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# Fuzzy FMEA Application Combined with Fuzzy Cognitive Maps to Manage the Risks of a Software Project

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## ABSTRACT

The failure rate of an Information Technologies (IT) software project is pretty high because of their uncertain and risky structure. Managing well this kind of projects becomes important. Failure Mode and Effect Analysis (FMEA) is an extensive method that is used for identifying the importance level of risks in a project by using risk priority numbers (RPN). This method is based on experts' experience and cognitive skills at gathering data in order to make risk assessment. This situation causes inaccurate conclusions in the final risk ranking. Fuzzy logic is widely integrated into FMEA to handle these inaccuracies and inconsistencies in the literature while making assessment and calling Fuzzy FMEA method that we proposed. In this study, we explored another uncovered weaknesses of the proposed method. FMEA and Fuzzy FMEA do not consider the relationships among the risks of a project. To overcome this disadvantage, we proposed to integrate the idea of cognitive maps into these two methods (FMEA w/FCMs and Fuzzy FMEA w/FCMs). Finally, we got a comprehensive risk assessment methodology by considering the relationships among the risks under ambiguous circumstances.

**Keywords:** FMEA, Fuzzy logic, Fuzzy cognitive maps, Risk analysis.

## 1 Introduction

Information technologies have an important role in business life. To be able to compete with other companies, a company needs to have a successful information technology (IT). A successful IT construction can come true after a successful IT project. IT projects are high risky, complicated, expensive and they have uncertainty conditions. Because of these reasons IT projects have a high rate about being unsuccessful.

Companies need to manage well the risks of their IT projects under environmental conditions with high uncertainty, discrete small and incomplete data sets and lack of knowledge. There are some methods to manage the risks in literature. One of them is Failure Mode and Effect Analysis (FMEA). FMEA is an effective and highly used method to make risk assessment. FMEA uses experts' views to make risk prioritization by finding Occurrence value (O), Severity value (S) and Not Detection value (D). FMEA calculates the Risk Priority Number (RPN) values by multiplying O, S and D values and finally sorts the RPN values by descending. This helps analysts to manage the risks of IT project. They easily realize the risks which they need to handle at first. But FMEA have some weaknesses while making risk assessment.

Fuzzy Logic is a method of reasoning that resembles human reasoning. Fuzzy logic produces acceptable but definite output in response to incomplete, ambiguous or inaccurate input. To overcome weaknesses of FMEA, there are lots of successful applications which contain fuzzy logic and FMEA together in literature. These methods aim to manage the risks of IT projects in spite of all deficiencies and uncertainty. On the other hand this method doesn't consider the relationships among the risks as a weakness.

Fuzzy Cognitive Maps (FCMs) is a technique that is used for modeling complicated systems and representing the cause and effect relationships among the components of complicated systems. In that study FCMs method is used in order to overcome the weakness of Fuzzy FMEA method. This final method calls as Fuzzy FMEA with FCMs. This new method aims to make risk management to consider the relationships among the risks in an IT project.

## 2 Literature Review and General Information

### 2.1 Failure Mode and Effect Analysis

FMEA is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry(1). To help reliability-related problems, FMEA has been widely used in various manufacturing areas (2). In recent years FMEA has increased its scope and it is applied in service sector (3). In service sector, FMEA was offered providing the generic guidelines required applying to the service setting together with system FMEA, design FMEA and process FMEA (4). FMEA method was applied to IT Projects in service sector and they took interpretable results from it.

Moreover, FMEA is integrated to other methods in the literature. Braglia (2000) (5) extended FMEA method which is called Multi Attribute Failure Mode Analysis. Author has embedded FMEA to Analytic Hierarchy Process (AHP) in order to define importance levels of failure modes. Pillay and Wang (2003) (6) suggested a new approach and this approach covers Fuzzy logic and grey theory with FMEA. To weight the risk factor values, Chang (2009) (7) suggested the ordered geometric averaging method (OWGA) and decision making trial and evaluation laboratory method (DEMATEL) to make prioritization the failure modes in FMEA.

FMEA is a reliability tool that is used for defining potential failures before they occur to minimize the risks' effects (8) (9). The purpose of evaluation in FMEA method is to define the risks numerically which will occur and to prioritize them. In that stage the criticality level of each risk is defined, independently. In traditional FMEA, a risk priority number (RPN) is calculated to evaluate the risk level of a component/process (1). After RPN values are calculated, the results are sorted in by descending order. Since the higher value of RPN means that the associated risk is more critical, the resulting order helps analyst to investigate the solutions for preparedness and to determine the prevention and/or mitigation plans before risk occurrence. The RPN is obtained by finding the multiplication of three factors, as given in $RPN{=}O * S * D$ (2.1):

Representing this mathematically will give:

$$RPN = O * S * D \qquad (2.1)$$

where O denotes the probability/occurrence of the failure, S denotes the severity of the failure and D denotes the probability of not detecting the failure. The process of FMEA is given in (Figure 2.1 FMEA Method).

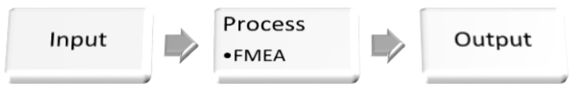



Figure 2.1 FMEA Method

### 2.2 Fuzzy FMEA

There are important applications have been made in FMEA literature to overcome the shortcomings of the traditional RPN (10). Fuzzy FMEA logic uses experts' view who describe the risk factors $O$, $S$ and $D$ by using the fuzzy linguistic terms. To evaluate three risk factors $O$, $S$ and $D$ the linguistic variables were used. Bowles and Pelaez described a fuzzy logic based approach for prioritizing failures in FMEA which uses fuzzy linguistic terms to describe $O$, $S$ and $D$ and the risks of failures (11). According to expert knowledge, fuzzy if-then rules were obtained and expertise provided finding the relationships between a risk and its $O$, $S$ and $D$ values for every risk. Fuzzification process was run for crisp ratings for $O$, $S$ and $D$ to match the premise of each possible if–then rule. All the rules that have any truth in their premises were fired to contribute to fuzzy conclusion. The defuzzification process was finally applied to get the fuzzy conclusion the weighted mean of maximum method as the ranking value of risk priority (1).

Pillay and Wang (6) proposed a fuzzy rule base approach to avoid the use of traditional RPN. They tried to set up the membership functions of the three risk factors O, S and D. Membership functions have been developed and FMEA is applied in its traditional way with the use of brainstorming techniques. Each failure mode is assigned a linguistic term for each of the three risk factors. The three linguistic terms are integrated using the fuzzy rule base generated to produce a linguistic term representing the priority for attention. This linguistic term represents the risk ranking of the failure mode.

Fuzzy logic is a form of multi-valued that is obtained from fuzzy set theory to overcome reasoning that is approximate rather than precise (1). The fuzzy logic variable may have a membership value not only 0 or 1 but also a value inclusively between 0 and 1 (1). In fuzzy logic the degree of truth of a statement can range between 0 and 1 and is not constrained to the two truth values {true (1), false (0)} as in classic propositional logic (1). Approximate reasoning which is a made of reasoning that is not exact or very inexact is a basis provided by the fuzzy logic (1). The fuzzy logic proposes a more down to earth framework for reasoning than the traditional two-valued logic.

The name of *fuzzy logic* emerged by Lotfi Zadeh (12) as an outcome of the development of the theory of fuzzy sets. In 1965, Zadeh proposed fuzzy set theory (12), and later established fuzzy logic based on fuzzy sets. The process of fuzzy logic is given in (Figure 2.2 The methodology of Fuzzy FMEA) (1).

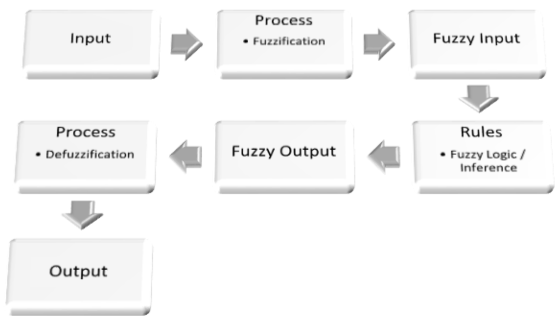



Figure 2.2 The methodology of Fuzzy FMEA

In the proposed approach, a fuzzy rule base is used to rank the potential causes identified within the FMEA, which would have identical RPN values but different risk implications. The approach then extends the analysis to include weighting factors for $O$, $S$ and $D$ using defuzzified linguistic terms.

Algorithm of fuzzy logic is as follows:

1. Calculate average O, S, D values for every risk ($\bar{O}, \bar{S}, \bar{D}$).
2. Find the membership functions and function levels for every input variable of risks.
3. Get the results according to membership function that is used.
4. Use Mamdani min/max method of inference mechanism and find the function levels and the minimum input value among $\bar{O}, \bar{S}, \bar{D}$ values for every risk.
5. Find the function levels for output function by using output rules table.
6. Defuzzify the results by using center of gravity method.

### 2.3 Fuzzy Cognitive Maps (FCMs)

The origin of FCMs is the concept of CMs which is first proposed by Tolman (13). In order to represent the cause and effect relationships among the elements of a given environment in political and social sciences CMs has been applied (13) (14). Then, Axelrod claimed that CM with causality value + and - is adequate for simulating human cognition and following this decision makers don't tend to prefer more complicated set of relationships to solve problems(14).

Kosko (15) proposed the Fuzzy Cognitive Maps (FCMs) technique in order to evolve a CMs model because of two important conditions.

Fuzzy logic can make casual relationships between nodes have different intensities. An uncertain value is more preferred rather than an exact value. Because of this reason, Kosko (16) proposed the Fuzzy Cognitive Maps (FCMs) technique in order to evolve a CMs model. A fuzzy number in that model can have a value between 0 and 1 or -1 and 1, including both

(17). Each numerical value in the interval represents the grade of membership to a fuzzy set, where 0 is the non-membership and 1 the full membership (18). In addition to them, in FCMs, there is an initial vector of nodes which contains initial values at the instant *0* and the model simulate this vector at the instant t until it reaches a stable vector. So this technique can forecast the future behaviors of a system which is working on. In addition, FCMs provide excellent mechanisms to develop forecasting exercises. Specifically, this technique enables us to develop what-if analysis, supporting the critical decision-making (19).

The nodes show dynamic variables in a dynamic system. The edges show directions and intensity of casual relationship among the variables. Each cause is assessed by its intensity $w_{ij}$, where $i$ is the pre-synaptic (causal) node and $j$ the post-synaptic (effect) node. The $w_{ij}$ values are represented in the $nxn$ ($n$ is the number of nodes) matrix called adjacency matrix($A$), see $\boldsymbol{A}= \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \boldsymbol{w_{ij}} & \cdots \\ \cdots & \cdots & \cdots \end{matrix}$ (2.2) (17).

$$\boldsymbol{A} = \begin{pmatrix} \cdots & \cdots & \cdots \\ \cdots & \boldsymbol{w_{ij}} & \cdots \\ \cdots & \cdots & \cdots \end{pmatrix} \qquad (2.2)$$

There are three possible types of causal relationships between nodes (17):

- $w_{ij} > 0$: Positive causality between nodes $x_i$ and $x_j$.
- $w_{ij} < 0$: Negative causality between nodes $x_i$ and $x_j$.
- $w_{ij} = 0$: No causal relationship exists between nodes $x_i$ and $x_j$.

It is possible to develop forecasting exercises, especially what-if analysis in FCMs. For this purpose, what-if scenarios at the instant $t = 0$ are defined. In this way, the values of all nodes of FCM are entered in a $1xn$ initial state vector $C^t$, see $C^t = (C_1^t, C_2^t, \dots, C_i^t, \dots, C_n^t)$ (2.3). The value of each node in the input vector can be 1 (element is activated) or 0 (element is not activated) (17).

$$C^t = (C_1^t, C_2^t, \dots, C_i^t, \dots, C_n^t) \qquad (2.3)$$

where $C^t$ is the initial vector state (at the instant $t$), and $C_i^t$ is the initial value of the $i$ node (at the instant $t$) (17).

Subsequently, scenarios are simulated computing $\boldsymbol{A}= \begin{matrix} \cdots & \cdots & \cdots \\ \cdots & \boldsymbol{w_{ij}} & \cdots \\ \cdots & \cdots & \cdots \end{matrix}$ (2.2) and $C^t = (C_1^t, C_2^t, \dots, C_i^t, \dots, C_n^t)$ (2.3) through $C_j^{t+1} = f_{\begin{matrix} i=1 \\ i \neq j \end{matrix}} C_i^t * w_{ij}$ (2.4).

Activation functions such as the sigmoid, hyperbolic tangent, step and threshold linear can be used in the FCM inference process (20), (21), (22).

$$C_j^{t+1} = f\left(\sum_{\substack{i=1 \\ i\neq j}} C_i^t * w_{ij}\right) \qquad (2.4)$$

where $f(x)$ is the activation function, $C_j^{t+1}$ the value of the post-synaptic (effect) node $j$ at the instant $t+1$, $C_i^t$ the value of the pre-synaptic (causal) node $i$ at the instant $t$, and $w_{ij}$ indicate the intensity of the relationships between the pre-synaptic (causal) node $i$ and the post-synaptic (effect) node $j$ (17).

The nonlinear function f allows the activation to take an allowed value. In this study, we used sigmoid function.

## 3 Integrated Methodology for Risk Assessment: Fuzzy FMEA Integrated with Fuzzy Cognitive Maps

FMEA and Fuzzy FMEA processes are used for defining the importance of risks of projects but all these processes have a weakness. They don't consider the relationships among risks of projects. In order to overcome this weakness we used Fuzzy Cognitive Maps by extending of these processes. For this extension we aimed to reach an extension coefficient to define a new Severity (S) value when the risks of a project affect each other by using Fuzzy Cognitive Maps. By this way the relationships among risks are considered to overcome the weakness of FMEA and Fuzzy FMEA. All these processes are applied after this extension.

The last $C_j^t$ value shows impact of node $j$. At the end of FCM process every node reach an affected value. According to activation function that is chosen by practitioner, there is a sub limit of nodes. It means if the beginning value of node $j$ equals to zero, the result will be equal to sub limit. According to these values that are obtained at the end of FCM process, the coefficient value is calculated for every node. It means every risk will have a coefficient value and severity value of every risk will be calculated by these coefficient values.

$$\lambda_j = \delta_j - \varphi \qquad (3.1)$$

where $\varphi$ is the sub limit of nodes. $\delta_j$ is the last $C^t$ value of node $j$. $\lambda_j$ is the coefficient value of the risk $j$. A new Severity value is obtained by $S_j' = \begin{cases} S_j * (1+\lambda_j), S_j * (1+\lambda_j) < 10 \\ 10 \qquad ,S_j * (1+\lambda_j) \geq 10 \end{cases}$ (3.2).

$$S_j' = \begin{cases} S_j * (1+\lambda_j), S_j * (1+\lambda_j) < 10 \\ 10 \qquad ,S_j * (1+\lambda_j) \geq 10 \end{cases} \qquad (3.2)$$

where $S_j'$ is the new severity value that will be used for calculating the new importance levels by FMEA, and Fuzzy FMEA. For example, RPN value in FMEA is calculated by $RPN_j' = O_j * S_j' * D_j$ (3.3).

$$RPN_j' = O_j * S_j' * D_j \qquad (3.3)$$

The process of FMEA is given in (Figure 2.1 FMEA Method). After FMEA process is expanded by Fuzzy Cognitive Maps the new FMEA process is given (Figure 3.1 FMEA Process by FCM).

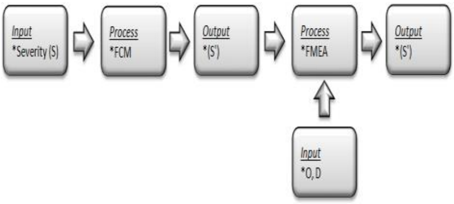



Figure 3.1 FMEA Process by FCM

The process of Fuzzy FMEA is given in (Figure 2.2). After Fuzzy FMEA process is expanded by Fuzzy Cognitive Maps the new Fuzzy FMEA process is given (Figure 3.2).

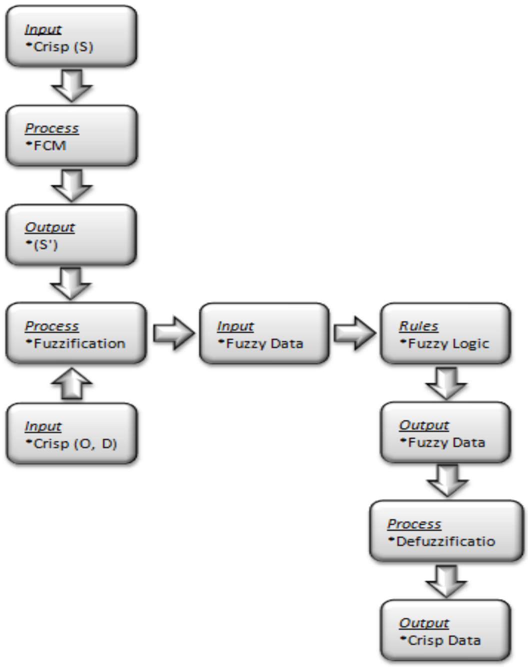



Figure 3.2 Fuzzy FMEA Process by FCM

# 4 Case Study

## 4.1 Data Collection

IT software projects have risky, complex and hard-to-understand structures for managing by project managers. That's why risk management plays an important role to achieve projects' goals successfully.

We will investigate the risks of a real IT software project. The top management of a company needs a new software application to assign tasks, to follow users' tasks, to watch the current situation and to have reports about these tasks. They have decided to develop an in-house project which satisfies their requirements by IT department. So all these processes have risks and these risks need to be managed. At the end of this investigation we will put them in order according to their importance and then we will make suggestions to managers to lead this project. In this investigation FMEA and Fuzzy FMEA were used as known methods. Risk prioritizations of these methods were compared and interpreted. In addition to this, to consider the relations among the risks we integrated Fuzzy Cognitive Maps to every method and then we compared all results to observe the changing risks' priorities.

For this project we specified 23 risks as follows:

Table 4.1 Risks of IT Project

| Risk Code | Risk |
|---|---|
| **R1** | Conflicts between organization and consultants/ vendor |
| **R2** | High rate of system customization |
| **R3** | Data management issues |
| **R4** | Inadequate education and training |
| **R5** | Inadequate user involvement |
| **R6** | Ineffective communications system |
| **R7** | Internal conflicts between departments |
| **R8** | Inadequate change management |
| **R9** | Lack of performance measurement system |
| **R10** | Misfit between organization culture and ERP system |
| **R11** | Misfit between organization structure and ERP system |

| | |
|---|---|
| **R12** | Misfits between the IT and business strategies |
| **R13** | Environmental pressures |
| **R14** | Poor business process reengineering |
| **R15** | Poor consultant |
| **R16** | Poor project management |
| **R17** | Poor risk management |
| **R18** | Poor top management support |
| **R19** | IT Technical issues |
| **R20** | Language barriers |
| **R21** | Poor project team |
| **R22** | Poor knowledge transfer |
| **R23** | Poor quality of testing |

These risks are defined according to character of the case in point. So for other projects, the risks need to be characterized according to conditions of the case or problem.

### 4.2 Application of New Method: Fuzzy FMEA Integrated with FCMs

To make prioritization we used a new method called Fuzzy FMEA and we also surveyed its stability the whether it is applicable or not. The simulation results showed us that it is a suitable method to assessment risks for projects under conditions with high uncertainty, under discrete small and incomplete data sets. After all this method still have a weakness that actually comes from nature of FMEA. This weakness is *ignoring the relationships among the risks*. FMEA and Fuzzy logic in that study are not enough to overcome that. As stated above in order to consider the relationships among the risks we used Fuzzy Cognitive maps.

In order to measure effects of FCMs on the other methods, we firstly applied it to FMEA and compared the results of two methods in themselves. Then secondly we applied it to Fuzzy FMEA and again compared the results of two methods in themselves. Finally Fuzzy FMEA integrated with Fuzzy Cognitive Maps is the goal that we want to reach. Comparisons in themselves of every couple methods also show that the integration process is a practicable process.

#### 4.2.1 Fuzzy Cognitive Maps

This approach consists in adding the FCM drawing by each expert. A group of experts was carefully selected to participate in our study. Each expert individually designed his/her own FCM model, which represent his/her knowledge in IT projects. They thus pointed out which risks had threatened their projects' risks. The experts also drew the interactions that exist between IT project risks nodes. That is, they specified the type and intensity of the casual relationships existing among nodes. Experts can indicate the causal connections using linguistic variables or real numbers. Those participating in the present study expressed all relations with a numerical value in a range of [-1, 1]. We thus achieved one adjacency matrix for each expert.

The Augmented FCM method finishes by adding the adjacency matrices of each one of them. This depends on if there are or are not common nodes. If there are not common risks, adjacency matrices will be solely added up. Otherwise, if there are common nodes, then the elements $w_{ij}^{AUG}$ in the augmented matrix ($A^{AUG}$) are computed according to the following

$$w_{ij}^{AUG} = \frac{\sum_{i=1}^{m} w_{ij}^{k}}{m} \qquad (4.1):$$

$$w_{ij}^{AUG} = \frac{\sum_{i=1}^{m} w_{ij}^{k}}{m} \qquad (4.1)$$

where $m$ is the number of FCMs added, one per expert, $k$ is the identifier for each FCM, and $i$ and $j$ are identifiers of the connections.

We computed the elements for the $A^{AUG}$ using (*see Appendix A*) because the experts' FCM had common nodes.

You can reach all experts' views by this link:

https://drive.google.com/file/d/0B-OGfN4no_-TVmw4TTNmMUt0cjg/view?usp=sharing

Subsequently, we compared the FCM obtained with respect to the research conceptual framework to guarantee the logical validation. For the partial graphical representation of the model, see *Appendix B*.

In this way, we applied the hyperbolic tangent function **Error! Reference source not found.**), with a function slope ($\lambda$) e qual to 1 in the FCM simulations. The value of the FCM nodes is located within the range [0, 1] because we chose the risks according to positive causality or no causality. There is no negative causality among the nodes. In addition, this usually requires a lower number of interactions to reach a stable scenario in comparison to other activation functions.

In this study we defined the initial vector by looking RPN values of the risks. If RPN value of a risk is above 250, we set its initial value as 1 otherwise its initial value is 0 (*see Appendix C*).

Finally, all simulations reached a stability threshold. *Appendix D* also shows the results obtained at the end of each simulation.

Fuzzy Cognitive Maps end up when all simulations reached stability threshold. It means values of nodes don't change after this stability. **Error! Reference source not found.***Appendix E* shows every steps of simulation as a graphical notation.

These final values show how the risks were affected by the others. The findings show that these impacts are from 0.500 to 0.998. The average impact is 0.842. This indicates that the activated risks have a moderate and positive influence on the rest. The nine most highly impacted risks that their values are over 0.900 were R7 (0.998), R18 (0.996), R1 (0.995), R22 (0.990), R19 (0.988), R10 (0.986), R8 (0.948), R16 (0.948) and R4 (0.914).

R13 (0.500) has no affect because if there is no interaction, the value of node would be 0.500. This is a kind of result of the function method that we chose for application (sigmoid function). If the augmented matrix contained negative values, we would see interaction values under 0.500 as a result but as noted above while specifying the augmented matrix we just gave the values according to positive causality or no causality because when a risk occurred in a project, it will affect the project negatively and when the risk triggered another risk, this risk affected by first risk will also affect the project negatively. This makes a positive causality between two risks. All risks have been chosen in defiance of this logic. According to the function method the interactions of nodes are located within [0,1]:

Interaction value between two nodes < 0.500. It means negative causality is more than positive causality for the node that is affected by other nodes.

Interaction value between two nodes > 0.500. It means positive causality is more than negative causality for the node that is affected by other nodes.

Interaction value between two nodes = 0.500. It means there is no causality for the node.

### 4.2.2 Getting New Severity Values

To consider the relationships among the risk of project we firstly applied FCM to FMEA and compared affects on FMEA results.

Firstly we have indicated a non-interactivity limit of nodes. This is 0.500 and it is a feature of the sigmoid function. Then we calculated the coefficient values of risks by using the non-interactivity limit $\lambda_j = \delta_j - \varphi$ (3.1). Finally we obtained the new Severity (S') values and RPN (RPN') values by respectively using $S_j' = \begin{cases} S_j * (1+\lambda_j), & S_j * (1+\lambda_j) < 10 \\ 10 & , S_j * (1+\lambda_j) \geq 10 \end{cases}$ (3.2) and $RPN_j' = O_j * S_j' * D_j$ (3.3).

For example (For R1):

$\varphi = 0{,}500$

$j = 1$

$\lambda_1 = 0{,}995 - 0{,}500 = 0{,}495$

$$S_1' = \begin{cases} 7{,}2 * (1 + 0{,}495), & 7{,}2 * (1 + 0{,}495) < 10 \\ 10 & , \quad 7{,}2 * (1 + 0{,}495) \geq 10 \end{cases}$$

In that example, the new Severity value would be more than 10 but in FMEA O, S, D values' range is between 1 and 10. That's why we set 10 the value when the value is more than 10.

$S_1' = 10\,(10{,}764 \geq 10)$

$RPN_1' = 3 * 10 * 6 = 180$

According to this information, for all risks, the new $S$ values ($S'$) would be like in *Appendix F*.

In addition, if the value of a node was under 0,500 at the end all simulations, its coefficient value would be negative and it would make new severity value of the node less than old severity value.

### 4.2.3 FMEA Integrated with Fuzzy Cognitive Maps

The evaluation of the failure modes is carried out by scoring the respective risk factors of occurrence (O), severity (S), and not detection (D). For this purpose, usually 10-level scales are being used. While scoring the risk factors a variety of statistical techniques or expert opinion is referred to. In this study, all the risk factors were based on expert opinion.

In this project we have 5 experts and we asked to them O, S, D values for every risks and finally we calculated the arithmetic mean of their opinions to use them in FMEA application.

When we applied FMEA to the risks, the results are as follows in Table 4.2 as *Old RPN and Old Prioritization*.

According to FMEA results, while project managers consider the risks, they need to be careful R8, R2, R23, R19 and R14. If we assume that risks which their RPN value are above 300 are important, we could say that these risks has critical importance level according to FMEA method.

R17 – R22 and R3 – R7 risk groups have different risk factor values in themselves but their RPN values are same. It means they need to be evaluated in same level despite the fact that they have different values.

Table 4.2 Results of FMEA Integrated with FCM (Comparison)

| Risks | Old RPN | Old Prioritization | New RPN | Effect on RPN | New Prioritization |
|---|---|---|---|---|---|
| **R8** | 662,888 | 1 | 770,800 | 107,912 | 1 |
| **R2** | 512,992 | 2 | 557,600 | 44,608 | 2 |
| **R23** | 392,496 | 3 | 479,834 | 87,338 | 3 |
| **R22** | 276,08 | 7 | 394,400 | 118,320 | 4 |
| **R19** | 337,92 | 4 | 384,000 | 46,080 | 5 |
| **R17** | 276,08 | 6 | 357,539 | 81,459 | 6 |
| **R14** | 313,2 | 5 | 348,000 | 34,800 | 7 |
| **R21** | 266,112 | 8 | 316,800 | 50,688 | 8 |
| **R16** | 202,176 | 10 | 280,800 | 78,624 | 9 |
| **R5** | 167,04 | 12 | 219,188 | 52,148 | 10 |
| **R13** | 209,088 | 9 | 209,088 | 0,000 | 11 |
| **R7** | 126,72 | 14 | 189,819 | 63,099 | 12 |
| **R9** | 174,064 | 11 | 180,824 | 6,760 | 13 |
| **R1** | 120,96 | 15 | 168,000 | 47,040 | 14 |
| **R6** | 119,784 | 16 | 163,669 | 43,885 | 15 |
| **R3** | 126,72 | 13 | 144,000 | 17,280 | 16 |
| **R11** | 101,376 | 17 | 139,539 | 38,163 | 17 |
| **R18** | 90,72 | 18 | 129,600 | 38,880 | 18 |
| **R12** | 73,728 | 19 | 99,847 | 26,119 | 19 |
| **R10** | 53,76 | 21 | 79,910 | 26,150 | 20 |
| **R15** | 63,36 | 20 | 74,574 | 11,214 | 21 |
| **R4** | 28,16 | 22 | 39,824 | 11,664 | 22 |
| **R20** | 13,552 | 23 | 15,496 | 1,944 | 23 |

While making prioritization we considered the old prioritization. Otherwise the risks that their RPN values are equal to each other would have randomly been ordered in themselves.

According to results, there are two important effects above 100 (R8: 107,912 and R22:118,320) by means of this *integration of FCM* haven changed prioritization of R22. It made its prioritization from 7 to 4. It means integration of FCM have made it more important risk. There is one more risk like R22 but this time Integration of FCM have made it more unimportant risk by changing its priority from 13 to 16 (R3). These two risks have the largest changes $(7-4=3=16-13)$ according to other risks' changes. That means FCM didn't make a dramatic change.

In FMEA, R17 and R22 have same RPN values and their prioritizations are respectively 6 and 7. After integration of FCM R17 kept its place same (6) but R22 became more important risk (4) as mentioned above. There is a similar situation with a little difference for R3 and R7. In FMEA their RPN values are same and their prioritizations are respectively 13 and 14. After FCM while R7 increased its priority from 14 to 12, R3 has lost its importance a little bit and became from 13 to 16. This shows that when we considered the relationship among the risks this application could change their prioritizations. So we can conclude that integration of FCM can affect the risks in three ways:

- FCM can *increase* risks' importance levels: *R22 (7→4), R16 (10→9), R5 (12→10), R7 (14→12), R1 (15→14), R6 (16→15), R10 (21→20)*
- FCM can *decrease* risks' importance levels: *R19 (4→5), R14 (5→7), R13 (9→11), R9 (11→13), R3 (13→16), R15 (20→21)*
- FCM can *keep same* risks' importance levels: *R8 (1→1), R2 (2→2), R23 (3→3), R17 (6→6), R21 (8→8) , R11 (17→17) , R18 (18→18), R12 (19→19), R4 (22→22), R20 (23→23)*

### 4.2.4 Fuzzy FMEA Integrated With Fuzzy Cognitive Maps

A model was established for the FMEA technique having 3 inputs and 1 output variable. The RPN values were calculated by combining the associated 3 input factors. For the input variables of occurrence, severity and not detection a 5-level; and for the output variable RPN a 10-level triangular membership functions.

For input values, the 10-level scale is stated 5 regions as triangular membership functions. Input variables' membership functions would be as below (Almost None, Low, Medium, High, Very High):

Table 4.3 Membership Functions of Input Variables

| Membership | Function | Limits |
|---|---|---|
| **Almost N.** | μ(x) = (2-x)/2 | 0,00≤ x ≤ 2,00 |
| **Low 1** | μ(x) = (x-1)/(3/2) | 1,00≤ x ≤ 2,50 |
| **Low 2** | μ(x) = (4-x)/(3/2) | 2,50≤ x ≤ 4,00 |
| **Medium 1** | μ(x) = (x-3)/2 | 3,00≤ x ≤ 5,00 |
| **Medium 2** | μ(x) = (7-x)/2 | 5,00≤ x ≤ 7,00 |
| **High 1** | μ(x) = (x-6)/(3/2) | 6,00≤ x ≤ 7,50 |
| **High 2** | μ(x) = (9-x)/(3/2) | 7,50≤ x ≤ 9,00 |
| **Very High** | μ(x) = (x - 8)/2 | 8,00≤ x ≤ 10,00 |

For output values, the 10-level scale is stated 10 regions as triangular membership functions. Output variables' membership functions would be as below (None, Very Low, Low, High Low, Low Medium, Medium, High Medium, Low High, High, Very High):

Table 4.4 Membership Functions of Output Variables

| Membership | Function | Limits |
|---|---|---|
| **None** | μ(x) = (2 – x)/2 | 0,00≤ x ≤ 2,00 |
| **Very Low 1** | μ(x) = x – 1 | 1,00≤ x ≤ 2,00 |
| **Very Low 2** | μ(x) = 3 – x | 2,00≤ x ≤ 3,00 |
| **Low 1** | μ(x) = x – 2 | 2,00≤ x ≤ 3,00 |
| **Low 2** | μ(x) = 4 – x | 3,00≤ x ≤ 4,00 |
| **High Low 1** | μ(x) = x – 3 | 3,00≤ x ≤ 4,00 |
| **High Low 2** | μ(x) = 5 – x | 4,00≤ x ≤ 5,00 |
| **Low Medium 1** | μ(x) = x – 4 | 4,00≤ x ≤ 5,00 |
| **Low Medium 2** | μ(x) = 6 – x | 5,00≤ x ≤ 6,00 |

| | | |
|---|---|---|
| **Medium 1** | μ(x) = x – 5 | 5,00≤ x ≤ 6,00 |
| **Medium 2** | μ(x) = 7 – x | 6,00≤ x ≤ 7,00 |
| **High Medium 1** | μ(x) = x – 6 | 6,00≤ x ≤ 7,00 |
| **High Medium 2** | μ(x) = 8 – x | 7,00≤ x ≤ 8,00 |
| **Low High 1** | μ(x) =x – 7 | 7,00≤ x ≤ 8,00 |
| **Low High 2** | μ(x) = 9 – x | 8,00≤ x ≤ 9,00 |
| **High 1** | μ(x) = x – 8 | 8,00≤ x ≤ 9,00 |
| **High 2** | μ(x) = 10 – x | 9,00≤ x ≤ 10,00 |
| **Very High** | μ(x) = x – 9 | 9,00≤ x ≤ 10,00 |

*How to Get Output Rules*

To get output values, we have developed a new logic. In that way, every output values will have a mathematical calculation and same logic with the others.

Firstly, we have divided low, medium and high functions of input variables into two-side functions and then we have defined mathematical notations of input variables' membership functions (as it is seen Table 4.3).

After we got the functions, we have calculated CoG values (center of gravity) of every input function.

| | |
|---|---|
| Almost None (AN) | $CoG_{(AN)} = 0{,}67$ |
| Low (L) | $CoG_{(L)} = 2{,}50$ |
| Medium (M) | $CoG_{(M)} = 5{,}00$ |
| High (H) | $CoG_{(H)} = 7{,}50$ |
| Very High (VH) | $CoG_{(H)} = 7{,}50$ |

After input variables were processed we have divided out of none and very high functions of output variables into two-side functions and then we have defined mathematical notations of output variables' membership functions (as it is seen Table 4.4).

We have calculated CoG values (center of gravity) of every output function to define ranges of output functions.

| **Output Variables** | **CoG** | **Ranges** |
|---|---|---|
| **None** | 0,67 | 0,00 – 1,33 |
| **Very Low** | 2,00 | 1,33 – 2,67 |
| **Low** | 3,00 | 2,67 – 3,33 |
| **High Low** | 4,00 | 3,33 – 4,67 |
| **Low Medium** | 5,00 | 4,67 – 5,33 |
| **Medium** | 6,00 | 5,33 – 6,67 |
| **High Medium** | 7,00 | 6,67 – 7,33 |
| **Low High** | 8,00 | 7,33 – 8,67 |
| **High** | 9,00 | 8,67 – 9,33 |
| **Very High** | 9,67 | 9,33 – 10,00 |

After we calculated CoGs and ranges of functions we have taken averages of every combination and then according to average values we have found fuzzy output function of every combination. Here is the Output rules table:

https://drive.google.com/file/d/12vNv3OQi4qmRefY2EmjNUcuGGpuvbjRA/view?usp=sharing

*Results of Fuzzy FMEA*

As to the types of failure, the fuzzy RPN values provided in the model are given in a descending order in (Table 5.5 **Results of Fuzzy FMEA**) in comparison with the RPN values of classical FMEA. The failure types containing the same RPN values were arranged according to the values of occurrence, severity and not detection (priority queues).

According to results the first 3 risks' prioritizations and the last 6 risks' prioritizations didn't change but there are some prioritization variations for other risks but in general results show two methods have similar risk prioritizations. In Fuzzy FMEA, priorities of R17 (*6 → 4*), R22 (*7 → 5*) and R21 (*8 → 6*) has increased two steps according to FMEA. For R9, R19 and R14 we can say that they have the biggest changes in comparison of two methods. While R9 has increased its priority from 11 to 7, R19 and R14 have decreased their priorities four steps (*R19: 4 → 8, R14: 5 → 9*). In addition to that R5 has decreased its priority three steps. There is just one-step change for priorities of R13, R16, R3, R7 and R1. In general we can say there is o an important variation.

As an example, R3 and R7 have same RPN values (126,72) while they have different risk factor values (*R3:2,00*8,80*7,20=126,72, R7:6,60*4,80*4,00=126,72*). According to FMEA, they need to be evaluated at same risk level and Fuzzy FMEA has set new risk levels for each risk but they still follow each other.

As a consequence Fuzzy FMEA can keep a risk's priority stable or can decrease/increase it.

In this study we have to be careful while prioritizing the risks. For example, difference between FMEA RPN values of R19 (337,92) and R1 (120,96) is 216,96 even though they have same Fuzzy RPN values (6,00). For this study we can say it is pretty much difference. If we prioritized the risk by looking only Fuzzy RPN values, it would be a random prioritizing and consequently their priorities would take any number between 2 and 8. In response to this while prioritizing the risks we consider FMEA priorities of the risks. We firstly sort the risks according to Fuzzy RPN values and then we sort them again according to their FMEA priorities.

We have the new severity (S') values from previous section to search how integrating FCM affects the Fuzzy FMEA results. This is just to apply Fuzzy FMEA method with new severity values. Membership functions, rule base for fuzzy output and methods in Fuzzy are same (Table 4.4 Membership Functions of Output Variables.

According to results, R8, R2, R23, R21, R16, R1, R11, R18, R12, R15 and R20 have still same Fuzzy RPN values and prioritizations. Integration of FCM to Fuzzy FMEA increased the importance levels of the risks: R22, R7, R5, R6 and R4 but however it decreased the importance levels of the risks: R17, R9, R19, R14, R13, R3, R10.

To put in a nutshell, the risk R7 has the largest dramatically variation. Its priority became from 13 to 7. That means it became much more important risk than before. Also its Fuzzy RPN values increased to 7,000 from 6,000. However the risk R3 has same Fuzzy RPN values in two methods but its priority has fallen back to 16 from 12. These two risks have same RPN values and same Fuzzy RPN values. But when considered the relationships among the risks they are taking different positions and behaviors.

However we can conclude that there is no dramatically change as well as FMEA integrated with FCM.

There are some priority changes though their RPN values (Fuzzy RPN and Re-Fuzzy RPN) are equal in themselves. For example R9 has same RPN values (7,000) but while its priority number is 7 in Fuzzy FMEA, its priority number is 8 in Fuzzy FMEA integrated with FCM. While making prioritization in Fuzzy FMEA we considered FMEA prioritization as mentioned above. This is also valid for Fuzzy FMEA with FCM. While making its prioritization we also considered prioritization of FMEA with FCM. That's why this risk's priority is different.

## 5 Conclusion

To sum up all processes, in the literature there are many methods to make risk assessment. In this study we investigated two of them: FMEA and Fuzzy FMEA. FMEA is a technique to make prioritization by descending RPN values which are taken by multiplying O, S and D values of risks.

To overcome the shortcomings of the traditional RPN, fuzzy logic is widely used in the literature. Fuzzy FMEA logic uses experts' view who describe the risk factors $O$, $S$ and $D$ by using the fuzzy linguistic terms. In this study, we applied these two methods (FMEA and Fuzzy FMEA) to the real IT case and compared the results. Results showed us that there are some changes (not so dramatic) and the analysts can have a better and deeper method while making risk assessment.

In spite of this, these two methods have a weakness. They don't consider the relations among the risks. That's why we have decided to integrate Fuzzy Cognitive Maps to overcome this weakness of these methods. FCMs can make casual relationships between nodes have different intensities. The nodes show dynamic variables in a dynamic system. The edges show directions and intensity of casual relationship among the variables. In this way, we can observe when a risk happened, how affects the other risks.

After we applied these methods to the case by integrating FCM to each of them and compared the results. Results showed us that there are much more changes according to previous two methods but these changes are not so dramatic in general. That also means the new method can be used by practitioners to make risk assessment.

**Table 5.5 Results of Fuzzy FMEA**

| Risks | O | S | D | RPN | FMEA Prioritization | Fuzzy RPN | Fuzzy Prioritization |
|---|---|---|---|---|---|---|---|
| **R8** | 8,20 | 8,60 | 9,40 | 662,89 | 1 | 9,000 | 1 |
| **R2** | 6,80 | 9,20 | 8,20 | 512,99 | 2 | 8,000 | 2 |
| **R23** | 6,80 | 7,40 | 7,80 | 392,50 | 3 | 8,000 | 3 |
| **R17** | 5,80 | 7,00 | 6,80 | 276,08 | 6 | 7,000 | 4 |
| **R22** | 6,80 | 7,00 | 5,80 | 276,08 | 7 | 7,000 | 5 |
| **R21** | 4,80 | 8,40 | 6,60 | 266,11 | 8 | 7,000 | 6 |
| **R9** | 2,20 | 9,20 | 8,60 | 174,06 | 11 | 7,000 | 7 |
| **R19** | 6,00 | 8,80 | 6,40 | 337,92 | 4 | 6,000 | 8 |
| **R14** | 5,80 | 9,00 | 6,00 | 313,20 | 5 | 6,000 | 9 |
| **R13** | 5,40 | 8,80 | 4,40 | 209,09 | 9 | 6,000 | 10 |
| **R16** | 5,40 | 7,20 | 5,20 | 202,18 | 10 | 6,000 | 11 |
| **R3** | 2,00 | 8,80 | 7,20 | 126,72 | 13 | 6,000 | 12 |
| **R7** | 6,60 | 4,80 | 4,00 | 126,72 | 14 | 6,000 | 13 |
| **R1** | 2,40 | 7,20 | 7,00 | 120,96 | 15 | 6,000 | 14 |
| **R5** | 4,80 | 5,80 | 6,00 | 167,04 | 12 | 5,000 | 15 |
| **R6** | 4,60 | 6,20 | 4,20 | 119,78 | 16 | 5,000 | 16 |
| **R11** | 4,80 | 6,60 | 3,20 | 101,38 | 17 | 5,000 | 17 |
| **R18** | 5,40 | 7,00 | 2,40 | 90,72 | 18 | 5,000 | 18 |
| **R12** | 3,20 | 6,40 | 3,60 | 73,73 | 19 | 4,000 | 19 |
| **R15** | 4,80 | 6,00 | 2,20 | 63,36 | 20 | 4,000 | 20 |
| **R10** | 3,00 | 5,60 | 3,20 | 53,76 | 21 | 3,000 | 21 |
| **R4** | 2,00 | 6,40 | 2,20 | 28,16 | 22 | 3,000 | 22 |
| **R20** | 1,40 | 4,40 | 2,20 | 13,55 | 23 | 3,000 | 23 |

Table 5.6 Results of Fuzzy FMEA Integrated with FCM

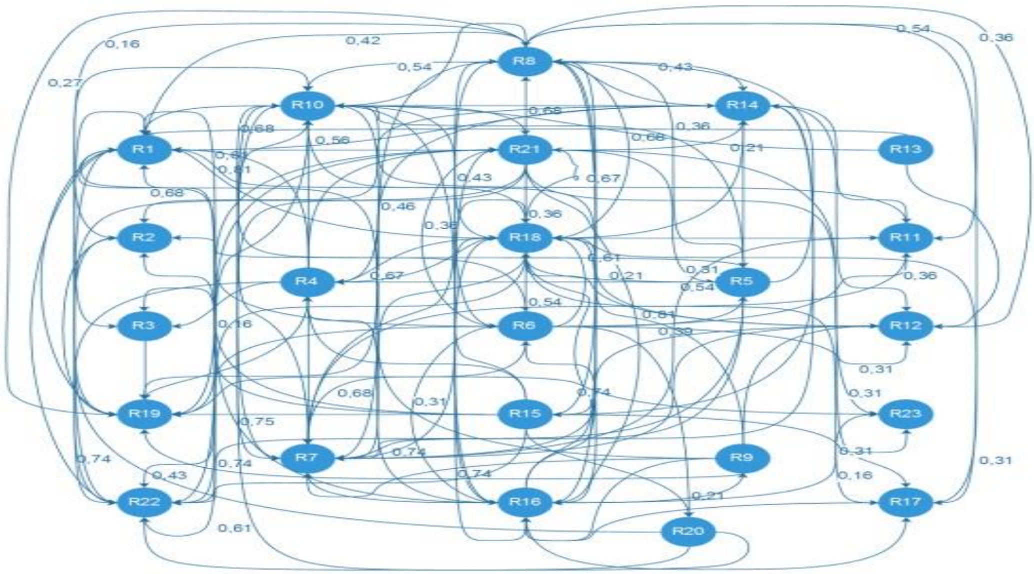
| Risks | O | S | Re-S | D | Fuzzy RPN | Old Prioritization | Re-Fuzzy RPN | New Prioritization |
|---|---|---|---|---|---|---|---|---|
| **R8** | 8,2 | 8,6 | 10,00 | 9,4 | 9,000 | 1 | 9,000 | 1 |
| **R2** | 6,8 | 9,2 | 10,00 | 8,2 | 8,000 | 2 | 8,000 | 2 |
| **R23** | 6,8 | 7,4 | 9,047 | 7,8 | 8,000 | 3 | 8,000 | 3 |
| **R22** | 6,8 | 7 | 10,00 | 5,8 | 7,000 | 5 | 7,000 | 4 |
| **R17** | 5,8 | 7 | 9,065 | 6,8 | 7,000 | 4 | 7,000 | 5 |
| **R21** | 4,8 | 8,4 | 10,00 | 6,6 | 7,000 | 6 | 7,000 | 6 |
| **R7** | 6,6 | 4,8 | 7,190 | 4 | 6,000 | 13 | 7,000 | 7 |
| **R9** | 2,2 | 9,2 | 9,557 | 8,6 | 7,000 | 7 | 7,000 | 8 |
| **R19** | 6 | 8,8 | 10,00 | 6,4 | 6,000 | 8 | 6,000 | 9 |
| **R14** | 5,8 | 9 | 10,00 | 6 | 6,000 | 9 | 6,000 | 10 |
| **R16** | 5,4 | 7,2 | 10,00 | 5,2 | 6,000 | 11 | 6,000 | 11 |
| **R5** | 4,8 | 5,8 | 7,611 | 6 | 5,000 | 15 | 6,000 | 12 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **R13** | 5,4 | 8,8 | 8,800 | 4,4 | 6,000 | 10 | 6,000 | 13 |
| **R1** | 2,4 | 7,2 | 10,00 | 7 | 6,000 | 14 | 6,000 | 14 |
| **R6** | 4,6 | 6,2 | 8,471 | 4,2 | 5,000 | 16 | 6,000 | 15 |
| **R3** | 2 | 8,8 | 10,00 | 7,2 | 6,000 | 12 | 6,000 | 16 |
| **R11** | 4,8 | 6,6 | 9,085 | 3,2 | 5,000 | 17 | 6,000 | 17 |
| **R18** | 5,4 | 7 | 10,00 | 2,4 | 5,000 | 18 | 6,000 | 18 |
| **R12** | 3,2 | 6,4 | 8,667 | 3,6 | 4,000 | 19 | 6,000 | 19 |
| **R15** | 4,8 | 6 | 7,062 | 2,2 | 4,000 | 20 | 5,000 | 20 |
| **R4** | 2 | 6,4 | 9,051 | 2,2 | 3,000 | 22 | 5,000 | 21 |
| **R10** | 3 | 5,6 | 8,324 | 3,2 | 3,000 | 21 | 4,000 | 22 |
| **R20** | 1,4 | 4,4 | 5,031 | 2,2 | 3,000 | 23 | 3,000 | 23 |

## Appendix A. Augmented Matrix

$$A = \begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}21 & 0 & 0 & 0 & 0 & {,}54 & 0 & 0 & {,}54 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}31 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}74 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}67 & 0 & 0 & 0 & 0 \\
{,}31 & 0 & {,}74 & 0 & 0 & 0 & {,}74 & 0 & 0 & {,}56 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}74 & {,}36 & 0 & {,}54 & {,}75 & 0 \\
0 & {,}81 & 0 & {,}61 & 0 & 0 & {,}46 & {,}54 & 0 & {,}61 & 0 & 0 & 0 & {,}16 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}21 & 0 \\
{,}68 & 0 & 0 & 0 & {,}39 & 0 & {,}68 & 0 & 0 & {,}68 & {,}36 & {,}31 & 0 & 0 & 0 & {,}31 & 0 & {,}61 & 0 & {,}21 & 0 & {,}43 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}27 & 0 & {,}21 & {,}49 & {,}31 & 0 & 0 & 0 & 0 & 0 & {,}39 & 0 & 0 & 0 & 0 & 0 \\
{,}42 & 0 & {,}16 & 0 & {,}36 & {,}43 & {,}46 & 0 & 0 & {,}54 & {,}54 & {,}36 & 0 & {,}43 & 0 & {,}21 & {,}31 & {,}68 & {,}27 & 0 & 0 & 0 & 0 \\
{,}16 & 0 & 0 & 0 & 0 & 0 & {,}16 & 0 & 0 & 0 & 0 & {,}61 & 0 & 0 & 0 & {,}60 & 0 & {,}21 & {,}36 & 0 & 0 & 0 & 0 \\
{,}46 & 0 & 0 & {,}43 & 0 & 0 & {,}67 & {,}61 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}27 & 0 & {,}67 & 0 & 0 & {,}21 & {,}67 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & {,}54 & 0 & 0 & {,}31 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}31 & 0 & 0 & 0 & 0 & 0 \\
{,}27 & 0 & 0 & 0 & 0 & 0 & {,}61 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}56 & 0 & 0 & 0 & 0 & 0 \\
{,}68 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}36 & 0 & {,}60 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & {,}67 & 0 & 0 & 0 & 0 & {,}54 & {,}54 & 0 & {,}68 & {,}81 & {,}27 & 0 & 0 & 0 & 0 & 0 & {,}54 & {,}74 & 0 & 0 & 0 & 0 \\
{,}54 & {,}67 & 0 & {,}56 & 0 & 0 & 0 & {,}54 & 0 & 0 & 0 & 0 & 0 & {,}68 & 0 & 0 & 0 & {,}54 & {,}81 & {,}61 & 0 & {,}67 & {,}74 \\
{,}60 & 0 & 0 & {,}42 & 0 & {,}67 & {,}61 & {,}27 & {,}16 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}67 & {,}61 & 0 & 0 & {,}16 & 0 & {,}21 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}54 & 0 & {,}16 & 0 & 0 & 0 & 0 & 0 \\
{,}81 & 0 & 0 & {,}67 & {,}54 & {,}54 & {,}74 & 0 & 0 & {,}56 & 0 & 0 & 0 & 0 & {,}74 & {,}74 & {,}16 & 0 & 0 & 0 & {,}67 & {,}61 & 0 \\
0 & {,}54 & {,}54 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
{,}36 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}21 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}74 & 0 \\
{,}61 & 0 & 0 & 0 & {,}31 & {,}36 & {,}75 & {,}68 & 0 & 0 & 0 & 0 & 0 & {,}21 & 0 & {,}81 & {,}31 & {,}36 & {,}16 & 0 & 0 & {,}74 & {,}31 \\
{,}54 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & {,}86 & 0 & 0 & 0 & 0
\end{pmatrix}$$

## Appendix B. FCM of IT Risks



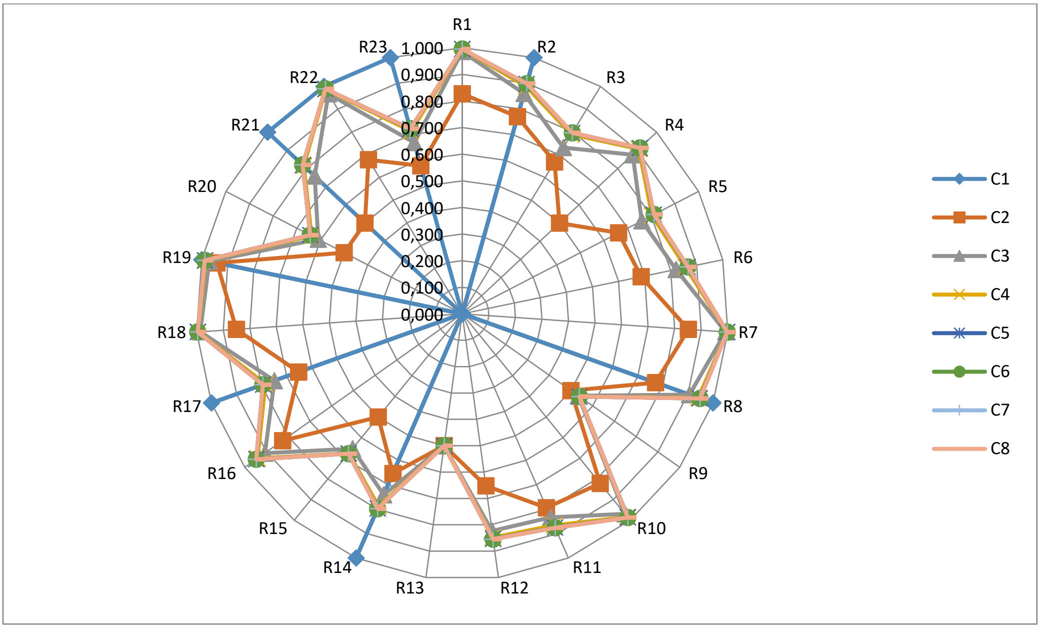

**Appendix C. Initial Vector**

$$C_1 = (0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0 \quad 1 \quad 0 \quad 1 \quad 1 \quad 1)$$

**Appendix D. Steps of Simulation**

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| **R1** | 0,000 | 0,827 | 0,986 | 0,995 | 0,995 | 0,995 | 0,995 | 0,995 |
| **R2** | 1,000 | 0,770 | 0,860 | 0,888 | 0,897 | 0,898 | 0,899 | 0,899 |
| **R3** | 0,000 | 0,668 | 0,732 | 0,789 | 0,795 | 0,796 | 0,796 | 0,796 |
| **R4** | 0,000 | 0,500 | 0,876 | 0,908 | 0,913 | 0,914 | 0,914 | 0,914 |
| **R5** | 0,000 | 0,662 | 0,760 | 0,803 | 0,811 | 0,812 | 0,812 | 0,812 |
| **R6** | 0,000 | 0,687 | 0,820 | 0,858 | 0,865 | 0,866 | 0,866 | 0,866 |
| **R7** | 0,000 | 0,852 | 0,992 | 0,997 | 0,998 | 0,998 | 0,998 | 0,998 |
| **R8** | 1,000 | 0,771 | 0,906 | 0,941 | 0,947 | 0,948 | 0,948 | 0,948 |
| **R9** | 0,000 | 0,500 | 0,534 | 0,537 | 0,539 | 0,539 | 0,539 | 0,539 |
| **R10** | 0,000 | 0,822 | 0,969 | 0,984 | 0,986 | 0,986 | 0,986 | 0,986 |
| **R11** | 0,000 | 0,794 | 0,834 | 0,867 | 0,875 | 0,876 | 0,876 | 0,876 |
| **R12** | 0,000 | 0,652 | 0,823 | 0,848 | 0,853 | 0,854 | 0,854 | 0,854 |
| **R13** | 0,000 | 0,500 | 0,500 | 0,500 | 0,500 | 0,500 | 0,500 | 0,500 |
| **R14** | 1,000 | 0,654 | 0,741 | 0,789 | 0,797 | 0,798 | 0,798 | 0,798 |
| **R15** | 0,000 | 0,500 | 0,653 | 0,675 | 0,677 | 0,677 | 0,677 | 0,677 |
| **R16** | 0,000 | 0,826 | 0,908 | 0,942 | 0,947 | 0,947 | 0,948 | 0,948 |
| **R17** | 1,000 | 0,652 | 0,749 | 0,785 | 0,794 | 0,795 | 0,795 | 0,795 |
| **R18** | 0,000 | 0,850 | 0,987 | 0,995 | 0,996 | 0,996 | 0,996 | 0,996 |
| **R19** | 1,000 | 0,942 | 0,971 | 0,985 | 0,988 | 0,988 | 0,988 | 0,988 |
| **R20** | 0,000 | 0,500 | 0,610 | 0,638 | 0,643 | 0,643 | 0,643 | 0,643 |
| **R21** | 1,000 | 0,500 | 0,759 | 0,815 | 0,820 | 0,820 | 0,820 | 0,820 |
| **R22** | 1,000 | 0,678 | 0,968 | 0,988 | 0,989 | 0,990 | 0,990 | 0,990 |
| **R23** | 1,000 | 0,578 | 0,668 | 0,713 | 0,722 | 0,722 | 0,723 | 0,723 |

**Appendix E. Graphical Notation of Simulation**




**Appendix F. S Values and New S Values**

$S = (7{,}2 \quad 9{,}2 \quad 8{,}8 \quad 6{,}4 \quad 5{,}8 \quad 6{,}2 \quad 4{,}8 \quad 8{,}6 \quad 9{,}2 \quad 5{,}6 \quad 6{,}6 \quad 6{,}4 \quad 8{,}8 \quad 9{,}0 \quad 6{,}0 \quad 7{,}2 \quad 7{,}0 \quad 7{,}0 \quad 8{,}8 \quad 4{,}4 \quad 8{,}4 \quad 7{,}0 \quad 7{,}4)$

$S' = (10 \quad 10 \quad 10 \quad 9{,}05 \quad 7{,}61 \quad 8{,}47 \quad 7{,}19 \quad 10 \quad 9{,}56 \quad 8{,}32 \quad 9{,}09 \quad 8{,}67 \quad 8{,}80 \quad 10 \quad 7{,}06 \quad 10 \quad 9{,}07 \quad 10 \quad 10 \quad 5{,}03 \quad 10 \quad 10 \quad 9{,}05$

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# An Analysis of Occupational Incidents, Prioritization of Factors Causing These by Using Multi Criteria Decision Making Methods and Identification of Ways for Reducing These: Case Study in Oil and Gas Fields

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**Abstract**

The aim of the Occupational Health and Safety studies conducted in the oil and gas sector is; to protect workers and to ensure occupational safety in works performed on drilling fields. The aforementioned studies of the companies operating in this field in Turkey are inadequate and are not given due importance to. In such companies, occupational incidents become inevitable for that reason. A vast number of studies have been conducted in many other countries around the world to reduce the number of occupational incidents, and those have led to a substantial reduction in those incidents. In Turkey, it is necessary to take measures to reduce the number of occupational incidents in the oil and gas sector. In this study, occupational incidents occurred in the company investigated as a case study and the other occupational incidents occurred in similar companies and the measures taken to reduce them have been discussed in detail. This study aims to explain what occupational incidents occur in the sector, what the root causes of them are and how to reduce the occupational incidents by taking measures.

**Keywords**: Multi Criteria Decision Making, Occupational Health and Safety, Occupational Incident, Petroleum and Natural Gas Drilling.

## INTRODUCTION

It is difficult, costly and dangerous work to extract various mines by drilling. However, there is a great energy deficit increased with technology and progress in the world. For this reason, countries are resorting to a variety of ways to extract oil and similar products to meet this energy deficit. In many countries having underground resources, there are fields for land and deepwater drilling in order to extract resources such as oil or natural gas for obtaining energy.

Those drilling works, as significant element of the energy sector, bear the risk of occupational incidents. Because natural or legal entities with exploration licenses, who would like to conduct drilling work which is highly expensive, prefer to hire small companies that are not the experts in that field, in order to get their drilling works done in a more economical way.

In drilling works, as one of the most hazardous sectors of activity alongside with mining, lots of occupational incidents and occupational injuries and deaths occur where the occupational health and safety regulations are not applied.

In the literature, there are various reports and studies conducted by various institutions that address the various aspects of occupational incidents in oil and gas sector concentrated in extractive works. For example, in the study of Hill (2012), it has been identified that the rate of occupational incidents occurred in USA's oil and gas extraction sector between 2003 and 2009 was seven times higher than the occupational incidents occurred in all other sectors. According to the statistics of U.S. Department of Labor's Bureau of Labor Statistics (US BLS), 823 people working in extractive activity in the oil and gas sector lost their lives between 2003 and 2010. This figure is seven times higher than the rate of occupational incidents in all other industries of USA. Mulloy (2014) stated that the oil and gas extraction sector is growing rapidly and occupational diseases, injuries and deaths will bring along with them. In the last five years since 2007, this sector has grown by 40%, and it has been surprisingly found that the most common occupational incidents occurred are occupational motor vehicle accidents and the most dangerous hazards in terms of occupational diseases are caused by the exposure to silica dust. According to a report of the Centers for Disease Control and Prevention (CDC), work-related mortality rates in the oil and gas extraction sector have increased by 27.6% between 2003 and 2013. The report International Labor Organization (ILO) published in 2016 indicates that the hard labor of oil and gas extraction sector shows itself in the form of occupational incidents. According to the reports of Occupational Safety and Health Administration (OSHA), the leading cause of fatalities from occupational incidents is occupational vehicle accidents. The long journeys to the area of work, transport of staff from and to there, transport of heavy loads, the weather conditions, prolonged accumulation of acute fatigue caused by working for a long time can result in occupational motor vehicle incidents. Another cause of accidents is identified as crashing-shearing-trapping. According to OSHA, 3 of every 5 casualties caused as a result of crashing-shearing-trapping.

American federal statistics of US BLS show that fire accidents are more common in this sector than in other sectors. There are standards published by NFPA and API to prevent fire and explosion. In Turkey, the available standards are Regulations of the Ministry of Labour and Social Security of June 2013 on Emergency Situations in the Workplace, which is published on Official Gazette No. 28681 dated on 18 June 2013; and Regulation on Fire Protection of Buildings Issued by the Council of Ministers No. 12937 on 27 November 2007.

According to Canadian Center for Occupational Health and Safety (CCOHS), another kind of occupational incident is fall accidents. According to statistics of US BLS related to fall accidents, in 2014 247,120 non-fatal cases involving slips and falls and around 800 fatalities were reported. According to the data of CCOHS, more than 42,000 people are injured at work due to fall accidents.

According to a report published in Industrial Safety and Hygiene News, working in enclosed working areas also pose a danger to the workers in oil and gas sector. Drilling workers often work in enclosed sheds. For example; enclosed working areas in drilling fields such as petroleum and other storage tanks, mud-pit pits, sand storage tanks, etc.

In this study, what kind of occupational incidents occur in oil and gas sector in Turkey and what the root causes of them are will be identified by using TOPSIS method. On the other hand, a statistical comparison between the occupational incidents occurred in the firms at other countries within the same sector and occupational incidents in Turkey will be presented. This study aims to contribute the occupational health and safety studies of Turkey in oil and gas sector; to provide a guideline document that explains what occupational incidents occur in the sector, what the root causes of these incidents are and how to reduce these incidents by taking measures for the companies operating in petroleum, natural gas, geothermal drilling sector in Turkey in order for them can benefit from.

## STATISTICS OF OCCUPATIONAL INCIDENTS

The statistical comparison between Turkey and other countries regarding the occupational incidents occurred in Oil, Geothermal, Gas Drilling Sector, has been made by using the incident analysis provided in International Association of Drilling Contractors (IADC) Incident Statistics Program.

IADC is an organization, which is working actively worldwide since 1940. Among the IADC studies, the Incident Statistics Program (ISS) was created to monitor the occupational safety and occupational incident data for the drilling industry. The aim of using the IADC data in this study is to benefit from this organization, which provides a comprehensive study by using the data of many different firms operating worldwide.

There are many methods for calculating incidence rate described in the literature in order to make comparisons between occupational incidents statistics. These methods for calculating incidence rate have been developed to be able to make comparison independently of the size and structure of a firm. For example, there is a difference between the probability of 1 worker per 100 full-time workers involved in a recordable occupational incident in 1 year within an establishment with 100 employees and the probability of 1 worker per 50 full-time workers involved in a recordable occupational incident in 1 year within an establishment with 50 employees. In order to be able to compare the probability of occupational incidents between the two firms, various "incident rate" calculations have to be used. For the comparisons between the data of IADC member countries and the data of Turkey, the incident rate calculation formulas, examples of which are provided in Table 1, are used.

More detailed information can be found on the website regarding the incident rate calculation data published by OSHA, which is provided below in the References.

The formulas given in Table 1 are used to find the number of incidents per 1,000,000 or 200,000 labor hours. Incidence Rate represents the formula using the 1,000,000 ratio, and frequency rate represents the formula using the 200,000 ratio. Depending on the type of the occupational accident, various incidence rate or frequency rate calculations can be made. For example, incidence rate and frequency rate calculations can be made for lost time incidence rate. Making such calculations allow making comparison with the situation at other countries, as described above.

Figure 1 shows the comparison of lost time incident rate between Turkey and Europe and lost time incident rate of the firm from Turkey, which is chosen as an example case for this study. These calculations are made by using the formulas regarding lost time incident rate provided in Table 1.

Table 1

*Incident Rate Calculations Formula*

| Incident Rate Criteria | Formula |
|---|---|
| Accident Frequency Rate[1] | Total Accidents X 1,000,000[2]/ MAN-HOURS |
| Accident Severity Rate[1] | Total Lost Work Days X 1,000/ MAN-HOURS |
| Accident Incidence Rate[1] | Total Accidents X 100,000/ MAN |
| Medical Treatment Incidence Rate[3] | Medical Treatment Incidences X 200,000 / MAN-HOURS |
| Medical Treatment Frequency Rate | Medical Treatment Incidences X 1,000,000 / MAN-HOURS |
| Lost Time Incidence Rate | Lost Time Cases X 200,000 / MAN-HOURS |
| Lost Time Frequency Rate | Lost Time Cases X 1,000,000 / MAN-HOURS |
| Recordable Incidence Rate | Total Incidents X 200,000 / MAN-HOURS |
| Recordable Frequency Rate | Total Incidents X 200,000 / MAN-HOURS |

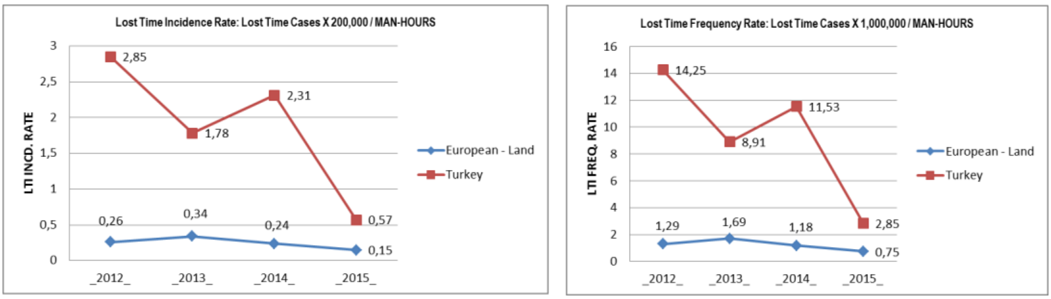


*Figure 1.* Comparison between lost time incident rates of Europe and Turkey, 2015. The European average data was adopted from the *2015 report* by IADC, retrieved from http://www.iadc.org/wp-content/uploads/2017/08/2016-Annual-Report-for-Industry-Totals.pdf

As can be observed here, there is a significant difference between lost time incident rate occurred in oil and gas sector in Europe and Turkey average. Lost time incident rate occurred in Europe between 2012 and 2015 is 248, whereas lost time incident rate occurred in Turkey between 2012 and 2015 is 74. The data received in Turkey's case indicates the need for more effective implementation of occupational health and safety management systems. Lost time incident rates occurred in other years also provide similar results. The analysis of lost time incident rates occurred is provided in Appendix-1. The analysis provided in Appendix-1 are dividing lost time incident rates occurred between 2012 and 2015 according to the criteria of Equipment, Time of Day, Operation Type, Occupation, Body Part, Age, Time in Service For Company, Month, Injury Cause Type and Location and provide the comparisons between Turkey and Europe in that regard. Criteria were selected by taking root cause analysis following an incident into account. At the same time, the data in the figures were selected according to the reasons with the highest frequency. The results of TOPSIS analysis, which will be explained in the next section, will show which of these criteria are effective in the occurrence of lost time incidents and which of these criteria influence lost time incidents more.

## MULTI CRITERIA DECISION MAKING METHODS

Decision making problems are a process of finding the best option from all available alternatives. The comparison of the alternatives by considering many criteria in the problems has become quite widespread. After the objectives, criteria and alternatives are identified, various methods can be used. Some of the problem solving methods can be listed as SAW (Simple Additive Weighting), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), ELECTRE (Elimination and Choice Translating Reality), Bayesian Network Based Framework, AHP (The Analytic Hierarchy Process), SMART (The Simple Multi Attribute Rating Technique), ANP (Analytic Network Process).

One of the multi criteria decision making methods, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was presented with reference to the study of Hwang and Yoon (1981). The basic idea of this method is to select the alternative closest to the positive ideal solution while maximizing benefit criteria of the solution whereas minimizing its cost criteria. In the same way, the aim is to obtain the solutions, which are selecting the criteria having farthest distance from the negative ideal solution while maximizing the cost criteria whereas minimize the benefit criteria.

The application of the TOPSIS method consists of 6 steps. These steps can be listed respectively as constructing decision matrix, constructing standard decision matrix, calculating weighted decision matrix, determining ideal and negative ideal solutions, calculating the separation measures and calculating the relative closeness to the positive ideal solution.

## TOPSIS METHOD

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS); which was developed by Hwang and Yoon in 1981 as a method to sort alternatives by calculating their proximity to the ideal and negative ideal solutions. The application steps of the TOPSIS method tailored for this study are presented below (Iç et al., 2015):

Step 1:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1m} \\ a_{21} & a_{22} & \dots & a_{2m} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nm} \end{bmatrix} \qquad (1)$$

Step 2: *Obtaining the normalized decision matrix (R):* The normalized decision matrix (eq'n (3)) is determined by using eq'n (2):

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{n} a_{ij}^2}} \qquad (2)$$

and,

$$R = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \dots & \dots & \dots & \dots \\ r_{n1} & r_{n2} & \dots & r_{nm} \end{bmatrix} \qquad (3)$$

Step 3: *Obtaining the weighted normalized decision matrix (V):* In this step, firstly, the weights (importance values) of the ten criteria ($w_j$; $j=1,\dots,m$) are assigned. The weighted decision matrix $V$ is formed by multiplying elements in each column in the normalized decision matrix ($r_{ij}$, $i=1,\dots,n$) and its corresponding criterion weight ($w_j$, $j=1,\dots,m$):

$$V = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \dots & w_m r_{1m} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_m r_{2m} \\ \dots & \dots & \dots & \dots \\ w_1 r_{n1} & w_2 r_{n2} & \dots & w_m r_{nm} \end{bmatrix} \qquad (4)$$

Step 4: *Identification of ideal and negative ideal solutions:* In order to obtain an ideal *($A^*$)* solution, Eq. (5) is used to determine the highest value for each column of the matrix *V* (the lowest value if the relevant criterion has the minimization direction) and to obtain the negative ideal (*$A^-$)* solution, Eq. (6) is used to determine the lowest values for each column of the matrix *V* (the highest value if the corresponding criterion has the minimization direction).

$$A^* = \left\{ (\max_i v_{ij} \,\middle|\, j \in J), (\min_i v_{ij} \,\middle|\, j \in J') \right\} \rightarrow A^* = \{v_1^*, v_2^*, \dots, v_m^*\} \quad (5)$$

$$A^- = \left\{ (\min_i v_{ij} \,\middle|\, j \in J), (\max_i v_{ij} \,\middle|\, j \in J') \right\} \rightarrow \quad A^- = \{v_1^-, v_2^-, \dots, v_m^-\} \quad (6)$$

Step 5: Calculation of distance to the ideal solution ($S_i^*$), distance to the negative ideal solution ($S_i^-$) and performance score ($C_i^*$) for each year

Distances to the ideal solution and negative ideal solution and performance scores are obtained according to Eq. (7), Eq. (8), and Eq. (9) respectively. $C_i^*$ gets a value between 0 and 1 ($0 \le C_i^* \le 1$).

$$S_i^* = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^*)^2} \quad (7)$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2} \quad (8)$$

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad (9)$$

Here $C_i^*$ gets a value between $0 \le C_i^* \le 1$.

Values in table indicate that nearest distance to '1' shows that the influence of the causes of accidents on the related solution is high (absolute), that nearest distance to '0' shows that the influence is low (ineffective when it has the value of 0).

The factors that caused the accidents in this study are selected as follows:

- Number of accidents that occurred during night shift
- The place of the accident (location / Derrick / Mast)
- The profile of the employee experiencing the occupational accidents mostly (the number of rig workers)
- Accident type (caught between, struck by)
- Rig type drilling where the occupational accidents seen mostly
- Age average of employees experienced the occupational accident
- Number of inexperienced employees (less than 1 year) experienced the occupational accidents
- Number according to the most injured body part (finger)
- Number of the occupational accident related to equipment (car / truck, bus, casing, pipe, tubular, drill collar)
- Number of the occupational accident related to operation (material handling - forklift, installation, maintenance, drilling routine)

There is a need for the use of multi criteria decision making (MCDM) methods in the joint evaluation of ten selected measurement criteria.

In this study, factors that lead to lost time incidents occurred in a real firm operating in Turkey are analyzed by using TOPSIS method

Table 2.

*Decision Matrix Constructed Regarding Lost Time Incidents Occurred Between 2012 and 2015*

| Criteria | Equ | Opr | Tim | Loc | Ocp | Ict | Mon | Age | Tis | Bod |
|---|---|---|---|---|---|---|---|---|---|---|
| Equ | 21 | 23 | 37 | 27,5 | 33,5 | 31 | 25 | 28 | 26,5 | 22,5 |
| Opr | 23 | 25 | 39 | 29,5 | 35,5 | 33 | 27 | 30 | 28,5 | 24,5 |
| Tim | 37 | 39 | 53 | 43,5 | 49,5 | 47 | 41 | 44 | 42,5 | 38,5 |
| Loc | 27,5 | 29,5 | 43,5 | 34 | 40 | 37,5 | 31,5 | 34,5 | 33 | 29 |
| Ocp | 33,5 | 35,5 | 49,5 | 40 | 46 | 43,5 | 37,5 | 40,5 | 39 | 35 |
| Ict | 31 | 33 | 47 | 37,5 | 43,5 | 41 | 35 | 38 | 36,5 | 32,5 |
| Mon | 25 | 27 | 41 | 31,5 | 37,5 | 35 | 29 | 32 | 30,5 | 26,5 |
| Age | 28 | 30 | 44 | 34,5 | 40,5 | 38 | 32 | 35 | 33,5 | 29,5 |
| Tis | 26,5 | 28,5 | 42,5 | 33 | 39 | 36,5 | 30,5 | 33,5 | 32 | 28 |
| Bod | 22,5 | 24,5 | 38,5 | 29 | 35 | 32,5 | 26,5 | 29,5 | 28 | 24 |

*Note.* Criteria = Incidents Root Cause. LTI = Lost time incidence Equ= LTI's by Equipment (car/truck, bus, Casing ve Drill Collar). Opr = LTI's by Operation (Rig/Equip. Repairs/Maint., Routine Drilling Operations.) Tim = LTI's by Time Of Day (Morning/Day Shift) Loc. = LTI's by Location (Rig Floor/Derrick/Mast) Ocp. = LTI's by Occupation (Floorman, Roustabout). Ict =. LTI's by Injury Cause Type (caught between, struck by) Mon = LTIs by Months (January, February, June) Age= LTI's by Average of Age. Tis= LTIs by Time in Service For Company (>1 yr. < 5 yrs.) Bod= LTI's by Body Part (fingers).

Table 3.

*Weighted Normalized Decision Matrix*

| Criteria | Equ | Opr | Tim | Loc | Ocp | Ict | Mon | Age | Tis | Bod |
|---|---|---|---|---|---|---|---|---|---|---|
| Equ | 0,02378 | 0,02433 | 0,02673 | 0,02532 | 0,02629 | 0,02593 | 0,02481 | 0,02542 | 0,02513 | 0,02420 |
| Opr | 0,02605 | 0,02645 | 0,02818 | 0,02716 | 0,02786 | 0,02760 | 0,02679 | 0,02723 | 0,02702 | 0,02635 |
| Tim | 0,04190 | 0,04126 | 0,03829 | 0,04006 | 0,03885 | 0,03931 | 0,04068 | 0,03994 | 0,04030 | 0,04141 |
| Loc | 0,03115 | 0,03121 | 0,03143 | 0,03131 | 0,03139 | 0,03136 | 0,03126 | 0,03132 | 0,03129 | 0,03119 |
| Ocp | 0,03794 | 0,03755 | 0,03576 | 0,03683 | 0,03610 | 0,03638 | 0,03721 | 0,03676 | 0,03698 | 0,03765 |
| Ict | 0,03511 | 0,03491 | 0,03396 | 0,03453 | 0,03414 | 0,03429 | 0,03473 | 0,03449 | 0,03461 | 0,03496 |
| Mon | 0,02831 | 0,02856 | 0,02962 | 0,02901 | 0,02943 | 0,02927 | 0,02878 | 0,02905 | 0,02892 | 0,02850 |
| Age | 0,03171 | 0,03174 | 0,03179 | 0,03177 | 0,03179 | 0,03178 | 0,03175 | 0,03177 | 0,03176 | 0,03173 |
| Tis | 0,03001 | 0,03015 | 0,03071 | 0,03039 | 0,03061 | 0,03053 | 0,03026 | 0,03041 | 0,03034 | 0,03012 |
| Bod | 0,02548 | 0,02592 | 0,02782 | 0,02670 | 0,02747 | 0,02718 | 0,02630 | 0,02678 | 0,02655 | 0,02581 |

*Note.* Criteria = Incidents Root Cause. LTI = Lost time incidence Equ= LTI's by Equipment (car/truck, bus, Casing ve Drill Collar). Opr = LTI's by Operation (Rig/Equip. Repairs/Maint., Routine Drilling Operations.) Tim = LTI's by Time Of Day (Morning/Day Shift) Loc. = LTI's by Location (Rig Floor/Derrick/Mast) Ocp. = LTI's by Occupation (Floorman, Roustabout). Ict =. LTI's by Injury Cause Type (caught between, struck by) Mon = LTIs by Months (January, February, June) Age= LTI's by Average of Age. Tis= LTIs by Time in Service For Company (>1 yr. < 5 yrs.) Bod= LTI's by Body Part (fingers).The decision matrix, which is the first step of the TOPSIS method, is constructed by using Table 2 and the normalized decision matrix is obtained by normalizing the numerical values by using Eq. (2) in the first step of the method. For the criteria provided in Table 1, average number of the accidents occurred has been considered. On the other hand, in order to identify the weights of the each mentioned criterion, three experts of the firm were asked to evaluate each criterion with a score from 1 to 10 (1 refers to the least important; 10 refers to the most important) and then the criteria weights were identified by considering the averages of the expert evaluations by rounding them up to nearest whole numbers. Then, the table of normalized criteria weights was obtained (Table 3). Then, weighted normalized matrix was obtained as a result of multiplying normalized decision matrix by the normalized criteria weights identified for each criterion. At the last step, by using Eq.(5-8) in the in the implementation steps of TOPSIS method the distances to the ideal and negative ideal solutions; by using Eq.(9), the influence of the causes of occupational accidents on lost time incidents, TOPSIS ranking scores were obtained.

## CONCLUSION

As a result of the analysis, the causes of the accident are mathematically expressed by ranking the causes of the accidents according to the accident results.

In Figure 2, ranking scores can be seen clearly. Values in table indicate that nearest distance to '1' shows that the influence of the causes of accidents on the related solution is high (absolute), that nearest distance to '0' shows that the influence is low (ineffective when it has the value of 0).

As observed from these calculation results, as the factors determined as the cause of the accidents, Equipment (Pipes/Collars/Tubulars/Csg., Material, Engine/Pump, Machinery), Operation *(Rig/Equip. Repairs / Maint., Routine Drilling Operations.)*, Body Part (fingers) shines out as the highest scores in the results of total lost time incidents.

There three causes are followed by Month, Time in Service for the Company, Location, Age, Incident cause type, Occupation, Time in Service respectively. In the analysis provided in the appendix, most seen ones are Pipe, tubular, casing tubing in equipment-related accidents. At the same time, the finger injuries are within the first three ranks in TOPSIS analysis in analysis provided in appendix. These results show that engineering measures are required to reduce occupational accidents in oil drilling. It is thought that it would be beneficial to make the drilling works by using the machines, that is to say, by transition to new technology; rather than by using hands. In the risk analysis to be applied to the oil and gas drilling fields, addressing the high risk areas mentioned here will reduce the occupational accidents.

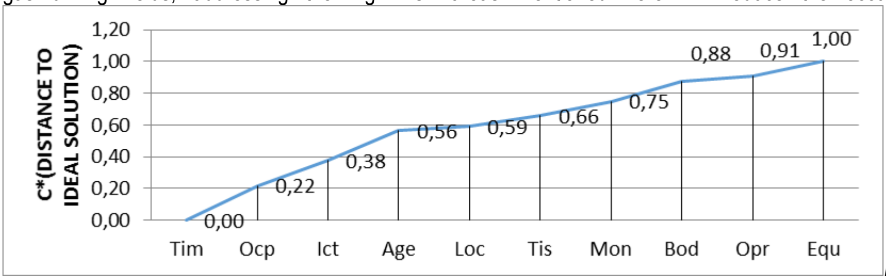


*Figure 2.* TOPSIS Ranking Scores of Criteria of Occupational Accidents ($C^*$)

*Note.* Criteria = Incidents Root Cause. LTI = Lost time incidence Equ= LTI's by Equipment (Pipes/Collars/Tubulars/Csg., Material, Engine/Pump, Machinery). Opr = LTI's by Operation (Rig/Equip. Repairs/Maint., Routine Drilling Operations.) Tim = LTI's by Time Of Day (Morning/Day Shift) Loc. = LTI's by Location (Rig Floor/Derrick/Mast) Ocp. = LTI's by Occupation (Floorman, Roustabout). Ict =. LTI's by Injury Cause Type (caught between, struck by) Mon = LTIs by Months (January, February, June) Age= LTI's by Average of Age. Tis= LTIs by Time in Service For Company (>1 yr. < 5 yrs.) Bod= LTI's by Body Part (fingers).

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## FOOTNOTES

[1] It has been decided in 16th International Conference of Labour Statisticians in Geneva in 1998.

[2] It is used to find the lost time due to occupational accidents in 1,000,000 labor hours.

[3] It is provided as described by The Bureau of Labor Statistics (BLS).

## APPENDIX

### Appendix-1

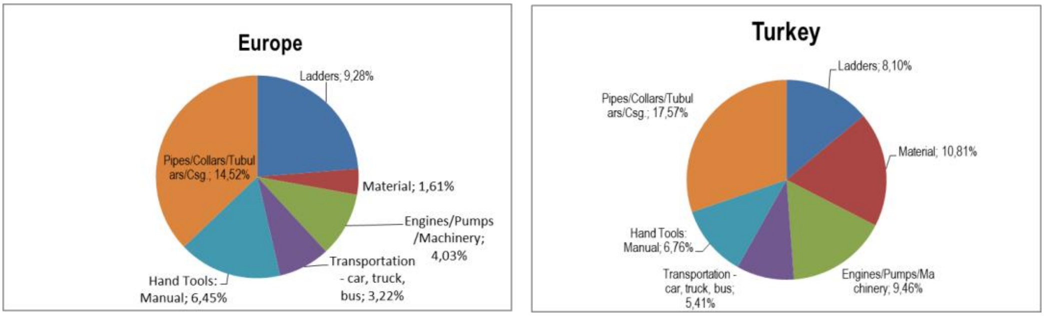


*Figure 3.* LTI's by Equipment in Turkey and Europe

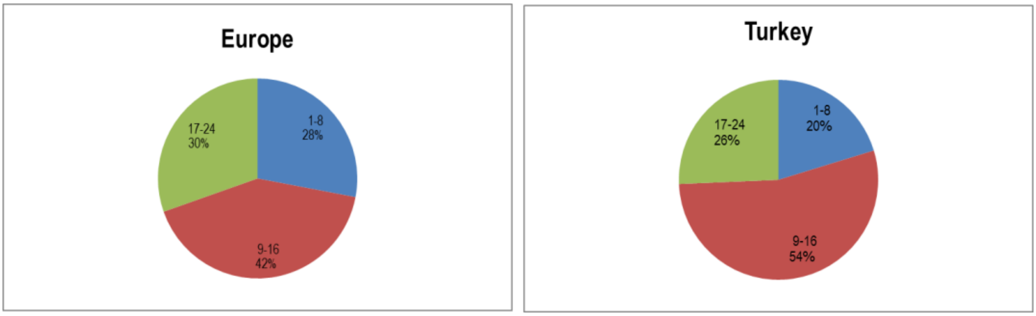


*Figure 4.* Comparison of Lost Time Incidents by Time of Day in Turkey and Europe

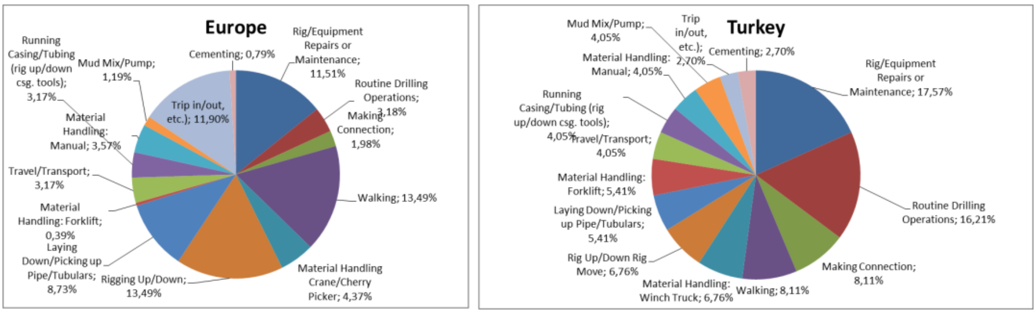


*Figure 5.* Comparison of Lost Time Incidents by Operation Type in Turkey and Europe

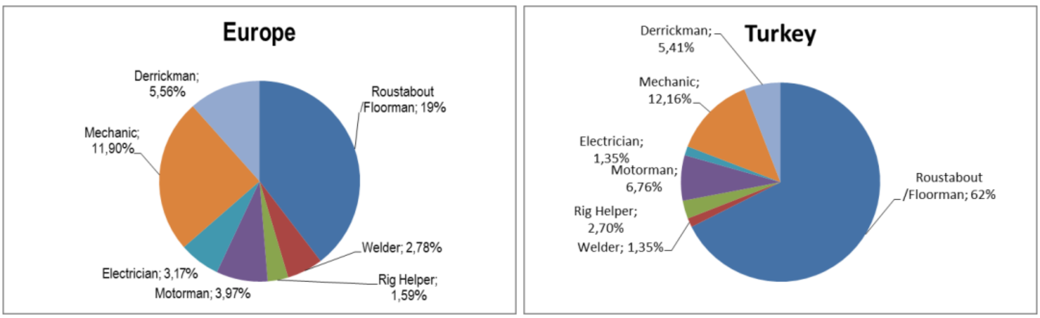

*Figure 6.* Comparison of Lost Time Incidents by Occupation in Turkey and Europe

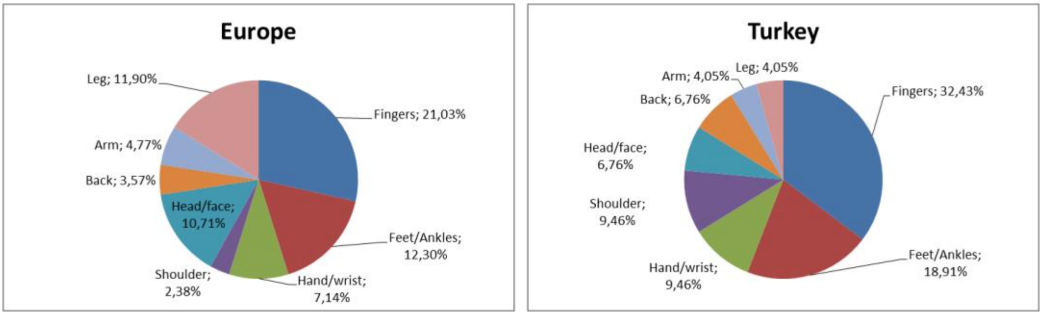


*Figure 7.* Comparison of Lost Time Incidents by Body Part in Turkey and Europe

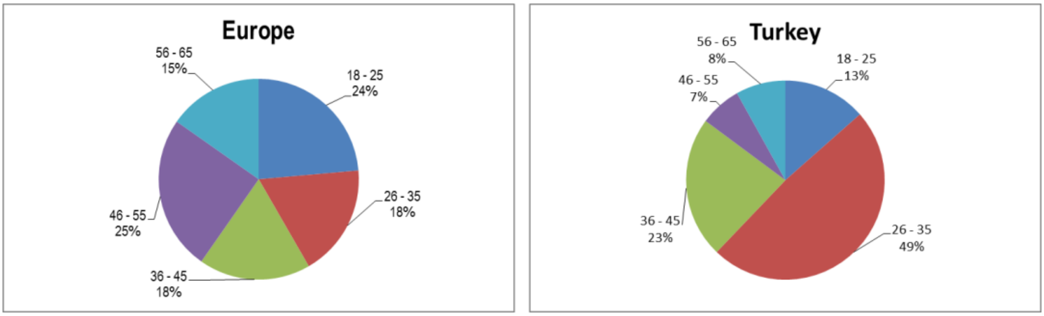


*Figure 8.* Comparison of Lost Time Incidents by Age in Turkey and Europe

Note. Data of Europe has only been analyzed based on 2014-2015 data. No data on age of staff before 2014 is available.

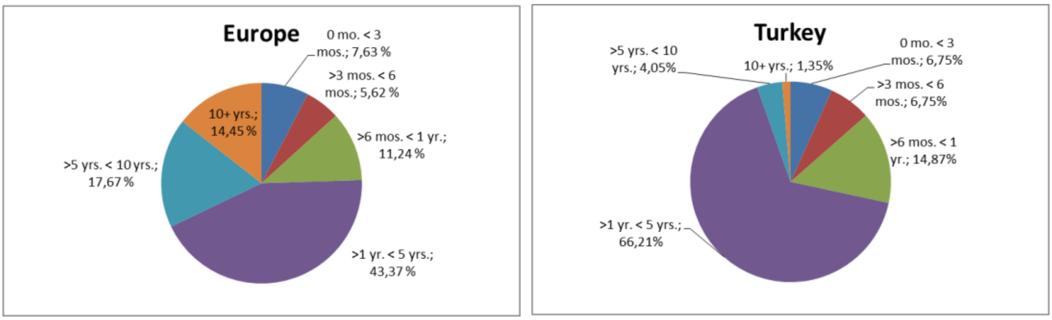

*Figure 9.* Comparison of Lost Time Incidents by Time in Service For Company in Turkey and Europe

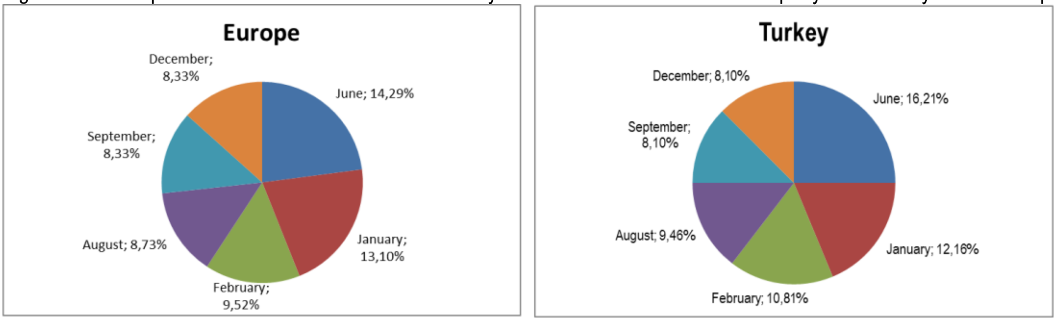


*Figure 10.* Comparison of Lost Time Incidents by Month in Turkey and Europe

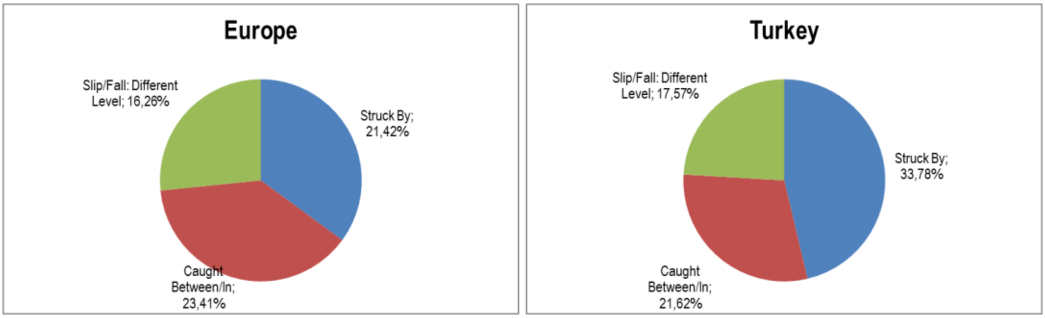


*Figure 11.* Comparison of Lost Time Incidents by Injury Cause Type in Turkey and Europe

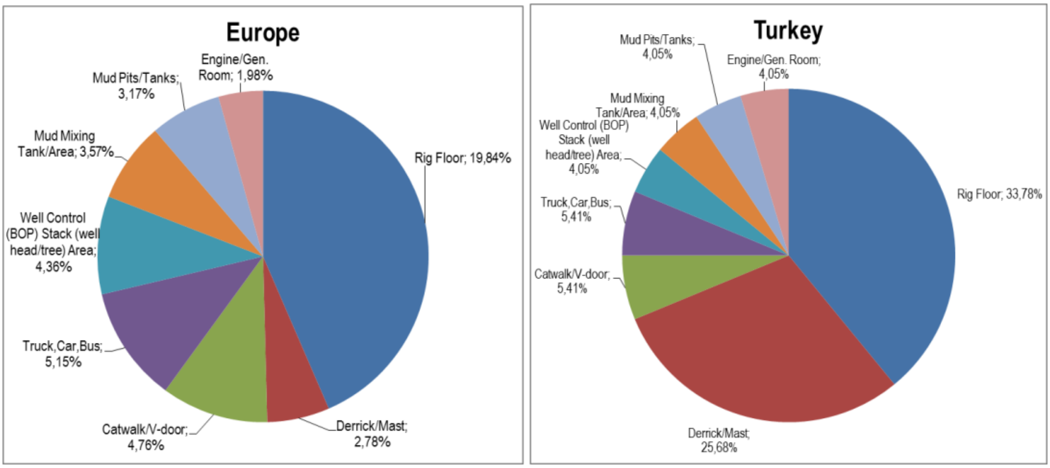


*Figure 12.* Comparison of Lost Time Incidents by Location in Turkey and Europe

# A Single Band Antenna Design for Future Millimeter Wave Wireless Communication at 38 GHz

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**Abstract**

In this proposed paper, a single band microstrip patch antenna for fifth generation (5G) wireless application was presented. 28, 38, 60 and 73 GHz frequency bands have been allocated for 5G mobile communications by International Telecommunications Union (ITU). In this paper, we proposed an antenna, which is suitable for the millimeter wave frequency. The single band antenna consists of new slot loaded on the radiating patch with the 50 ohms microstrip line feeding used. This single band antenna was simulated on a FR4 dielectric substrate have relative permittivity 4.4, loss tangent 0.02, and height 1.6 mm. The antenna was simulated by Electromagnetic simulation, computer software technology High Frequency Structural Simulator. And simulated result on return loss, VSWR, radiation pattern and 3D gain was presented. The parameters of the results well coherent and proved the literature for millimeter wave 5G wireless application at 38 GHz.

**Keywords:** Single-band antenna, rectangle and cylindrical slots, millimeter wave, 5G

## I. Introduction

Communication system standards have been a challenge for modern wireless communications. As a trend, until now, fourth generation (4G) communication is already standardized. And next, the standard for 5G is just confirmed as the technology is to be matured. And it is estimated to be launched in 2020. As seen on Figure 1, some of the candidate bands are suggested for 5G communications in the frequency of 20 GHz to 50 GHz, which are called as millimeter wave band [1-3].

Millimeter wave band technology puts in the way easier and speeder data transfer and high capacity, high data rate and lower latency, which will be demanded by end user heartily in near future. Moreover, the technology brings flexible design to ensure the adaptability of 5G communication with advanced features for mobile [3]. Nevertheless, rapid development in wireless communications demand antenna design that can operate at millimeter frequency band in a compact size. To design a millimeter band antenna, increasing the bandwidth must be apart of to cover multiband applications [4-6]. Current research show that, bigger antenna than conventionals is needed to cover 28 GHz millimeter wave frequency as unique frequency [7]. As for dual band antenna was designed, that can operate at two frequencies, which are 24.25 GHz and 38 GHz [8]. In this paper, a single band antenna was proposed for future wireless communication that can operate at 38 GHz.

Microstrip antennas, which was proposed, are suitable for global positioning system (GPS) and biomedical radiator. However, these antennas have a beneficial physical dimension including light weight, low cost and more. So, they are suitable for mobile radio and wireless communications as well, due to their planar configuration, easy integration ability into arrays [9-10]. Because low-profile antenna is required for these applications, microstrip antennas, which can be integrated within a given shape easily, are particularly suitable. Although several substrates can be applied to design a microstrip antenna, while applying 1 to 100 GHz frequencies, the dielectric constant should be selected within the range of $2.2 \leq \varepsilon_r \leq 12$.

So, in this paper, a new design of patch antenna was proposed to fulfill several requirements of the modern mobile wireless technology, especially the actual one, 5G. The paper is organized as follows; Section II describes the design of the proposed antenna. Section III presents the results and discussion in details. Lastly, section IV concludes the design with some prospective future agendas.

## II. Antenna Design

The antenna was designed on a FR4 substrate with a thickness of 1.6 mm to operate at 38 GHz millimeter wave band frequency. As Nachabe et al. states that the antenna, printed on FR4 substrate, was found to perform well on millimeter wave technology [9]. Our proposed antenna was designed with 4.4 of dielectric permittivity. The front and side view of the antenna is illustrated in Figure 2. The proposed antenna specification is seen on Table I.

## III. Results and Discussions

The performance of this single band slotted microstrip patch antenna was determined by HFSS software. The analysis was made on S-parameter, VSWR, E and H field radiation pattern and 3D radiation pattern with a frequency range of 20 to 50 GHz. This antenna shows resonance at single different band. The analysis is illustrated below with Figure 3 – Figure 6.

As seen on the Figure 3 of reflection coefficient that the propagating wave crossed the -10dB line twice within the range of 20 to 50 GHz. The resonance was approximately found at 38 GHz and the return loss is -24.35 dB. The corresponding 10 dB return loss bandwidth of the center frequency is 1.021 GHz. Proposed antenna has one resonant frequency at 5G band appeared in the range of 37.10 to 38.12 GHz. This resonant frequency along with its corresponding band and return loss is seen on Table II.

VSWR is used to measure the imperfections of the transmission line like VSWR represents the efficiency of transferring RF power into the load via a transmission line from the power source. On Figure 4, the VSWR parameter of the patch antenna were illustrated. The propagating wave intersected the 1 dB line at desired frequency. So, the VSWR value was found approximately 1 dB pointing out the good matching condition.

Directivity measures, how 'directional' an antenna's radiation pattern is. The directivity of the antenna at resonant frequency in E and H plane is seen on Figure 5 from the relevant pattern from $\varphi = 0$ and $\varphi = 90$ degrees. The directivity is shown on Table III at resonant frequency.

Microstrip patch antennas are used in a wide range of applications because of their advantageous features. But there are two major disadvantages are low gain and narrow bandwidth of antenna. Antenna gain describes, how much power is transmitted in the direction of an isotropic source. The gain of the antenna within the range of 20 to 50 GHz is seen on Figure 6, that is low at 38 GHz.

## IV. Conclusion

In this paper, a single band antenna was proposed, simulated and analyzed compatible with 5G application frequency. The simulation results proved, that it can operate at 38 GHz millimeter wave band compatible with the required 5G candidates band (20 GHz to 50 GHz). The simulation result was compared by several sizes of the antenna in order to achieve the best results especially in terms of frequency drop, gain and efficiency of the antenna. The antenna has a good result of return loss $|S_{11}|$ of-24.35 dB at desired frequency and achieved a ultra wide bandwidth of 1.021 GHz.

## Acknowledgments

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**Table I.** Dimension of proposed antenna.

| Parameter | mm | Parameter | mm |
|---|---|---|---|
| $L_1$ | 3.1 | $W_3$ | 1.9 |
| $L_2$ | 4.4 | $W_4$ | 1 |
| $L_3$ | 0.5 | $W_5$ | 1 |
| $L_4$ | 1.4 | $W_6$ | 0.2 |
| $L_5$ | 1.6 | r | 0.3 |
| $W_1$ | 1 | t | 1.6 |
| $W_2$ | 1 | | |

**Table II.** Return loss and bandwidth of the proposed antenna.

| Resonant Frequency (GHz) | Band covered | Return loss (dB) | Bandwidth (GHz) |
|---|---|---|---|
| 38 | Ka | -24.35 | 1.021 |

**Table III.** Directivity in E and H plane at operating frequency.

| Resonant Frequency (GHz) | Directivity in E plane (dB) | Directivity in H plane (dB) |
|---|---|---|
| 38 | 2.37 | 2.37 |

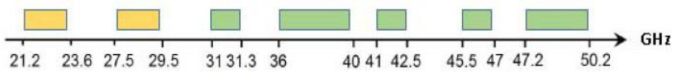



Figure 3. Candidate bands for 5G.

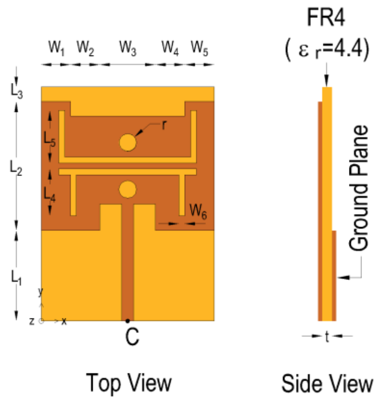



Figure 4. Structure of proposed single band antenna.

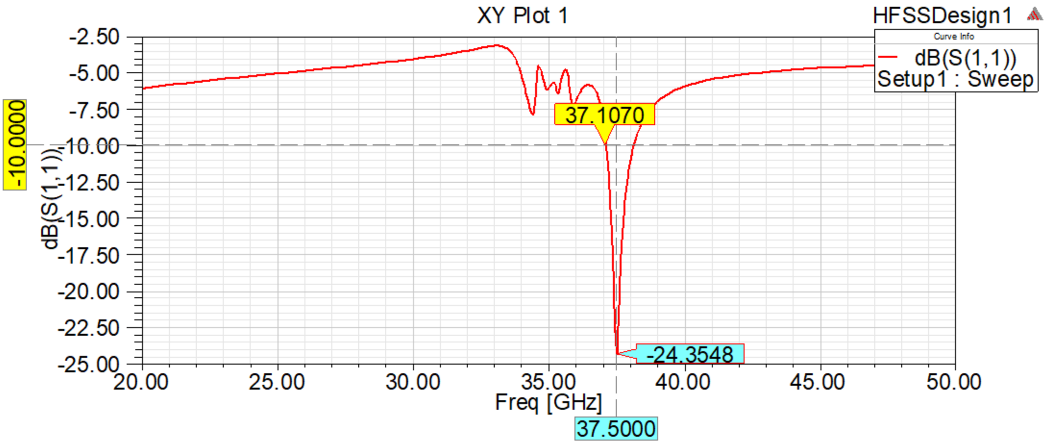



Figure 5. Reflection coefficient ($S_{11}$) of the antenna.

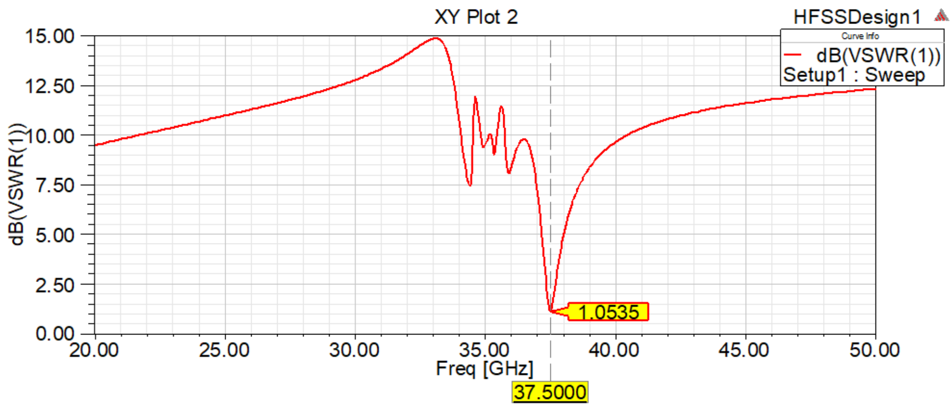
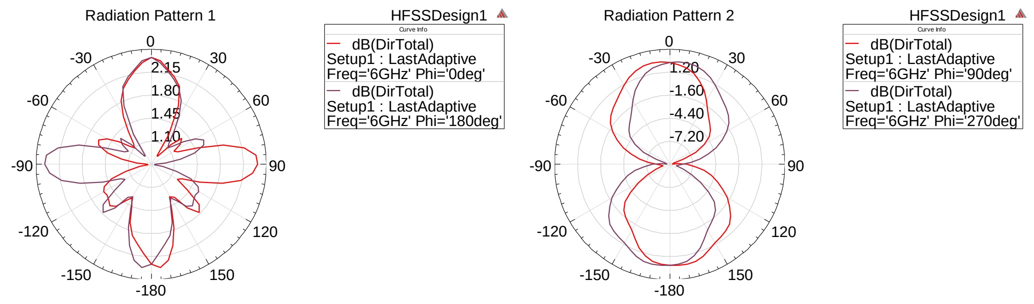



Figure 6. Voltage standing wave ratio of proposed antenna.




(a) (b)

Figure 5. Directivity at 38 GHz (a) in E-plane (b) in H-plane.


Figure 6. Gain of the patch antenna.

# Public Expenditures Through Public Procurement

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**Abstract**

Treaty of Rome of 1957 and following treaties on amending the Treaty of Rome contain a number of basic principles on which the EU is founded. Among these principles, the most important ones related to the public procurement are: prevention of discrimination based on nationality, free movement of goods; right and freedom of establishment of a business; the right to provide services. Spending of public money in Kosovo pursuant to the Law on Procurement is found on the following principles: economization and efficiency; equal treatment and non-discrimination; transparency; value for money. The average of open procedure application in EU countries is 73% based on notices, whereas in Kosovo is 82.80% based on notices. In the end of 2014, Kosovo commenced the development of electronic procurement platform. This project takes place within the Public Sector Modernization Project. The importance of the electronic procurement is stated in the statement of European Commission: “Modernization and opening of procurement markets across borders – including through the electronic procurement expansion – are crucial for the competition in Europe and creating new opportunities for businesses in EU”. A good procurement system in Kosovo will have an impact on elimination of negative phenomena (corruption and bad management) in the management of public expenditures from spending agencies, as well as an impact on increase of budget saving.

**Key words:** public expenditures, value for money, bad management, procurement, electronic procurement.

## Introduction

Public procurement in Kosovo started to appear shortly after the 1999 war. Considering the importance of a new area created in Kosovo, the United Nations Interim Administration Mission in Kosovo (UNMIK) prepared and formalized the first document on public procurement on 15 December 1999, known as the Financial Administrative Instruction no. 2/1999 on Public Procurement, through which, the rules on expenditures and funds of the Kosovo Consolidated Budget were established. Instruction no. 2/1999 is the second official document in Kosovo immediately after the Administrative Instruction no. 1/1999, which regulates the spending procedures of budget funds of the Kosovo Consolidated Budget.

These two documents, issued shortly after the war in Kosovo, have been the main basis for the implementation and management of all procurement activities for goods, labour and services, both in terms of procurement and financial aspects. FAI no. 2/1999 has been based on the procurement rules of the World Bank and the United Nations Commission on International Trade Law ”UNCITRAL”, the rules that have been used by most Central and Southeastern European countries during the transitional period.

Law on Public Procurement in Kosovo No. 2003/17 was promulgated by the SRSG on 9 February 2004, and entered into force on 9 June 2004. This law provides a far more comprehensive framework for public procurement in Kosovo compared to FAI no. 2/1999. The law, to a large extent, enables the increase of transparency in carrying out public procurement activities in Kosovo. The establishment of two central public procurement bodies foreseen by law for implementation of this law - the PPRC and the PPA - has been done with a considerable delay. There was a delay of three years, from the moment of finalization of the LPP by the working group appointed by the Government of Kosovo, in March 2003, until the full constitution of the institutions foreseen for the implementation of the law, in March 2006.

On 8 February 2007, the Assembly of Kosovo adopted the Law on Public Procurement in Kosovo, known as the Law No. 02/L-99. This amendment was signed and promulgated on 6 June 2007. The Law on Public Procurement No. 02/L-99 was followed by the establishment of three central procurement bodies in Kosovo: Public Procurement Regulatory Commission

(PPRC); Public Procurement Agency (PPA); Procurement Review Body (PRB). There have been changes to the public procurement law and the public procurement rules that were intended to comply with the requirements of the EC Procurement Directives. Finally, the Law on Public Procurement No. 04/L-042 is in force, approved on 29 August 2011, which has finally been amended and supplemented with Law No. 05/L-092.

Kosovo started to develop the public procurement platform by the end of 2014. This project is funded by the World Bank, within the Public Sector Modernization Project. The Public Procurement Regulatory Commission (PPRC) is implementing the electronic procurement platform in Kosovo, where from the start of implementation as a pilot project in some contracting authorities, since January 2018, started the implementation of all procurement activities with a value over € 1000 through through the electronic procurement platform by all Contracting Authorities that are obliged by law. The importance of e-procurement is highlighted in the modernization and opening of markets beyond borders, including through the expansion of e-procurement, which is crucial to competitiveness and creation of new business opportunities. Appropriate use of information technology contributes to cost reduction, improved efficiency, and removal of barriers to trade, which will ultimately lead to taxpayer money savings.

The main objectives to ensure a comprehensive increase are also focused on the social aspect: promoting employment and supporting the labour force movement; promoting social inclusion and combating poverty; investment in education, skills and lifelong learning; and enhancing institutional capacity and an efficient public administration. Public procurement is one of the market-based instruments that can be used to achieve the intended objectives in the future. Contracting authorities should use public procurement to advance these types of broader policy objectives.

**Research Methodology**

The study was carried out based on research in the field of public procurement that deals and analyzes with particular emphasis issues of this field, the applicable regulative for regulation of this field. During this research, I have used notes and publications from the official websites of CPA, PPRC, Ministry of Finance, Kosovo Agency of Statistics and other relevant institutions.

Unlike the cost-benefit analysis, the Comparative Cost-Effectiveness Analysis method is intended to determine alternative programs that, at a lower cost, ensure the achievement of the previously defined goal or the set of goals that are mutually complementary. The problem of selecting alternative programs can be divided into three ways: a) choosing the program that enables the achievement of the goal or some goals set at the lowest possible cost, b) choosing the program that, within limited financial means, to the greatest extent, enables the achievement of the goal or some goals set, and c) choosing the program that provides the most favorable ratio between the achievement of the goal or some goals and means committed.

**Public procurement activities in Kosovo during 2007 - 2016**

The following report presents the procurement activities for all contracts signed by contracting authorities, making an analysis of contracts signed between 2007 and 2016.

The signed contracts are presented with the division of contracting authorities into budget organizations - Government, Public Companies, and Other-NGOs. Based on this division, we will reflect the number of contracts signed as follows:

Table no. 1, Value of contracts signed during 2007 - 2016

| The value of contracts signed during years, expressed in millions € | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Contracting Authorities: | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| Governmental | 187.46 | 456.69 | 529.85 | 286.73 | 284.71 | 318.59 | 348.63 | 259.68 | 250.25 | 359.74 |
| Public company | 213.82 | 369.62 | 245.38 | 194.57 | 267.26 | 188.56 | 93.62 | 129.57 | 149.81 | 62.06 |
| Other/NGO | 0.94 | 0.16 | 2.92 | 0.75 | 0.17 | 0.70 | 1.92 | 0.47 | 1.77 | 2.76 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Total[1]: | 402.22 | 826.48 | 778.15 | 482.06 | 552.15 | 507.86 | 444.18 | 389.73 | 401.84 | 424.57 |

Source: Report on Public Procurement Activities for 2007 - 2016, PPRC.

The values of signed contracts are reflected from the data above, where it can be seen that Government Contracting Authorities have a higher value compared to public companies and other authorities. In the participation of the value of the contracts signed during 2016, Budgetary organizations - the Governmental ones participate with 84.73%, public companies with 14.62%, whereas other authorities participate with only 0.65% in the total value of signed contracts. If a comparison is made over the years, it can be seen that government-financed Institutions financed by the State Budget participate in the largest amount of signed public contracts in comparison with public companies and other authorities.

Table no. 2, Value of contracts signed by funding sources during 2007 - 2016

| The value of contracts signed in years by funding sources, expressed in millions € | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Funding sources | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| Own Source Revenues | 145.81 | 145.26 | 178.93 | 149.54 | 222.24 | 188.56 | 93.99 | 129.80 | 147.48 | 60.06 |
| Kosovo Budget | 250.15 | 676.56 | 586.53 | 326.25 | 323.84 | 314.12 | 343.48 | 258.87 | 251.04 | 352.09 |
| Donations | 6.25 | 4.65 | 12.67 | 6.27 | 6.06 | 5.17 | 6.7 | 1.05 | 3.31 | 12.41 |
| Total: | 402.22 | 826.48 | 778.15 | 482.06 | 552.15 | 507.86 | 444.18 | 389.73 | 401.84 | 424.57 |

Source: Report on Public Procurement Activities for 2007 - 2016, PPRC.

Based on the data above, it can be seen that the State Budget participates in the main part of funding sources in the financing of signed contracts, then own source revenues, and a part from donations. In 2016, there is a tendency of increase in the value of contracts signed by the sources of financing, the main part of the funding is part of the State Budget with 82.93%, own source revenues participate with 14.15%, whereas donations participate with 2.92%. The supply contracts participate with 44.97%. Service contracts with 16.88%, contracts for design competitions with 0.12%, while contracts for work participate with 41.03%.

The trend of value increase in 2016 is because the value of Prishtina - Hani i Elezit Motorway foreseen for 2016 is added to it, in the amount of 155,97 mil € where the value of work contracts during 2016 amounts to 330.19 mil €

The analysis of the structure or participation of the procedures implemented during 2016 indicates that the participation of the open procedure in the total value of the signed contracts is 84.55%, which is one of the most used procedures and known as the most transparent. Also, participation of the negotiated procedure after publication of the contract notice is 0.04%, and participation of the negotiated procedure without publishing the contract notice during 2016 is 11.76%. The participation of procedures according to the price quotation is 2.39% and it participates with 0.66% according to the minimal value, limited with 0.52%, whereas design competitions participate only with 0.08% in the value of total contracts signed in 2016.

Based on the analysis of the value of contracts signed in 2016, divided by contract award to a local and non-local economic operator, the total value of the signed contracts is 66.55% with the local operators registered in Kosovo. While from non-local operators, it is 33.45% in the total structure of signed contracts, where the value of 155.97 million € relates to the contract of Prishtina-Hani i Elezit Motorway.

[1] Contract: Motorway Prishtina - Hani i Elezit, Street 6. For 2010, in the amount of 106.88 million €, for 2011, in the amount of 236.16 million €, for 2012, in the amount of 235.37 million €, for 2013, in the amount of 210.54 million €, for 2014, in the amount of 55.46 mil €, for 2015, in the amount of € 114.57 mil, and for 2016, in the amount of € 155.98 mil.

Chart 1, The average number of bidders competing for a tender during 2008 - 2016.

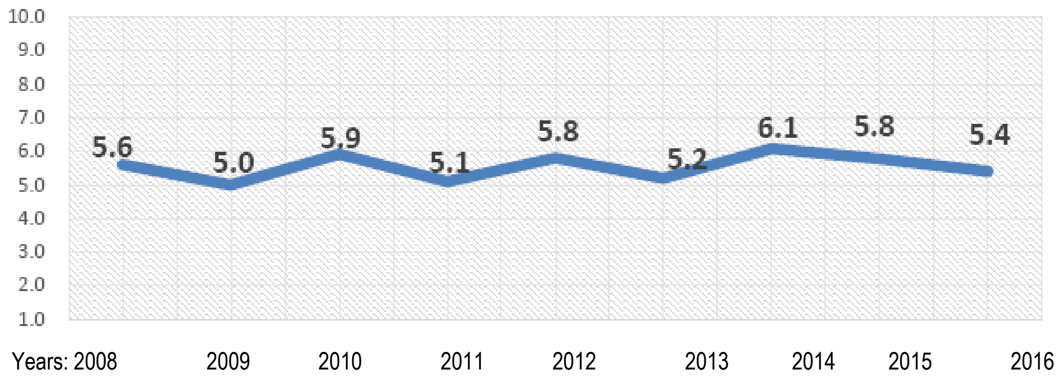



Chart No. 1 displays the average number of bidders who have competed for a procurement activity in Kosovo from 2008 to 2016. The average during these years shows that 5.5 economic operators have bid for a tender, which we think the principle of encouragement of competition is of an average level.

Chart 2 displays the value of contracts signed between 2010 and 2016

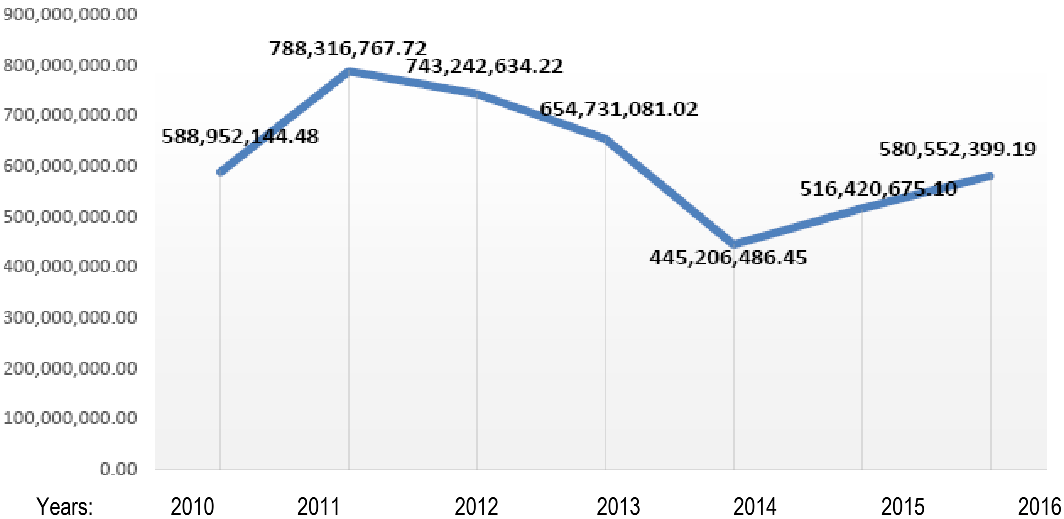
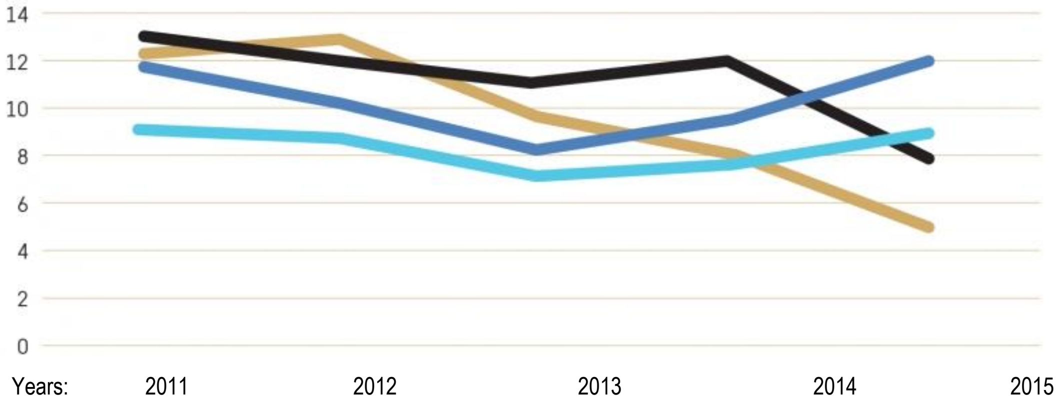



Chart No. 2 displays the value diagram of the contracts signed between 2010 and 2016, including two contracts with the highest value of motorway construction: 1. Morine - Merdar, and 2. Prishtina - Hani i Elezit. Also, in 2011, 2012, the value of contracts is higher because public companies have signed long-term contracts, and there has been higher spending on the Morine-Merdar Motorway project.

**Value of public procurement contracts in the Region**

Chart 3, Annual public procurement value in the region as a % of GDP




Source: Balkan tender watch 2016.

Serbia, Montenegro, Macedonia, Bosnia and Herzegovina

Public procurement is the process that public institutions pursue to carry out purchases of goods, services and works, mainly from the private sector. Public procurement is a significant part of the economy. At certain times, public procurement in Kosovo has reached the value of 1/5 of GDP (Gross Domestic Product). Moreover, public procurement is a key process for ensuring responsible governance that supports a sustainable economic development.

However, the decrease in the proportion of public procurement contracts as a percentage of GDP is not necessarily an indicator of good state budget management. What makes public procurement successful is the strengthening of transparent practices. The biggest challenges for supporting transparency in public procurement arise from the fact that domestic (Kosovo and regional) institutions are mostly new in the fight against corruption. There is plenty of room for conflict of interest among politicians and businesses that contract with the government, and at the same time, there is a lack of technology integration in public procurement at central and local level.

The high value of public contracts executed through public procurement matters not only to get the best value for taxpayer money, but also to create an equitable environment where private companies can compete for these contracts. Consequently, the way this process is executed remains of particular importance.

The importance of public procurement can also be seen in terms of the amount of expenditure compared to the national budget and GDP or amount of government purchases. In Kosovo, public procurement of goods, services and works is about 9.4% of the GDP, for 2015, the second largest expense after wages and salaries.

According to the 2014 Annual Audit Report, public institutions, through the procurement process, have spent about 488 million Euros, or about 33% of the Kosovo Budget expenses, a little higher than the average of OECD member countries during 2013, which was 29% (see the chart below). According to the PPRC report, the value of contracts signed in 2015 was about 401 million Euros, excluding the value of the contract for the Prishtina - Han i Elezit motorway, the value of which reaches about 114 million Euros for 2015 (in total, about 516.4 million Euros). The public procurement market in 2014 accounts for 8.9% of the gross domestic product, which is a slight decrease compared to the previous three years, while lower than the OECD average in 2013, which was 12.1%.

These figures indicate that public procurement is vital to the country's economy and therefore, this very important public expenditure must be guided by a set of public principles, values, good practices, laws, regulations and procedures arising from a National Strategy of Public Procurement.

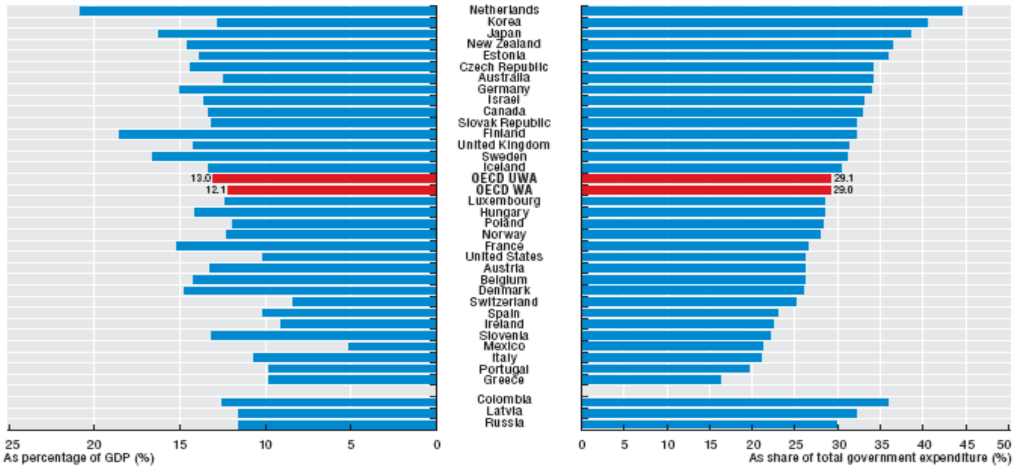
The modern public procurement system requires high standards of efficiency and transparency since public procurement is done for the public interest and it is a precondition for sustainable development, considering that it accounts for 33% of public expenses. The efficiency of the work of the bodies responsible for implementation of public procurement and the use of public funds is one of the principles of the Law on Public Procurement. On the other hand, transparency serves to inform the public, for access to legislation, policy and in carrying out procurement procedures by responsible institutions. One of the principles of Good governance requires the existence of central institutional and administrative capacity to develop implement and monitor procurement policy effectively and efficiently.

Therefore, the monitoring of the implementation of public procurement and institutional capacities is the main tool for assessing and increasing the efficiency of the functioning of the public procurement system. If carried out independently and professionally, monitoring can yield documented results on the weaknesses of the system and lead to useful suggestions and generalizations, taking into account the specifics of any known problem.

Monitoring requires sufficient capacities and appropriate organizational structure within the PPRC and a coordination between it and the CPA, PRB and other institutions responsible for implementing the procurement law.

Among the segments that directly affect the increase of efficiency in the work of public procurement bodies is coordination between central level institutions for public procurement work, centralized procurement, e-procurement, which also combine with the fulfilment of the principle of transparency in procurement.

Chart 4, The next diagram outlines overall government procurement as a percentage of total government spending (2013) for OECD countries (Government at a Glance 2015: Procurement Data, Paris, OECD, 2015, pg. 136.)




Source: OECD National Accounts Statistics (database). Data for Australia are based on a combination of Government Finance statistics and National Accounts data provided by the Australian Bureau of Statistics.

## Electronic Procurement in Kosovo

The use of information technology for the public sector, and in particular the procurement system, is a driving force for increasing efficiency and effectiveness in the implementation of the procurement law. Electronic procurement will have multi-dimensional effects such as increasing transparency, preventing misuse, increasing competition and increasing accountability and confidence in implementing procurement procedures. Electronic procurement, amongst other things in the future, will also help facilitate monitoring as data on the performance of contracting authorities can be extracted from the system. But the challenge will be how electronic procurement can generate data and how much capacities exist at the PPRC, CPA, and contracting authorities in the management and use of the electronic system.

Kosovo has started by the end of 2014 to develop the e-procurement platform. This project is funded by the World Bank, within the Public Sector Modernization Project. The project application started at the end of 2014, where on behalf of the Government of Kosovo, the main beneficiary of this project is the PPRC, which will be the implementing institution of this project.

This project will contain:

- Development or adaptation, as well as the implementation of the procurement system from start to finish, transferring the ownership (source code) to the Government of Kosovo;
- The software package of the project will function as a complete system to assist the Government of Kosovo in conducting electronic procurement;
- The establishment of the Data Center will be done at the Ministry of Public Administration, with the same replication, as the second data center within the Ministry of Finance;
- Provide trainings for procurement staff, and hardware and software data that will be maintained by support staff;
- The e-procurement system will be prepared in three official languages in Kosovo: Albanian, Serbian, and English;

E-Procurement will complete all stages of the procurement process electronically, including these core modules:

- General Registration of Interested Operators, CAs, PPRC, CPA, PRB and other parties using the platform;
- Electronic bidding (from the procurement process planning, to the signing of the contract);
- Framework Agreements;
- Electronic auctions;
- Contract management;
- Procedures for handling complaints;
- Communication via electronic platform;
- Online Assistance.

In view of this, in January 2016, the Government of the Republic of Kosovo has begun to apply the electronic procurement system initially as a pilot in seven contracting authorities, including ministries, public companies and municipalities. Piloting has initiated the application in practice of the platform for a six month period in order to test the functionality of the system and will also serve as a Kosovo market test in response to the application of the e-procurement system. In March 2016 the Government decided that electronic procurement for centralized procurements should become mandatory from 1 April 2016, for central level budget organizations from 1 September 2016, and from 1 January 2017 electronic procurement has become mandatory for all budget organizations. A prerequisite for e-procurement readiness is the capacity building of procurement staff in e-Procurement. Therefore, the training plans will include training on electronic procurement.

Appropriate use of information technology contributes to cost reduction, improved efficiency and removal of barriers to trade, which will ultimately lead to taxpayer money savings. While technological aspects of procurement processes based on information technology (IT) are discussed infinitely, much less attention is paid to the impact on the organizational aspects and the one that is most relevant to the current discussion, the level of public procurement concentration.

Even if electronic procurement would be limited to the bidding process stage by using e-bidding, the fact that electronic procedures may be less costly than the document-based procedure leaves room for debate. Consequently, e-procurement solutions should make centralized procurement less advantageous, as each contracting authority would spend less resources by initiating its own electronic tendering procedure. However, such an argument ignores the technological choice behind the foundation of a simple electronic auction. In other words, there is no unique technology standard for organizing electronic auctions. Hence the more independent the local purchasing units are brought, the greater the chance that technological choices are not fully compatible, thus increasing the firm's costs to get familiar with different standards.

Since it is based on a single standard, a centralized procurement strategy would reduce these costs, thus promoting the participation of smaller firms in the procurement market, while all other factors should be equitable .In addition, concentration tends to increase the benefits of e-procurement. Purchasing of resources via the internet increases efficiency gains if procurement becomes more centralized, as such achievements would affect larger volumes of transactions and impact on a larger number of organizational structures.

**Contract management**

Contract management may be defined as the steps that enable the contracting authority and the economic operator to fulfill their obligations within the contract in order to achieve the objectives set out in the contract.

When a contracting authority agrees to a contract with an economic operator, the agreement cannot be left to move alone - it must be managed. Contracts are often complex and may involve many people, may take or last too long, and may consume many resources. It is therefore essential that they are managed properly.

The key to the process of successful contract management is the awareness that procurement officers should plan, do, check and operate. The "Plan, Do, Check, and Act" cycle (PDCA) was created by 1950s American theorist Edward Deming, who spent considerable time advising Japanese industry on overall quality management.

Regarding the procurement process, the "plan" phase of the Deming cycle refers to the phases preceding the award of the contract and the phase "do" refers to the activity of the economic operator over the duration of the contract. Many procurement officers are very careful during the "planning" phase, but then they leave the economic operator to "do" and forget to "check" and "act". In the context of the procurement, "check" refers to the verifications and controls involved to monitor performance, and "act" refers to the actions required to ensure that any performance that has run out of forecasts is brought back within the required parameters.

Efficient contract management is essential to the success of the contract. This includes the procurement officer and other interested parties in the contracting authority who work actively with the persons from the economic operator to achieve a supply in accordance with the agreed specifications.

Contracts with PDCAs that are not implemented actively have far fewer chances to be successful.

Contract management activities can be broadly grouped into three areas covering the "do", "check" and "act" phases of the PDCA. They are:

- Service supply management,
- Relationship management,
- Contract management.

Service Supply Management ensures that the service is provided according to the required level of performance and quality, as provided in the contract. Service Supply Management considers performance and manages the risk through the 'do', 'check' and 'act' steps of the PDCA. Includes setting up controls and agreements on the service level.

The relationship management aims to maintain the relationship between the economic operator and the open and constructive contracting authority, aiming at solving or relieving tensions and identifying potential problems at an early stage, while identifying opportunities for improvement. Relationships should be thoroughly professional throughout the 'do' phase of the PDCA, and should also include a professional approach to problem-solving and settlement of disputes.

Contract management addresses formal contract management and changes in documentation during contract lifespan. These areas of contract management ensure that the day-to-day implementation aspects of the contract are carried out efficiently and effectively. They can form activities related to any aspect of the PDCA.

Accountability is the central pillar of any public procurement system. Without transparent and accountable systems that enable institutions and citizens to engage with mutual accountability, large resources channeled through public procurement systems allow the risk of increased corruption and misuse of funds. Even in low-level corruption systems, public and civic oversight can help identify inefficiencies, thus increasing the efficiency and effectiveness of procurement in order to improve service delivery, where citizens benefit.

**Conclusions**

The essential elements required to ensure accountability are: a proper organization of state administration, access to public information, a system of control and balance between the powers, and an efficient internal administrative appeals system, as well as independent oversight and judicial review of administrative cases. Accountability should be supplemented with responsibility for the decisions of state institutions or their absence.

Budget implementation (executions) in Kosovo needs to be improved. Effective spending control is required at each stage of the budget cycle (ex-ante control, intern, external, etc.); adequate budget monitoring at each stage of the spending cycle (commitment, verification and payment); strengthening the internal control system (internal audit) in spending agencies.

A good procurement system in Kosovo will have an impact on the elimination of negative phenomena (corruption and mismanagement) in the management of public spending by spending agencies and will affect the increase of budget savings.

Other issues to be addressed in the coming period are:

- Procurement planning, a clear specification of each activity is required as well as their specification with the procurement plan and with the budget of the respective fiscal year, and other years if the activities have budgetary implications for more than one year period. The clear and complete specification of each activity that is expected to be implemented in the budget period should be followed with the provision of adequate budget funds approved by the respective levels. Adequate and timely specification of requests from the demanding units, especially the demand specifications but also the budget needed for realization is more than necessary.
- Strengthening of internal processes in the Contracting Authority starting from the requesting and approving units to the Procurement Department for the purpose of harmonizing the activities, especially at the stage of preparation of procurement planning. The challenge is that the requesting units do not submit their requests on time or submit them without specifying at the appropriate level, as they provide contradictory data for the necessary budget. Such a practice should be changed as soon as possible.
- Contract management - contract management and data implementation process, payments and other aspects of implementation remain one of the main challenges of the Public Procurement System, and relevant audit institutions will need to be more focused on this area in order to improve the part of contract management and their implementation.
- Organize further training related to contract management for the Contract Manager and technical and other staff involved in the implementation of the contract;
- Raise public awareness of the work that institutions do for implementing public procurement legislation and create citizens' trust in bodies implementing public procurement procedures. There is a perception among citizens that the public procurement sector has been exposed to abuse, corruption and mismanagement, which in many cases is also caused by the lack of activity of procurement bodies to inform citizens about achievements in the procurement system and raise awareness of citizens, businesses but also the staff responsible for the implementation of procurement procedures.
- Supporting small and medium Enterprises in public procurement activities without having demands, discriminatory criteria, but by promoting competition with special emphasis on new businesses;
- In addition to training of procurement officers from the field of public procurement, trainings should be organized for other parties, such as for managerial staff, for technical experts who prepare technical specifications for auditors and other parties that may be affected and give their input;
- The concept of e-learning can be considered as allowing an opportunity to improve professional skills and credentials through accessible online training. In addition, electronic teaching can be easily renewed (if designed appropriately) as the system grows and develops;
- allowing the use of non-competitive negotiated procedures without the publication of a contract notice only in exceptional cases;

- Electronic Procurement is a procurement system that uses the opportunities created by the information and communication technology to increase the efficiency of the procurement process. The current size of paper on different levels of government should gradually be stored electronically on national and local databases for easy retrieval and usage when needed.

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# Evaluation of Sentinel 2 Multispectral Satellite Imagery for Serpentinites Outcrops Mapping in Italy

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### Abstract

This study will address the benefit of accurate serpentinites outcrops maps to the geologist's planning phase of selecting important mineral targets in the field and for the environmental monitoring, and to Public Authorities in terms of healthy hazard assessment. The wide distribution as well as the variety and extent of asbestos-bearing rocks make the selected areas in Italy a significant case study for the evaluation of the feasibility of free available new generation Sentinel 2 (S2) satellite imagery for serpentinites outcrops mapping and monitoring. The exact location of these outcrops could be very useful as there is a high probability of asbestos fibres dispersion from weathered serpentinites rocks either by natural events and processes (i.e., erosion/transport sedimentary cycle) or because of anthropic intervention. In situ and laboratory 0.4 to 2.5μm reflectance spectra acquired on serpentinites outcrops show correspondingly MgOH absorption caused by absorption in the magnesium silicate minerals that compose the serpentinites outcrops. Suitable Sentinel 2 bands in the 0.4-2.5 spectral region were used in a spectral classification procedure to produce accurate serpentinites outcrops occurring in the Italian Alps and Appennines (Fig. 1). In our study, we found a reasonable agreement between ground spectral measurements, laboratory analysis and satellite data, also verified by field visual checking on some accessible areas. The method presented here could result in reduction of time and effort in the field, because it leads to an efficient mapping of weathered serpentinites outcrops even by using Sentinel 2 multispectral satellite data, but by no means replaces the field geologist work.

**Keywords:** Multispectral satellite data, serpentinites outcrops mapping, asbestos minerals

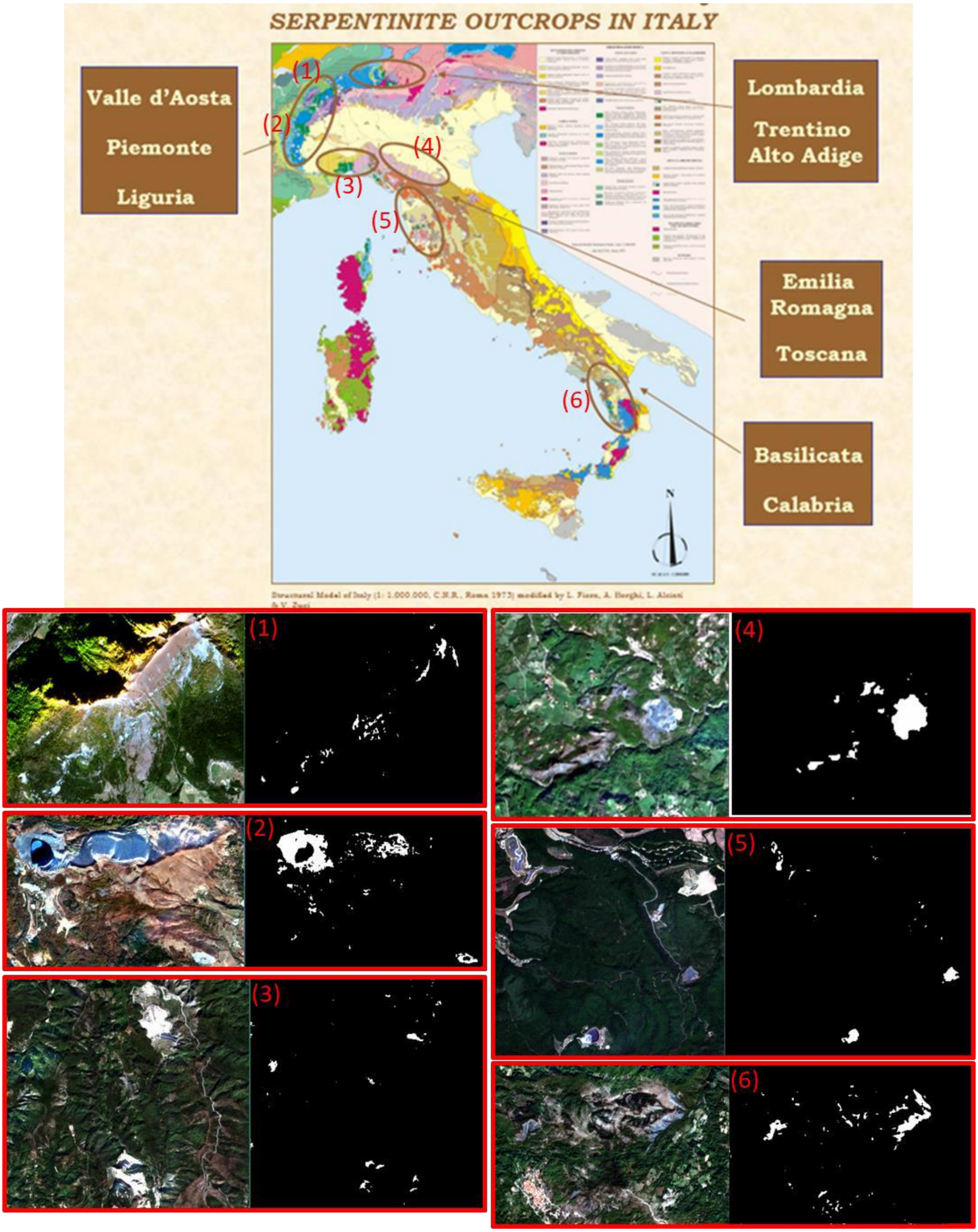


Fig.1. Serpetnites outcrops maps obtained applying a spectral classification procedure to S2 reflectances. Left side, the S2 RGB images; right side the classification results (white color depicts the serpentinites outcrops).

# Albanian Gas Master Plan and Selection of the Gas Pipeline Corridors

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**Abstract**

The Albanian Gas Master Plan (GMP) project, approved in 2017, includes the Strategic Environmental Assessment (SEA) on GMP, and the Prefeasibility Study (PFS) and the Initial Environmental and Social Evaluation / Examination (IESE) on three selected priority projects (PIPs). The purpose of each IESE was as follows: a) To highlight any significant environmental and/or social barriers that may impede the project implementation; b) To compare the considered gas corridor alternatives/options from the environmental and social point of view; and c) To help the national environmental authorities and the future lender(s) to decide (screening decision) on the ESIA level/category to which the project should be submitted during its future development phases. The IESE preparation procedure should take into consideration, within the possible limits, the national, EU, and IFIs environmental regulations, as well as the best practice for such projects. The approach for selecting the potential gas corridor alternatives/ options was based mainly on: the location of the gas supply sources and of the gas consumers; the specific environmental and social constraints; the expected cumulative effects with other development plans in the same project area and/or in the same sector (energy) at different levels; the significance of the main potential residual effects, and the SEA findings and recommendations. The impacts' significance was weighted according to a scoring criterion. In absence of a detailed national methodology, the SEA was carried out by adapting the British methodology that has been elaborated in accordance with the SEA Directive, while the consultations were based on the national regulations. The case study deals with the specific approach and difficulties to select the most friendly gas corridor options.

**Keywords***:* Gas pipeline corridor option, Environmental constraint, Strategic Environmental Assessment, Impact's significance, Environmental objective

# Comparison of Hydrochemical Indicators to Analyze the Groundwater Chemical Composition - Case Study on Quaternary Deposits in the Lower Course of Erzeni River, Albania

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**Abstract**

Alluvial deposits in the lower course of Erzeni River are part of the Albanian Western Lowland. The spatial evolution of the groundwater chemical composition of the alluvial deposits in the lower course of Erzeni River depends mainly on: the chemical composition of river waters at the recharge zone; the sedimentation conditions of the gravelly deposits; the hydrodynamic conditions; the underground flow; etc. This evolution is expressed in distance from the recharge area with changes of dominant ions from $HCO_3^-$ to $Cl^-$, Simpson's coefficients, Ca/Mg ratio, Na/Mg ratio, etc. It is also accompanied by increasing of total dissolved solids (TDS) and ions of $Na^+$. Chemical analysis in the western and north-western part of the aquifer show that a cationic exchange occurs; $Ca^+$ ion is replaced by $Na^+$. In this part of the aquifer there are two areas of total hardness less than 25 and 20 German degrees, respectively. Groundwater chemistry is also controlled by the groundwater flow. The complexity of the geological and hydrodynamic factors make possible that the changes between the chemical composition of the groundwater and the river waters at the recharge zone increase with the distance from this zone. Toward the western and north-western part of the aquifer the fresh waters are mixed with the remained sea waters and therefore show signs of metamorphism. The seawater intrusion affects the western extremity of the river aquifer, close to the coastline.

**Key words**: Spatial evolution, Groundwater chemical composition, Erzeni River aquifer, seawater intrusion.