ERA Metamodel of the Analytical Hierarchy Process and Risk Matrix

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Abstract – This paper has been motivated by the project *Ivanscica for a better tomorrow* which was supported by the European Commission funds. The main goal of the project was to build a dialogue between the City of Zlatar and the City of Ivanec. To achieve that, several alternatives were proposed, and decision has been made by using the AHP. To successfully implement the decision, risk analysis was done. This integrated approach applied on the project became a trigger to propose general framework of integration of those two methods – which is the main goal of this paper. In general, after a specific strategic decision has been made, the process of its implementation starts. However, before the implementation of the strategic decision, it is recommended to conduct a risk analysis. First, this is necessary for predicting possible risks, that is, situations or events that might threaten the process of implementation and the decision effects. Second, the classification of risks in terms of two variables must be done. Those two variables are the probability of risk occurrence and the strength of the risk's negative effect on the implementation process. Last, the activities of risk management must be defined. In this paper, after providing a theoretical background, we present an entity-relationships-attributes (ERA) model of two complementary methods: the analytical hierarchy process (AHP) method (used for strategic multi-criteria decision-making) and a risk matrix (used for risk management). In the practical part, we provide an overview of how those two methods have been used in the case mentioned project.

Keywords - AHP, risk matrix, ERA, local government unit

I. INTRODUCTION

Information and communication technology (ICT)-supported decision making offers great possibilities, but unfortunately, it is seldom used in decision making in the public sector. This should change because decisions made in the public sector are financed by taxpayers' funds and have far-reaching consequences. Further, the advanced usage of ICT in Croatian self-government units are rare [1]. Some examples of possible ICT usage in the public sector are found in paper [2].

One of the few examples of decision making supported by ICT in Croatian local self-government units is the project *Ivanscica for a Better Tomorrow,* the main goal of which was to build a dialogue between the City of Zlatar and the City of Ivanec. The purpose of the established cooperation was to define the strategic development of the mountain Ivanscica and the activities that take place there. The project was funded by European Union (EU) funds from the Youth in Action program and was launched by the Zlatar Youth Association (ZUM). The project was implemented by young people from both Zlatar and Ivanec (ZUM and the Youth Council of the City of Ivanec) and the decision makers in these two local self-government units (the City of Zlatar and the City of Ivanec) [3].

The mountain Ivanscica represents a natural border between the two cities (Zlatar and Ivanca) and between the two counties (Krapina-Zagorje County and Varazdin County). Although the potential for tourism development is unquestionably present, tourist attractions on Ivanscica are underdeveloped. Given the divisions of ownership over Ivanscica, which in the past has caused conflict, and due to the limited resources of the two cities separately, the cities need to develop the tourist offerings through joint efforts.

The youth representatives from both cities decided to encourage a solution to this problem through the project *Ivanscica for a Better Tomorrow*, with which they wanted to create a basis for the future development of tourist offerings on Ivanscica. Through three three-day meetings over a period of four months, they analyzed the problem, identified the tourism potential of Ivanscica, and suggested the first step in addressing the problem: defining the forms of cooperation between the two cities using the analytical hierarchy process (AHP) method. Before this, local authorities had not used the AHP method [3]. In the paper [3], the implementation of the AHP method in the project is described in detail.

In this paper, we present an overview of the application of the risk matrix method, which was implemented after the application of the AHP method, with respect to the chosen alternative. Based on the practical example, we will show how the AHP and risk matrix methods are compatible, and a common entity-relationships-attributes (ERA) metamodel will be provided based on the two methods. The proposed ERA metamodel can, through the appropriate software application, become a useful tool for decision making and performing a risk analysis of implementing the decision in the public sector. This kind of application can then generally be applied, independently of the project or decision problem.

The second section of the paper presents the steps of AHP method application. In the third section, the risk matrix application will be explained, while the fourth section presents the details of the ERA metamodel. The benefits of the ERA metamodel are explained in the conclusion.

II. AHP METHOD

The AHP method is one of the best-known methods for decision making and the scientific analysis of scenarios by consistently evaluating a hierarchy, the elements of which are goal(s), criteria, sub-criteria, and alternatives. It has been widely used in management, resource allocation, and distribution [3].

In terms of the decision-making level, the AHP is mainly used for making strategic decisions, followed by making tactical decisions (such as in big organizations). It is rarely used for making short-term operative decisions. Strategic decisions influence a whole organization; they are long-term and expensive. Also, the implementation of strategic decisions often requires many resources, including human and financial decisions and hardware and software.

The application of the AHP can be described in four main steps [4], [5]:

1. Decision-making problem structuring. The problem must be structured in the form of a hierarchy, with a goal at the top, criteria and their sub-criteria at a lower level, and finally, alternatives at the bottom.
2. Pairwise comparisons. At each level of the hierarchy, elements are pairwise compared with respect to the higher-level element. Criteria are compared with respect to the goal, sub-criteria are compared with respect to the criteria, and alternatives are compared with respect to the sub-criteria. In the pairwise comparison process, the Saaty scale of relative importance is used, which consists of nine degrees.
3. Global priorities. Based on pairwise comparisons from the previous step, criteria weights and local priorities of alternatives have been calculated. Criteria weights and local priorities are then synthesized into global priorities. The alternative with the highest priorities becomes a candidate to be a final decision.
4. Sensitivity analysis. In this step, an analysis of results stability is done. Decision makers examine how changes in criteria weights (+-5%) influence the alternatives' rankings.

III. RISK MATRIX

Risk is defined as a possible uncertain situation in the future that can have a positive or negative impact. Decision making within risk conditions is a situation that occurs when decision makers know the consequences of the alternatives that are expected for each situation (or event), but do not have information about the probabilities of these risks occurring [7]. Paying attention to the risks of the project is important. The basic idea of risk management is to anticipate the future, identify the problems that may arise, and define activities that can successfully solve these problems. Therefore, successful project managers today develop different models for the future, in which they anticipate the projected risk impacts and undertake preventive actions and activities accordingly. Risk management benefits can be divided into two groups [8]:

- Hard benefits: producing reliable plans and budgets to achieve a more detailed project

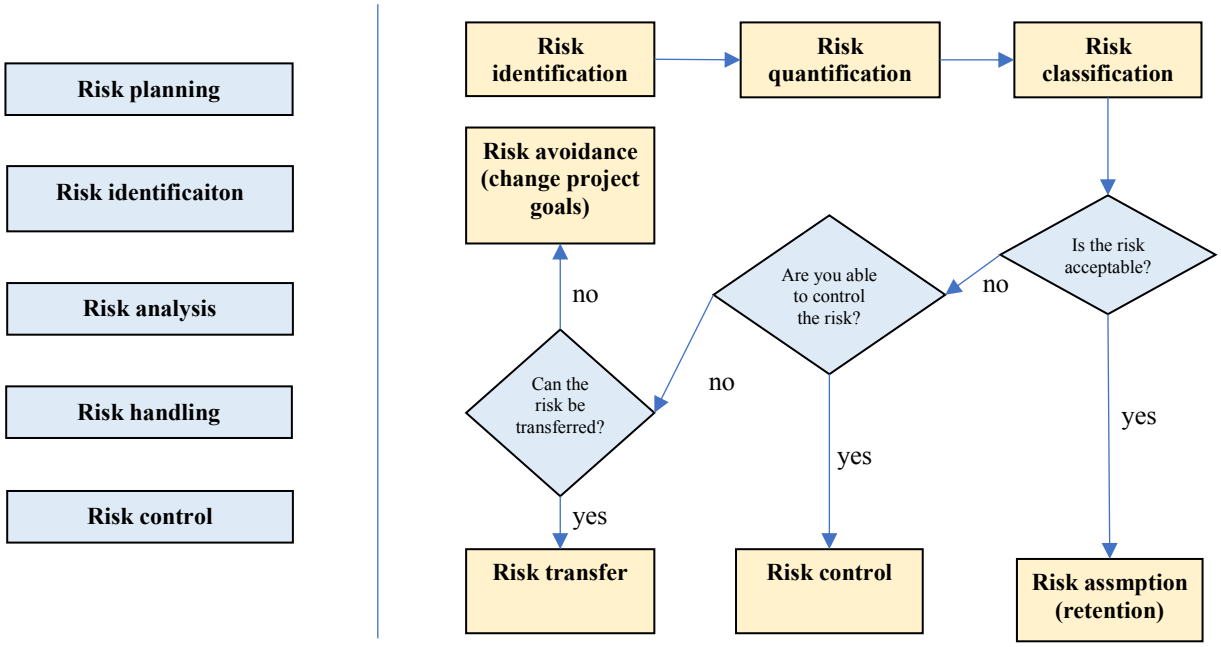

Figure 1. Risk management

analysis; increasing the probability of meeting the deadlines and budgets; allowing a more objective comparison of alternatives; reducing the probability of carrying out unprofitable or cost-ineffective activities.

- Soft benefits: improving communication; improving the understanding of project participants; fostering teamwork.

Two main risk components in terms of risk quantification include the following [7], [8]:

- Risk probability
- Risk impact

Depending on the project, data on risk components are collected by the analysis of historical data in similar situations and through various simulations and models for predicting the risk and impact of the project. Also, experts in the problem area may be helpful in defining risk components.

Risk management can be defined as the continuous and disciplined process of planning, assessing, processing, and controlling risks. It is important to start risk management on a project as early as possible and to implement it throughout the project's lifetime. The risk management implementation steps are described in the left side of the diagram appearing in Fig. 1 (above) [8]:

1. In the first phase, risk planning, strategies and methods for identifying risks, analyzing risks, developing a risk management plan, and monitoring risks are developed and adopted.
2. The second and third phases, those of the identification and analysis of risks (risk assessment), incorporate the operational execution of the risk management plan. Here, decision makers identify the risks that are threatening the enterprise, determine to what extent (probability) they threaten, and establish what the possible consequences (impacts) are.
3. In the risk handling phase, decision makers choose a risk reduction strategy that mitigates the risk to an acceptable level according to the risk management plan.
4. In the risk control phase, we monitor the success of the chosen strategy and, if necessary, determine additional activities that will reduce the risk impact to the acceptable level.

Risk planning is not a single activity; the plan is revised some time into the process due to specific changes in the environment as well as the results of plan to mitigate risk. Once the risk has been identified, the steps of risk management plan, from the analysis to the control, continues until the risk is resolved. The right side of Fig. 1 (above) presents a slightly different view of risk management. There are four main strategies decision makers can use when reducing risk [8]:

1. Risk assumption, risk retention: This strategy is used when decision makers are aware of a risk and its consequences but feel that they can cope with these consequences. Therefore, they do not take any specific action in the direction of risk resolution.
2. Risk control: In this situation, decision makers are aware of the risk and its consequences and feel that the consequences can be detrimental and that a reaction is required. In this strategy, decision makers feel that they can solve this risk alone, so they do not look for any help. The essential part of this strategy is to oversee the risk measures taken and to continuously measure the probability and impacts of the risk on the project.
3. Risk transfer: In this strategy, decision makers are aware of the existence of the risk and the strong negative impact of the risk's consequences but are not able to deal with the risk alone. They must, therefore, look for partners to help them deal with the risk by decreasing or eliminating the negative impact of the risk on the project.
4. Risk avoidance: In this strategy, decision makers are aware of the existence of the risk and its estimated severity, but it would be too expensive to either fight it alone or to seek help. As such, decision makers change the project's goals instead of dealing with the risk.

It is important to note that some authors use a different definition of *risk avoidance*, referring to it as a situation in which decision makers are aware of the risk, its consequences, and the dangers it brings, but choose not to do anything. They do not change the project goals, seek help, or transfer the risk, instead continuing to proceed with the project no matter what might happen in the future. Simply, they take the risk. This strategy is also called *risk ignorance*, and it differs from risk assumption (or risk retention) because decision makers know in advance that the risk is not acceptable and that its consequences can have a high negative impact on the project.

Because risks are not equally dangerous to an organization, they therefore need to be classified according to their potential impact. Depending on the risk consequences, there are several different risk types [8]:

- High risk: the consequences of the risk have a high impact on the realization and results of the project.
- Moderate (medium) risk: the consequences of the risk have a moderate impact on the project.
- Low risk: the consequences of the risk have a low impact on the project

Risk classification into the above categories can be completed based on the two previously mentioned risk components: the impact of the risk on project realization (i.e., the consequences of the risk) and the probability of

risk occurrence. Based on the experience of project managers, the risks are classified into the three categories, as presented in Table 1. In addition to this, it is possible to classify risks more precisely using five categories (Very Low, Low, Moderate, High, and Very High [7]) or even more [9].

Values 1, 2, and 3 in Table 1 are related to the intuitive scale of each of two variables. For the specific situation, the assessment of impact and probability must be given by the problem area experts. This method is one of the simplest methods for risk assessment. More complex methods used in risk management are Monte Carlo simulation, decision trees, and sensitivity analyses. Tools that can be used to support this method include TreePlan,[1] @RISK,[2] and SensIt.[3]

TABLE I. RISK MATRIX [7], [8]

		Impact of risk on the project		
		1	2	3
Probability of risk occurrence	1	Low	Low	Moderate
	2	Low	Moderate	High
	3	Moderate	High	High

IV. APPLICATION OF AHP-RISK MATRIX INTEGRATION ON THE PROJECT IVANSCICA FOR A BETTER TOMORROW

A strategic decision related to the project *Ivanscica for a Better Tomorrow* is already presented in [6]: two cities had to decide on the type of collaboration that should be conducted to revitalize the mountain Ivanscica, which is currently undeveloped, but has huge tourism potential. The two cities needed to collaborate because the mountain is placed between them, with the top of the mountain being a natural border. Three possible types of collaboration were *considered: the establishment of the Ivanscica Foundation, town* twinning, and the creation of a Cooperation agreement between the two cities. The AHP method suggested that a cooperation agreement should be established.

This solution was presented to the units of local self-governments, and the City of Zlatar and the City of Ivanec accepted the proposed solution and decided to implement it. This was a step forward in the cooperation between the two cities. To increase the chances of the successful implementation of the decision, a risk analysis was performed.

When we discuss the *Ivanscica for a Better Tomorrow* project, the identified risks are related to the realization of the project continuation, meaning the implementation of the cooperation agreement. The identified risks are presented in Table 2, together with the corresponding estimations of risk probabilities and risk impacts on the project continuation. Table 2 also contains the proposed risk management activities. Some of the risk management activities in Table 2 were implemented in advance through the provisions of the cooperation agreement. Some risk management activities are only planned to be implemented when the related risks occur during the implementation of the agreement.

Finally, some situations have been identified as potential risks, but no real risk management activities have been assigned to them. Such risks arise mainly in relation to the characteristics of the decision makers and the public administration system. Namely, decision makers in public administration (especially in the local government unit) are often very passive and, in the end, are not interested in implementing the decisions that have been made. The main idea of risk management is also to overcome this passivity and to implement the agreement; however, further problems arise when there is passivity about implementing the risk matrix results. This is a disadvantage of a risk management system in which the same people implement the decision as control the implementation process.

V. ERA METAMODEL OF THE AHP AND RISK MATRIX

During the project implementation, it was concluded that the two methods can easily be integrated. The integration contributed to achieving the project goals because the whole context was analyzed more in detail. This became a trigger to propose general framework of integration of those two methods. Any other multiple-criteria decision can benefit from risk analysis integrated with applied multiple-criteria decision-making method.

The AHP method can be used as a part of risk management in three ways:

1. For the prioritization of risks (for an example, see [10]),
2. As a prediction-assessment tool used to determine the probability of a risky situation,
3. For prioritizing activities that can be used to influence a specific risky situation.

In this paper, we propose a slightly different approach for connecting the AHP and risk management. Some multiple-criteria decision-making problems can be solved by the AHP, and when the decision is ready to be implemented, a risk analysis can be done. This is a sequence of two methods that are applied separately (even though the AHP can be additionally applied as a part of risk management in the sequence, which is recommended if the situation is complex).

There are different tools and apps that can be used to apply the AHP and to create the risk matrix, but these require that the two steps be done separately. The idea of this paper is to propose the integration of the two methods into one software application. One of the first steps in software development is the creation of an ERA model. The proposed ERA model describes how data about the decision-making problem, as well as data about the implementation of two methods, will be designed,

[1] Webpage: http://treeplan.com/
[2] Webpage: http://www.palisade.com/risk/
[3] Webpage: http://tornadocharts.com/

TABLE 2. RISK MANAGEMENT IN THE PROJECT *IVANSCICA FOR BETTER TOMORROW*

Risk	Classification	Risk management activities
Lack of interest of the Committee members for the performance of their duties (since it is a voluntary work)	Low risk	No action is required.
	Medium risk	The superiors to the Committee members should talk to them and motivate them to complete their assumed tasks.
	High risk	The usage of an employment instrument created by the Croatian government which encourages one-year training of young people without the commencement of employment. Those trainees would be in charge of implementing the continuation of project co-operation.
Lack of knowledge of the Committee members about creating application forms for NGOs to apply on the tender	Low risk	No action is required.
	Medium risk	The project participants have developed templates for the application forms and listed the criteria for the evaluation of applications. These should be given to the Committee members so they could check them and potentially use.
	High risk	Use the existing templates to create forms, such as the templates proposed by Office for Cooperation with NGOs, Government of the Republic of Croatia.
Lack of interest for the tender application among the potential applicants	Low risk	Organization of the exemplary activity on the top of the mountain within the third project meeting so the potential applicants would understand that nothing difficult is expected from them Creating a project brochure with detailed descriptions that will be send to potential applicants Promotional activities for the tender
	Medium risk	Promotional activities for the tender. Sending letters to potential applicants.
	High risk	Reallocation of funds which are usually intended for associations in the budgets of local self-government units, into this tender so the potential applicants would be motivated to apply due to less money available for their usual way of financing
Lack of knowledge among the potential applicants about completing the application forms	Low risk	An example of the filled application form should be made available on the web.
	Medium risk	Organizing workshops about the tender, discussions on the potential topics for application and workshops about forms filling
	High risk	Along with workshops, ensuring the expert assistance in tender application (possibly also through recruiting a young person for training)
Inability to connect with a potential applicant from another city since it is mandatory that the applicants come from two different cities	Low risk	The brochure of the initial project contains a list of associations that make up the largest group of potential partners in the future projects
	Medium risk	Creating a web site (web 2.0) for the purpose of establishing contacts with other associations, discussing potential partnerships, and the like
	High risk	Organizing additional new events at the top of the mountain (similar to the third project meeting) by the two cities.
Lack of funding for project implementation since the tender provides only 50% of the required funds	Low risk	No action is required.
	Medium risk	Organization of workshops about financial planning, sponsorship opportunities and application for other available tenders
	High risk	Increase of co-financing to 75%
Incomplete documentation (at first deadline)	Low risk	No action is required.
	Medium risk	Allow documentation to be added after the submission deadline (applies only to the first cycle)
	High risk	
Lack of final report after project implementation	Low risk	No action is required.
	Medium risk	By e-mail remind organizations which implement project on the obligation to submit the final report and all the necessary attachments before expiry of the submission deadline
	High risk	Along with an e-mail reminder of the final report submission, remind the organization that in the absence of reporting, they will no longer be considered for any funding from the local government unit in which they operate, and the premises that they may got for usage from the local government unit, will be given to another organization
Reduced revenues in the budgets of local self-government units which can result in reduced funds available for tender	Low risk	No action is required.
	Medium risk	Reallocation of funds which are usually intended for associations in the budgets of local self-government units, into this tender so the annual amount for tender would not be reduced
	High risk	With an attempt to implement the activity from the upper cell, look for the available tenders for local self-government units to finance activities that would otherwise be funded by the local self-government's budget so that the money could be redirected to the project continuation (e.g., designing a project for the EU program " Youth in Action "or" Erasmus + "- there are subtypes in these programs on which self-government units may apply and some of their regular activities finance from such projects – e.g., employee salaries, different representational and dissemination costs for celebration of the city day, etc.)
Incomprehensible withdrawal of local self-government units from participating in the implementation of the project "Ivanscica for a Better Tomorrow"	Low risk	Continually reminding on the ultimate goal - a joint application of two cities to EU funds with the aim of developing infrastructure and content on Ivanscica
	Medium risk	Discussions with decision-makers about the continuation of cooperation
	High risk	Point out to the decision makers on negative media publicity that might arise in the event of withdrawal from the project's continuation. They might be called for not wanting to do what they themselves signed, even though it only costs 30,000 HRK a year and can bring a lot of good things. In addition, by withdrawal the leaders of the local self-government units would show how they treat young people who initiated and led the project.

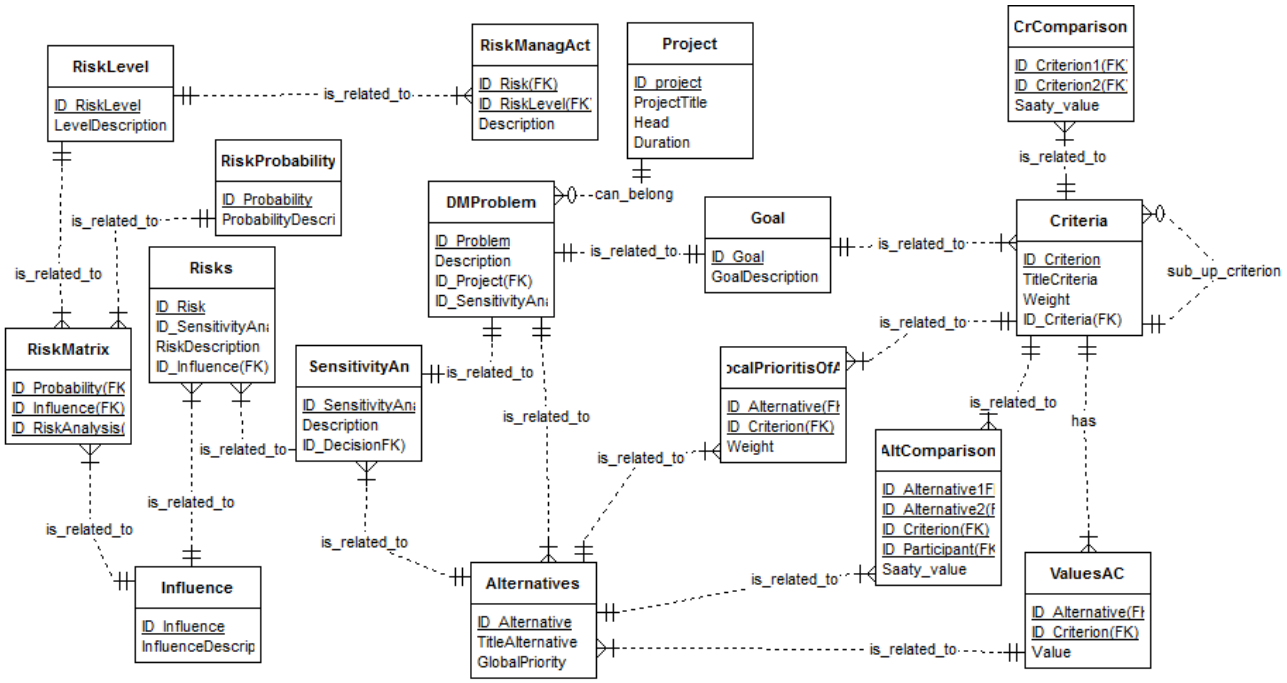

Figure 2. ERA model of AHP and risk matrix

connected, and stored. The initial ERA model consists of tables in which the decision-making problems are described, through alternatives, criteria and subcriteria, goals, pairwise comparisons, consequences, and risks and their impacts and probabilities. The proposed ERA metamodel for AHP–risk matrix integration is given in Fig. 2.

The integration of these two methods can improve both the methods for two reasons: (1) when the AHP is used, historical data from risk analyses can influence the criteria in the decision-making problem and, accordingly, the final decision, and (2) when the risk matrix is applied and the risk management activities are brainstormed, they can be gathered from AHP data, which contains descriptions of all the alternatives.

CONCLUSION

The application of the integrated AHP-Risk Matrix approach on the project *Ivanscica for a Better tomorrow* brought benefits to the project (when compared to applying the AHP only). The decision-making problem was much more deeply analyzed which increased the prepareness of the decision to be implemented.

We concluded that this approach can be successful in other situations as well – not only on this project, especially in the area of local governments where many strategic decisions are made.

We proposed an ERA model for possible software application that would support such integration and increase the quality of decisions and prepare them for the implementation process.

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