Journal of Public Policy and Administration
2020; 4(1): 9-15
http://www.sciencepublishinggroup.com/j/jppa
doi: 10.11648/j.jppa.20200401.12
ISSN: 2640-2688 (Print); ISSN: 2640-2696 (Online)

Project Customer Requirements Management Using Fuzzy Numbers

Jan Betta

Faculty of Computer Science and Management, Wroclaw University of Science and Technology, Wroclaw, Poland

Email address:
jan.betta@pwr.edu.pl

To cite this article:
Jan Betta. Project Customer Requirements Management Using Fuzzy Numbers. *Journal of Public Policy and Administration*. Vol. 4, No. 1, 2020, pp. 9-15. doi: 10.11648/j.jppa.20200401.12

Received: February 1, 2020; **Accepted**: February 20, 2020; **Published**: March 10, 2020

Abstract: Project Management (PM) takes into account a large number of parameters of different nature. Their diversity and mutual dependencies are one of the main hindrances to successful management of projects. Certain parameters such as time, cost, risk are measurable, nevertheless they should be estimated before the project realization. These estimations are to an extent always vulnerable to uncertainty, owing to a multitude of unstable factors. Therefore, despite the measurability of such quantities, the problem of uncertainty remains, affecting negatively the project management process. In case of parameters that are immeasurable, the situation is much more complicated. As examples, let us take elements (phenomena, states) of mental, psychological character like Project Manager's and project team qualities, stakeholders satisfaction, or customer ability to formulate his requirements. The fuzzy approach is commonly recognized as an apparatus to pattern uncertainty in a large family of research and practical applications. Since several years one can observe this trend in PM research. There is a number of papers on project time, cost, and risk management, employing fuzzy numbers as a tool of uncertainty modelling of these project parameters management. On the contrary, one can seldom encounter conceptual or applied research for immeasurable PM parameters. The objective of this paper is to offer a contribution to partially fill this gap. It will be achieved in the form of Project Customer Requirements Management Model, using fuzzy numbers.

Keywords: Project Management, Customer Requirements Process, Customer Requirements Management, Requirements Recognition, Requirements Definition, Fuzzy Numbers

1. Introduction

Shortage of time nowadays accompanies nearly all projects, for several reasons. First, the constantly growing level of customers' demands when it comes to project completion time incentive the rush to outrun competitors. The second reason for a shortened project life cycle is the impact of new technologies, and the resulting pullback of old ones. The project contractor tries to accelerate the completion of a project using an old technology in a "race to finish" and avoid the necessity to work using a new one, not yet known to her.. The third cause of the race against the clock is a general acceleration driven by the processes of globalization in almost all dimensions: social, cultural, educational, technological and consumptive.

Apart from these external factors, which are independent of the project contractor, there exists another serious internal one. This is – paradoxically, in spite of the commonplace race against the clock – a well-known phenomenon of wasting time. Time-wasting appears in many areas of the project and in many ways [1-3]. Frequent examples include inadequate customer requirements recognition and management, ineffectual communication, Project Manager incompetence, inappropriately composed project team, failure to take risks into account, subcontractors inefficient management or lack of an adequate motivation system.

R. Darnall [4] wrote "You either spend time in planning meetings, or later you will spend time in problem solving meetings." Errors at the project's start are the most threatening, because they lead to the rise the next ones, and to their accumulation. Every project is born as a response to some identified need and consists in providing a product, meeting the customer requirements. It is evident that the correct understanding of customer requirements is the beginning of a new project and the absolutely necessary condition for its success. Total or even partial misapprehension could lead to completing a product partially or even completely divergent with customer expectations. A false understanding of customer needs is a simple consequence of impossibility to define accurately parameters of the process of expectation evaluation. According to Darnall, it is necessary to focus all attention on understanding customer needs. It requires some time of course, but this time devoted to a customer needs understanding will be significantly recompensed during the project performing, less encumbered with problems that typically result from a false or inaccurate understanding of customer needs.

The problem of a correct understanding of customers' requirements is particularly acute in traditional methodologies of project management, which practically do not allow any changes to the project scope during project's realization. Another approach is practiced in agile methodologies, where the relations and information exchanges between the project team and the customer are frequent, even constant, during the whole life cycle of a project. According to the Scrum Methodology for instance, the Customer is an integral part of a Scrum Team, which provides opportunities for mutual understanding and acceptance of customer's true requirements. The contents of this paper are therefore valuable for traditional project management methodologies only.

The objective of this paper is to propose the Customer Requirements Management Model, using fuzzy numbers.

2. Method - Background

The reflections above became the inspiration to write this conceptual paper. The apparatus of fuzzy numbers is applied to propose a model of project customer requirements management. Fuzzy numbers are applied successfully in different areas of project management, primarily with regards to time, cost, or risk. For examples of fuzzy time, cost and risk project management, let us refer to several pieces of existing scholarship. In the paper [5], a fuzzy mixed integer nonlinear programming model with multiple routes is presented, under uncertain conditions, as well as a new two-phase heuristic algorithm to solve large-sized problems. As example of a fuzzy approach let us mention the paper [6], presenting time, cost, risk, quality and safety on critical paths determination. A new extended method of uncertainty is proposed with method under type-2 fuzzy uncertainty to aggregate rankings. An interesting management of energy optimization (cost, risk), using fuzzy approach, is given in the paper [7]. A new risk assessment method, safety and critical effect analysis, with Pythagorean fuzzy sets integrated, robustness of the proposed method shown by comparison with other methods are subject of another paper [8]. In the next study, classic PERT and CPM, which are project management techniques, fuzzy PERT and fuzzy CPM, which are used in the fuzzy project management, are used to improve an online internet branch and to plan the project of an online internet branch [9]. Guidelines are presented to achieve the best alignment between project and program strategy. It is envisaged that their application will help in achieving maximum benefits and value during program management in the presence of uncertainty [10]. A methodology is developed for valuing options on R&D projects, when future cash flows are estimated by trapezoidal fuzzy numbers. In particular, a fuzzy mixed integer programming model for the R&D optimal portfolio selection problem is presented [11].

Unlike the "hard" parameters above (time, cost, risk) which are adequately visible among all approaches to use fuzzy numbers in Project Management, more "soft" parameters characteristic for Project Customer Requirements Management using Fuzzy Numbers are very seldom objects of researchers interest. Nevertheless, some of them will mentioned. One embeds the degree of compensation among Customers Requirements into Quality Function Deployment, which is expressed as a symmetric triangular fuzzy number, and develops a fuzzy non-linear regression model using the minimum fuzziness criterion to identify it [12]. In another paper we are presented with 16 fuzzy regression models to understand the relationship between customer satisfaction and new product design. Fuzzy regression models are built on the 4Ps marketing mix (product, price, place, and promotion) concept in a fuzzy environment. A flexible algorithm is proposed based on the index of confidence, error measures, and data envelopment analysis for selecting the best model. Next study [13] is devoted to cross-functional integration in solution delivery projects, which relates to managing customer information in a Projects Based Firm across functional interfaces. In such an enterprise, sales, project operations, and services functions are often separated and have their own tasks and responsibilities throughout the project life cycle, but they all need customer information to carry out their work. The necessity is shown to integrate and manage customer information flows. The objective of the consecutive paper [14] is to demonstrate the dependency of the scope of the decision process on the understanding of factors and properties which affect the decision scope of quality requirements.

Section 3. presents two processes of project customer requirements management. Section 4. contains basic uncertainties of the project customer requirements management. In Section 5. basic notions on fuzzy numbers are defined. In the section 6. main random or borderline elements are discussed. Section 7. is a central one of the paper, where a fuzzy numbers model of the project customer requirements management is proposed. This model provides the best management strategies, resulting from careful interpretations of fuzzy parameters estimations. In Section 8., discussion summarizing the content of this paper is given.

3. Method - Process of the Project Customer Requirements Management

The process of managing project customer requirements marks the first step in the management of practically all projects. With exaggeration, one can say that the main goal of the project consists in meet the people needs. Understanding correctly the customer's requirements is a sophisticated enterprise, exposed to many internal and external factors, disturbing, even forefending it. These factors have mostly borderline or random character. Hence, this stage is sensitive to each such disturbance or error.

The process discussed in this paper is typically composed of three parts: requirements recognition, requirements definition and requirements appropriate management, presented consecutively below in sections 3.1, 3.2 and 4, according to [1].

3.1. Requirements Recognition

During this stage, Project Manager, (PM), should be endowed with three features: innovation attitude, creativity and openness to change. All these features are objects of borderline or random perception and evaluation. So, it is impossible to measure them in a determinist way. In such situations, the probabilistic approach is not appropriate, neither [15, 16].

3.2. Requirements Definition

At this stage, PM should precise the requirements of the customer. The definition of requirements is a complex, interactive process, engaging the PM and the customer. At its end, the customer and the project manager must be sure sharing both the same understanding of customer's needs, which should be satisfying for the customer and possible to meet by the project manager and the project team. The process of requirements definition is put on three main threats:

1. Definition inadequate to real needs of the customer because of communication problems or misapprehension of the project substance by customer PM,
2. Definition is imprecise/ambiguous for the same reasons as above,
3. Definition is evolving with time because of project matter (technology) rapid changes or customer's hesitation.

4. Method - Appropriate Management of Requirements

The appropriate management of customer requirements should accompany two stages mentioned above: requirements recognition and requirements definition, taking into account their specific nature:

1. Requirement recognition is the first opportunity to understand the customer needs. The objective is not a very detailed image of the project product, but rather its general draft. The project manager's task is to use all his or her abilities to understand the customer – be innovative, creative, open to changes and act courageously, proposing different points of view.
2. Requirement definition appears in form of an iterative process, with cyclical activities:
   a. Inviting the customer to define his/her requirement
   b. Answering all questions
   c. Exploiting the above steps, define the requirement
   d. Asking the customer to evaluate it
   e. Modifying it, returning to a. if necessary

During these two stages, a project manager should note all elements having borderline or random character. In the section 6., such typical elements are presented. It will be a base of a fuzzy numbers model of the project requirements management, proposed in the section 7.

5. Method - Fuzzy Numbers – Basic Notions

For two reasons, probabilistic methods are not always sufficient for modelling unknown values. Two situations can occur while estimating an unknown value of a parameter:

i. An expert, estimating an unknown value, gives different degrees of possible realization for different, potentially possible intervals.
ii. Among several experts estimating an unknown value A, there are some admitting larger intervals of the estimating value realization, and another ones propose the intervals narrower.

In both cases, the estimation of an unknown value is not an interval, but a set of intervals, called a fuzzy number [15]. For this paper objective, let us adopt definitions, properties and dependencies below [16].

Definition 1

A fuzzy number $\tilde{A}$ is a set of real closed intervals $\{A^t\}(t\epsilon[0,1])$, accomplishing the following conditions:

1. $t < r \Rightarrow A^r \subseteq A^t$,
2. $I \subseteq.[0,1] \Rightarrow A^{supI} = \cap_{r\epsilon I} A^r$.

Definition 2

For a fixed $t \in [0,1]$, the interval A^t is named t-level of a fuzzy number $\tilde{A}$.

The level A^{1-t} corresponds to the opinion of the expert, cautious at the degree t. If $t < r$, A^r is the estimation of an expert less reserved or better informed than the author of the estimation A^t.

Definition 3

Let be given a fuzzy number $\tilde{A}$. The function $\mu_A: R \rightarrow [0,1]$, defined as $\mu_A(x) = \sup\{t: x \in A^t\}$, is called the function of affiliation or participation of a fuzzy number $\tilde{A}$.

In the case i. above, $\mu_A(x)$ shows the level of possibility that x is the realization of an unknown value A. For the case ii. above, for a fixed value x, $\mu_A(x)$ can be interpreted as a number of experts admitting x as a realization of $\tilde{A}$, divided by the number of all experts asked.

For every $\tilde{A}$ and $t \in [0,1]$, the following relation is truth: $A^t = \{x: \mu_A(x) \geq t\}$ [15]. In the situation i., t-level of unknown value A contains all real numbers, for which the level of the possibility to be a realization of unknown value A was estimated by the expert as not lower than t. In the situation ii., t-level of the fuzzy number contains all real numbers, which are considered as possible realizations of unknown value A by tN experts (N is a number of all experts).

6. Method - Fuzzy Numbers Ability to Model Uncertainty of the Project Customer Requirements Management

The object of this section considerations will be the parameters, essential for correctness of the investigated process run. From a practical point of view, the situation i. (sec. 3.) will only be taken into account. In practice, it is seldom possible to invite several experts to participate in the customer requirement management, because of time and cost limited. It means that we limit our considerations to the case of PM as the only expert, auto-estimating levels of parameters, being – in fact – his abilities to go correctly through the process. In requirements recognition stage the absolutely necessary parameters are innovation attitude, creativity, and openness on changes of PM [1]. In requirements definition stage – threats of inadequacy, ambiguity/inaccuracy and time non-validity of requirements definition [1]. In the situation i. PM as the only expert, auto-estimates the levels of the process of project customer requirements management parameters.

6.1. Requirements Recognition Stage

The parameters analyzed in this subsection are defined as fuzzy numbers: Innovation Attitude $\tilde{I} = \{I^r\}(r\epsilon[0,1])$, Creativity $\tilde{C} = \{C^s\}(s\epsilon[0,1])$, and Opening up to Changes $\tilde{O} = \{O^t\}(t\epsilon[0,1])$. So, I^r is a level of a fuzzy number $\tilde{I}$ estimated by PM; it means that I^{1-r} corresponds to his auto-opinion on his own Innovation Attitude level, cautious at the degree r.

PM can – for instance – propose three estimations: for fixed values h, m and l - highly reserved in degree h (I^h), mean reserved in degree m (I^m) and little reserved in level l (I^l), where h < m < l.

The analogous interpretations (degrees: highly, mean, little) are valuable for two other parameters - Creativity $\tilde{C}$ with its degree C^s and Opening up to Change $\tilde{O}$ with its degree O^t.

Generally, PM can give n estimations with possibilities t_1, t_2,... t_n for all three parameters $\tilde{I}$, $\tilde{C}$ and $\tilde{O}$. His estimations depend of the domain of project – all the three will be less cautious in the case of projects in the domain known well by him, and more cautious in the opposite one.

Example: Let us admit the percentile scale of all possible estimations of Innovation Attitude $\tilde{I}$ values. Expert (PM) can, for instance, state that his of auto-evaluation of this parameter is [40%-70%] with level 0.8, but he can add another possibility - [20%-80%] with level 0.5. He is aware of two possible situations. The first one – a1 - his Innovation Attitude is more exactly defined ([40%-70%]) but with relatively small degree of caution 1 - 0.8 = 0.2. It means that he estimates his own Innovative Attitude relatively exactly, but with relatively big possibility 0.8 of mistake. The second one – a2 - the Innovation Attitude is less exact ([20%-80%]), but with average degree 0.5 of caution.

Analogously for two other fuzzy numbers $\tilde{C}$ and $\tilde{O}$, one can consider similar cases of intervals and degrees of caution.

6.2. Requirements Definition Stage

In the situation i., with PM as the only expert evaluating him/herself, let us define three other fuzzy numbers, representing three parameters of this stage: for inadequacy $\tilde{I}N$ with IN^h, IN^m and IN^l; for ambiguity/inaccuracy N with N^l, N^m and N^h; for time non-validity of requirements definition A with A^h, A^m and A^l (fixed values h – high, m – mean and l – little levels of respective parameters, l < m < h). The whole line of reasoning, all interpretations and meanings in corresponding case i. of one expert – PM, from the subsection 4.1 stay analogous.

7. Result - Fuzzy Numbers Model of the project Customer Requirements Management

The model's proposal is presented for the case i. only from section 3.

Stage 1. Requirements recognition

First meeting between the Customer and the PM provides a general understanding by PM of the Customer's requirements. PM should be conscious of his or her own features: innovation attitude - $\tilde{I}$, creativity - $\tilde{C}$ and opening up to changes – $\tilde{O}$, and estimates for each of them its own t-levels: I^t, C^t and O^t, respectively. The PM has a choice between two possibilities. First of them is to summarize the result of this meeting as a fuzzy number $\mathfrak{R}$ with its f-level $\mathfrak{R}^f$, defining the final, global level of customer requirements understanding, resulting from PM knowledge, experience, self-estimations I^r, C^s, O^t and general PM impression after the meeting. Such construction of a final result in the form of a fuzzy number $\mathfrak{R}$, synthetizing of all elements above could be very difficult, quasi-impossible or even impossible. So, the second possibility appears to treat his three self-estimations I^r, C^s, O^t as independent values, which give to PM several possibilities of understanding the customer requirements, as combinations of I^r, C^s, O^t for fixed values of r, s and t.

Let us come back to the example from section 4.1. Apart from [40%-70%] with level 0.8 (situation a1), and [20%-80%] with level 0.5 (situation a2) as two self-estimations of $\tilde{I}$, PM makes two analogous estimations for each of another two parameters – creativity $\tilde{C}$ and opening up to changes $\tilde{O}$. For instance: $\tilde{C}$ [50%-70%] with degree 0.9 (situation c1) and [30%-80%] with level 0.7 (c2); $\tilde{O}$ [60%-80%] level 0.7 (situation o1) and [30%-90%] level 0.4 (o2). All the self-estimations above allow PM have an overview of eight possible combinations of results of this stage and interpret each of them. For each of these eight situations, the appropriate strategy for the studied process is proposed. This analysis is shown in the Table 1.

Table 1. *Stage 1. parameters estimations with interpretations and strategies (example).*

Result item	**Situations combination**	**Estimations combinations**	**Interpretations of Results, Conclusions, Strategy for Identification Requirements Stage**
1.	a1, c1, o1	Ĩ, a1 [40-70%], lev. 0.8 C̃, c1, [50-70%], lev. 0.9 Õ, o1, [60-80%], lev. 0.7	Innovation Attitude Ĩ interval short (precise), very small degree of caution; Creativity interval C̃ short (precise), very small degree of caution; Opening up to changes Õ interval short (precise), small degree of caution. Conclusion 1.: result tempting for the second step of requirements management, but risky. Strategy1.: Equilibrated effort on all three parameters.
2.	a1, c1, o2	Ĩ, a1 [40-70%], lev. 0.8 C̃, c1, [50-70%], lev. 0.9 Õ, o2, [30-90%], lev. 0.4	Innovation Attitude Ĩ interval short (precise), very small degree of caution; Creativity interval C̃ very short (precise), very small degree of caution; Opening up to changes Õ interval very large, average degree of caution. Conclusion 2.: result tempting for the second step of requirements management. Strategy 2.: attention focussed on requirements changes management.
3.	a1, c2, o1	Ĩ, a1 [40-70%], lev. 0.8 C̃, c2, [30-80%], lev. 0.7 Õ, o1, [60-80%], lev. 0.7	Innovation Attitude Ĩ interval short (precise), very small degree of caution; Creativity interval C̃ large, small degree of caution; Opening up to changes Õ interval very short (precise), small degree of caution. Conclusion 3.: result tempting for the second step of requirements management. Strategy 3.: attention focussed on creativity effort.
4.	a1, c2, o2	Ĩ, a1 [40-70%], lev. 0.8 C̃, c2, [30-80%], lev. 0.7 Õ, o2, [30-90%], lev. 0.4	Innovation Attitude Ĩ interval short (precise), very small degree of caution; Creativity interval C̃ large, small degree of caution; Opening up to changes Õ interval very large, average degree of caution. Conclusion 4.: result tempting for the second step of requirements management. Strategy 4.: attention focussed on requirements changes management.
5.	a2, c1, o1	Ĩ, a2 [20-80%], lev. 0.5 C̃, c1, [50-70%], lev. 0.9 Õ, o1, [60-80%], lev. 0.7	Innovation Attitude Ĩ interval very large, medium degree of caution; Creativity interval C̃ short (precise), very small degree of caution; Opening up to changes Õ interval short (precise), small degree of caution. Conclusion 5.: result tempting for the second step of requirements management. Strategy 5.: attention focussed on innovative aspects of requirements management.
6.	a2, c1, o2	Ĩ, a2 [20-80%], lev. 0.5 C̃, c1, [50-70%], lev. 0.9 Õ, o2, [30-90%], lev. 0.4	Innovation Attitude Ĩ interval very large, medium degree of caution; Creativity interval C̃ short (precise), very small degree of caution; Opening up to changes Õ interval very large, average degree of caution. Conclusion 6.: result permitting the second step of requirements management. Strategy 6.: attention split into requirements changes and innovative aspects management.
7.	a2, c2, o1	Ĩ, a2 [20-80%], lev. 0.5 C̃, c2, [30-80%], lev. 0.7 Õ, o1, [60-80%], lev. 0.7	Innovation Attitude Ĩ interval very large, medium degree of caution; Creativity interval C̃ large, small degree of caution; Opening up to changes Õ interval short (precise), small degree of caution. Conclusion 7.: result tempting for the second step of requirements management. Strategy 7.: attention split into innovative aspects of requirements management and creativity effort.
8.	a2, c2, o2	Ĩ, a2 [20-80%], lev. 0.5 C̃, c2, [30-80%], lev. 0.7 Õ, o2, [30-90%], lev. 0.4	Innovation Attitude Ĩ interval very large, medium degree of caution; Creativity interval C̃ large, small degree of caution; Opening up to changes Õ interval large, medium degree of caution. Conclusion 8.: result tempting for the second step of requirements management. Strategy 8.: high attention split evenly into innovative aspects of requirements management, creativity effort and requirements changes management.

Source: author.

The eight strategies above can be characterized as follows:

1. Strategy 1. is highly risky, because of a very small or small degree of PM caution;
2. Strategy 8. is highly risky, because of a necessity to split high attention into all three parameters, which could menace of PM attention dispersion;
3. Strategies 6. and 7. are medium-level risky, because of necessity to split high attention into two parameters;
4. Strategies 2., 3., 4. and 5. are low-level risky, because each of them is focused on one parameter only.
5. Which strategy for the second stage - Project Customer Requirements Definition will be the optimal one? Logically, PM should adopt the following criteria:
6. Avoid strategies with attention split into three parameters, in our example items 1. and 8. The explication is their high level of risk;
7. Among remainder items, smaller is the sum of parameters levels, more is valuable its presence in the strategy. Smaller value of levels means a higher degree of PM caution and – consequently – more careful management.

For our example, it means the following – decreasing priority of strategies to be adopted in the next stage: 6., (4. or 7.). (5. or 2.), 3. As 2. is – in fact - a part of 6., and 3. a part of 7., we obtain – as a final priorities order – the sequence 6., (4. or 7) and 5. This range allows PM to choose the appropriate strategies for the second stage.

Stage 2. Requirements definition

The objective of this stage is to precise the real requirements of the customer. As mentioned in section 2, the Customer and the PM want to ensure the same understanding of Customer's needs, satisfying for the Customer and possible to meet by the project manager and the project team. Following the steps a. – e. indicating in section 2, the PM must be conscious of three threats (s. 2), and, at each step, representing them with fuzzy numbers and evaluating their degrees, respectively:

1. definition inadequate to real needs of the customer $\tilde{IN}$ with its IN^r
2. definition is imprecise/ambiguous $\tilde{A}$ and A^r
3. definition is evolving with time $\tilde{N}$ and N^r

The occurrence of most dangerous threats with their fuzzy-representations and the most valuable strategies (Stage 1.) in consecutive steps a. – e. (Sec. 2) are shown in the Table 2:

Table 2. *Threats, theirs fuzzy representations, accompanying five steps of customer requirement definition process and strategies recommended.*

Steps	Threats	Fuzzy numbers representing and levels	Appropriate strategies
Invite the customer to define his/her requirement	definition inadequate to real needs of the customer; definition is imprecise/ambiguous	$\tilde{IN}$ and IN^r $\tilde{A}$ and A^r	7.
Answer all questions	as above	as above	7.
Exploiting the above steps, define the requirement	all three threats	$\tilde{IN}$ and IN^r $\tilde{A}$ and A^r $\tilde{N}$ and N^r	6., 4
Ask the customer to evaluate it	all three threats	$\tilde{IN}$ and IN^r $\tilde{A}$ and A^r $\tilde{N}$ and N^r	6, 4
Modify it, returning to a. if necessary	definition inadequate to real needs of the customer; definition is imprecise/ambiguous	$\tilde{IN}$ and IN^r $\tilde{A}$ and A^r	6., 4., 7

Source: author.

One can see that all threats are present throughout the whole process of customer requirement definition.

The analysis above could be generalized as follows:

1. n levels of estimations $r_1, r_2, \ldots, r_n$ for each of parameters $\tilde{I}$, $\tilde{C}$ and $\tilde{O}$;
2. n^3 possible strategies: str.1, str.2, … str.n^3;
3. Sequence of strategies {str. k}, $k \in \{1, 2, \ldots n^3\}$, defined by increasing values of sum of three parameters levels;
4. Taking into account a risk level only, the most valuable is the first strategy in the sequence above;
5. Another strategies are not excluded for special reasons others than risk level; lack of time, or the project contract, for instance.

8. Discussion

An attempt has been made to show the possibility and usefulness of project customer requirements using fuzzy numbers model. Unambiguous and precise understanding of customer's requirements is the first step towards the project's successful end. In order to ensure it, an adequate management process should be applied, composed of two sub-processes. First of them – Requirements Recognition, is strongly dependent on PM features: innovation attitude, creativity and openness to changes. The second one – Requirements Definition, is accompanied by threats of inadequacy, ambiguity/inaccuracy and time non-validity of requirements understanding. It has been shown how these six main parameters of such management could be presented using fuzzy numbers.

Using an example, a fuzzy numbers model of the project customer requirements management was built. It is composed of eight possible in this example combinations Results, Conclusions and Strategies for Identification Requirements Stage. Next, strategies were analyzed from risk point of view accompanying them. In the second stage – requirements definition - the least risky strategy was proposed to avoid three threats of this stage. Finally, a generalization of the model for any number of strategies taking into account six fuzzy parameters was given.

Further research should be done, particularly.

9. Conclusion

Project Management is an extremely large domain of human activity in practically all branches. The projects themselves and their management depend on various, sophisticated factors. Such of them are measurable which make them easy to understand and process as data. Nowadays, it is commonly recognized that there exist numerous features and parameters, which are not directly quantitative, but decisive for project's success. As examples, let us take elements (phenomena, states) of mental, psychological character like Project Manager's and project team qualities, stakeholders satisfaction, or customer ability to formulate his requirements. The fuzzy approach is commonly recognized as an apparatus for nonpattern uncertainty in a large family of research and practical applications. Nevertheless the fuzzy approach appears very seldom in immeasurable aspects of project management. The model proposed in this article should fill – partially – this absence.

As directions of the next research seem be:

1. Application of particular cases of fuzzy numbers – triangular, trapezoidal
2. Application of fuzzy numbers type 2.
3. Other parts of project management immeasurable in their nature, like PM necessary qualities, a project team members qualities, resistance to change, stakeholders requirements and satisfaction
4. Empirical studies to check the model.

Fund

This research was supported by the National Science Centre (Poland), under Grant 394311, 2017/27/B/HS4/01881:“Selected methods supporting project management, taking into consideration various stakeholder groups and using type-2 fuzzy numbers”.

References

[1] Frame J. D., Managing Projects in Organizations. How to make the Best Use of Time, Techniques, and People, Jossey-Bass Inc., Publishers, 1995.

[2] Kerzner H., Advanced Project Management, Helion, Gliwice 2005 (in polish).

[3] Patzak G. and Rattay G., Project Management. Guideline for the management of projects, projects portfolios, programs and project-oriented companies, Linde Verlag, Wien 2012.

[4] Darnall R. W., The World’s Greatest Project. One Project Team on the Path to Quality. Project Management Institute, 1996.

[5] Alireza B. and Meysam S. M., Fuzzy resource-constrained project scheduling with multiple routes: A heuristic solution, Automation in Construction 2019, Vol. 100, pp. 84-102.

[6] Dorfeshan Y. et al., Selecting project-critical path by a new interval type-2 fuzzy decision methodology based on MULTIMOORA, MOOSRA and TPOP methods, Computers & Industrial Engineering 2018, Vol. 120, pp. 160-178.

[7] Zhang Bei-Bei et al., Explicit cost-risk trade-off for optimal energy management in CCHP microgrid system under fuzzy-risk preferences, Energy Economics 2018, Vol. 70, pp. 525-535.

[8] Karasan A. et al., A new risk assessment approach: Safety and Critical Effect Analysis (SCEA) and its extension with Pythagorean fuzzy sets, Safety Science 2018, Vol. 108, pp. 173-187.

[9] Mazlum M. and Fuat Güneri A., CPM, PERT and Project Management with Fuzzy Logic Technique and Implementation on a Business, Procedia - Social and Behavioral Sciences 2015, Vol. 210, pp. 348-357.

[10] Maravas A. and Pantouvakis J-P., Guidelines for Modelling Time and Cost Uncertainty in Project and Programme Management, Procedia - Social and Behavioral Sciences 2013, Vol. 74, pp. 203-211.

[11] Carlsson Ch. et al., A fuzzy approach to R&D project portfolio selection, International Journal of Approximate Reasoning 2007, Vol. 44, Issue 2, pp. 93-105.

[12] Yuanyuan Liu, Jian Zhou, Yizeng Chen, Using fuzzy non-linear regression to identify the degree of compensation among customer requirements in QFD, Neurocomputing 2014, Vol. 142, pp. 115-124.

[13] Ståhle M. and Ahola T., Martinsuo M., Cross-functional integration for managing customer information flows in a project-based firm, International Journal of Project Management 2019, Vol. 37, Issue 1, pp. 145-160.

[14] OlssonT. and Wnuk K., Gorschek T., An empirical study on decision making for quality requirements, Journal of Systems and Software 2019, Vol. 149, pp. 217-233.

[15] Zadeh L. A., Fuzzy Sets, Information and Control 1965, no 8.

[16] Kuchta D., Soft Mathematics in Management, Wroclaw University of Science and Technology ed., Wroclaw 2001 (in polish).