A RISK MANAGEMENT MODEL FOR MEASURING PROJECT COMPLEXITY

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ABSTRACT

Any project is subjected of high risk, which can lead to a project failure and economical loss. Thus, risk management analysis is a key role in project management. Several research models have been developed to analyze and manage project risks. The aim of this work is to develop a multi-criteria decision support system to define and evaluate risks in a project development. More specifically, the purpose of the research is to define a risk management model that combines AHP methodology and project management approach to measure complexity and riskiness of a project. The model analyzes a real case study concerning the construction of a new industrial plant.

Keywords: risk management, project management, AHP, decision support system

1. INTRODUCTION

Today, project management is strongly linked to the risk analysis. It is necessary to identify and assess the major risks that could cause the failure of the project (McComb and Smith, 1991). Risk is any event that has a probability of realization: if the effect risk is negative, it is a threat, while it is an opportunity (Remenyi, 1999). Risk may affect the achievement of objectives. During the last years, academic literature has highlighted the importance of risk management during a project development (Nguyen *et al*., 2017). Ward and Chapman (2003), outline how project risk management processes might be modified to facilitate an uncertainty management perspective. Raz and Michael (2001) find which tools are more likely to be used in the project management and those to be used for the contribution of risk management processes. International Standard Organization (ISO) creates a working group to guide the development of risk management. This working group develops ISO 31000:2009 "Risk Management – Principles and Guidelines" which represents the views and the experience of hundred of knowledgeable people involved in risk management (Purdy, 2010). Project management tools related to the decision-making models allow to identify and manage project risk factors (Marques *et al*., 2011). In this context the present paper tries to develop a new integrated model based on project management and AHP methodology to evaluate the project riskiness according to ISO31000:2009 standard . The model is implemented in a real case concerning the construction of a new industrial plant. Firstly, the project is decomposed into elementary work packages through the use of work breakdown structure. Secondly, project risks are identified using the "Ishikawa" diagram (cause and effect diagram) that defines causes (risks) that produce an effect (project failure). Risks are assessed through the implementation of Analytic Hierarchy Process (AHP) that allows to define a project risk ranking. Finally, the model proposes two performance indices to measure risk and complexity of the project. These two indices allow to the project manager to develop optimal planning strategies to complete project within certain constraints. The rest of the paper is organized as follows. In section 2 a literature review on risk project management and multi criteria approach is presented. Section 3 describes the proposed model and a case study is analyzed. Section 4 presents discussion. Finally, in section 5, conclusion are analyzed.

2. LITERATURE REVIEW

Risk management is the methodology that improves the project success probability (Olechowski *et al.*, 2016). Several studies show that project risks can affect industrial performance. For example Mishra et al., (2016), have collected 82 federal technology projects across 519 quarterly time periods. The research highlights that each of the three types of risks has a significant negative effect on project performance. While Wallace and Keil (2004), have explored how different types of risk influence both process and product outcomes in software development projects by analyzing input from more than 500 software project managers representing multiple industries. It is evident that risk management is a topic that covers many fields of application. It is necessary to manage critically the risk management practices, because they often allow the project realization. In fact, Oehmen *et al.*, (2014) examined 291 projects, showing that more than 70% of management practices are not relative to product or

process, but they depend by risk management. Risk management is tackled through the most advanced project management tools. A standardized model for project management may increase project success (Milosevic and Patanakul, 2005). The growing importance of risk management issues led to the creation of a standardized norm for risk management: "ISO 31000:2009". The norm aims to standardize the effects of risk management to better address the effects of uncertainty in project management. The standard emphasizes the development of risk management in organizations. The framework ensures that the process is supported in an iterative and effective way. Thus, risk management becomes a key component in the company's governance (Gjerdrum and Peter, 2011). ISO31000:2009 requires risk identification and assessment. Risk assessment is a very complex task, and to manage it, often it is necessary to make a choice. For this reason we rely on multi-criteria decision-making systems that allow to make the best possible choice (De Felice and Petrillo, 2013). Among the multi criteria model, one of the most popular is the AHP, used to solve complex decision problems and introduced by Saaty (1977). AHP model breaks down a problem into several levels forming a hierarchy with a unidirectional relationship between levels. AHP model is very flexible and it can be used in different fields. De Felice et al., (2016) use the AHP model to define a key performance indicators for safety management. AHP model is widely used for the risk management analysis. Da Silva and Camanho, (2015) use the AHP model to define an IT project priorization in a Brazilian multinational company in the oil & gas segment. The research identifies the influence of AHP methods in each of several variables which represent the IT project.
Yassine and Brahim (2016) propose a supply chain risk management framework that identifies and monitors risks. AHP model tries to assess factors which influence risk management. Zhang *et al.* (2015), define a hierarchy level to analyze risk management in a construction project. The model also analyzes the economic losses from any project failures. Mustafa and Al-Bahar (1991), analyze construction project considering: time, budget and quality. They use the AHP model to assess the riskiness constructing of a bridge in Bangladesh. Grekul, *et al.* (2015) try to decrease the subjectivity of decisions made during the risk management process. AHP is used for risk assessment. Dey (2012) uses AHP and decision tree analysis for risk assessment in an Indian oil refinery.

3. METHODOLOGICAL APPROACH

According to several studies, the risk analysis plays a key role in the project of a new system. The risk analysis allows the project manager to allocate efficiently resources to minimize future problems. The research develops an integrated model of project-risk analysis through the AHP model application. The study follows the steps of ISO31000 for risk management. The aim of this paper is to demonstrate the application of AHP to assess the risk factors of a project and it define an overall index that quantifies risk. Figure 1 shows the research framework.

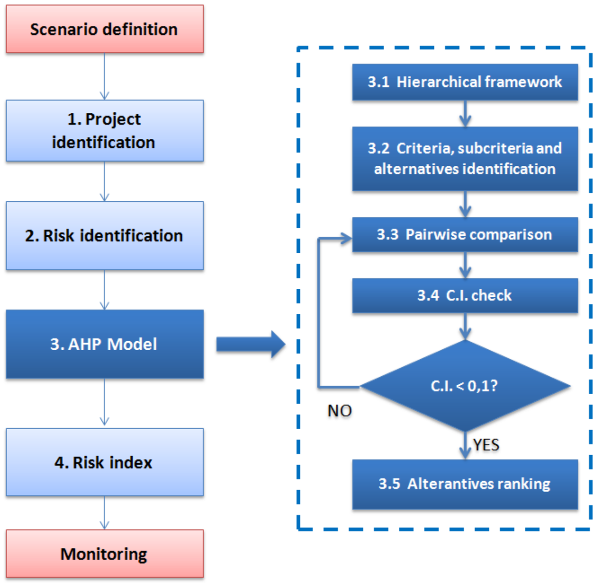

Figure 1:Research framework

3.1. Scenario definition

The analyzed case study defines a project management for new industrial plant construction for a medium enterprise in a central area of Italy. The study follows the steps of ISO31000:2009 about risk management. The considered model is subject to high variability depending on many factors, among them, some of the most important are:

- time;
- climate;
- forecast uncertainty.

3.2. Project identification: Phase#1

Project involves construction of three main elements:

- infrastructures;
- mechanical plants;
- electrical plants.

Customer wants to reduce time construction as much as possible. Project description includes work breakdown structure (WBS) to identify: activity, sub-activity and work packages easier to manage (Tausworthe, 1979). WBS of project (Figure 2) is divided into three hierarchies. Obviously, for each element represented in Figure 2, there will be another WBS more specific, to describe even the most basic activities.

3.3. Risk identification: Phase#2

ISO31000:2009 defines risk identification as the most important process of risk management. Risk identification requires a brainstorming work by a selected expert group (Winch, 2002). In this case the

expert group includes: project manager, architect, mechanical engineer and electrical engineer.
Experts are chosen based on their knowledge and based on previous experience in the construction industry.
Risk identification can be supported by a valuable tool: Ishikawa diagram (Hishikawa, 1986). This tool was created for qualitative analysis, but it is used to identify general problems. Considering work packages of WBS, the expert group has identified the associated risks. Figure 3 shows the Ishikawa diagram, which represents the main risks associated with the project failure.

3.4. AHP model: Phase#3

AHP model was developed through a three-level hierarchy. The top level of the hierarchy is the main goal of the decision problem. The lower levels are criteria and sub-criteria that contribute to the goal. Finally, there are alternatives of the model. In this case criteria and subcriteria are risk factors identified in phase #2, while alternatives are the work packages identified in phase#1. The design of hierarchy required experience and knowledge of the specific problem. It is necessary to define a team of experts which consists in 1 project management, 1 mechanical engineer, 1 electrical engineer and 1 architect. Figure 4 shows the hierarchy of the problem under study. The model prioritizes alternatives, based on their failure probability according to the criteria and sub-criteria analysis.
The model is divided into three different steps:

- pairwise comparison and relative weight estimation considering: criteria, sub criteria and alternatives;
- priority weight vector calculation;
- consistency index estimation to verify the accuracy of the judgments.

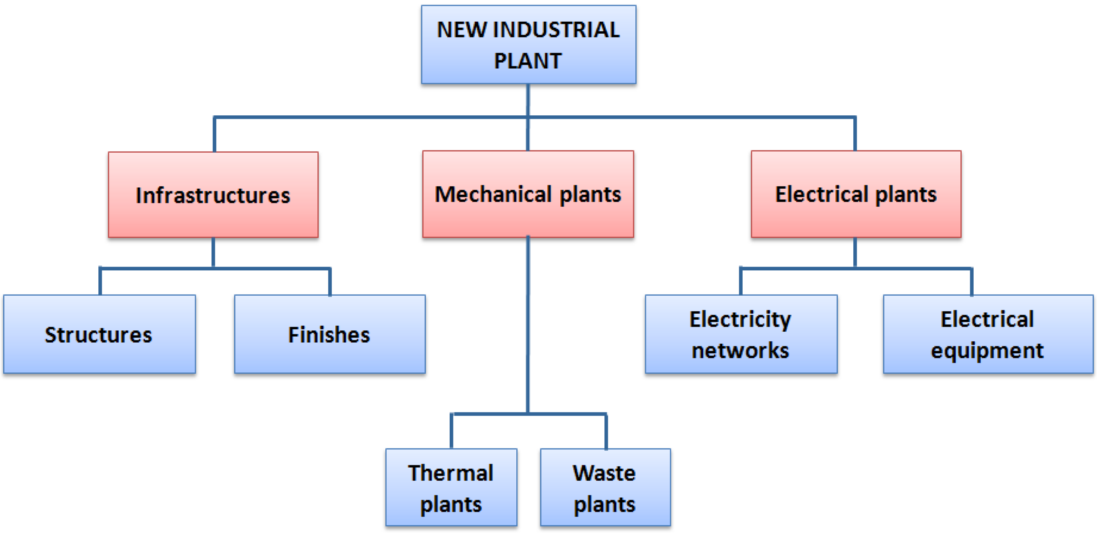

Figure 2: Work breakdown structure of the project

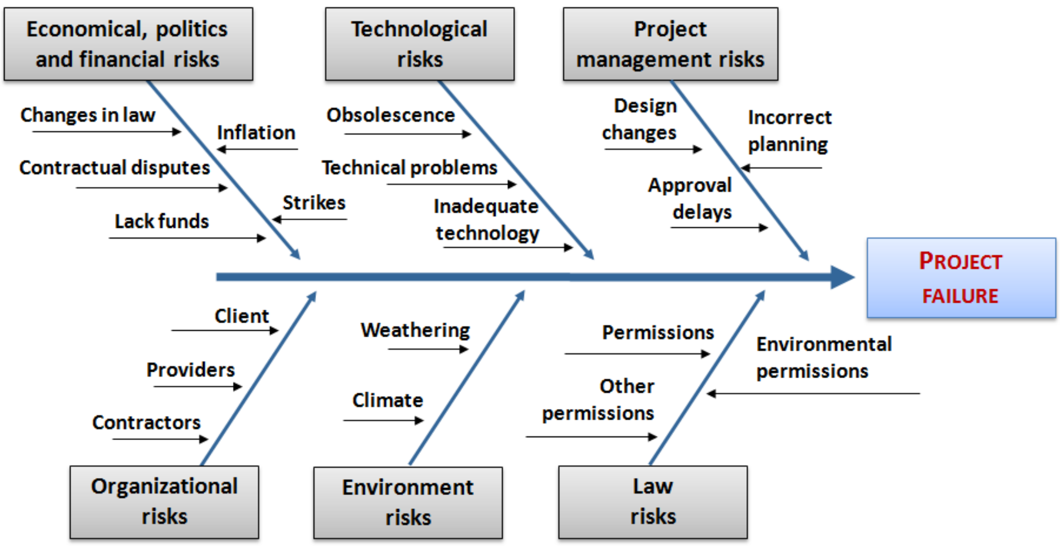

Figure 3: Ishikawa diagram

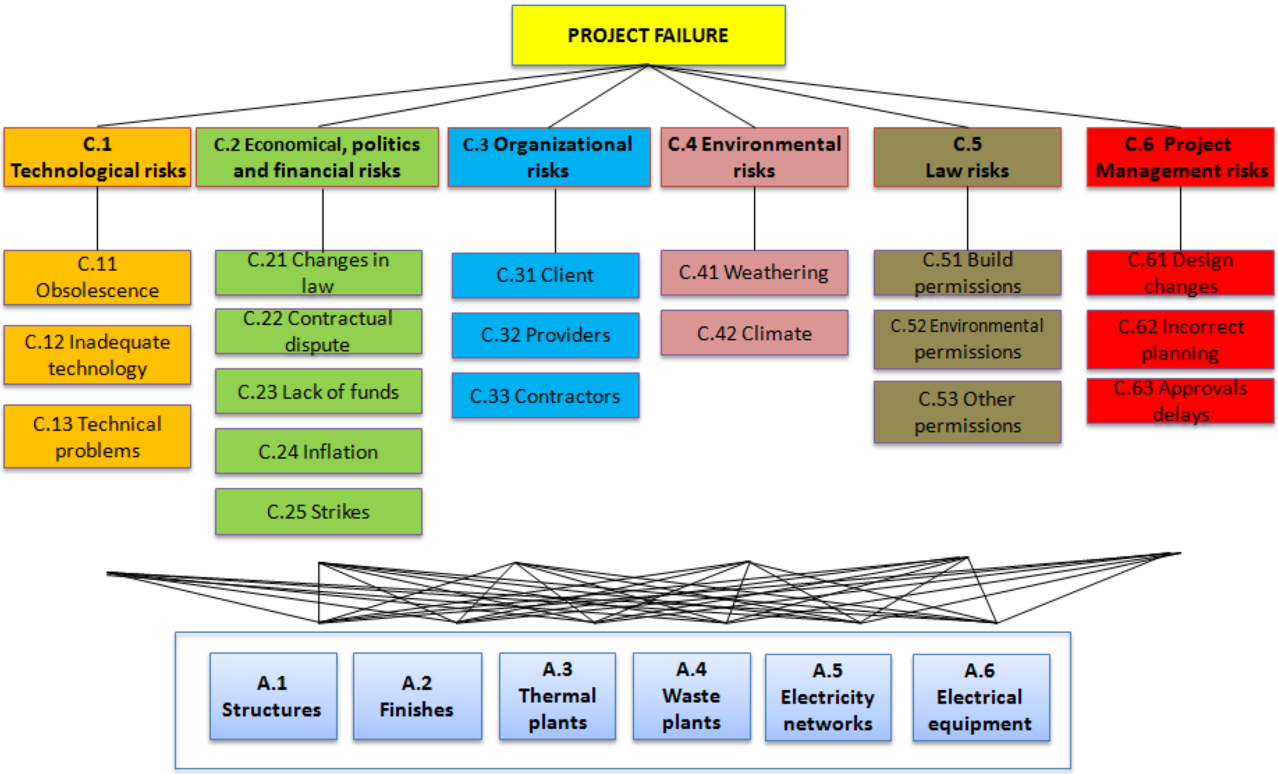

Figure 4: AHP risk management Model

After hierarchy definition, the pairwise comparison matrices were developed to determine criteria, sub criteria and alternatives weights. Table 1 shows a parwise comparison of technological risks sub-criteria. Values in the matrix are the arithmetic average of the ratings according four experts.

Table 1: Pairwise comparison–technological sub criteria

Sub criteria comparison				
	C.11	C.12	C.13	Priority Vector
C.11	1	1.429	0.669	0.327
C.12	0.700	1	1.000	0.295
C.13	1.495	1.000	1.000	0.378

In this case vector identifies “Technical problems” as the most important sub-criteria in technological risks with a score of 37.8%. Figure 5 shows a summary of priorities for criteria and subcriteria. The most important criteria are C.1 (Technological risks) with a score of 22.6%; C.6 (Project management risks) with 19% etc.

The most important subcriteria are C.31 (client) with a score of 0.564 and C.61 (design changes) with 0.512. Table 2 shows the consistency index obtained from all comparison matrices of criteria and subcriteria. Consistency index is acceptable if is less than 0.10. Table 2 shows that all judgments are consistent.

Table 2: Consistency index – Criteria and sub criteria

Consistency index	
Comparison	C.I
Criteria	0.023
Technological subcriteria	0.033
Economical subcriteria	0.082
Organizational subcriteria	0.048
Environmental subcriteria	0
Law subcriteria	0.015
Project management subcriteria	0.039

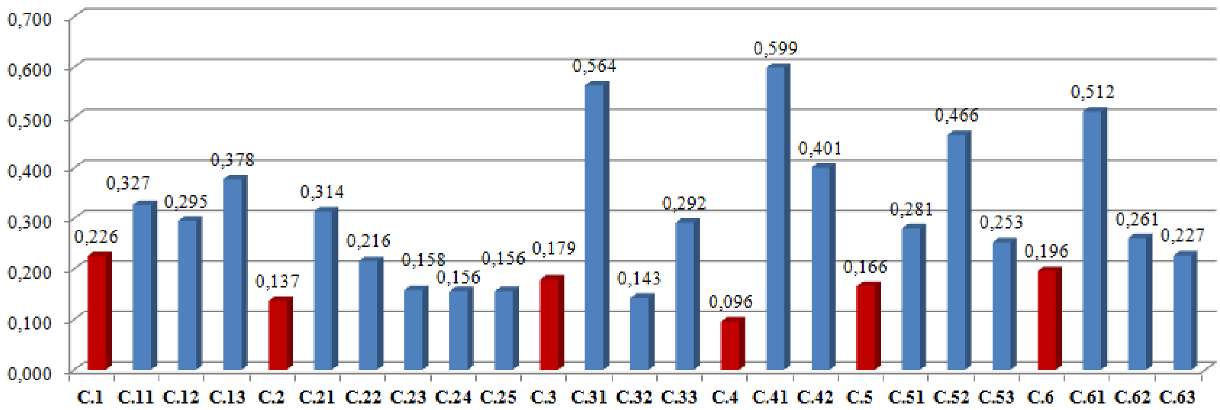

Figure 5: Priorities for criteria and sub criteria

Following, alternatives are compared with sub-criteria. Table 3 shows the comparison of alternatives with the sub-criterion C.11. Values in the matrix are the arithmetic average of the ratings according four experts.

Table 3: Pairwise comparison – alternatives with C.11

Alternatives comparison							
C.11	A.1	A.2	A.3	A.4	A.5	A.6	Priority
A.1	1	3.364	2.632	0.904	0.816	0.760	0.224
A.2	0.297	1	1.732	1.000	0.904	0.841	0.142
A.3	0.380	0.577	1	1.189	1.000	1.414	0.146
A.4	1.107	1.000	0.841	1	1.316	1.000	0.164
A.5	1.225	1.107	1.000	0.760	1	0.707	0.150
A.6	1.316	1.189	0.707	1.000	1.414	1	0.174

Finally, alternatives are compared with the goal (Table 4). Values in the matrix are the arithmetic average of the ratings according the four experts.

Table 4: Pairwise comparison – alternatives with goal

Alternatives comparison							
GOAL	A.1	A.2	A.3	A.4	A.5	A.6	Priority
A.1	0.156	0.217	0.160	0.268	0.171	0.155	0.188
A.2	0.096	0.116	0.123	0.161	0.171	0.107	0.129
A.3	0.104	0.097	0.099	0.080	0.079	0.128	0.098
A.4	0.202	0.261	0.296	0.239	0.300	0.273	0.262
A.5	0.208	0.116	0.222	0.139	0.171	0.209	0.178
A.6	0.234	0.193	0.099	0.113	0.107	0.128	0.146

The comparison of alternatives, defines some CI index, which are less to 0.1. So judgments are consistent. Finally, the principle of hierarchical composition, identifies the global priority of alternatives (Table 5).

Table 5: Global priority of alternatives

Priorities	
Alternatives	Global priority
A.1	27.22%
A.2	18.45%
A.4	16.44%
A.5	13.04%
A.3	12.43%
A.6	12.42%

Considering goal, criteria and sub-criteria the alternative A.1 (structures) is the most critical element in the construction of new industrial plant, with a score of 27.22%. Figure 6 shows the ranking of alternatives.

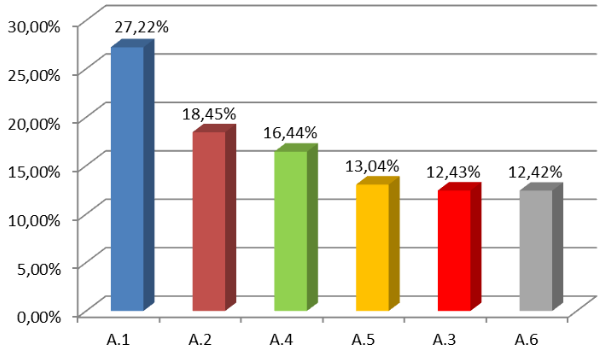

Figure 6: Priorities for alternatives

3.5. Risk index: Phase#4

According to the above results, two risk indices were identified in order to evaluate two fundamental elements in a project:

- complexity level;
- risk level.

Project complexity is its distinctive feature. According to Vidal et al., (2010), project complexity can be measured through an index defined as follows:

$$CI_i = S(i) / \max [S(i)] \quad (1)$$

where:

- CI is the complexity index;
- i is the number of alternatives;
- S(i) is the priority of alternative "i";

$0 \leq CI_i \leq 1$ (2)

The complexity index allows to identify the critical aspects of the project to optimally manage them. Table 6 shows the critical indices for the analyzed project. While Figure 7 presents data with a color complexity scale.

Table 6: Critical index

Critical index		
Alternative	Priority	CI_i
A.1	27.22%	1.000
A.2	18.45%	0.678
A.4	16.44%	0.604
A.5	13.04%	0.479
A.3	12.43%	0.456
A.6	12.42%	0.456

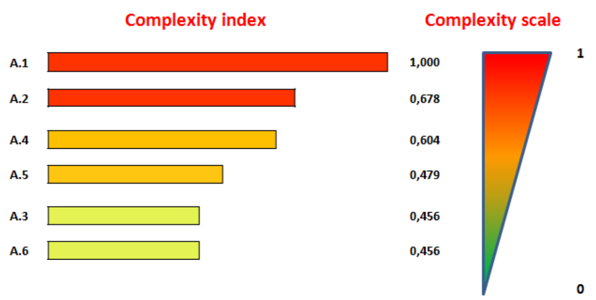

Figure 7: Complexity index

According Zayes *et al.*, (2007), it is possible to calculate a risk rating of a project, using a synthetic number as follows:

$R = \sum Wi * Vi\ (xi)$ (3)

Where:

- R is risk index;
- Wi is risk priority;
- xi is the risk;
- Vi is the impact of each risk on the project.

$0 \leq R \leq 1$ (4)

Wi are the global priority of subcriteria obtained with AHP model. Vi(xi) is calculated as an average of the opinions expressed by four decision makers (Table 7).

Table 7: Riskiness index

Riskiness index			
	W_i	$V_i(x_i)$	Wi * Vi (xi)
C.11	0.074	0.36	0.02664
C.12	0.067	0.38	0.02546
C.13	0.086	0.28	0.02408
C.21	0.043	0.21	0.00903
C.22	0.030	0.30	0.009
C.23	0.022	0.20	0.0044
C.24	0.021	0.10	0.0021
C.25	0.021	0.18	0.00378
C.31	0.101	0.41	0.04141
C.33	0.052	0.33	0.01716
C.32	0.026	0.36	0.00936
C.41	0.057	0.24	0.01368
C.42	0.038	0.23	0.00874
C.52	0.077	0.29	0.02233
C.51	0.047	0.38	0.01786
C.53	0.042	0.19	0.00798
C.63	0.044	0.29	0.01276
C.61	0.100	0.41	0.041
C.62	0.051	0.36	0.01836
		TOT	0.31

Figure 8 shows riskiness value for each sub-criterion.

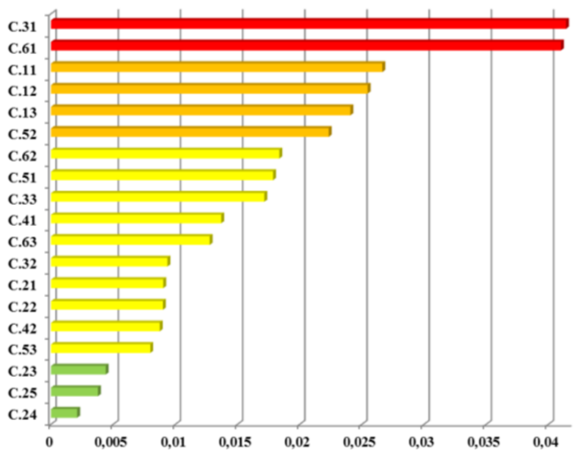

Figure 8: Risk index

The total project risk index is 0.31. Zayes et al., (2007) propose a scale for the risk analysis:

- $0 \leq R \leq 0.3$ low risk;
- $0{,}3 < R \leq 0.6$ medium risk;
- $0{,}6 < R \leq 0.8$ high risk;
- $R > 0.8$ very high risk.

In this case the analyzed project is subject to a low level of overall risk. Two most hazardous sub-criteria are C.31 (Customer) with a score of 0.04 and C.61 (Design changes) with a score of 0.041

3.6. Monitoring

The analysis defines a set of risk indicators. Through this ranking is possible to continuously monitor several critical processes of the project to avoid inefficiencies. If the system changes, it is possible to repeat the analysis to identify new critical issues of the project. The continuous control is a fundamental for the project successful.

4. DISCUSSION

The application of this analytical model allows to analyze the project of industrial plant construction and to calculate the complexity and the riskiness index of the project. The AHP model has identified an important ranking on criteria, sub-criteria and finally alternatives. AHP analysis highlights that “structures” (A.1) is the most critical system related to the project failure with a score of 27.22%, while the less critical element is “electrical equipment” (A.6) with a score of 12.22%. The analysis of consistency index (CI) showed uniformity of the judgments of the four experts. The consistency index is always less than 0,10. The complexity index has traced the results obtained with AHP model defining alternatives A.1 and A.2 the most critical. It will therefore be necessary to invest more resources in these activities because they have a higher index of complexity than the other. Finally the model calculates an overall risk ratio with a score of 0.31. Comparing it with scale proposed by Zayes et., (2007), the project is evaluated as “low risk”.

5. CONCLUSION

The necessity to control and monitor risks during the development of a project, pushes research towards increasingly sophisticated and accurate analysis. The presented research, allowed to identify and quantify project risks, using an integrated model that uses different tools of project management, such as: work breakdown structure, Ishikawa diagram, AHP model to define two indices that summarize the attribute of the project. It is important to emphasize the model validity. Its application allows to analyze and identify risks during the implementation of a project, defining a set of indicators to identify criticality of the project and to develop appropriate strategies for improvement. The presented model is a decision support system useful to the decision maker in the design phase of the project. The analyzed case study is the project of the development of a new production plant. The results presented show that the model is a valuable diagnostic tool that allows to identify the highest risks in a project and to evaluate them, supported through an AHP model run by a group of four experts. The two proposed indices allow us to identify complexity and riskiness of the project. The advantages of the model are:

- It provides a structured model for risk analysis;
- It allows to define optimum strategies for resource allocation;
- It reduces project delays due to unforeseen events;
- It is a flexible model applicable in many fields.

Future work will focus on the possibility to define a financial and economical profile, to assess the loss of costs related to the risk management during the project planning.

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