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HASAN KALYONCU UNIVERSITY

GRADUATE SCHOOL OF

NATURAL & APPLIED SCIENCES

STRATEGIC FRAMEWORK FOR ANFIS AND BIM USE ON RISK MANAGEMENT AT NATURAL GAS PIPELINE PROJECT

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Strategic Framework For ANFIS and BIM use on Risk Management at Natural Gas Pipeline Project

Ph.D. Thesis in

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Supervisor

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

İsmail ALTUNHAN

ABSTRACT

STRATEGIC FRAMEWORK FOR ANFIS AND BIM USE ON RISK MANAGEMENT AT NATURAL GAS PIPELINE PROJECT

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Risk management and assessment is a multi-criteria decision-making problem involving various factors, according to literature research and expert opinions. In order to establish effective models and resolve the relationship between these criteria's; Researchers and Academics have presented a wide range of methods or models in the literature. In order to overcome the most strategic issue that affects the project performance scales, such as Risk Management, the most appropriate method and criterion selection is required.

Risk management and assessments of industrial facility works in the world and in Turkey are far away from the desired level. In general, the risk score is evaluated over the decision matrix, which is one of the traditional methods, and reduction or mitigation plans apply accordingly.

In this study; In the TANAP project, which is called the Mega project around the world, a model has been presented through risk management and assessment. The model offered is; A case study conducted using the multi-criteria Adaptive Neuro Fuzzy Inference System (ANFIS), which provides the rating of 104 recorded risk types covering the design and construction processes. Combining the structures and advantages of adaptive networks with fuzzy inference methodology has shown that a more comprehensive and effective risk management and assessment made. It has been shown with Root mean square error (RMSE) and Mean Absolute Percentage Error (MAPE) performance indicators that it gives better results in artificial intelligence supported risk management or assessment created with Adaptive Neuro Fuzzy Inference System.

In the last stage of the study; Risks that defined by omni-class classes transferred to 3D visuals with color and linguistic expressions in order to increase visualization and information sharing with the help of BIM Navisworks/Dynamo software, and Risk maps created and the study concluded.

The main contribution of this study; is the approach of artificial intelligence to evaluate and rate the risk correctly with hybrid learning method and then to obtain risk maps by integrating them into BIM as visual and linguistic term expressions.

The practical significance of this study; the proposed approach enables the development of Artificial intelligence based Adaptive Neuro Fuzzy Inference System

(ANFIS) and BIM-based risk management software to improve risk identification, analysis and management during the project development and construction process. This research provides evidence that traditional techniques can be aligned with ANFIS and BIM for risk management. A key advantage of the proposed method is that it combines the benefits of ANFIS and BIM for lifecycle project risk management and has minimum disruption to existing work processes and maximum performance impact.

Keywords: Risk Management, Neural Fuzzy Logic, Artificial Neural Networks, Adaptive Network Based Fuzzy Inference System (ANFIS) and BIM

ÖZET

DOĞALGAZ BORU HATTI PROJELERİNİN RİSK YÖNETİMİNDE YAPAY ZEKÂ VE BİM KULLANIMININ STRATEJİK ÇERÇEVESİ

ALTUNHAN, İSMAİL
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Haziran 2022
128 Sayfa

Risk yönetimi ve değerlendirilmesi literatür araştırmaları ve uzman görüşlerine göre çok çeşitli faktörler içeren çok girdili bir karar verme problemidir. Etkili modeller kurmak ve bu kriterler arasındaki ilişkiyi çözmek adına araştırmacı ve akademisyenler literatürde geniş bir kapsamda yöntemler veya modeller sunmuştur. Risk Yönetimi gibi proje performans ölçeklerini etkileyen en stratejik konunun üstesinden gelmek adına en uygun yöntem ve kıstas seçimi gerekmektedir.

Dünya ve Türkiye'de bulunan endüstriyel tesis işlerinde risk yönetimi ve değerlendirmeleri istenilen seviyeden uzaktır. Genel olarak geleneksel yöntemlerden olan karar matrisi üzerinden risk skoru ile değerlendirme yapılmakta ve buna göre azaltma planları uygulanmaktadır.

Bu çalışma da; Mega proje olarak adlandırılan TANAP projesinde risk yönetimi ve değerlendirilmesi üzerinden bir model sunulmuştur. Sunulan model de tasarım ve yapım süreçlerini kapsayacak şekilde kayıt altına alınan 104 risk türünün derecelendirmesini sağlayan çok kriterli sinirsel bulanık mantık yaklaşımı(ANFIS) kullanılarak bir vaka çalışması yapılmıştır. Adaptif ağların yapıları ve avantajlarının ve bulanık mantık metodolojisi ile bir araya getirilmesi daha kapsamlı ve efektif bir risk yönetimi ve değerlendirmesi yapılabileceği göstermiştir. Hata kare ortalamaları karekökü ve Ortalama Mutlak Yüzde Hata performans göstergelerince sinirsel bulanık mantık ile oluşturulan yapay zekâ destekli risk yönetimi veya değerlendirmesinde, daha iyi sonuçlar verdiği ortaya konulmuştur.

Çalışmanın en son aşamasında omni-class sınıfları ile tanımlanabilen riskler, renk ve dilsel ifadeler ile BIM Naviswork/Dynamo modülü yazılımı yardımı ile görselleştirme ve bilgi paylaşımını arttırmak için, 3D görsellere aktarılarak risk haritaları oluşturulmuş ve çalışma sonlandırılmıştır.

Bu araştırmanın ana katkısı, yapay zekânın hybrid öğrenme yöntemi ile riski doğru değerlendirerek derecelendirmek ve daha sonra görsel ve dilsel ifadeler olarak BIM'e bütünleşmiş ederek risk haritaları elde etme yaklaşımıdır. Bu araştırmanın pratik önemi, önerilen yaklaşımın proje geliştirme ve yapım sürecinde risk tanımlama, analiz ve yönetimini iyileştirmek için Yapay zekâ (ANFIS) ve BIM tabanlı risk yönetimi yazılımının geliştirilmesine olanak sağlamasıdır. Bu araştırma, geleneksel tekniklerin risk yönetimi için ANFIS ve BIM ile uyumlu hale getirilebileceğine dair kanıt sağlar.

Önerilen yöntemin önemli bir avantajı, yaşam döngüsü proje risk yönetimi için ANFIS ve BIM'in faydalarını birleştirmesi ve mevcut çalışma süreçlerinde minimum kesintiye ve maksimum performans etkisine sahip olmasıdır.

Anahtar Kelimeler: Risk Yönetimi, Sinirsel Bulanık Mantık, Yapay Sinir Ağları, Adaptif Ağ Yapısına Dayalı Bulanık Çıkarım Sistemi (ANFIS) ve Yapı Bilgi Modellemesi(BIM)

To my Worthy Family

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LIST OF SYMBOLS/ABBREVIATIONS

BIM	Building information modelling
AECO	Architects, engineering, construction, operations
ICT	Information and communication technology
CAD	Computer aided design
RFI	Requests for information
AIA	American Institute of Architects
IFC	Industry Foundation Class
MEP	Mechanical, electrical, plumping
AEC	Architecture, engineering, construction
TS	Turkish standard
ANFIS	Adaptive neuro fuzzy inference system
ANN	Artificial Neural Networks
FIS	Fuzzy Inferance System
RMSE	Root Mean Square Error
MAPE	Mean Absulate Percantage Error
CLIENT	Employer
EPCM	Engineering,Procurement, Construction Management
2D	Three-Dimensional
3D	Three-Dimensional
4D	Four-Dimensional
AI	Artificial Intelligence
WBS	Work Breakdown Structure
SWOT	Strength-weakness-opportunity-threats
SQL	Structural Query Language

CHAPTER 1

INTRODUCTION

1.1. Problem Discription

1.2. Background of the Research

In today's rapidly changing, developing and digitalizing world, increasing uncertainties and risks play an active role in the decision mechanisms of companies. In this environment of increasing uncertainty, companies need to understand and apply the risk management system well in order to determine their future strategies and achieve their goals.

In order for the project to reach its goals, it will be able to see the risks with their possible consequences early and accurately, evaluate their effects, and take and follow up the necessary measures with effective project planning and control systems and methods in order to reduce and keep all these risks under control; There is a need for a risk management power that will reduce the potential harmful consequences that will hinder project success. Issues such as keeping the risk level in construction projects under control and minimizing, taking the right precautions against different risks, preventing the reflection of risks on project performance scales by reducing or eliminating their effects are issues that can solve some problems of the oil and natural gas industry and contribute to its development.

In addition to the risks created by uncertainties, the systematic evaluation of risks in the oil and natural gas industry, which has many risk factors due to its dynamic structure, and the determination of strategies and targets by taking part in decision processes are of vital importance for companies operating in this sector.

Risk management in projects has not been studied in detail yet. In addition, the detailed work has not been done in the Oil and Gas Sector too (Suda, 2015). Although risk management in the oil and natural gas industry is a very important issue for companies operating in the oil and natural gas industry, it has not yet gained clarity and prevalence in our country.

Considering this situation, the subject of this thesis study has been determined as "Strategic Framework for ANFIS and BIM Use on Risk Management at Natural Gas Pipeline Project ". It can be converted to Oil&Gas Industry too.

Within the scope of this subject, the aims of the thesis are as follows:

- Defining the concept of risk in general and risks in oil and gas projects,
- To address new methods and methodologies used in risk management and analysis,
- Determining the risk management approaches in the Oil and Natural Gas sector, examining the current situation and making forward-looking predictions and visualitions.

For these purposes, literature research method and case study method were used in the thesis study. Literature research or survey; It has served to define the risks seen in the projects and to explain the stages and methods of risk management. The case study method was used to study the risks seen in the Tanap project with an artificial intelligence-based application and to make up-to-date determinations on risk management and assessment.

In this study; The subject of risk management and its projection in the projects are examined, then a risk management model created with an Adaptive network-based fuzzy inference system approach for the oil and natural gas sector is presented.

1.3. Statement of Research Problem

In the rationale part of the study; Risk management is discussed in general, including the risks in other sector projects.

Risk Management is the struggle to minimize the probability of realization (risk) of dangers that threaten all planned activities of enterprises or the magnitude of loss and damage (risk) that may arise in case of their realization.

Risk Management and analysis aims to reduce the damage that may occur due to the sudden and unexpected occurrence of an undesirable event in the future, and thus to protect the business, employees and business subject. Although the expenditures made in Risk Management are generally seen as expense-based, this struggle makes it possible to compensate for the damage and enables businesses or projects to know themselves better, which brings new ways and opportunities for them to develop.

Risk Management, which starts with the perception of risk and awareness of the danger, represents an approach that should be maintained in a systematic and continuous manner. In other words, it continues throughout the entire project life cycle. This approach; It is obligatory to create the document and documentation that determines the standardization over time. Such a Risk Management record is the basis for future projects. This helps Risk Management become a policy and have a risk culture. This culture will carry the project performance parameters upwards over time.

This struggle is due to the nature of man and the businesses or projects he has established. People and organizations, who have a sense of uncertainty as a result of the perception of risk, react to risks with the motive of getting rid of the fear and doubt they fall into. The drive to get rid of fears and doubts by eliminating uncertainty and the desire to know what the final outcome will be in each bad scenario has led to the development of methods of avoiding risks and the implementation of new solutions. With this approach logic, Adaptive network-based fuzzy inference system was used in risk grading for risk management and analysis and then transferred to BIM 3D-4D with visual and linguistic expressions.

1.4. The Need for the Research

The Need for the Research; using the neural fuzzy logic approach in risk management and assessment based on the project data, risk assessment was made and risk values were calculated. Evaluation of oil and natural gas industry risk parameters with neural fuzzy logic was used for the first time in the literature and the results obtained were compared with the results of classical risk assessment methods in terms of error indicator criteria.

In an effective risk management, it envisages avoiding delays, changes and discussions while ensuring the best use of resources, ensuring the scope and objectives of the work, achieving quality in design and implementation. In short, it refers to an approach that aims and ensures that a targeted result (construction product) is achieved in a prescribed manner (within time, cost and quality limits).

In the model development part of the study, it was investigated that the Adaptive network-based fuzzy inference system approach could be an option instead of traditional methods when dealing with uncertainty in cases where data accumulation in the oil and natural gas sector is insufficient, and its applicability to the sector was examined in the fourth section. Uncertainty, which is an indispensable part of life, is the main source of risks that need to be reacted in some way. Because there is uncertainty, there is risk. In this sense, in fact, risk management is nothing but an effort to eliminate uncertainty and to know what the outcome will be in any situation.

This approach, which means a kind of formation or formulation of uncertainty, is the principle of creating an artificial intelligence. In fuzzy logic, data is taken with sampling logic, assumptions are made and a probability value is obtained accordingly. A program that can produce one or more results that can vary depending on the data and the assumption is created from an undetermined number of data stacks. Artificial intelligence and fuzzy occur in problems in uncertain situations where the accuracy criterion cannot be precisely defined.

Contribution has been made to the literature in terms of expanding the scope and combating dangers more effectively by adding different parameters, such as sensitivity to not using personal protective equipment, sensitivity to not being cared, and inability to see the result, to risk assessment studies based on two or three parameters such as severity and probability (Chen, 2000).

The application of the model includes the evaluation and visualization of the risks in the design and construction processes of the project, which is known as the mega project in the world.

1.5. Research Questions

Based on the problem established for this research, it forwards a general question of "How to manage risks for risk management in Oil & Gas Industry projects implementing Adaptive network-based fuzzy inference system-ANFIS and BIM?". This question subsumes several underlying questions, which are:

Resarch Question 1: How can existing traditional techniques align with Adaptive network-based fuzzy inference system-ANFIS for risk management at Oil and Gas Industry?

Research Question 2: How can Risks be visualised in the BIM environment during the project' design and constuction stages and also it is applicable for project life cycle?

1.6. Research Aim and Objectives

The aim of the research is to develop and manage a conceptual framework of risk management and analyses in Oil & Gas Industry projects implementing Adaptive network-based fuzzy inference system-ANFIS and linkage with BIM. The objectives of the study are:

- Expanding the scope of classical risk assessment studies based on two parameters such as severity and probability by adding different parameters such as sensitivity to not using personal protective equipment, sensitivity to lack of care and inability to see the result;
- Working more sensitively on classical risk assessment studies with Adaptive network-based fuzzy inference system-ANFIS approach
- Selection of appropriate and correct risk reduction methods for the risk scores obtained by increasing the number of parameters and artificial intelligence support.
- Transferring the obtained risk scores to the dynamo module by using color and linguistic expressions and ensuring the visualization of the risk
- Conceptualizing the framework linking risk and risk management strategies and validating the model created.

1.7. Research Methodology

The research methodology followed the CIFE "Horseshoe" Method (Kunz, 2007) for transitional research (see figure 1.1). Chapter 5 covers the research methodology comprehensively.

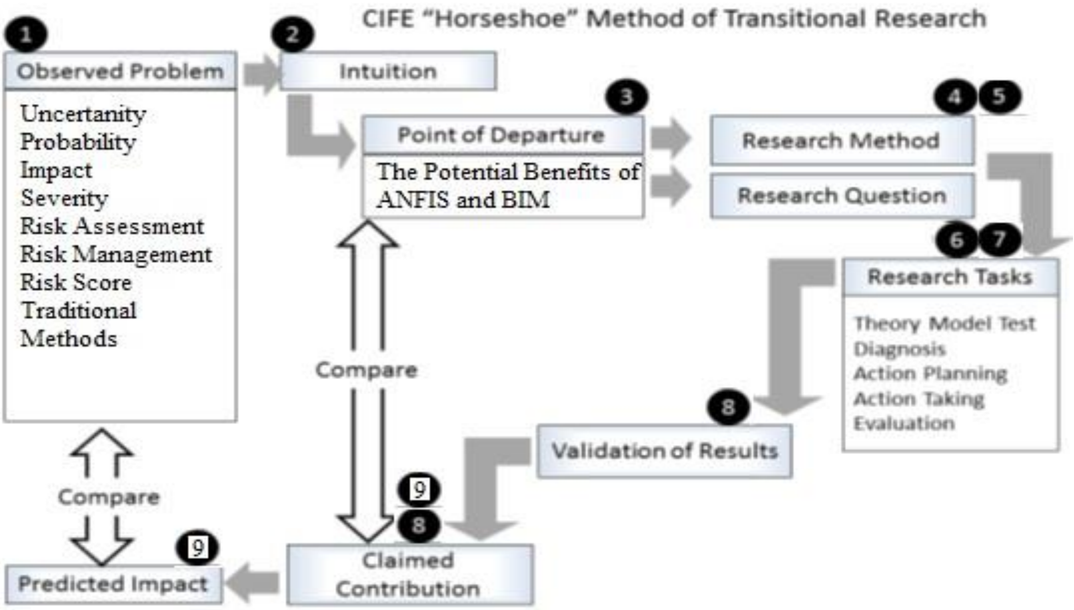


Figure 1.1: The CIFE Horseshoe method of Transitional

The research method is briefly introduced chapter1.7. and further explained and discussed in Chapter 5. Fuzzy Set Theory and Artificial Intelligence methods are frequently used in order to eliminate this uncertainty and turn human evaluations into meaningful results.

In the thesis, an approach based on the Adaptive Network Based Fuzzy Inference System (ANFIS) method has been developed for risk management and assessment. Later, this system has been transferred to 3D-dimensional images with color codes and linguistic expressions and risk maps have been created.

The purpose of applying a neural fuzzy technique in Risk Management and assessment is not only to capture the learning ability of neural networks, but also to offer a quantitative approach of human knowledge and causality mechanism.

It is aimed to combine fuzzy logic and artificial neural networks by making use of the features such as nonlinear mapping from numerical data, learning ability and parallel work, so that the risks of the study are more understandable by combining machine learning and visualization parameters.

1.7.1. Research Philosophy

The main philosophy of this study is a different view of the interpretation and analysis of the collected data. In addition, detailed philosophical methods are explained in Sounder's onion research. These are positivism, realism, interpretation and pragmatism **(Saunders, 2007)**. The main philosophy to be applied as a basis in this research is pragmatism. The research focuses on questions and question groups that will be a problem and a new method analysis that will be examined in detail in general terms.

1.7.2. Research Approach

The second circle of Saunders Research methodology describes the research approach in detail. There are two types of approaches to research, namely deductive and inductive. Each of these helps to collect data in different ways (Saunders, 2007). The preferred method in this research is the deductive research approach.

1.7.3. Research Strategy

Research strategy is one of the third and most critical circle in Saunders' research methodology. It is a planning phase in which research questions are formed and their answers are elaborated. There are various types of strategies such as experiment, survey, action research, case study (Saunders, 2007).

The strategy adopted in this research is a case study and action research. Making use of case studies, where there is not enough information or theory, will allow to focus on research questions in general and to make in-depth research on the answers to these questions. In addition, the in-depth artificial intelligence analysis capability required by this study is achieved through this strategy due to its ability to address various question groups such as why, what and how, and to develop quantitative and qualitative data (Saunders, 2007). The field of study conducted in practical settings such as Action Research, etc. unlike controlled environments, it helps inform and supports researchers about the pros or cons of real-world interactions.

1.7.4. Research Choises

Research selection is the fourth circle of the research onion methodology. These choices are; It can include quantitative, qualitative or mixed research methods (Saunders, 2007). In this research, the mixed method was chosen as the research option, that is, the data were collected by using two methods (qualitative and quantitative) simultaneously and then analyzed.

1.7.5. Time Horizons

As mentioned by Saunders et al. (Saunders, 2007), there are two types of time horizons and they are cross-sectional and longitudinal research. In the cross-sectional time horizon, the data are collected at once and analyzed and analyzed in a short time. With the longitudinal time horizon, the data is collected over a longer period of time, which will allow understanding of changes over time. The time horizon type adopted by the researcher in this study is the longitudinal time horizon method.

1.7.6. Technique and Procedure

The sixth circle in the Saunders Research method is technique and procedures. In this research, the procedure set by (Denscombe, 2005) adopted for a case study, a more detailed and comprehensive explanation is presented in Chapter 5.

1.8. Scope and Limitations of the Research

The aim of this research is to relate the risk management and assessment process with the neural fuzzy logic approach (ANFIS) and BIM. The software usage risks associated with the neural fuzzy logic approach (ANFIS) and BIM were not covered.

The focus of the research is a case study using the multi-criteria neural fuzzy logic approach (ANFIS), which provides the rating of 105 risk types recorded with traditional methods in an oil and gas project. While making this evaluation, 4 parameters were defined in addition to the parameters used in traditional methods and the risks were studied more sensitively.

Combining the structures and advantages of adaptive networks with fuzzy logic methodology, a more comprehensive and effective risk management and assessment was considered.

Oil and gas projects were chosen as the project type to examine the connection between the emerging neural fuzzy logic approach (ANFIS) and BIM. Although the scope of this research is limited to oil and gas projects, the basic methods and principles presented in this research can be applied to other types of projects.

Another aim of this research is to integrate neural fuzzy logic approach (ANFIS) and BIM to support lifecycle risk management and decision making. It is an approach to correctly evaluate and rate the risk with the hybrid learning method of artificial intelligence and then integrate it into BIM as visual and linguistic expressions to obtain risk maps.

1.9. Ethical Issues

General research ethics or principles express respect for the rights of study subjects. The researcher is obliged to observe confidentiality, institutional privacy, personal privacy and obtaining approval from relevant institutions and organizations throughout the study (Denscombe, 2005).

The ethical approval form for this research was submitted to Tanap Gas Tranmission A.Ş to provide data for the development of this research. With the approval of the relevant institution, the data were used. In addition, within the scope of the thesis, the process was continued by obtaining approval from the Compliance, Risk and Corporate Departments of the Tanap Project and the thesis was completed.

1.10. Contribution to the Knowledge

Within the Contribution to the Knowledge of the thesis, based on the data in the design and construction processes of the Tanap project, a risk assessment was made by using the neural fuzzy logic approach in risk management and the risk values were calculated. Evaluating the risk parameters of Industrial Stations and pipelines with neural fuzzy logic in risk management and then displaying them with color codes and linguistic expressions was used for the first time in the literature and the results obtained were compared with the results of classical risk assessment methods in terms of error indicator criteria.

Contribution has been made to the literature in terms of expanding the scope and combating dangers more effectively by adding different parameters, such as sensitivity to not using personal protective equipment, sensitivity to lack of care and inability to see the result, to risk assessment studies based on two parameters such as severity and probability. At the last stage of the study, risks that can be defined by omni-class classes, color and linguistic expressions and risk maps were created by transferring them to 3D visuals in order to increase visualization and information sharing with the help of BIM Naviswork/Dynamo module software and the study was concluded.

The main contribution of this research is the approach of artificial intelligence to evaluate and grade the risk with the hybrid learning method, and then to obtain risk maps by integrating them into BIM as visual and linguistic expressions.

1.11. Guide to Thesis

This chapter one involves the entire structure guide to the thesis just as an introductory study overview to provide information on the chapter contents.

The second chapter deals with review of literature on Risk Management and Assessment in all management applications. Also; The literature review in the field of Adaptive Network Based Fuzzy Inference System (ANFIS) and BIM in the field of risk management is also explained in this section.

The third chapter; All details about the risk management and assessment carried out within the scope of the Tanap project are given. All the details of the risk management in the tanap project, which was selected as the best project of 2020 by PMI, were explained and became an example of good practice.

The fourth chapter; As a new modeling tool, detailed information about artificial neural networks, fuzzy logic and Adaptive Network Based Fuzzy Inference System (ANFIS) and their usage areas are given. Also; Detailed information was also given about BIM and BIM applications.

The fifth chapter; Details about the research methodology are discussed in this section.

The sixth chapter ; provides an Framework Development for Adaptive Network Based Fuzzy Inference System (ANFIS) and Building Information Modelling(BIM) use in the Risk Management at NGPP . The established model is described in this section as a step-by-step method.

The seventh chapter ; provides application of improved Framework Development for AI and BIM use in the Risk Management in the pipeline Project. Thus, this chapter explains matlab applications and their execution and BIM integration.

The eight chapters ; It is the validation and discussion part of the established model. This is the part where the results from the model are discussed in detail. Also ; This is the part where the answers to the research questions written in the first chapter are given.

The nineth chapter ; This is the part where the results of the established model are processed in detail. It also mentions in detail the contributions of the research to the industry, both academically and practically. It is the place where the limit parts of the research are mentioned. Finally, the study is concluded with the suggestions given for future studies.

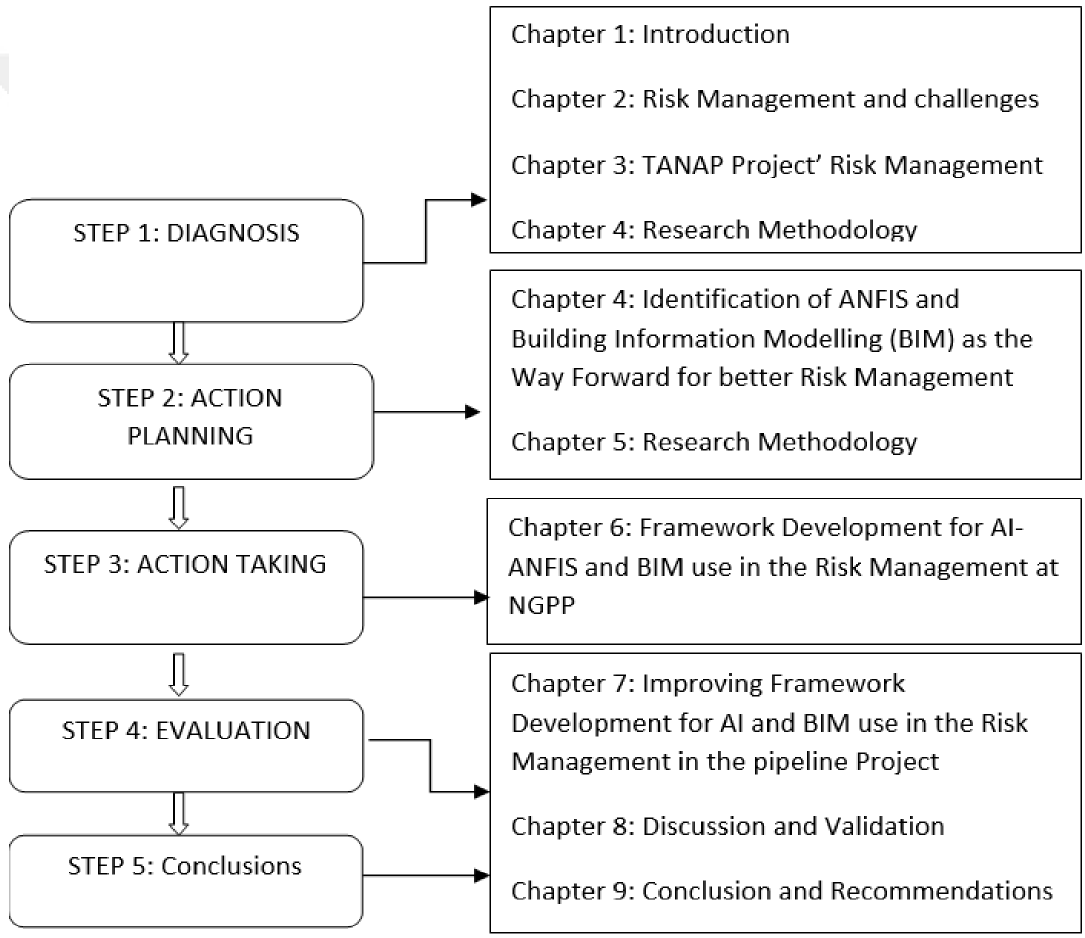


Figure 1.2: Structure of Thesis

CHAPTER 2

Risk Management and Challenges

2.1. Definition of the Risk

The future is uncertain for both individuals and businesses. Risk can be defined as the probability of an undesirable event occurring in the future. The occurrence or probability of the event, albeit at a low rate, may lead to difficult problems in the future. For this reason, the risks that affect the performance parameters the most and their management should be considered in the entire project life cycle.

The concept of risk is thought to be a simple and easy to understand concept at first glance. But nowadays it is only evaluated on the basis of assumptions. It is not possible to find a constant and consistent use in the literature. Many definitions of the concept of risk have been made in the literature, one of them is; Risk is the factor that prevents the successful completion of the project. Risk can be defined as what causes a problem to occur.

Risks may adversely affect the progress of the project and make the outcome uncertain, while increasing costs, time and scope. In other words; An uncertain event or condition that, when a risk occurs, has a positive or negative impact on at least one project objective, such as scope, cost, quality, or schedule. (PMI, 2004).

Risk in projects is the probability of occurring in a project. events and results and their effects on the project. Successful completion of projects condition is not always guaranteed. Sometimes even in the most unexpected simple activity problems may occurThe factors that prevent the successful completion of the project are called risks. Risk is not a problem, it is the factor that causes the problem. When the project risks are realized; An uncertain event or situation that adversely affects at least one project objective, such as time, cost, scope, or quality (PMI, 2004).

Project risk is the emergence of the consequences of adverse events that affect the project objectives. degree (PMI, 2004). That is, the risk is that the results of Project activities will change. impacts that are likely to occur. Project and project when risk occurs may be obliged to change team members.

The conclusions to be drawn from these definitions above, to plan the identified risks, data to future processes on possible constraints to manage and control they form. Risk components, risk, probability of risk, consequence or effect of risk and risk is the status. Risks have both positive and negative effects. Risks are only for events. It depends not only on future project conditions but also on future project conditions. Conditions can be good or bad.

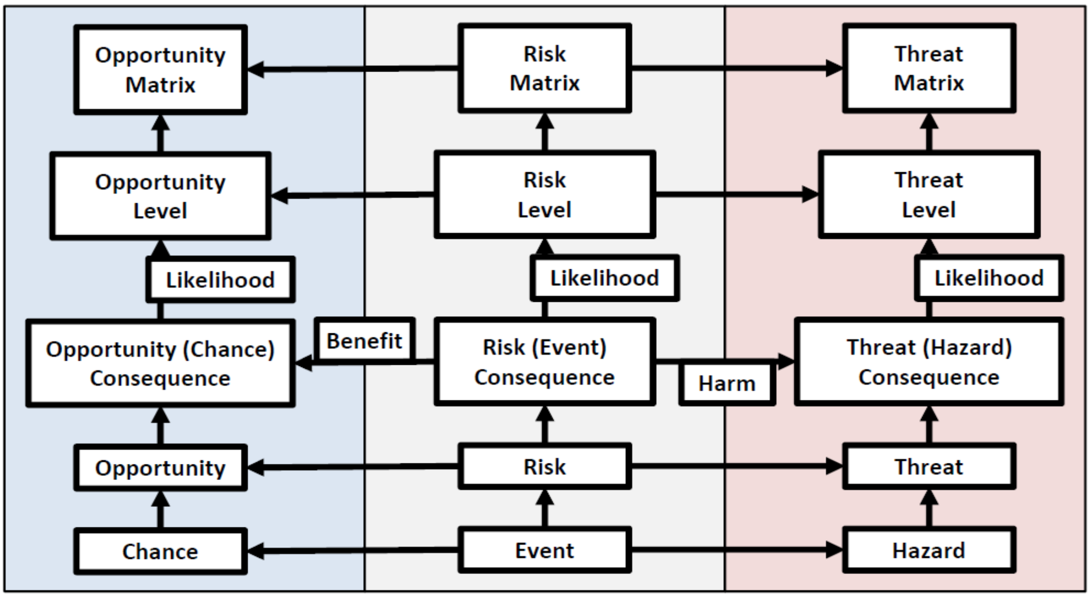


Figure 2.1: Relation in risk terminology (Tomek, 2014)

The important thing is to make a sound estimation in the early stages of project continuity and minimizing risks. Conditions within the project continuity due to its changeability. All risks will have a negative impact there is no such rule. There may be partial effects.

Risk; It can be explained as the probability of occurrence of damage, loss, profit, gain, etc., whether it is calculated or not in future projects. Financial risk; The risk of loss that may occur in the valuation of assets. In another approach, it is defined as the dangers to which all kinds of economic activities are subject and that threaten the planned activities of the enterprises.

As explained above, the concept of risk can be evaluated as a risk of capital loss or failure for businesses. The biggest risk for a business; It is the failure to provide the expected income from the investment made or the failure to receive the return for the service rendered. This means loss of capital in the construction company.

As mentioned (Al-Bahar, 1990) preferred to consider the concept of risk with its positive and negative aspects and made the definition as follows:

Risk is the realization of the possibility of exposure to events that, due to an uncertainty, will positively or negatively affect the purpose of the project.

With this definition, risk;

- Risk event
- uncertainty of the event
- potential gain/loss

expressed as three items. A risk event is an event that, if it occurs, will affect the project positively or negatively. This event must be likely to occur (uncertainty of the event). Whether it is a gain or a loss, an event does not pose a risk if it is certain that it will occur. The occurrence of the event must result in a win or loss (potential loss/gain). The concept of gain includes the concepts of benefit or profit, and the concept of loss includes concepts such as damage or loss.

It may be interesting to consider an uncertain potential gain as a risk.

The fact that the earnings are uncertain or unknown generally makes these earnings unattractive. For this reason, it is usual that risk is generally expressed with its negative aspects in the literature and there is no study on opportunities. As mentioned earlier, it is common to confuse the terms risk and uncertainty and use them interchangeably.

2.2. Categorizing of Risks

The risks in the construction sector and the measures to be taken against them have started to gain importance in the world, and various researches have been carried out on this subject.

In qualitative methods, instead of a concrete risk assessment with numbers, a risk assessment is made in verbal sentences, risks are identified based on the estimations of the risk assessment team and the experience of the team leader and ranked according to their importance. There is no conversion to numeric values, terms such as very risky, risky, low risk, light risk are used. As expected, results may vary from person to person. Therefore, evaluating only with a qualitative method may not be enough for a long time. Quantitative risk assessment methods use numerical methods to calculate risk. The identified risks are converted into numerical values and a prioritization order is made according to these numerical values. It is much more rational and systematic than the qualitative method. Often the risk results for the same hazard sources are similar, although the evaluators may differ. Carr and Tah determined a hierarchical risk breakdown structure in order to determine a formal model for qualitative risk analysis. Relationships between risk factors, risks and their results are presented with case studies and impact diagrams.

They came up with a scheme to classify risks and possible solution actions in an appropriate way. They showed the relationships between risk factors, risks and their consequences with cause-effect diagrams (Tah J.H.M., 2001)

2.3. Risk Management

The purpose of risk management is to develop practical and simple techniques that clearly demonstrate risk and uncertainty to individuals or organizations in investment projects, to help the decision maker to identify, analyze and manage risk by providing clear and informative information based on his judgment.

Quantitative Techniques serve the whole purpose of risk analysis. These techniques are based on the planning structures used and fit the natural planning and forecasting process, despite cost and process disruptions. Quantitative risk assessment requires the use of computer-based tools and the amount of information available. Risk management is a process consisting of several dimensions that are formed by successive activities (Ersar, 1996).

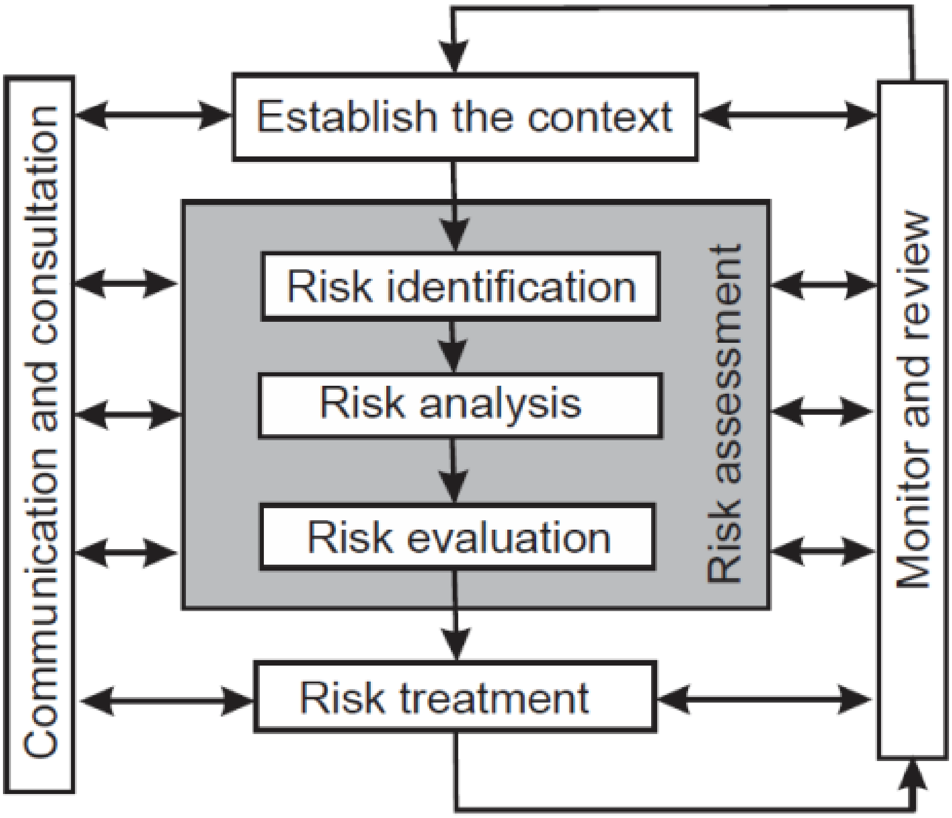


Figure 2.2: Risk management process (Purdy, 2009)

In risk planning, the aim is to provide management with an organized view to mitigate, mitigate, or eliminate risk as much as possible, develop activities, and allocate time and money resources to unavoidable risks. Risk planning is a dimension that is integrated with continuous management activities. While making risk planning, a systematic approach and method should be applied properly.

It is the stage where all risk management activities such as control and documentation are planned after the techniques that measure or scale the risk, risk analysis and risk assessment. In risk assessment, the risks that will prevent reaching the solution goals should be quantified and prioritized according to their effects. The main subject of risk assessment is to define each risk well and the cost of its impact to the project. According to the importance of these effects, it is an activity within the dimension of developing plans a and b.

The dimension of developing a solution for the risk that comes after the risk identification and evaluation stage is the stage where it is decided what activities done against the identified risks. One of the qualitative, quantitative or survey methods can be used in risk determination.

These techniques are based on the planning structures used and adapted to the natural planning and forecasting process, despite cost and process disruptions. Quantitative risk assessment requires the use of computer-based tools and software and the amount of information available. At the last stage of the risk management process, the activities carried out in the whole process are revealed and actively maintained.

While the risk management process continues, it is important for the success of the process to constantly control the effects of alternative activities developed against risk and to determine their degree of success.

2.4. Risk Analyses vs Uncertainty

Today, risk analysis has become much easier and more understandable thanks to various software, mathematical models and new software that can be considered as a combination of traditional forecasting and technical methods.

Risk Analysis is a process used to manage and plan the situation by anticipating potential problems and predicting what might happen. To reveal the problems or disruptions that may occur in any plan, project or operation, to make feasibility, to evaluate the threats that may arise in the future, to determine their probability and seriousness,

In order to ensure that the current activities will continue successfully in the future, it requires developing a plan that includes measures against risks, developing and implementing measures to protect certain areas of your plan, and incurring the cost of prevention. All data in economic assessments are subject to risk and uncertainty.

According to the difference between risk and uncertainty (Alpan, 1994) it can be summarized as follows; “Risk is used to describe situations related to probability data of identifiable project outcomes. Risk only relates to projects that can be estimated with the probabilities of the outcomes. Historical data to predict road accident or death or available. Uncertainty refers to situations that do not have appropriate historical data on either project outcomes or known probabilities. For example, sales for a new product can be defined as uncertain (Alpan, 1994).

Another view makes a sharp distinction in the literature on the difference between risk and uncertainty. However, if they cannot make the same determinations about the outcome and probability, there is an uncertainty here. “Uncertain events that have a negative impact on project outputs are risks, and uncertain events that have a positive and profitable impact on project performance are opportunities” (Perminova, 2008).

Another view is; “When acting with risks, there is potential for improvement. Risks tend to increase in direct proportion to each opportunity. There is a saying that sums up risk very well: “As a turtle takes a risk, it moves forward with its head out of its shell. The high-risk ratio makes the opportunity and project value to be evaluated high. Opportunities and threats can rarely occur independently or simultaneously. Risk is a state of uncertainty, but not every uncertain situation can be described as a risk” (Filiz, 2007).

“Risk is a measure of uncertainty. If there is no uncertainty, there is no risk. When the probabilities of alternative possible outcomes are known, risk is defined as uncertainty when their probabilities are not known. Forward-looking uncertainties are mostly due to lack of information. Uncertainties about the future can affect the outcome positively or negatively, but lack of information about future events causes uncertainty. happens” (Ababneh, 2000).

Thus, uncertainty is the combination of all possible outcomes, positive or negative. While benefit is obtained from the possibility of positive results, there is a risk in the realization of negative results. Many researchers have preferred the concept of uncertainty, which includes more than it includes, instead of risk. The concept of uncertainty reflects the variability and uncertainty of risk well. However, uncertainty always has a negative connotation. If uncertainty could distinguish between positive and negative aspects, it would replace the concept of risk.

“The factors causing uncertainty include; human factor, business size, organizational problems, legal structure of the institution, political factors, state economics, the degree of continuity in policy changes and decisions, the possibility of the enterprise to see ahead and take measures accordingly, legal factors, technological and social factors (Uğur, 2007).

“Uncertainties can have positive and negative effects on project outcomes. Uncertainties may arise from internal or external sources in projects” (Perminova O., 2008).

Some researchers are of the opinion that there is no difference between risk and uncertainty. “Newendrop, Moavenzadeh and Rossow see no difference between risk and uncertainty. They use these two terms as if they are synonymous” (Ababneh, 2000).

“Uncertainty, opportunity and risk are similar concepts. Risk is measurable uncertainty, uncertainty is unmeasurable risk” (Amos J., 1997). According to Newton, risk and uncertainty are intertwined concepts (Newton S., 1992).

“Lindley is of the view that statistical events are risk, non-statistics are uncertainty. Statistical events are repeated many times, and non-statistical events are one-time events” (Ababneh, 2000). “Morris, on the other hand, is of the opinion that when the probabilities of alternative possible outcomes are known, risk is considered, and when the probabilities are not known, it is characterized as uncertainty” (Ababneh, 2000). Since risk is the evaluation of alternatives by knowing all kinds of possibilities and their consequences, and uncertainty is the state of not knowing all possibilities and their results, it is tried to realize the project in the most accurate way with risk and uncertainty analysis.

“Perry and Hayes, Healy, Porter, and Al-bahar and McKim characterize risk as the resulting economic loss or gain from developments in the construction process. On the other hand, Moavenzadeh and Rossow characterize risk only as loss” (Ababneh, 2000).

“Perry and Hayes and Al-bahar are of the opinion that it is unnecessary and will not be beneficial to distinguish between the concepts of risk and uncertainty in construction risk management” (Ababneh, 2000).

“Chapman and Ward argue that uncertainties in projects are important to that project and that uncertainty is linked to more than the time and cost constraints of the project”.

Managing uncertainties in projects effectively very important for management. In projects, risks arise because there is no certainty, and such uncertainties are usually encountered at the beginning of the projects. “Another meaning of risk is the occurrence of undesirable situations resulting from loss, damage or other undesirable consequences. Uncertainty arises from a lack of information about past, present, or future events, values, or increases. This means that there is a lack of confidence in the accuracy of the estimated probability distribution" (Charette, 1990).

"Chapman and Ward argue that uncertainties in projects are important to that project and that uncertainty is linked to more than the time and cost constraints of the project". Managing uncertainties in projects effectively is very important for project risk management. Risks arise in projects because there is no certainty, and such uncertainties are usually encountered at the beginning of the projects. "Another meaning of risk is the occurrence of undesirable situations resulting from loss, damage or other undesirable consequences. Uncertainty arises from a lack of information about past, present, or future events, values, or increases. This means that there is a lack of confidence in the accuracy of the estimated probability distribution" (Charette, 1990).

2.5. Causes of Risk and Uncertainty

In project management, it is unthinkable that there are no risks in my production, construction or manufacturing sector investments. Some of the main causes identified by (Canada, 1971) and the most important of them are shown as below:

- Change of the internal economic environment and invalid past experiences (History data is invalid for expected future conditions and carries a risk when used directly).
- Misinterpretation of data (Relationships between one or more factors may be misinterpreted when the important factors behind the predictors are too complex).
- Analysis errors (Errors occur either in the analysis of the technical process characteristics of the project or in the analysis of the financial applications of the project).
- Existence and importance of managerial capability, Recoverability of Investment (Recoverability of Investment is the main consideration in risk assessments) and Obsolescence."

2.6. Traditional Approaches to Uncertainty and Risks

Uncertainty and risk form the core of resource allocation problems. Because it's unclearAll decisions about the future are based on guesswork. Therefore, risk and uncertainty attract the attention of many theorists and practitioners.

“Some of the commonly used approaches to uncertainty and risk in the industry available. These some approaches are given below” (Alpan, 1994).

Intuitive Method - Probably the most widely used approach to risk problems is a pointguessing and then using intuitive judgment. The procedure is primarily making the best estimate for each of the uncertainty quantities and prices. Then, the cash flows and the performance measures of the project are calculated (Harrıson, 1973).

- Reducing Expected Project Life - Another procedure still often used to compensate for uncertainty is to reduce the expected project cycle. The remote results are more favorable than unfavorable, such that long-term forecast cash flows are generally positive (derived from net revenues) and recently forecasted cash flows are negative (derived from initial cost).
- Reducing the expected life of the project hinders marginally effective proposals that allow risk, which has the effect of blocking the draft by preventing possible future profits, thereby increasing the minimum effective return rate in the same way” (Alpan, 1994).
- Sensitivity Analysis - Uncertainty means things that can happen rather than things that will happen. Thus, when confronted with an analyst's cash flow forecast, he or she should try to discover what else could happen. The purpose of the sensitivity analysis is to determine the range of positive changes for a variable and to find out how sensitive the profitability of the project is to changes in that variable.
- Variables generally do not change once at a time. However, many businesses try to overcome these problems by examining the impact of alternative plausible combinations of variables on the project. In other words, they will estimate the performance measure of the project under different scenarios and compare this estimate with the baseline” (Brealey, 1988).

2.7. Risk Management in Projects

As projects become more complex and competition becomes more and more difficult, risk management becomes critical to successful project management.

“There is a direct relationship between effective risk management and project success, as risks are assessed by their potential impact on the objectives of the project” (Baloi D., 2003).

“Customer satisfaction comes in addition to providing time, budget and quality at the expected level among the most common project objectives” (Özorhon B., 2007).

“Companies survive by seizing opportunities in an environment of uncertainty, and projects aim to take advantage of these opportunities. To take on a project, to achieve or introduce something new, is to take a risk. Therefore, risk is the core of the project element. However, it is inevitable to take risks in difficult competition conditions, advanced technology and difficult economic conditions. Therefore, risk management is done in projects to identify project risks and develop strategies to greatly reduce risks. These studies are also done to increase opportunities.

Project risk management is the processes of planning, detecting, analysing, reacting, monitoring and controlling for carrying out risk management. The aim of project risk management is to increase the impact and probability of positive events and to reduce the impact and probability of negative events (PMI, 2004)The main purpose of project risk management is to keep uncertainty away from risks by directing it towards opportunities. While there is a simple management with the cycle of inputs, processes, outputs and feedbacks in any project, there are uncertainties, possibilities or unpredictable situations in risk management. Project risk management is not intervention after potential adverse events occur, but preparations before they occur. With forward-looking plans, it is possible to choose an alternative plan that can make the project successful without deviating from the goals.

Large uncertainties arise in the early stages of the project. All risks should be identified and assessed at the beginning of the project. Risk management should be a continuous activity and should continue throughout the project” (Amos J., 1997).

"In order to provide a systematic approach to risk management, sources of risk are identified, their effects are measured, solutions are developed for these risks and other risks estimated in the project are taken under control" (Tah J.H.M., 2001).

Risk management, risk analysis and risk assessment; necessary measures are taken in advance to eliminate the danger. The cost of prevention is less than the cost of reimbursement. With risk management, problems are prevented before they occur, so it becomes easier to reach the targets set in the performance, cost and schedule program.

2.8. Risk Uncountered in Projects

One of the biggest problems encountered in projects is that the project cannot be completed on time and behind budget.

Experienced project managers prefer risk management to crisis management. The stress rate in the hours spent for risk management is quite low compared to crisis management. In risk management, events are under the control of the project manager, while in crisis management, the project manager is under the control of events. Solving problems takes time and money. Although the problems cannot be solved completely with risk management, risks can be reduced at low cost by making some plans before they occur. Uncontrollable project risks cause uncertainty in firms' cash flows, increase the cost of doing business in firms, which means providing funds and resources to the firm for project management. "The future is unpredictable, so it is unnecessary to plan for events that will never happen.

Listing the risks of a project is the first challenge in risk management. Unidentified risks are difficult to manage. Grouping risks as business risk, project risk, and mission risk makes it easy to analyze risks. Some of the operational risks occur outside the control of the project manager, but all are observable and can be directed accordingly if identified in a timely manner. If the risks are determined separately for each task, it becomes easier to take precautions by following the risks in the project. A well-detected problem is a half-solved problem.

2.9. Techniques in Risk Analyses

Identifying and measuring project-related risks and evaluating risky projects are not easy tasks. There are several advanced techniques that use probability concepts to measure uncertainty about economic alternative" (Rose, 1976). Some of them are written as below;

- Expected Net Present Value Method
- Decision Tree Method ((Ahmed, 2007), de (De Reyck, 2008)).
- Correlation in Risk Analysis
- Simulation Methods- Monte Carlo, Pertmaster, Palisade etc.
- Multi criteria decision method (MCDM) ((Ahmed, 2007).
- Failure mode effect analyses (FMEA) ((Ahmed, 2007), (Wang, 2009)).
- Correlation in Risk Analysis
- CPM and PERT Analyses

2.9.1. Pertmaster Primavera Risk Analyses

Since the schedule risk analysis in Tanap Project is done through this software, it is mentioned simply. It is Monte Carlo based software. It is a decision support tool for questioning how secure the developed plans for managing time, resource and cost risk are. The program provides the application of qualitative and quantitative risk analysis techniques to time, resource and cost dimensions. Models risks and uncertainties and relates them to project schedule and cost estimates. Risk templates and risk records for projects

It is loaded with and analyzed with Monte Carlo simulation. In addition, risk points and degree of confidence in plans can be determined using risk histograms, tornado and scatter plots before risk-adjusted plans are converted into live actionable plans. Risks; to risk ratios that the computer program can understand. should be brought. The results will also appear in the histograms.

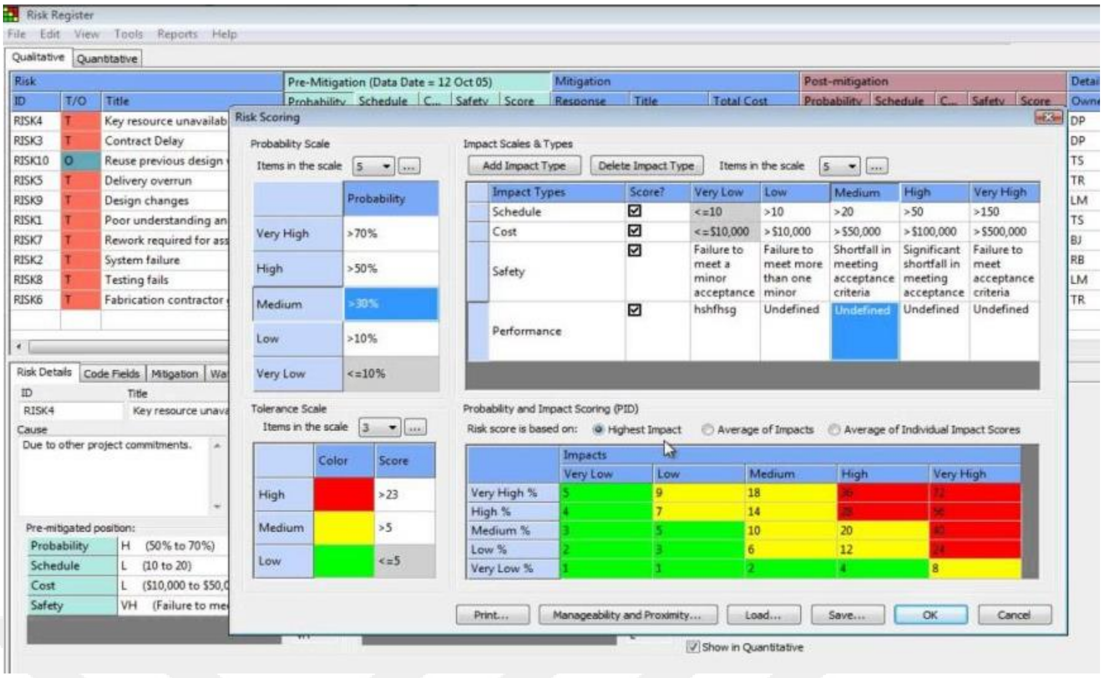


Figure 2.3: Sample of Primavera Pertmaster Risk Analyses

2.10. Risk Response Plans or Attitudes

According to PMI® Risk Response Plans can be created under the following 4 headings. Which is also used at Tanap project too. After Risk analyses , Risk Team has decided to apply a mitigation plan or response plan and then risk will be analyized again to make sure that risk score is accaptable ranges such as medium or less.

- Avoidance: Avoiding the risk that may arise by making changes in the project plan. In short, do not look for other ways to get the job done.
- Transfer: Transfer the risk to another institution or individual. In this application, the risk will not be eliminated, only the responsibility of the risk will be assumed by someone else. In this way, while the risk response plan is being prepared, insurance companies are also a contractor of the project.
- Mitigation: It is the study of creating a risk response plan by taking additional measures to reduce the impact or probability of occurrence of these risks after identifying the risks that may be encountered. In response to the risk of delaying the project duration, we can reduce the likelihood of the risk by hiring additional human resources (by increasing the budget).
- Acceptance: Acceptance is also a risk response plan. Trying to take precautions against all the identified risks can increase the project budget considerably. Therefore, the risks that can be ignored are accepted by the project parties. In

this case, the project parties monitor such risks throughout the project and initiate other response plans when they are more likely to affect the project.

2.11. Artificial Intelligence-based Risk management

In the field of risk management, many studies have been carried out to benefit from the logic of AI-Artificial Intelligence.

(Paek, 1993) aimed to use fuzzy sets for the bid price approach in construction projects. They analyzed the risks resulting in loss of money in construction contracts, and proposed a risk pricing method, which is represented by fuzzy sets related to construction projects and considers uncertainty.

Construction risks are classified in many ways by risk types (i.e., natures and magnitudes, etc.), the sources and/or origins, or the project phase ((Chapman, 1987); (Edwards, 1998) ; (Klemetti, 2006); (He, 2006)). Some present-day researchers propose a hierarchical structure of risks, which classifies risks according to their origin and the location at which the risk impacts on the project ((Tah, 2000); (Wirba, 1996).

Other advanced approaches have been proposed as follows: A Monte Carlo Simulation (Wirba, 1996) for stochastic quantitative modeling and analysis; a scenario analysis (Rainer, 1991) and fuzzy set theory for qualitative judgments (Rainer, 1991). There are many factors which should be considered when a project risk manager selects a risk assessment method, i.e., the cost of employing the technique, the level of any external party`s approval, the organizational structure, agreement, adoptability, complexity, completeness, level of risk, organizational size, organizational security philosophy, consistency, usability, feasibility, validity, credibility, and automation (Lichtenstein, 1996).

(Wirba, 1996) also developed a model using verbal variables and quantifying the similarity of occurrence of a risk event, the level of dependency between risks and the significance of a risk event, using verbal variables and fuzzy logic.

The simple classical methods integrate deterministic risk modeling and analysis into CPM scheduling. The deterministic methods include sensitivity analysis (White, 1995), the critical path method ((Kaufmann, 1988)), fault tree analysis (Terano, 1992), event tree analysis (Huang, 2001), failure modes, and effects and criticality analysis, etc. (Bowles, 1995).

(Tah, 2000) presented the computer program called PRIME and the infrastructure of this model, which they developed using fuzzy logic approach for risk assessment in their three studies. Developed system; It consists of I-Identification of Risks, II-Evaluation of Risks, III-Risk Analysis, IV-Risk Processing and V-Risk Size Determination. Depending on the risk sources, risk factors are classified as internal and external risks. It is stated that external risks are uncontrollable and should be monitored continuously throughout the project period, while internal risks are controllable because they are related to the project. After defining the probabilities and severity of the risks identified for the project as low, low-medium, medium, medium-high and high, the duration, cost, quality and safety risk sizes of the project can be calculated using PRIME.

(Dikmen, 2007) presented a model of evaluating the risk of contract price in international construction projects with a fuzzy logic approach. Contract price risk is divided into two risk groups at country and project level. According to this classification, the magnitudes of country and project risks were calculated separately, and the resulting risk sizes of these groups were determined by considering the experience of the contractor regarding this country or the project and the terms of the contract. The effect of both groups of risks on the contract value was calculated again with the fuzzy logic approach. It is stated that the experience of the contractor in the country or the project and the terms of the contract will be more effective on risk than other risk factors. If the contractor has experience in similar projects, the expected project risk will be low and the contractor will be more advantageous for this project than other companies.

(Hastak, 2000)presented a risk assessment model for international construction projects in their study called ICRAM-1 (International Construction Risk Assessment Model-1). According to this model, it is suggested that risks should be evaluated at three different levels. These are defined as I-Country Level, II-Market Level and III-Project Level. All three levels defined include both tangible indicators (increase in inflation, foreign exchange reserves, etc.) and intangible indicators (government's attitude towards foreign entrepreneurs, markets' suitability for technological developments, etc.).

(Hastak, 2000) state that in no existing model, all three levels of intangible and tangible risks faced by foreign companies operating in the construction sector and the effects of these levels on each other are not examined, and the proposed ICRAM-1 model will fill this important gap.

Assessing risks is a step which prioritizes the risks for further analysis by quantifying their occurrence rates. The risk assessment method is an essential component of this step. The existing methods are classified into (1) simple classical methods, and (2) advanced mathematical models (KarimiAzari, 2011). The existing risk assessment methods are either qualitative or quantitative and require different information and levels of detail (Bennett, 1996)

When the previous approaches to the use of fuzzy logic and Adaptive Neuro Fuzzy Inference System (ANFIS) in project risk management are examined, approaches that target a partial area or focus on specific types of risk in their application to construction projects are 1-2 examples found in the literature. One of them is an empirical study on probability and effect (Ebrat, 2014). In the other; It is a study on the problem of crowding in train stations (Alawad, 2020).

The studies are general and representative not enough to apply in all areas, and scalable and robust in solving the main problems in an industrial construction field. It can be said that serious thought in the construction industry requires the presentation of information that is general enough to be applied throughout the entire project service life and throughout the construction resource chain, and enough to be applied in practice.

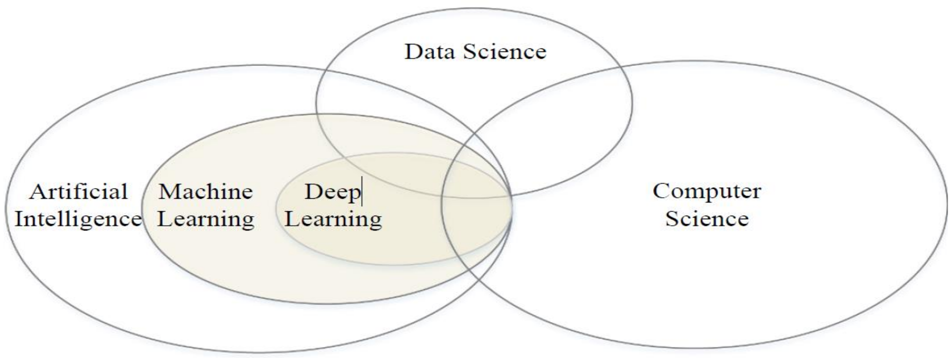


Figure 2.4: Venn diagram representing the components of AI adapted from (Goodfellow, 2016)

2.11.1. Contributions of AI-based (ANFIS) in Risk Management

Risk management is a complex system whose stages are difficult to observe. In addition, high quality data is required for statistical and operational risk analysis techniques such as decision tree, sensitivity analysis, and Monte Carlo analysis to produce more logical results. However, it is very difficult to obtain such quality data in the construction industry. In addition, due to these reasons, such techniques cannot be generalized, categorize risks as limited, and make limited analysis. In other words, these techniques do not fully respond to risk analysis.

Therefore, in recent years, the use of techniques such as fuzzy logic clusters and Adaptive Network Based Fuzzy Inference System (ANFIS) has become increasingly common. These techniques, in turn, diversify the limited applications of risk analysis techniques that are still valid in the literature, allowing for a more general approach to classifying, analyzing and responding to risks. However, risk management systems created using techniques such as fuzzy logic clusters and Adaptive Network Based Fuzzy Inference System (ANFIS) are also valid in a limited area and not generally representative. However, with the increase in artificial intelligence integration, these systems will be used more and create an effective risk management structure.

As a result, the development of computer technology enables the identification and analysis of risks, leading to the development of software or models where users can systematically monitor their management processes and to take an active role in risk management.

In order to minimize the effects of possible risks on people, the environment and the project in industrial establishments, it is necessary to ensure a high level, effective and continuous risk update. In this context, Industrial facilities or projects are expected to make decisions with the highest level of accuracy possible, using the Risk Assessment Methods, with the Fuzzy Inference System Based on Adaptive Network Structure (ANFIS).

Models have been developed for risk management, risks and probability of occurrence of hazards in projects with risks and hazards, by handling them with Adaptive Network Based Fuzzy Inference System (ANFIS). The performances of the developed models were evaluated in terms of the coefficient of determination (R2) and the Root Mean Square Error criteria. With the model developed with the Adaptive Network Structure Based Fuzzy Inference System (ANFIS), training can be carried out by applying the input and desired output values to the network repeatedly, and learning that predicts the frequency of possible risks can be realized by minimizing errors.

2.12. BIM-based Risk Management System

There is no much literature that discusses Project Risks and BIM system integration in details. Because these systems are widely based on the knowledge and understanding of the experts in the company. Specific BIM tools are described when talking about the risks associated with the BIM System. For instance; crush analysis tools and security planning (Tomek, 2014). However, the risk management knowledge area covers the processes of identifying the risks that may occur at each stage of the project, prioritizing them, determining the possible effects on the project, developing the reactions to these effects, and monitoring the effectiveness of the risks and responses given during the project. For this reason, BIM-based risk management studies take place in the literature, especially in relation to other knowledge areas such as occupational health and safety (Zou, 2016).

2.12.1. Contributions of BIM in risk management

With the most basic definition of BIM, it is the digital depiction of the physical and functional properties of a building. According to another definition, the concept is the concept of an intelligent 3D virtual building model in which the features of all the elements that make up the building can be digitally constructed before the project. It is stated as optimizing construction with low risk and high value.

Since the documents shared within the scope of the project through the data exchange platform are not used in manual systems, the risks of erroneous measurements or erroneous costs can be minimized by supporting communication between stakeholders or eliminating other integrated process methods. BIM System applications use parametric modeling. Parametric Modeling; It is the process of defining the model with certain variables in the computer aided modeling process and making the desired change easily by entering these variables with the program interface.

Advantages of modelling; Automatic updating of the model with the change made in the design, Section, size, material, etc. of an element. Easy identification of changes in the structural behavior of the model when its properties are changed, Easy identification and automatic creation of structural elements of the model, Integration with production processes to reduce production time.

To using BIM Systems, design deficiencies or errors can be reduced with the help of data exchange platform. The main benefit of BIM-based systems is that it can reduce the mistakes get by the project stakeholders such engineering and quality teams by contacting the relevant departments by using the conflict detection mechanism through visualization. By integrating this feature into risk planning and management, risks can be visualized.

BIM based systems Ideal for high cost and high-risk projects. Making BIM Systems accessible to all stakeholders will improve communication and collaboration, thereby reducing consolidation risks among project actors (Ammari, 2014).

In projects using BIM system integration, cost or time risks can be reduced by obtaining earlier and more reliable estimates. This helps make systems more reliable.

BIM-based systems significantly reduce costs from bidding and tender risks as they reduce process uncertainties associated with material procurement. In addition, BIM System that get to identify risks such as conflict or conflict detection and security planning (Tomek, 2014).

2.12.2. Communication

Communications management plays an important role in the analysis, planning and management of project risks so that information dissemination can take place with the required frequency and quality. Thanks to the continuous transfer of change and innovation, a project failure can be detected early.

Perceptive may change or be updated due to differences in risk appetites, assumptions and concepts, and stakeholders' needs, comments, issues, and concerns about risk or the issues being discussed. Because stakeholders can have a significant impact on decisions made, it is crucial to identify and document perceptions of benefit as well as risk perceptions, and to understand and address their underlying causes **(Cioffi, 2005)**.

Adoption of BIM-based systems brings increased communication opportunities. Since these systems are 3D, it helps to establish an effective communication mechanism between stakeholders, such as owners, architects, engineer consultants, contractors, fabricators and potential operators, as they are much closer to everyday reality, which improves the understanding of design ((Deutsch, 2011); (Eastman, 2011)).

Because a BIM-based model is also in a 4D model environment, it has a good advantage in visualizing the construction phases and especially the risks that can improve communication: (Eastman, 2011) explains it this way: 'Planners can communicate the planned construction process to all project stakeholders visually. A 4D model captures both the temporal and spatial aspects of a chart and makes it more effective to understand than a traditional Gantt chart'. It can also visually communicate the risk planning and management process to all project stakeholders with a well-designed method.

(Bryde, 2013) In some case studies on BIM-based systems and communication; 'Communication management in BIM systems was completely positive. The main benefits of communication management are: 'facilitating the exchange of information', 'information is much easier to access and then use' and 'to manage diversity well'.

The McGraw-Hill construction report (2010) examined the advantages of BIM-based systems in construction projects. The clearest result of the study is that the biggest advantage in construction management is that when BIM-based systems are used, a better understanding of collective design emerges and it becomes clearer that the underlying thoughts of the different parties are shown in figure 7.

Project Stakeholders involved in the project often clash with each other when it is not fully understood what their discourse or views are. An improvement at this stage of the project phase will result in an improvement in cooperation as there will be less conflict between different stakeholders. In the end, this system improves the quality of the overall project and the benefits of communication management are maximized.

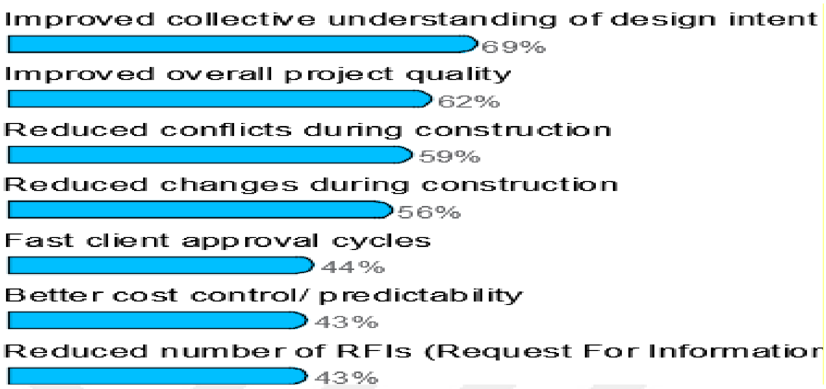


Figure 2.5: Biggest advantages according to BIM users, (Constructions, 2010)

2.12.3. Opportunities for a BIM-based risk management tool

Based on the parts clearly expressed by the literature review; It can be concluded that Project Communication management is the most important parameter in Project risk management.

(Tah, 2000) emphasizes that communication in project risk management was weak, incomplete and inconsistent throughout the project process. In addition, Project stakeholders often do not have the same opinion about the project risk or risks. For this reason, in processes where there is no consensus, they cannot implement sufficiently effective measures and mitigation strategies with the problems arising from the decisions taken. This is a basic indicator of the lack of communication management. It is essential that different stakeholders, who have basic knowledge in the project management stages, manage the communication in an open and efficient manner. This study aims to develop a tool that can be implemented in a BIM-based construction project where risks can be easily specified or identified and project stakeholders can be visualized.

This helps Project risk managers respond more efficiently to project risks. It helps all stakeholders involved in the project process to better understand what actions need to be taken and what the rationale for it is. It also helps project risk management activities to be more easily traceable, which is important for improving the methods and tools to be implemented (Purdy, 2009).

Studies investigating the application of BIM-based tools to visualize processes in construction project management are available in the literature. (Hartmann, 2012) examined the application of a BIM-based tool to overcome the problems experienced in project management processes. Among others; (Kang, 2013) developed a 4D object-based system to visualize project risk management info's, focusing on time, cost, and operating conditions.

Some other situations seen in literature reviews; They discuss the use of BIM-based systems to visualize certain parts in construction project management processes. For example, (Mushamalirwa, 2016) proposed a tool to visualize cost and time performance during construction project stages in a 3D model by developing a color-based coding system in his research study. (Sacks, 2013) proposed a 'KanBIM' tool. Its main purpose is to combine a lean management system with a BIM-based system. The tool proposed in this thesis can be based, among others, on this research. The main aim of the study is to visualize the risks and try to make the risks clear by using a color/linguistic code system by focusing on an artificial intelligence assessment-based risk score or rubric in a 4D environment.

2.13. Summary

In this chapter; In general, the definition of risk was emphasized. The risk categories in the projects are mentioned. Risk Management is explained in general terms. Risk Analysis techniques and response plans are explained by scanning the literature.

For artificial intelligence based and BIM based risk management, literature review has been done and its benefits have been mentioned in this chapter.

CHAPTER 3

TANAP Projects and Risks Management Challenges

3.1. Brief Project Description

Trans-Anatolian Natural Gas Pipeline (TANAP) Project is part of the Southern Gas Corridor, which aims to transport natural gas from Shah Deniz 2 Gas Field and other fields in the South Caspian Sea to Turkey and Europe in Azerbaijan.

The Southern Gas Corridor comprises the South Caucasus Pipeline (SCP), TANAP and the Trans-Adriatic Pipeline (TAP) as shown in Figure 3.1.

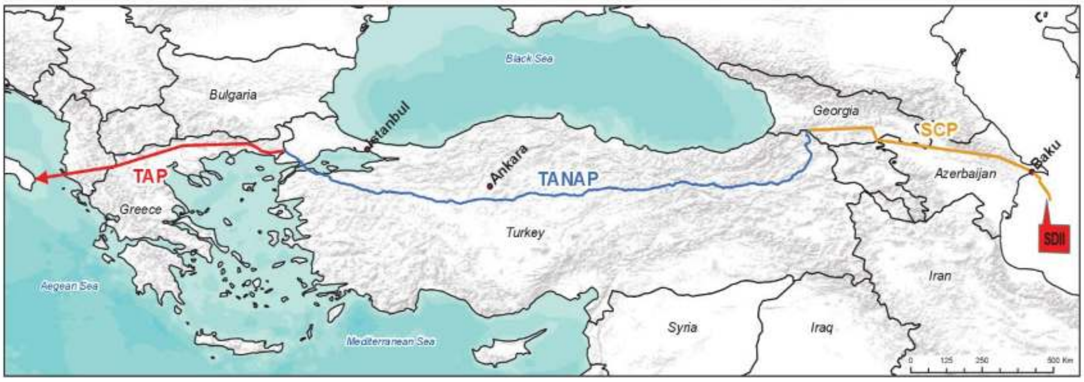


Figure 3.1: The site location map showing the southern gas corridor the South Caucasus Pipeline (SCP), TANAP and the Trans-Adriatic Pipeline (TAP)

TANAP Project is a 56-inch and 48-inch pipeline system of 1850 km, and will transport natural gas to the required specifications and quantity in stages starting with 16 bcma as initial phase leading up to a high flow case of 31 bcma which is the last phase. 6 bcma will be delivered to BOTAŞ (Boru Hatları ile Petrol Taşıma A.Ş.) to be used within the Republic of Turkey via off-take stations by Gas Transport Agreement (GTA).

The construction of the Project is expected to last for 4 years, and a phased approach will be pursued where the target for completion of the construction and starting operation is by the middle of 2018. The initial capacity of 16 bcma (First Stage) is expected to expand to 24 bcma by 2023 (Second Stage) and to 31 bcma by 2026 (Third Stage), upon construction of the required additional compressor stations.

TANAP is planned to begin from the Georgia/Turkey border and go through the provincial borders of Ardahan, Kars, Erzurum, Erzincan, Bayburt, Gümüşhane, Giresun, Sivas, Yozgat, Kırşehir, Kırıkkale, Ankara, Eskişehir, Bilecik, Kütahya, Bursa, Balıkesir, Çanakkale, Tekirdağ and Edirne.

At the beginning of process the pipeline was planned to be divided into two branches after crossing Marmara Sea and the second branch would pass Tekirdağ and enter Bulgaria through Kırklareli. However, due to the change in the marketing strategy of Azerbaijan, natural gas to Europe by the Bulgarian section was cancelled. The baseline studies were performed for both sections and the baseline reports include all the results.The cancelled section is indicated with yellow line in Figure 3.2.

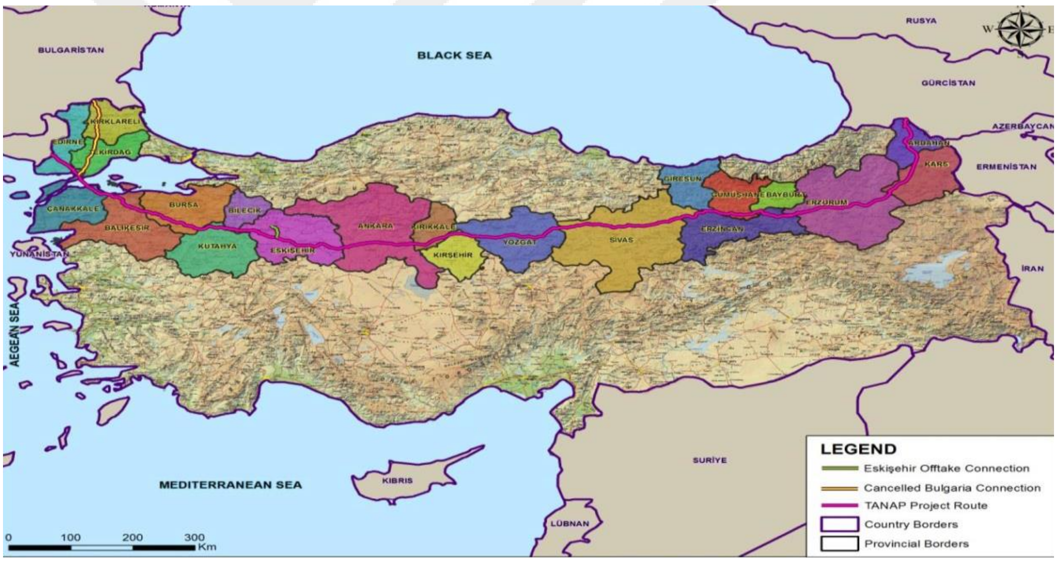


Figure 3.2: TANAP Project Route

The TANAP system will be fully automated with main and back-up control centres to meet the requirements of gas transmissions and associated environmental and safety considerations. The main pipeline facilities include the required number of compression facilities, block valve stations, distribution and custody transfer metering facilities. The pipeline crosses terrain with challenging geotechnical features, including landslides and other geo-hazards, in addition to crossing regions with different levels of urbanization and economic activity.

TANAP, for the purpose of the project, includes:

1. Onshore pipeline:

- A main natural gas pipeline from the Turkey/Georgia border to the Turkey/Greece border
- Diameter: 56 inches to the Eskişehir Compressor Station and 48 inches from Eskişehir
- Compressor Station to the Turkey/Greece border
- Total pipe length: 1850 km
- Onshore length: 1832 km
- Nominal capacity: 31 bcma in high-flow case
- Design Pressure: 95.5 barg

2. Offshore pipeline section:

- Looping at Marmara Sea crossing
- Diameter: 2 x 36 inches
- Length: 18 km, approximately.

3. Compressor Stations:

- 7 compressor stations (2 at First Stage, 2 more at Second Stage, and 3 more at ThirdStage) at intermediate points for fulfilling pressure requirements. A separate compressortrain is foreseen for the gas supply to BOTAS

4. Metering Stations:

- 1 custody receiving border metering station at the entry point
- 1 delivery border metering station at the exit point.
- 2 fiscal metering stations at Eskişehir and Thrace Offtakes

5. Pig Launcher and Receiver facilities:3

- at each compressor station (including phase compressors)
- at each metering station
- at both sides of the shore approaches of the Dardanelles Strait Crossing

6. Block Valve Stations:

- 49 in accordance with ASME B31.8, 2012 requirements.

7. Off-take Points:

- 2 in Turkey, with metering stations.

8. Supervisory Control and Data Acquisition (SCADA) automation, control and Telecommunication equipment:

- Main Control Centre in Ankara, Turkey.
- Back-up Control Centre located with Compressor Station CST-5A in Eskişehir, Turkey

3.2. Risk Assessment Purposes on Project

The purpose of this Risk Management is to outline the threat and opportunity management activities that will be undertaken for the TANAP project. This RM outlines the procedures and processes that will be used to manage project threats and opportunities throughout the life of the project. This updated RM flows will be used progressively on the project and will have retrospective application only when agreed by CLIENT.

The process will help ensure that the Project is designed, constructed, commissioned, operated and maintained with an acceptable level of risk to its financial viability, the environment, the community and the health and safety of personnel and plant integrity.

Risk management will involve identification, assessment and management of threats and opportunities with the ability to impact any of the objectives including those relating to:

- Health & Safety
- Natural Environment
- Assets
- Schedule /Production
- Project Return
- Community / Government
- Reputation
- Security

3.3. Process Overview

The TANAP Project will execute a formalised risk management process for the identification and management of all Project-related risks (threats and opportunities). The basic driver behind these processes is to identify and manage Project risks so that the best objectives can be achieved.

Although there are different areas (HSSE, project, technical, cost and schedule) of risk management within the Project, th basic process follows the same overarching methodology. The process defined within this Risk Management Plan is based broadly on the International Standard, (Purdy, 2009), “Risk Management- Principles and Guidelines. The Project Risk Management Procedure should be followed as part of the implementation of the Risk Management Plan.

The process involves the following steps:

- The risks are identified, generally by a facilitated brainstorming session or the use of key guidewords involving key stakeholders in the project.
- The risks are evaluated, analysed and prioritised into broad categories (e.g. high, medium and low risks) based on the probability of the risk occurring and the impacts if it were to materialise.
- The critical risks are assessed and treated. Treatment can include actions to reduce either the Probability or the Impact or both, the transfer of risks to another party more suitable to accept such risks, or the acceptance and on-going management of a risk. The treatment of a risk will generally involve allocating some resources/money to implement the treatment.
- Opportunities are also identified utilising this process by focusing on the possible additional benefits which could be materialised either through technical design or through considering the wider context in which the project operates. Details of the specific areas of risk management are documented in the following sub-sections.

3.4. Risk Matrix

The overarching risk matrix to be used for all risk-based assessments is derived from TANAP Risk Management Procedure(It is an internal document) and which has been modified specifically to align with the Project’s objectives. The risk matrix, impact and probability criteria to be used on the project are presented below figure.

INCREASING PROBAPILITY ↑	INCREASING IMPACT → 1 Low	2 Medium	3 High	4 Major	5 Massive	6 Catastrophic
F Frequent	1F	2F	3F	4F	5F	6F
E Often	1E	2E	3E	4E	5E High Risk	6E
D Probable	1D	2D	3D	4D Medium Risk	5D	6D
C Seldom	1C	2C	3C Low Risk	4C	5C	6C
B Unlikely	1B Notable Risk	2B	3B	4B	5B	6B
A Rare	1A	2A	3A	4A	5A	6A

Figure 3.3: Risk Matrix

Risk Level	High Level Risk Management Actions
High	Develop robust Risk Treatment Plan to take action with the aim of reducing the risk. These RTP must be implemented even if they require significant resources or fundamental changes in the activities and systems.
Medium	These risks fall in the yellow region in the risk matrix. Monitor the risk and take reasonable actions to further reduce the risk. There should be a transparent bias on the side of Health & Safety. The RTP should correspond to relevant good practice
Low	Monitor the risk and take reasonable actions to further reduce the risk without introducing extra cost to the Project.
Notable	Monitor the risk and prevent occurrence where possible or control the consequences.

Figure 3.4: Risk Priority

The Risk Priority Levels (Figure 3.4) define the 4 priority levels in the risk matrix. Risk Prioritization stimulates the utilization of available resources in the most effective manner and targets the most critical risks first.

3.5. Project Risk Process

The Project will utilize the Primavera risk management software and Palisade risk to aid in the overall project risk analysis process. This process covers seven key steps and is discussed in detail below. Risk workshops will be organized by Risk Manager in collaboration with Tanap and Risk Team. Project Director will advise the discipline

Managers/Leads that will attend the risk workshop and it is taken that the attendees are competent in their respective fields as subject matter experts to identify and evaluate risks. At the commencement of the risk workshop, session objectives and overview of the risk management process will be given as training to the attendees.

The risk process is cyclical being broadly based on (Purdy, 2009) requiring that the Project:

- Establish the context
- Identify risks
- Analyse risks
- Evaluate risks
- Treat risks
- Monitor and review
- Communicate and consult

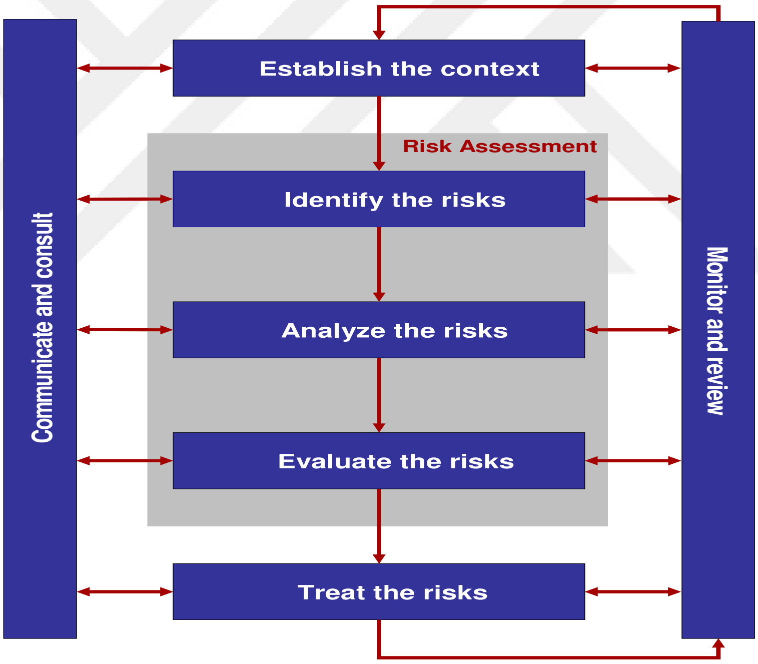


Figure 3.5: Risk Process

3.5.1. Establish the Context

- Define the parameters and scope for the risk workshop. The formal description of the context under which the risk session will proceed; a written statement is agreed up-front by the participants on the precise purpose of the session.
- Identify the key stakeholders in the project. Typically, the key stakeholders encompass a broad group including government, Customer, suppliers and non-

government organizations. They are identified during the risk workshops by the attendees.

- List assumptions and limitations. This is also done during the risk workshop by the attendees and this ensures alignment.
- Overview the project and internal/external environment context.
- Identify the key success factors for the project and of the needs of the key stakeholders - by definition, a risk is anything that impacts on these.
- Lessons learnt. Participants review and discuss lessons learnt from previous projects / experience and how this information may assist in the achievement of the key success factors. These lessons may be taken from the active lessons on the corporate lessons learnt database.
- Review the probability and impact risk criteria as defined for the Project.

3.5.2. Identify Risks

Risk is identified in two ways, either during risk workshops or on an ongoing basis outside the workshop environment.

In determining the attendees to risk workshops, the Project Director shall determine the appropriate participants based on the subject matter. Tanap collaboration shall be requested to finalise the attendee list. During the workshop, the following occurs:

i. A brainstorming session, aided with the use of the keyword risk brainstorming prompt list is used to identify and threats and opportunities. The prompt list contains key words to assist in the brainstorming of technical and non-technical risks such as under the following categories:
   - Regulations / Permissions
   - Contract and contract liabilities
   - Finance
   - Community / Cultural risk
   - Environmental risk
   - Health and Safety
   - Human Resources
   - Project Management / Plans
   - Design / Engineering
   - Quality
   - Procurement
   - Site / Construction

ii. Participants consider what could impact on the Project meeting the success factors identified during the establishing the context step. This may include review of any previous workshop findings.

Outside of the workshop environment any new risks identified shall use the Risk Threat and Opportunity Form. This form is to be submitted to the Risk Manager, who will discuss the risk with the Project Leadership team. If approved, the risk will be transferred to the Project Risk Register and Action Plan or Mitigation for management.

3.5.3 Analyse Risks

A qualitative risk analysis will be conducted for the identified risks. The participants will:

- Agree on a credible risk scenario and record the current controls.
- Agree on the risk scenario's impact, followed by the associated probability using the Project defined risk criteria.

3.5.4 Evaluate Risks

Once risks have been analysed they will be assigned and alphanumeric risk score (See Figure 10 – Risk Matrix) and a severity ranking, which determines their overall priority on the project. The ranking will fall in either Priority 1, 2, 3 or 4. Risks should be treated in order of priority. The table below summarises risk, priority and associated action required.

Table 3.1: Project Risk Severity Rating

Risk Severity Rating	Priority (1 is highest)	Action Required
High (Red)	1	Immediate attention.
Medium (Yellow)	2	Action as soon as practicable
Low (Green)	3	Low priority
Notable	4	Lowest priority

3.5.5 Treat Risks

In General ; Risk treatment should be relevant to its nature and severity. Risk treatment action plans (Risk Treatment Plans) are developed for high risks as a minimum. However, action plans for medium, low and notable risks should still be undertaken if the level of effort to undertake the action does not disproportionately outweigh the level of risk reduction possible through implementation. Possible ways to treat risks include (defined in the (Purdy, 2009)):

- Avoidance: Eliminating a specific threat, usually by eliminating the cause. The project management team can never eliminate all risk but specific risk events can often be eliminated.
- Mitigation: Reducing the probability of a risk (e.g. formal reviews, testing, quality assurance, preventative maintenance, project management). Reducing the impact of a risk (e.g. design features, structural and engineering barriers, change in activity, separation or relocation). Reducing both the probability and impact of a risk.
- Sharing or Transferring: Another party or parties bearing or sharing part of the risk; (e.g. includes the use of contracts, organisational structure such as Joint Ventures).
- Retaining or Accepting: For example, developing a contingency plan to execute should the risk event occur, PPE, signs etc. This may result in accepting the risk as defined currently (generally not acceptable for high risks and may require management sign-off).

All risks shall be assigned to a responsible person or risk owner (Accountable for Risk Response). Any risk treatment actions will be assigned to a Risk Action Party (which may or may not be the risk owner) with an expected completion date.

The output of this process is referred to as the Risk Register. The closure of risks due to its mitigation or inapplicability on the Risk Register shall be subject to CLIENT approval.

3.5.6 Monitor and Review

The Risk Register and Action Plan resulting from a risk workshop becomes an ongoing strategic project management tool and is kept alive throughout the Project. The Register:

- Requires regular monitoring and review. Risks and associated actions shall be formally reviewed monthly in one to one meetings or group sessions, or when there is a significant change in the project (e.g. Project enters a new phase).
- Requires review for any new or increased risks resulting from Project changes.

- Requires a person (Risk Manager) to be assigned the responsibility of monitoring and updating the action items
- Requires updating for any new risks identified and for the progress of the implementation of the action plan.
- May requires quarterly review of closed items with action parties to ensure any relevance.

3.5.7 Communicate and Consult

Communication and consultation are important elements of the risk management process. Specifically,

- Stakeholders in the Project shall be kept informed of risks that the Project faces and the plans to address the risks via the Project Risk Register.
- All relevant personnel on the Project will be consulted, through direct involvement in the workshops, with respect to risks in their particular area of responsibility and expertise. Appropriate personnel will be consulted with respect to the development of risk control plans. This consultation shall be performed as part of the risk workshop process and review of the resulting reports.
- New or amended risks that emerge during the course of the Project shall be communicated
- Assessed risk and treatment plans are to be reviewed and endorsed by the level of management appropriate to the nature and level of the risk
- The Project Risk Register will be available for all personnel working on the Project to view via a designated area on the project SharePoint site.

3.6. HSSE Risk Process

HSSE risk analysis covers the field execution aspects of the Project. The Project HSSE plan details the process and requirements for risk management related to the health and safety of personnel involved in the Project. The main risk register used for the management of HSSE related risks is the HSSE Hazard Register. This will not preclude any HSSE specific hazards and associated risks from being captured in the Project Risk Register, however, the two respective registers will not necessarily align on a like for like basis.

3.7. Technical Risk Process

Technical risk analysis covers the engineering and design components of the Project. It is a risk-based approach to planning, design development, decision making and engineering execution.

3.8. Cost Risk Process

The assessment of potential cost overrun and the estimation of appropriate contingency levels is an important element of project risk management as it typically addresses some of the major risks to a project.

The basis of the analysis will be the Project Risk Register. The analysis will be conducted by the Estimation Team.

Formal cost risk analyses (as detailed below) will be conducted in line with the Risk Analysis Procedure. These techniques will be used to establish the baseline cost and raise Project team awareness of change in risk criticality.

The cost risk analysis generally involves:

- Utilising the base cost generated by the Project as detailed in the Capital Cost Estimate.
- Analysing each element of the base cost to determine uncertainty ranges. The ranges will be quantified as minimum, most likely and maximum costs.
- Considering potential impact to the estimated values arising from uncertainties in scope, duration and productivity along with the impact of technological, environment, market conditions, and statutory requirements and experience factors.

The final agreed process is subject to discussions with CLIENT and the receipt of the Total Installed Cost estimate and Estimate Plan at the time of writing. The CAPEX Risk Analysis Report provides the process in detail as well as assumptions and limitations.

Risks are analysed by using Cost Risk Analysis software @ RISK. Contingency is established for anticipated, but undefined cost. Contingency is based upon risk and uncertainty within the current Project scope. A spreadsheet formula is used for data input. ‘Monte-Carlo’ simulation methods are used for sampling. Input data is modelled using the appropriate distribution functions that best suit the variables.

3.9. Schedule Risk Process

A qualitative schedule risk analysis will be performed to analyse the impact of risk events on the base schedule.

The results of the risk analysis assist with the following:

- Forecasting the most likely outcome of project completion.
- Identifying the elements of uncertainty that have the greatest impact on overall project schedule.
- Ranking of activities by uncertainty level.

The basis of the analysis will be the Project Risk Register. The analysis was conducted by the Planning Team. The TANAP Pipeline Project EPC Schedule Risk Analysis provides the process in detail as well as assumptions and limitations. The deterministic Risk Model will be created using Primavera Risk Analysis software. A draft model will be provided by CLIENT and this model will be amended / expanded to approximately 100 activities. This will be sufficient to give a robust risk analysis of the overall Project. The model utilises a similar Work Breakdown Structure to the Integrated Level 3 Schedule.

3.10. Risk Management Requirements

3.10.1 Competency

The Risk Manager will generally facilitate risk workshops. Where this is not the case, Risk facilitators for certain risk workshops shall be internally approved. The following risk facilitator types and approvals are itemised below:

- Project risk workshop facilitators need to be approved.
- Technical risk workshop facilitators specialising in HAZOPs need to be approved by the Safety and Risk engineering discipline, in accordance with HAZOP Guideline.These people are listed on the Safety and Risk Engineering Global Discipline Portal.
- Discipline Managers/Leads are deemed to be specialists in their field and are therefore competent to participate in the risk workshops.

- Decision settling shall be conducted during the Project Management Risk Review meetings with CLIENT and EPCM participation from Project Management.

3.10.2 Management of Change

Change can introduce new risks or change unfavourably current risk profiles identified on the Project and hence it is important that a robust change management process, which considers risk, is applied.

All changes impacting on the project shall be identified and managed in accordance with the Project Management of Change process as defined within the TANAP Project Change Management Procedure.

The risk impact of the change on the project shall be assessed in accordance with the Project Execution Plan with appropriate risk action plans put in place to control the risk.

3.10.3. Document and Record Management

All risk documentation generated on the Project, whether hard copy or electronic, shall be controlled in accordance with the Project's Document Management Plan and Data Management Plan.

The plans include EPCM' archiving requirements in accordance with the Location Archiving Plan and, as modified for the Project, additional statutory, CLIENT and Project specific document retention and management requirements.

3.10.4. Ongoing Project Risk Management

The following requirements apply to the Project risk undertakings:

Project Risk workshops to be facilitated by the Risk Manager or an approved EPCM risk facilitator.

Regular monthly review and updating of the Project Risk Register and Action Plan. This is to be led by the Risk Manager with participation from the project team.

Review of the current controls and status of action closure is to be undertaken. This review will be documented in a monthly risk management meeting report.

In addition to the monthly review, the Risk Register and Action Plan will be reviewed under any of the following circumstances:

- when there are substantive scope changes
- when entering a new project phase
- when additional risks are identified
- changes in the operating environment of the project (i.e. Management of Change)

Report monthly risk metrics for the Risk Register review session.

Deliverable:

- Initial Project Risk Register and Action Plan developed from the risk workshop. This comprises the meeting records and the retention of same.
- Project Risk Management Report from the initial risk workshop. This also comprises the meeting record and retention.
- Monthly Risk Register and Action Plan update for risk status, actions and target close out dates
- Monthly Risk Management report

3.10.5. Communication

The following communication requirements apply to the Project:

- Communicate Project Risk Management plan to Project team
- Communicate Risk Register location to Project team to enable viewing and action management for individuals with risk actions

3.10.6. Audit

The Project Assurance Plan and the Quality Management Plan establish the organisation, responsibilities and processes employed to achieve the defined quality assurance (QA) requirements of the Project.

Risk management, along with other project functions, will be audited against the Risk Management Plan and its associated procedures and forms.

3.10.7. Lessons Learnt

During the Project, any issues or non-conformances will be fully investigated when they arise. Appropriate root cause analysis tools will be utilised and resultant learning's will be incorporated into the Project Risk Register. These learning are shared through the Project and WorleyParsons operational networks.

Towards the end of the Project, before key personnel are demobilized, a facilitated 'lessons learnt' workshop will be conducted in accordance with the Lessons Learnt Guideline. The lessons identified will be recorded on the Lessons Learnt Register and uploaded onto the EPCM Lessons Learnt Database.

3.10.8. Project Close out

On completion of project, identification of any outstanding risks that need to be handed over to the Customer. These include but are not limited to items such as the Risk Register, HAZOP actions, HSSE Hazard register etc.

<u>Deliverable:</u>

- Final revision of Risk Register with action status
- Risk related registers and actions as defined in the Project HSSE Plan and Project Engineering Plan.

3.11. Summary

In this section, the risk management and assessment applied in the Tanap Project are explained in detail. The Tanap project, which was selected as the best project in the world in 2020 by PMI, is a project where risk management is well implemented. In the next section, information will be given on Artificial Intelligence and BIM.

CHAPTER 4

ANFIS and Building Information Modelling (BIM) as the Way Forward for better Risk Management

4.1. Artificial Neural Networks(ANN)

Artificial neural networks (ANNs) are algorithms developed with the aim of directly realizing abilities such as deriving new information, creating and discovering new information through learning, which are the characteristics of the human brain, without any assistance.

The human brain can be thought of as a perfect computer that can run very fast. Artificial neural networks have been developed inspired by the biological nervous system. The performances of biological neural networks are too high to be underestimated, and they are capable of processing complex events. With artificial neural networks, it is aimed to bring this ability to computers. Therefore, it is useful to briefly touch on the biological nervous system.

4.1.1. Biological Nerve Cells

Biological neural networks are one of the most fundamental stones that enable the human brain to work. It enables people to understand all their behaviors and their environment. Biological neural networks are a collection of many nerve cells in our brain. Nerve cells perform their functions by connecting with each other.

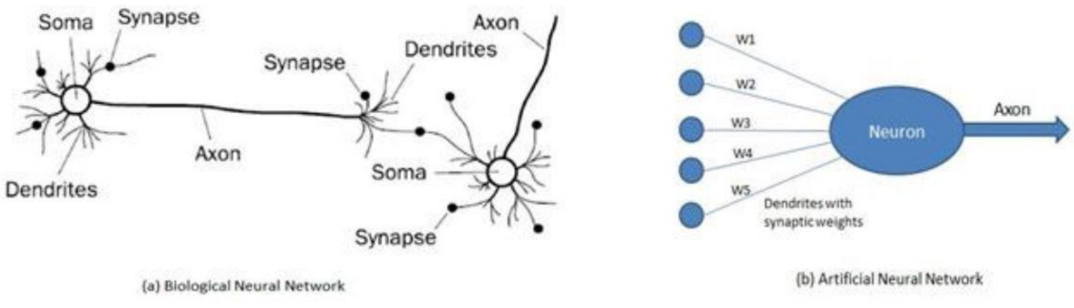


Figure 4.1: Biological Nerve Cells(a), Artificial Neural (b) (Bais, 2020)

Figure 4.1. In (a), a basic biological nerve cell consists of synapses, soma, axon, and dendrites. Snaps can be seen as connections between nerve cells. These are not physical connections, but gaps that allow electrical signals to pass from one cell to another. These signals go to the soma. Then it processes these signals and creates its own electrical signal and sends it to the dendrites via the axon. Dendrites transfer these signals to the synapses and thus the signal flow continues from one cell to the other.

4.1.2. Artificial Neuron Cells

The ability to learn from data, generalize, work with an unlimited number of variables, etc., with ANNs that mimic the way the human brain works. It has many important features. Just as biological neural networks have nerve cells, artificial neural networks also have artificial nerve cells.

The smallest units that form the basis of ANN's work are called artificial nerve cells or process elements. (See Figure 4.1.(b)). An artificial neuron consists of 5 main components: inputs, weights, sum/addition function, activation function and output.

Generally, the sigmoid function is used as the activation function (See Figure 4.2). The formula for this function is as follows:

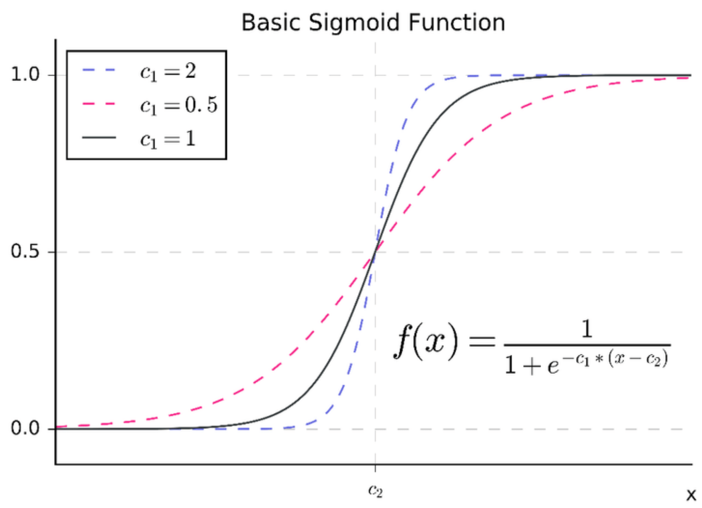


Figure 4.2: Function of Sigmoid (Leibovich-Raveh, 2018)

When shown as a network, a process element seems to have more than one output. This is for illustration purposes only. In fact, a single output value from a process element goes as input to more than one process element.

4.1.3. Structure of Artificial Neural Network

Artificial nerve cells come together to form an artificial neural network. In general, cells come together in 3 layers. These layers are:

- Input layer
- Interlayer(s)
- Output layer (Figure 4.3)

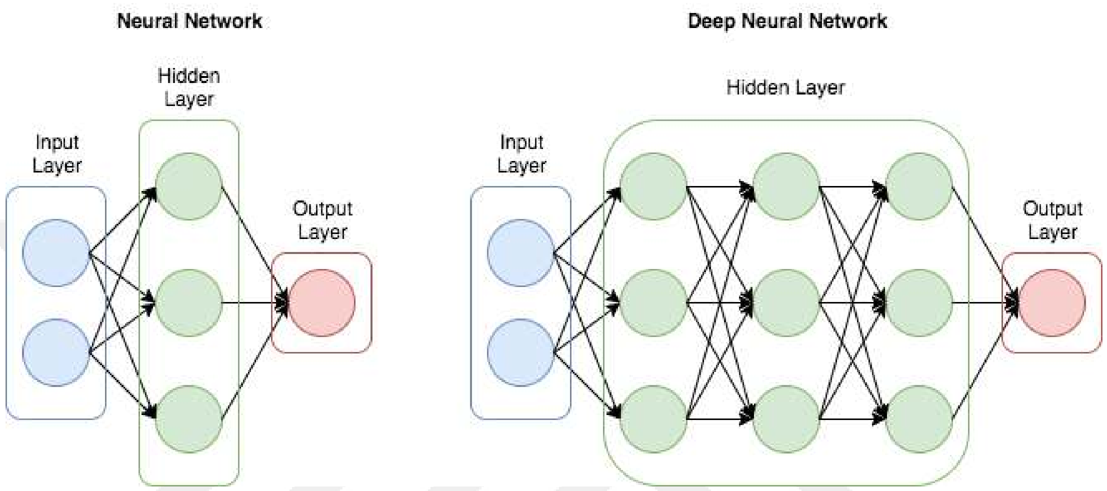


Figure 4.3: Structure of Multilayer Artificial Neural Network

4.1.4. Learning in Neural Networks

Determining the weight values of the connections of the process elements in artificial neural networks is called "training the network". Initially, these weights are randomly assigned, and ANN changes these weights as samples are shown. Changing the values of the weights is carried out according to certain rules. These rules are called "learning rules" (Öztemel, 2006).

The learning event has two stages. In the first step, the output that the network will produce is determined for the example shown to the network. In the second stage, the weights of the connections are changed according to the accuracy of this output value.

Reaching the correct weight values of the network means that it has the ability to make generalizations about the event represented by the samples. The process of acquiring this generalization feature is called network learning. The tests made to measure whether the network learns (performance) after the training is completed is called testing the network. It is tested using samples that the network has not seen before.

The weight values of the mesh do not change during testing. The accuracy of the outputs obtained in the test phase gives information about the learning of the network.

The ability of artificial neural networks to interpret (generalize) about unknown examples by extracting certain information from known examples is called “Adaptive learning”.

4.1.5. General Properties of ANN

Artificial neural networks create their own experiences with the information they obtain from the examples and then make similar decisions in similar situations.

- In artificial neural networks, information is measured by the values of the connections in the network, that is, the information is hidden on the network.
- The fact that the information is distributed on the network indicates that they have a distributed memory.
- They can only work with numerical information.
- After ANN is trained, they can work with incomplete information and produce results even though there is incomplete information in new samples.
- They can process vague, incomplete information. After learning about the events, they can make decisions by establishing relationships about the events.

Artificial neural networks can be considered as one of the most up-to-date and perfect pattern recognizers and classifiers developed today. With the ability to work with incomplete information and process abnormal data, many problems that cannot be solved with traditional computer software technologies can be solved with artificial neural networks. Especially in jobs that require processing a large number of data, very advantageous results can be obtained.

4.1.6. Advantages of Artificial Neural Networks

Artificial neural networks can solve complex problems that are not possible or difficult to model mathematically, by modeling very easily (Öztemel, 2006).

In order to successfully solve problems using artificial neural networks, the problem must be modeled very well.

- This modeling will only help to identify and collect examples related to the event in question in order to solve the problem. There is no need for any prior knowledge other than the examples.
- For artificial neural networks, it is not important whether the relationships between events are linear or not. Unlike traditional systems, it is not difficult to model nonlinear relationships with artificial neural networks. Decisions made by the example-learning network are more realistic as they do not involve assumptions.
- Artificial neural network applications are cheaper in terms of both practicality and cost.
- Artificial neural networks work very efficiently in terms of time.
- Artificial neural networks can be retrained when new information emerges and some changes occur in the environment, ie they are adaptive.
- The fact that artificial neural networks can work in parallel facilitates their real-time use.

4.1.7. Disadvantages of artificial neural networks

Artificial neural networks have many advantages as well as some disadvantages. These:

- There is no rule set for creating artificial neural networks, choosing a model, and determining the topology of the network.
- Artificial neural networks can produce acceptable solutions, they do not guarantee the optimum solution.
- Since artificial neural networks only work with numerical information, the problem needs to be converted to numerical representation.
- The behavior of the network is not explainable. When a solution is produced for a problem, it is not possible to find information on how and why it is produced. This reduces the confidence in the result of the network. It limits the usage areas especially in the problems related to human life.
- It may take a long time to carry out the training.
- Hardware dependent operation of artificial neural networks can be seen as an important problem. Their ability to process real-time information depends on

their ability to run on parallel processors. Most computers today can operate in series. Performing parallel operations on serial machines causes loss of time.

- Artificial neural networks are generally seen to be applied to perform the following functions: Prediction, Classification, Data association, Data filtering, Recognition and matching, Diagnosis, Interpretation (Öztemel, 2006).

4.2. Fuzzy Logic

4.2.1. Fuzzy Logic Concept

Classical logic is based on the assumption that "every proposition is either true or false". However, the accuracy of some propositions may be uncertain due to the fundamental limitations of the measurements. In fuzzy logic, a third proposition called uncertainty is put forward between two propositions in classical logic. Thus, the true and false truth values of classical bivalent logic have been made more flexible. The subject of fuzzy logic was first introduced by Zadeh in 1965 (Zadeh L. , 1965).

In this study, Zadeh attributes the reason why people can control some systems better than machines, because people have the ability to make decisions using certain (uncertain) information. According to L. Zadeh, fuzzy logic in the narrow sense is approximate/predictive reasoning logic that can be considered as an extension and generalization of very valuable logic. In a broad sense, fuzzy logic is an extension of the theory of fuzzy sets (Zadeh L. A., 1973). According to Zadeh, fuzzy logic and fuzzy set theory says:

“There is no such thing as certainty. There is nothing that is absolutely certain. Everything changes in the border between 0 and 1, to put it mathematically” (Semed, 2000). The International Fuzzy Systems Association held a conference in Tokyo in 1987. With this conference, a sudden increase in interest in fuzzy logic was observed. At this conference, a robot programmed with fuzzy logic managed to leave a flower on a thin stick without falling.

More intriguing than that was the fact that a bystander who saw the robot do this offered the engineer to remove a circuit from the system. The engineer did not accept this because he was worried that the flower would fall when he removed the circuit, but when the audience said that he wanted to see which way the flower would fall, he removed the circuit. When the robot dropped the flower on the stick with the same precision, no one could hide his surprise. Even if insufficient information is provided, fuzzy logic systems can perform conclusive logical operations using a kind of "common sense", that is, with the help of available information, just like humans do. Similarly, fuzzy logic systems used in cameras minimize image disturbances caused by concussions (Isıklı, 2008).

Fuzzy logic operations consist of analyzing and defining a problem, transforming the information found into fuzzy sets without developing variable sets and logic relations, and interpreting the model. The fuzzy logic algorithm may not be suitable for all kinds of problems. In case another model is suitable, using fuzzy logic may not give the desired result. Fuzzy logic can be applied in cases where there is one or more control variables and in cases where a mathematical model of the system does not exist or is difficult to code even if it is found, and where detailed computation is too complex for real-time operations (Anderson, 1995).

4.2.2. Advantages and Disadvantages of Fuzzy Logic

The fact that fuzzy logic does not have a specific formal design method and still has good metrics makes it difficult to predict when fuzzy logic should be used and how well it will yield than traditional methods. In addition, the need for the rules used in fuzzy logic applications to be determined according to the experience of experts and the loss of time can be counted among the disadvantages of fuzzy logic because membership functions are found by trial.

It is also among the advantages of fuzzy logic that it allows the creation of systems that are very complex, nonlinear, contain uncertainty and cannot be created by traditional methods. In addition, fuzzy logic is close to human thinking, adapts to mathematical models, its applications are fast and cheap, it formulates human behaviors, it defines decision stages in a way that does not leave any room for human intervention in the systems, and the system can be implemented in a short time and is open to new possibilities. It is one of the advantages of logic (Tekin, 1995).

4.2.3. Fuzzy modeling and its stages

Formulas and equations are commonly used tools to describe systems. Expressing systems with the help of mathematical formulas requires mathematical modeling. However, the structure of some systems is not suitable for mathematical modelling.

Features such as complex structure, non-linearity and uncertainty make it necessary to obtain approximate results. “Fuzzy system modeling” is one of the most effective tools for approximate description of complex systems using membership functions and rule system (Babuska, 1998).

Rules are important tools in determining the relationships between variables. The most important difference of fuzzy models from closed box models (eg neural networks, genetic algorithms); It simplifies system identification and allows transparent analysis (Setnes, 1998).

The most general fuzzy modeling techniques are: (Piegat, 2001)

- Mamdani (linguistics) model (Mamdani, 1977)
- Takagi-Sugeno Model (Takagi, 1985)

4.2.4. Membership functions

In fuzzy logic, uncertainty states are defined by assigning membership functions to the set elements that represent this state. If the items with the highest severity are assigned a value of 1, the others range from 0 to 1. In this way, the value of the change between 0 and 1 for each item is called the membership degree, and its change within a subset is called the membership function (Sen, 2004).

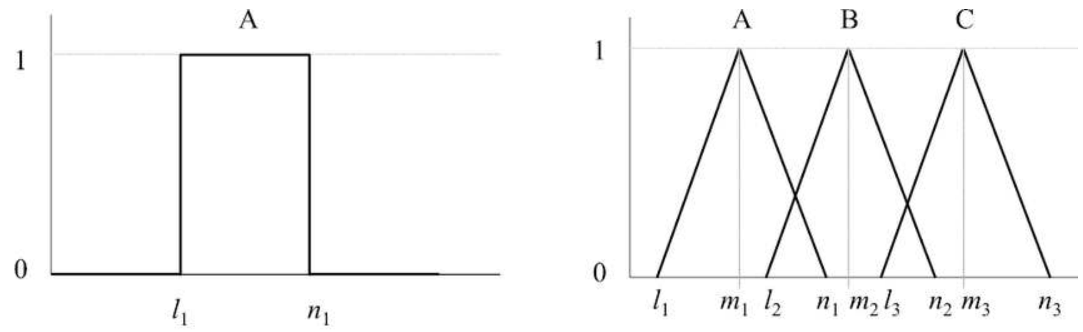


Figure 4.4: (a) Classical Representation and (b) Fuzzy Representation (Yi, 92)

As shown in Figure 4.4.(a), when classical cluster A is evaluated within the scope of fuzzy set, being or not being a member of the cluster is expressed with certain membership degrees (Figure 4.4. (b)).

4.2.5. Fuzzy Inference System

The first step of fuzzy logic modeling is to define the problem and to create membership functions by selecting the appropriate parameters accordingly. Then, a set of rules or rule base containing the solution of the problem is created according to the relevant parameters and the fuzzy subsets created. In the third stage, some inference methods (such as greatest-smallest, greatest multiplication etc.) developed by induction or deduction are selected from these rules [Ross, T.,1995]. In the last step, the method of clarification of the fuzzy value or conversion to classical numbers (center of gravity, weighted average, etc.) is determined.

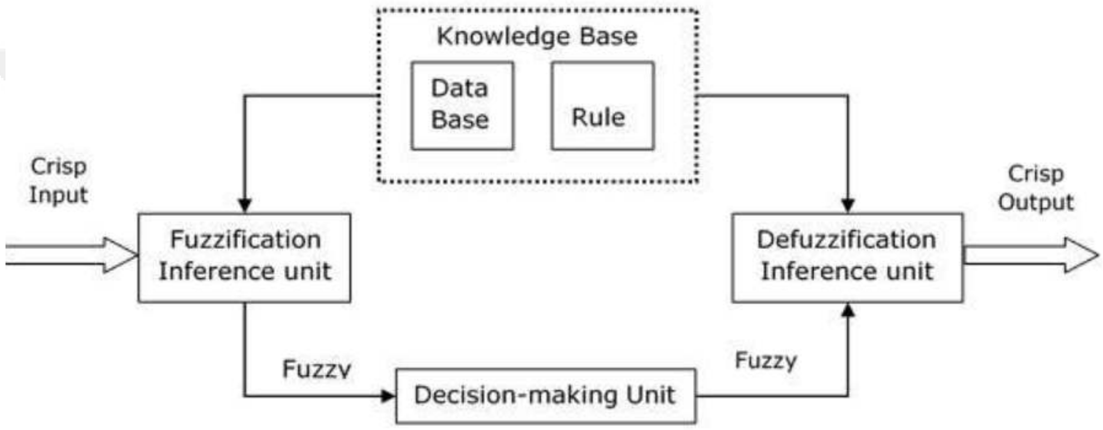


Figure 4.5: The Fuzzy Inference System (Tutorialspoint, 2018)

The working structure of the fuzzy logic system is shown in Figure 17. First, the inputs are fuzzied by evaluating them with membership functions. Then, inference is made according to the selected inference method and using the rule base, and the fuzzy result obtained is converted into a classical number by clarification. As it can be understood from the expressions above, with the help of fuzzy logic, problems with uncertainties, non-linear and incomplete data can be easily modeled. Due to this structure, fuzzy logic is widely used in many areas, primarily in control, decision making and estimation problems.

4.3. Neural Fuzzy Systems

4.3.1. Definition of Neural Fuzzy Systems

In the information given in the neural networks section, attention should be paid to; Neural networks have two important properties. The first of these is the feature of nonlinear mapping from numerical data, and the second is the feature of parallel operation. Besides all this, neural networks have many weaknesses. For example; In multi-layered network structure, it is very difficult to explain the semantic properties of the weights because the system information is distributed with all the weights and it is almost impossible to combine the previous information in the network.

Fuzzy logic uses human-understandable verbal expressions to explain system information. This feature enables a closed interaction between the system and the human. This is also desirable (Barnard, 1992). The most important shortcoming of fuzzy logic is its inability to learn.

With artificial neural networks, learning ability can be gained to fuzzy logic. The difficulty in understanding the information presented with neural networks can also be eliminated with the verbal terms of fuzzy logic and if-then rules, and intelligible outputs can be obtained. The purpose of neural-fuzzy systems is to collect and combine the benefits of both approaches. The combination of fuzzy logic and ANN is in two ways:

- Fuzzy Neural Networks
- Neural Fuzzy Systems

While it is desired to express an artificial neural network with fuzzy information processing capability with fuzzy neural network; neural fuzzy systems and fuzzy inference systems are enriched with neural network capabilities (Baykal, 2004).

To put it more clearly, the information presentation capabilities of classical neural networks are enriched with fuzzy logic in fuzzy neural networks. In fuzzy-neural networks, there are steps to fuzzy the training process of the network, to express the neural network outputs with a fuzzy set, and to use various operations such as union and intersection used in fuzzy set theory instead of standard product and sum operations of nerve cells. In neural fuzzy systems, on the other hand, features such as flexibility, speed and adaptability are added to the fuzzy system with neural networks (Baykal, 2004).

4.3.2. Advantages of Neural-Fuzzy Systems

- Learning ability

- Linguistic expressiveness of imprecise inputs and system outputs
- Adaptability
- Ability to process information simultaneously

ANFIS (Jang, 1993), FALCON (Fuzzy Adaptive Learning Control Network) (Lin, 1991), FUN (FUzzy Net) (Sulzberger, 1993), GARIC (Generalized Approximate Reasoning based Intelligent Control)) (Bherenji, 1992), NEFCLASS (NEuro Fuzzy CLASSification) (Nauck D. D., 2003), NEFCON (Neuro Fuzzy CONtrol) , and NEFPROX (NEuro Fuzzy function apPROXimation)) (Nauck D. R., 1999), FINEST (Fuzzy Inference and Neural Network in Fuzzy Inference Software) (Tano, 1996), among the neural fuzzy systems developed in recent years are the most well known. The ANFIS model includes a Sugeno-like fuzzy system and uses back propagation learning.

Considering the RMSE error criterion, it was seen that Sugeno type fuzzy inference systems gave better results than Mamdani type fuzzy systems. However, Sugeno type fuzzy systems require more computation (Abraham, 2001).

Each of these methods has advantages as well as disadvantages over the others. Methods can be superior to each other according to calculation time, performance level or rule base significance criteria.

ANFIS is one of the best known neural fuzzy systems. It was developed by (Jang, 1993) based on the Takagi - Sugeno fuzzy model (Takagi, 1985).

The learning algorithm of Takagi-Sugeno fuzzy inference system is a hybrid learning algorithm consisting of least squares method and back propagation algorithm. In this algorithm, while the membership function parameters are determined by the back propagation algorithm, the appropriate result parameters are accepted by the least squares method. In the second step, the parameters are reproduced and the result parameters are replaced by the previous parameters while remaining constant.

4.3.3 Adaptive Neuro-Fuzzy Inference System - ANFIS

Various methods have been developed to contribute to the adaptation technique in increasing the efficiency of fuzzy systems. One of them is the ANFIS technique, in which the identification process is performed with a fuzzy model, the operation of which takes place within the adaptive network structure. Neural adaptive learning techniques enable to develop a model that “learns” the related system by using the data set for fuzzy modeling procedure.

The fuzzy model, which will be used in the identification of the system, has the ability to update itself by using both the environmental information about the system and the input and output data of the system, thanks to its adaptive network structure. Essentially, the ANFIS structure consists of the representation of Sugeno type fuzzy systems as a network structure with neural learning capability. This network consists of a combination of nodes, each of which is placed in layers to perform a certain function (Tsoukalas, 1996).

ANFIS is a neural fuzzy technique called an adaptive network-based fuzzy inference system. ANFIS methodology consists of a hybrid system combining fuzzy logic and artificial neural network technique. Using this hybrid method, initially an initial fuzzy model structure with input variables is derived with the help of rules derived from the system's input and output data. The neural network is then used to organize the rules of the first fuzzy model to produce the final ANFIS model of the system. (Chen, 2000)

4.3.3.1. General Architecture and Operation of ANFIS System

It is assumed that the fuzzy inference system is basically a system consisting of two inputs and one output. The rule base includes Takagi and Sugeno's fuzzy if-then rules. This is the typical rule set for the first-order Sugeno fuzzy model;

Rule–1: If x is A1 and y is B1, then f1 = p1 x + q1 y + r1

Rule–2: If x is A2 and y is B2 then f2 = p2 x + q2 y + r2

is expressed as. Figure 4.6 shows the fuzzy inference mechanism for the Sugeno fuzzy model and the corresponding ANFIS structure (Jang, 1993).

Neural adaptive learning techniques enable to develop a model that “learns” the relevant system using the data set for the fuzzy modeling procedure. In other words, ANFIS creates a fuzzy inference system (FIS) by arranging the membership function parameters by using the input/output data set, the back propagation algorithm in ANN alone or together with the least squares method. This arrangement allows our fuzzy system to learn the relevant system with the help of the data it models. In other words, it adapts/adapts itself to the data it will model. Therefore, it is adaptable (Demuth, 2000).

Thanks to its adaptive network structure, it has acquired the ability to update itself by using both the environmental information about the system and the input and output data of the system. In addition, ANFIS includes advanced data analysis techniques such as numerical grouping and rule making.

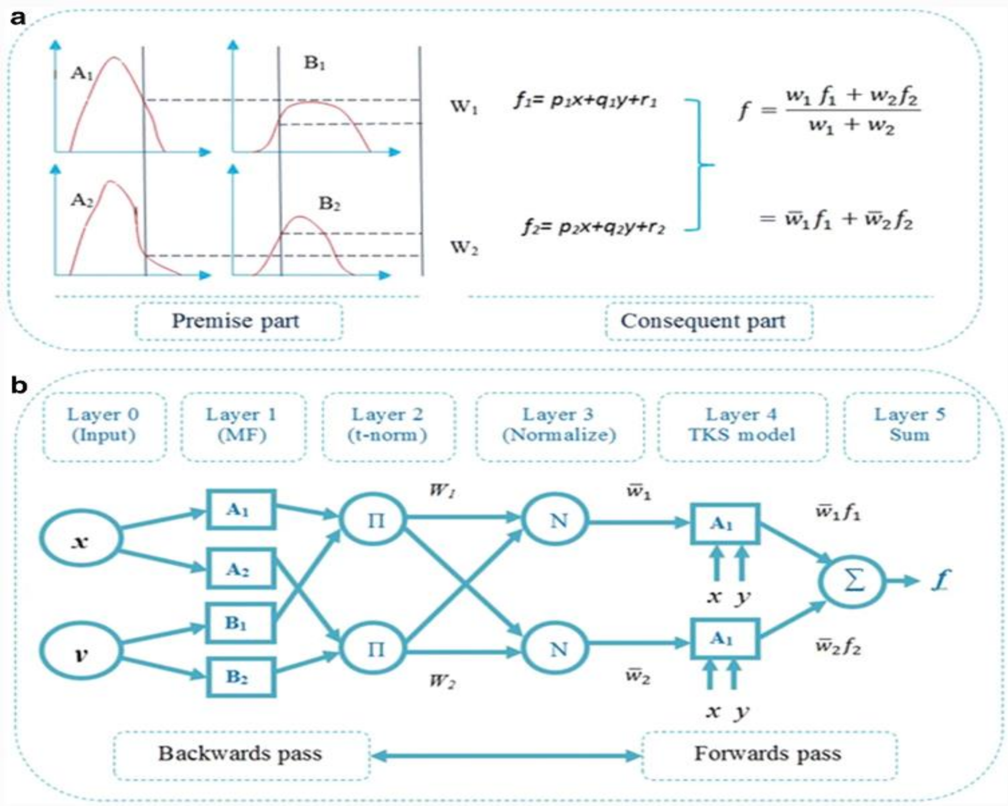


Figure 4.6: (A) Sugeno Fuzzy Model With Two Rules, (B)Typical ANFIS Architecture (Ghorbanzadeh, 2018)

ANFIS can assign all possible rules according to the structure created for the problem under consideration, or it allows the rules to be assigned by the expert with the help of data. The fact that ANFIS can create rules or enable rule creation means that it benefits from expert opinions. For this reason, it makes it possible to obtain better results than the mean error squares criterion, as it allows artificial neural networks to benefit from expert opinions in many estimation problems.

The structure of the layers of the ANFIS structure is described below; This system is shown in Figure 4.7. The node functions of each layer in the ANFIS structure and the operation of the layers are as follows:

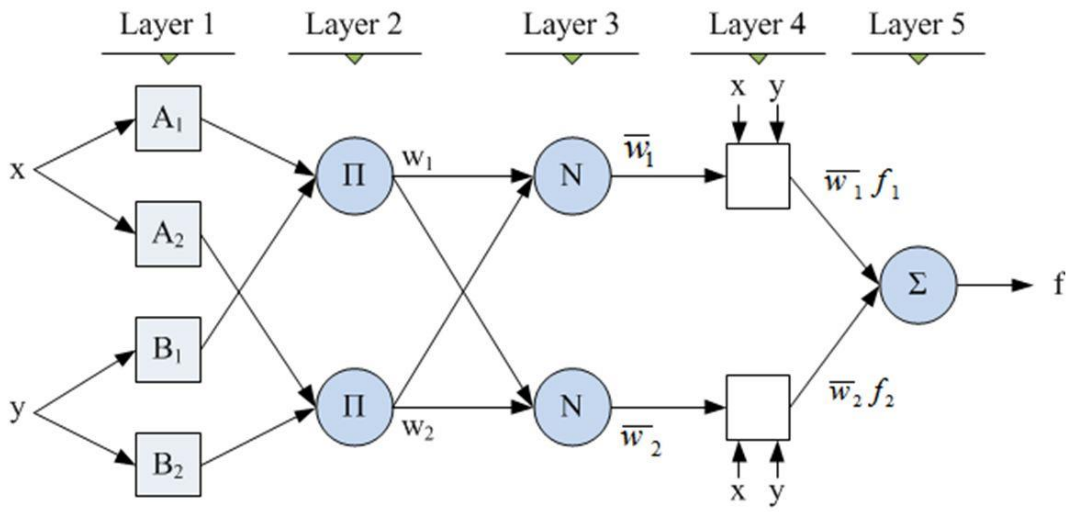


Figure 4.7: Adaptive (Adaptive) Network Based On Fuzzy Logic Inference System

1. Layer

It is called the input layer. Input signals received from each node in this layer are transferred to other layers. The output for each node i is defined as follows:

$$O_{1,i} = \mu A_i(x), \qquad i=1,2$$

$$O_{1,i} = \mu B_{i-2}(x), \qquad i=1,2$$

2. Layer

It is called the fuzzification layer. In separating the input values into fuzzy sets, Jang's ANFIS model uses the generalized Bell activation function as a membership function. Here, the output of each node consists of the input values and the membership degrees that depend on the membership function used. The membership degrees obtained from the 2nd layer are shown as i A μ (x) and i B μ (y).

$$O_i^2 = w_i = \mu_{A_i}(x) \times \mu_{B_i}(y), \quad i = 1,2 \qquad \text{Equ.4.1}$$

3. Layer

It is the rule layer. Each node in this layer represents the number and rules created according to the Sugeno fuzzy logic inference system. The output μi of each rule node is the product of the membership degrees from the 2nd layer. Obtaining Mi values, (j=1,2) and (i=1…n),

$$O_i^3 = \overline{w_i} = \frac{w_i}{w_1 + w_2}, \quad i = 1, 2 \qquad \text{Equ.4.2}$$

4. Layer

It is the normalization layer. Each node in this layer accepts all nodes from the rule layer as input values and calculates the normalized firing level of each rule. If the calculation of the normalized ignition level μi is

$$O_i^4 = \overline{w_i} f_i = \overline{w_i}\,(p_i x + q_i y + r_i), \quad i = 1, 2 \qquad \text{Equ.4.3}$$

5. Layer

It is the purification layer. The weighted result values of a given rule are calculated at each node in the purification layer. i in the 5th layer. If the output value of the node is,

$$\boldsymbol{Q_i^5} = \sum_{\boldsymbol{i}} \boldsymbol{\overline{w} i f_i} = \frac{\sum_i \boldsymbol{w_i \cdot f_i}}{\sum_i \boldsymbol{w_i}} \qquad \text{Equ.4.4}$$

6. Layers

It is the total layer. There is only one node in this layer and it is labeled with ∑ sum. Here, the output value of each node in the 5th layer is summed to obtain the actual output value of the ANFIS system. The calculation of y, which is the output value of the system, is based on equation as below;

$$\begin{aligned} f &= \frac{w_1}{w_1 + w_2} f_1 + \frac{w_2}{w_1 + w_2} f_2 \\ &= \overline{w_1}\, f_1 + \overline{w_2}\, f_2 \\ &= (\overline{w_1}\, x) p_1 + (\overline{w_1}\, y) q_1 + (\overline{w_1}) r_1 + (\overline{w_2}\, x) p_2 + (\overline{w_2}\, y) q_2 + (\overline{w_2}) r_2 \end{aligned} \qquad \text{Equ.4.5}$$

4.3.3.2. Learning Algorithm for ANFIS

The learning algorithm of ANFIS is a hybrid learning algorithm consisting of the use of the least squares method and the back propagation learning algorithm. This learning algorithm is based on error backpropagation.

A step in the learning process has two parts; In the first part, input samples are produced and the antecedent parameters are considered constant, and the best final parameters are determined by the least mean square method. In the second part, the input samples are reproduced and the antecedent parameters are changed by the gradient descent method, assuming the final parameters are constant. This process is then repeated (Demuth, 2000).

4.4. What is the Building Information Modelling(BIM)

BIM (Building Information Modeling), which is one of the leading developments in the architecture, engineering and construction sectors in recent years, combines traditional computer-aided design with a digital project database that keeps all the data defining the building; All data generated during the design, construction and post-production operation process is managed. BIM is also a three-dimensional display that includes all this data.

It appears as a method that allows the management of project data in digital environment by incorporating different tools and processes into the design. While minimizing the time and cost loss caused by the lack of simultaneous operation, it also enables environmentally friendly buildings, thanks to various energy simulations to be integrated into its structure.

BIM is a process for creating and managing all information about a construction throughout the life cycle of a project. The Building Information Model, which is a key part of this process, is the digital description of every aspect of the built asset. This model is based on information collected and updated in collaboration with the key stages of a project. It is widely accepted that it will provide significant improvements in design processes and facilitate collaboration (Bjork, 2007).

4.4.1. Analysis of BIM's Widespread Usage

Building information modeling (BIM) was introduced as a term in the 1962 article of Douglas C. Engelbart, computer and internet pioneer and inventor of the computer mouse, “Auginging Human Intellect: A Conceptual Framework”. has been addressed in various studies.

The importance of design and construction integration in the construction sector and in academic studies related to construction has been noticed since the early 2000s and the value of BIM technology has been understood.

In order to facilitate interoperability and information exchange with related software applications, it focused on the digital representation of an object-oriented three-dimensional model or a repository of project information (Miettinen, 2014).

It focuses on simulating and managing a facility with a data-rich, object-based, intelligent and parametric digital model (Cheng, 2013).

They are rapidly developing collaboration tools that facilitate integrated design and construction management (Lester, 2013).

BIM is a collaborative approach that involves integrating various disciplines to build a structure in a virtual environment (Castagna, 2008).

In addition to design and visualization, BIM has become the basis of the design and production production process due to the requirements for performance analysis, planning, programming, preparation of construction-related documents, assessment of visual risks, and providing data on time and cost.

Building Information Modeling has been integrated into this thesis due to its visualization ability and to eliminate interdisciplinary inefficiency in the construction industry. Considering the work of individual disciplines in the current construction industry, how can BIM be integrated into this process? the question arises.

Figure 4.8: Ultimate Colloboration with BIM Process (Hui, 2018)

The process here refers to the development in an industrial project organization. It is a tool suitable for the construction process in terms of BIM application management and project management. When adopting a new technology such as BIM, it is essential to understand the core activities of this technology. The main titles of these activities can be listed as follows;

- 3D modeling and visualization
- Coordination or Interoperability
- Conflict Analysis
- Planning
- Cost Estimation
- Sustainability
- Analyzes
- Facility Management

4.4.2. Benefits of BIM

(Eastman, 2011) identified the benefits of BIM in four sections: pre-construction benefits, design benefits, construction and manufacturing/operation benefits, and post-construction benefits. The pre-construction benefits are as follows:

- The realistic and accurate presentation of the building model accelerates the decision processes in feasibility and design and shows whether the expectations will be met,
- With a detailed model, design alternatives can be evaluated and building quality and performance can be improved.

The design benefits provided by BIM are explained below:

- Automatic updates resulting from the parametric structure reduce the effort for design changes,
- BIM supports cooperation between parties with open standards,
- More accurate and detailed cost estimates,
- Early energy analysis provides opportunity for modifications to improve building quality.

Construction and manufacturing benefits are described below:

- The construction process can be simulated day by day and possible problems can be solved,
- Automatic update helps to react quickly to parametric model, design or field problems,
- BIM facilitates better implementation of rough construction practices with the right design model and material requirements,
- Accurate quantities and specifications facilitate the procurement process.

Finally, the post-construction benefits are defined as:

- Use of building model information for better study,
- Integration into facility management systems can facilitate monitoring of real-time control systems, providing a natural interface for sensors and remote operating management of facilities.

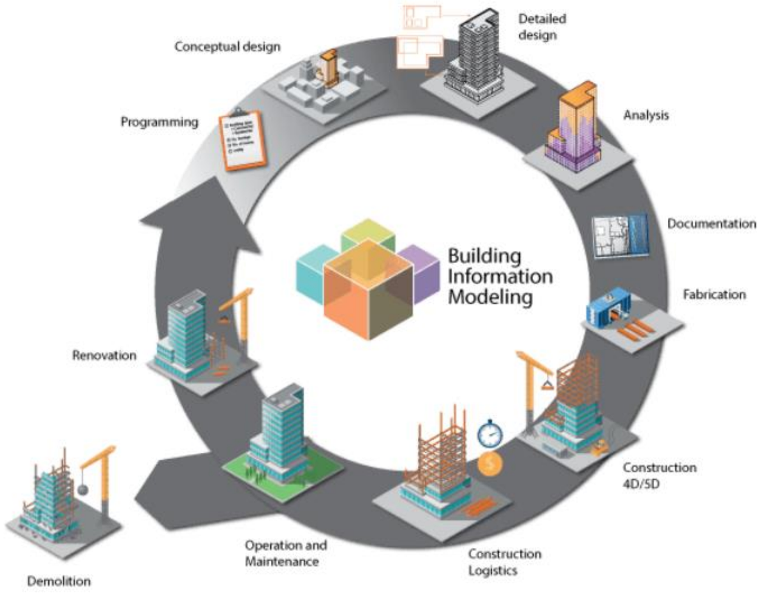


Figure 4.9: Step by Step BIM Process (Aydınlık, 2016)

4.4.3. ROI of Building Information Modeling

Return on investment (ROI) is an analysis method to evaluate the profitability of investment. It can be easily calculated by dividing the gains by the costs. In adopting BIM, owners may be skeptical about profitability and resist such a fundamental change. Returns on investment offer the long-term benefits of adopting BIM and speed up the decision-making process. While BIM is accepted, it is expected that the design efficiency will decrease drastically during the training period. After that, it slowly increases and exceeds efficiency in the old system. Decreased productivity, system purchase costs, training costs, etc. As a result, ROIs are relatively low in BIM's early years. After a while, staff training is completed and the return on investment increases with increased productivity.

Using BIM as a lifecycle tool instead of a modeling program will increase ROI. In addition, indirect savings such as reliable database with BIM, improved collaboration, better comfort and integrated processes will be much higher when included in ROIs ((Azhar, 2011), (Eastman, 2011)).

4.5. Summary

In this section, general information on Artificial Neural Networks, Fuzzy Logic, Neural Fuzzy Systems-ANFIS and BIM are given.

CHAPTER 5

Research Methodology

5.1 Introduction

Research can be defined as the process of seeking solutions to problems through various methodological inquiries, generating solutions and adding to knowledge through important insights (Herbert, 1990). To achieve this, several research methodologies exist. A research methodology is expressed as follows; It is a systematic and organized approach to the collection, interpretation and analysis of data. It will be shown that this research project mainly tries to analyze, explain and reconstruct existing knowledge by means of quantitative and qualitative methods. Deductive reasoning was used to develop a new "advanced" approach.

(Saunders, 2007) describe the research process within a concept of “Research Onion” that includes different layers, in which each layer of the onion refers to a research approach that ultimately formulates the research process. It raises questions about the first layer research philosophy, the second layer research approach, the third layer research strategy, the fourth layer time horizon, and the fifth layer data collection methods.

In this study, the research methodology will be discussed on the axis of the research bulb. This method was chosen because the research onion approach provides a wider range of evaluation. Regarding the “Research Onion”, the choices made within the scope of this research are shown. The accepted selections were as follows:

- Philosophy - Pragmatism
- Approach - Deductive approach
- Options - Mixed Methods
- Time Horizons - Longitudinal
- Techniques and Procedures - Literature Analysis, Expert Judgment

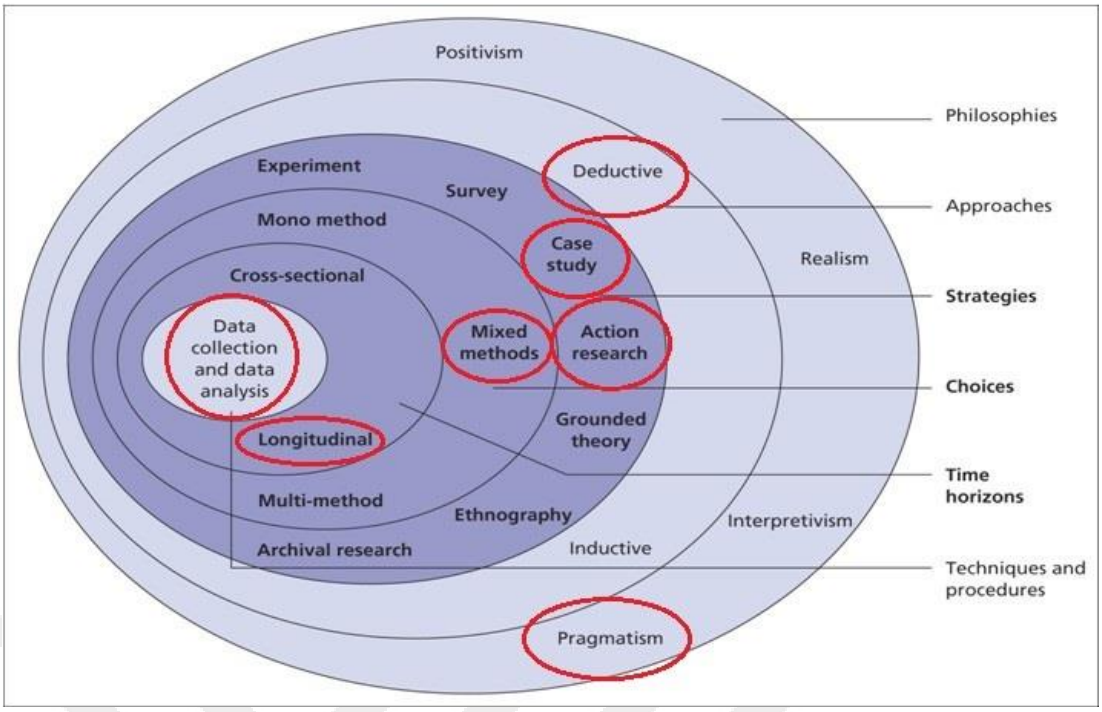


Figure 5.1: Sounders Research Onion (Saunders, 2007)

The reasons and background for making such choices are explained later in this chapter.

5.2 Research Philosophy

The concept of research philosophy refers to the advancement of scientific practice based on people's opinions, interpretations and assumptions. Saunders (2006) lists philosophies as positivism, realism, interpretation, objectivism, subjectivism, pragmatism, functionalist, interpretive, radical humanist and radical structuralism.

Pragmatism is roughly based on the following hypotheses: Pragmatism emphasizes the importance of using the best possible tools to investigate phenomena. The main aim of pragmatism is to approach research from a practical point of view, where knowledge is not fixed, but is constantly questioned and interpreted. Therefore, pragmatism consists of an element of researcher involvement and subjectivity, especially when drawing conclusions based on participants' responses and decisions. In other words, pragmatism is not tied to (or limited to) any particular philosophy.

The most important idea; The outcome of the person doing the thought experiment is more important than the philosophical ideas behind the experiment. The research philosophy adopted for this thesis is one of an paradigm and a paradigm of praxis.

5.3 Research Approach

The choice and application of the research approach is critical and critical in allowing the researcher to achieve the stated goals. The research approach can be inductive or deductive.

Deductive reasoning works from the more general to the more specific. Sometimes this is called the top-down approach. The result of this type of research is logically due to existing facts. A deductive research approach is suggested to be appropriate for scientific research, in which the researcher develops a hypothesis that is tested and studied to form a theory (Hussey, 1997).

The outcome of this thesis will use a Deductive systems approach to take specific observations made in the Tanap project and then develop it with further AI-powered precision studies and visualized them in BIM Softwares.

5.4 Research Strategy

Research strategy options to be adopted in research include experiment, survey, case study, action research, grounded theory, action research, and archival research.

A case study is a detailed, in-depth study of a single topic—for example, a person, group, or institution, or an event, phenomenon, or issue. In this type of research, the subject is analyzed to provide an in-depth understanding of problems in a real-life setting. The goal here is not (necessarily) to generalize the findings, but to gain an in-depth understanding of the context of the study.

The simplest way to describe action research is to say that it involves learning…wait…action. Action research, unlike controlled environments like laboratory, classroom, hospital, workspace, etc. carried out in practical environments such as Action research helps inform researchers about problems or weaknesses with real-world interactions. With action research, there is a strong focus on the participants (the people involved in the subject under study), which is why it is sometimes referred to as "participatory action research".

The scope of research strategies and their interdependencies are revealed. The adopted research strategy is a case study and action research strategy in which the researcher is actively involved in the process of risk management and assessment of the Tanap

Project project. The reason for adopting two strategies in this study; Action research was adopted because fuzzy logic was used, and case study strategy was adopted because it was transformed into a AI model.

5.5. Research Choises

The research choice is the fourth layer in the research onion. It can be either quantitative, qualitative or multiple research methods (Saunders, 2007). To use both quantitative and qualitative data, to be taking the mixed method approach. For this, to collect quantitative data and then analyze the results statistically, producing quantitative results in addition to your qualitative results.

In this research, a mixed method is chosen as a research choice, which means that the data were collected through the use of two methods (qualitative and quantitative) at one time.

5.6. Time Horizons

The type of time horizon adopted by the researcher is the longitudinal time horizon. This will allow the researcher to examine changes over time, and not just momentarily. In this research, the methods applied in the Tanap project were adopted to examine the dynamics of the risk management and assessment problem.

This is done by examining the same situation repeatedly and continuously throughout the project's duration, where the problem runs its course. Because Risk Management and assessment is a process that lives throughout the project cycle.

5.7. Research Process Design

This section provides details about the research design process and methodology applied for this study. The methodology and research chosen more clearly determine the outcome of the design.

Therefore, it is necessary to discuss and interpret all the philosophy, assumptions, strategy, design and methodology applied to the study. A diagram showing the editing, development and result stages of the framework of making a more sensitive artificial intelligence-based application for Risk Management and assessment in industrial facilities in Turkey and a BIM-based application for visualization/communication is presented.

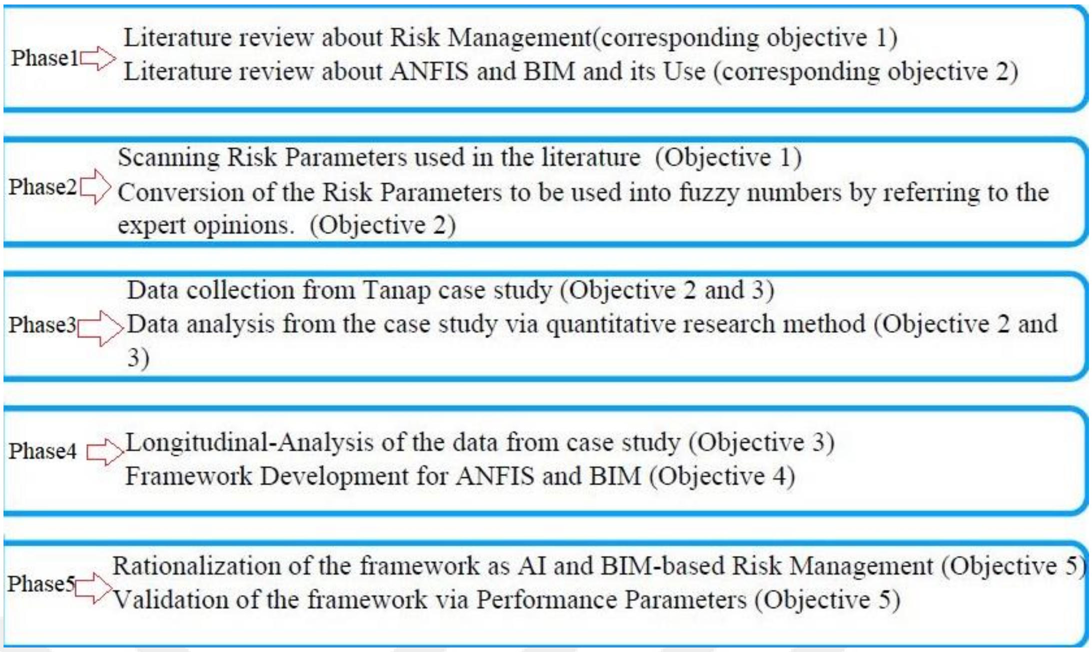


Figure 5.2: Research Process Plan

5.7.1. Research Techniques for Data Collection

Initial data collection is usually done by following three different practical approaches. Therefore, various sources of primary data collected are gathered from interviews with experts, surveys, case studies, and discussions.

Two of them as shown as below;

- Case study approach - Case studies are used when there is a need to find in-depth information on a particular topic. The case study approach is divided into descriptive case study, analytical case study and explanatory case study.
- Problem solving and remodelling approach - This approach is usually carried out by people with a professional background. This approach is taken when a professional detects any problem in any system during his work and wants to suggest changing the situation.

The research in this study; primary data source, using the probability&impact matrix used to determine risk scores in the design and construction processes within the scope of the Tanap project.

The primary data collection based on Tanap Risk team opinions is carried out with the Risk team in the project. Workshops, mind mapping and brainstorming were conducted with a total of 30-40 Risk team players to determine the probability and impact of the risks that occur during the initial phase and construction phase of the Project.

Collection of secondary data; In general, it is a less time-consuming part than primary data. Because a specific data scan is made and the data starts to be scanned through the constructed model. Secondary data sources can be many sources in the literature. These can be journals, reports, research sites, and related articles.

In this study, secondary data collected about the research topic from various materials. Secondary collected data consisting of information, books, Artificial Intelligence and BIM journals, reports, websites and some articles were designed and used for the study. It has been seen that there are not many documents for Artificial intelligence, BIM and Risk management in industrial structures.

5.7.2 Research Techniques for Data Analysis

Data analysis gives the right direction to the study. While large amounts of data provide this, it is difficult to analyze accurately (Naoum, 2007). The data is summarized in the following three ways:

- <u>Exploratory data analysis</u> (Open-ended questions)
- Inferential statistical analysis method including: t-tests, chi-square, Spearman 'rho' rank correlation and product moment correlation coefficient.
- Define analysis methods including: measurement of central tendency, normal curve and frequency distribution.

Exploratory data analysis will be used to analyze the results of the research. The probability and impact values given by the Tanap risk team and the data obtained from the studied cases will be analyzed and summarized both qualitatively and quantitatively. The qualitative approach is descriptive, while the quantitative approach is objective **(Naoum, 2007)**. For risk assessment, risk parameters will be increased to 5 and re-evaluated based on an article referenced from the literature. Normal numbers will be converted to fuzzy numbers for import to ANFIS and the model will be reconstructed.

5.6 Ethical Considerations

General research ethics or principles express respect for the rights of study subjects. The researcher is obliged to observe confidentiality, institutional privacy, personal privacy and obtaining approval from relevant institutions and organizations throughout the study (Denscombe, 2005).

The ethical approval form for this research was submitted to Tanap Gas Tranmission A.Ş to provide data for the development of this research. With the approval of the relevant institution, the data were used. In addition, within the scope of the thesis, the process was continued by obtaining approval from the Compliance, Risk and Corporate Departments of the Tanap Project and the thesis was completed.

5.7 Summary

This section provides detailed information about the research methodology used for the study, from posing the research problem to writing the thesis. In this section, the philosophical stance, theoretical orientation, strategies, methods and techniques of the study are discussed. This study used case study strategy with multi-method methodological approach with deductive reasoning as the main theoretical driving force. The quality criteria of the study were also discussed. In the following section, the establishment of the model of the study will be done.

CHAPTER 6

Framework Development for ANFIS and BIM use in the Risk Management at NGPP

6.1. Introduction

The features of the ANFIS method and the studies carried out using ANFIS in the literature are briefly mentioned in the previous section. In this section, how the methodology developed for Risk Management can be implemented using MATLAB and BIM-Naviswork/Revit will be discussed.

In the selection of the criteria in the presented structure, the parameters with the highest frequency value in the literature were selected. The ANFIS method will be used throughout the process by taking expert opinions in order to create the model suitable for the relevant selected parameters. Then, the risks that can be defined with omni-class classes will be visualized using the BIM Naviswork/Dynamo module software with the help of Risk Color Levels defined in the Project.

6.2. Methodology of Conceptual Model for ANFIS

In this part of the study, how to program the MATLAB Fuzzy Logic Module, which we will use in neural fuzzy-based risk assessment, will be explained.

When the MATLAB program is opened, the Fuzzy Logic Module is opened by typing “fuzzyLogicDesigner” on the command line. Under the Fuzzy Logic Module, there is a fuzzy inference system editor that allows the user to specify rules and membership function styles in a unique way. At this point, we will use the FIS editor to describe the Matlab Fuzzy Toolbox. (Figure 6.1 and Figure 6.2).

On the screen that opens, the “Membership Functions” option under the “Edit” menu allows access to the “Membership Function Editor” window for editing membership functions and editing the number and structures of input variables. In order to determine the membership functions of each variable, the input1 and input2 boxes are double-clicked. At this point, when the “Add Variable” button is selected, inputs and outputs can be added/removed from the model, and when the “Rules” button is selected, it will be possible to edit the rules under the “Rule Editor” window (Figure 6.3).

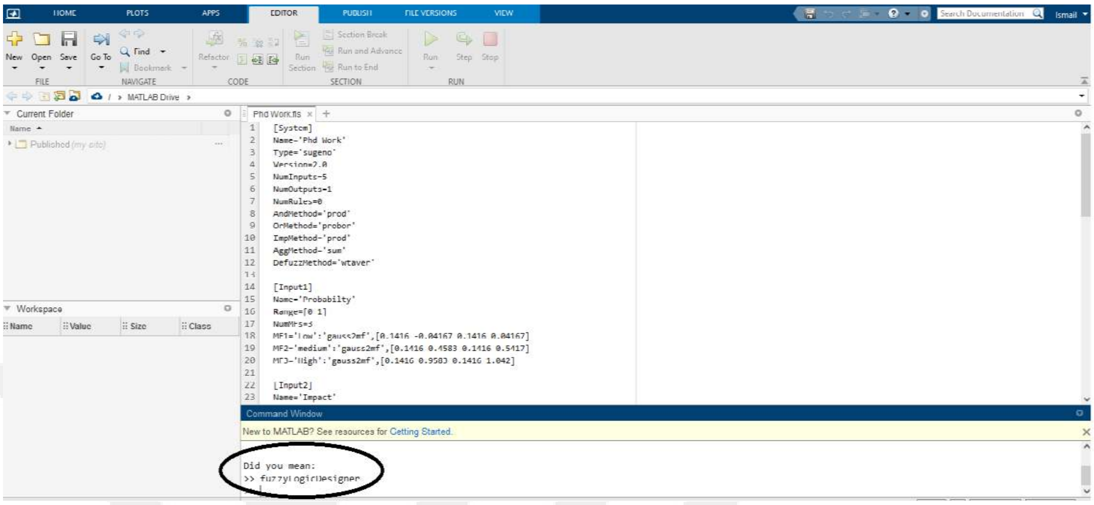


Figure 6.1: MATLAB Entrance Screen and command “fuzzyLogicDesigner”

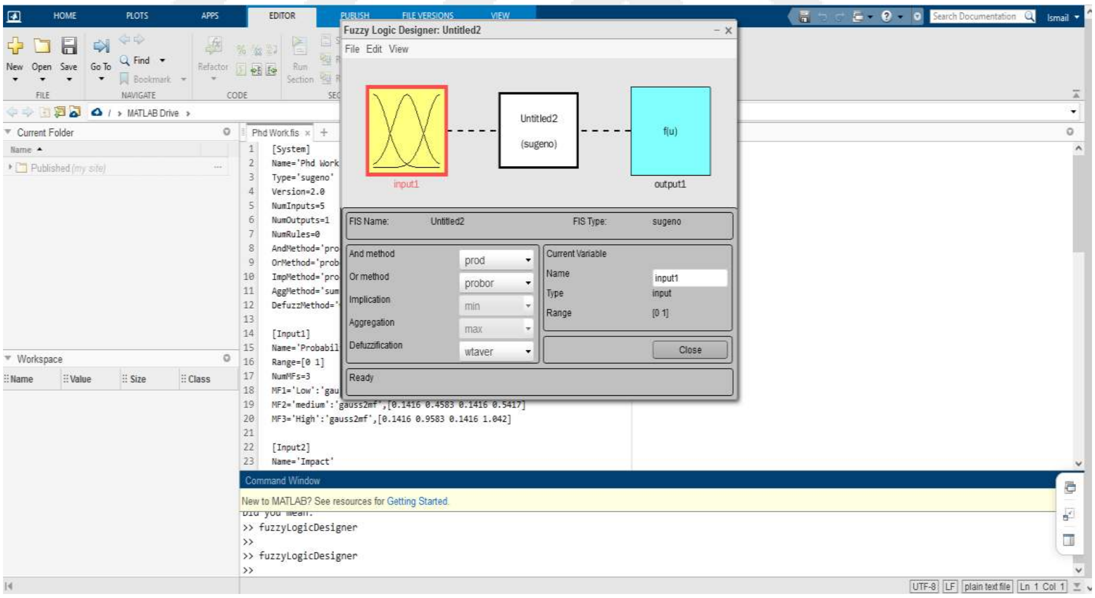


Figure 6.2: MATLAB ANFIS (Sugeno Model) and FIS Editor View

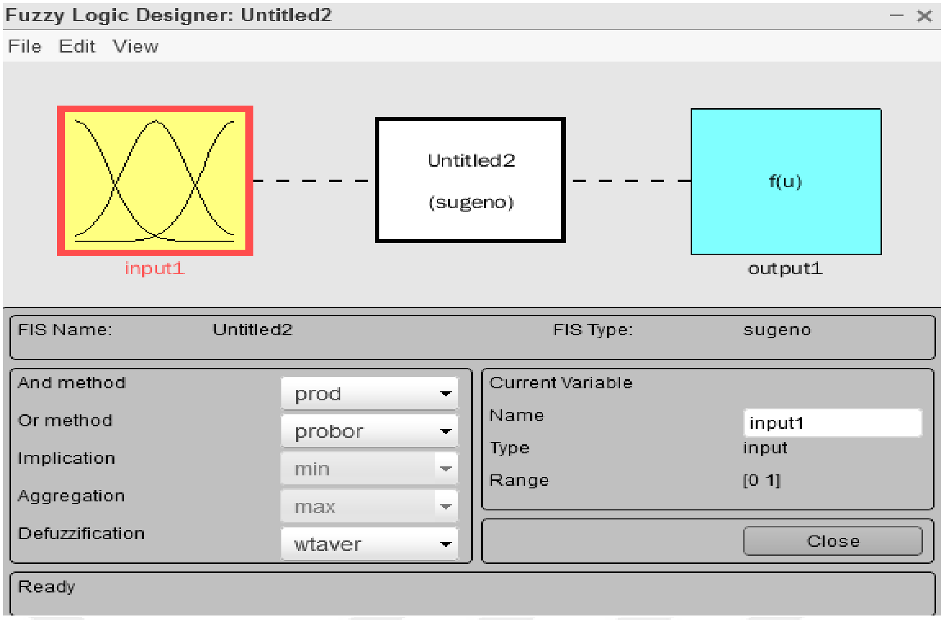


Figure 6.3: "fuzzylogicdesigner" commend ve FIS editor

There is a structure in the FIS window where editing can be done by the user (experts). At this point, input and output structures can be determined by double clicking the rule editor.(Fig.6.4).

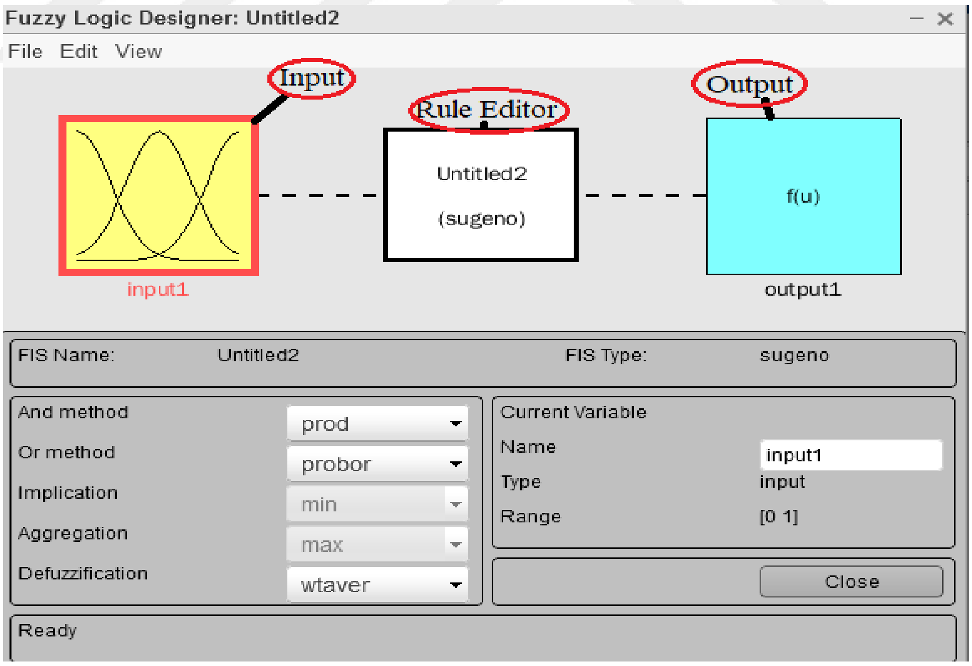


Figure 6.4: FIS Editor View Compenents

Membership function types and ranges of the inputs determined by experts can be determined in the window that opens when the input button (inputs) is double-clicked.

At this point, the number of entries can be increased and their structures can be updated. (Fig. 6.5).

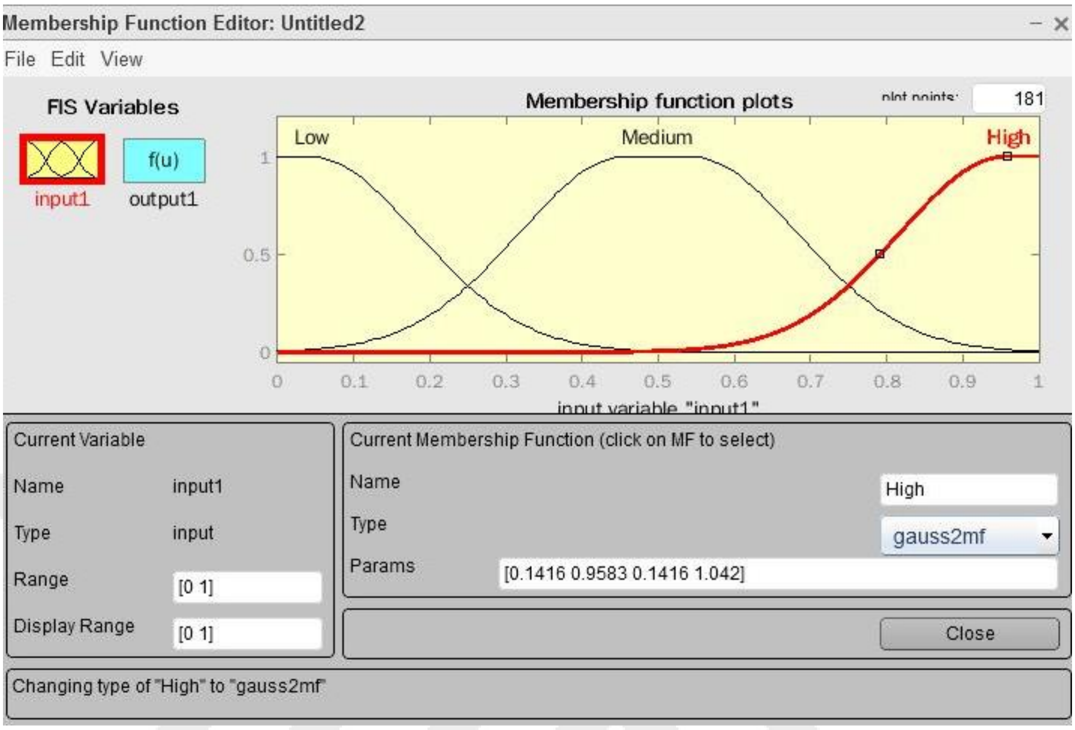


Figure 6.5: Membership Function Editor – Input

When the Rule Editor button is double-clicked, rules can be added in the window that will determine the connection of the inputs with the outputs within the intervals determined by the experts. The connection at this point and/or can be selected and weighted. (Figure 6.6).

In the window that opens when the Output button is double-clicked, the membership function types and ranges of the output determined by experts can be determined similarly to the inputs. The output structure at this point can also be updated. (Fig. 6.7).

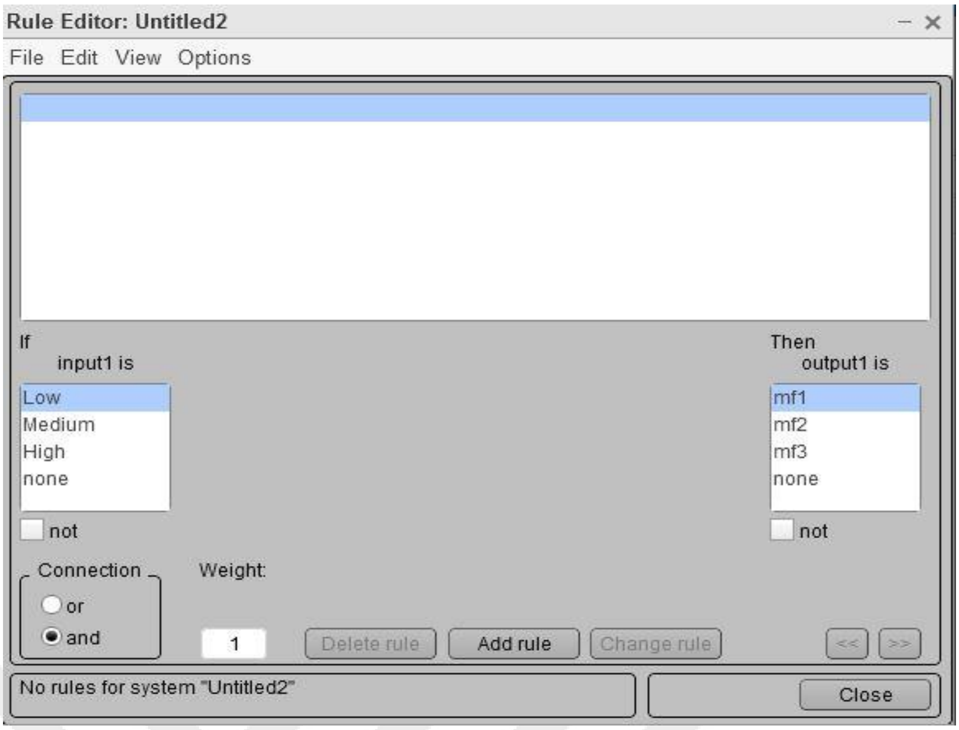


Figure 6.6: Rule Editor

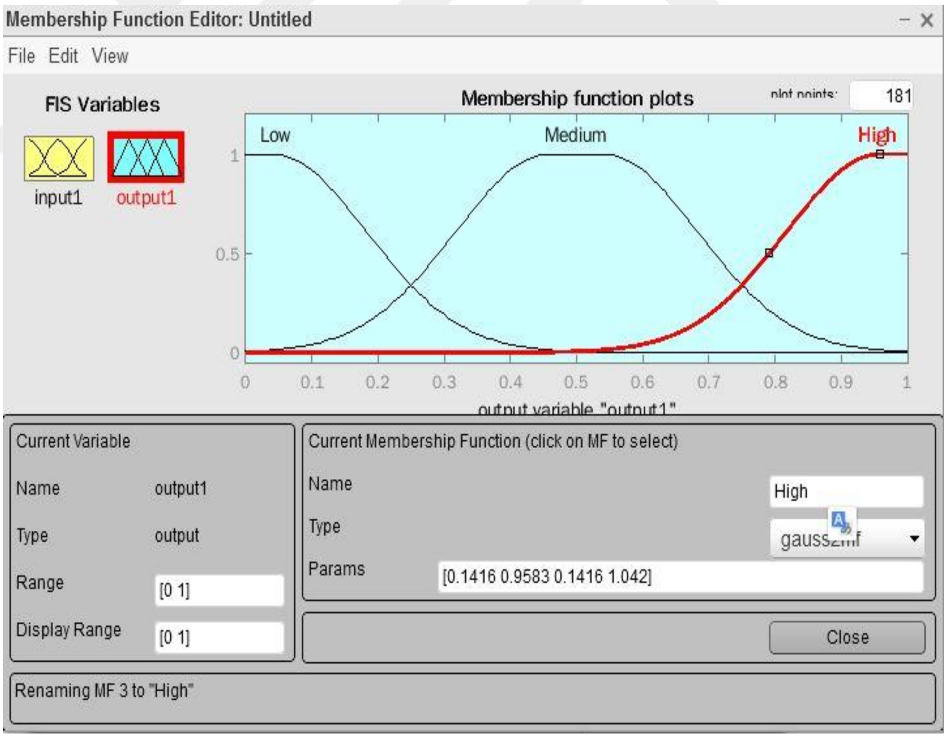


Figure 6.7: Membership Function for Outputs

The MATLAB FIS structure forms a whole based on the expert opinion structure. In order to switch to neural fuzzy logic based structure, it is necessary to reach the ANFIS editor. At this point, when it comes to the edit part of the FIS Editor Module, the ANFIS editor can be accessed on the bottom tab. (Fig. 6.8)

The ANFIS Editor structure allows experts to determine membership functions and rules suitable for the inputs and output data available.

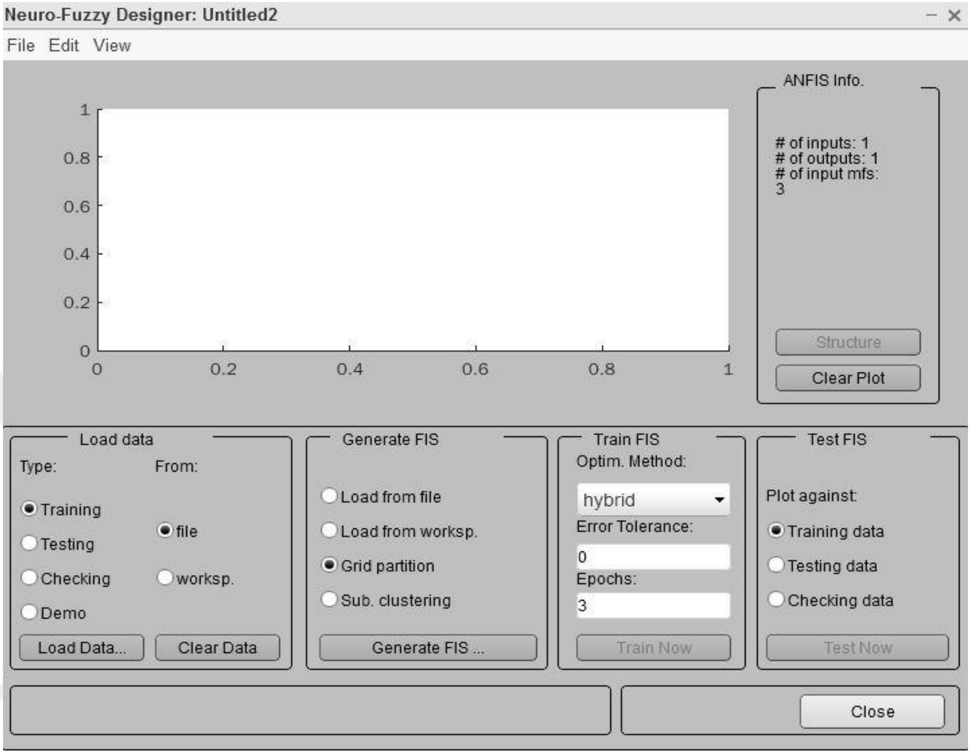


Figure 6.8: ANFIS Editor View

With the help of the "Load data" option in the ANFIS editor user interface, data is loaded into the model. There are a total of 4 types of data: training, testing, validation and demo. Worksp. With the option, the files in the MATLAB workspace can be loaded, and with the file option, the files saved in any folder on the computer outside the workspace can be uploaded.

“With the "load from file" command, the fuzzy inference system files that have been saved on the computer can be loaded, and with the "load from workspace", the fuzzy inference system files in the workspace can be loaded. Here, the user can easily apply the fuzzy inference systems that he has built and created for other problems in the new problem. With the grid spread command, the user can determine whether the membership function and number for each of the specified inputs and the membership function type for the output are fixed or linear on the screen that appears. They are Sugeno fuzzy models that are meant to be expressed with a fixed or linear output type.

In the "Train FIS" window, the learning algorithm is selected to train the data set. 3 types of learning algorithm options are offered. These are the least squares method, the back propagation learning algorithm, and the hybrid learning algorithm where the two are combined. For the "Error Tolerance" command, it is recommended to select "0" if there is not enough information about the data. With the "Epochs" option, how many cycles the data set will be trained is determined.

Three different options are offered in the "Plot Against" command in the "Test FIS" field. By using training, test or verification data, the user has the opportunity to test the FIS developed with the ANFIS method. With the “Structure” button, the input-output structure of the problem can be observed, and with the clear plot button, the data uploaded to the fuzzy inference system can be deleted.

6.3. ANFIS Input Selection

ANFIS input selection was introduced by (Jang, 1993) and applied to two different nonlinear problems. In the study, it is aimed to present an effective method for input selection, taking into account the fact that problems can be difficult to solve and explain if they contain too many inputs.

Input selection can be performed using the Fuzzy Logic Module of the MATLAB program, similar to the setup and training of the ANFIS model. (Jang, 1993) used the method he developed to estimate miles per gallon in non-linear automobiles.

In our study, on a 4-input single-output model, 5,5,3, and 3 different intervals were added for the consistency of our different rule model for the membership functions. A total of 221 rules are available in the model.

After this stage, the training test and control data of the model were loaded via the "Load data" option in the ANFIS editor. Worksp. While files in the MATLAB workspace can be transferred with the file option, files saved in a folder outside the workspace can be transferred with the file option. After pressing the "Load data" button, train_data (training data) was transferred to the ANFIS editor with the worksp option. (Figs 6.9 and 6.10).

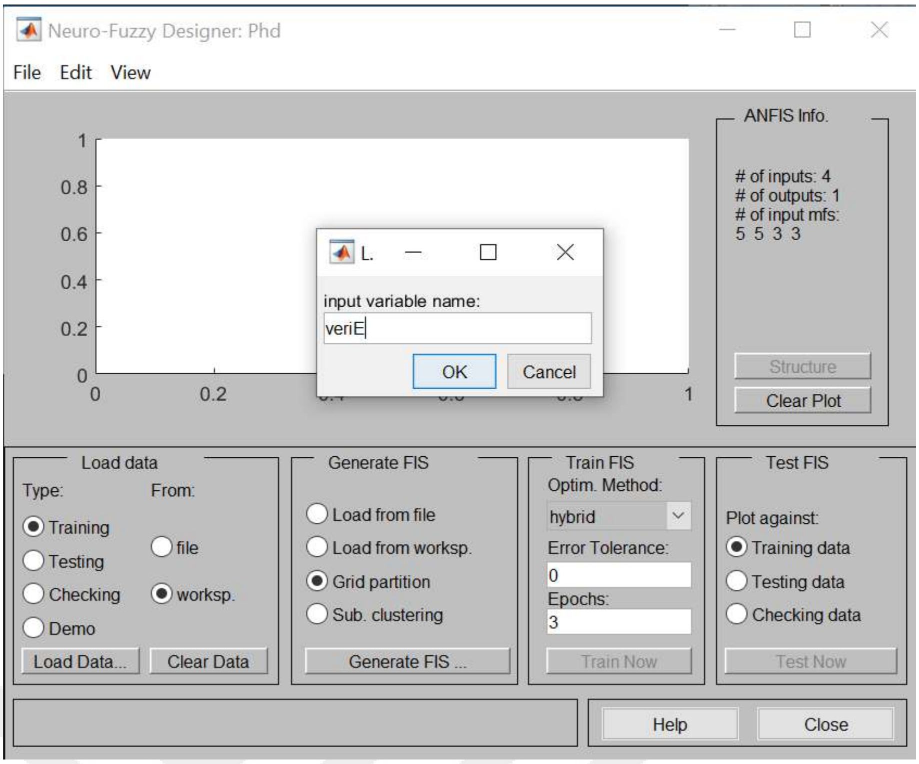


Figure 6.9: Load Training Data to ANFIS

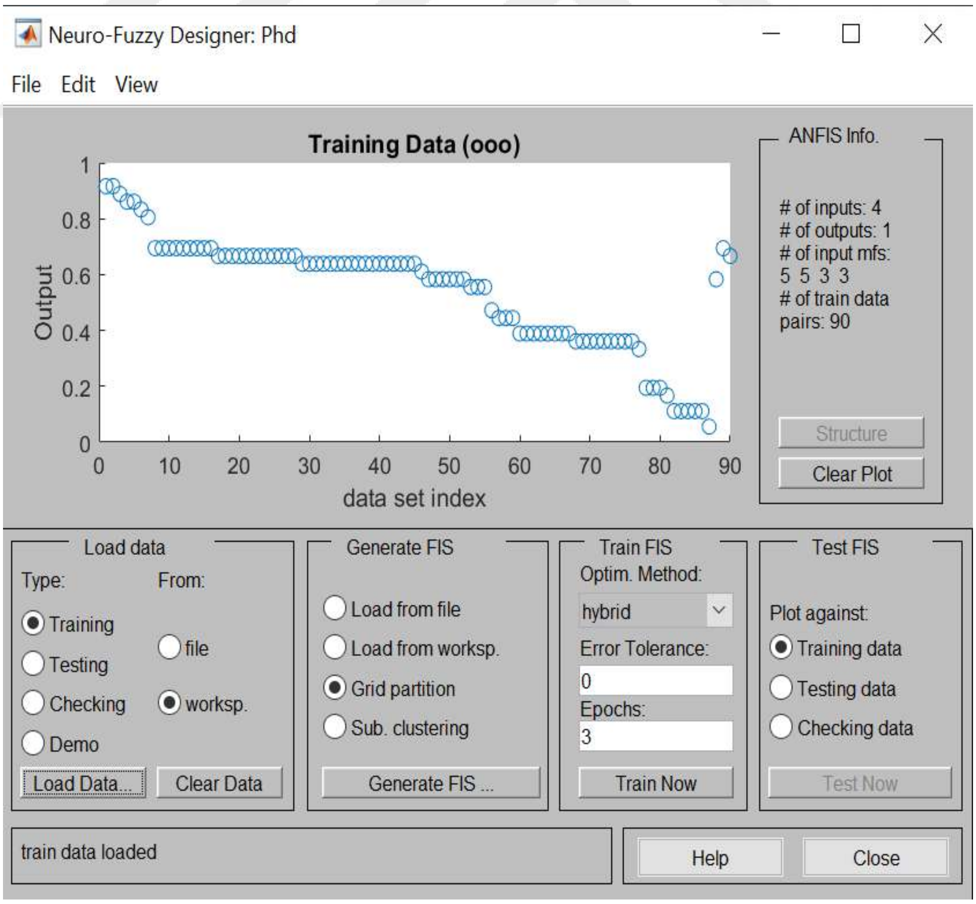


Figure 6.10: Scatter Diagram on ANFIS for Training Datas

The “Generate FIS” part, where the membership function number and function type will be determined for each input in the ANFIS editor, is shown in Figure 6.11. In this section, the type of membership functions and the number of membership functions are determined by writing them in numbers. Likewise, the output membership function type is selected as one of two types, either fixed or linear.

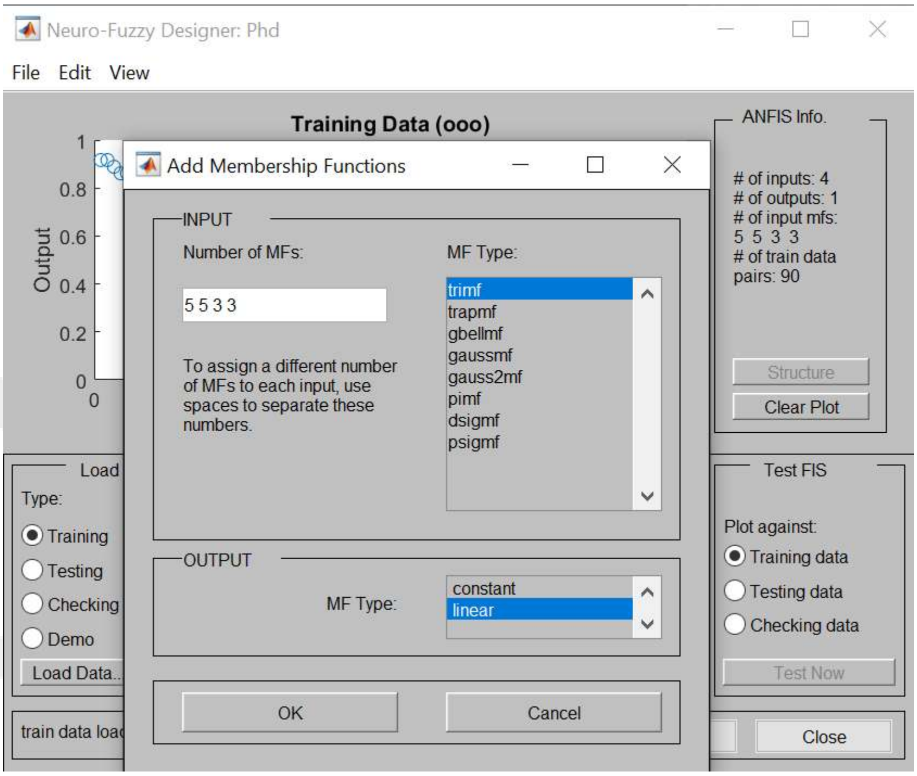


Figure 6.11: ANFIS Membeships Function Number and Type Selection

6.4. BIM-based Risk Visualization Tool

This designed software tool allows users or project managers to visualize different risks and how they affect the project in 3D. As the first part, a conceptual and conceptual model is developed showing how to design and use the software tool.

Real data is taken from the project risk register. Then these data are exported to excel format. The data in Excel format is evaluated over 4 parameters. As a result of this valuation, the final risk value is found and reduction plans are made over this value.

All of these processes are transferred to matlab for machine learning and artificial intelligence use. Risks are reassessed with AI-based software. Since the parameters are matched with verbal expressions, numerical values are assigned to the parameters with the help of reference articles by making a literature review. Finally, the risks are re-evaluated by machine learning and their final values are found.

According to the risk assessment scale used in the project, the colors suitable for the risks are determined and assigned to the relevant risks. With the help of Revit/Dynamo software, the risk objects whose color codes are determined are matched to the products with the help of omniclass codes. Finally, the Risk Map model, which consists of a 4-dimensional model made in Navisworks, was developed. In the application part, these processes will be explained step by step.

The main purpose of the BIM software-based risk visualization tool is to provide a clear overview of the project with the 3D mapping method for all internal and external stakeholders. As a result, the different and visualizable risks involved will be presented with a risk map that the user or all stakeholders can navigate through the 3D model of the project.

6.4.1. Project Risk Matrix and Ranking for Color Codes

Risk assessments are evaluated over 4 parameters- probability, impact, manageability, and proximity. These 4 parameters are completely risk assessment parameters used in the Tanap Project. Numerical parameters of the modified (Chen, 2000) model were used for the integration of these 4 parameters into the ANFIS system. Please see below chart (Chen, 2000) ;

Table 6.1. Linguistic terms and related fuzzy values for risk parameters and assessments

AS	(2, 5/2, 3)	Absolutely strong	AS	(2, 5/2, 3)	Absolutely strong
VS	(3/2,2, 5/2)	Very strong	VS	(3/2,2, 5/2)	Very strong
FS	(1,3/2,2)	Fairly strong	FS	(1,3/2,2)	Fairly strong
SS	(1,1,3/2)	Slightly strong	SS	(1,1,3/2)	Slightly strong
E	(1, 1, 1)	Equal	E	(1, 1, 1)	Equal
SW	(2/3, 1, 1)	Slightly weak	SW	(2/3, 1, 1)	Slightly weak
FW	(1/2,2/3,1)	Fairly weak	FW	(1/2,2/3,1)	Fairly weak
VW	(2/5,1/2,2/3)	Very weak	VW	(2/5,1/2,2/3)	Very weak
AW	(1/3,2/5,1/2)	Absolutely weak	AW	(1/3,2/5,1/2)	Absolutely weak

The evaluation is completed with the first part Probability, the second part impact, the third part manageability and the last part proximity parameter. All assessments were made by the risk assessment team involved in the project. This team consists of 60 or more experts on average. Correspondingly, a color defined in the risk scale on the project will be assigned. These colors will be applied sequentially to the 3D BIM model and then to the 4D model with the help of the dynamo to show the degree of risks involved.

Four risk ranking ranges determine in the project. These are notable, low, medium and high. The resulting Risk scores are evaluated according to these ranges and classified by taking the relevant color code. At this stage, the current application will be made in the thesis. However, in the final valuation phase, risks will be re-evaluated using AI-based matlab.

Table 6.2: Project Risk Matrix (also uses of ISO9001)

INCREASING PROBAPILITY	INCREASING IMPACT					
	1 Low	2 Medium	3 High	4 Major	5 Massive	6 Catastrophic
F Frequent	1F	2F	3F	4F	5F	6F
E Often	1E	2E	3E	4E	5E High Risk	6E
D Probable	1D	2D	3D	4D Medium Risk	5D	6D
C Seldom	1C	2C	3C Low Risk	4C	5C	6C
B Unlikely	1B Notable Risk	2B	3B	4B	5B	6B
A Rare	1A	2A	3A	4A	5A	6A

Table 6.3: Risk Priority for the Project (also assigned risk color for Risk Color)

Risk Level	High Level Risk Management Actions
High	Develop robust Risk Treatment Plan to take action with the aim of reducing the risk. These RTP must be implemented even if they require significant resources or fundamental changes in the activities and systems.
Medium	These risks fall in the yellow region in the risk matrix. Monitor the risk and take reasonable actions to further reduce the risk. There should be a transparent bias on the side of Health & Safety. The RTP should correspond to relevant good practice
Low	Monitor the risk and take reasonable actions to further reduce the risk without introducing extra cost to the Project.
Notable	Monitor the risk and prevent occurrence where possible or control the consequences.

6.4.2 Coupling using Omniclass system

The continued development of BIM and construction technologies encourages us to improve our habits of storing and sharing the ever-increasing amount of information. Thus, the use of classification standards becomes important. Information prepared according to a common standard can be used in many areas such as asset management, cost analysis and work schedule.

Recently, with the increase in software that can be used by construction site teams, tasks such as preparing/following work schedules, calculating/following up costs can be done easily via BIM models. Once the "digital twin" of the structure is prepared, a significant amount of time is saved by classifying and reporting the already existing information, and the error rate is reduced.

- Classification; Who uses how?
- Employer: Facility/asset management, planning and cost estimation
- Contractor: Building management, schedule and cost estimation
- Architects and Engineers: Preparation of specifications

Classification Systems;

- MasterFormat: Issued by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).

- UniFormat: Issued by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).
- Uniclass: Issued by the Construction Industry Project information Committee (CPIC) and the National Building Specifications (NBS).
- Omniclass: Issued by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).

The OmniClass Building Classification System (OCCS) is a standard in which the construction industry classifies the methods used in the process from the planning phase to the demolition phase, with different features. The first publication of the system, which symbolizes this set of concepts, was made in October 2001 under the name OCSS (Overall Construction Classification System), and its improved version was published under the name OmniClass in December 2004. Similar to UniClass, the OmniClass system was developed according to the ISO 12006-2 standard and consists of 15 tables. OmniClass tables have a hierarchical order, unlike the UniClass system. Tables; It is structured from broadly high level to narrower specific levels.

Tables 11 and 12 cover building construction, while Table 13 includes 14, 21, 22 and 23 classify building construction components. Each table expands up to level 4 with binary numbering. OmniClass tables are organized by topics and activities in construction information. These tables can be used independently or in combination with various combinations. Some of the tables covering the OmniClass system are presented in table 5.

Table 6.4: Example OmniClass tables

OmniClass table	Name	Examples	Name element	OmniClass number
Table 22	Work Results	Structural Steel Framing, Finish Carpentry,	Operation and Maintenance of Plumbing	22-22 01 10

The Omni-Class classification system can also be used to associate all system elements within the project with their respective tasks. In Revit, all system elements can be divided into categories or groups according to their respective Omni-Class classifications. When an element is selected in the system, a list of OmniClass numbers opens, where the user can choose the desired number or group. With the help of Dynamo software, this element list and OmniClass numbers or groups can be exported to an Excel file. An example of this is shown in Table 5. For each selected system element, the OmniClass number of the related element or group must be matched and integrated into the system one by one and it must be manually. The system that demonstrates this is illustrated with an example given in Table 6.5.

Table 2.5: Example list of tasks with OmniClass number and use to ANFIS analysis

Risk ID	Probability Levels	Impact Levels	Manageability	Proximity	Risk Score	OmniClass Number	Risk Color Code
R1	Frequent	Massive	Difficult	Long Term	33	**22-22 01 00**	
R2	Frequent	Massive	Difficult	Medium Term	33	**22-22 01 10**	
R3	Often	Massive	Difficult	Long Term	32	**22-22 01 10 16**	
R4	Frequent	Major	Difficult	Short Term	31	**22-22 01 10 51**	
R5	Frequent	Major	Moderate	Medium Term	31	**22-22 01 10 61**	
R6	Often	Major	Moderate	Long Term	30	**22-22 01 10 62**	
R7	Frequent	High	Difficult	Long Term	29	**22-22 01 30**	
R8	Probable	Major	Moderate	Medium Term	25	**22-22 01 40**	
R9	Probable	Major	Moderate	Medium Term	25	**22-22 01 00**	
R10	Probable	Major	Moderate	Short Term	25	Etc.	

The OmniClass numbers are compared with the element list and the task list, and then assignments are made to the relevant elements.

The selected element of the Omni-Class classification element or group will receive the color code found in the relevant project risk scale. Colors and Omni-Class elements or groups selected for risk identification or assignment imported or transferred back to the model driving the BIM-based dynamo Software.

The main and most important advantage of the Omni-Class classification system is that it is set to a certain standard and can be used internationally. In addition, this classification system provides sustainability and applicability now and in the future

(Lou, 2008). One of the downsides of this classification system is that it is not a well-established system for integrating different risk classes into different elements in the same group. Because the same group numbers will be assigned to the same system elements, confusion will occur when searching for 3D or 4D drawing details.

6.4.3. Coupling using Task ID

In the Revit software program, it is possible to add plus parameters to elements to define a particular element. As with the Omni-Class classification system, assignments between elements or groups must be made individually and manually. It can be done by completing the group assignment numbers in the Risk_ID parameter of the relevant element. With these additional parameters, the elements determined by searching the Risk_ID number in the model can be selected or changed. As an example, to this; a Plumbing weld location or Plumbing Elbow Point, etc.

This concept method described is simplified and can be easily integrated by someone with little experience by establishing a system. Users can look and confirm, if necessary, in the Risk Log Excel interface to see what risks have been assigned to these particular elements or groups. This system control can also be done with a simple artificial intelligence system algorithm.

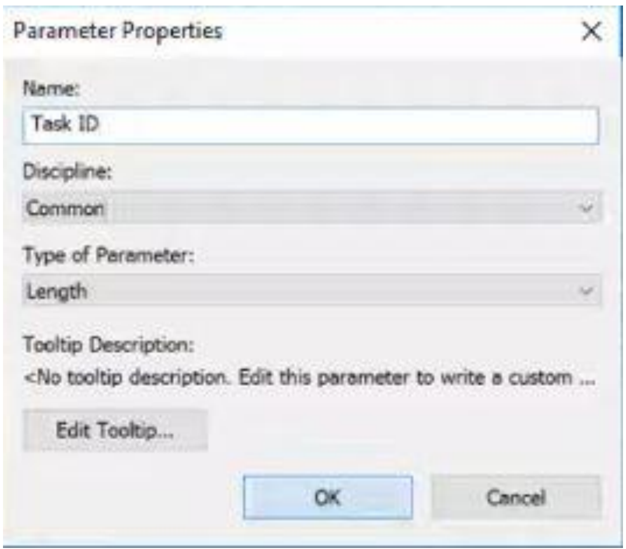


Figure 6.12: Risk_ID parameter in Revit

6.5. Association between Risk Register Excel Interface and BIM Software

A visual programming software is used to convert the information from the Risk Log interface into a 3D BIM model. It automatically connects the colors and additional information created according to the risk list to the Revit software and it allows its users to see the changes in the 3D model in the Risk Register format.

6.5.1. Visual programming

Visual programming, also known as Object Oriented Programming, is a form of object-oriented programming as the name suggests. The objects used in the software are the modeling of the objects around us on the computer. This is called object-oriented programming or visual programming.

The software stores the states of the objects in "variables", and the behaviors are realized by means of "methods". Methods are functions and procedures. When objects will be represented in the software, object classes and instance objects can be created from these classes at any time, and this structure can be interpreted much faster and easier by those who do not know or understand. The most well-known software products are Grasshopper, Dynamo and Marionette.

6.5.2. BIM Based Module and working with Nodes

Dynamo is a tool that creates automatic or complex models without code knowledge with its visual programming interface. Parametric modeling is provided by establishing relations between 3D models and entered parameters.

The Dynamo tool, which has become popular with the increase in parametric modeling studies, works by itself (as a separate program) and as an add-on. The software, which can work as an add-on with Revit, Civil 3D, Alias Design, Formit, Advance Steel, tools, comes installed in Revit (2019 version and later).

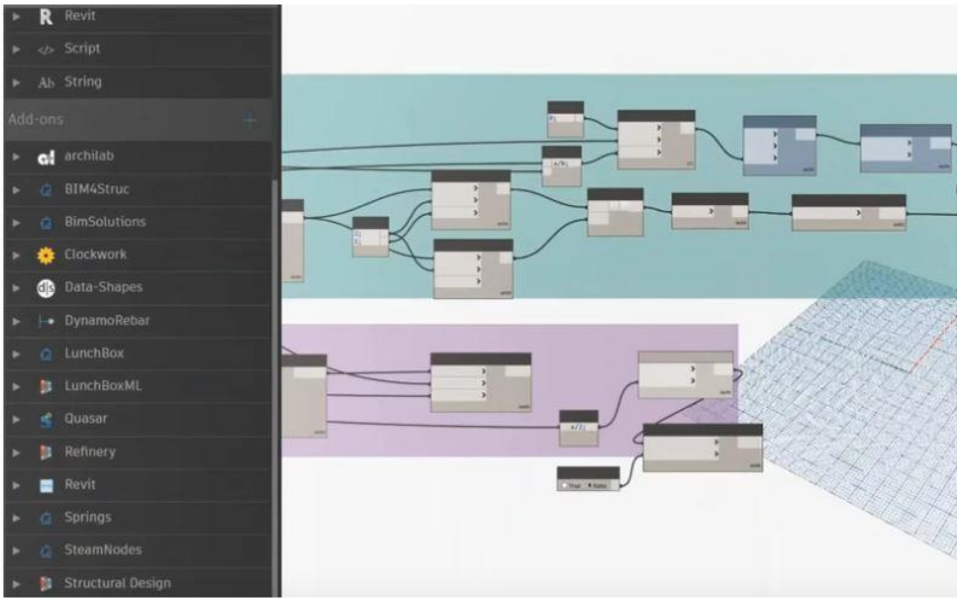


Figure 6.13: BIM Based Module Interface

In the Dynamo tool, commands and desired actions are provided by nodes. Nodes with different features are available for each command. The Node to be used is found from the panel on the left side of the interface and when it is clicked on, it is transferred to the workspace.

The By Coodinates(x,y) Node creates coordinates from the entered point values. On the left side of the chart are the X and Y ports. Values are entered into these ports. Within the entry of values, a Node with a number must be added. 'Number' is added, which is a Node where a number is entered.

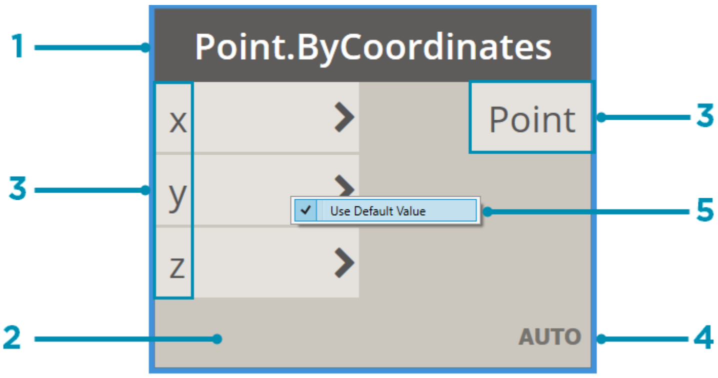


Figure 6.14: Example node from Autocad

Communication between nodes is carried out with connections called Wire. In order to connect the nodes, the part that looks like the less than/greater than sign is selected and clicked on the desired location.

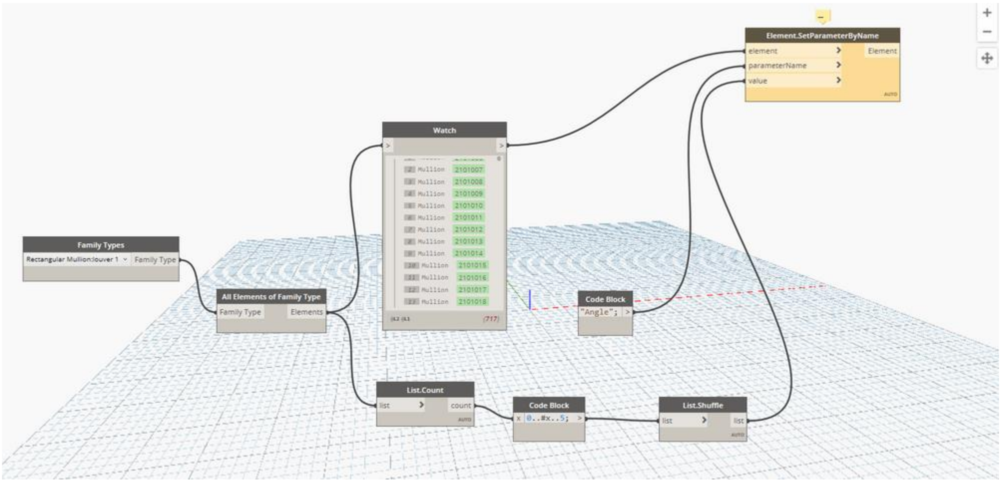


Figure 6.15: Example of Data Flow on Dynamo Module

The Dynamo visual programming interface has an integrated library with various node systems or structures. Since Dynamo is an open-source software, node points created by other users and converted into software can be used free of charge in systems created without any cost. However, if a special node is desired to be created, these special nodes can be created with the help of programming software languages and added to the Dynamo system library.

The main role and purpose of Dynamo software in the risk visualization tool is to extract the data from the Risk log with a certain method and integrate them in a traceable way into the relevant elements or groups in the 3D BIM model.The main reason for choosing Dynamo software chosen because it can easily read and extract data from any data file or dataset. This data is then incorporated into the elements in the 3D model with the help of specific mappings as an add-on to Revit with a traceable and easy integration. The connection between the elements in the Risk Register excel interface and the elements in the 3D model is made by defining the Risk_ID parameters, and the processes are completed.

Dynamo software can provide a function that when an element or group is selected, it is displayed in a separate window with a pop-up message containing linguistic expressions entered in the Risk Register excel interface. However, this feature will not be included in this study, since it is generally studied on risk maps. This will complete the work of both 3D visualization and adding linguistic expression to the relevant element for the considered system. The advantage is that it will allow users to get all the information that is hardly visible in the full 3D BIM model. In the thesis, linguistic expressions related to risk are considered, but the system can be used to convey all information.

The dynamo software code used in the software tool is generated incrementally. First, a list of elements or groups is extracted from the Revit model, and then the relevant information is matched to be integrated with each other after the application of ANFIS to the real data obtained from the Risk Register Excel interface. These real data are then compared with each other and subjected to filtering. The matching results of this filtering are integrated into the 3D model with the help of the risk color scale used in the project, and risk maps are created. As a final step, linguistic expressions or pop-ups can be transferred to the relevant risk elements if desired.

Step 1: Exporting information from BIM based Software

A more automatic option is to select by category using a node called "All Items of Category"; All elements are selected automatically by selecting all categories in the BIM model.

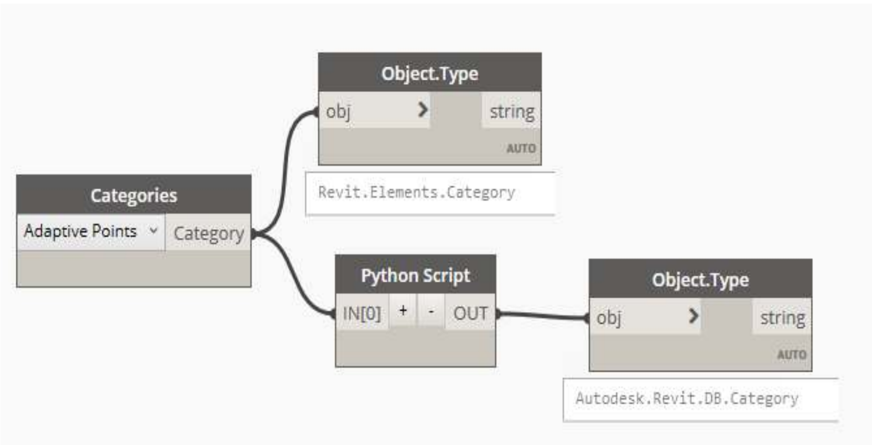


Figure 6.16: Exporting information from Revit Software elements with dynamo

Step 2: Exporting info from Excel Risk Register (figure 6.17)

To simplify the export of information by the Dynamo software, it is necessary to link to a different sheet in Excel. Working with numeric expressions in Dynamo software is more convenient than working in text format, so in Excel the risk assessment is converted to numeric numbers ranging from 0 to 1. The “File Path” node is used to export information from Excel. A file is selected and then the “Excel.readFromFile” node will allow the program to retrieve information from the selected page.

In order to extract the correct column containing information from the Dynamo software, the “List.GetItemAtIndex” node is added last, where the desired column numbers are added with the code block from which it is called, and the rest continues.

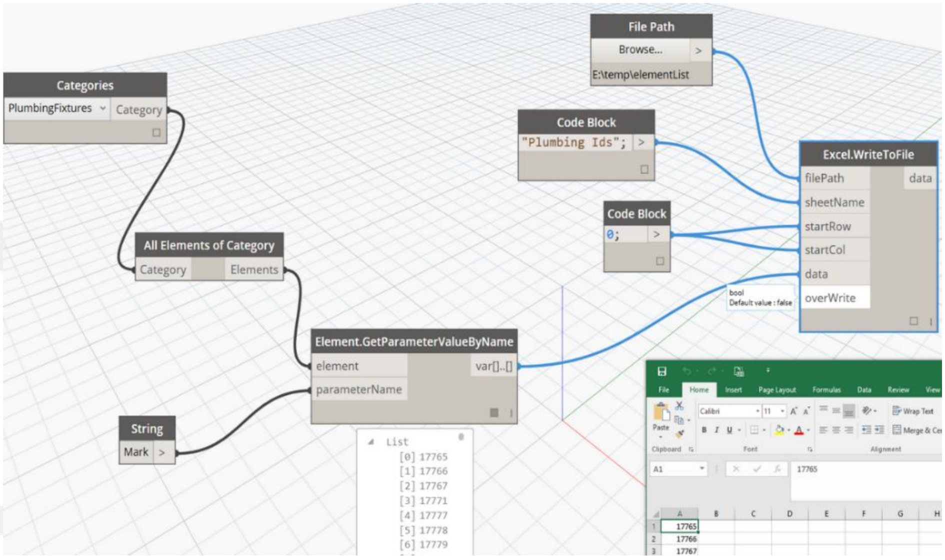


Figure 6.17: Extraction of the info from Excel -Dynamoworks

Step 3: Comparing info from the Excel Risk Register and Revit (figure 6.18)

The "Springs.Dictionary.ByKeysValues" node is used to compare the information with each other. In the "Search Keys" entry, the list of elements or groups in Revit is gradually imported with the Element or group numbers that can be integrated. Element or group numbers list is taken from Risk Excel Interface in "Keys" entry and after ANFIS is applied in "Values" entry, the list with color scale assigned is made interoperable with each other.

Both datasets exported from Excel are of the same length and this node indicates that the first Element or group number whose Risk score and color is assigned after ANFIS application, the second matched Risk score and color belongs to the second Element or group number. It then compares and matches the node, Element, or group numbers.

Thus, the result of the node is a list of all elements in the Revit model with their corresponding Risk score and color charts.

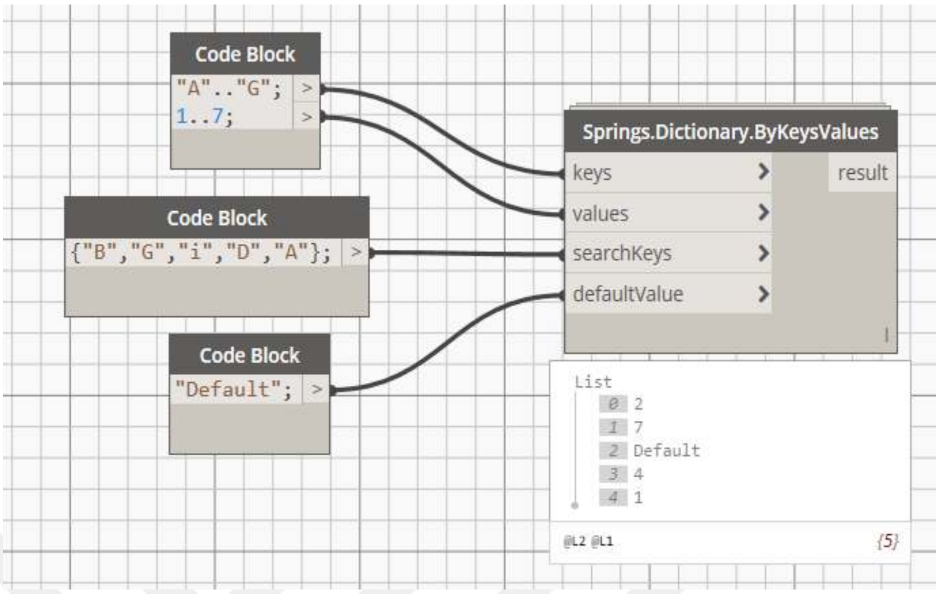


Figure 6.18: Comparison of info – DynamoBIM

<u>Step 4: Filtering Risk Elements Phase (figure 6.19)</u>

The main purpose of this phase is to filter risky items into 4 different groups according to their Risk Scores. Initially, the "==" node is used to compare the list with a given Risk Score and the probable risk score. Then, with the “List.FilterByBoolMask” node, all elements and groups in the 3D model will be filtered, leaving only the correct elements and groups there.

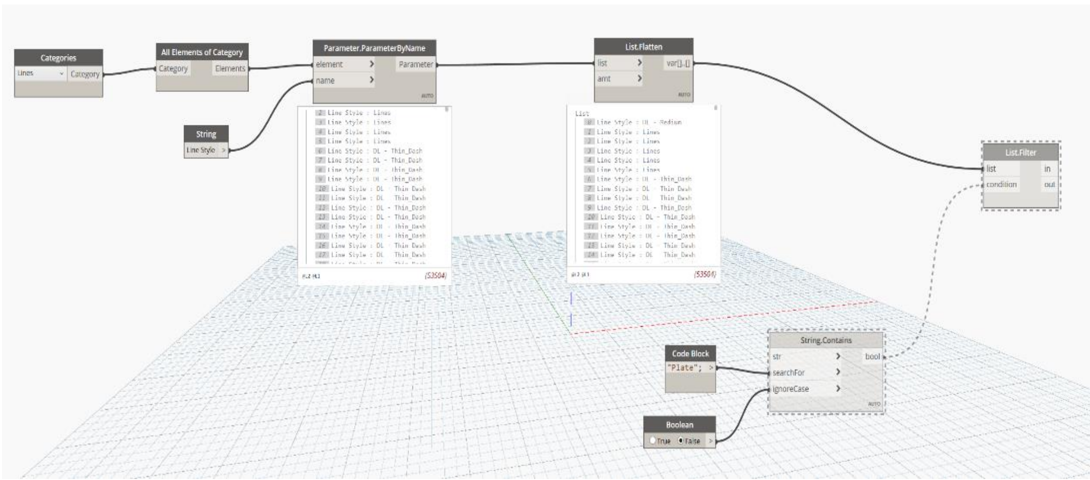


Figure 6.19: Filter of the elements – Dynamo

<u>Step 5: Creating Risk Maps with 3D BIM model</u>

The “Element.OverrideColorInView” node is used to update the created BIM model with the risk colors specified in the project. In the "Elements" entry, the list of elements in the "List.FilterByBoolMask" node will be made as detailed 2 steps ago.

This list is compared with the list in the "Element.OverrideColorInView" node. The "SetIntersection" node compares the created data sets with each other and then creates a new data set with the elements or groups in both data sets. This is complemented by a data set with the same Risk score and color. Elements or groups of this dataset will have the same risk color and a transparency will be added using the "OverrideGraphicSettings.ByProperties" node.

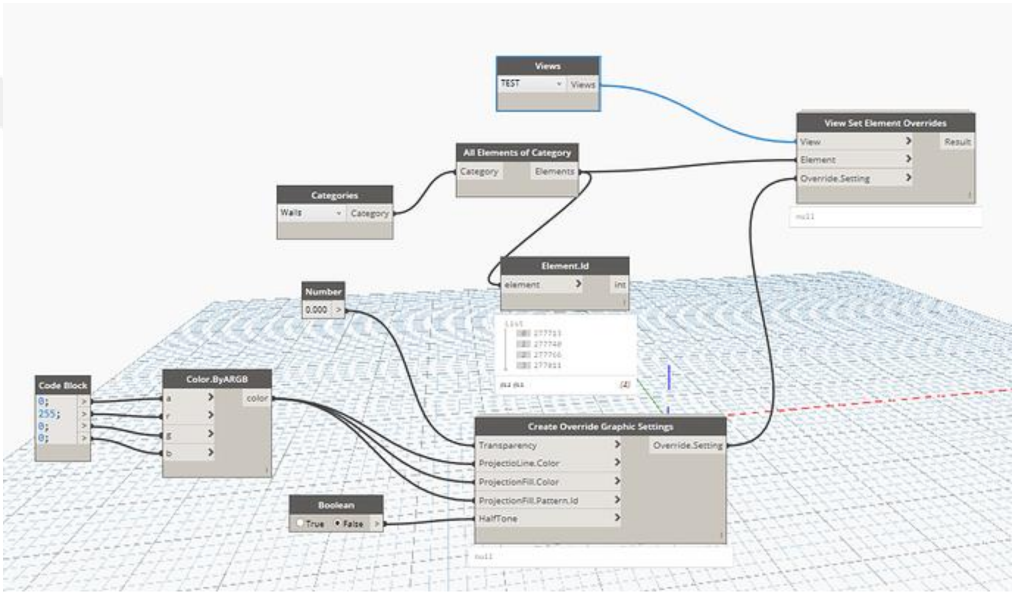


Figure 6.2: Modelled BIM model with colors

<u>Step 6: The process of separating risky items or risk groups in a separate window</u>

The "Element.TemporallyIsolateInView" node can be used to summarize a particular element or group in a separate section. This node can be selected by connecting the node "views" to the entry portion of the point. In this case, the 3D view of the risk item or group can be selected. To select the element that should be displayed in a separate window, the "Select Model Element" node must be mapped to the "element" entry. Project developer Stakeholders will be able to select a particular risk item they want to examine more carefully by clicking the "edit" button where they can select a risk item or group in the 3D BIM model.

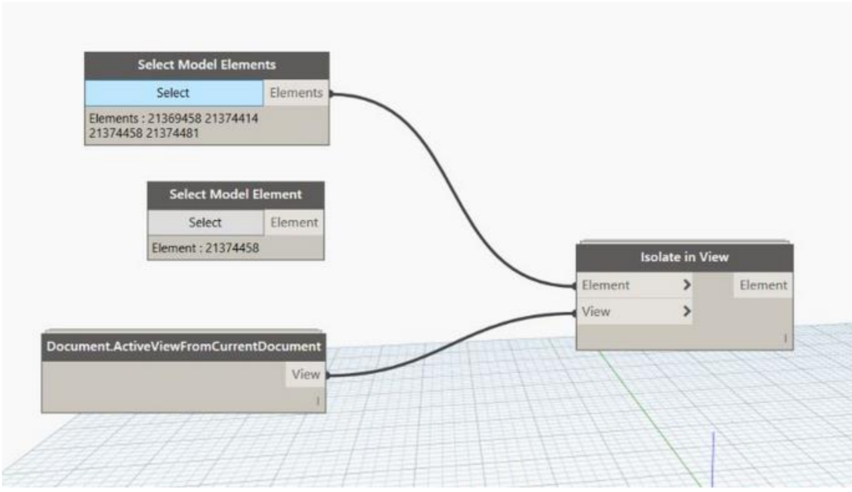


Figure 6.21: Isolate Risk element in separate window

Step 7: Add a linguistic terms for additional info

When an element or group is selected and displayed in a separate window, a linguistic expression with additional information about the 3D BIM model may be displayed, but this has not been done at this stage of the thesis.

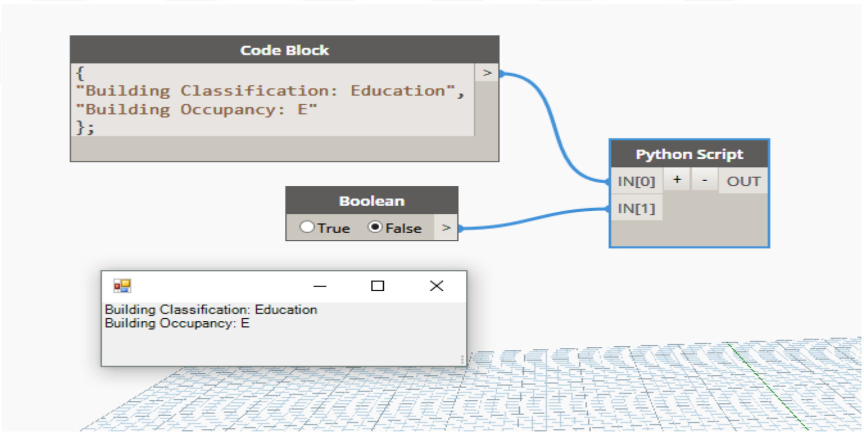
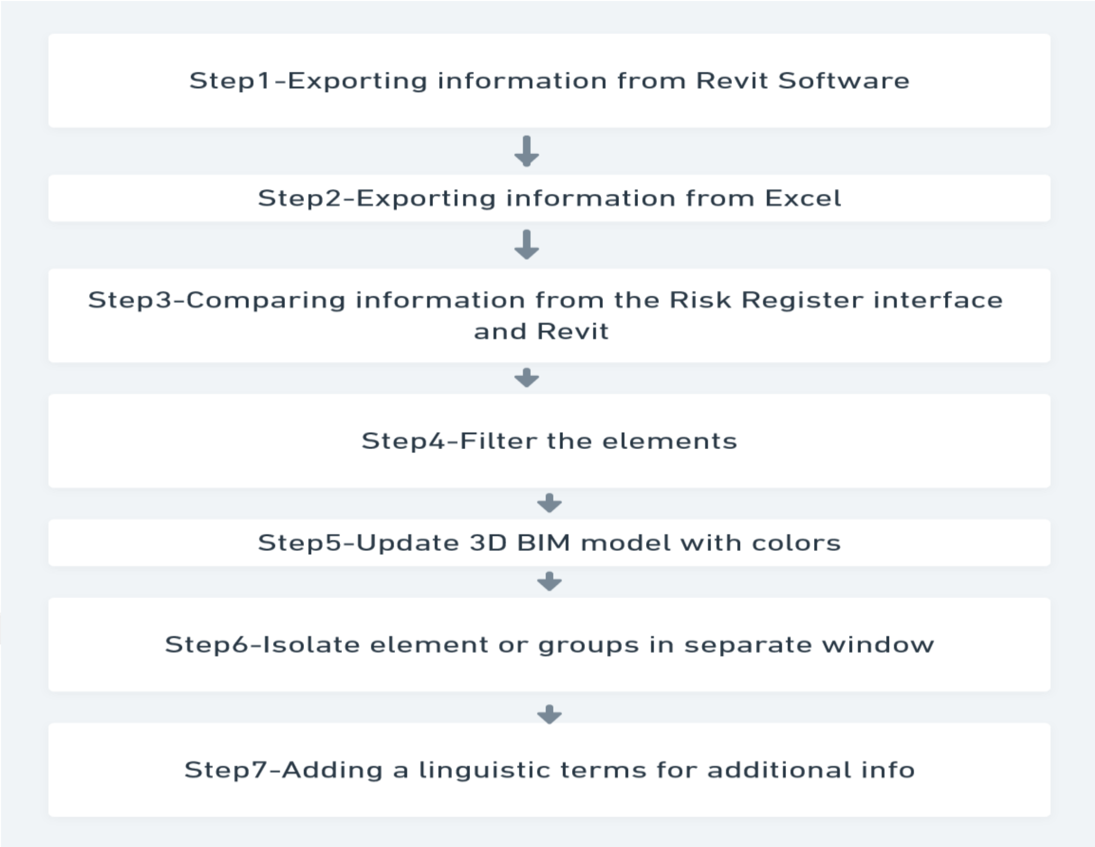


Figure 6.22: Temporary view in Revit

Figure 44 briefly summarizes the Revit and Dynamo processes. In practice, users or project stakeholders will simply need to run the dynamo software to update the risk colors of elements or groups in the 3D BIM model.

Figure 6.23: Briefly of the Dynamo Process



6.6.Development of the 4D Model

It can be integrated into a 3D BIM model using the Timeline option in Navisworks software. This system is then transferred to the 4D model option. It is recommended to use the .CSV file as the Risk Record is in Excel format. Also , You should use commas to separate it.

The .CSV file must be opened in the notebook on computers. It clearly states a "search" and "replace all" that allows this app to easily replace all semicolons with regular commas for users or project stakeholders.

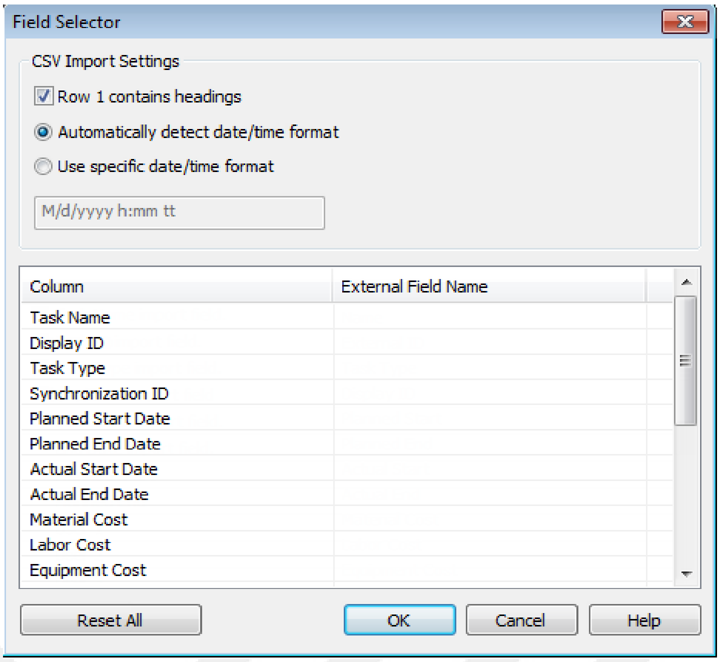


Figure 6.24: Link between Navisworks and Risk Register- Field Selector on Naviworks

Elements or groups imported from the project construction schedule or planning and elements or groups imported from the 3D model must be manually reconnected one by one. This can be done because items in the BIM model already have an element or group ID number. In Navisworks it is possible to search for elements or groups by their parameters. The advantage of this type of connection is that when an addition or subtraction is made in the BIM model, it also automatically changes in the 4D Model.

To change the color of the element or group with the associated risk assessment, the 'Risk Score' column is linked to the 'Element type' (Navisworks) column. All tasks with this task type (Risk Score Value) will automatically change to the color evaluated in the Risk Register Excel interface.

The model created with the Navisworks modeling program has a simulation option to increase the visualization at various phases of construction. As explained earlier, a risk element or group may have different definitions of risks during construction phases. With this 4D model, these different risks can be made visible and incorporated into these processes throughout the construction phases. This makes risk visually monitor and manageable in pre-construction, construction or any previous process.

6.7. Tool guidelines

The tool is primarily intended for use in the initial, planning and execution phases of projects. This is also the stage where possible risk measures can have a greater impact through a smaller investment. After the project initiation, planning, execution, monitor/control and end stages are completed, the tool can also be used and the results can be communicated to the relevant project stakeholders through communication management. Figure 6.25 is explained step by step how to use it at the initiating and planning stages of the project.

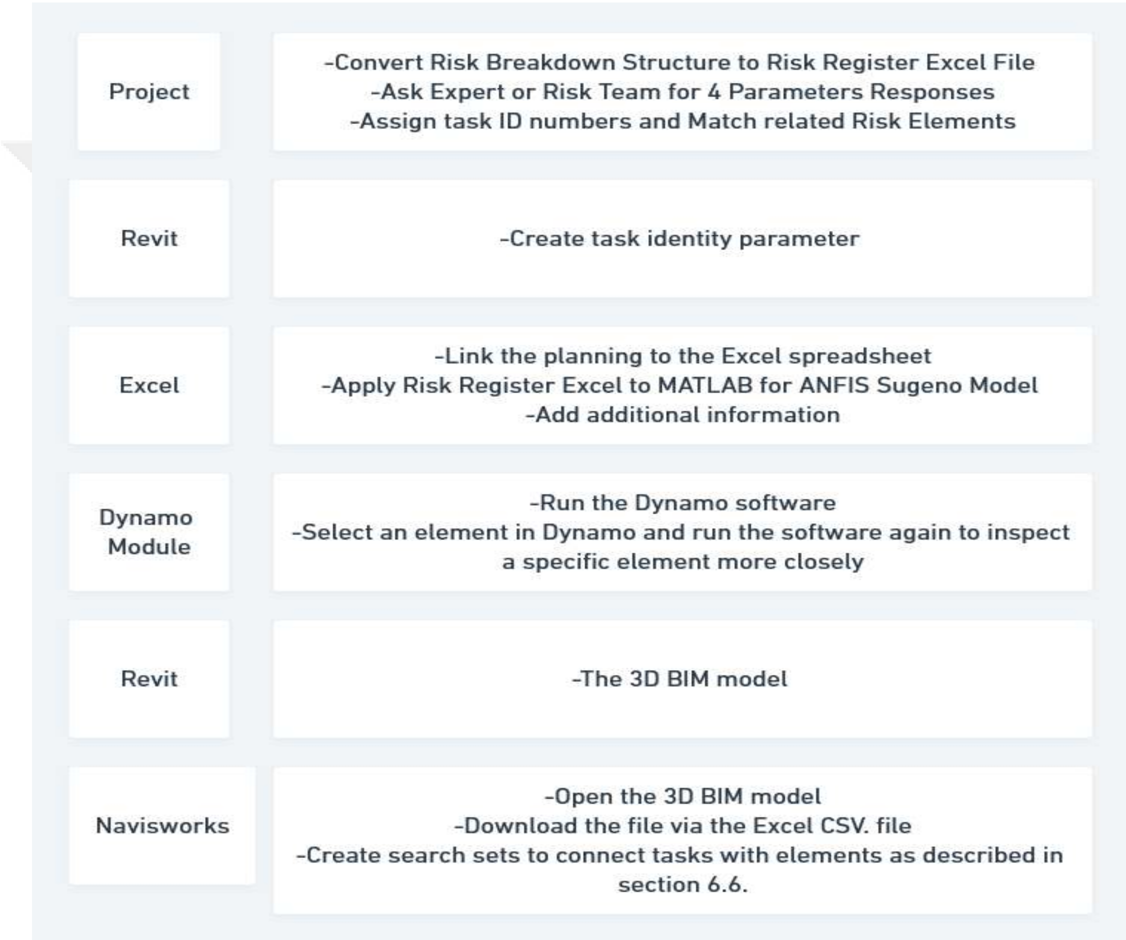
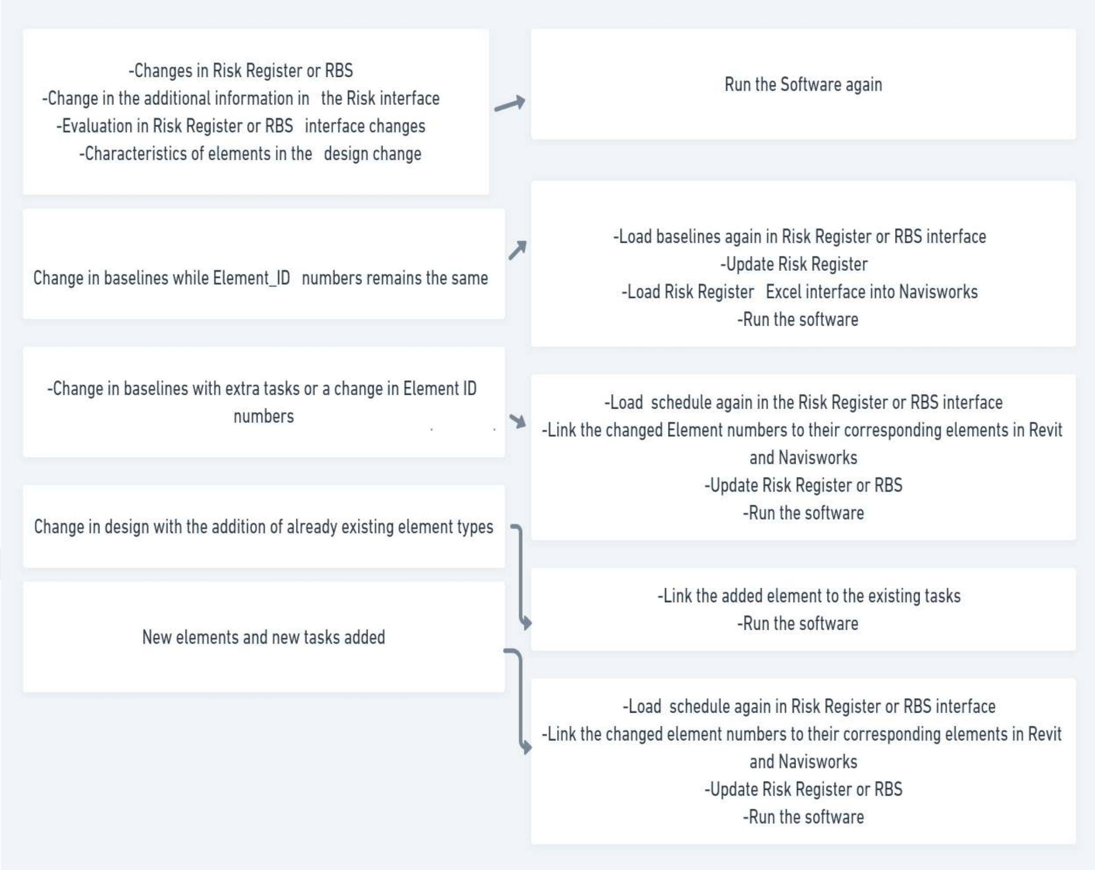


Figure 6.25: Step progresses for running the RMT for Initiating and Planning Phases

During the project construction phase, many things can change compared to the initial phases of the project. These possible changes and the steps to be taken accordingly are chamatized in table 6.6. At these stages, it is sufficient to run the software constantly up-to-date at certain intervals. Define the current risk register, run it by integrating it with Dynamo software, Save the BIM model created with the latest updated risk register in .NWC and run the Navisworks simulation and observe the Risk maps.

Table 6.6: Step progresses for running the RMT for Execution Phases



6.8. Summary

In this part of the thesis, general information about the matlab program, application stages, pre-application method stages about entering fuzzy logic module information are explained. Also; The method of how to do 3D and 4D risk color integration to BIM-based is explained.

CHAPTER 7

Application of Framework Development for ANFIS and BIM use in the Risk Management at NGPP

7.1 Introduction

In the study, a three-step ANFIS-oriented model will be applied based on the neural fuzzy approach to the risk analysis problem in natural gas pipelines and stations.

Using a total of 104 risk assessment data used within the scope of the Tanap Project, the risk assessment study was carried out on the basis of neural fuzzy logic, and the L-Matrix risk assessment methods used in the project were compared over error criteria.

The stages of the study using the neural fuzzy logic approach are shown in Figure 7.1. By integrating the neural fuzzy logic into the risk analysis, the aim of the application will be to obtain a more effective assessment with the total risk value as a measurable output and to obtain better results than the classical risk assessment models used.

In the light of the methodology described in Chapter 6, the inputs for an effective and effective risk assessment study in ANFIS were determined as probability, impact, manageability and proximity, and the data set shown in Appendix-A was obtained as a result of detailed work with Risk Team Professionals.

7.2. Application of Adaptive Neuro Fuzzy Inference System (ANFIS) System

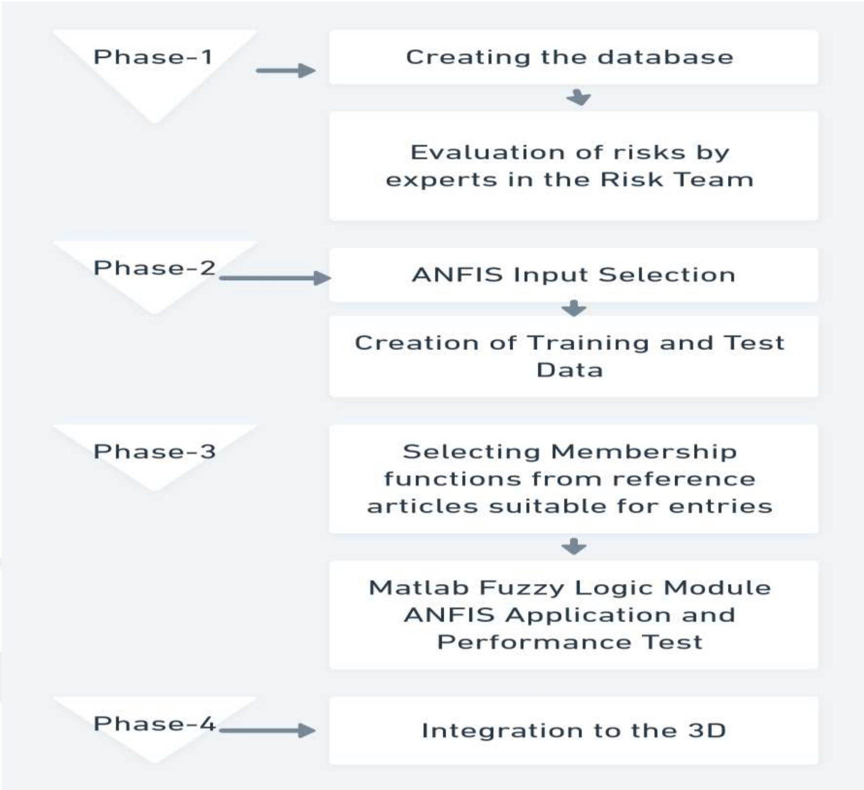


Figure 7.1: Stages of risk assessment by Matlab/ANFIS and 4D Integration model for Application

Within the framework of the first step of the study, it is necessary to select the appropriate number and type of membership functions for each criterion (input). Determining the number of membership functions is one of the important issues in the application of the ANFIS model. In order to obtain a more comprehensive study within the framework of Risk Management and Evaluation, it was decided to select three and five membership functions. Afterwards, the most suitable membership function type for the model should be determined. In the study, as a result of the error values obtained for 40 cycles in the selection of the membership function types of the inputs, it resulted that the gauss2mf function type gave the least error value. (Table 7.1).

At this point, the data specified in Annex-A are named as dataE and dataT and loaded. (Figure 7.2) After the selection of criteria, the problem turned into a neural fuzzy system consisting of 4 inputs and 1 output. In order to determine the membership types and numbers of the entries, the “Generate FIS” button seen in Figure 49 is used. membership function is selected. The linear expression is also selected for the output

"MF Type" expression. As mentioned in the previous sections, it represents the Sugeno fuzzy model in the first order.

Table 7.1: Membership functions error values

Membership Function Type	40 Epoch Error Value
trimf	0.01576795033886
trapmf	0.015768
gbellmf	0.01576795033887
gaussmf	0.01576795033887
gauss2mf	0.01576795033885
pimf	0.015768
dsigmf	0.01576795033886
psigmf	0.01576795033886

Figure 7.2: Transfer of model datasets to the system

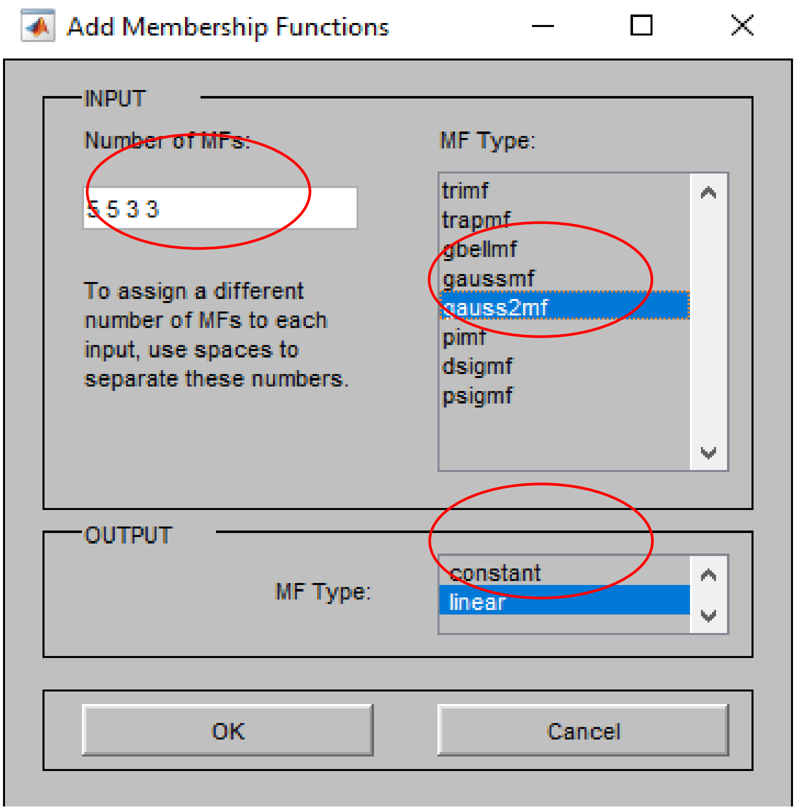


Figure 7.3: Transfer of model datasets to the system

When the data set to be trained is loaded and tested in the ANFIS editor, information about the model can be observed as seen in Figure 7.4 and it is displayed in the lower left corner.

It says "Epoch 40: error = 0.01576795033885". This means that the selected membership function type and for each of the inputs 5 5 3 3 triangular membership functions, the training data was trained 40 cycles with a hybrid learning algorithm and the output value was estimated correctly with an error value of 0.01576795033885.

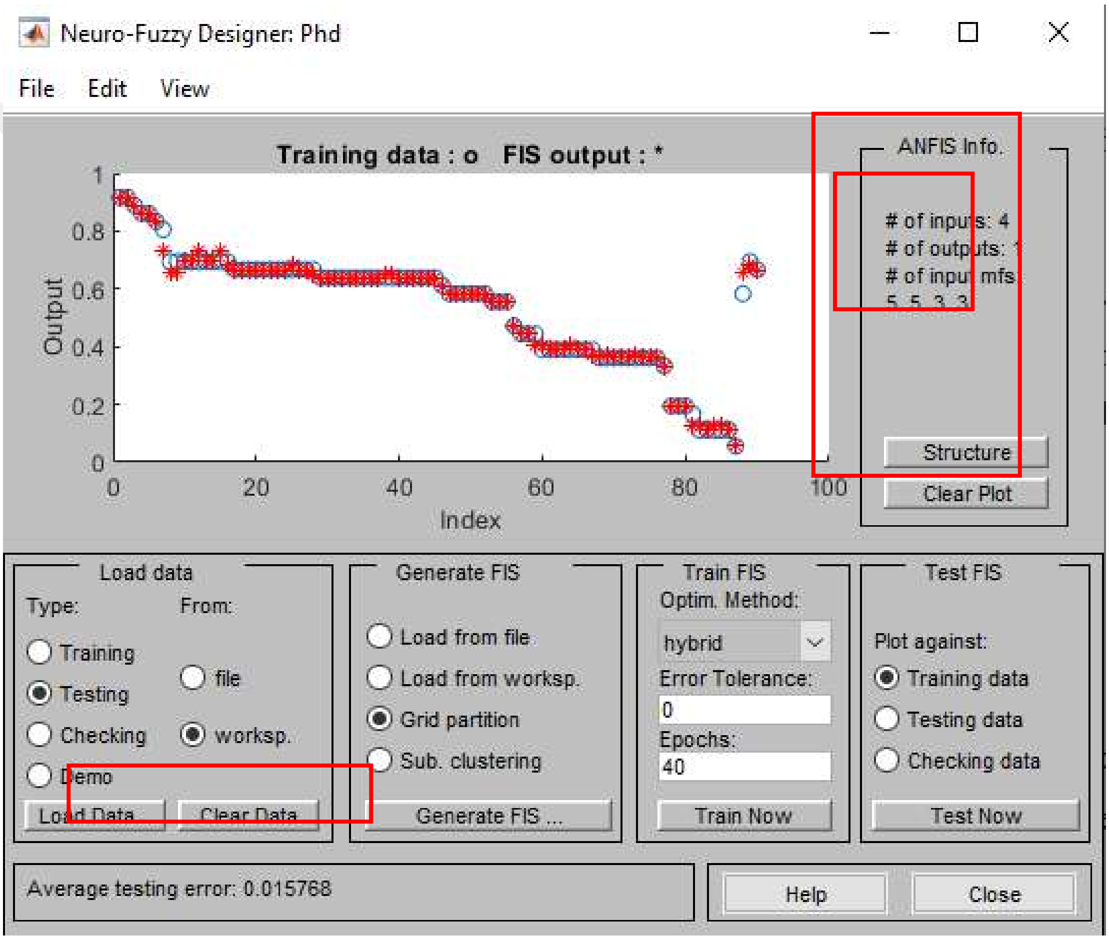


Figure 7.4: Gauss2mf membership function error graph

In the ANFIS editor window structure displays the ANFIS model structure. (Figure 7.5) In the figure, the leftmost black nodes entries represent the membership functions of the 2nd layer nodes, which contain 5 5 3 3 connections for each node.

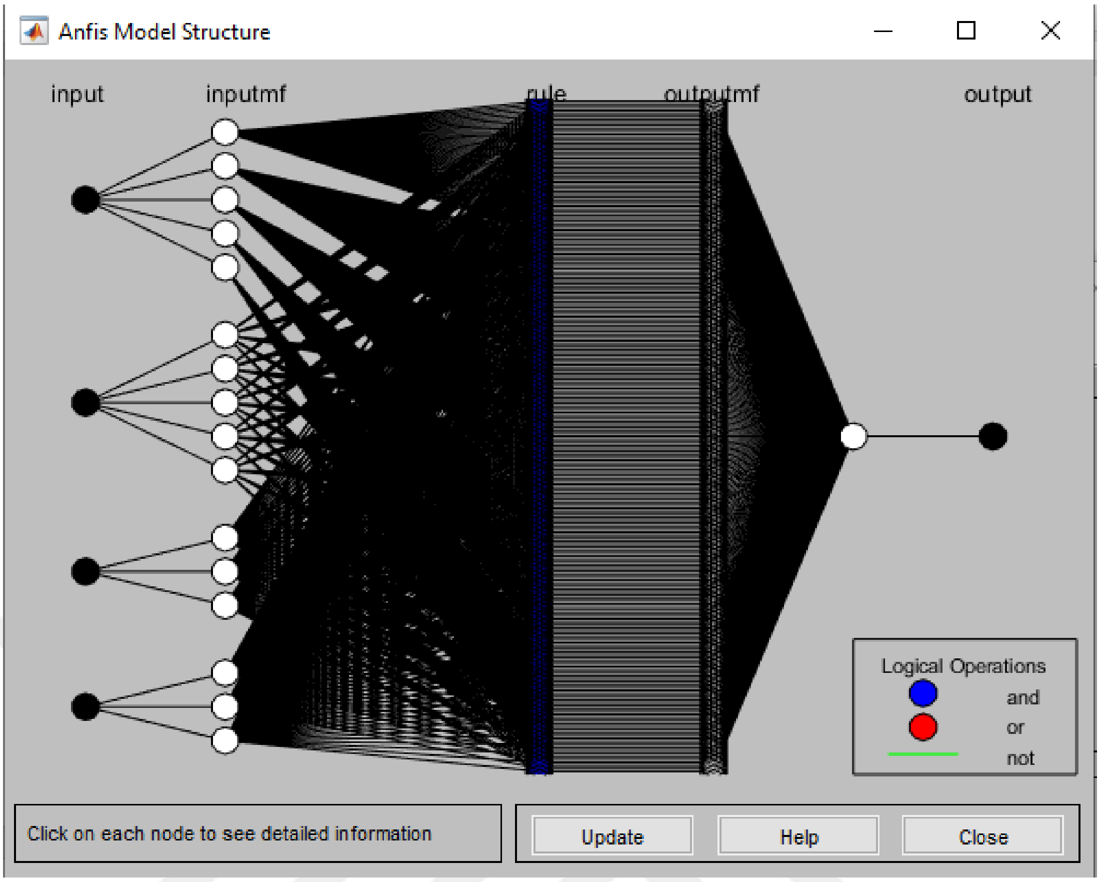


Figure 7.5: ANFIS Model Structure

As can be observed in Figure 7.5, 221 different rules are formed in the next step, since each input (4 inputs) is a membership function of 5 5 3 3 respectively. The output from the linked rules is shown in the fourth layer as the system's estimated risk value output value in the fifth layer. In Figure 7.6, the rules depending on the established model are seen.

Figure 7.6: ANFIS Model Rules

The rules defined in the model can be edited by users (experts) under the "Rule Editor". The risk assessment model can be observed in Figure 7.7 of the top 9 rules.

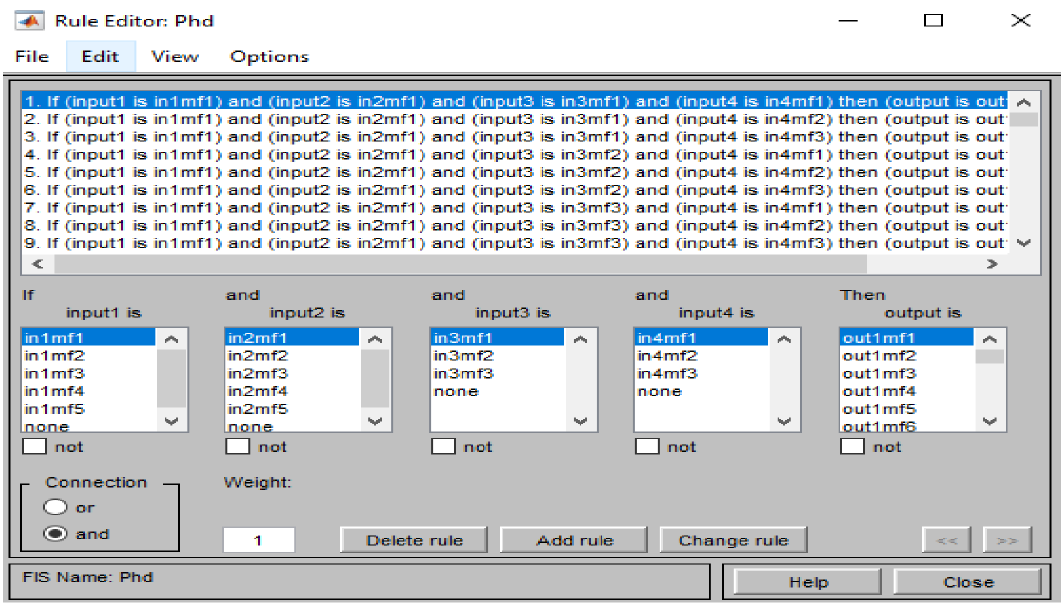


Figure 7.7: Rules for first 9 Rules

With the "evalfis" command used on the command screen in Matlab, 104 output values can be listed. For this, it is necessary to define the model and send a command as evalfis(input,model).

For the risk analysis study in the Tanap Project, the effect of each input (risk parameter) on the total risk value in the system was investigated after the database creation. Since the risk value is expressed with a probabilistic concept between 0 and 1, the normalization process in the results obtained was done via excel. This study is shown in Table 7.2. Error tolerance values are very low due to the data used in the study and the general structure of the Petroleum/Natural Gas Industry. Therefore, the data show differences in percent and thousandth basis. The first 90 data sets are training and the last 14 are test data sets. 14 values randomly select from the test data set added to the model and tested on the matlab m5533 model. The results are shown with the last 14 values in the excel table.

Table 7.2: ANFIS model output values

	Risk Score Normalization	ANFIS Score	ANFIS Score-Normalization
R1	0.916666667	0.9167	1
R2	0.916666667	0.9167	1
R3	0.888888889	0.8889	0.96967383
R4	0.861111111	0.8611	0.93934766
R5	0.861111111	0.8611	0.93934766
R6	0.833333333	0.8333	0.90902149
R7	0.805555556	0.7315	0.797970983
R8	0.694444444	0.6574	0.717137559
R9	0.694444444	0.6574	0.717137559
R10	0.694444444	0.6944	0.757499727
R11	0.694444444	0.6944	0.757499727
R12	0.694444444	0.7315	0.797970983
R13	0.694444444	0.6944	0.757499727
R14	0.694444444	0.6944	0.757499727
R15	0.694444444	0.7315	0.797970983
R16	0.694444444	0.6852	0.747463729

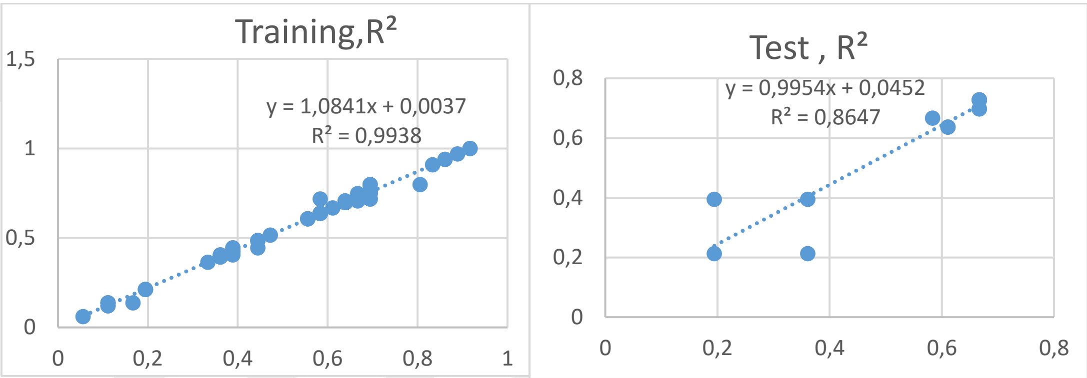
R17	0.666666667	0.6667	0.727282644
R18	0.666666667	0.6667	0.727282644
R19	0.666666667	0.6667	0.727282644
R20	0.666666667	0.6667	0.727282644
R21	0.666666667	0.6667	0.727282644
R22	0.666666667	0.6667	0.727282644
R23	0.666666667	0.6667	0.727282644
R24	0.666666667	0.6667	0.727282644
R25	0.666666667	0.6852	0.747463729
R26	0.666666667	0.6667	0.727282644
R27	0.666666667	0.6667	0.727282644
R28	0.666666667	0.6481	0.706992473
R29	0.638888889	0.6389	0.696956474
R30	0.638888889	0.6389	0.696956474
R31	0.638888889	0.6389	0.696956474
R32	0.638888889	0.6389	0.696956474
R33	0.638888889	0.6389	0.696956474
R34	0.638888889	0.6389	0.696956474
R35	0.638888889	0.6389	0.696956474
R36	0.638888889	0.6389	0.696956474
R37	0.638888889	0.6389	0.696956474
R38	0.638888889	0.6481	0.706992473
R39	0.638888889	0.6481	0.706992473
R40	0.638888889	0.6389	0.696956474
R41	0.638888889	0.6389	0.696956474
R42	0.638888889	0.6389	0.696956474
R43	0.638888889	0.6389	0.696956474
R44	0.638888889	0.6389	0.696956474
R45	0.638888889	0.6389	0.696956474
R46	0.611111111	0.6111	0.666630304
R47	0.583333333	0.5833	0.636304134
R48	0.583333333	0.5833	0.636304134
R49	0.583333333	0.5833	0.636304134
R50	0.583333333	0.5833	0.636304134
R51	0.583333333	0.5833	0.636304134
R52	0.583333333	0.5833	0.636304134
R53	0.555555556	0.5556	0.606087051
R54	0.555555556	0.5556	0.606087051
R55	0.555555556	0.5556	0.606087051
R56	0.472222222	0.4722	0.515108542
R57	0.444444444	0.4444	0.484782372
R58	0.444444444	0.4444	0.484782372
R59	0.444444444	0.4074	0.444420203

R60	0.388888889	0.4074	0.444420203
R61	0.388888889	0.3889	0.424239119
R62	0.388888889	0.3889	0.424239119
R63	0.388888889	0.3889	0.424239119
R64	0.388888889	0.4074	0.444420203
R65	0.388888889	0.3889	0.424239119
R66	0.388888889	0.3889	0.424239119
R67	0.388888889	0.3704	0.404058034
R68	0.361111111	0.3611	0.393912949
R69	0.361111111	0.3704	0.404058034
R70	0.361111111	0.3611	0.393912949
R71	0.361111111	0.3611	0.393912949
R72	0.361111111	0.3611	0.393912949
R73	0.361111111	0.3704	0.404058034
R74	0.361111111	0.3611	0.393912949
R75	0.361111111	0.3611	0.393912949
R76	0.361111111	0.3611	0.393912949
R77	0.333333333	0.3333	0.363586779
R78	0.194444444	0.1944	0.212065016
R79	0.194444444	0.1944	0.212065016
R80	0.194444444	0.1944	0.212065016
R81	0.166666667	0.125	0.136358678
R82	0.111111111	0.125	0.136358678
R83	0.111111111	0.1111	0.121195593
R84	0.111111111	0.125	0.136358678
R85	0.111111111	0.125	0.136358678
R86	0.111111111	0.1111	0.121195593
R87	0.055555556	0.0556	0.06065234
R88	0.583333333	0.6574	0.717137559
R89	0.694444444	0.6852	0.747463729
R90	0.666666667	0.6667	0.727282644
R91	0.666666667	0.6667	0.727282644
R92	0.666666667	0.6667	0.727282644
R93	0.666666667	0.6667	0.727282644
R94	0.666666667	0.6389	0.696956474
R95	0.611111111	0.5833	0.636304134
R96	0.666666667	0.6667	0.727282644
R97	0.666666667	0.6667	0.727282644
R98	0.666666667	0.6389	0.696956474
R99	0.611111111	0.5833	0.636304134
R100	0.583333333	0.6111	0.666630304
R101	0.361111111	0.3611	0.393912949
R102	0.361111111	0.1944	0.212065016

R103	0.194444444	0.1944	0.212065016
R104	0.194444444	0.3611	0.393912949

In our risk analysis study with neural fuzzy logic approach, how to calculate the effect of risk parameters on the total risk value with ANFIS was examined. The representation of the inputs in the fuzzy inference interface is given in Figure 7.8. The structure of the entries can be edited through the membership function editor. An example illustration for the probability risk parameter is given in Figure 7.9.

Table 7.3: ANFIS model output values for R^2



For each input, 5 5 3 3 membership functions were assigned, respectively. Verbal values were assigned to the specified membership functions by showing references from the literature.

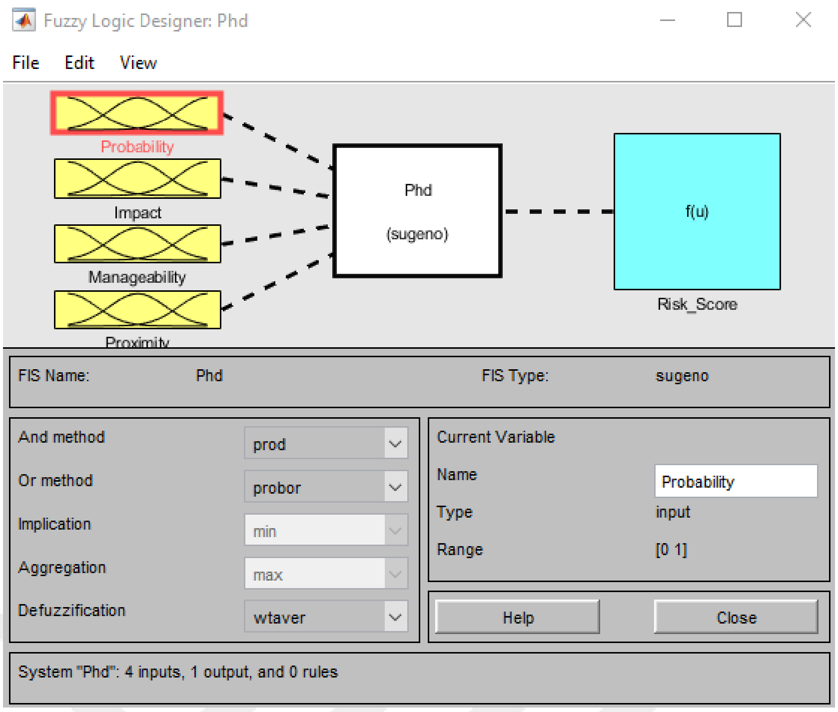


Figure 7.8: Model FIS Structure

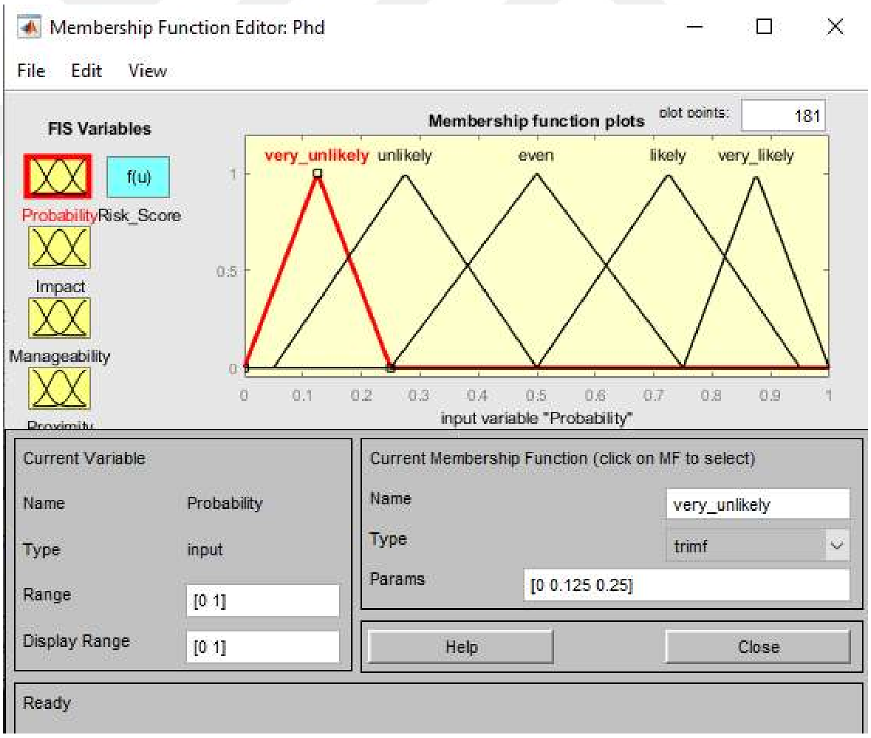


Figure 7.9: Inputs Memberships Structure

The risk assessment model includes 221 rules, which creates 221 distinct output types. Four verbal values were assigned for each output rule: noteworthy, low, medium, and high. These 4 values are taken from the ranges used in the project.

As a result of all these verbal value definitions, the rule structure has become meaningful. Rules are displayed with the Rules option under the Edit menu.

7.3 Multiple Regression Analysis

Regression is one of the most commonly used econometric methods. The purpose of multiple regression is to describe the relationship between dependent variables and independent variables. Multiple regression is based on the least squares method, which is based on the fact that the sum of the squares of the differences of the observed and predicted values is the least.

In this part of the study, in order to compare the results obtained from the ANFIS model, Risk Score Evaluation was made using multiple regression analysis, which is one of the classical statistical methods. Various regression equations were established based on the training data set used in the ANFIS model with Excel. Considering the correlation and determination coefficients, the appropriate ones were selected from these equations, and the control and test data sets used in the ANFIS model and the error rates in the estimations of these equations were calculated and compared with the results obtained with the ANFIS model. The training data set (the first 5 sets are shown) was entered into the data entry page of Excel in five columns in order to create the regression equation, as seen in Table 7.4.

Table 7.4: Entering the Data Set into Excel

	Pnormalization	I-normal	M-normal	Proximity-normal	Risk Score Normalization
R1	0.875	8.75	0.875	0.5	0.916666667
R2	0.725	8.75	0.875	0.9	0.888888889
R3	0.875	7.25	0.875	0.11	0.861111111
R4	0.875	7.25	0.875	0.5	0.861111111
R5	0.725	7.25	0.5	0.9	0.833333333

After data entry, after selecting the Regression option from the Data section in Excel, as in 56, the probability, impact, manageability and proximity independent variables are added to the "Risk Parameters" line, and the Risk Score dependent variable is "result" and the OK button is pressed. (Figure 7.10).

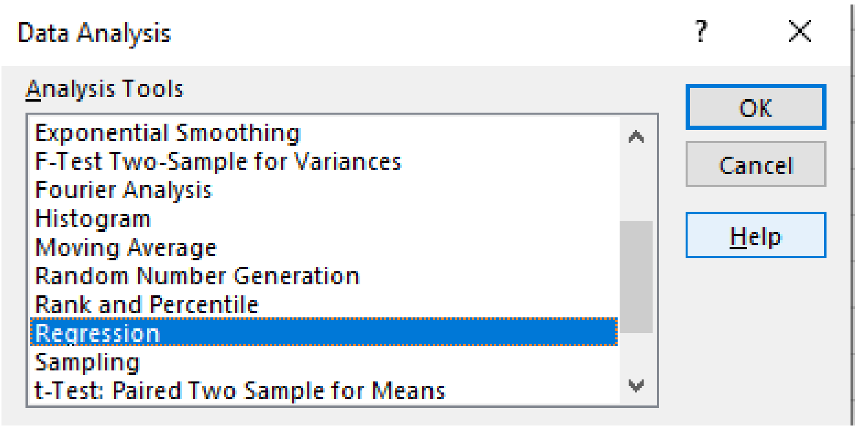


Figure 7.10: Regression Analyses Starting Screen on Excel

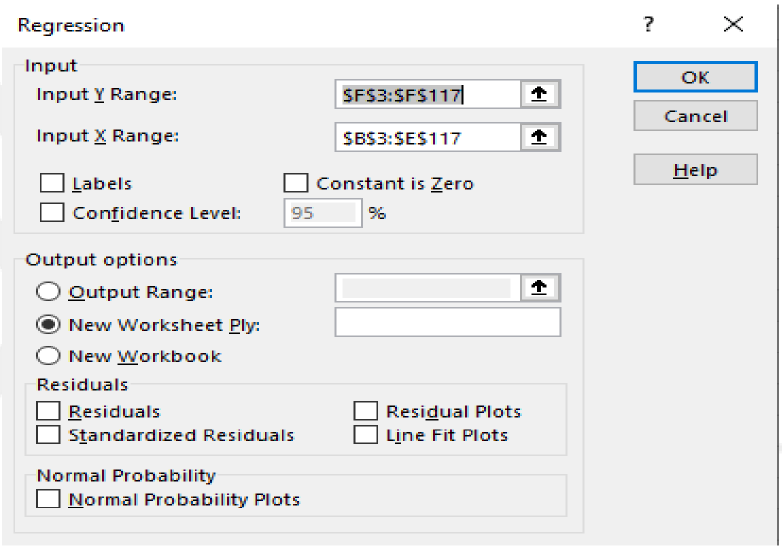


Figure 7.11: Regression Analyses Data Entrance

Multiple regression analysis result screen

Regression Analysis ; Probability, Impact, Manageability and Proximity

The regression equation is ; Risk Score = - 0.079 + 0.54 probability + 0.055 Impact + 0.038 Manageability + 0.073 Proxity

Table 7.5: Result of Regression Analyses

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.788718175
R Square	0.622076359
Adjusted R Square	0.608333682

Standard Error	0.12479333			
Observations	104			
	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.078912959	0.05078345	-1.553910949	0.123078153
X Variable 1	0.537284227	0.059135835	9.085594701	4.85396E-15
X Variable 2	0.055364683	0.005973548	9.268308455	1.85762E-15
X Variable 3	0.038462428	0.042845106	0.897708781	0.371301488
X Variable 4	0.073015148	0.035719021	2.044153074	0.043326694

Considering the results of the regression analysis, this model is an important model in explaining the link between Risk Score and 4 different variables - Probability, Impact, Manageability and Proximity. In this model, the coefficients of the Probability, Impact and Proximity variables were significant ($p < 0.01$), while the coefficients of the Manageability variable were insignificant ($p > 0.05$). Also , Regression results will be added to Annex-B.

R^2 value, which expresses the determining power of the model, is R-Sq(R^2) = 62%, R-Sq(adj) (R^2 corrected) = 60% for this model.

The multiple correlation coefficient is $R=(R_{adj})^{1/2}=(0.60)^{1/2}=0.77$. The importance of the regression model indicates that the correlation is also important. For this reason, there is an important relationship between the independent variables included in the model and the dependent variables.

In the established model, 62% of the Risk Score change is determined by these four variables, while the remaining 38% is determined by the variables that are not included in the model. While performing multiple regression analysis, it is necessary to put the correct variables in the model and to examine the model logically.

When Table 12 is examined, when all the independent variables used in the ANFIS model in the estimation of Risk Score are also used in the multiple regression model, the estimation error rate for 104 data is as high as 60%. This means that the regression model is insufficient in estimating the Risk Score as it stands. Other error tolerances parameter will be shown as below table.

Table 7.6: Error Indicators

	Training Data Set			Test Data Set		
Error Indıcator	RMSE	MAPE	R²	RMSE	MAPE	R²

ANFIS	0.99	0.09	0.9097	1.43	0.11	0.8647
Multiple Regression	1.28	0.17	0.8628	2.34	0.13	0.7145

7.4 The BIM-based risk visualization tool

The BIM-based risk visualization tool has been tested in a trial sample of a BIM model and in the baselines-scope, schedule and cost-program of an industrial facility. First, the construction programs are changed in the correct format and the related risk elements are transferred to the risk register interface with codes. The assessment is then transferred to Revit and Navisworks and 3D Risk Maps are created. If desired, related elements can be defined in pop-ups.

7.4.1. Description Application of the Case

The prototype of the installed 3d model was tested on the Model of the Measurement Station of a large Industrial plant. A view from the trial situation of this facility, which is built on approximately 80 decares, is shown in Figure 7.12. This model was created for experimental purposes and with the approval of the compliance department. The aim is to control the effectiveness of the constructed 3d Risk Model and color code system.

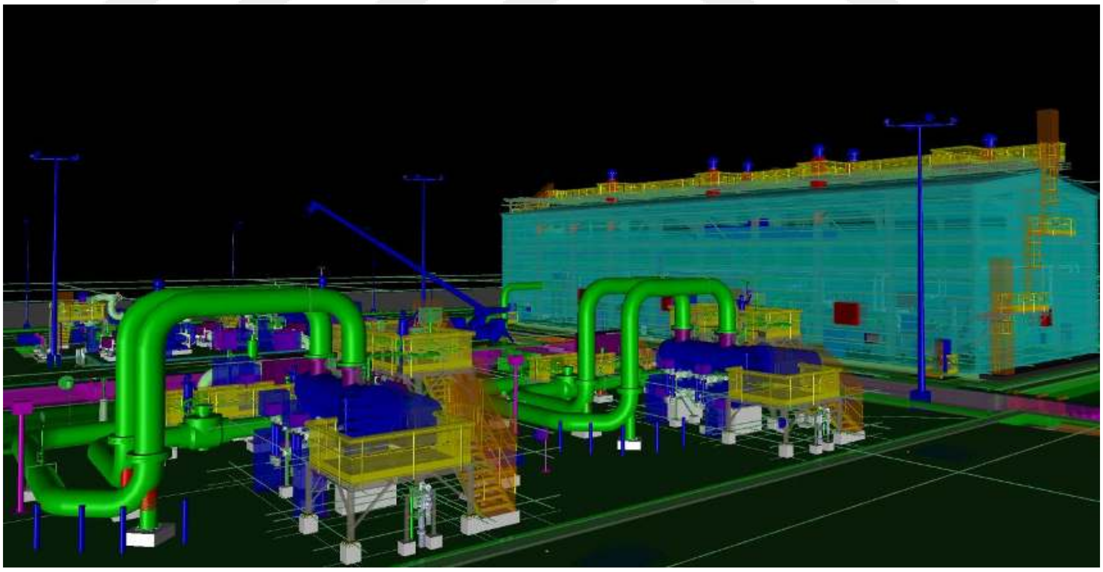


Figure 7.12: Station 3D- Risk Map-Tanap Metering Station

7.4.2. Baselines – Scope , Schedule and Cost

The constructed 3D BIM-based model has an element approach, implying that all objects are already in a finished state, so the construction risk assessment setup is constructed and tailored such that the round numbers are directly related to an element or a particular set of elements.

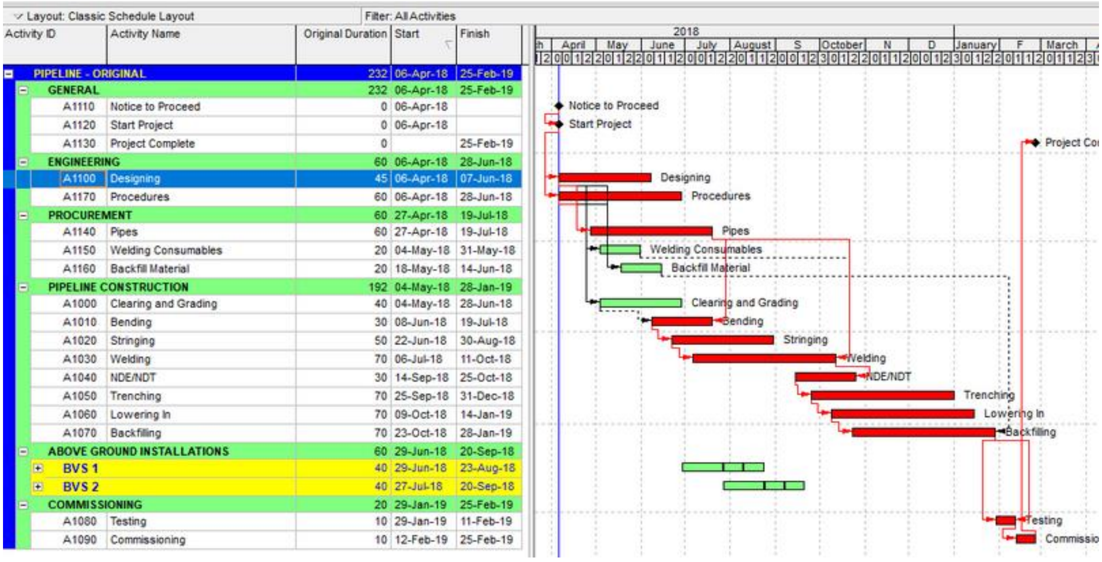


Figure 7.13: Schedule Baseline-Projec tCubicle

7.4.3. Risk Register Interface

Schedule Baseline and Risk Register Excel interface are easily linked with Primavera with the help of paste special option. Because of this connection, any changes to the Schedule Baseline are immediately changed in the Risk Register interface after they are saved. In the pilot case, the Risk Register is populated with values between 0 and 1 used in the project. This valuation was made with the help of values taken from reference articles. All possible color results can be tested by entering actual values. An additional comment is added per item to check if the tool is processing this information correctly. The Risk Register Interface used in the pilot case is presented in Annex C.

7.4.4. BIM Based Module automation

The project used as a pilot is a very big project. Therefore, using a node that selects all elements in the model, the list can be very long and takes a lot of time to create. Programming this node by a python or matlab script reduces the job time to very small values. Elements or elements belonging to the reference planes are selected by these nodes. These items are filtered from the Dynamo code as they do not have a Risk ID number. Therefore, their assessment will be “blank” and assigned a color white or the desired color code. This method, in which all nodes are selected one by one, is preferred because it is fully automatic, regardless of the model used, and makes the process logical.

This means that this setup is much faster than selecting all items per category and will greatly reduce the likelihood of model users missing some items.

7.4.5. BIM Based Software Integration

The 3D BIM model is imported into Navisworks and a business calendar baseline is downloaded in .CSV file format. In the Build Simulation, only items that are already created or already created are shown on the work schedule baseline. Thus, during the constructed simulation, the model is gradually created as it is in reality. This will clearly show if the items are properly linked to their task.

Since the search sets have already been created, it is sufficient to save the model and the established simulation can be performed again. The simulation has proven to be a good tool to easily check whether all the connections between the Risk ID and the elements are made correctly.

7.5. Summary

In this section, the matlab and 3D application described in the previous section were applied step by step and the results are shown in tables and visuals.

CHAPTER 8

Discussion and Validation

8.1. Introduction

After the risk records created from real data in the risk assessment of natural gas and pipeline projects, the solution of the model was started by choosing this function, since **the gauss2mf** membership function gave results at the lowest RMSE level. The model, which was determined and developed at the beginning, consists of 4 inputs, 1 output and 221 rules. The results were obtained and normalized. The training data set consists of 90 data and the test data set consists of 14 data. Then, the thesis was completed by trying to visualize this process with the help of BIM-based programs.

Risk assessment and management is one of the most important parts of a project. Considering the related risk assessment studies in the literature, risk assessment is a Multiple Decision Making problem that deals with risk value optimization and includes many criteria.

In the thesis, a risk assessment model was obtained by considering the studies in the literature and expert opinions. The data set used in our Oil and Natural Gas-based risk assessment study resulted in lower error than classical methods with the learning feature and adaptive network-based structure of ANFIS. The proposed risk assessment model can also be used in risk assessment stages worldwide. Then, risk elements can be visualized with 4D visuals.

In the stations and pipelines, which are one of the most important parts of the Petroleum and Natural Gas industry, the necessity of reducing the risk coefficient to the minimum level as much as possible, the model consists of a total of 4 inputs with 5 5 3 3 membership functions and the number of output membership functions is 4 parameters applied in the project. It is a structure that can take a long time when a large data set is used.

In order to compare the superiority of the neural fuzzy logic approach to classical and fuzzy risk assessments in Risk Management, whose model is presented, RMSE and MAPE error values of Multiple Regression output results were compared on the same data set. These values are given in the previous application section and below.

Table 8.1: Error Indicators

	Training Data Set			Test Data Set		
Error Indıcator	RMSE	MAPE	R^2	RMSE	MAPE	R^2
ANFIS	0.99	0.09	0.9097	1.43	0.11	0.8647
Multiple Regression	1.28	0.17	0.8628	2.34	0.13	0.7145

8.2. Re-addressing the Research Questions

As the scope of the thesis, the questions asked in the first chapter will be answered in the final stages of the thesis. These answers made by taking expert opinions from the risk team of the project.

In the last section of this dissertation, these answers will be included and the conclusion section will be written.

8.2.1. Research Question 1: How can existing traditional techniques align with Adaptive network-based fuzzy inference system-ANFIS for risk management at Oil and Gas Industry?

Traditional risk analysis is the most widely used risk assessment method in the world, as it is one of the simplest systematic methods. This method, which is especially preferred for low and medium risky works, is based on the logic of grading the outcome of an event with the probability of occurrence. For this reason, it is ideal to be used for simple systems in low and medium hazardous jobs.

The matrix risk assessment relies heavily on the predictions of the person or team doing the risk assessment. Therefore, using it for the analysis of complex systems will give erroneous results. Likewise, when used for simple systems or processes, it may give different results depending on the knowledge and experience of the person doing the risk assessment.

It has been observed that methods such as fuzzy logic theory have become more useful in risk analysis and management models in recent years to determine the effect size of the risks encountered in projects, which are often verbally expressed.

8.2.2. Research Question 2: How can Risks be visualised in the BIM environment during the project' design and constuction stages and also it is applicable for project life cycle?

With the development of computer technology, it will enable the identification of risks throughout the project, and it is seen that software are developed where users can systematically monitor their management processes, and a more conscious and active role is assumed in risk management.

Moreover; The development of AI-based technology enables analyses, monitoring and controlling of risks, leading to the development of software or models where users can take an active role in risk management systems.

This has shown that risk management, which is always a live system for the projects, could be applied at every stage of the project life cycle.

8.3. Finalizing the Conceptual Framework of Risk Management for NGPP Projects Implementing AI and BIM

Risk management is a process that covers all stages, starting from the thought stage of the product to the presentation of it to the customer as a product. Continuity of risk management with quick decisions and actions

It is a systematic structure in which risks are determined, which risks need to be resolved first, strategies and plans are developed and implemented to deal with risks, or it is a discipline that aims to reduce uncertainties and the negative effects of uncertainty to a more acceptable level. In order to pass this process with the least losses, Firms should not ignore the technology support, which is the necessity of the age. It is essential for companies to fully integrate the organization in **AI and BIM** in the governance of these two issues.

8.4. Summary

In this section, Answers given to the research questions whose answers sought in the first chapter of the dissertation, and the final goal or scope of the thesis has been completed.

CHAPTER 9

Conclusion and Recommendations

9.1. Conclusion

Risk Management in companies operating in the international oil and natural gas sector generally follows the decision of people who have worked and experienced in this sector for many years. In fact, this situation, which should be passed through a correct and detailed preliminary study and made a decision within the framework of the prepared report, takes place depending on the predictions of the experienced people in a very short time, and the decision mechanism works accordingly.

Generally, based on the problem of making Risk Management decisions in line with knowledge and experience, the necessary literature study was conducted and a new Risk Management model study was prepared. In the prepared model, the real data of Tanap firm operating in the international arena were collected. In the next stage, a modeling was created with the Adaptive Network-Based Fuzzy Inference System-ANFIS, which works together with the MATLAB program, which includes the features and advantages of artificial neural networks such as the learning ability of fuzzy logic and the ease of making decisions like humans and providing expert knowledge.

Quantitative and qualitative factors in risk problems cause blurriness and uncertainty. Researchers and academics frequently refer to Fuzzy Logic Theory in order to resolve the related fuzziness and ambiguity. In addition, a structure in accordance with the principle of explaining events by using verbal expressions of experienced and expert people with fuzzy logic is presented.

In the thesis, a new ANFIS-based approach to the Risk Management problem in the Oil and Natural Gas sector is presented. ANFIS is a method that brings together the learning ability of neural networks and the harmony of fuzzy inference system with human reasoning ability, enabling the establishment of a model suitable for the input-output set at hand. It has been widely used in different fields in the literature.

A two-stage model has been applied in the thesis. In the first stage, the membership function and the number of the inputs were determined and the ANFIS model was established. In addition to the rule that the number of parameters trained should not be greater than the number of training data in the establishment of the model, a special importance was given to the selection of the membership function type with the lowest error. In the second stage, risks were visualized by transferring them to 3D/4D maps with the help of BIM-based software.

In order to demonstrate the effectiveness of the applied method, multiple regression method was also applied to the problem using the same data set. The results show that the ANFIS model is much more consistent and offers a structure suitable for the available input-output set. Risk output values obtained at the last stage were matched with the project risk assessment scale and transferred to 3D/4D maps with the help of BIM-based software to visualize the risks.

As a result, in the thesis, it has been tried to present a consistent, effective and fast solution for the Risk Management problem, which is difficult to manage in projects. Considering the suggestions expressed above, ANFIS etc. in the Risk Management problem. It is believed that artificial intelligence and information modeling based applications can be increased by diversifying.

9.2. Research Contributions

The purpose of creating this model; To provide a risk management tool that helps companies with a model prepared by re-evaluating the verbally expressed parameters in the Risk management process, which is determined by benefiting from the opinions of people who have worked in this sector for many years, for companies operating in the international arena, with the help of artificial intelligence-based ANFIS and building information modeling-based software.

As a result, while companies working in the international arena make decisions in risk management, country factors, risk factors that are effective in the construction of the project, contract factors and factors for the firm's earnings, etc. they will have the opportunity to evaluate all of them together.

9.2.1. Contribution to academic works

The applied model includes a risk score with four inputs and one output. In academic studies, different model combinations can be established by changing the number of inputs and outputs. Risk models with more than one output can be established to guide future studies. One of the ANFIS-named CANFIS- methods developed in this direction and suitable for multiple output structure can be applied to the problem. In addition, the mamdani ANFIS module can be applied instead of the sugeno type applied in the model.

Instead of the Revit and Dynamo model, which are used as application visualization models, other software such as bentley, Rhyno etc. can be used. Visualization of risks can also be done using GIS coordinates.

9.2.2. Contribution to Practice

Starting from the problem that companies operating in the oil and natural gas sector generally have experience-based and personalized decision-making mechanisms, investigating the factors that are effective in the risk management process and collecting them in a database, taking the right and strategic decisions in a shorter time within the framework of the possibilities provided by the developing technology. A model was created considering that an auxiliary system could be created. By creating systems similar to the adaptive network-based fuzzy inference system described in this study, they will be able to make faster, more efficient and economical decisions in line with their own strategies. In addition, with the help of an artificial intelligence-based assessment and visualization model, companies will be able to control the accuracy of their risk management decisions and help them visualize them.

9.3. Limitation of the Study

The scope of the study is limited to natural gas and pipeline projects. Evaluations and analyzes were carried out for mega-sized projects. From this point of view, it is argued that the methods described in this thesis can be used in other large-scale construction projects. In the thesis, a new artificial intelligence-based risk assessment compared to the traditional methods used in Risk Management is emphasized and results are presented in this context.

As a result of the differences revealed, it is explained that Artificial intelligence and BIM technology are viewed from the perspective of Risk management and the Artificial intelligence and BIM-based application and management model to be applied in natural gas and pipeline projects is explained.

Within the scope of the thesis, in line with the real data obtained from the Tanap Project, how Risk Management is done with traditional methods has been examined and the points that are open to improvement have been tried to be revealed. It has been tried to show why a two-stage integrated model should be used as a result of the studies.

9.4. Recommendations for Future

In future studies, it is planned to use the ANFIS model actively in risk management, for which different scenarios or different input systems are created. It is highly probable that this will increasingly continue in the near future.

In addition, due to the network structure of ANFIS, as the number of samples shown to it increases, the accuracy of the network's prediction also increases. For this reason, it is obvious that ANFIS will make more accurate predictions in systems with a large number of data.

The visualization of risk is proven in the thesis content. However, this system can be moved to more advanced dimensions with visual artificial intelligence detection in the coming years. It is possible that the programs used for these are already out.

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APPENDIX-A: Risk Datas

	Pnormalization	I-normal	M-normal	Proximity-normal	Risk Score Normalization
R1	0.875	8.75	0.875	0.875	0.916666667
R2	0.725	8.75	0.875	0.5	0.916666667
R3	0.875	7.25	0.875	0.875	0.888888889
R4	0.875	7.25	0.875	0.125	0.861111111
R5	0.725	7.25	0.5	0.5	0.861111111
R6	0.875	5	0.5	0.875	0.833333333
R7	0.5	7.25	0.875	0.875	0.805555556
R8	0.5	7.25	0.5	0.5	0.694444444
R9	0.5	7.25	0.5	0.5	0.694444444
R10	0.5	7.25	0.5	0.125	0.694444444
R11	0.5	7.25	0.5	0.875	0.694444444
R12	0.5	7.25	0.875	0.875	0.694444444
R13	0.5	7.25	0.125	0.125	0.694444444
R14	0.5	7.25	0.875	0.5	0.694444444
R15	0.5	7.25	0.875	0.875	0.694444444
R16	0.725	5	0.5	0.5	0.694444444
R17	0.725	5	0.875	0.5	0.666666667
R18	0.725	5	0.5	0.875	0.666666667
R19	0.725	5	0.5	0.125	0.666666667
R20	0.725	5	0.125	0.875	0.666666667
R21	0.725	5	0.875	0.875	0.666666667
R22	0.725	5	0.875	0.875	0.666666667
R23	0.725	5	0.125	0.875	0.666666667
R24	0.725	5	0.125	0.875	0.666666667
R25	0.725	5	0.5	0.5	0.666666667
R26	0.725	5	0.5	0.875	0.666666667
R27	0.725	5	0.5	0.875	0.666666667
R28	0.5	5	0.875	0.5	0.666666667
R29	0.5	5	0.125	0.125	0.638888889
R30	0.5	5	0.5	0.875	0.638888889
R31	0.5	5	0.125	0.5	0.638888889
R32	0.5	5	0.5	0.875	0.638888889
R33	0.5	5	0.875	0.875	0.638888889
R34	0.5	5	0.5	0.875	0.638888889
R35	0.5	5	0.875	0.875	0.638888889

R36	0.5	5	0.5	0.875	0.638888889
R37	0.5	5	0.125	0.875	0.638888889
R38	0.5	5	0.875	0.5	0.638888889
R39	0.5	5	0.875	0.5	0.638888889
R40	0.5	5	0.5	0.875	0.638888889
R41	0.5	5	0.5	0.125	0.638888889
R42	0.5	5	0.5	0.5	0.638888889
R43	0.5	5	0.5	0.125	0.638888889
R44	0.5	5	0.5	0.125	0.638888889
R45	0.875	2.75	0.125	0.125	0.638888889
R46	0.725	2.75	0.125	0.125	0.611111111
R47	0.725	2.75	0.5	0.125	0.583333333
R48	0.725	2.75	0.5	0.875	0.583333333
R49	0.725	2.75	0.875	0.875	0.583333333
R50	0.725	2.75	0.875	0.125	0.583333333
R51	0.725	2.75	0.875	0.125	0.583333333
R52	0.875	1.25	0.875	0.125	0.583333333
R53	0.875	1.25	0.5	0.875	0.555555556
R54	0.875	1.25	0.875	0.875	0.555555556
R55	0.125	8.75	0.875	0.125	0.555555556
R56	0.275	7.25	0.875	0.125	0.472222222
R57	0.275	7.25	0.125	0.5	0.444444444
R58	0.275	7.25	0.125	0.5	0.444444444
R59	0.275	5	0.875	0.875	0.444444444
R60	0.275	5	0.875	0.875	0.388888889
R61	0.275	5	0.125	0.875	0.388888889
R62	0.275	5	0.5	0.875	0.388888889
R63	0.275	5	0.5	0.875	0.388888889
R64	0.275	5	0.875	0.875	0.388888889
R65	0.275	5	0.875	0.125	0.388888889
R66	0.275	5	0.5	0.875	0.388888889
R67	0.5	2.75	0.875	0.125	0.388888889
R68	0.5	2.75	0.5	0.875	0.361111111
R69	0.5	2.75	0.875	0.125	0.361111111
R70	0.5	2.75	0.5	0.125	0.361111111
R71	0.5	2.75	0.5	0.125	0.361111111
R72	0.5	2.75	0.875	0.875	0.361111111
R73	0.5	2.75	0.875	0.125	0.361111111

R74	0.5	2.75	0.875	0.875	0.361111111
R75	0.5	2.75	0.125	0.875	0.361111111
R76	0.725	1.25	0.875	0.875	0.361111111
R77	0.275	2.75	0.875	0.875	0.333333333
R78	0.275	2.75	0.875	0.125	0.194444444
R79	0.275	2.75	0.5	0.125	0.194444444
R80	0.125	2.75	0.5	0.5	0.194444444
R81	0.5	1.25	0.5	0.125	0.166666667
R82	0.5	1.25	0.5	0.125	0.111111111
R83	0.5	1.25	0.125	0.875	0.111111111
R84	0.5	1.25	0.5	0.125	0.111111111
R85	0.5	1.25	0.5	0.125	0.111111111
R86	0.125	1.25	0.5	0.125	0.111111111
R87	0.5	7.25	0.125	0.5	0.055555556
R88	0.5	7.25	0.5	0.5	0.583333333
R89	0.725	5	0.5	0.5	0.694444444
R90	0.725	5	0.875	0.5	0.666666667
R91	0.725	5	0.875	0.875	0.666666667
R92	0.725	5	0.5	0.875	0.666666667
R93	0.725	5	0.125	0.875	0.666666667
R94	0.875	2.75	0.125	0.125	0.666666667
R95	0.725	2.75	0.5	0.875	0.611111111
R96	0.725	5	0.5	0.875	0.666666667
R97	0.725	5	0.125	0.875	0.666666667
R98	0.875	2.75	0.125	0.125	0.666666667
R99	0.725	2.75	0.5	0.875	0.611111111
R100	0.725	2.75	0.125	0.125	0.583333333
R101	0.5	2.75	0.875	0.875	0.361111111
R102	0.275	2.75	0.5	0.125	0.361111111
R103	0.275	2.75	0.5	0.125	0.194444444
R104	0.5	2.75	0.875	0.875	0.194444444

APPENDIX-B: Regression Datas

	Risk Score Normalization	Regression	Regression Normalization
R1	0.916666667	0.971875	1
R2	0.916666667	0.8635	0.877749577
R3	0.888888889	0.889375	0.906937394
R4	0.861111111	0.834625	0.845177665
R5	0.861111111	0.76675	0.768612521
R6	0.833333333	0.751375	0.751269036
R7	0.805555556	0.686875	0.678510998
R8	0.694444444	0.64525	0.631556684
R9	0.694444444	0.64525	0.631556684
R10	0.694444444	0.617875	0.600676819
R11	0.694444444	0.672625	0.662436548
R12	0.694444444	0.686875	0.678510998
R13	0.694444444	0.603625	0.584602369
R14	0.694444444	0.6595	0.647631134
R15	0.694444444	0.686875	0.678510998
R16	0.694444444	0.643	0.629018613
R17	0.666666667	0.65725	0.645093063
R18	0.666666667	0.670375	0.659898477
R19	0.666666667	0.615625	0.598138748
R20	0.666666667	0.656125	0.643824027
R21	0.666666667	0.684625	0.675972927
R22	0.666666667	0.684625	0.675972927
R23	0.666666667	0.656125	0.643824027
R24	0.666666667	0.656125	0.643824027
R25	0.666666667	0.643	0.629018613
R26	0.666666667	0.670375	0.659898477
R27	0.666666667	0.670375	0.659898477
R28	0.666666667	0.53575	0.508037225
R29	0.638888889	0.479875	0.44500846
R30	0.638888889	0.548875	0.52284264
R31	0.638888889	0.50725	0.475888325
R32	0.638888889	0.548875	0.52284264
R33	0.638888889	0.563125	0.53891709
R34	0.638888889	0.548875	0.52284264
R35	0.638888889	0.563125	0.53891709

R36	0.638888889	0.548875	0.52284264
R37	0.638888889	0.534625	0.50676819
R38	0.638888889	0.53575	0.508037225
R39	0.638888889	0.53575	0.508037225
R40	0.638888889	0.548875	0.52284264
R41	0.638888889	0.494125	0.46108291
R42	0.638888889	0.5215	0.491962775
R43	0.638888889	0.494125	0.46108291
R44	0.638888889	0.494125	0.46108291
R45	0.638888889	0.558625	0.533840948
R46	0.611111111	0.477625	0.442470389
R47	0.583333333	0.491875	0.458544839
R48	0.583333333	0.546625	0.520304569
R49	0.583333333	0.560875	0.536379019
R50	0.583333333	0.506125	0.474619289
R51	0.583333333	0.506125	0.474619289
R52	0.583333333	0.504625	0.472927242
R53	0.555555556	0.545125	0.518612521
R54	0.555555556	0.559375	0.534686971
R55	0.555555556	0.512125	0.481387479
R56	0.472222222	0.510625	0.479695431
R57	0.444444444	0.5095	0.478426396
R58	0.444444444	0.5095	0.478426396
R59	0.444444444	0.441625	0.401861252
R60	0.388888889	0.441625	0.401861252
R61	0.388888889	0.413125	0.369712352
R62	0.388888889	0.427375	0.385786802
R63	0.388888889	0.427375	0.385786802
R64	0.388888889	0.441625	0.401861252
R65	0.388888889	0.386875	0.340101523
R66	0.388888889	0.427375	0.385786802
R67	0.388888889	0.384625	0.337563452
R68	0.361111111	0.425125	0.383248731
R69	0.361111111	0.384625	0.337563452
R70	0.361111111	0.370375	0.321489002
R71	0.361111111	0.370375	0.321489002
R72	0.361111111	0.439375	0.399323181
R73	0.361111111	0.384625	0.337563452

R74	0.361111111	0.439375	0.399323181
R75	0.361111111	0.410875	0.367174281
R76	0.361111111	0.478375	0.443316413
R77	0.333333333	0.317875	0.262267343
R78	0.194444444	0.263125	0.200507614
R79	0.194444444	0.248875	0.184433164
R80	0.194444444	0.19525	0.12394247
R81	0.166666667	0.287875	0.228426396
R82	0.111111111	0.287875	0.228426396
R83	0.111111111	0.328375	0.274111675
R84	0.111111111	0.287875	0.228426396
R85	0.111111111	0.287875	0.228426396
R86	0.111111111	0.085375	0
R87	0.055555556	0.631	0.615482234
R88	0.583333333	0.64525	0.631556684
R89	0.694444444	0.643	0.629018613
R90	0.666666667	0.65725	0.645093063
R91	0.666666667	0.684625	0.675972927
R92	0.666666667	0.670375	0.659898477
R93	0.666666667	0.656125	0.643824027
R94	0.666666667	0.558625	0.533840948
R95	0.611111111	0.546625	0.520304569
R96	0.666666667	0.670375	0.659898477
R97	0.666666667	0.656125	0.643824027
R98	0.666666667	0.558625	0.533840948
R99	0.611111111	0.546625	0.520304569
R100	0.583333333	0.477625	0.442470389
R101	0.361111111	0.439375	0.399323181
R102	0.361111111	0.248875	0.184433164
R103	0.194444444	0.248875	0.184433164
R104	0.194444444	0.439375	0.399323181

APPENDIX-C: Risk Register Interface

Risk ID	P-normalization	I-normal	M-normal	Proximity-normal	Risk Score	Risk Color Code	Risk Score Normalization
R1	0.875	8.75	0.875	0.875	33		0.916666667
R2	0.875	8.75	0.875	0.5	33		0.916666667
R3	0.725	8.75	0.875	0.875	32		0.888888889
R4	0.875	7.25	0.875	0.125	31		0.861111111
R5	0.875	7.25	0.5	0.5	31		0.861111111
R6	0.725	7.25	0.5	0.875	30		0.833333333
R7	0.875	5	0.875	0.875	29		0.805555556
R8	0.5	7.25	0.5	0.5	25		0.694444444
R9	0.5	7.25	0.5	0.5	25		0.694444444
R10	0.5	7.25	0.5	0.125	25		0.694444444
R11	0.5	7.25	0.5	0.875	25		0.694444444
R12	0.5	7.25	0.875	0.875	25		0.694444444
R13	0.5	7.25	0.125	0.125	25		0.694444444
R14	0.5	7.25	0.875	0.5	25		0.694444444
R15	0.5	7.25	0.875	0.875	25		0.694444444
R16	0.5	7.25	0.5	0.5	25		0.694444444
R17	0.725	5	0.875	0.5	24		0.666666667
R18	0.725	5	0.5	0.875	24		0.666666667
R19	0.725	5	0.5	0.125	24		0.666666667
R20	0.725	5	0.125	0.875	24		0.666666667
R21	0.725	5	0.875	0.875	24		0.666666667
R22	0.725	5	0.875	0.875	24		0.666666667
R23	0.725	5	0.125	0.875	24		0.666666667
R24	0.725	5	0.125	0.875	24		0.666666667
R25	0.725	5	0.5	0.5	24		0.666666667
R26	0.725	5	0.5	0.875	24		0.666666667
R27	0.725	5	0.5	0.875	24		0.666666667
R28	0.725	5	0.875	0.5	24		0.666666667
R29	0.5	5	0.125	0.125	23		0.638888889
R30	0.5	5	0.5	0.875	23		0.638888889
R31	0.5	5	0.125	0.5	23		0.638888889
R32	0.5	5	0.5	0.875	23		0.638888889
R33	0.5	5	0.875	0.875	23		0.638888889
R34	0.5	5	0.5	0.875	23		0.638888889
R35	0.5	5	0.875	0.875	23		0.638888889

R36	0.5	5	0.5	0.875	23		0.638888889
R37	0.5	5	0.125	0.875	23		0.638888889
R38	0.5	5	0.875	0.5	23		0.638888889
R39	0.5	5	0.875	0.5	23		0.638888889
R40	0.5	5	0.5	0.875	23		0.638888889
R41	0.5	5	0.5	0.125	23		0.638888889
R42	0.5	5	0.5	0.5	23		0.638888889
R43	0.5	5	0.5	0.125	23		0.638888889
R44	0.5	5	0.5	0.125	23		0.638888889
R45	0.5	5	0.125	0.125	23		0.638888889
R46	0.875	2.75	0.125	0.125	22		0.611111111
R47	0.725	2.75	0.5	0.125	21		0.583333333
R48	0.725	2.75	0.5	0.875	21		0.583333333
R49	0.725	2.75	0.875	0.875	21		0.583333333
R50	0.725	2.75	0.875	0.125	21		0.583333333
R51	0.725	2.75	0.875	0.125	21		0.583333333
R52	0.725	2.75	0.875	0.125	21		0.583333333
R53	0.875	1.25	0.5	0.875	20		0.555555556
R54	0.875	1.25	0.875	0.875	20		0.555555556
R55	0.875	1.25	0.875	0.125	20		0.555555556
R56	0.125	8.75	0.875	0.125	17		0.472222222
R57	0.275	7.25	0.125	0.5	16		0.444444444
R58	0.275	7.25	0.125	0.5	16		0.444444444
R59	0.275	7.25	0.875	0.875	16		0.444444444
R60	0.275	5	0.875	0.875	14		0.388888889
R61	0.275	5	0.125	0.875	14		0.388888889
R62	0.275	5	0.5	0.875	14		0.388888889
R63	0.275	5	0.5	0.875	14		0.388888889
R64	0.275	5	0.875	0.875	14		0.388888889
R65	0.275	5	0.875	0.125	14		0.388888889
R66	0.275	5	0.5	0.875	14		0.388888889
R67	0.275	5	0.875	0.125	14		0.388888889
R68	0.5	2.75	0.5	0.875	13		0.361111111
R69	0.5	2.75	0.875	0.125	13		0.361111111
R70	0.5	2.75	0.5	0.125	13		0.361111111
R71	0.5	2.75	0.5	0.125	13		0.361111111
R72	0.5	2.75	0.875	0.875	13		0.361111111
R73	0.5	2.75	0.875	0.125	13		0.361111111

R74	0.5	2.75	0.875	0.875	13		0.361111111
R75	0.5	2.75	0.125	0.875	13		0.361111111
R76	0.5	2.75	0.875	0.875	13		0.361111111
R77	0.725	1.25	0.875	0.875	12		0.333333333
R78	0.275	2.75	0.875	0.125	7		0.194444444
R79	0.275	2.75	0.5	0.125	7		0.194444444
R80	0.275	2.75	0.5	0.5	7		0.194444444
R81	0.125	2.75	0.5	0.125	6		0.166666667
R82	0.5	1.25	0.5	0.125	4		0.111111111
R83	0.5	1.25	0.125	0.875	4		0.111111111
R84	0.5	1.25	0.5	0.125	4		0.111111111
R85	0.5	1.25	0.5	0.125	4		0.111111111
R86	0.5	1.25	0.5	0.125	4		0.111111111
R87	0.125	1.25	0.125	0.5	2		0.055555556
R88	0.5	7.25	0.5	0.5	25		0.583333333
R89	0.5	7.25	0.5	0.5	25		0.694444444
R90	0,725	5	0,875	0,875	24		0.666666667
R91	0,725	5	0,5	0,875	24		0.666666667
R92	0,725	5	0,125	0,875	24		0.666666667
R93	0,875	2,75	0,125	0,125	24		0.666666667
R94	0,725	2,75	0,5	0,875	24		0.666666667
R95	0,725	5	0,5	0,875	22		0.611111111
R96	0,725	5	0,125	0,875	24		0.666666667
R97	0,875	2,75	0,125	0,125	24		0.666666667
R98	0,725	2,75	0,5	0,875	24		0.666666667
R99	0,725	2,75	0,125	0,125	22		0.611111111
R100	0,5	2,75	0,875	0,875	21		0.583333333
R101	0,275	2,75	0,5	0,125	13		0.361111111
R102	0,275	2,75	0,5	0,125	13		0.361111111
R103	0,5	2,75	0,875	0,875	7		0.194444444
R104	0,725	5	0,875	0,875	31		0.861111111

APPENDIX-D: Curriculum Vitae(CV)

Name and Surname	İsmail ALTUNHAN
Language	Turkish and English

Degree	**Area**	**University**	**Graduated**
Bsc	Civil Engineering	Gaziantep University	2011
Msc	Civil Engineering	Gaziantep University	2017

Experiments

Year	**Company**	**Positon**
2011-2012	Ministry of Defense	Site Civil Engineer
2012-2013	Manas Construction	Site Civil Engineer
2013-2014	Akselcan Construction	Site Civil Engineer
2014-2014	Emta Construction Co.	QC Civil Engineer
2014-2015	ICTAS and ASTALDI JV (ICA)	Civil Engineer-Drainage
2015-2016	Sicim Spa-Yüksel-Akkord (SYA) JV	Lead Civil Engineer
2016-still	TANAP Gas Transmission Company	Lead Project and Construction Engineer

APPENDIX-E: Publications

- 3rd International Conference on Artificial Intelligence and Applied Mathematics in Engineering (ICAIAME 2021) – Paper No: 3141, 1-3 October 2021, A paper application made for the conference to Its accepted to be published on **Springer Book 2021 (SCI-E Index) and some TR-Index Journals**.
- 2nd International Symposium on Implementations of Digital Industry and Management of Digital Transformation 2021 (ISIDIMDT'21), 11 November 2021, A paper application made for the conference to Its accepted to be published on some **TR-Index Journals**.
- Artificial Intelligence Review , SCI Journal , STRATEGIC FRAMEWORK FOR ANFIS AND BIM USE ON RISK MANAGEMENT AT NATURAL GAS PIPELINE PROJECT **,It's under review.**