Improving Offshore-Outsourced Software Development requirement Risk Prioritization, Scheduling and Prediction with Using a Fuzzy Analytic Hierarchy Process

Zaiynab Salarian, Hassan Rashidi
Department of Computer Engineering Islamic Azad University, Qazvin Branch, Qazvin, Iran
Email: salarian.shima@gmail.com, hrashi@gmail.com

Abstract - Researchers consider requirements uncertainty and risk as a problem to be addressed during software development by choosing an appropriate strategy to mitigate the uncertainty because it maybe riskiness and thus must mitigate. Project risk evaluation should be performed by using one of the multi-attribute evaluation methods because of the multidimensional nature of risks. This requires a method that allows the use of decision makers’ vague judgments in the pairwise comparison of attributes. The fuzzy AHP method meets this requirement. Offshore-outsourced software development is gaining popularity because companies are continuously forced to reduce production costs while keeping sustainable competitive strength. However, this trend of software development increases projects’ complexity and brings up risks to the overall project environment. Therefore, risks of offshore software development require to be managed as early as possible for a successful project. This paper considers a risk management model from a holistic perspective to manage offshore software development risk, integrated into early stages of development that improve by using of a fuzzy decision making method. The approach explicitly identifies and specifies the goals of a project and the related requirement risk factors and then prioritize them by using of fuzzy analytic hierarchy process and determine that the software project is acceptable or not. We show how to trace and control these risks already during early requirements engineering activities.

Keywords: software engineering; software development; Offshore-Outsourced Software Development requirement engineering; Requirement Risk; multicriteria decision making; Analytic Hierarchy Process.

1. Introduction

Offshore-outsourced software development (O-Osd) has become a highly favoured topic for companies aiming at cost savings while achieving final product delivery within estimated time schedules. Still, this type of development has several challenges due to its inherent nature. For instance, decreased degrees of communication, lack of knowledge about customers’ business domains, disputes on legal issues may pose any potential risks to the project. A recent report suggested that outsourcing magnifies existing risks and creates additional threats to the offshore projects. These risk factors are not only given by technical issues, but also by non-technical issues. There is in general and observable tendency to over manage the technical issues and underestimate the nontechnical ones. Consequently, O-Osd has to emphasize particular goals, such as an effective co-ordination of project works between offshore customers/users with local development teams, building trust, attain security besides generic software development goals like schedule, cost and quality [1].

This paper evaluates a fuzzy goal-driven risk management model (FGSRM) that is integrated into Requirement Engineering (RE) activities in order to manage risks of OOsD, and Fuzzy Analytic Hierarchy Process (FAHP) to as a suitable and practical way of evaluating project risks based on the heuristic knowledge of experts is used to evaluate the riskiness of software project. Because projects’ risks are multidimensional, they must be evaluated by using multi-attribute decision-making methods. The aim of this article is to provide an analytic tool to evaluate the OOsD risks under incomplete and vague information.

The approach explicitly defines the relations between the goals relating to project success from offshore environment and the risk factors that obstruct the goals respecting technical as well as non-technical development components. Then FAHP method based on Chang’s extent analysis will be applied to measure its risk level. The first step of the fuzzy AHP method requires constructing an appropriate hierarchy of the fuzzy AHP model, which consists of the goal, criteria, and the alternatives. The top management categorizes the risk levels as high risk, moderate risk, and low risk. If the final result of the risk evaluation based on the experts’ opinions is revealed as high risk, the top management will reject the project; otherwise the OOsD project will be acceptable. In addition, it defines the control actions that enable the satisfaction of the goals. Therefore, GSRM assesses and manages risk as a problem to be solved. The field of Multiple Criteria Decision Making (MCDM) evolved since 1980 into a set of powerful
approaches suitable for complex managerial problems. These can be summarized in three groups: Multi-attribute Utility Theory (MAUT), the French Outranking Methods like PROMETHEE and the Analytic Hierarchy Process (AHP) (see Saaty, 1994, Saaty, 2008a)[2][3]. The latter method has gained the widest acceptance in the world by practitioners and scholars (Yu and Chen (2005))[4][4] . It is true that it is criticized by proponents of the other two schools of thought. Criticism by proponents of utility theory is based on the questionable assumption that its axioms can be used to judge a different decision making approach like AHP, which is based on different axiomatic foundations (see Saaty, 1994)[2][2] . Then the decisive criterion for the validity of an approach should be how widely it is used in practice and on this indicator AHP is unsurpassed (Yu and Chen (2005))[4][4]

A complex problem is structured in AHP in the form of a hierarchy. The upper levels contain the goals while the following layers hold factors affecting them and the alternative choices to be made. Unlike mathematically naive “scoring” approaches in which an alternative is assigned an absolute score usually with respect to the overall goal, the Analytic Hierarchy Process breaks down the task of prioritization into simpler problems related to the pairwise evaluation of factors in the hierarchy with respect to their contribution only to the element in the root of a particular cluster of the hierarchy (see Saaty, 2008a)[3].

To address the fact that some variables are quantitative while others are qualitative, a measurement ratio scale from 1 to 9 is used in these comparisons translating thus all quantitative and qualitative facts into human judgments (see Saaty, 1994, Saaty 2008a). When two compared factors are considered equally important, then a value of 1 is entered. If the first factor is slightly more important than the second, then a value of 3 represents that, while 5 means strong importance, while 7 and 9 mean respectively very strong and absolute importance. Values of 2, 4, 6 and 8 represent intermediate cases. It can be noted that these comparisons form a matrix of comparisons for each cluster. As the matrix is reciprocal, meaning that the elements below the main diagonal are symmetrically reciprocal to those above it, it is sufficient to provide only the judgments above the main diagonal, while those that are on the main diagonal are equal to 1[5].

Notice that the judgments described in the preceding paragraph represent ratios of the weights of the factors that are being compared. The purpose of an AHP model is to restore the actual weights. The mathematics involved in the calculation of these weights is based on the theory of matrix eigenvalues and eigenvectors (see Saaty,1994). The resulting weights of the factors obtained as the elements of the eigenvector corresponding to the largest eigenvalue of the comparison matrix represent their local priorities towards the root of the respective cluster (see Saaty, 1994). These are used for the synthesis or calculation of the overall importance of an element in the hierarchy towards the main goal in the root of the hierarchy. It is also called global priority of a factor within the hierarchy. Note that these global priorities are normalized which means that the sum of the priorities of the elements within a level of the hierarchy is equal to 1. The latter is convenient in ranking and in using priorities for the allocation of resources in proportion to the weights of the alternatives.

The steps in AHP modelling (see Saaty, 2008a) are implemented using several software packages such as Expert Choice and Creative Decisions. The application of AHP leads to improved transparency of decision processes, the creation of a decision audit trail and greater acceptance and legitimacy of the decisions (see Saaty, 1994, 2008a). The discussion on AHP leads to a conclusion on the relevance and applicability of MCDM for operationalizing the process for design science research suggested by Peffers et al. (2006) [6] to outsourcing decisions.

Traditionally, in software engineering risk analysis is used to identify the high risk elements of a project and provide ways of documenting the impact of risk mitigation strategies. Risk analysis has been also shown important in the software design phase to evaluate criticality of the system, where risks are analysed and necessary countermeasures are introduced. Usually, countermeasures correspond to a design/system fine-tuning and then with a limited margin of change. However, it may happen that the risk reduction results in the revision of the entire design and possibly of the initial requirements, introducing thus extra costs for the project. Considering risk since the early phases of the software development process can be useful to prevent such problems and, as effect, to contain costs. Particularly, analysing risk along stakeholders’ needs and objectives, namely before requirements elicitation, can introduce good and valuable criteria to evaluate and choose among different alternative requirements.

Goal-oriented requirement engineering is an emerging research area where the concept of goal is used to model early requirements and non-functional requirements for a software system. The use of goals facilitates the analyst to understand the objectives of stakeholders and then motivate within the organizational setting the system’s requirements.

KAOS [7], i* [8], GBRAM [9] and Tropos [10] are examples of goal-oriented methodologies and frameworks that have recently gained popularity in the community. Particularly, Tropos is a requirement-driven development methodology based on the i* modelling framework. Tropos proposes an early requirements analysis phase, where the analyst identifies the relevant stakeholders and models them as social actors, who depend on one another for goals to be fulfilled, tasks to be performed, and resources to be furnished. Through these dependencies, one can answer why questions, besides what and how, regarding system functionalities/requirements. Answers to why questions ultimately link system functionalities to stakeholders’ needs, preferences and objectives. Moreover, the methodology analyses goals by a refinement process in which each goal is decomposed into subgoals and positive/negative contributions are established among
goals. For example, in the case of a loan origination process the goal of assess loan applications can be OR-decomposed in assessed by in-house and assessed by Credit Bureau, while the goal receive electronic application may help (i.e., contributes positively) to verify loan application, the bank can indeed validate automatically the application with appropriated agencies.

Through goal models, the analyst can analyze alternative ways for the satisfaction of stakeholders’ goals and choose among them on the base on specific criteria, like for example minimum-cost [11]. However, Tropos, as well as other goal-oriented approaches, does not consider risk within its requirements analysis process, and it may happen that the cheapest alternative corresponds to the most risky one. For instance, suppose that in order to receive loan application the bank can either receive electronic application or receive hard-copy application. Although, the electronic solution can economize the loan originating process, it can introduce a high level of risk due, for example, to the forgery of the application by external hackers or even by internal employees.

The remainder of this paper is organised as follows. The remainder of this paper is organised as follows. In section 2 will consider some related work in this area, in section 3 we will describe integrating software development risk management into requirement engineering, in section 4 hierarchical structured risk management systems will consider, in section 5, requirement risk evaluation of an offshore-outsourced software project using fuzzy AHP and finally in section 6 in section 7 we give concluding remarks and suggestions.

2. Related Work

Outsourcing offers several advantages, such as enabling existing staff to concentrate on core competencies, focusing on achieving key strategic objectives, lowering or stabilizing overhead costs, obtaining cost competitiveness over the competition, providing flexibility in responding to market conditions, and reducing investments in high technology. Thus software outsourcing is becoming increasingly popular. However, because of the difference between outsourcers and outsources in terms of geography, culture, law, view of value and management methods, there are also disadvantages to outsourcing agreements. These include becoming dependent on an outside supplier for services, failing to realize the purported cost savings from outsourcing, locking into a negative relationship, losing control over critical functions, and lowering the morale of permanent employees (Kliem, 1999)[12]. The largest risk comes from the choice of the outsourcers. A wrong choice may make the outsourcer fail to achieve the development scale, time, cost, and quality and benefit goals.

The purpose of outsourcing is to pursue potential benefits, but this cannot guarantee that outsourcing will come successful [13]. Though much research has been done about outsourcing risks, there are few research reports about the fuzzy risk evaluation of outsourcers.

Because unanticipated risks or unmanaged risks are two of the main causes of project failure, organizations or project teams need to be prepared for project risks in order to attain the desired level of project success. This requires being aware of project risks and managing them. Risk management in projects has been practiced since the mid-1980s and is one of the nine main knowledge areas of the Project Management Institute’s Project Management Body of Knowledge. Risk management is defined as the systematic process of identifying, analyzing, and responding to project risks. There are different project risk management approaches in the literature, the aim of project risk management is the same, which is to increase the project performance and also to achieve the project objectives by identifying and evaluating the possible risks and developing appropriate responses to them.

There are several valuable contributions in the research area of software risk management, including models, process descriptions and techniques. Still, only a few focus on the integration with Requirement Engineering (RE). Boehm proposed a risk-driven spiral model in [14] including an iterative approach to manage risks in software project. Karolak proposed the Software Engineering Risk Management (SERM) framework based on four interconnected risk trees including 81 risk factors, in turn, categorized by technology, cost and schedule[15]. Kontio proposed the Riskit methodology [16] by initially identifying stakeholder goals and risks that threaten the goals. Risks are analyzed and prioritized by deriving scenarios which is a non-trivial task when a scenario depends on more than one probabilistic element. A recent contribution that focuses on integrating risk management into RE is the one of Ansar et al.[17]. It contributes by using Tropos a goal-driven approach to identity and manage risks that obstruct the goals within RE. Procaccino et al.[18], identifies seven early development factors and discusses how these contribute to the success or failure of a software project. Other directions of work empirically analyze risk factors. Iacovou et al. summarize for example in [19] the top ten risk factors for offshore-outsourced development projects. Aspray et al. consider in the ACM task force report [20] risks from both technical and non-technical issues. Tsuji et al. [21] propose questionnaires assessment schemes based on software, vendor, and project properties to quantify risks in offshore software outsourcing. The survey shows that vendor properties including communication and project management abilities affect more the result to development in comparison to software (technical) properties like requirement volatility. However, our risk management model is goal-driven and extends the basic concepts of the KAOS approach. We focus on a holistic view of technical and non-technical issues.

This paper mainly focuses on the assessment or evaluation layer of the goal-driven risk management model (GSRM) for project risk management process, which is a certain common element in all approaches.
Because risks are multidimensional, they should be evaluated with respect to more than one criterion or more than one factor to get more accurate and reliable results. Multicriteria decision-making (MCDM) methods are an important set of tools for addressing challenging business decisions because they allow the manager to better proceed in the face of uncertainty, complexity, and conflicting objectives. The analytic hierarchy process (AHP) is one of the extensively used multicriteria decision-making methods. One of the main advantages of this method is the relative ease with which it handles multiple criteria. The risk level evaluation of project risks is a complex subject including uncertainty. The imprecise and vague terms will exist, because most project managers find it more practical and easier to evaluate risk in linguistic terms. Fuzzy sets theory introduced by Zadeh is especially powerful when there is a need to take into consideration the ideas and judgments of people because of complexity and lack of proper information. Fuzzy sets provide representation of the knowledge of project managers in a better and more natural way. Because AHP does not take into account the uncertainty associated with the mapping of one’s judgment to a number and also the subjective judgments, selection, and preference of decision makers exert a strong influence in the AHP; fuzzy sets theory can be used to overcome these shortcomings of AHP.

In this paper we want to integrate FAHP as a MCDM method for outsourcing decisions in GSIRM framework. the significant contribution of this paper, as the first, is the suggestion of the use of FAHP in risk evaluation of outsourcing decisions of software project.

We have focused on AHP for modelling outsourcing decisions as it is the most widely used MCDM approach as noted earlier (see Yu and Chen, 2005)[4] and for the advantages of the pairwise comparison method that it utilizes as discussed in Saaty (2008a; 2008b)[22]. The next paragraphs present an analysis of outsourcing decision modelling that has been reported predominantly in the literature on operations research. Pandey and Vasal (2004)[23] propose two AHP models: one for choosing activities to outsource and another to choose the appropriate outsourcing methodology. For the first one they provide without any particular justification three criteria: criticality, stability and simplicity associated with the activities under consideration. These are verified subsequently through interviews with twenty IT managers. We may note however that there is no particular link between their work and past traditional research on IS outsourcing. Hwang (2005)[24] presents a web based decision support system using fuzzy AHP to assist in the make or buy decision. The AHP model however does not include any elements from previously published research on the make or buy decision. Wang and Yang (2007)[25] have considered six criteria: economics, resources, strategy, risk, management and quality in their proposed use of a combination of AHP and PROMETHEE. Their literature review covers relevant traditional research on outsourcing and the derived criteria are based on it. However the criteria in their approach are determined at the end by a group of managers and hence it is hard to judge to what degree their knowledge reflects the state of the art on the decision whether to outsource or not.

Udo, Kirs and Bagchi (2008)[26] provide an AHP model for evaluating what activities to outsource. They quote a practitioner source for justifying the criteria included in their model: the strategic importance of the information system (IS) function in question, economic considerations, project attributes, vendor issues, and industry or environment issues.

While these criteria make sense, they are based on a single source that is not reflecting fully the vast amount of IS research associated with IT outsourcing. It may be concluded that past research on applying MCDM to IT outsourcing decisions is based mostly on intuitive selection of criteria that are not justified sufficiently by earlier behavioural research in IT outsourcing. Hence our conclusion that there is a disconnect between MCDM outsourcing models and traditional IT research. to resolve this issue through an application of AHP to outsourcing decision making which is informed by the best behavioural outsourcing research following a similar process to the one suggested by Peffers et al. (2006)[6] are proposed.

In this paper we want to integrate software development requirement engineering (in our case requirement risk assessment) with AHP as a decision making method. AHP is a structured technique for organizing and analyzing complex decisions. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It has particular application in group decision making, and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education. Risk-based decision making is a process that organizes information about the possibility for one or more unwanted outcomes to occur into a broad, orderly structure that helps decision makers make more informed management choices. We integrate requirement risk assessment of an OOSD project with FAHP method and assess the top event as riskiness of project and show how could improve this goal-driven risk management with using fuzzy decision making method. In this way decision maker can make decision that whether he/she accept or reject the project. If the final result of the risk evaluation is revealed as high risk, the top management will reject the project; otherwise the software project will be acceptable. Hence they can assess the risk of requirement of an OOSD project in the early stage of project in a risk-goal-driven-based decision making framework.

3. Integrating Software Development Risk Management into Requirement Engineering

Customer requirements are in development projects often not deeply understood what results in expansions of the system scope, in missing business needs or even in a rejection of the final system. Software risk
management can effectively contribute to control these problems before they occur to improve the overall project outcomes. But even though the awareness of the importance of risk management, risk management is not always well-applied in practice. A study showed that 75% of analysed project managers did not follow any detailed risk management approach (Ropponen and Lytinen, 2000) [27]. The cause of most project failures has little to do with technical issues despite the common tendency among project managers to focus more on these. Several software risk management approaches and standards emphasise the importance of performing risk management activities as early as possible. However, there is still a lack of comprehensive detailed guidelines on how to integrate risk management activities into a specific phase of the development life cycle. We believe that the integration of risk management into requirement engineering effectively contributes to reduce requirements errors. The reasons is that requirement errors are the most expensive software errors that are numerous and persist throughout the life cycle (van Lamsweerde, 2009) [28].

Thus, this work contributes:

To propose a goal-driven modelling framework to support more effective, systematic and straightforward method and activities for software development risk management from holistic perspective.

To integrate risk management activities into RE by considering the dependency among the requirement and risk artefacts and inherent similarities among the activities and techniques.

To develop a goal-risk taxonomy along with questionnaires for effectively identifies the risk factors from the early development components.

3.1 Goal-Driven Software Development Risk Management Model

We analyze early software development components and project success factors from the existence literature as a background foundation to develop the model. This lays the foundation for goal-driven risk management Model (GSRM) considering a holistic view from a both technical and a non-technical. We consider technical issues in software development as those aspects that directly relate to hardware and software while nontechnical issues relate to human, managerial, organizational and environmental factors. Based on a literature survey, we categorized development components according to project constraints, development process, product, human and finally (internal & external) environment. These components are described through the essential elements that are required for software development. The elements may be described by single or by multiple factors. Therefore, elements and factors together represent the activities, the activities’ results (the artifacts) and the general characteristics of the individual components. For instance, project planning and control is an element under the component project constraints that represents project schedule, budget, staffing and other project planning and management related issues. This hierarchy eases the identification of goals to be satisfied and risk factors that obstruct these goals like maintaining a realistic project schedule. Based on this hierarchical framework, we consider a conceptual view for the risk management model within GSRM, as shown by Fig. 1. Goals are derived from the development components by considering the factors relating to project success. Project stakeholders are responsible to these goals. Risk factors certainly obstruct these goals and support casual relationships to the risk event. Likelihood of risk events along with the risk impact supports to prioritize the risks. Finally, control actions are implemented to reduce the risk event and contribute for the goal satisfaction [1].

Figure 1 - Conceptual view for the risk management model.

3.2 Offshore-outsourced Goal-Driven Software Development Risk Management Model

GSRM is based on existing goal modeling techniques to accommodate risk management activities. We extend the KAOS (van Lamsweerde, 2009) [28] goal modeling approach to support risk management activities and integrate it with Requirement Engineering(RE) respecting Offshore-outsourced software development (O-OSD). Goals in general provide an anchor to analyse the risks in software development. Therefore, risk management requires the identification, the analysis and the refinement of the goals and the risk factors that obstruct the goals. KAOS defines an obstacle as an undesirable behavior against stakeholders’ strategic interests. GSRM adopts this concept of KAOS and defines software risks as obstacles that contribute negatively to the fulfillment of specific goals. In GSRM we extend KAOS furthermore with risk assessment and treatment techniques [7]. This is done by using four layers of abstraction within the modeling structure of GSRM. Fig. 2 depicts the four different layers that are subsequently described [1].
Goal Layer - Goals are the objectives, constraints and expectations that have to be achieved by a software development project through the cooperation of system agents. These agents represent the development components and the project stakeholders. Therefore, the model initiates with the goals by following the development component, the elements and the factors hierarchy besides the project stakeholders’ expectations. Goals can be stated at different levels of abstraction from higher level coarsely grained to lower level finely-grained goal assertions. This goal hierarchy enables developers to model all system agents, even though these often are somewhat fuzzy. GSRM follows informal temporal pattern as stated in KAOS to represent each goal. The pattern structures an assertion into a prefix and a condition/property. For instance, a statement could be “reduce [erroneous requirement]”, whereby the prefix “reduce” represents a goal that demands a reduction of defected requirement.

Risk Obstacle Layer - The risk obstacle layer encompasses the potential obstacles and specifies which goals they obstruct, i.e. incurred problems within the development environment. The layer allows the practitioner to directly link all types of obstacles to the goals. Same and similar risk obstacles can be relevant to more than one goal. This is important in order to consider effective treatment options. Risk factors that cross-cut several goals are in general more effective to counter since the treatment effect often then propagate also to goals that are not directly linked with the particular risk factor. In GSRM, we follow a set of questionnaires based on the early development components and brainstorming techniques to identify these risk obstacles. All identified obstacles are then analyzed further within the assessment layer.

Assessment Layer - The assessment layer mainly analyses the risk events that influence single or multiple risk factors. Each risk event is characterized by two properties: likelihood and impact. Likelihood specifies the rate of occurrences of a risk event and is modelled as a property of the risk event itself. The impact is a measure over the negative outcome of the risk event occurrence. All risk events and goal relationships are modelled by adding an obstruction link from the risk event to the specific goal that it obstructs, and in cases where several goals are affected, an obstruction link is established between the risk event and each of these goals. GSRM supports the use of risk metric values to identify the likelihood of the risk event by estimating the casual relationship of the related risk factors. GSRM uses for this purpose the Bayesian interpretation and in particular Bayes theorem to estimate the risk events based on their causal relationship with the risk factors. Risk events likelihood and impact in particular with high-bajhs, high-mediums and medium-mediums while ignoring low-lows give us certain beliefs about the dissatisfaction (DSAT) and the satisfaction (SAT) of the goal fulfillment. Finally, risks are prioritized based on their likelihood and impact. We want to integrate this layer with Fuzzy Analytic Hierarchy Process (FAHP).

Treatment Layer - Once the goals, risk factors and risk events are identified and analyzed, it is crucial to identify and then implement suitable and cost effective countermeasures. Therefore, the aim of the treatment layer is to gain control of the risks as early as possible and preferable during RE activities by assigning appropriate countermeasures. To visualize the relationship between treatment, risk obstacle and goal, we establish a contribution link from chosen control actions to the goal by specifying the ability of the treatment to support the goal and by reducing the effect or likelihood of removing the associated risk factors. Additionally it is also necessary to analyze the cost-benefits before implementing a suitable control action.

3.3 GSRM within the Context of RE

Integration of software development risk management in general and GSRM in particular into RE is one of the main contributions by this research. Therefore, we consider a comprehensive analysis regarding the underlying issues relating to the integration. Our focus is from two different perspectives: artefact orientation, activities along with the roles require to perform the activities to provide certain rationale within this context [Islam et al., 2009] [29].

Artifact oriented RE is a systematic methodology that describes the problem space of the system to-be as comprehensively as possible and produces several requirement artifacts [van Lamsweerde, 2009] [28]. Requirement artifacts rely on attributes to specify the properties of the artifact and syntax to represent the attribute through textual or graphical based way. Highly structured text is mainly used to represent the requirement artifacts. Risk artifacts also consist of
certain predefined highly structured attributes. Graphical visualization is limited supported by UML use case or activity diagram when representing user requirements. But GSRM requires visual notation to model the goal-risk-treatment, to represent the casual relationship between risk factors and events. Several goals from the project context such as business, stakeholder expectations and constraints from the organizational environment are one of the main inputs for eliciting requirement and risk factors. Elicited requirement in particular user and system requirement indeed support to create several risk artifacts such as detailed risk list, goal-risk model, etc. In fact requirements are among one of the elementary inputs for risk identification. The reduction of project risks is a critical requirement for any project. Risk control actions also contribute to goal satisfaction such as an active customer/user involvement, an effective RE process, and finally facilitates the systematic performance of RE activities. The activities and underlying techniques for both RE and GSRM are interrelated. For instance RE mainly comprised of activities such as elicit, analyse and validate of requirements which further decompose into sub-activities also provide similarities. Several techniques within the activities are similar. For instance, requirement, goal and risk identification rely on checklists, brainstorming sessions and several organizational documents. Elicited requirement are reviewed to identify the errors that pose any potential risk. The result of risk management supports to make decision to priorities requirements. Risk monitor similar like requirement validation is a continuous activity and if require persist throughout the development life cycle. Customer/user representative in particular members of user groups provide certain input to elicit user requirements, goals and risk factors. We believe both project manager and requirement engineer with certain domain knowledge about risk management can perform the risk management activities under GSRM. Because generally in real project situation, there might not have adequate support to appoint expert for performing risk management activities in particular for project with having limited budget and time constraints. Figure 3 outlines the requirement and risk artifacts along with the artifact from the business specification [31].

4. Hierarchical Structured Risk Management Systems

Statistical methods-based reasoning models in crisis situations need long time experiments and enough reliable data elaborated by experts. Additionally, they are time- and computing-demanding. The problems to be solved are full of uncertainties, and complexity of the systems increases the runtime factor of the decision process [30]. Considering all those conditions fuzzy set theory helps manage complexity and uncertainties, and represents the inputs and outputs of the model in an emphatic form. The relationship between risk factors, risks and their consequences are represented in different forms, but in a well-structured solution, suitable for the fuzzy approach is given. A risk management system can be built up as a hierarchical system of the risk factors (inputs), risk management actions (decision making system) and direction or directions for the next level of risk situation solving algorithm. A possible preliminary system construction of the risk management principle can be given based on this structured risk factor classification and on the fact, that some risk factor groups, risk factors or management actions have a weighted role in the system operation. The system parameters are represented with the fuzzy sets, and the grouped risk factors’ values give intermediate result. Considering some system input parameters, which determine the risk factors’ role in the decision making system, intermediate results can be weighted and forwarded to the next level of the reasoning process.

![Figure 3](image-url) - Artifact oriented view to integrate GSRM into RE.

4.1 Fuzzy Set

Fuzzy sets are sets whose elements have degrees of membership. Fuzzy sets were introduced simultaneously by Lotfi A. Zadeh in 1965 [32]as an extension of the classical notion of set. In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition — an element either belongs or does not belong to the set. By contrast, fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1]. Fuzzy sets generalize classical sets, since the indicator functions of classical sets are special cases of the membership functions of fuzzy sets, if the latter only take values 0 or 1. In fuzzy set theory, classical bivalent sets are usually called crisp sets. The fuzzy set theory can be used in a wide range of domains in which information is incomplete or imprecise, such as bioinformatics.
The most important factors contributing to the risk of failure for any type of organization or system are related to poor performance, time pressure, low quality and high cost.

The major problem associated with the estimation of risks is that the input data are imprecise by nature and it is difficult to represent them with crisp numbers.

To deal with vagueness of human thought, Zadeh (1965) first introduced the fuzzy set theory, which was based on the rationality of uncertainty due to imprecision or vagueness. A major contribution of fuzzy set theory is its capability of representing vague knowledge. The theory also allows mathematical operators and programming to apply to the fuzzy domain [33] (2006).

Usually the risk analyst prefers to estimate in linguistic terms such as High or Low rather than in exact probabilistic terminology. To this end, the application of Fuzzy Set Theory (FST) to risk analysis seems appropriate, as such analysis can handle inexact and vague information (2010).

The basic idea of the fuzzy approach, which were developed by L.A. Zadeh in 1965, is to allow an element to belong to a set with degrees of membership ranging in the continuous real interval [0,1], rather than in the set. A fuzzy number is a normal and convex fuzzy set with membership function \( \mu_A(x) \), which both satisfies normality, \( \mu_A(x)=1 \), for at least one \( x \epsilon R \), and convexity,

\[
\mu_A(x') \geq \mu_A(x) \leq \mu_A(x_2) \quad \text{with} \quad M', \text{ where} \quad \mu_A(x) \epsilon [0,1] \mu_A(x) \in [0,1], \quad \text{and} \quad \forall x' \epsilon [x_1, x_2].
\]

A tilde will be placed above a symbol if the symbol represents a fuzzy set. A fuzzy number is a special fuzzy subset of the real numbers. The membership function of a triangular fuzzy number (TFN), \( M' \), is defined by

\[
\mu(x|\tilde{M}) = \frac{(m_1 - x) / (m_1 - m_2)}{m_2 - m_3}, \quad \alpha \epsilon [0,1], \quad \text{and} \quad \frac{(x - m_2) / (m_3 - m_2)}{m_3 - m_1}
\]

Where \( m_1 < m_2 < m_3, f_1(y|M') \) is a continuous monotone increasing function of \( y \) for \( 0 \leq y \leq 1 \), with \( f_1(0|M') = m_1 \), and \( f_1(1|M') = m_3 \), \( f_2(y|M') \) is a continuous monotone decreasing function of \( y \) for \( 0 \leq y \leq 1 \) with \( f_2(0|M') = m_2 \), \( f_2(1|M') = m_3 \), \( \mu_A(x|M') \) is denoted simply as \( \mu(x|M_1, M_2, M_3) \) Fig. 4 presents a TFN[32]. The extended operations of fuzzy numbers can be found in [35].

### 4.2 Fuzzy Risk Management

Risk management is a complex, multi-criteria and multi-parametrical system full of uncertainties and vagueness. Generally the risk management system in its preliminary form contains the identification of the risk factors of the investigated process, the representation of the measured risks, and the decision model. The system can be enlarged by monitoring and review in order to improve the risk measure description and decision system. The models for solving are knowledge-based models, where linguistically communicated modeling is needed, and objective and subjective knowledge (definitional, causal, and statistical, and heuristic knowledge) is included in the decision process. Considering all these conditions, fuzzy set theory helps manage complexity and uncertainties and gives a user-friendly visualization of the system construction and working model.

![Figure 4 - A Triangular fuzzy number.](image)

Fuzzy-based risk management models assume that the risk factors are fuzzified (because of their uncertainties or linguistic representation); furthermore the risk management and risk level calculation statements are represented in the form of if premises then conclusion rule forms, and the risk factor calculation or output decision (summarized output) is obtained using fuzzy approximate reasoning methods. Considering the fuzzy logic and fuzzy set theory results, there are further possibilities to extend fuzzy-based risk management models modeling risk factors with type-2 fuzzy sets, representing the level of the uncertainties of the membership values, or using special, problem-oriented types of operators in the fuzzy decision making process.

The hierarchical or multilevel construction of the decision process, the grouped structural systematization of the factors, with the possibility of gaining some subsystems, depending on their importance or other significant environment characteristics or on laying emphasis on risk management actors, is a possible way to manage the complexity of the system. Carr and Tah describe a common hierarchical-risk breakdown structure for developing knowledge-driven risk management, which is suitable for the fuzzy approach [30].

Starting with a simple definition of the risk as the adverse consequences of an event, such events and consequences are full of uncertainty, and inherent precautionary principles, such as sufficient certainty, prevention, and desired level of protection. All of these can be represented as fuzzy sets. The strategy of the risk management may be viewed as a simplified example of a precautionary decision process based on the principles of fuzzy logic decision making.
4.3 Grouped, Weighted Fuzzy Model

Based on the main ideas from a risk management system can be built up as a hierarchical system of risk factors (inputs), risk management actions (decision making system) and direction or directions for the next level of risk situation solving algorithm. Actually, those directions are risk factors for the action on the next level of the risk management process. To sum this up: risk factors in a complex system are grouped to the risk event where they figure. The risk event determinates the necessary actions to calculate and/or increase the negative effects. Actions are described by ‘if … then’ type rules.

With the output those components frame one unit in the whole risk management system, where the items are attached on the principle of the time-scheduling, significance or other criteria (Figure 5).

Input Risk Factors (RF) grouped and assigned to the current action are described by the Fuzzy Risk Measure Sets (FRMS) such as ‘low’, ‘normal’, ‘high’, and so on. Some of the risk factor groups, risk factors or management actions have a different weighted role in the system operation. The system parameters are represented with fuzzy sets, and the grouped risk factors values give intermitted results. Considering some system input parameters, which determine the risk factors’ role in the decision making system, intermitted results can be weighted and forwarded to the next level of the reasoning process [30].

4.4 Multicriteria Methods Integration Process

Researches on several engineering fields (systems engineering, process engineering, method engineering, and so on) show that there are many development cases where information system (IS) engineers has critical choices to carry out. As a matter of fact, they have to deal with a large number of characteristics, artifacts, ideas, possibilities, etc. Many strategies are offered to manage them and choosing one over the others is often a very difficult task to handle. Some development activities aim to sort possible alternatives by prioritizing them. However, these priorities are often applied intuitively and there is a great need for a better periodization support.

Generally, a decision-making (DM) problem is defined by the presence of alternatives. The traditional approach consists in using only one criterion in order to select alternatives. The usual example is the selection of the projects according to the net present value. However, using a single criterion is not sufficient when the consequences of the alternatives to be analyzed are important. The goal of the Multicriteria (MC) DM methods consists in defining priorities between alternatives (actions, scenarios, projects) according to multiple criteria. In contrast to a monocriterion approach, MC methods allow a more in-depth analysis of the problem because they consider various aspects. However, their application has proved more difficult [36].

MCDM methods have shown their qualities for over 30 years and they currently dominate in the field of decision-making. They appeared at the beginning of the Sixties, and their number and application contexts increase continually. For example, these methods are employed for requirements periodization, to choose evolution scenario, or to make operational decisions.

Five families of MC methods can be considered: MAUT, AHP, outranking methods, weighting methods, and fuzzy methods. These methods will be detailed in the following. We propose in this work to improve any development process with the use of multicriteria methods as a way to choose the most adapted alternative to each situation. We propose a process, illustrated by an example, which integrates MC methods at the DM point of the development process. Our aim is to propose a formal approach for periodization in order to enhance DM in development process.

Our proposal consists of the integration of MC methods in the methodologies of software development. It is described by an “integration process” (IP) which is presented on Fig. 6.

Figure 5 - The hierarchical risk management construction.

Figure 6 - Process of integration of MC method into software development methodologies.

The integration process includes four steps: 1) Identify requirements for periodization, 2) Specify requirements for MC methods, 3) Select a MC method, and 4) Apply the MC method and validate results. This IP includes both direct steps and flashbacks. The former indicate the normal IP development, and the latter enable returns to the previous steps if necessary.

5. Requirement Risk Engineering (In Our Case) Evaluation OFAN Offshore-Outsourced Software Project using Fuzzy AHP

The most important risks which can occur in this area are the following:
The number of requirements can become unmanageable if they are not under control.
- Requirements are related to one another and also to other deliverables in the solution delivery process.
- Requirements need to be managed by multiple cross-functional entities.
- The requirements modification process is not implemented or insufficiently implemented.
- Requirements are not reviewed at all or inadequately reviewed.
- Requirements describe only the design specification.
- There is an over-improvement of the requirements.
- Functional requirements are only considered.
- The user or customer is not enough involved.
- Critical requirements are overlooked.
- The business case is incomplete.

To reduce risks in large software projects, managers should bear in mind that people view the project from their own perspective with different expectations. When the initial objectives, assumptions, and requirements are not clearly and precisely defined in writing, there is no (good) common starting point. An inherent expectation gap exists which can be a major cause of trouble at the end of the project [37].

### 5.1 Classifying Software Requirement Risks for use in Hierarchical Process

Classification is fundamental to the insurance business. On the one hand, risks need to be properly classified and segregated for pricing purposes; while on the other hand, classification is basic to the underwriting of potential coverage. As indicated before, the main aim of risk evaluation is to determine the relative significance of different sources of risk on the overall project. In other words, it is for determining which risk events warrant response. This is because every project has different risks and, indeed, different levels of risk [38]. Chapman and Ward [39] suggest the approach of evaluating and assessing the risk as groups, and then determining the impact on the project in a cumulative manner [38]. There are different classifications of risk groups in the literature. Elkington and Smallman [38] classify project risks in four groups, which are business risks, procurement risks, management risks, and technical risks. Miller and Lessard [40] classify project risks in a more general way as market-related risks, technical risks, and institutional risks. Mustafa and Al-Bahar [41] classify different sources of risk in construction projects as acts-of-God risks, physical risks, financial and economic risks, and job-site-related risks.

Kerzner [42] gives a more detailed classification of risks, which are cost, funding, schedule, contract relationship, political, technical, production, and support risks.

These classifications are important and can especially be used in the identification phase of risk factors. Because every project is different from another, not every risk factor valid for a certain project will be valid for others. Risk factors for a project should be considered as specific to that project.

The primary purpose of classifying risk is to get a collective viewpoint on a group of factors, which will help the managers to identify the group that contributes the maximum risk. A scientific way of approaching risks is to classify them based on risk attributes. Risk classification is an economical way of analyzing risks and their causes by grouping similar risks together into classes.

Software project risks can affect requirements, scheduling, cost, quality and business. Therefore, classification on the basis of these groups can be done [43]. Table 1 represents a classification of software project risk. These risks are gotten through studies and experiences in projects.

### 5.2 Fuzzy Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then.

It has particular application in group decision making, and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education. Rather than prescribing a “correct” decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood—anything at all that applies to the decision at hand. Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgments about the elements’ relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations. The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques. In the final step of the process, numerical priorities are
calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action. Multicriteria decision-making methods are an important set of tools for addressing challenging business decisions because they allow the manager to better proceed in the face of uncertainty, complexity, and conflicting objectives. Because risks are multidimensional, they should be evaluated with respect to more than one criterion to get more accurate and reliable results [44]. The analytic hierarchy process (AHP) is one of the extensively used multicriteria decision-making methods. One of the main advantages of this method is the relative ease with which it handles multiple criteria. In addition to this, AHP is easier to understand and it can effectively handle both qualitative and quantitative data. Mustafa and Al-Bahar [45] introduce the approach of using AHP for project risk evaluation. They apply AHP in assessing the riskiness of a construction project in Bangladesh. The importance of their work is that it is the first on the utilization of AHP in risk evaluation. Dey [46] uses AHP and decision tree analysis as a quantitative approach to construction risk management. He uses the AHP for determining the probability of occurrence of various risk factors and displays the benefits of using it.

The risk level evaluation of project risks is a complex subject including uncertainty. The imprecise and vague terms will exist, because most project managers find it more practical and easier to evaluate risk in linguistic terms. Fuzzy sets theory introduced by Zadeh [32] is especially powerful when there is a need to take into consideration the ideas and judgments of people because of complexity and lack of proper information. Fuzzy sets provide representation of the knowledge of project managers in a better and more natural way. Because AHP does not take into account the uncertainty associated with the mapping of one’s judgment to a number and also the subjective judgments, selection, and preference of decision makers exert a strong influence in the AHP; fuzzy sets theory can be used to overcome these shortcomings of AHP. In this article, we propose the use of fuzzy AHP (FAHP) as a suitable and practical way of evaluating project risks based on the heuristic knowledge of project managers [44]. Although fuzzy logic and AHP have been separately used in the evaluation of project risks, the significant contribution of this article, as the first, is the suggestion of the use of FAHP in project risk evaluation.

Table 1 - Classifying of a software project requirements.

<table>
<thead>
<tr>
<th>Requirement risk factor group</th>
<th>Risk sub factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impossible requirements = e₁</td>
<td>1. invalid requirements = e₁₁ \n 2. ambiguous requirements = e₁₂</td>
</tr>
<tr>
<td>Change and extension in requirements = e₂</td>
<td>3. inadequate report = e₁₃ \n 4. unclear requirements = e₁₄</td>
</tr>
<tr>
<td>Priority review risk = e₃</td>
<td>1. inhibit act = e₁₅ \n 2. add or delete in requirements = e₁₆</td>
</tr>
<tr>
<td>The other qualitative and quantitative events = e₄</td>
<td>1. inadequate of requirements = e₁₇ \n 2. poor definition of requirements = e₁₈</td>
</tr>
<tr>
<td>Lack of requirements prioritization = e₅</td>
<td></td>
</tr>
</tbody>
</table>

5.3 Extent Analysis Method on Fuzzy AHP

Let \( X=\{x_1, x_2, \ldots, x_n\} \) be an object set, and \( G=\{g_1, g_2, \ldots, g_n\} \) be a goal set. According to the method of Chang’s extent analysis model, each object is taken and extent analysis for each goal, \( g_i \), is performed, respectively. Therefore, \( m \) extent analysis values for each object can be obtained, with the following signs:

\[
M^1_{g_{i1}}, M^2_{g_{i2}}, \ldots, M^m_{g_{im}}, \quad i = 1, 2, \ldots, n \quad (1)
\]

Where the entire are triangular fuzzy numbers (TFNs). The value of fuzzy synthetic extent with respect to the \( i \)th object is defined as:

\[
S_i = \sum_{j=1}^{m} M^j_{g_{i1}} \otimes \left[ \sum_{i=1}^{n} \sum_{j=1}^{m} M^j_{g_{ij}} \right]^{-1}
\]

The degree of possibility of \( M_1 \geq M_x \geq M_2 \) is defined as:
When a pair \((x, y)\), exists such that \(x \geq y\), and \(\mu_{M_1}(x) = \mu_{M_2}(y)\) then we have \(V(M_1 \geq M_2) = 1\)

Because:

\[
V(M_1 \geq M_2) = \text{sup}_{x \geq y} \left[ \min \left( \mu_{M_1}(x), \mu_{M_2}(y) \right) \right] = 1 \quad \text{iff} \quad m_1 \geq m_2
\]

Where \(d\) is the ordinate of the highest intersection point \(D\) between \(\mu_{M_1}, \mu_{M_2}\) (Fig. 7).

\[\text{Figure 6} - \text{The intersection between } M_1, M_2.\]

To compare \(M_1, M_2\), we need both the values of \(V(M_1 \geq M_2), V(M_2 \geq M_1)\). The degree possibility for a convex fuzzy number to be greater than \(k\) convex fuzzy numbers \(M_1, M_2\) can be defined by:

\[
V(M \geq M_1, M_2) = \text{sup}_{x \geq y} \left[ \min \left( \mu_{M}(x), \mu_{M_1}(y), \mu_{M_2}(y) \right) \right]
\]

Assume that:

\[
\hat{d}(A_i) = \min V(s_i \geq s_k) \quad \text{for } k = 1, 2, \ldots, n; k \neq i
\]

Then the weight vector is given by:

\[
\hat{w} = \left( \hat{d}(A_1), \hat{d}(A_2), \ldots, \hat{d}(A_n) \right)^T
\]

Via normalization, the normalized weight vectors are:

\[
w = \left( d(A_1), d(A_2), \ldots, d(A_n) \right)^T
\]

Where \(w\) is not a fuzzy number. The issue of consistency in fuzzy AHP is another subject that needs to be examined. The consistency of a comparison matrix in crisp AHP is measured by the consistency ratio \(CR\), which is equal to:

\[
CR = \frac{CI}{RI}
\]

Where \(RI\) is a random index. If the \(CR \geq 0.10\), the decision maker has to make the pairwise judgments again. A fuzzy comparison matrix is defined to be consistent within tolerance deviation \(\delta\), if \(\alpha\)-level cut feasible region \(S'_{\alpha}\) is not empty:

\[
S'_{\alpha} = \left\{ w : (1-\delta)\beta_{ij} \leq \frac{w_i}{w_j} \leq (1+\delta)\beta_{ij}, i \neq j, \sum_{j=1}^{n} w_j = 1 \right\}
\]

Where \(w_i, w_j\) are the weights of the \(i\)th and \(j\)th elements, respectively. Here \(\delta\), represents deviations from the upper bound \(U_{ij}U_{ij}^\alpha\), and the lower bound \(L_{ij}L_{ij}^\alpha\).

A practical way to test the fuzzy comparison consistency within tolerance deviation \(\delta\) is to solve the following auxiliary linear program:

\[
\min \beta = \beta_1 + \beta_2 \\
\text{s.t. } \ln(1-\delta)\beta_{ij} \leq \ln(w_i) - \ln(w_j) + \beta_1 \leq \ln(1+\delta)\beta_{ij}, i \neq j, 1, 2, \ldots, n \quad \beta_1, \beta_2, \beta_{ij} \geq 0
\]

Where \(\beta, \beta_{ij}, \beta_{ij}^\alpha, \beta_1, \beta_2, \beta_{ij}\) are decision variables. If \(\beta=0\), the fuzzy comparison matrix is consistent within tolerance deviation \(\delta\), if \(\beta>0\), this means that there are no feasible weights \((\phi=S'_{\alpha}\delta\), that the fuzzy comparison matrix is not consistent within \(\delta\). In this case, the decision maker would make the judgments again.

### 5.4 Requirement Risk Evaluation of a O-OSD software Project using Fuzzy AHP

In this part of the study, the fuzzy AHP method based on Chang’s extent analysis will be applied to a software project to measure its requirement risk level. The first step of the fuzzy AHP method requires constructing an appropriate hierarchy of the fuzzy AHP model, which consists of the goal, criteria, and the alternatives.

The triangular fuzzy conversion scale used in the model is given in Table 2.
Table 2 - Triangular fuzzy conversion scale

<table>
<thead>
<tr>
<th>Linguistic scale</th>
<th>Triangular fuzzy scale</th>
<th>Triangular fuzzy reciprocal scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Just equal</td>
<td>(1, 1, 1)</td>
<td>(1, 1, 1)</td>
</tr>
<tr>
<td>Equally important</td>
<td>(1/2, 1, 3/2)</td>
<td>(2/3, 1, 2)</td>
</tr>
<tr>
<td>Weakly more important</td>
<td>(1, 3/2, 2)</td>
<td>(1/2, 2/3, 1)</td>
</tr>
<tr>
<td>Strongly more important</td>
<td>(3/2, 2, 5/2)</td>
<td>(2/5, 1/2, 2/3)</td>
</tr>
<tr>
<td>Very strongly more important</td>
<td>(2, 5/2, 3)</td>
<td>(1/3, 2/5, 1/2)</td>
</tr>
<tr>
<td>Absolutely more important</td>
<td>(5/2, 3, 7/2)</td>
<td>(2/7, 1/3, 2/5)</td>
</tr>
</tbody>
</table>

Our goal is to evaluate the riskiness of a software project and it is at the top of the hierarchy as shown in Figure 8.

Figure 8 - The hierarchy of the AHP risk evaluation model.

Risk factors used in the model are selected from the studies of requirement risk of a software project. They are divided into five different risk factor groups and shown on the second level. The third level consists of 14 sub-risk factors. The top management will make its decision depending on the opinions of the software experts of the firm in an O-OSD environment. By using Formula (2), fuzzy synthetic values are obtained and by using Formulas (6), (7) and (8) we do pairwise comparison and construct the fuzzy evaluation matrix with respect to the goal and evaluation of the subattributes with respect to risk factors and risk

Table 3 - The fuzzy evaluation matrix with respect to the goal.

<table>
<thead>
<tr>
<th></th>
<th>$e_1$</th>
<th>$e_2$</th>
<th>$e_3$</th>
<th>$e_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e_1$</td>
<td>$(1, 1, 1)$</td>
<td>$(0.852, 1.246, 1.657)$</td>
<td>$(0.386, 0.478, 0.629)$</td>
<td>$(0.688, 0.922, 1.201)$</td>
</tr>
<tr>
<td>$e_2$</td>
<td>$(0.603, 0.803, 1.173)$</td>
<td>$(1, 1.1)$</td>
<td>$(0.57, 0.803, 1.108)$</td>
<td>$(0.64, 1.135)$</td>
</tr>
<tr>
<td>$e_3$</td>
<td>$(1.589, 2.091, 2.593)$</td>
<td>$(0.903, 1.246, 1.755)$</td>
<td>$(1, 1.1)$</td>
<td>$(1.246, 1.657, 2.141)$</td>
</tr>
<tr>
<td>$e_4$</td>
<td>$(0.833, 1.084, 1.507)$</td>
<td>$(0.740, 1.203)$</td>
<td>$(0.467, 0.603, 0.803)$</td>
<td>$(1, 1.1)$</td>
</tr>
<tr>
<td>$e_5$</td>
<td>$(1.431, 1.949, 2.460)$</td>
<td>$(1.084, 1.461, 2.371)$</td>
<td>$(0.437, 0.561, 0.784)$</td>
<td>$(0.768, 1.046, 1.516)$</td>
</tr>
</tbody>
</table>

Table 4 - Evaluation of the sub risk factor with respect to $e_1 | e_1$

<table>
<thead>
<tr>
<th></th>
<th>$e_{11}$</th>
<th>$e_{12}$</th>
<th>$e_{13}$</th>
<th>$e_{14}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e_{11}$</td>
<td>$(1, 1, 1)$</td>
<td>$(0.924, 1.32, 1.733)$</td>
<td>$(0.715, 1.013, 1.362)$</td>
<td>$(0.786, 1.176, 1.585)$</td>
</tr>
<tr>
<td>$e_{12}$</td>
<td>$(0.577, 0.758, 1.082)$</td>
<td>$(1, 1.1)$</td>
<td>$(0.574, 0.813, 1.134)$</td>
<td>$(0.684, 1.108, 1.496)$</td>
</tr>
<tr>
<td>$e_{13}$</td>
<td>$(0.734, 0.987, 1.398)$</td>
<td>$(0.882, 1.046, 1.741)$</td>
<td>$(1, 1.1)$</td>
<td>$(1.176, 1.585, 2.064)$</td>
</tr>
<tr>
<td>$e_{14}$</td>
<td>$(0.631, 0.851, 1.272)$</td>
<td>$(0.668, 1.084, 1.679)$</td>
<td>$(0.367, 0.631, 0.85)$</td>
<td>$(1, 1.1)$</td>
</tr>
</tbody>
</table>

The weight vector from Table 5 is calculated as $W = (0.22, 0.18, 0.22, 0.18)^T$. 
subfactor.

The top management categorizes the risk levels as high risk, moderate risk, and low risk. If the final result of the risk evaluation based on the experts’ opinions is revealed as high risk, the top management will reject the project; otherwise the software project will be acceptable. The risk evaluation matrix with respect to the goal is given in Table 3.

The experts now compare the sub-risk factors with respect to the main risk groups. First they compare the sub-risk factors of environment and ownership. The fuzzy comparison matrices for main risk groups and the weight vectors of each matrix are given in Tables 4-7. Finally, the experts assess the risk level of sub-risk factors by again making pairwise comparisons between high risk, moderate risk, and low risk. Sample questionnaire forms to receive the experts’ assessments are given in Appendix (Tables A1 and A2). By using Formula 2, fuzzy synthetic values are obtained

**Table 5 - Evaluation of the sub risk factor with respect to e2**

<table>
<thead>
<tr>
<th>e21</th>
<th>e22</th>
<th>e23</th>
<th>e24</th>
<th>e25</th>
<th>e26</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1.1, 1)</td>
<td>(0.66, 0.922, 1.285)</td>
<td>(0.752, 1.496, 1.922)</td>
<td>(0.786, 1.176, 1.585)</td>
<td>(0.561, 0.833, 1.11)</td>
<td>(0.549, 0.803, 1.134)</td>
</tr>
<tr>
<td>(0.778, 1.084, 1.516)</td>
<td>(1.1, 1)</td>
<td>(0.891, 1.431, 1.949)</td>
<td>(0.944, 1.351, 1.821)</td>
<td>(0.574, 0.956, 1.334)</td>
<td>(0.441, 0.668, 0.944)</td>
</tr>
<tr>
<td>(0.652, 0.668, 1.33)</td>
<td>(0.513, 0.669, 1.122)</td>
<td>(1.1, 1)</td>
<td>(0.549, 0.871, 1.246)</td>
<td>(0.574, 0.813, 1.134)</td>
<td>(0.407, 0.693, 0.91)</td>
</tr>
<tr>
<td>(0.631, 0.85, 1.272)</td>
<td>(0.549, 0.74, 1.059)</td>
<td>(0.803, 1.149, 1.821)</td>
<td>(1.1, 1)</td>
<td>(0.582, 1.149, 1.511)</td>
<td>(0.699, 0.922, 1.246)</td>
</tr>
<tr>
<td>(0.901, 1.201, 1.783)</td>
<td>(0.75, 1.046, 1.741)</td>
<td>(0.882, 1.233, 1.741)</td>
<td>(0.662, 0.871, 1.719)</td>
<td>(1.1, 1)</td>
<td>(0.506, 0.668, 0.922)</td>
</tr>
<tr>
<td>(0.882, 1.261, 1.821)</td>
<td>(1.059, 1.496, 2.268)</td>
<td>(1.099, 1.443, 1.974)</td>
<td>(0.803, 1.084, 1.431)</td>
<td>(0.708, 1.149, 1.974)</td>
<td>(1.1, 1)</td>
</tr>
</tbody>
</table>

The weight vector from Table 5 is calculated as \( W_2 = (0.22, 0.23, 0.19, 0.19, 0.20, 0.25) \)

**Table 6 - Evaluation of the sub risk factor with respect to e3**

<table>
<thead>
<tr>
<th>e31</th>
<th>e32</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1.1, 1)</td>
<td>(1.661, 2.169, 2.674)</td>
</tr>
<tr>
<td>(0.374, 0.53, 0.708)</td>
<td>(1.1, 1)</td>
</tr>
</tbody>
</table>

The weight vector from Table 5 is calculated as \( W_3 = (0.43, 0.20) \)

**Table 7 - Evaluation of the sub risk factor with respect to e4**

<table>
<thead>
<tr>
<th>e41</th>
<th>e42</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1.1, 1)</td>
<td>(0.776, 1.035, 1.443)</td>
</tr>
<tr>
<td>(0.693, 0.967, 1.289)</td>
<td>(1.1, 1)</td>
</tr>
</tbody>
</table>

The weight vector from Table 5 is calculated as \( W_4 = (0.19, 0.23) \)

One sample comparison matrix for risk levels for each sub-risk factor under main risk groups is given in Tables 9 – 12.

**Table 9 - Evaluation of riskiness with respect to e11**

<table>
<thead>
<tr>
<th>High risk</th>
<th>Moderate risk</th>
<th>Low risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1.1, 1)</td>
<td>(0.596, 0.977, 1.33)</td>
<td>(0.944, 1.272, 1.719)</td>
</tr>
<tr>
<td>(0.693, 0.967, 1.289)</td>
<td>(1.1, 1)</td>
<td>(0.944, 1.28, 1.864)</td>
</tr>
</tbody>
</table>

The weight vector from Table 9 is calculated as \( W_{11}=(0.37, 0.38, 0.25) \) and \( W_{12}=(0.34, 0.36, 0.30) \) and \( W_{13}=(0.73, 0.27, 0.00), W_{14}=(0.38, 0.44, 0.18) \)
The weight vector from Table 10 is calculated as $W_{e21} = (0.70, 0.30, 0.00)^T$, $W_{e22} = (0.69, 0.31, 0.00)^T$, $W_{e23} = (0.51, 0.36, 0.13)^T$, $W_{e24} = (0.63, 0.37, 0.00)^T$, $W_{e25} = (0.60, 0.40, 0.00)^T$, $W_{e26} = (0.87, 0.13, 0.00)^T$.

The weight vector from Table 11 is calculated as $W_{e31} = (0.73, 0.27, 0.00)^T$, $W_{e32} = (0.61, 0.39, 0.00)^T$.

The weight vector from Table 12 is calculated as $W_{e41} = (0.55, 0.44, 0.01)^T$, $W_{e42} = (0.73, 0.27, 0.00)^T$.

By applying Formulas (6), (7) weight vector is calculated and then normalized weight vector with respect to goal $W_G$ is obtained. The result of the risk evaluation, which is given in Table 14, for the software project, is obtained as 0.62 for high risk, 0.33 for moderate risk, and 0.05 for low risk. The top management of the firm should reject investing in this project because it is a high risk project.

<table>
<thead>
<tr>
<th>Subfactor of $e_1$</th>
<th>$e_{11}$</th>
<th>$e_{12}$</th>
<th>$e_{13}$</th>
<th>$e_{14}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight/Risk levels</td>
<td>(0.22)</td>
<td>(0.28)</td>
<td>(0.22)</td>
<td>(0.28)</td>
</tr>
<tr>
<td>High risk</td>
<td>(0.37)</td>
<td>(0.34)</td>
<td>(0.73)</td>
<td>(0.38)</td>
</tr>
<tr>
<td>Moderate risk</td>
<td>(0.38)</td>
<td>(0.36)</td>
<td>(0.27)</td>
<td>(0.44)</td>
</tr>
<tr>
<td>Low risk</td>
<td>(0.25)</td>
<td>(0.30)</td>
<td>(0.00)</td>
<td>(0.18)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subfactor of $e_2$</td>
<td>$e_{21}$</td>
<td>$e_{22}$</td>
<td>$e_{23}$</td>
<td>$e_{24}$</td>
</tr>
<tr>
<td>Weight/Risk levels</td>
<td>(0.12)</td>
<td>(0.13)</td>
<td>(0.16)</td>
<td>(0.19)</td>
</tr>
<tr>
<td>High risk</td>
<td>(0.70)</td>
<td>(0.69)</td>
<td>(0.51)</td>
<td>(0.63)</td>
</tr>
<tr>
<td>Moderate risk</td>
<td>(0.30)</td>
<td>(0.31)</td>
<td>(0.36)</td>
<td>(0.37)</td>
</tr>
<tr>
<td>Low risk</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.13)</td>
<td>(0.00)</td>
</tr>
</tbody>
</table>
6. Conclusion and Suggestion

Project risk evaluation should be performed by using one of the multi-attribute evaluation methods because of the multidimensional nature of risks. This requires a method that allows the use of decision makers’ vague judgments in the pairwise comparison of attributes. The fuzzy AHP method meets this requirement. There are many fuzzy AHP methods developed in the literature. In this study, Chang’s extent analysis method on fuzzy AHP is selected and applied to the risk evaluation of an information technology project. For further research, applying other fuzzy AHP methods to project risk evaluation and then comparing their results with the results of this study are recommended. In addition to this, some of the other multiattribute evaluation methods such as TOPSIS, DEA, multi-attribute utility analysis, outranking methods (PROMETHEE, ELECTRE, ORESTE) of which fuzzy forms have been developed, can be used for comparing the results.

This paper demonstrated how MCDM in general and the Analytic Hierarchy Process in particular can be used within a Design Science context to integrate significant existing knowledge in behavioral outsourcing research into a multicriteria model for outsourcing decisions. The MCDM approach provides a richer multidimensional perspective for understanding outsourcing decisions in a particular situation. Possible future work includes research on applying the proposed model to different organizational settings and gathering the reflections of the stakeholders on such interventions as is recommended by Carlsson (2006) [49]. Another direction for future work is linked to the need to assess how interdependent are the factors involved in the model and if relevant, the possible application of an AHP extension for such problems, called the Analytic Network Process (ANP) (see Saaty, 2008a). Hence our starting assumption that it is sufficient to model the problem as a hierarchy without feedback dependencies might be a limitation of our work reported here which however should be addressed by investigating in the future the appropriateness of a relevant ANP model. This possibility requires further field applications and comparisons between appropriate hierarchical and network analytic models for outsourcing decisions.

Saaty (2008a) [3] indicates the need in future work in AHP to “integrate and catalogue of the structure of a variety of carefully studied decisions to create a dictionary to serve as a source of reference for others to consult, so they can benefit from the knowledge that went into making these decisions”. However as was pointed earlier in the paper, our literature review on AHP applications to outsourcing raises an issue about...
the quality of the existing models to be considered for such a catalogue. We found that past research on applying MCDM to the IT outsourcing decision is based mostly on an intuitive selection of criteria that is often not justified sufficiently or not grounded well in traditional IS research on IT outsourcing.

The challenge for the IT field in general is to integrate best practices and the body of knowledge in behavioral IS research in a particular problem area with the expressive power of AHP modeling as is demonstrated in this paper and generate through such activities design science artifacts in the form of relevant MCDM models following a structure and a process by analogy to the one outlined in this paper.

The proposed MCDM model for outsourcing decision making aims to improve decision making in outsourcing through integrating the findings from extensive empirical research in IT outsourcing management with MCDM as a design science approach. Such a model needs to reflect the knowledge base associated with outsourcing management (see further discussion of its content in King (2008) [50] and has to be applicable to the conditions of a specific organization, combining the various quantitative and qualitative factors affecting a decision to outsource. This paper attempts to show how the Design Science process suggested by Peffers et al (2006) [6] can be operationalized for the development of a holistic multicriteria model for the selection of IT activities to be outsourced. The results from this research aim to contribute to improvement of decision making in IT outsourcing and for the wider use of MCDM to build Design Science artifacts in Information Technology research.

References


