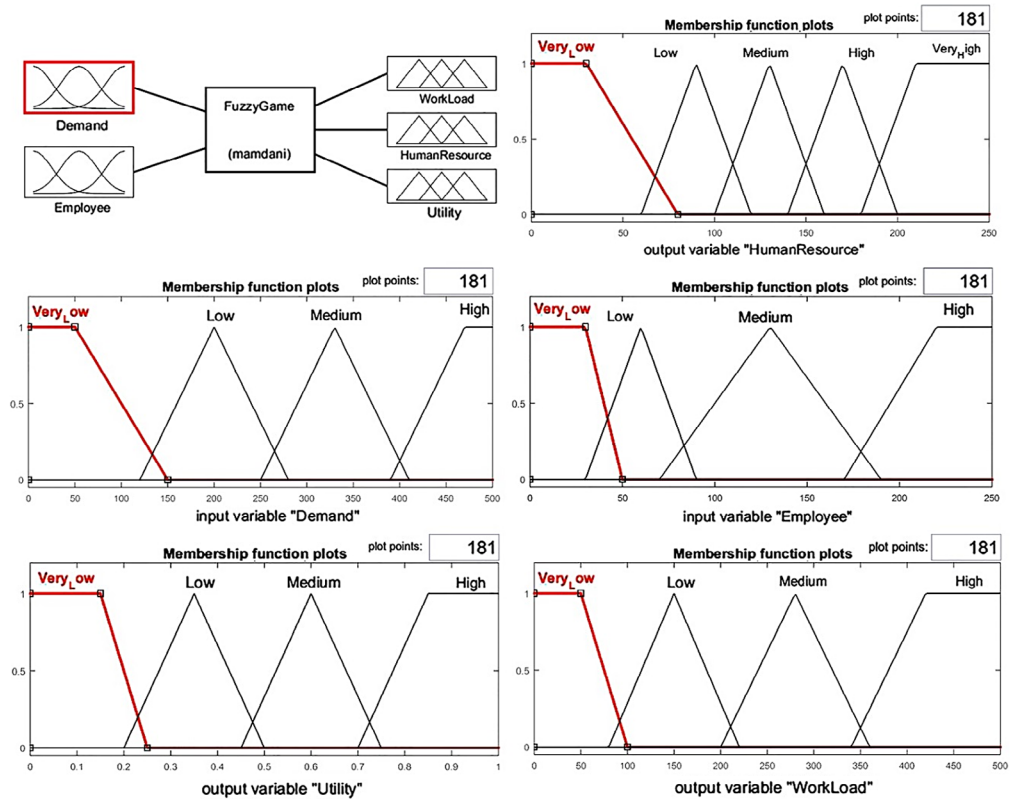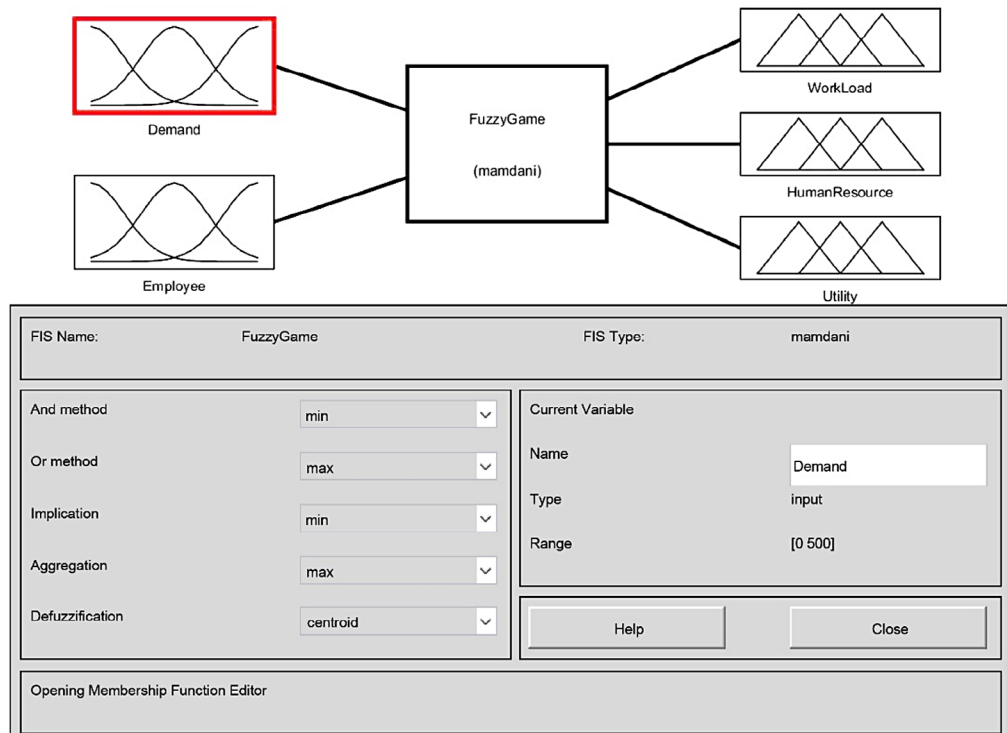

Figure 3. Inputs and outputs of the fuzzy inference system.

The output of Defuzzification process shows the number of human resource and the amount work and the rate of utility for the organizational unit for input of human resources and the work. After starting the game, the agents present their suggestions and the system converts the inputs to fuzzy numbers to provide more overlap between the demands of agents as well as to facilitate the negotiation process.

In fact, the decision-making of agents is done based on the fuzzy numbers in this game that has fuzzy values for the number of human resources, the amount of work and ultimately the fuzzy output for the rate of utility. Fuzzy Decision-Making System that has been designed based on the feedback of the game space, allows the agents to increase their utility as much as possible. Thus, in addition to the highest possible utility has been guaranteed for each of agents (organizational units), total utility (the performance of the units) also has reached to the highest possible value.

Fuzzy Decision-Making System based on feedback of the game space has been shown in Figure 4.

The formal problem statement can be stated as follows.

Suppose that in the organizational environment with two (or any specific number) units (agents) (N = {1, 2}), agents are negotiating for a higher utility to distribute the human resources and the amount of work (M = {1, 2}). The rate of each one of these resources is in range of $T \in \mathbb{N}, [0, T]$).

Any agent has detail information and the utility preferences of its own unit and as a self-interesting agent, try to maximize the utility of its represented unit. Agents use the Fuzzy Inference System in negotiation process.

Negotiations are performed periodically and, in every round, ($R \in \mathbb{N}$)) agents present their offers to other agents. This is continued until achieve an agreement or a level that one of the agents refuses from continue the negotiations. This way, if $X_i \in (0, 1)^2$ is the offer of agent $i (i \in N)$ (based on the considerable utility rate) in a round for a number of human resources and the amount of work (number 2 shows the offer for both resources) and $x_{ij} \in X_i$ is the rate of distributable resource j ($j \in M$) then agreement is defined as Equation (4). (X_i is the offer of agent i and x_{ij} is the utility rate from resource j):

$$\sum_{i=1}^{2} x_{ij} \leq 1 j \in M, \quad \forall X = (X_1, X_2) \tag{4}$$

In which, X is the offer by two agents in one of the rounds of the game. This equation guarantees that the number of distributed resources is not higher than the available amount. If the negotiations go on for their whole rounds, then it stops.

Figure 4. Fuzzy decision system based on feedback from space of game.
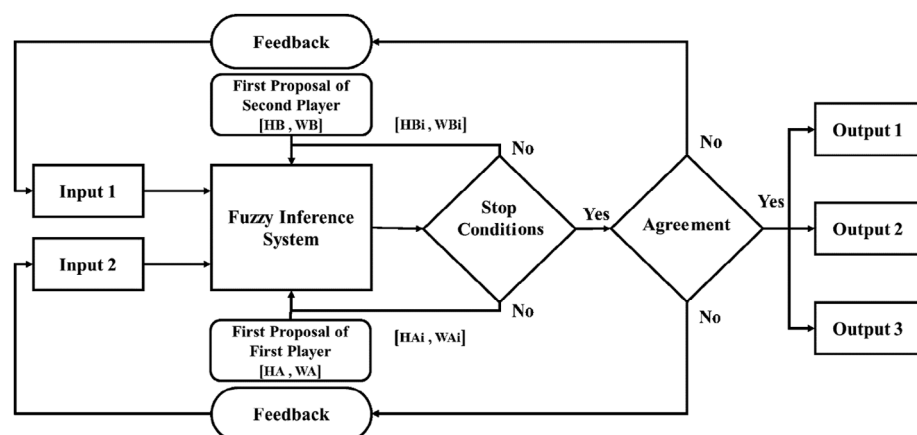
The objective is to identify optimal strategy for allocating the available human resources and the amount of work while maximizing organization productivity.

Obviously, the other condition for ending the negotiations is when agents agree on one solution. With this presupposition, utility function will be as $u_i:(0, 1)^{2*2}$ in which u_i, (X, n) is utility rate of agent i in round R with agreement. As a result, each organizational unit in case of agreement can utilize this model for calculation of utility and performance of the human resources.

Agents first present their initial suggestions using a fuzzy decision-making system model, and then receive the outputs, If the conditions are prepared for the continuation of the game, the new suggestion is presented fit into the best situations (highest utility) and this process continues until stop conditions are achieved. If the result is obtained, the outputs will be presented, otherwise the game is repeated, and the agents modify their own utility conditions and the process continues until the game finds the result or the number of repetitions of the game reaches the preset repetitions that in this case the game will be stopped.

6. The results of game and evaluation the model

The results of the game in different rounds have been shown in Table 7. After any round of the game, we apply the defuzzification process for the number of human resources for each organizational unit, the amount of work that he/she is responsible for it and the rate of utility for each agent (organizational unit) to convert fuzzy values to accurate numbers as well as the total utility for the whole of organization that is calculated by sum of the utilities of each agent.

The obtained results for each variable and for each organizational unit were defuzzed (from fuzzy mode converted to the numerical form) in each round of the game and then will be recorded as output. The results for total utility (last column of table) show that based on the result of the game, it can be said that the highest efficiency will be created for the whole organization in the second, fourth, tenth and twelfth rounds, respectively. These values show the amount of human resources for each of the units as well. Thus, the organizational units will be able to distribute the human resources to achieve the highest efficiency in the organization between themselves with knowledge of the effect of the amount of their own human resources on the other units as well as on the general performance of the organization.

To evaluate the model of sharing the work and allocation of the human resources presented in this research, validation of the presented model has been done based on opinions of experts and

Table 7. The results of the game and revenue of each unit and the total utility for organization							
Round of play	First actor (unit 1)			Second actor (unit 2)			Total of utility
	Number of human resource	Work amount	Utility	Number of human resource	Work amount	Utility	
1	90	280	0.60	137	201	0.56	1.16
2	124	150	0.83	89	341	0.73	1.56
3	210	320	0.45	30	168	0.48	0.93
4	177	256	0.67	57	203	0.70	1.37
5	152	302	0.56	91	186	0.37	0.93
6	121	178	0.71	106	279	0.69	1.4
7	158	271	0.38	87	204	0.28	0.66
8	180	196	0.28	54	294	0.78	1.06
9	98	172	0.61	152	305	0.59	1.2
10	101	234	0.82	142	234	0.71	1.53
11	145	263	0.49	84	189	0.57	1.06
12	197	302	0.57	53	198	0.68	1.25

cogent ·· engineering

compare to the similar works. For this purpose, the outputs of the proposed model (the number of human resources and the amount of work) as well as the proposed model in (Fang, 2015) has been given to the experts and its utility is questionable for experts of each of the units. The rate of utility of experts of each unit along with the utility of units in the proposed model have been shown in Table 8. As observed, the output of the model presented in this study is very close to opinions of experts and sometimes is also able to improve and optimize the organizational performance in addition to create understanding between units by suggesting how to allocate the human resources and sharing work. To illustrate this matter, the correlation between the expected utility of experts of units and the rate of utility (efficiency) in the model of Lee Fang has been shown with the rate of utility in model using Pearson correlation coefficient in Table 9. The correlation had been 0.831 for the first unit and 0.761 for the model of Lee Fang that has also been superior in some cases.

Table 8. The comparison of the opinions of experts of units and the model of Lee Fang and the outputs of the model

Second unit				First unit			
Utility in model	The amount of utility (efficiency)in Lee Fang model	Work amount	Number of human resource	Utility in model	The amount of utility in Lee Fang model	Work amount	Number of human resource
0.56	0.65	201	137	0.60	0.53	280	90
0.73	0.61	341	89	0.83	0.75	150	124
0.48	0.38	168	30	0.45	0.44	320	210
0.70	0.67	203	57	0.67	0.58	256	177
0.37	0.48	186	91	0.56	0.69	302	152
0.69	0.61	279	106	0.71	0.65	178	121
0.28	0.37	204	87	0.38	0.48	271	158
0.78	0.69	294	54	0.28	0.37	196	180
0.59	0.71	305	152	0.61	0.57	172	98
0.71	0.62	234	142	0.82	0.65	234	101
0.57	0.47	189	84	0.49	0.56	263	145
0.68	0.55	198	53	0.57	0.46	302	197

Table 9. The correlation between the opinions of experts of units and Lee Fang model with the outputs of the model

The correlation between the amount of the expected utility of experts of the first unit and amount of utility in the model

		The expected utility of experts	The amount of utility in the model
The expected utility of experts	Pearson correlation	1	0.831**
	Sig. (2-tailed)		0.001
	N	12	12
The amount of utility in the model	Pearson correlation	0.831**	1
	Sig. (2-tailed)	0.001	
	N	12	12

High correlation in the level of 0.01**

The correlation of utility amount (efficiency) in Lee Fang model with the amount of utility in the model

		Utility in Lee Fang model	The amount of utility in the model
Utility in Lee Fang model	Pearson correlation	1	0.761**
	Sig. (2-tailed)		0.004
	N	13	12
The amount of utility in the model	Pearson correlation	0.761**	1
	Sig. (2-tailed)	0.004	
	N	12	12

High correlation in the level of 0.01**

cogent ··engineering

7. Conclusion and suggestions

Optimal distribution of the human resources to achieve optimal performance is one of the organizational challenges that is investigated in this article. The rate of productivity of the organization has direct relationship with the number of human resources and the amount of works allocated. Researches shows that the organization needs to take to account some other criteria such as the current and previous performance rate of the units, the whole organizational performance beside the unit's performance, dynamic and vagueness in some conditions and capability to consider the changes in organizational environment in the allocation process. Using simple models and algorithms could not consider all these criteria's in the allocation process. According to researches, interaction between the organizational units has a key role in the optimal allocation process. Meanwhile considering expert's opinions about performance of the units as a historical input is necessary in the allocation process.

This research applies the game theory model and the fuzzy theory to model the environment of organization, the allocation process and interactions between the organizational units by deploying the productivity and utility for them. So that we try to simulate the organizational environment and consider more realistic factors in our model.

Utility of having different numbers of human resources and the amount of work were considered as the revenue of the organizational units by creating the game conditions for the organizational units for dividing human resources. Then the organizational units participated in a negotiating process by design a cooperative game and using the fuzzy theory to convert the accurate values to fuzzy values. The primary inputs for the number of human resources and amount of work in the organization have been considered 250 people and 500 working shifts, respectively. Fuzzy decision-making system in the negotiation process helps the possibility to achieve the result of game through facilitating the possibility of overlapping the demands of units and for this purpose, fuzzy inputs are used for the number of human resources, the amount of work and the rate of utility during the game by the units. Fuzzy results obtained from the game were defuzzed and the numerical results of the game have been shown for the number of human resources and the amount of work, and the rate of utility for the units for their different demands that show the highest organizational performance for units is when 124 and 89 human resources, respectively and 150 and 341 working shifts, respectively to be allocated for the first and second units, that in this case the total utilities (organizational efficiency) is at the highest level. Thus, the organizational units could participate in a cooperative game using fuzzy game theory and achieve their own and organization' maximum utility and performance and organization through negotiation with other units. The opinions of experts and comparison of the model with similar researches were used to evaluate the model.

Our model has been used in a hospital case that has more clear structure for different units and expert people of any unit simply is available. We need to implement our model in different cases and organizations to improve its reliability and robust to suggest using widely.

According to the results of present research, for future researches we will try to design a self-learning process of the organizational units to update the information of performance of the units and using it in the negotiating process to strengthen the more dynamic of the model. Attention to other key elements such as observing the fair and justice of work among employees in the process of allocation of the human resources to improve the organizational efficiency. Also, we follow using the proposed model in allocation of the resources except the human resources and in the other areas.

Author details
Rahim Khanizad[1]
E-mail: Rahim.Khanizad@modares.ac.ir

ORCID ID: http://orcid.org/0000-0002-8031-8507
Gholamali Montazer[2]
E-mail: Montazer@modares.ac.ir

[1] Faculty of Management and Economics, ITM Department, Tarbiat Modares University, Jalal e Ale Ahmad, Tehran, Iran.
[2] Faculty of Engineering, IT Department, Tarbiat Modares University, Jalal e Ale Ahmad, Tehran, Iran.

cogent ·· engineering

Citation information

Cite this article as: Optimal allocation of human resources based on operational performance of organizational units using fuzzy game theory, Rahim Khanizad & Gholamali Montazer, *Cogent Engineering* (2018), 5: 1466382.

References

Aickelin, U., & Li, J. (2007). An estimation of distribution algorithm for nurse scheduling. *Annals of Operations Research, 155*(1), 289–309.

Ammar, A., Elkosantini, S., & Pierreval, H. (2012). Resolution of multi-skilled workers assignment problem using simulation optimization: A case study. *IEEE International Conference on Automation Science and Engineering, 1,* 748–754.

Azimi, M., Beheshti, R. R., Imanzadeh, M., & Nazari, Z. (2013). Optimal allocation of human resources by using linear programming in the beverage company. *Universal Journal of Management and Social Sciences, 3*(5), 48–54.

Banerjee, N., Biswas, S., & Chintada, S. (2006). A game – theoretic analysis of converged cellular-voip services. In *IEEE Third consumer communications and networking conference CCNC 2006* (Vol. 2, pp. 715–719). Nevada: IEEE.

Bard, J. F., & Purnomo, H. W. (2006). Incremental changes in the workforce to accommodate changes in demand. *Health Care Management Science, 9,* 71–85.

Barreto, A., Barros, M. O., & Werner, C. M. L. (2008). Staffing a software project: A constraint satisfaction and optimization-based approach. *Computers & Operations Research, 35,* 3073–3089.

Bennour, M., Addouche, S., & El Mhamedi, A. (2012). RCPSP sous contraintes de compe'tences dans un service de maintenance. *European Journal of Information Systems, 46*(8), 877–907. doi:10.3166/jesa.46.877-907

Borba, L., & Ritt, M. (2014). A heuristic and a branch-and-bound algorithm for the assembly line worker assignment and balancing problem. *Computers & Operations Research, 45,* 87–96.

Bouajaja, S., & Dridi, N. (2017). *International Journal of Operational Research, 17,* 339. doi:10.1007/s12351-016-0247-8

Braathen, S., & Sendstad, O. J. (2004). A hybrid fuzzy logic/constraint satisfaction problem approach to automatic decision making in simulation game models. *IEEE Transactions on Systems, Man, and Cybernetics-Part B: Cybernetics, 34*(4), 1786–1797.

Burke, E. K. (2004). The state of the art of nurse rostering. *Journal of Scheduling, 7*(6), 441499.

Burke, E. K., Curtois, T. E., Post, G., Qu, R., & Veltman, B. (2007). A hybrid heuristic ordering and variable neighborhood search for the nurse rostering problem. *European Journal of Operational Research, 188*(2), 330–341.

Cheang, B., Li, H., Lim, A., & Rodrigues, B. (2003). Nurse rostering problems–a bibliographic survey. *European Journal of Operational Research, 151,* 447–460.

Costa Filho, C. F. F., Rocha, D. A. R., Costa, M. G. F., & de Albuquerque Pereira, W. C. (2012). Using constraint satisfaction problem approach to solve human resource allocation problems in cooperative health services. *Expert Systems with Applications, 39*(1), 385–394.

Costantino, F., & Gravio, D. G. (2009). Multistage bilateral bargaining model with incomplete information, a fuzzy approach. *International Journal of Production Economics, 117*(2), 235–243.

Daher, S. F. D., & Almeida, A. T. (2010). Recent patents using group decision support systems: A short review. *Recent Patents on Computer Science, 3,* 81–90.

De Bruecker, P., Van den Bergh, J., Beliën, J., & Demeulemeester, E. (2015). Workforce planning incorporating skills: State of the art. *European Journal of Operational Research, 243,* 1–16.

De Wilde, P. (2010). Dynamics of business games with management of fuzzy rules for decision making. *International Journal of Production Economics, 128*(1), 96–109.

Dowsland, K. (1998). Nurse scheduling with Tabu search and strategic oscillation. *European Journal of Operational Research, 106,* 393–407.

Dweiri, F. T., & Kablan, M. M. (2006). Using fuzzy decision making for the evaluation of the project management internal efficiency. *Decision Support Systems, 42*(2), 712–726.

Endriss, U., Maudet, N., Sadri, F., & Toni, F. (2006). Negotiating socially optimal allocations of resources. *Journal of Artificial Intelligence Research, 25,* 315–348.

Famuyiwa, O., Monplaisir, L., & Nepal, B. (2008). An integrated fuzzy-goal-programming based framework for selecting suppliers in strategic alliance formation. *International Journal of Production Economics, 113*(2), 862–875.

Fang, L. (2015). Centralized resource allocation based on efficiency analysis for step-by-step improvement paths. *Omega, Elsevier, 51*(C), 24–28.

Fisher, R., & Ury, W. (1981). *Getting to yes: Negotiating agreement without giving in.* Boston, MA: Houghton Mifflin.

Fitzgerald, M. E., & Ross, A. M. (2015). Effects of enhanced multi-party trade space visualization on a two-person negotiation. *Procedia Computer Science, 44,* 466–475.

Gerogiannis, V. C., Rapti, E., Karageorgos, A., & Fitsilis, P. (2015, March 3–5). A fuzzy linguistic approach for human resource evaluation and selection in software projects. In *Proceedings of the international conference on industrial engineering and operations management.* Dubai: United Arab Emirates (UAE). doi:10.1109/IEOM.2015.7093709

González, E., Espín, R. A., & Fernández, E. (2015). *Negotiation based on fuzzy logic and knowledge engineering: Some case studies.* Business Media Dordrecht, Springer Science. doi:10.1007/s10726-015-9446-6

Güler, M. G., Keskin, M. E., Döyen, A., & Akyer, H. (2015). On teaching assistant-task assignment problem: A case study. *Computers & Industrial Engineering, 79,* 18–26.

Gunawan, A., & Ng, K. M. (2011). Solving the teacher assignment problem by two metaheuristics. *International Journal of Information and Operations Management, 22*(2), 73–86.

Haspeslagh, S., De Causmaecker, P., & Berghe, G. V. (2012). *Framework for negotiation in Distributed Nurse Rostering Problems* (pp. 426–431). PATAT.

Huang, H., & Wang, D. (2010). Double auction modeling based on fuzzy game. In *3rd International conference on intelligent networks and intelligent systems (ICINIS)* (pp. 374–377).

Kang, D., Jung, J., & Bae, D.-H. (2011). Constraint-based human resource allocation in software projects. *Software Practice Experience, 41,* 551–577.

Korhonen, P., & Syrjänen, M. (2004). Resource allocation based on efficiency analysis. *Management Science, 50*(8), 1134–1144.

Korobkin, R. (2008). Against integrative bargaining. *Case Western Reserve Law Review, 58*(4), 1323–1342.

Kyriklidis, C., Vassiliadis, V., Kirytopoulos, K., & Dounias, G. (2014). Hybrid nature-inspired intelligence for the resource leveling problem. *Journal of the Operational Research Society, 14*(3), 387–407.

Lanzarone, E., & Matta, A. (2014). Robust nurse-to-patient assignment in home care services to minimize overtimes under continuity of care. *Operations Research for Health Care, 3*(2), 48–58.

Lewicki, R., Weiss, S., & Lewin, D. (1992). Models of conflict, negotiation and third-party intervention: A review and synthesis. *Journal of Organizational Behavior, 13*(3), 209–252.

Lucas, Teixeira, & Huzita, E. H. M. (2014). DiSEN-AlocaHR: A multi-agent mechanism for human resources allocation in a distributed software development environment. *Distributed Computing and Artificial Intelligence, Advances in Intelligent Systems and Computing, 290*, 227–234.

Lukas, S., Aribowo, A., & Muchri, M. (2013). Solving timetable problem by genetic algorithm and heuristic search case study: Universitas Pelita Harapan timetable. *Real-World Applications of Genetic Algorithms, 378*, 303–317.

Menkel-Meadow, C. (1993). Lawyer negotiations: Theories and realities what we learn from mediation. *The Modern Law Review, 56*(3), 361–379.

Mircica, N. (2014). Constructive communication in effective negotiation. *Analysis and Metaphysics, 13*, 64–72.

Moreira, M. C. O., Miralles, C., & Costa, A. M. (2015). Model and heuristics for the assembly line worker integration and balancing problem. *Computers & Operations Research, 54*, 64–73.

Mota, C. M. M., Almeida, A. T., & Alencar, L. H. (2009). A multiple criteria decision model for assigning priorities to activities in project management. *International Journal of Project Management, 27*(2), 175–181.

Murakami, K., Tasan, S. O., Gen, M., & Oyabu, T. (2011). A case study of human resource allocation for effective hotel management. *Industrial Engineering and Management Systems, 10*(1), 54–64.

Mutlu, Ö., Polat, O., & Supciller, A. A. (2013). An iterative genetic algorithm for the assembly line worker assignment and balancing problem of type-II. *Computers & Operations Research, 40*(1), 418–426.

Negnevitsky, M. (2005). *Artificial intelligent systems*. England: Pearson Education.

Nembhard, D. A., & Bentefouet, F. (2015). Selection, grouping, and assignment policies with learning-by-doing and knowledge transfer. *Computers & Industrial Engineering, 79*, 175–187.

Oderanti, F.O., & De Wilde, P. (2009). Automated fuzzy decision-making system with learning in business networks of varying connectivity. In *Proceedings of UK workshop on computational intelligence, 7th–9th September (UKCI), Nottingham* (pp. 31–36).

Ornek, A., & Ozturk, C. (2016). Optimization and constraint based heuristic methods for advanced planning and scheduling systems. *International Journal of Industrial Engineering: Theory, Applications and Practice, 23*(1).

Osman, M. S., Abo-Sinna, M. A., & Mousa, A. A. (2005). An effective genetic algorithm approach to multi objective resource allocation problems (moraps). *Applied Mathematics and Computation, 163*(2), 755–768.

Otero, L. D., Centeno, G., Ruiz-Torres, A. J., & Otero, C. E. (2008). A systematic approach for resource allocation in software projects. *Computers and Industrial Engineering, 56*(4), 1333–1339.

Oussedik, S. (2007). ILOG. ODMS: A system for developing interactive. Optimization-Based Planning and Scheduling. Applications. In *MISTA'07*. Paris: Plenary Talk.

Özcan, E. (2005). Memetic algorithms for nurse rostering. In *Proceedings of the 20th International Symposium on Computer and Information Sciences. Springer Lecture Notes in Computer Science* (Vol. 3733, pp. 482–492).

Parsons, S., & Wooldridge, M. (2000). *Game theory and decision theory in multi-agent systems*. Dordrecht: Kluwer Academic Publishers.

Roque, L., Araújo, A. A., Dantas, A., Saraiva, R., & Souza, J. (2016). Human resource allocation in Agile software projects based on task similarities. In F. Sarro & K. Deb (Eds.), *Search based software engineering. SSBSE 2016. Lecture notes in computer science* (Vol. 9962, pp. 1–1). Cham: Springer.

Ross, P. (2005). Chapter 16: Hyper-heuristics. In E. K. Burke & G. Kendall (Eds.), *Search methodologies: Introductory tutorials in optimization and decision support methodologies*. Springer.

Santos, T. J. A., Lima, A. M., Reis, C. A. L., & Reis, R. Q. (2014). Automated support for human resource allocation in software process by cluster analysis. In *Proceedings of the 4th International Workshop on Recommendation Systems for Software Engineering (RSSE 2014)* (pp. 30–31). New York, NY: ACM. doi:10.1145/2593822.2593830

e Silva, L. C., & Costa, A. P. C. S. (2013). Decision model for allocating human resources in information system projects. *International Journal of Project Management, 31*, 100–108.

Turocy, T. L., & von Stengel, B. (2001). *Game theory*. CDAM Research Report LSE-CDAM-2001-09.

Vilà, M., & Pereira, J. (2014). A branch-and-bound algorithm for assembly line worker assignment and balancing problems. *Computers & Operations Research, 44*, 105–114.

Wang, Q., & Liu, M. (2010). Optimization of task allocation and knowledge workers scheduling based on ant colony algorithm. In *International Symposium on Intelligence Information Processing and Trusted Computing (IPTC)* (pp. 386–389).

Wang, S. Q., Gong, L. H., & Yan, S. L. (2009). The allocation optimization of project human resource based on particle swarm optimization algorithm. In *Proceedings of the 2009 IITA International Conference on Services Science, Management and Engineering* (pp. 169–172).

Wang, S., Wang, L., Li, Y., & Sun, J. (2012). Study on ant colony optimization for people assign to job problem. In *Proceedings of 24th Chinese control and decision conference (CCDC)* (pp. 872–874).

Wooldridge, M. (2012). Does game theory work? *IEEE Intelligent Systems, 27*(6), 76–80.

cogent •• engineering

Cogent Engineering (ISSN: 2331-1916) is published by Cogent OA, part of Taylor & Francis Group.

Publishing with Cogent OA ensures:

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

Submit your manuscript to a Cogent OA journal at www.CogentOA.com