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Designing a Fuzzy Expert System With a Hybrid Approach to Select Operational Strategies in Project-Based Organizations with a Selected Competitive Priority

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ABSTRACT
This research was conducted in order to solve the problem of selecting an operational strategy for projects in project-based organizations by designing a fuzzy expert system. In the current research, we first determined the contributing parameters in operational strategy of project-based organizations based on existing research literature and experts' opinion. Next, we divided them into two groups of model inputs and outputs and the rules governing them were determined by referring to research literature and educational instances. In order to integrate rules, the revised Ternary Grid (revised TG) and expert opinions were applied according to a hybrid algorithm. The Ultimate rules were provided in Fuzzy Inference System format (FIS). In this FIS, proper manufacturing decisions are recommended to the user based on selected competitive priority and also project properties. This paper is the first study in which rules and relations governing the parameters contributing operational strategy in project-based organizations are acquired in a guided integrated process and in the shape of an expert system. Using the decision support system presented in this research, managers of project-based organizations can easily become informed of proper manufacturing decisions in proportion with selected competitive priority and project properties; and also be ensured that theoretical background and past experiences are considered.

Keywords: Operational Strategy, Project-based Organization, Rules Extraction, Expert System

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1. INTRODUCTION

Since operational strategy is of high importance in manufacturing organizations in achieving the manufacturing goals of the organization, widespread studies have been conducted and different models have been developed in this area. In spite of the fact that many organizations today have a project-oriented entity, and despite the worthwhile role that executing projects play in different civil sections and the industry, few research studies have been conducted for operational strategy of project-based organizations.

There have been several definitions for operational strategy or manufacturing strategy. Among them, Skinner (1969) is the pioneer in defining manufacturing strategy. In his view, manufacturing strategy points to special features of manufacturing as a competitive arm. Operational strategy is a pattern of related decisions and proceedings, both structural and infrastructural, which determine the manufacturing system capability and determine how to act to meet a set of manufacturing goals, compatible with firm major objectives (Karacapilidis *et al*., 2006). There are two views toward the process of operational strategy. Market-based view (MBV) develops firm analysis from the outside. It is expected that manufacturing performance depends on the situation of the market (Großler, 2007). While in the resource-based view (RBV), the firm gets more profit from focusing on improvement, protection, and the influence of resources and its operational advantages to change the rules of competition (Gagnon, 1999).

The first step in operational strategy is to determine what the system is going to achieve. Operational competitive priorities must be in line with commercial objectives, meet the market needs, consider the competitors' performance, and find strengths and weaknesses. For any manufacturing organization or system like project-based organizations, a series of competitive priorities could be defined that are what the manufacturers present to their customers. For instance, we can point to competitive priorities like cost, time, quality, reliability of delivery, contribution and flexibility.

In surveying research studies conducted on project-based organizations, it is realized that there are other factors besides competitive priorities considering which influences manufacturing decisions and makes them more effective, and ignoring which leads to improper decisions.

In this regard Wysocki (2003) investigated the effect of project size, complexity, type and uncertainty on project performance. Cleland and Ireland (2006) also investigated the effect of project size (number of people, project value and duration), level of project risk and project complexity on the implementation of the project. In different studies, other factors in this context such as project life cycle or others have been referred to as being known as project properties.

To benefit from the advantage of operational strategy, it is required to have this strategy developed and implemented. Therefore, once the competitive priorities are determined, the next step is to develop methods through which these priorities are derived (Tan and Platts, 2004). Manufacturing decisions are defined as a set of proceedings contributing to the achievement of special manufacturing goals (Diaz *et al*., 2007). Despite lack of consensus over the conception of operational strategy, it seems that two main groups of components titled priorities and decision domains are the matter of consensus (Leong *et al*., 1990). Competitive priorities are defined as a constant set of goals while decision domains are those trying to hold key choices for operational strategy (Oltra *et al*., 2005). Manufacturing decisions consist of main decisions like structural and infrastructural ones (Hayes *et al*., 1984). Decisions regarding the equipment, organization or work force; and all related variables that are used in project management configuration are also placed at this level (Oltra *et al*., 2005).

There are two general orientations in research background related to operational strategy. In a series of these research studies, the relationship among existing variables in operational strategy is studied while in the other series, integrated algorithms and models are presented to develop operational strategies.

From the first orientation point of view: Miltenburg (2005) divided manufacturing decisions in manufacturing strategy into two structural and infrastructural classes. Infrastructural decisions consist of three manufacturing sub-systems: human resource, manufacturing control and planning, and organizational structure. Structural decisions are related to three manufacturing sub-systems: resources (vertical integration), process technology and infrastructures. Gareis and Huemann (2000) studied project management qualifications in project-based organizations. In order to have project management as a competitive advantage for these organizations, the qualifications of project manager, project team, and the relevant organization must be consistent with each other. Five roles are defined for people active in projects and qualifications are mentioned for each of them. Bevilacqua *et al*. (2014), studied the relationship between the personality of project manager and project performance in the domains of cost and time in multinational firms by using value stream mapping. They used Myers-Briggs indices to analyze the personality of project managers.

Cleland and Ireland (2006) studied the relationship between competitive priorities of cost, time and innovation with manufacturing decision of organizational structure in project-based organizations. Wysocki (2002) also presented relationships between the project type and project importance with proper organizational structure, and relationships between the project size, project complexity, time and cost competitive priorities with leadership style. Oltra *et al*. (2005) configured the operational strategy in project firms. They considered operational strategy as a proper medium between subjects in project management and strategic management and analyzed operational strategy in 130 Spanish project-based firms. The authors have studied the relationship between identified operational strategies and other important variables in project management configuration. Müller and Turner (2007) studied the relationship between different leadership styles of project managers and types of project and the level of their success. In this research, six characteristics are used to categorize different types of projects. The results show that the project manager's leadership style affects the success of the project and different leadership styles are suitable for different projects. In a research study, Maylor *et al*. (2015) presented a model for operational strategy process in project-based organizations. The competitive priorities used in this study were quality, cost, delivery and flexibility.

From the second orientation's point of view: Applying competitive priorities, a structured model from the creation and evaluation of practical action that could be helpful in achieving the required priorities is essential. For this reason, a general overview of potential practical plans which count on past experiences is essential. One of these models is the connectance model developed by Burbidge (1984). In this model, a manufacturing system is defined as a set of variables such that a change in each of them introduces a change in at least another one. Showing the variables and their relationship in a grid diagram helps us present a general view of the situation being studied.

According to the improvement made on Burbidge's Connectance Model, Tan and Platts (2004) presented a tool for the improvement of manufacturing goals. The presented model in this research is now available for users as a software abbreviated as TAPS programmed in Visual Basic.

Karacapilidis *et al*. (2006) have presented a computerized knowledge management system for the process of manufacturing strategy. In this study, Co-Mass application running under Internet Explorer environment was designed to acquire an organization's managerial knowledge based on various experiences and career cases in order to make decisions for solving issues in the field of manufacturing strategy.

Cil and Evren (1998) recommended a framework in which connectance among manufacturing strategy, market requirement, and manufacturing properties were used to determine new manufacturing technology. To achieve this, some researchers designed an expert system and implemented it by VP-Expert. Tamura (2013) presented an expert system to recommend a new product improvement strategy for firms. In this system, a new product improvement strategy was recommended by considering the market, the consumers' demands, and the firm's capabilities as inputs,

Although various models and tools have been presented in the operational strategy domain, there has not been enough research studies conducted in this field for project-based organizations as it is evident from the literature. Using a single approach for leading all projects even in a single organization cannot practically provide the desired results since every project has its special and exclusive properties. Therefore, project-based organizations must use different operational strategies for any project or group of projects. Hence, one main concern of project-based organizations is choosing a proper operational strategy in such a way as to become able to achieve competitive priority in the best possible way by making right manufacturing decisions.

On the other hand, according to what has been mentioned before, operational managers in project-based organizations are facing project management considerations plus market considerations related to products or services. Now the question to be addressed is the considerations that an operational manager must prefer.

The aim of this research is to identify key variables in the process of operational strategy of project-based organizations and present a model and consequently a tool to enable its users to benefit from research literature, experts' experiences in this domain, and results of previous projects at the same time. A very helpful tool in this regard is the use of expert systems. For this purpose, an algorithm is presented in which all mentioned resources are applied to acquire rules with a hybrid approach; and the revised Ternary Grid (revised TG) method is applied in order to integrate the rules.

The main innovation in this study is thematic contribution, to the best of our knowledge, no previously reported research study has presented a comprehensive model for operational strategy process in project-based organizations, identified important factors and the relations between them. Moreover, no previous research study has extracted causal rules between the inputs and outputs of the model. These are precisely the contributions of the present research study. Another innovation of this study is providing an expert system for the first time plus a hybrid algorithm that uses different sources to extract rules and reduces mere affiliation to the experts for preparation of the expert system. This has also not been done so far. Development of Ternary Grid method for fuzzy rules, was also conducted for the first time in this study.

Using the decision support system presented in this research, managers of project-based organizations, can become aware of proper manufacturing decisions in proportion with competitive priority and project properties without spending too much time and in a guided integrated process and without spending too much time; and ensure that theoretical background and past experiences are considered.

For this purpose, the structure of the manuscript will be as follows: In section two, research method and the algorithm used in the research is discussed; in section three an expert system for operational strategy in project-based organizations is implemented with a selected competitive priority; and in section four, conclusions are presented about the research subject.

2. RESEARCH METHODOLOGY

The population studied in this research is project-based organizations. However, the realm of study is limited to organizations doing design and construction projects due to the variety of projects and the fact that the nature of some of them like organizational improvement projects and software projects are totally different. In this study, the view toward operational strategy is market-based which was revised by the authors in proportion with project-based organizations. Its schematic view is depicted in Figure 1.

In order to determine the constituting variables for every operational strategy parameter (competitive priorities, project properties, and manufacturing decisions) , the results obtained were given to 15 experts in industry and university for adding and rating items in Delphi questionnaire after extensive analysis of textual content. Final selected variables are presented in Table 1.

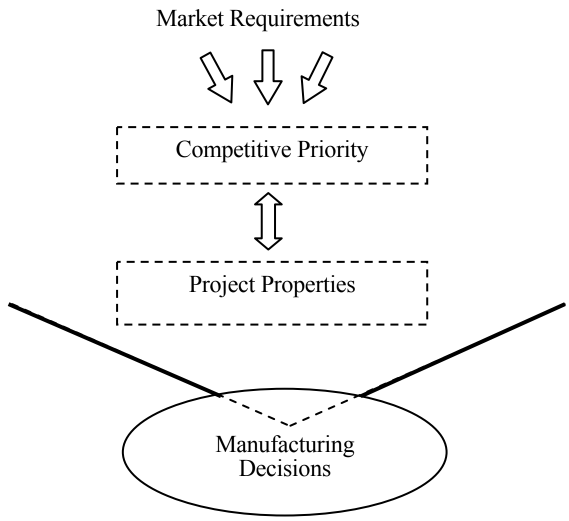

Figure 1. Research conceptual model: project-oriented operational strategy process.

Table 1. Results of Delphi method for variables constituting operational strategy in project-based organizations

Parameter Type	Code	Title	Some of the resources
Competitive Priorities	C1	Cost	Cleland and Ireland (2002), Lamvik *et al*. (2003), Söderlund (2004), Oltra *et al*. (2005), Mun *et al*. (2008), da Conçeião Júnior (2009), Levitt (2012), Maylor *et al*. (2015)
	C2	Quality	Cleland and Ireland (2002), Söderlund (2004), Oltra *et al*. (2005), Mun *et al*. (2008), da Conçeião Júnior (2009), Levitt (2012), Maylor *et al*. (2015)
	C3	Time	Cleland and Ireland (2002), Lamvik *et al*. (2003), Söderlund (2004), Mun *et al*.(2008), da Conçeião Júnior (2009), Levitt (2012), Maylor *et al*. (2015)
	C4	Flexibility	Cleland and Ireland (2002), Oltra *et al*. (2005), da Conçeião Júnior (2009), Maylor *et al*. (2015)
	C5	Innovation	Oltra *et al*. (2005), da Conçeião Júnior (2009)
	C6	Reliability of Delivery	Lamvik *et al*. (2003), Oltra *et al*. (2005), da Conçeião Júnior (2009), Maylor *et al*. (2015)
	C7	Service	Oltra *et al*. (2005), da Conçeião Júnior (2009), Maylor *et al*. (2015)
Project Properties	P1	Project Complexity	Dvir *et al*. (1998), Cleland and Ireland (2002), Söderlund (2004), Müller and Turner (2007)
	P2	Project Type	Dvir *et al*. (1998), Cleland and Ireland (2002), Müller and Turner (2007)
	P3	Project Size	Turner and Keegan (2001), Cleland and Ireland (2002), Söderlund (2004), Oltra *et al*. (2005),
	P4	Project Uncertainty	Dvir *et al*. (1998), Cleland and Ireland (2002), Söderlund (2004), Oltra *et al*. (2005),
Manufacturing Decisions	M1	Organizational Structure	Galbraith (1971), Gareis and Huemann (2000), Turner and Keegan (2001), Cleland and Ireland (2002), Oltra *et al*. (2005), da Conçeião Júnior (2009)
	M2	Leadership Style	Cleland and Ireland (2002), Turner and Müller (2005), Müller and Turner (2007)
	M3	Implementation Method	Turner and Keegan (1999), Maylor *et al*. (2015)
	M4	Procurement Method	El Wardani *et al*. (2006), Eriksson and Westerberg (2011), Love (2002)
	M5	Project Manager Competences	Gareis and Huemann (2000), Müller and Turner (2007), da Conçeião Júnior (2009)

In three runs of the Delphi method, the values obtained for Kendall's coefficient of concordance, as a scale for determining the degree of concordance and agreement among experts, were 0.31, 0.56, & 0.6, respectively. These figures show the efficiency of the number of run times and desired agreement among the group of experts (Zar, 1999).

Regarding the competitive priorities, in the first round of the Delphi method, six variables that have been frequently reported in the literature were presented to the experts for commenting and rating. In the second and third rounds, some other variables were presented by the experts, in addition to confirmation of the proposed items, but only the service variable was approved and added. Regarding the project properties, in the first round of the Delphi method, four frequent variables reported in the literature were presented to the experts for commenting and rating. In the second and third rounds, the company type variable was omitted and some other variables were presented by the experts. However, only project type in terms of ownership was approved and added. Regarding the manufacturing decisions, in the first round of the Delphi method, six frequent variables reported in the literature were presented to the experts for commenting and rating and the planning type variable was omitted.

The experts who were interviewed were in two groups. A group of them consisted of University professors in industrial management and industrial engineering who had the experience of/familiarity with industrial issues, particularly in project form. The other group of experts consisted of industry experts selected from amongst the managers of project-based organizations or project managers with at least 10 years of experience and at least managing three projects. Those who had high education or at the same time taught at the University were given a priority.

The main problem of designing management expert systems is inaccessibility of experienced experts in all dimensions related to the topic and acquiring all the rules from their knowledge (even if we have any) requires a lot of time and their full time presence that is not possible in practice. Therefore, in order to acquire and integrate rules from different sources like research literature, educational instances, and expert views, an applicable hybrid approach is presented in this research study. The related algorithm is depicted in Figure 2.

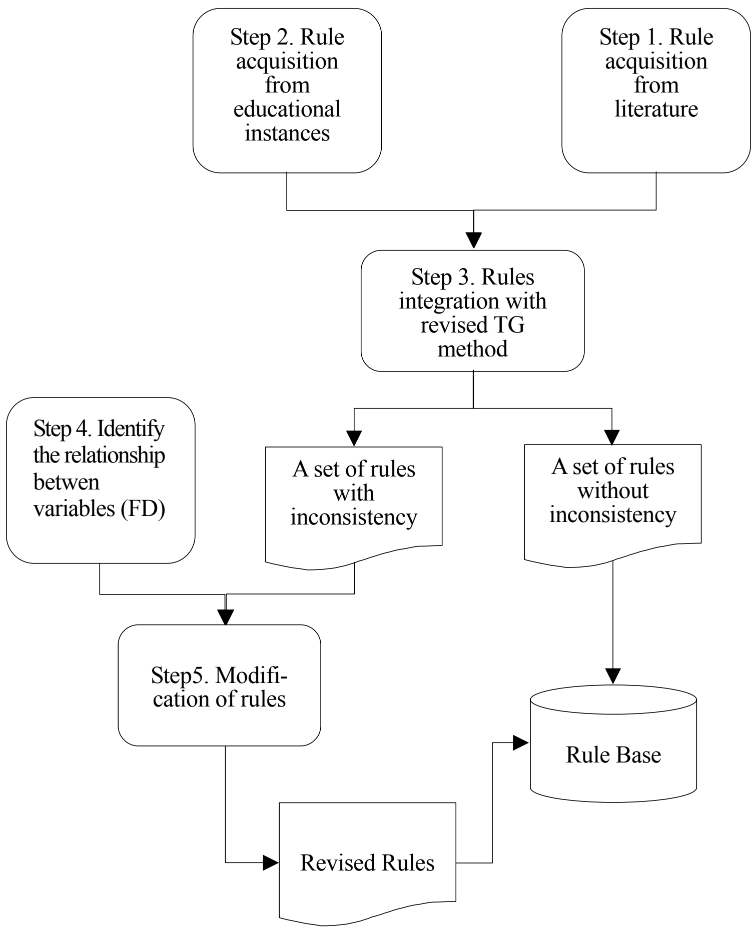

Figure 2. Algorithm for acquiring and integrating rules

This algorithm increases the reliability of the final rules along with decreasing the dependence on experts.

Step 1. In this step, rules in this domain are acquired and recorded through extensive study of research literature.

Step 2. In order to collect educational data from project instances, a researcher made questionnaire was used that comprised of three sections. In section one, some questions were devised for selected competitive priority and every property of the project according to measures presented in previously reported research studies in order to identify the level of importance for related competitive priority, and the condition of other properties in the related project within continuous spectrum of 1 to 4.

As the measures used are acquired from different projects, their validity was studied using confirmatory factor analysis over the initial samples in SPSS 19.0; and all the items were confirmed. Reliability was also confirmed as the calculation of Cronbach's alpha shows to be higher than 0.7. In the second section of the questionnaire, the condition of the pertinent project was questioned in line with the identified manufacturing decisions, according to Table 2. In section three that is the final section of the questionnaire, performance of the pertinent project in selected competitive priority was questioned.

According to the data obtained from educational instances in accordance with the designed questionnaire, a decision tree was formed and rules were acquired using Clementine 12.0 and C5 algorithm.

The fundamental and distinguishing point in applied educational instances of the current study compared to other items (from which a series of rules are to be acquired), is that each educational instance might be successful or unsuccessful according to each competitive priority.

Therefore, one of the research limitations is that at first only one competitive priority must be selected the success or failure of every educational instance be determined and based on that priority. Then, successful instances of using samples to acquire rules were noted in the original form without modification and unsuccessful samples are used after modification in manufacturing decisions. Thus, the following method was applied in order to acquire rules.

Step 2.1 This step includes determining the type of sample from the view of success for all samples according to pertinent competitive priority. In addition, it includes using the rules mentioned in Table 3, to determine whether these samples have been successful or not.

The method of acquiring the rules mentioned in Table 3 is by considering Importance-Performance Analysis (IPA) that is shown in Figure 3.

Step 2.2 Forming decision tree: for every group of manufacturing decisions as is explained here a decision tree is formed separately and rules are acquired.

According to the processing in previous step, if that sample is successful in pertinent competitive priority, the same decision is used in forming the tree and if the sample is unsuccessful or it is somewhere in the middle, then the revised decision, starting with V or N (meant relative or complete contradiction) is used in forming the tree.

Table 2. Possible choices for every manufacturing decision

manufacturing decision	Possible choices
Organizational Structure	Functional, Weak Matrix, Balanced Matrix, Strong Matrix, Projectized
Leadership Style	Laissez-faire, Democratic, Autocratic, Bureaucratic
Implementation Method	in house (single-factor); design-built (two-factor); design-bid-built (three-factor); construction management (four-factor)
Procurement Method	Competition, coopetition, cooperation
Project Manager Competences	Technical, Managerial

Table 3. Measures of determining the success level for every competitive priority

Competitive priority value (X)	Project performance in that priority (Y)	Result
X > 3	Y >= 3	Successful
	Y < 3	Unsuccessful
2 < X <=3	Y >= 3	Successful
	Y = 2	Middle
	Y = 1	Unsuccessful
X <= 2	Negligible	-

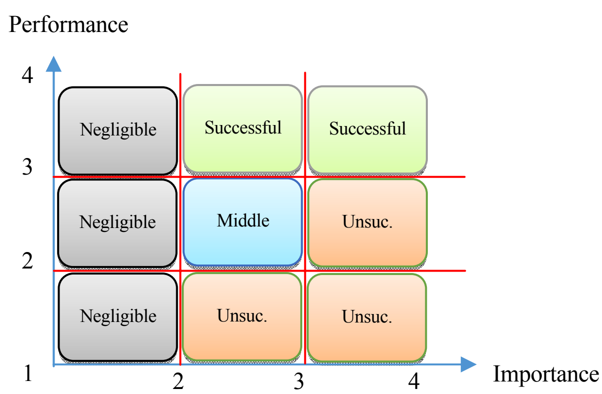

Figure 3. Importance-Performance Analysis for competitive priorities.

The mentioned output is used in such a way that the rule with contradictory manufacturing decision in its result implies that the manufacturing decision is improper or relatively proper.

Step 3. In this step, the rules acquired from educational instances are integrated with the rules acquired from research literature through Ternary Grid (TG), and discrepancies are also outlined. This step was conducted based on comments we received from industry experts.

The Ternary Grid method is a model of rule based knowledge in a grid format in which each cell is representative of the relationship between a rule and a fact. Grid cells can only have 0, 1, & 2-called triple values. 1 shows condition of the rule, 2 shows the result of the rule, and 0 shows that there is no relationship between the rule and the fact. Grid has elements like domains of problem solving that could be divided into subdomains or rule groups, rows as rules, columns as facts and values in *if-Then* format (Erdani, 2005).

Despite the advantages and simplicity of the ternary grid method, it cannot be used directly in this study since it is designed for crisp rules. This method was modified in this study to make it applicable in case of having fuzzy rules. This is one of the aspects of innovation in this study.

In revised Ternary Grid (revised TG), value 1 in rule condition is converted into 11, 12 and 13 showing little, average, or high amount of pertinent parameter in the condition of rule, respectively while value 2 in rule result is converted into 21, 22, and 23 showing improper, average or proper amount of pertinent manufacturing decision, respectively.

Thus, by using revised Ternary Grid we can represent and integrate any fuzzy rule with ambiguous linguistic phrases in condition and result of rules.

Step 4. The results of Fuzzy DEMATEL (FD) analysis and identified relations are used in this step in order to remove contradiction among rules. This is done in such a way as to consider more weigh for inputs with higher influence. This step was conducted based on the comments of industry and academic experts.

DEMATEL is an effective method to analyze the relationships among system elements by integration of group knowledge. The most important property of this method is in multi-criteria decision making domain and its performance in creation of relation and structure among elements (Lee *et al*., 2011). Because of ambiguity in expert judgment, the combination of this method with the concept of fuzzy is beneficial (Zhou *et al*., 2011). The results obtained from the implementation of fuzzy DEMATEL show the level of influence (R) and being influenced (J) for every element. To analyze deeper, these results are presented in schematic form which shows the real place of each element in the hierarchy of influencing. Elements having positive (R-J) are certainly penetrating and those having negative are certainly under penetration. Values for (R+J) show the severity of an element, both from the view of penetrator and being penetrated.

The most common techniques for systematic structuring of existing data using the judgment of experts include ISM, DEMATEL and Cognitive-MAP. Other MADM models do not have the ability of identify the relations. In the ISM technique, the affecting relations are only determined as 0 and 1 and in Cognitive-MAP technique affecting relations are only determined as plus, minus, and zero. However, in the DEMATEL technique experts can determine the intensity of relations. That is the reason why the DEMATEL techniques were used in this study.

Step 5. In the final step of the algorithm, the final rules are studied by industry experts and revised if needed to have the most possible accordance with reality and least contradiction. The last phase in the research is implementation of the rules acquired in previous steps in a fuzzy expert system. An expert system is a computerized system that copies decision making of experts by applying a series of rules. In classic rule based systems, if the condition is correct the result is correct too. In fuzzy systems in which the condition is a fuzzy phrase, all the rules act to some extent. The common procedure in the development of a fuzzy expert system comprises of 5 steps likewise:

1. Determine the problem and define linguistic variables.
2. Determine fuzzy sets.
3. Acquire fuzzy rules.
4. Code process, rules, and fuzzy sets and implement the fuzzy expert system.
5. Evaluate and adjust the system (Negnevitsky, 2005).

Two common methods for fuzzy inference in fuzzy expert systems have been presented by Sugeno and Mamdani. Since the Mamdani method is better for recording expert knowledge and the Sugeno method is better for controlling issues, the Mamdani method that helps us describe a special knowledge with a method similar to human beings is used in this study for fuzzy inference. The fuzzy inference module of MATLAB 2012 is used for the final implementation of the model

The schematic model of the expert system developed for this study is depicted in Figure 4.

3. IMPLEMENTING EXPERT SYSTEM OF OPERATIONAL STRATEGY WITH A SELECTED COMPETITIVE PRIORITY

The way the expert system is implemented is discussed in the following in accordance with the steps mentioned in the research methodology and according to the model shown in Figure 4 by selecting cost as a competitive priority.

Definition of fuzzy sets for input and output parameters is made according to Table 4:

After identifying rules in research literature, 152 projects in the electricity industry, mechanical structures, civil engineering and construction, industrial improvement, power transmission lines, transportation, electronic, communication and complex and hybrid products were studied in order to acquire rules from educational instances. According to the results obtained from educational data analysis and decision tree formation for every manufacturing decision, pertinent rules were identified using the C5 algorithm.

To exploit the algorithm presented in Figure 2 and to identify the relationships between model inputs, the Fuzzy DEMATEL method was used and the results are presented in Figure 5. For implementing fuzzy DEMATEL, industry and academic experts were asked to determine the relations between variables of the model with linguistic variables according to the values shown in Table 5. In addition, the method of Converting Fuzzy Data into Crisp Scores (CFCS) is used for defuzzification of numbers in the calculations. For further details regarding the steps of the method, refer to Zhou *et al*. (2011).

As Figure 5 shows, the impact of project properties on related competitive priority is much higher and among the project properties, the most influencing features are project complexity, project type, project size and project uncertainty, respectively. The way to use these results is as follows. For example, if the proposed manufacturing decision by competitive priority is different from the proposed manufacturing decision in terms of project complexity, then more weight is given to the second offer in the conclusion.

At the end, integrated and finalized rules are implemented in the fuzzy inference module of MATLAB 2012 as shown in Figure 6. As it was mentioned earlier, the Mamdani inference method is applied, in this fuzzy expert system. The computing speed of the software outputs is very high and it is less than one second in all cases after inserting inputs to the software, when the expected output is displayed. This is while, without this system, if an operational manager wants to decide, several hours should be spent for determining appropriate manufacturing decisions based on relevant competitive priority and project properties and handling the conflicts between them.

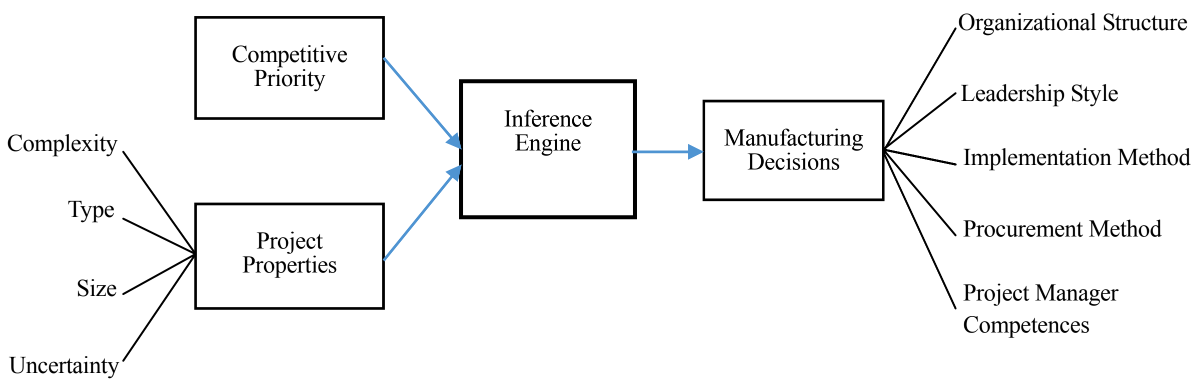

Figure 4. Schematic model of the expert system

Table 4. Fuzzy sets defined for model parameters

Type of variable	Title	Type of fuzzy numbers	Linguistic variable	Corresponding fuzzy number
Input	Competitive Priority (Cost)	Triangular	Unimportant	(1, 1, 2.4)
			Middle	(1.8, 2.5, 3.2)
			Important	(2.6, 4, 4)
Input	Complexity, size, and uncertainty properties	Triangular	Low/Small	(1, 1, 2.4)
			Middle	(1.8, 2.5, 3.2)
			High/Larg	(2.6, 4, 4)
Input	Project type property in terms of ownership	Trapezoidal	Private	(0, 0, 0.49, 0.5)
			Governmental	(0.5, 0.51, 1, 1)
Output	Each of items in manufacturing decisions	Triangular	Improper	(0, 0, 0.4)
			Middle	(0.3, 0.5, 0.7)
			Proper	(0.6, 1, 1)

Table 5. Linguistic variables and related fuzzy numbers

linguistic variables	triangular fuzzy numbers
No Effect	(0 , 0 , 0.25)
Very low effect	(0 , 0.25 , 0.5)
Low effect	(0.25 , 0.5 , 0.75)
High effect	(0.5 , 0.75 , 1)
Very high effect	(0.75 , 1 , 1)

Table 6. Results of testing the model with test samples

Number of samples	Accordance percentage of suggested manufacturing decisions with test samples				
	M1 Organizational Structure	M2 Leadership Style	M3 Implementation Method	M4 Procurement Method	M5 P. M. Competences
20	0.85	0.75	0.8	0.8	0.85

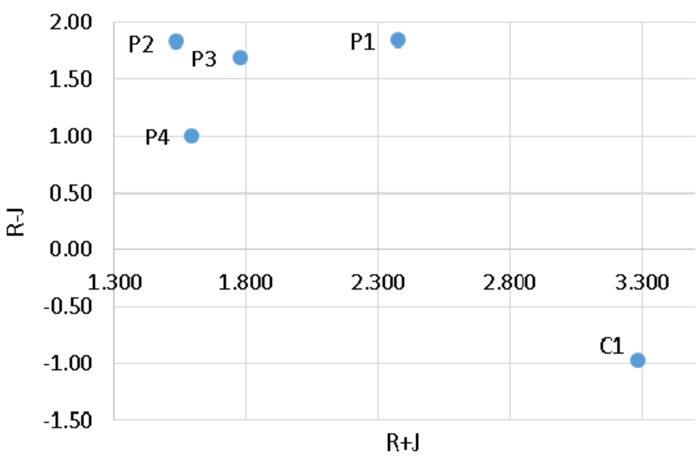

Figure 5. Condition of model inputs in terms of influence over each other.

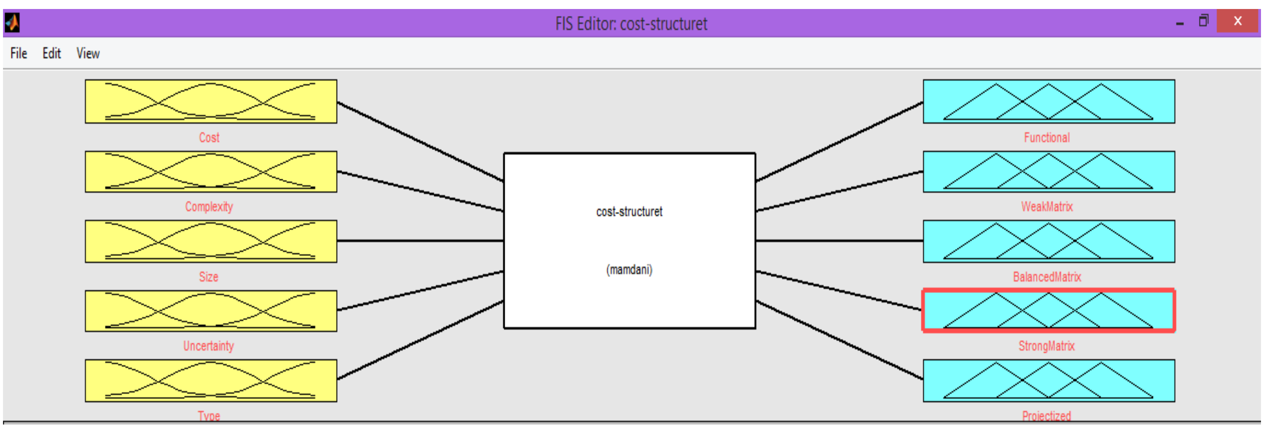

Figure 6. Schematic view of fuzzy inference software for organizational structure.

To test the model, test samples were used. For this purpose, for 20 sample projects in which cost competitive priority and being successful were important, data collection forms were filled in and the results obtained were studied along with the output results of the expert system. The information regarding each project was entered as input of the expert system, and the suggested manufacturing decisions were compared with applied manufacturing decisions. Percentage agreement between the results obtained was separately calculated for each manufacturing decision for all samples. The summary of results is presented in Table 6. The results obtained show an acceptable accordance percentage for outputs.

4. DISCUSSION AND CONCLUSION

Choosing the desired operational strategy in project-based organizations has been one of the main elements of success in such organizations. In this study, we tried to identify the relevant parameters and present a model for operational strategies in project-based organizations. We also presented a hybrid approach to acquire rules from different sources. Finally, an expert system was designed and implemented for selecting operational strategy based on the proposed approach.

According to the research findings, from a market-based perspective, operational strategy in project-based organizations is different from that of non-project manufacturing organizations whose main emphasis is on competitive priorities. In such organizations, we need to pay especial attention to project properties before competitive priorities in order to make effective manufacturing decisions.

With a review over research background in the introduction, we see that in first orientation, operational strategy was discussed based on reductionist thinking and in each research a limited area has been studied. For example, Gareis and Huemann (2000) studied project management qualifications and roles in projects; Bevilacqua *et al*. (2014) studied the relationship between the personality of project managers and project performance; Cleland and Ireland (2006) studied the relationship between some competitive priorities and organizational structure.

Also in two of the most relevant research studies that were conducted in the area of operational strategy in project-based organizations, Oltra *et al*. (2005) have identified and categorized competitive priorities in the form of three operational strategies. However, these cannot be practically used in the selection of appropriate manufacturing decisions. Although Maylor *et al*. (2015) proposed a four-step approach for implementing operational strategy, issues such as competitive priorities, manufacturing decisions and their relations have not been discussed practically.

Overall, no research has simultaneously studied the effects of competitive priorities and project properties on manufacturing decisions. In addition, in the mentioned cases there is a lack of an integrated framework for determining appropriate operational strategies.

Moreover, in the second orientation, other researches that have presented comprehensive models for operational strategies such as the TAPS model by Tan and Platts (2004) and Co-MASS model by Karacapilidis *et al*. (2006), have considered non-project organizations and a similar integrated model has not been provided for project-based organizations.

However, in this paper there has been an attempt to present a model by considering a holistic view, in order to show the impact of competitive priorities and project properties simultaneously on manufacturing decisions in project-based organizations.

One of the advantages of the approach that is used in this research compared to other items like Neural Networks which is not based on rules, is that its behavior analysis is conveniently possible through an analysis of output graphs and its comparison with literature. In addition, we can easily update or optimize the model by adding new rules or revising the previous ones with improvement of our knowledge and experience in this domain.

By studying expert systems in other areas, including those mentioned in the literature, it can be seen that mainly rules have been extracted based on expert opinions or based on educational data and training models. However, in this study, rules have been extracted with a hybrid approach based on literature, expert opinions and educational data at the same time.

Since project-based organizations comprise a wide spectrum, the limitation for this research is in addressing manufacturing project-based organizations that are active in the design and construction domain. In similar research studies, other project-based organizations like firms administering software projects, systematic projects and organizational improvement could be studied. A presentable suggestion for future research in this regard could be presenting an expert system for operational strategy in project-based organizations in which we can consider different competitive priorities with different degrees of importance.

REFERENCES

Baker, B. N., Murphy, D. C., and Fisher, D. (2008), Factors affecting project success, *Project Management Handbook*, Second Edition, 902-919.

Bevilacqua, M., Ciarapica, F. E., Germani, M., Mazzuto, G., and Paciarotti, C. (2014), Relation of project managers' personality and project performance: An approach based on value stream mapping, *Journal of Industrial Engineering and Management*, **7**(4), 857.

Burbidge, J. L. (1984a), *A Production System Variable Connectance Model*, Cranfield Institute of Technology, England.

Chen, W. H. (1999), The manufacturing strategy and competitive priority of SMEs in Taiwan: A case survey, *Asia Pacific Journal of Management*, **16**(3), 331-349.

Cil, I. and Evren, R. (1998), Linking of manufacturing strategy, market requirements and manufacturing attributes in technology choice: An expert system approach, *The Engineering Economist*, **43**(3), 183-202.

Cleland, D. L. and Ireland, L. R. (2006), *Project management*. McGraw-Hill Professional.

Da Conçeião Júnior, J. (2009), Achieving Breakthrough on Manufacturing Floor through Project-Based Organization, *SAE Technical Paper*.

Díaz-Garrido, E., Martín-Peña, M. L., and García-Muiña, F. E. (2007), Structural and customization practices as elements of content operations strategy, *International Journal of Production Research*, **45**(9), 2119-2140.

Dvir, D., Lipovetsky, S., Shenhar, A., and Tishler, A. (1998), In search of project classification: A non-universal approach to project success factors, *Research policy*, **27**(9), 915-935.

El Wardani, M. A., Messner, J. I., and Horman, M. J. (2006), Comparing procurement methods for design-build projects, *Journal of construction engineering and management*, **132**(3), 230-238.

Erdani, Y. (2005), Acquisition of Human Expert Knowledge for Rule-based Knowledge-based Systems using Ternary Grid (Doctoral dissertation, Universität Duisburg-Essen, Fakultät für Ingenieurwissenschaften» Elektrotechnik und Informationstechnik).

Eriksson, P. E. and Westerberg, M. (2011), Effects of cooperative procurement procedures on construction project performance: A conceptual framework, *International Journal of Project Management*, **29**(2), 197-208.

Gagnon, S. (1999), Resource based competition and the new operation strategy, *International Journal of Operations & Production Management*, **19**(2), 125-38.

Galbraith, J. R. (1971), Matrix organization designs How to combine functional and project forms, *Business Horizons*, **14**(1), 29-40.

Gareis, R. and Huemann, M. (2000), Project management competences in the project-oriented organization, *Gower handbook of project management*, **3**.

Großler, A. (2007), A dynamic view on strategic resources and capabilities applied to an example from the manufacturing strategy literature, *Journal of Manufacturing Technology Management*, **18**(3), 250-266.

Großler, A. and Grubner, A. (2006), An empirical model of the relationships between manufacturing capabilities, *International Journal of Operations & Production Management*, **26**(5), 458-485.

Hayes, R. H. and Wheelwright, S. C. (1984), *Restoring our Competitive Edje, Competing Through Manufacturing*, John Wiley and son, New York, NY. 3-24.

Hung, S.-W., Hung, S.-C., and Lin, M.-J. J. (2011), How different strategic alliances affect manufacturing competitive priority and firm performance: An empirical study of SMEs. ICSB World Conference Proceedings: Washington: *International Council for Small Business.*

Jayaram, J. and Narasimhan, R. (2007), The influence of new product development competitive capabilities on project performance, *Engineering Management, IEEE Transactions* on, **54**(2), 241-256.

Karacapilidis, N., Adamides, E., and Evangelou, C. (2006), A computerized knowledge management system for the manufacturing strategy process, *Computers in Industry*, **57**(2), 178-188.

Kruger, L. (2012), Developing operations strategies-reassessing the strength and importance of competitive operations priorities for South African businesses, *South African Journal of Business Management*, **43**(3), 13-28.

Lamvik, T., Moseng, B., and Gjerstad, T. (2003), *Manufacturing Strategy Best Practices and Cases*.

Lee, W. S., Huang, A. Y., Chang, Y. Y., and Cheng, C. M. (2011), Analysis of Decision Making Factors for Equity Investment by DEMATEL and Analytic Network Process, *Expert Systems with Applications*, **38**(7), 8375-8383.

Lee Gan Kai, W. (2007), *A decision model for manufacturing best practice adoption: Linking practices to competitive strategies*, Doctoral dissertation, Cranfield University.

Leong, G. K., Snyder, D. L., and Ward, P. T. (1990), Research in the process and content of manufacturing strategy, *Omega*, **18**(2), 109-122.

Levitt, R. E. (2012), The virtual design team: Designing project organizations as engineers design bridges. *Journal of Organization Design*, **1**(2), 14-41.

Love, P. E. (2002), Influence of project type and procurement method on rework costs in building construction projects, *Journal of Construction Engineering and Management*, **128**(1), 18-29.

Maylor, H., Turner, N., and Murray-Webster, R. (2015), "It worked for manufacturing…!" Operations strategy in project-based operations, *International Journal of Project Management*, **33**(1), 103-115.

Miltenburg, J. (2005), *Manufacturing Strategy: How to Formulate and Implement a Winning Plan*. CRC Press.

Müller, R. and Turner, J. R. (2007), Matching the project manager's leadership style to project type, *Interna-*

tional Journal of Project Management, **25**(1), 21-32.

Müller, R. and Turner, R. (2010), Leadership competency profiles of successful project managers, *International Journal of Project Management*, **28**(5), 437-448.

Mun, J., Shin, M., Wi, H., Lee, K., and Jung, M. (2008), A VO formation process of a project-based organization with trust evaluation using goal achievement probability, *Paper presented at the Management of Engineering & Technology, 2008*, PICMET 2008. Portland International Conference on.

Oltra, M., Maroto, C., and Segura, B. (2005), Operations strategy configurations in project process firms, *International Journal of Operations & Production Management*, **25**(5), 429-448.

PMBOK, A. (2000), *Guide to the Project Management Body of Knowledge*, Project Management Institute, Pennsylvania USA.

Sackett, P. J., Maxwell, D. J., and Lowenthal, P. A. (1997), Customizing manufacturing strategy, *Integrated Manufacturing Systems*, **8**(6), 359–364.

Söderlund, J. (2004), Building theories of project management: past research, questions for the future, *International Journal of Project Management*, **22**(3), 183-191.

Spring, M. and Dalrymple, J. F. (2000), Product customisation and manufacturing strategy, *International Journal of Operations & Production Management*, **20**(4), 441-467 .

Tamura, H. (2013), Expert system for new product strategy development, *Advances in Production Management Systems: Perspectives and future challenges*, 303.

Tan, K. and Platts, K. (2004), The connectance model revisited: a tool for manufacturing objective deployment, *Journal of Manufacturing Technology Management*, **15**(2), 131-143.

Theodorou, P. and Florou, G. (2008), Manufacturing strategies and financial performance-The effect of advanced information technology: *CAD/CAM systems. Omega*, **36**(1), 107-121.

Turner, J. R. (2014), *The Handbook of Project-Based Management* (Vol. 92), McGraw-hill.

Turner, J. R. and Keegan, A. (1999), The versatile project-based organization: Governance and operational control, *European Management Journal*, **17**(3), 296-309.

Turner, J. R. and Keegan, A. (2001), Mechanisms of governance in the project-based organization: Roles of the broker and steward, *European Management Journal*, **19**(3), 254-267.

Turner, J. R. and Müller, R. (2005), *The Project Manager's Leadership Style as a Success Factor on Projects: A Literature Review*, Project Management Institute.

Wysocki, R. K. (2002), *Building Effective Project Teams*, Wiley.

Wysocki, R. K. (2003), *Effective Project Management: Traditional, Adaptive, Extreme*, John Wiley & Sons.

Zar, J. H. (1999), *Bio Statistical Analysis*, 4th Ed. Upper saddle river, New Jersey: Prentice Hall.

Zhou, Q., Huang, W., and Ying, Z. (2011), Identifying critical success factors in emergency management using a fuzzy dematel method, *Safety Science*, **49**(2), 243-252.