Using B.I.M. in Design Stage of Construction Projects to Minimise Health and Safety Risks: Proposing a Model for Application of B.I.M. in P.t.D.

Kemal Dirgen Tözer

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Civil Engineering

Eastern Mediterranean University
May 2018
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Assoc. Prof. Dr. Ali Hakan Ulusoy
Acting Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy in Civil Engineering.

Assoc. Prof. Dr. Serhan Şensoy
Chair, Department of Civil Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Doctor of Philosophy in Civil Engineering.

Assoc. Prof. Dr. Gürkan Emre Gürcanlı
Co-Supervisor

Prof. Dr. Tahir Çelik
Supervisor

Examining Committee

1. Prof. Dr. M. Emre Bayraktar
2. Prof. Dr. Tahir Çelik
3. Prof. Dr. Özgür Eren
4. Prof. Dr. İrem Dikmen Toker
5. Assoc. Prof. Dr. Mürüde Çelikağ
6. Assoc. Prof. Dr. Gürkan Emre Gürcanlı
7. Asst. Prof. Dr. Mehmedali Egemen

ABSTRACT

In construction industry the conditions of work places inherently change continuously. Additionally, the construction activities conducted on construction sites vary from one project to another. Therefore, the construction industry is one of the most hazardous industry on all over the world and special effort is required to minimise the occupational accidents at construction sites. On the other hand, majority of the dangerous situations appearing on construction sites, are mostly the results of decisions produced during the briefing and design stage. It is beleieved that, considering some precautions during briefing and design stage of construction projects some occupational accidents can be eliminated. The aim of this study is to minimise the occupational risks due to the decisions made during briefing and design stage of the construction projects which may result with occupational accidents. In order to do so, a Hazard Identification System (HIS) was developed by using BIM. This system defines risky construction elements that may cause fall from height type of accidents and suggests safer design alternatives. Hence, much safer buildings can be designed in Occupational Health and Safety point of view. Within the scope of this study, the focal points was a multi-storey building that was designed first without applying the HIS and its risk scores was evaluated by Fine-Kinney method. Then the HIS is applied and the risk scores were re-evaluated in the same way. It was proved that, majority of the risks that caused fall from height type of accidents are detectable and in consideration with the proposed alternative design by HIS, the fall from height risks can mainly be eliminated.

Keywords: Prevention Through Design; Design for Safety; Northern part of Cyprus; Turkish Republic of Northern Cyprus; Construction Sector; Building Information Modelling; Health and Safety in Construction.

ÖZ

İnşaat sektöründe çalışma koşulları sektörün yapısı gereği sürekli değişim içerisindedir. Buna ek olarak, inşaat sahasında yürütülen aktiviteler projeden projeye değişmektedir. Bu nedenle, inşaat sektörü İşçi Sağlığı ve İş Güvenliği (İSİG) bakımından dünya genelinde en tehlikeli iş ortamına sahip sektörler arasındadır ve kazaları minimize etmek için özel çaba sarfedilmelidir. Dünya genelinde yürütülmüş olan bazı çalışmalar, inşaatlardaki tehlikelerin bir bölümünün tasarım sürecinde alınan bazı kararlarla ortaya çıktığını saptamıştır. Bu çalışmanın amacı, alınan tasarım kararlarıyla ortaya çıkan ve iş kazası yaşanmasını sağlayan tehlikeleri minimize etmektir. Bunu yapabilmek için, tasarımcıların tasarım sürecinde kullandığı BIM ortamında çalışan ve adına Hazard Identification System (HIS) denen bir sistem geliştirilmiştir. Bu sistem BIM ortamında geliştirilen bina modelini eleman eleman tarayarak yüksekten düşme riskini doğuran yapı elemanlarını tesbit edecek ve yapacağı alternatif tasarım önerileriyle riskleri minimize edecektir. Böylece, İSİG bakımından daha güvenli binalar tasarlamak mümkün olacaktır. Çalışma kapsamında çok katlı bir bina projesinin Fine-Kinney Yöntemi ile risk değerlendirmesi yapılmıştır. Daha sonra, aynı bina projesi HIS'in alternatif tasarım önerileri dikkate alınarak yeniden tasarlanmış ve ayni yöntemle risk değerlendirmesi yeniden yapılmıştır. Sonrasında, her iki durumun risk değerlendirmesinden çıkan risk skorları karşılaştırılmıştır. Çalışma sonucunda, yüksekten düşmeye neden olan tehlikelerin büyük bir bölümünün tasarım aşamasında giderilebileceği görülmüştür. Devamında, yapılan alternatif tasarım önerileriyle tehlikelerin büyük ölçüde ortadan kaldırılabildiği saptanmıştır.

Anahtar Kelimeler: Tasarım Yoluyla Koruma; Güvenlik İçin Tasarım; Kuzey Kıbrıs Türk Cumhuriyeti; İnşaat Sektörü; Bina Bilgi Modellemesi; İnşaat Sektöründe İşçi Sağlığı ve İş Güvenliği, Hazard Identification System

To my son……………

ACKNOWLEDGEMENT

First of all, I would like to thank my Supervisor Prof. Dr. Tahir Çelik and my co-supervisor Assoc. Prof. Dr. G. Emre Gürcanlı, who have guided me and did not leave any of my questions unanswered.

My special thanks to my instructors Assoc. Prof. Dr. Huriye Bilsel, and Prof. Dr. Ayhan Bilsel for their contribution during my PhD. study.

I would like to thank to my instructors Assoc. Prof. Dr. Serhan Şensoy, Prof. Dr. Zalihe Nalbantoğlu Sezai, Prof. Dr. Özgür Eren, Assoc. Prof. Dr. Umut Türker, Assoc. Prof. Dr. Mürüde Çelikağ, Assoc. Prof. Dr. Giray Özay, Assoc. Prof. Dr. Mustafa Ergil, Assist. Prof. Dr. Tülin Akçaoğlu, Assist. Prof. Dr. Mehmet M. Kunt and Assist. Prof. Dr. Eriş Uygar for their contribution to my academic development during my assistantship at Eastern Mediterranean University, Civil Engineering Department with their knowledge and great expertise. I acknowledge the friendship of Civil Engineering department assistants and staff.

I thank to Mr. Ulaş Deniz and Ms. Seda Argun for their help.

I would like to thank Director, Vice-Director and all the personnel of the Labor Office of the Northern Cyprus for their contributions.

Finally, I would like extend my gratitude to my mother, father, sister and my wife. Without their support I would not have been able to succeed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

1.1 Overview

One of the primary disciplines contributing to the organization of professional life and employment of labour force in humanitarian conditions in the developed countries is Occupational Health and Safety (OSH). Recently, developing countries have also started to make certain arrangements in this field. One example is Turkish Republic of Northern Cyprus (TRNC), has started to make certain arrangements in OSH field. With this awareness, departments of public sector in particular and firms having corporate structure tried to improve themselves in the field of OSH (Tözer and Çelik, 2016). Under the influence of the above cited developments, Department of Labour which can be considered as the authority in the field of OSH in the TRNC has started to record accidents taking place in workplace environment since 1994. The abovementioned records show that frequency of occupational accidents taking place in the construction industry is very high in proportion to other sectors. Actually, this case is not only valid in the TRNC, but also similar all around the world. Construction industry is at the top of the list of the sectors in terms of frequency of occupational accidents and financial and non-pecuniary damages incurred as a result of these accidents (Çelik and Tözer, 2014). For instance, in the USA, approximately 36% of the occupational accidents resulting in death would take place in construction industry (Zang et al., 2015).

One of the biggest problems of the Construction Industry is the occupational accidents constantly taking place in the construction sites (Manuele, 1997). Construction works performed have high risk of accidents due to their nature. Almost all activities carried out on the construction site are considered Hazardous by experts (Çelik et al., 2012). As a result of this dynamic structure of the sector, individuals working at construction industry face hazards at serious levels. The disturbing part of this situation is that, the majority of hazards on the construction site emerge due to the decisions during design phase and unfortunately they are not realized until the execution of the construction. However, Prevention Through Design (PtD) approach which has been frequently mentioned in the construction industry and Occupational Safety and Health (OSH) area recently argues that, OSH should be considered at the beginning of a project design. Accordingly it is possible to determine and minimise the hazards imediatly, which can emerge with the decisions at the design phase (Szymbersky, 1997; Manuele, 1997; Taiebat, 2011), with small changes (without damaging the character, function, aesthetic of the structure) in the design (Gambatese, 2008).

Another problem of the Construction Industry is that, the PtD approach has recently started to be accepted with increasing acceleration in the developed countries and it has not been adopted by many designers yet (Gambatese, 2008; Gürcanlı, 2015). Although its general framework is formed in some developed countries, unfortunately the approach has not been entirely included in the system yet. In fact, some designers consider it as an additional burden and responsibility for them and they insist that the necessity to have knowledge on OSH and considering these issues in their design is not their duty (Gürcanlı, 2011). In the TRNC, involvement of PtD approach in the sector is at the bottom of the ladder. The main reason for the necessity of preparing this study is the fact that, the aforementioned PtD approach has not been noticed in the country yet.

In this study, based on the abovementioned considerations, it is aimed to minimize occupational accidents on the construction site which are considered to be originating due to the design decissions. As it was depicted in figure 1.1, the ability to influence the safety at the start of a project is higher than all other stages.

For doing this, accident risks which are created by some design decissions have been defined and their risk assessments have been done. After that, alternative designs have been created for replacing them with the initial designs to minimize the level of accident risks.

Finally, a simple software algorithm named as Hazard Identificatiın System (HIS) that works in a BIM software has been developed to define risky design decision, propose alternative designs to minimize the responsibility designers regarding OHS issue. HIS is working in REVIT Architecture during the design process.

1.2 Research Question

Research Question that this study seeks to answer is determined as follow: “Is it possible to minimise the construction accidents related with design decisions during briefing and design stage of construction projects?

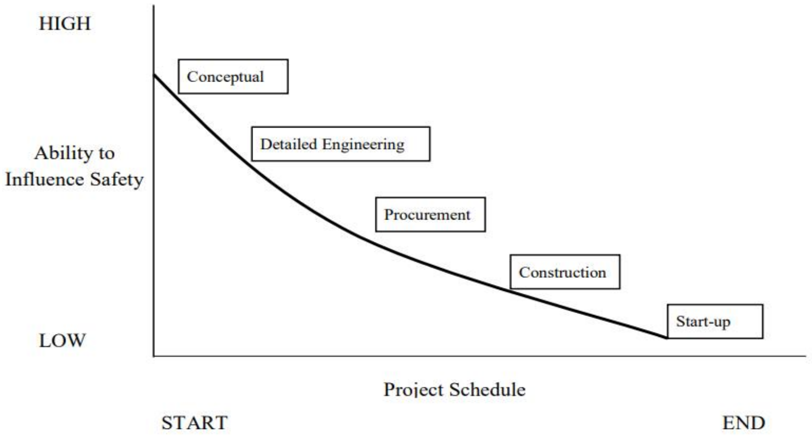


Figure 1.1: Time – Safety Influence Curve. The ability to influence safety diminishes as schedule goes to end (Lingard, 2015).

1.3 Problem Statement and Research Justification

As mentionad above, PtD argues that, OSH should be considered at the beginning of a construction project. Accordingly it is possible to determine and minimise the hazards imediatly, which can emerge with the decisions at the design phase, with small changes (without damaging the character, function, aesthetic of the structure) in the design (Szymbersky, 1997; Manuele, 1997; Taiebat, 2011; Gambatese, 2008). Considering PtD approach, it is more accurate to explain the problems which are required to search for solutions by dividing them into two such as problems around the world and problems in the developing countries such as TRNC.

- Considering the issue on a global scale; although the PtD approach has recently started to be accepted in the developed countries, but it has not been adopted by many designers yet (Gambatese, 2008). Although its general framework is formed in some developed countries such as England, USA, Australia, the approach has not been entirely included in the system yet, and it is exposed to the responses of designer in some cases. In fact, some designers consider it as an additional burden and responsibility for them and they insist that the necessity to have knowledge on OSH and considering these issues in their design is not their duty. On the other hand, designers who adopted PtD approach may face some challenges in seeing the risks that would be created by their design decisions which cause the design processes to take longer time (Gürcanlı, 2011).

- Considering the scale of the TRNC; involvement of PtD approach in the sector is at the start up phase. The biggest problem indicating the necessity of preparing this study is the fact that, the aforementioned PtD approach has not been noticed in the TRNC as well as in other developing countries yet.

To put in a nutshell, the PtD approach faces problems regarding its implementation in the developed countries (Gürcanlı, 2011; Gambatese, 2008). In the event that these obstacles are passed over, by the help of HIS developed by this study and it will be the solution for minimizing mentioned problems.

1.4 Scope and Objectives

The scope of this thesis was to answer the questions below:

- What is the propotion of accidents, related to Construction Industry in all occupational accidents in TRNC?
- Which are the most critical (frequent, injured and fatal) occupational acidents in TRNC?
- Are there any relation between design decisions and mentioned critical accidents?
- Which design decisions are creating risky construction activities and conditions to lead to occupational accidents?

- Which type of accidents are related with design decisions?
- What is the relation between design decisions, accidents and construction activities?
- How to define, control and change this design decisions and/or activities to minimize design related accidents?

Besides, the main objectives of this research are as follows:

- To organize and computerize all occupational accidents in TRNC between 1994 and 2014.
- Classify the accidents in construction industry and define the most critical type of accidents in TRNC.
- Identify the relationship between the most critical accidents and design decisions.
- Define the activities and sub-activities performed during the construction of mentioned design decisions which creates risks for accidents.
- Perform a risk analysis for activities and sub-activities to define the level of the risk. Case study is used to perform this objective
- Proposing design alternatives named as secondary design to minimize accident risks for above mentioned critical activities and sub-activities.

Developing a software algorithm named as Hazard Identificatıın System (HIS) that works with in the BIM software (REVIT) to define risky design decision, propose alternative designs to minimize occupational risks and accidents.

1.5 Contribution to Knowledge

This study attempted to organize and computerize all constructional accidents in TRNC and make them available to use for further academic and industrial studies. Thus, all accident records have been collected, ordered and classified according to the standart of ICD-10 Codes.

Besides, relation between the most critical occupational accidents, design decisions, structural elements and construction activities have been established. The method has been used while creating this relations will be good guidance for further studies.

In the present study, made an effort to find a way to propose safer design alternatives fastly and on time. At the end, HIS has been developed to do these. HIS helps designers to be more focus on their own design works instead of spending their time and effort to think OSH issues.

1.6 Research Methodology

It is easy to perform risk assessment, hazard identification etc. on the OSH field through the computer environment with the support of BIM. There are a number of studies conducted in this field (Taiebat, 2011; Gibb, 2006; Williams, 2006; Suermann et.al, 2009; Sorrensen et.al, 2009; Sulankivi et.al, 2009; Vries et.al, 2004; Vacharapoom & Sdhabhom, 2009; Golparvar-Fard et.al, 2009; Hu et.al, 2008). Such studies are mainly the systems conducting rule-based data check, which means that, such studies check the projects with complete design on BIM with regard to certain rules and take necessary measures. However, this study aims to combine PtD approach with BIM beyond the OSH. Hence, the developed system can be considered as performing the required checks for each design decision at the design phase.

Additionally, the related system can detect the potential risk situations at the time of occurrence and present it to the designer together with its alternatives.

In the first phase of study, the design decisions that the thesis would focus on are determined. For this, the following steps performed.

- The occupational accidents happened in the TRNC were analysed and construction accidents were focused on accordingly.
- Construction accidents were identified as the most common type of occupational accidents.
- The main activities (work items) that accidents occur were identified.
- The associated design decisions for such activities were detected. To do this, such activities required for the production of building elements were determined. Hence, the associated design decision for the related building element was identified. For instance; where the activity of exterior walls plaster works is originated from the design decision of building the exterior walls with bricks/block etc. materials.

In the second phase of study, the risk assessment was performed on the activities which are related with design decisions. Fine-Kinney method, which is widely used in the construction sector- was utilised respectively. Consequently, the risk scores for all activities that are performed in the construction of primary design decisions were calculated. The summation of risk scores for all activities performed in the construction process of design decisions is the risk score of that design decision. Hence, it was possible to make quantitative descriptions concerning the RISK of design decisions.

In the third phase of study, the secondary design decisions that are considered as alternatives to design decisions were discussed and all procedures conducted on the primary design decisions were also applied on the secondary design decisions. As a result of this, the quantitative description of secondary design decisions in terms of RISK was performed.

Afterwards, the risk scores of primary and secondary design decisions were compared. As a result of this comparison, primary design decisions that have high risk scores, and secondary (alternative) design decisions that have lower risk scores were interrelated on Revit Architecture.

This relation established on Revit was then converted into an automatic code functioning with an algorithm named Hazard Indentification System (HIS). The designers would be warned via HIS when they take a design decision with high risk score and informed that the proposed design decision would be safer.

1.7 Limitations

Although this study commenced by analysing the occupational accidents from all sectors, further on it only focused on the accidents in the construction sector. Upon the identification of occupational accident types in the construction sector, it only referred and elaborated the fall from height accidents, as they are the most frequent and fatal accidents.

Among the fall from height accidents, only multi-storey building constructions were focused and the accidents that were associated with the design decisions as exterior wall works, non-central air conditioning systems and roof parapet works were chosen respectively.

As indicated in other chapters of study, Standard Fine Kinney Method was utilised and in choosing the method, some experienced OSH experts were consulted respectively. When modified at likelihood and exposure aspects in accordance with the conditions of TRNC, the method would give more realistic and sound risk scores. However, since both alternative risk scores were compared rather than separately analysed, the final implications would not change that much.

Lastly, the main implication that is aimed from this study is to identify the methodology for the development of a system, which functions at BIM environment and provides sound results, rather than develop such system.

1.8 Structure of the Thesis

Aim of this section is to understand structure of the thesis and the sections composing the text. In this way, content of each section will be understood and it will be easier to perceive the study.

Different opinions and discussions taking place in the literature with regard to the subject of the study are dispersed throughout the text. Instead of gathering information and approaches collected through the literature under a separate section, dispersing them throughout the text enabled the thesis to be more fluent. By doing so, contribution of each study reached through the literature to the thesis was taken into consideration. Literature review dispersed throughout the text shows current situation of similar studies conducted in the world in parallel with the subject of the thesis and thus highlights the strengths and weaknesses of the aforesaid thesis. Contribution of the study to the literature will also be observed more easily through the literature review.

The first chapter of the thesis composing of 10 chapters is an introduction to the study. OSH issue and the PtD approach are shortly defined. In addition, situation assessment of the OSH issue and PtD approach was made on a global scale and on the scale of the Northern part of Cyprus. Besides this, problems established as a result of the study conducted are assessed and how they are going to be approached in this study are emphasized. Again, in this chapter, aim and the scope of this study, and contribution it is going to make to the literature are emphasized and information is given with regard to the structure of the thesis. Lastly, findings of the study and the conclusion reached are shortly conveyed in the first chapter.

In Chapter 2, situation of the construction industry and recent developments in the world and in the TRNC has been investigated. Share of the Construction Industry in territorial and global economies, its influences on employment capacity and unemployment has been examined. Furthermore, awareness of OSH in the construction industry and in the firms operating within this sector and the current situation as well as developments taking place in this regard have been investigated on a global scale and on the scale of the TRNC.

In Chapter 3, the significance of the design stage in the construction industry has been mentioned. By doing so, the importance of design for the course of life of structures and what kind of effects design has on other processes in terms of OSH are given. Detailed description of Prevention Through Design (PtD) approach has been made and what this approach is in today's context has been stated as well. The description of Risk Assessment methods, which are commonly used in the construction sector, is given and strengths and weakness of each method is mentioned.

In Chapter 4, an extensive description of BIM approach and development it has gone through in the course of time were mentioned. Besides, what kind of relationship will be established between BIM approach and OSH is pointed out.

In Chapter 5, problems which are subjects of this thesis are mentioned. Influences of the aforementioned problem on a global scale and reflections of these influences on the TRNC are pointed out. The subject is investigated under two different subheadings as global and territorial effects. Reasons contributing to the emergence of the problem and consequences which are created by or possible to be created by this problem are mentioned.

In Chapter 6, approach which will be followed and methods which will be adopted in the study conducted within the scope of this thesis will be explained in detail. Firstly, how the data used for the thesis is collected and characteristics of this data are explained. Later, other research methods required for collecting information apart from data collection and information reached as a result of these methods will be discussed. Lastly, data analysis methods which are used are reported in detail.

In Chapter 7, general analysis of occupational accidents that took place in the TRNC between the years of 1994-2014 is given. Firstly, sectoral distribution of occupational accidents is investigated and then a detailed categorization is made by focusing on accidents in the construction industry.

In Chapter 8, association of occupational accidents and design decision have been performed.

In Chapter 9, 10 and 11, mathematical analysis of accidents associated with design decision have been performed. While performing this mathematical analysis, Fine-Kinney analysis method has been used.

In Chapter 12, HIS is developed which will establish and eliminate hazardous situations that cause accidents associated with design at the design phase by suggesting them alternative design solutions.

Finally, findings obtained as a result of the study, strengths and weakness of the study, contribution of the study to the sector are mentioned and the study is concluded with proposals for future works.

Chapter 2

CONSTRUCTION INDUSTRY AND OCCUPATIONAL SAFETY AND HEALTH

2.1 Introduction

In Chapter 2, current situation of the construction industry and recent changes of it both in the world and in the TRNC have briefly been mentioned. Its share in territorial and global economies, its influences on employment and unemployment capacities have been examined. Furthermore, awareness of OSH in the construction industry has been verified.

2.2 Construction Industry

2.2.1 Situation of the Industry Around the World, in Turkey and in South Cyprus

The construction industry has an important position within the industries steering the world economy. On account of the fact that, many different specialties are actively operating within the sector, that is, being a multidisciplinary business segment is one of the factors highlighting the industry. What is more, having an extremely high potential in terms of employment opportunities and high budget of construction projects are some of the reasons why the construction industry is among one of the main industries for the world economy (Özorhon, 2012).

Besides direct influences of the construction industry, it is indisputable that it has serious indirect impacts. According to a research carried out in 2010, it was calculated that, total economic volume of the construction industry in the world is approximately 3.5 trillion dollars. In addition to this, it is argued that the sector will grow globally by

67% and will reach the volume of 7.2 trillion dollars within 10 years period between the years of 2010-2020 (Özdemir, Kiliç 2011; Ofluoğlu, Doğru 2011; Duman, Hamzaoğlu 2011; Gürcanli, 2013).

In 2010, it is known that the USA, China and Japan have been ruling the global construction industry. These countries in those years owned the share of 17.4%, 13.7% and 7.8% (respectively) of the global construction market whereas it is known that Germany, Spain, France and Italy follow the abovementioned countries with varying rates of 3-4% (Table 2.1). Subsequently, developments occurred in 2010 and 2011 upset the balances in the global market in that respect. Achieving an immediate growth in 2010, China left the USA behind. The estimations calculated in accordance with the above percentages show that growth impetus achieved by China will also prompt other Asian countries (YEM, 2010; GCP, 2011) (Table 2.1).

In 2008 and prior to 2008, housing demand in construction industry especially in the developed countries and the peak rate of growth showing an increase indexed to public expenditures severely decreased due to the collapse of Subprime Mortgage credit system. The growth reduced and came to a standstill during the years of 2006 - 2009 and the growth in the sector in 2009 fell below zero. The sector became steady through public investments put into action by the debts incurred by the western governments in 2010 and 2011 and it reached the level of 0.5% in 2011.

Table 2.1: Global Construction Volume by Countries 2009 and 2020 (YEM, 2010; GCP, 2011)

2009		**2020**	
Country	**%**	**Country**	**%**
USA	17.4	China	19.1
China	13.7	USA	16.9
Japan	7.8	India	5.1
Germany	4.0	Japan	5.1
Spain	3.9	South	3.2
France	3.6	Germany	2.9
Italy	3.5	Spain	2.7
Other	46.1	Other	45.0

Global construction expenditures achieved growth approximately by 4.0% in 2012 and 2013. Along with this growth, global construction expenditures reached USD 8 Trillion per annum in 2013. When global economic values are taken into consideration, total annual expenditure in the construction industry in the last 15 years reached a record high in 2008 and showed a decrease due to the mortgage crisis occurred later that year. The expenditures in the sector managed to reattain the level of total amount of the expenditures in 2008 only in 2013 (Turkish Contractors Association, 2016).

Considering Turkey which has close relationship with the TRNC, it can be seen that Gross National Product (GNP) of Turkey valued as 1.252 trillion dollars in 2010. The share of Construction Industry with 4.2%. In 2011, GNP was 1.431 trillion dollars while the share of the construction rose by 4.5%. The increase of GNP in Turkey also proceeded in 2012 and reached 1.528 trillion PPP dollars while the share of construction became 4.4%. In 2013, 4.3% of GNP valued at 1.676 trillion dollars that is, was in the construction industry (İNTES 2014; TİK 2014). Economy of Turkey showed growth performance resulting from domestic demand within the first 9 months of 2015; positive performance in agricultural sector, considerable decrease in the import depending on the decrease in energy costs and with the support of domestic consumption, the growth performance was pretty higher than the expectation of growth and it was recorded as 4.00% in the third quarter of the year in contrast to the same period of the previous year. Rate of growth on annual basis was at a level of 3.4% as of the first 9 months of 2015. The initial data with regard to the last quarter of 2015 show that propensity for improvement in economic activities has been continuing during the last period of the year along with the increase of the environment of trust. The expectations in consideration of the data show that the growth in 2015 will be between 3.5% - 4.00% (Turkish Contractors Association, 2016).

In accordance with the report of the World Bank, it was anticipated that the economy will show 3.43% and 4.08% growth performance in 2016 and 2017. In the revised report of the International Monetary Fund, on the assumption that political uncertainty will decrease domestic demand, expectation of growth for the economy of Turkey is decreased from 3.6% to 2.9% (Turkish Contractors Association, 2016). It was observed at the end of the year that this revised report is an appropriate projection. Interaction between general economic performance and construction industry are also observed in the growth figures. During periods of the rapid growth of the economy, the sector grows at a faster pace with multiplier effect and has a positive contribution to the growth, yet during periods of economic recession and slowdown, the sector becomes smaller at a faster pace because of the same correlation.

Growth of the construction industry follows a significantly parallel and fluctuating course with the growth curve of the GNP as of 1999. In this regard, as of the period after the global crisis, it is possible to define the years of 2008 and 2009 as trough in which effects of the crisis were massively felt in the sector. In addition, the years of 2010 and 2011 can be defined as the periods of rapid growth; the year of 2012 as recession and the year of 2013 as modest growth. The years of 2014 and especially 2015 are the periods in which growth achieved within the sector and the economy was lost. The construction industry which regressed in the last quarter of 2014 and the first quarter of 2015 grew same as the second quarter of the year in the third quarter with 1.90% and had a limited contribution to the Gross Domestic Product (GDP) with the score of 0.1. The sector whose share within the GDP is calculated as 5.7% barely grew by 0.4% as of the first 9 months of 2015. Public construction expenditures which grew by 30.2% in 2013 while it declined by 11.2% in 2014 continued to fall and declined by 2.6% within the first 9 months of 2015. Private sector construction expenditures which grew by 9.6% in 2014 had a limited growth with 1.2% during the same period (Turkish Contractors Association, 2016).

In accordance with the latest official figures published by the Statistics Department in the Greek Cypriot Administration of Southern Cyprus, construction industry is the leading sector in the economy of the Southern Cyprus. Developments in the construction industry also reflect credit upon the growth of the national economy. In accordance of April 2016, the volume of construction industry in the Southern Cyprus declined by 4.9% during the period of January-April 2016, which caused substantial loss of income and unemployment problem in the national economy. However, in the subsequent period, improvements have been observed and growth has been achieved during the period of March - June 2016 with the rate of 3.6% (Yorucu, 2016). When the first semi-annual period of 2015 and 2016 are compared in terms of the construction industry in the Southern Cyprus, it is possible to say that 2015 is a more successful year than 2016. There has been a decline by 4.36% in the construction volume in 2016 in contrast to 2015. This decline caused a decrease of approximately 40-50 million Euros in the total production value in all sectors of the Southern Cyprus (Yorucu, 2016).

2.2.2 Construction Industry in the TRNC

TRNC construction industry is at the top of the sectors contributing the economic growth of the country, and according to the data by State Planning Organisation (SPO), it affects 27 sub sectors, thus the state economy, directly. Therefore, developments in the construction sector run parallel with economic growth. While the average growth of the sector was 6.8% during the years 2000-2012, general economic growth average was around 4.9%. The construction sector grew above the general growth during the years of economic development, and showed sharp decline during periods of economic shrinkage. While the sectoral growth peaked during the 2004-2005 period, it went into a sharp shrinkage right after those years (SPO, 2013).

Construction sector is a field in which labor and work force are used intensely. Although various construction methods are used, it is estimated that cost of labor for the most widely used construction methods in the country is 40-50% of the total cost (SPO, 2015). With this aspect, the construction sector is one that creates employment opportunities. The ratio of employment the sector creates among general employment shows variations in time. The construction employment rate that was 5-6% in the 70s rose up to 19-20% after 2003. However, in parallel with the economic fluctuations, the shrinkage in the sector brought this rate under 10% again (SPO, 2012; SPO, 2015).

Unable to achieve a planned and sustainable growth from the point of employment and economic growth, the sector went through sharp declines because of the dead-ends. Parallel to this, unplanned development resulted in OH&S problems growing exponentially. This made the OH&S field a problem increasingly difficult to take under control. Table 2.1, created as a result of the study, examines the changing employment capacity of the construction sector throughout years. Moreover, the sector achieved a very rapid growth and development during the 2004-2005 period, right after the years 2001, 2002, and 2003, during which the state economy was revived. In parallel, the construction sector reached its highest levels of employment. The employment rate of construction sector, which was around 14% during the 90s, rose up to 18% in early 2000s, when an economic and sectoral revival was seen. As stated above, this unplanned development in the construction sector and unusual increase in employment capacity paved the way for a rise in occupational accidents.

When a study will be carried out with regard to the construction sector, in the first place, one should roughly know the sector, because unlike other sectors, the construction sector is under the influence of constantly changing conditions, changing manner of work, and of financial and durative variables. There is not the slightest chance that even two sequential projects can be the same. For instance, even two apartment projects which are exactly the same undisputedly differ from each other in terms of factors such as construction site, weather conditions, soil structure, condition of neighbouring plots, workers and equipments used. Under such circumstances, the abovementioned financial and durative differences become more obvious. However, process based production is used in other industry areas. To put it differently, there is a fixed production process and during the process of fixed production, identical products are manufactured. All stages and elements from raw material, to manufacturing process, from equipments to products are exactly the same. In addition, it is possible to produce quite different products with the help of minor differences made during the current process. Yet the situation is different in the construction industry. Even small changes in the weather conditions can cause serious differences to be made within the process.

2.3 Occupational Safety and Health in Construction Industry

One of the main reasons of occupational accidents constantly taking place in the construction industry is that construction works performed have high risk of accidents due to their nature. Changeable conditions and environments defined in the previous section enable many different hazards and risks to be encountered in constantly changing intense and in changeable environments. Therefore, almost all activities carried out in the site of construction are considered hazardous by the experts (Çelik, et al.,; 2012). The risks which are inherent within the construction industry and cause it to be hazardous increase with the size of projects, business volume, employment capacity of the sector, variety of the machine and equipments used in the sector. The countries that saw it was coming many years ago has experienced that they were right in their predictions and began to take measures in this regard and made a set of arrangements. In order for such measure and arrangements to be made systematically and sustainably, an instrument called OSH management system came to the help of experts. The arrangements made by the virtue of OSH management systems minimize possibility of undesirable situations such as accident and injuries even though it does not eliminate them thoroughly. By doing this, arrangements such as establishment and elimination of risks, adoption of proper working methods, selection of proper tools and equipments, use of personal and collective protective equipments and similar arrangements are hierarchically put into effect, inspected and managed. As a result, it contributes to overcome undesirable situations with minimum damage (Bareman et.al, 1996).

According to the publications of Health and Safety Executive (HSE), a globally known authority of OSH in the UK, more than 200 workers or people who are in workplace environment in the different sectors in England lose their lives per year because of occupational accidents. Besides this, the same resource emphasizes that more than 1 million people in England got injured in the workplace environment and more than 2 million people had to struggle with work related diseases. In addition, accidents taking place cause serious loss of time and money and result in a large number of lawsuits and penalties (HSE, 2008; HSE, 2010).

Having a long-established history, EU countries and other developed countries took the issue of OSH seriously well in advance because of the figures in the previous statistical data regarding occupational accidents, definitions made and for many more reasons. Territorial, sectoral and project based OSH politics developed in this regard have serious contributions to the decrease of occupational accidents in a controlled manner (Bareman, 1996; HSE, 2008). One of the instruments required to prepare the aforementioned OSH politics is the statistical data regarding previous occupational accidents. Availability and quality of statistical data offer very strong evidences to experts in the area of OSH as in all areas and act as a leading instrument (Doguwa, 2010).

2.3.1 Situation Around the World

Heinrich who is a well-known person in the area of OSH was one of the leading names of Theory of Accident Causation in 1930’s and had significant studies concerning human and machine interaction, reasons of unsafe activities, costs of accidents, relationship between severity and frequency and importance of management in prevention of accidents (Abdelhamid, 2000). Furthermore, Heinrich developed the theory of domino and emphasized that five main factors occur sequentially when an accident occurs. Comparing these five factors to dominoes, Heinrich listed them as social environment, ancestry (family), weaknesses of a person, unsafe activities, unsafe conditions and as a result, accidents and injuries (Heinrich, 1959; Heinrich et.al, 1980). In 1982, Petersen stated that “there are important points that can be deduced from the studies of Heinrich, one is that –people are the most fundamental factor behind accidents- and the other one is –management is the main instrument in prevention of accidents”. As also emphasized in the previous paragraphs, construction industry is at the top of the list of the sectors in terms of frequency of occupational accidents and financial and non-pecuniary damages incurred as a result of these accidents (Çelik and Tözer; 2014). In the USA, approximately 36% of occupational accidents resulting in death take place in construction industry (Zang, et.al; 2015). It was observed that 32% of occupational deaths in UK, during the 2013-2014 periods were in the Construction industry (HSE,2014). About 25% of all occupational accidents in Finland are in the Construction industry (Nenonen, 2013). Looking at Singapore, it can be seen that the Construction industry offers employment to 29% of the work force of the country, while being the scene of 40% of occupational accidents (Chua & Goh, 2004; Fang et.al, 2015). Lopeaz M. et al (2008) who carried out a study in Spain examined 1,630,452 construction accidents took place during 10 years period and emphasized that 1,598,765 (98%) of accidents resulted in slight injuries, 28,658 (1.8%) resulted in severe injuries and 3,029 (0.2%) resulted in death.

2.3.2 TRNC and its Neighbouring Countries Turkey, Greece and South Cyprus

Turkey and Greece are in high-level relationship with the north and south of Cyprus politically. Living in a close and similar geography, these countries have profoundly affected the lives of Cypriot communities through these close relationships. The worker population, and their families, which came to the northern part of the island from Turkey to find better jobs, have resulted in the integration of the work and social cultures of the people from Turkey and the people from Northern part of Cyprus. Besides this, construction techniques and prevalent construction types in Turkey, Greece, and in both sides of Cyprus show similarities. These similarities resulted in accidents being similar as well. This is the reason why most of the work accidents take place in building constructions when the recorded accidents in the above-mentioned countries are examined. Thus, when Turkey is examined for occupational accidents, it shows similarities with the Northern part of Cyprus. 30.5% of all occupational deaths in Turkey are in the Construction industry (Gürcanli & Mungen, 2013; Çelik and Tözer, 2014).

According to the data of Cyprus Association of Civil Engineers in the South of Cyprus, accident rate within the construction industry in 2013 was 985.2 for 100,000 workers. The report of European Social Statistics 2013, which is a eurostat study prepared within the body of European Commission show that the construction industry is the second most deadly sector with a death rate of 6.6 for 100,000 workers subsequent to mining and quarrying sector with a death rate of 10.9. Moreover, South Cyprus, member of the European Union (EU), ranks first with the death rate of 4.9 for 100,000 workers. Considering 10 years of data in the South of Cyprus, it is observed that accidents taking place within the construction industry is on a serious decline as a result of EU membership. In addition, economy in the South Cyprus being directly affected from the crisis burst out in Greece came to a standstill. Employment capacity of the construction industry whose volume reduced under the influence of this standstill decreased and thus more significant decrease in the number of occupational accidents was observed (Eurostat, 2014).

There is a population of around 313,000 in the Northern part of Cyprus and construction industry constitutes approximately 12.6% of the employment volume (SPO, State Planning Organization, 2015). The sector takes the first place by far in the list of work-related deaths. 48% of work-related deaths take place in construction in the country (Çelik and Tözer, 2014). In accordance with data of ILO, when occupational accidents data in many countries is considered, possibility of construction workers to die due to occupational accidents is 3-4 times more comparing to other sectors (ILO, 2015).

What is more, EU and UNDP Partnership for Future have been supporting entrepreneurship since 2003 in many areas from agriculture to education, from health to infrastructure and construction throughout the island particularly for Turkish Cypriots living in the Northern part of Cyprus. They have been informing Turkish Cypriots about current opportunities, providing financial support programmes and training regarding skills development and capacity enhancement intended for local business. In addition, launching significant support and improvement programmes also in the area of OSH by working cooperatively with the respective departments of the both communities in the north and south, EU has recently made remarkable contribution to the improvement observed in the area of OSH (URL2).

Chapter 3

DESIGN AND OCCUPATIONAL SAFETY AND HEALTH

3.1 Introduction

Design concept has briefly been defined in Chapter 3. In addition, the significance of design in the construction industry has been mentioned. Moreover, the type of association between design decision and OSH has been given in this chapter. Detailed description of Prevention Through Design (PtD) and its development progress has been done. What this approach is in today’s context has been stated as well. The description of Risk Assessment methods, which are commonly used in the construction industry, and the significance of OSH Management System have been also mentioned.

3.2 Structural Design

Design is the plan or idea developed for the solution of a problem. Design is an idea that consists in the mind first; however, it also carries the effort to acquire form to this idea with itself. As a result of the design process, ideas becomes concrete as an object.According to that, an idea, an effort to acquire a form and eventually a formed object are found in each design case (Tunalı, 2009). With respect to another definition, design is the action of research and problem solving within conditions. The object of this action is to find and present realizable solutions that meet the needs, which are stated in the definition of the problem (Giaccardi ve Fischer, 2008). Another definition defines design as a pursuit that is based on mental processes in order to obtain a spatial arrangement and formation (Onat, 2006). Stressing that design proceeds within a process, Mitchell (1999) defined it as “Design is a process, which proceeds with high level complex relations and partially sudden inspirations in particular and mostly with trial and error.”

Design process at structures is also assessed as a multilayered mental process that has multiple players. During the process, numerous decisions are required to be taken with the related actors at the same time and in communication with each other” (Kızılırmak, 2010). Designers set some design goals at the first phase of the design. There are many parameters that affect and change these goals. Even though these parameters can be in line with each other, they can contradict with each other (Mangan, 2006). For example the size of a window is kept large for achieving view and for ensuring heat gain from the sun in winter; its size can become smaller to prevent the place to become excessively warm in summer. It is important to ensure the design balance in this sense. Building design is an optimization problem among the systems that are waiting to be solved in the context of parameters that contradict with each other for fulfilling design goals. It is necessary to comprehend the significance of cooperation among disciplines by acknowledging that information and experience from different disciplines are required for making decisions that are based on the optimization of such and numerous complex and contradicting parameters (Taşoluk, 2014).

Every successive stage directly is affected by every life process stage of the building (Giaccardi and Fischer, 2008). With this opinion, it can be said that design phase, which is accepted as one of the first phases of life process of structures, affect every successive stages (in other words all of the life process of the structure).

3.3 Association of Design and OSH

Construction works that are carried out at construction site varies from project to projects and special methods can be developed for a specific projects. As a result of this dynamic structure of the construction industry, individuals working at construction industry face serious and changing level of risks. (Celik et al., 2012; Celik & Tozer, 2014). Its very well known that Protection and prevention are closely associated with each other. These two issues that are directly related are formed under the influence of the perception of shareholders, financial concerns and legal conditions. For the designer, occupational safety issue is not a point to be considered throughout the world and mainly for undeveloped and developing countries and it is required to be dealt by experts. This approach of the designers can be acceptable for food, industry and similar sectors, in which flow type production is carried out, except for construction. On the other hand, it is an issue that needs to be discussed for the construction sector, in which project based production is carried out (Gürcanlı, 2011).

OSH is an issue, which is usually ignored until the construction stage, and this point of view nearly conceals that the decisions taken by the designer has an effect on OSH. However, design plays a leading role in how a project will be realized and how to combine work items and subcomponents of the project together. In most of the cases, designers have already determined on how the construction work items would be applied unintentionally. However, most of the designers have not accepted it.

The disturbing section of the situation is that the hazards, whose majority emerge with the decisions that are taken at the design phase, are not realized until the construction begins (Gambatese et al., 2008). However, Prevention Through Design (PtD) or in other words Design for Safety (DfS) approach, has been frequently mentioned at the construction industry and OSH area recently, is trying to find a solution to this problem. Essentially, the approach argues that OSH is required to be considered when the project begins to be designed (Gambatese et al., 2008; Behm, 2005; Gambatese & Hinze, 1999). In his study, Gürcanlı (2011) described DfS concept that “DfS is not the designing of collective protection measures that are necessary for occupational safety (e.g. pier or safety railing design) it should completely focus on the changes at the design of the structure.” Again in the same study, Gürcanlı (2011) points that approximately 60% of accidents involving death were associated with design decisions which are taken before the work begins.

World Health Organization (WHO) brought the said approach to agenda in the mid1980s for the first time and recommended designers to make their designs by taking occupational safety into account. In the beginning of 1990s, the issue was started to be included in the agenda of the European Union. Fortunately, it is possible to determine and minimise the hazards, which can emerge with the decisions that are taken at the design phase, almost immediately with small changes (without damaging the character, function, aesthetic and etc. of the structure) in the design (Gurcanli, 2011; Gambatese et al., 2008; Behm, 2005; Gambatese & Hinze, 1999). In the study carried out by Zhang et al (2015) they had worked on a system that defines and tries to eliminate the hazard of fall from height and they found a solution for this problem with an algorithm they had developed at BIM environment. However, the study was concluded with finding the most suitable preventive measure for the problem instead of solving the problem by making a design change.

The significance of PtD has already been recognized in England, which has an established past in OSH field, the necessary studies had been made and they are already included in the related legislations. Despite this fact, it is considered even in England that one of the biggest obstacles for the settlement of this problem is the approach of designers. Although the PtD approach has started to be accepted with a recently increasing acceleration, it hasn’t been adopted by a large rate of designers yet (Zhang et al., 2015). This approach, which hasn’t been completely included in the sector in developing countries, may be exposed to the reaction of designers in some cases. Thus, it makes this approach difficult to reach large masses. In fact, some designers consider it as an additional burden and responsibility and they can insist on the fact that having knowledge on OSH and considering these issues is not their duty. Despite that, designers that adopted PtD approach may face some challenges in seeing the risks that would be created by design decisions. And this is a situation that can cause the design processes to take longer time.

On the other hand, OSH costs, which suddenly emerges as an additional cost at construction phase since they were not taken into consideration in time, cause serious disagreements to occur during construction process in developing countries. Most of the time, this situation causes problems for constructors and investors. As PtD approach bring OSH into agenda at design phase, long before the cost accounting, it would be much easier to determine and cost OSH items in time.

3.4 Classical Implementations in OSH Area

As in every sector, employers at the construction industry are stated to be obliged

- to take any measure to ensure OSH at work places

- to keep all of the tools and equipments that are necessary for the work completely
- to inspect if the taken OSH measures are obeyed or not
- to inform workers on occupational risks that exist, on the measures that are required to be taken and on their legal rights and obligations
- to give OSH training
- to inform the occupational accident that took place and the occupational diseases that would be determined to the related regional directorate.

The extent of the measure that would be taken by the employer will be determined in accordance with the situation of science, experience, technique and technology. Moreover, workers are obliged to obey any measure that is taken to ensure OSH.

In order to fulfil the abovementioned obligations, employers receive help from the OSH discipline and implement systematic management models that were developed by experts at work places. As it was already highlighted in the previous chapters, these systematic management models are called OSH Management System. Rules, measures and regulations, which are required to be obeyed by employees, were developed within the framework of this OSH Management Systems. OSH management systems have benefits such as;

- To reduce occupational diseases, injuries and disabilities caused from occupational accidents and to ensure the enhancement of employees and the community,
- To ensure the resource and work power to be used more efficient and productive and to reduce financial losses,

- To ensure that possible risks that may result with loss are determined before and that the necessary measures are taken,
- To provide a comfortable and safe work environment to employees and therefore ensure employee satisfaction,
- To participate in reduction in production costs and in the provision of increasing product and service quality and therefore increasing customer satisfaction,
- To minimize direct and indirect costs which are caused by occupational accidents and occupational diseases (NIOSH, 2017)

In order to benefit from the abovementioned advantages of OSH management system, it is required to prepare the cited systems and to always keep them up-to-date. Various methods are needed at different phases of the process for that. To mention briefly on these phases and methods would facilitate understanding the structure of traditional implementations in OSH.

According to that, the first phase of OSH management system is called "Planning Phase." All objectives and goals of the establishment are determined and implementation methods are developed in this phase. The second phase is when planning is started to be implemented and it is called "Action Phase." All of the risks are determined, all regulations are made in line with the establishment objective and goals and all of the measures are taken at the end of this phase. The phase which is known as "Evaluation Phase" begins at the third phase. Activities are controlled in terms of efficiency and competence within the plan and the results are compared with the plan at this phase. The sections, which are found unacceptable or which are seen insufficient/deficient are dealt with and improved at the final phase, which is

"Corrective Action Phase." The insufficiencies are fulfilled, the plan may be revised according to the changing conditions and the procedures are reconstructed as needed at the final phase. Risk Assessment process plays the key role in all of these phases. Therefore, it would be suitable to discuss the Risk Assessment process with more details.

3.4.1 Risk Assessment Process of Customary OSH Implementations

Risk assessment lays the foundation of OSH. Environment directive 89/391, which was prepared by EU, holds employers responsible for assessing OSH risks, taking the necessary remedial measures and keeping them up-to-date (Uzun, 2012). Convention 161 of the ILO is a reference convention in terms of the risk assessment approach. Definition and assessment of risk is given as the first step of OSH studies in Article 5 of the document (Yılmaz, 2010). Risk Assessment is at the intersection point of processes such as politics, organization, education, communication accident reporting, monitoring and inspection, corrective and remedial activities that are keystones of OSH management (ISGIP, 2016).

Aiming to show a proactive approach in protection and safety of workers' health, risk assessment is a process that investigates risks born from the hazards of the work that is being made before the accident takes place (Andaç, 2014). With this aspect it can be said that risk assessment determines predictable hazards and risks and enables implementing suitable methods to take the necessary measures. It also contributes to the increase of efficiency as it prevents situations like slowing down or stopping work for accident related reasons at the same time (Uzun, 2012).

3.4.1.1 Details of Risk Assessment Process

OSH works are supported with legal regulations, and this is one of the most important reasons for risk assessment processes to be materialized in practice. Risk assessment processes include all of the hazards that are seen frequently and rarely at constructions into assessment. Even though hazards that are seen in work environments that change in every project appear similar, their prevalence can be different and that causes differences in risk assessment process of that workplace. Therefore, another point that needs to be highlighted is that the risk assessment that is being made is required to be in conformity with the work that is being dealt with. The qualification of the work, tools, machines, equipments and materials, etc. that are being used, and elements that have the potential to pose a threat are assessed in determining hazards while risk assessment is being made. In addition, the period of workers' exposure to hazards and the dimension of the loss that would be caused by the hazard are important. Considering all of these facts, content of each hazard, in other words their structure is determined and control methods that are prepared accordingly are set according to order of priority. When the risks are being controlled, hazard elements are responded by starting from the most hazardous one according to the aforementioned order of priority (Uzun, 2012).

Another significant point in taking risks under control and monitoring them is the level of acceptability. In simple terms, it is the reduction of conditions, which pose high level threat, to an acceptable level as a result of the studies and continuously keeping them under control at these levels. While it is possible to make short term, simple and recurring arrangements, it is also possible to find long term and permanent control methods. Determining which one of these two methods is suitable is the critical decision. However, the qualification of the control method and its place in the risk order facilitates the decision to be taken. “Risk Control Hierarchy” is being used for that (Uzun, 2012).

While Gürcanlı was defining risk at his presentation named “Risk Management at Constructions”, which was presented at a lecture at the Eastern Mediterranean University Department of Civil Engineering in 2015, he mentioned that uncertainties that are related with work, worker, tool, machine and method are elements that may cause formation of a risk source. In addition, he described risk as a process that is composed of components and he defined these components as source, incident and effect, respectively. A system that is called “Risk Control Hierarchy” was mentioned in the same presentation so as to control the abovementioned risk process. According to that, in order to control risks it is necessary to;

- Avoid risks
- Asses inevitable risks, change the work items with less risky items if possible
- Handle risks at their source
- Make the work suitable for the person, who carries out the work
- Change hazardous substances, materials and working systems with nonhazardous or less hazardous substances
- Create a working environment that is suitable and in line with technical developments. In another word, isolate hazards in place
- Develop a policy to prevent occupational accidents that also considers employees’ health and their safety and comfort at work environment and also

takes technology, work organization, working conditions, social factors and factors related with work environment into account

- Take collective protection measures by creating an approach that particularly pays attention to collective protection measures more than personal protections and then provide personal protection.

If the risk control hierarchy, which is given in the items above is required to be broaden, first of all the elimination of hazards of any work should be underlined. For example, it is unquestionable to use silica sand in sanding process for carrying out the work in quite fast and quality way. However, when it is considered in terms of health, it may cause possible respiratory tract diseases in short time and these are serious disadvantages. In that case, risk assessment is required to be made and control prevention is required to be developed. If we continue on the same example, as a result of the assessments carried out on this matter, sanding works made with the silica sand are not preferred because of its destruction caused on the lives of the employees. In brief, the risks caused by this material are eliminated as working with the silica sand is not preferred. The next stage can be summarized as eliminating elements, which contain hazard at working method or at the work environment, by changing the working method or physical conditions. For example, let’s consider the situation that a circular saw, which is used in a construction site, doesn’t have a protective lid. That case has a great risk in terms of users. However, cutting the materials at another workshop, where they will be cut with suitable equipments and then moving them to the working area creates the results of changing the working method and reducing risk. Another control method, which is described as isolating hazards at their place, depicts the measures that are taken to reduce or remove existing risks. It is possible to prevent workers or third parties that will be exposed to the risks at the working environment with administrative measures at other steps of risk control hierarchy. For example, collective protection measures for employing less people or for improving physical conditions of the work (installing ventilation systems, etc.) can be considered in the situations, in which it is necessary to work in noisy or dusty environments. Moreover, arranging working hours and breaks for reducing the workers to be exposed to these physical factors can be given as an example for this control method. Lastly using personal protective equipment is accepted as the final step of the risk control hierarchy when no results are achieved from the previous control processes or when risks are not eliminated despite the fact that other methods had been used. Using personal protective equipment is quite inefficient control method when compared with the other control methods. To briefly sum up, the line in the risk control hierarchy is based on a specific reason. Priority in risk control is to eliminate or reduce the risk and using personal protective equipment is required to be considered as the final step after following all of the steps to control the risk (Uzun, 2012).

After the risk analysis is being made and control measures are developed, following the process of control measures regularly lay the foundation of a sustainable process. In addition, it is also possible to find previously overlooked hazards in controls that are made periodically and this increases the quality of the process. When the possibility of the hazards, which were taken under control before, might get out of control is considered, the only way to find it is the controls that are made periodically. Therefore it is required to make periodic controls for each risk, whose analysis had been made, and the existing situation to be followed up regularly. Revising the risk assessments that were already made can also be possible with the abovementioned controls (Uzun, 2012).

3.4.1.2 Frequently Used Risk Assessment Methods

As far as it is known, the number of risk assessment methods that are currently used is more than 100. Even though there are various methods that have specific similarities with each other, each method has specific and certain unique parts. Having so many risk assessment methods that are used naturally creates the necessity for the person, who will make the risk assessment, to choose the most accurate risk assessment method for the work that will be made.

Risk assessment methods are differentiated in relation with the structure and the individuality of the work. Risk assessment methods are basically divided into two. These are named as;

- Quantitative Risk Assessments
- Qualitative Risk Assessments

However, although hazards are determined in similar ways in both methods, differences are seen in the grading process of the risk. Numerical methods are used when calculating the risk grade at quantitative risk analysis; whereas qualitative methods are mainly used in the process for determining the grades of risks at qualitative risk analysis.

Basic formula of risk assessment in qualitative risk assessments is explained as:

$$\text{Risk: } L \times I \qquad (1)$$

L = Likelihood (Likelihood of hazard)

I = Impact (Impact of hazard)

In addition, there are “Mixed Risk Assessments” that include both of the methods. Risk assessment methods such as Check-List, Fine-Kinney, L shaped Matrix, Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis, Event Tree Analysis (ETA), Hazard and Operability Study (HAZOP) can be shown as an example for the “Mixed Risk Assessments” (Uzun, 2012).

3.5 A New Approach: Ensuring Occupational Safety Through Design

“Prevention through Design” concept is a name that is suitable to create question marks of the people that don’t have comprehensive knowledge on the subject when it is called. Therefore, it would be beneficial to continue with tangible examples in order to understand the subject and the concept correctly. Fall from scaffold, mould systems and similar temporary structures and from thresholds such as balconies, roofs, borders of flooring, gaps of lightning system and roof window in the accidents of fall from height that occur in construction sites are the most common types of fall from height and they are the accident that cause the highest number of deaths (Çelik and Tözer, 2014).

Therefore,

- reducing work items as much as possible such as external wall works that require working on scaffold with the correct design (choosing panel wall that requires only a slight plaster and paint instead of brick wall that requires an intense plaster and paint labour, etc.)
- designing parapet walls, which are low walls built as a barrier for roof – bridge – balcony edges, in a high form in a way to be in conformity with the exterior of the building aesthetically,

- scheduling the building of these walls for an earlier time as much as possible according to the schedule so that they are before some works, which require working at a threshold or which require intense work power,

can be considered as taking a natural measure against falling and falling risks will be eliminated at a large extent at the design phase.

However, it is necessary to consider the structure not only during construction, but also at maintenance and repair stages. Changes in design, which are comparatively very simple and cost efficient, will eliminate all of these problems to a great extend at the beginning of the work. This will give successful results that will deactivate many traditional OSH not only during the construction process, but also measures through life (CDM, 2015).

Frijiters and Swuste (2008) studied whether occupational safety hazards change or not according to flooring types in their studies and compared to hollow beam floor designs. Only accidents of falling and stumbling were analyzed in this study and only floor construction and sub-items of work were examined as work items. It was found that considering occupational accidents particularly falling at the design phase and choosing alternatives accordingly reduces risks and these findings were also shown with a case study. Eventually it was found that hollow beam floor designs are safer than occupational accidents like falling and stumbling.

In a study carried out by Gangolells et al in 2010, risks for possible occupational accidents such as fall from height and materials' falling for basic work items such as flooring, roofing and excavations was calculated. The writers used project drawings and quantity lists and made the subject matter calculations at the design phase. There are different manufactures, manufacturing amounts and materials for different design alternatives and their amounts are used in the risk calculation. All of these work items and the variety and the amount of the used materials are described by the authors as factors effecting occupational safety. For example when the level of the risk of "falling from gaps at the edges of floor" is being calculated, the number and the magnitude of the said gaps are taken into account as a factor affecting occupational safety and gaps larger than 0.40 m^2 have been considered while the risk is being calculated. The share within total manufacturing period, in other words, the excess of the amount of work is considered for some work items. With this point of view, alternatives of exterior made of brick and similar elements, plastering these exteriors or covering them with stone and similar material and precast concrete panels, which are manufactured at ground level and installed through a crane, were compared. All of the risk items have been reduced with manufacturing precast concrete wall according to the study. And once again, it clearly shows that occupational accident risks can be reduced to what extend at the design phase.

However, Prevention Through Design (PtD) which has been frequently mentioned at the construction industry and OSH area recently argues that OSH is required to be considered when the project begins to be designed. Accordingly, it is believed that it is possible to determine and minimise the hazards, which can emerge with the decisions that are taken at the design phase (Szymbersky, 1997; Manuele, 1997, Taiebat, 2011), almost immediately with small changes (without damaging the character, function, aesthetic and etc. of the structure) in the design (Gambatese, 2008).

Chapter 4

A HODIERNAL AND FUTURISTIC TREND: BUILDING INFORMATION MODELING (BIM)

4.1 Introduction

In Chapter 4, emergence of BIM approach, development it has gone through in the course of time and its technical/technological characteristics are discussed. Furthermore, what kind of association will be established between BIM approach and OSH is pointed out and general characteristics of BIM software that will be used are explained.

4.2 Prior to BIM

By the end of 1970’s, designers benefitted from orthographic drawings which were created in line with the principles of technical drawing in order to visualise their ideas. In those years, drawings were made by hand, special equipments were used for this purpose, and project details were given at limited levels so as to decrease loss of time (Dalcı, 2014).

At the beginning of 1980’s, due to recent developments in computer and information technologies and along with the fact that these developments were began to be offered at affordable prices, first seeds of software systems called Computer Aided Design (CAD) were planted.

CAD softwares, instead of drawing by hand, enabled to make faster, more accurate and much more detailed drawing. Being one of the most commonly used softwares of

CAD, AutoCAD and many more similar software were developed and strengthened in time and caused the emergence of object oriented CAD softwares (Bedrick, 2005). However, all systems used so far were systems making graphical descriptions (2D or 3D linear descriptions). Information that is intended to be given in addition to the form of product or structure was given through texts attached to drawings.

4.3 BIM: General Description

Building Information Modeling (BIM) is a name given to design solutions developed by the implementation of information technologies of today and tomorrow in building sector and it is a system comprised of these solutions. It is an approach developed in order for all disciplines having a part in the course of life involving all processes of design, construction, utilization and disposal to operate in company and in total conformity (Eastman et al., 2008; Eastman et al., 2011). As the phrase is, besides projects of a structure whose construction continues or already completed or is in the process thought, it is a system which enables to work on its virtual copy.

In building design process, a lot of data is produced in all its disciplines and at every stage of the process from the very first drafts created until the minute details. Considering especially building design process, such data is represented in documents independent of each other in CAD softwares. Although plans, view and sections, details, lists of quantities describe the same structure, they are independent documents in computer environment (Dalcı, 2014). Reproducing the same information for documents independent of each other is both time consuming and open to errors. All these independent documents are obliged to be edited one by one according to changes made to design (NBL, 2016). In fact, BIM systems operate with numerical database in which all data defining the structure is kept and as revisions are made on this database, any change made to any document reflects on all documents (section, views, plans, lists, tables, cost estimations, schedules etc.) which are produced by the database (Hunt, 2005; Jayasena & Wijayakumar, 2013; Woo, 2007).

Main aim of the BIM approach is to create a mutual language among stakeholders participating to the building design and construction process. Each expert taking part in the project works with different data and information related to his/her own discipline and prefers projection methods which will express him/her the best. This variety makes data interchange in the project difficult (Ofluoglu, 2009). However, with its developed and multilayered structure, BIM systems can combine data from different disciplines in the same structure and in conformity with each other. Thus, it functions as a bridge between different disciplines and prevents unnecessary waste of time arising from unconformity and lack of communication (Eastman et.al, 2008).

More clearly, instead of creating different building models including information of different specialties, BIM creates single model carrying information of all disciplines. On top of that, it gives warning regarding conflicting and incompatible points among this different information and minimizes errors (Eastman et.al, 2008).

As known, purpose of planning and management in construction projects is to do the delivery at the planned time, in the targeted quality and at the anticipated cost. For this reason, one of the indispensable things for customer satisfaction is planning and management. In projects that have time limitation in terms of design and construction process, importance of planning and management increase even more and possibility of parties participating in the design and production process to make mistakes increase. Especially in cases where traditional methods, 2D and 3D drawing and modelings are used and where stakeholders work on independent models, errors and delays become almost inevitable. These errors and delays can create serious crises at the construction phase or when delivery date approaches (Doglas, 2010). However, on the account of the fact that BIM technology is being used in similar situations and because of the above-listed superiorities of the system, these problems are eliminated (Lee, 2008).

In the study named "*Constructing the Future: nD Modeling"* published by Aouad and et. al in 2006, it is stated that beyond being 3 dimensional, BIM creates a smart information model and makes it available for not only designers, but all stakeholders. BIM models presenting form of the structure in 3D can implant programming and scheduling functions in 4D, cost estimation functions in 5D and facility management functions in 6D to the model (Gee, 2010). Besides all these, BIM can carry out engineering analysis operations and building and construction business functions in an extremely successful way. Especially, it is effectively used in analyses of structure and status of energy use and in planning of disaster management and emergency response operations (Wang et al., 2014).

Minimizing conflicts taking place during the design and construction phase, stakeholders are presented with outputs (models, plans, sections, technical specifications, analysis results, material lists, business items, working schedule, payment schedule etc.) which are required for the whole processes to proceed healthfully (Eastman et al., 2011; Smith & Tardif, 2009; Smith, 2008; Song et al., 2006; Grilo & Goncelves, 2010).

As also emphasized in the previous paragraphs, with the help of BIM which is used to create virtual copy of real conditions and elements, it has become possible to prevent emergence of reworks more easily, and to minimize unexpected expenses as well as loss of time. In addition to this, changes requested are made rapidly on the model that is presented in BIM environment to owner at the design phase and satisfactory service is provided (Dalcı, 2014; Hergünsel, 2011; Holness & Gordon, 2008).

There are BIM softwares for architecture, Mechanical - Electrical & Plumbing (MEP), structure, sustainability, construction and facility management purposes. Most popular ones can be listed as: Autodesk Revit Architecture, Autodesk Revit Structure, Autodesk Revit for mechanical, electrical and plumbing (MEP) engineers, Tekla Structures, Autodesk Robot Structural Analysis, Graphisoft ArchiCAD, Nemetschek Allplan Architecture, Nemetschek Vectorworks Architect, Gehry Technologies-Digital Project Designer, Bentley Architecture, 4MSA IDEA Architectural Design (IntelliCAD), CADSoft Envisioneer, RhinoBIM (Beta), Softtech Spirit, Bentley Structural Modeler, STAAD, Bentley RAM, Prosteel, CypeCAD, Nemetschek Scia, Graytec Advance Design.

4.4 Autodesk Revit Architecture

Revit Architecture is computer software intended for structural design and planning. Revit Architecture, being an Autodest product, is preferred by more than 70% of BIM market in the world (Autodesk, 2005; Autodesk, 2007; Autodesk, 2008; Dalcı, 2014; Douglas, 2010). Due to its parametric structure and Building Information Modeling System it develops, Revit minimizes documentation and enables more time to be allocated for design. Each data added to the design process with Revit is only added once and used throughout the whole process. Each change that is made is reflected on all documents immediately. Thus, productivity, coordination and quality increase. Revit involving tools which increase production, coordination and quality in all phases

from field and mass surveys to detailed working drawing and quantity survey is database based software that operates parametrically.
Each sheet, 2 or 3 dimensional view, list of quantities in Revit is different reflections of the same building database. While user works with views he/she is used to, Revit collects all information required for the building, stores it within Building Information Modeling System and reflects it on all other displays of the project. Through its parametric structure, Revit conveys each change (made on view, section, list of quantities, sheet, that is, regardless of where the change is made) to all documents. Each data added to the design process is added only once and used throughout the whole process.

Building Information Modelling System in Revit has three main features. Accordingly, the first feature of the system is that it has a numerical database where all data describing structure are stored. The second feature is that since revisions in the project are made on this database, any change that is made to any document reflects on all documents (plans, sections, views, tables, lists, vs.) produced by this database. Another feature is that all data collected during design process are stored so as to be used later. This creates a database which can be used by not only designer but also contractor and owner of structure. This system enables more qualified designs to be produced in less time and at fewer costs.

As also stated in the previous paragraphs, Revit has a parametric structure. The expression of “parametric” defines association of each object which constitutes a building model with each other. These associations are defined either by the software automatically or by user during operation. The aforementioned associations can be more precisely explained with the following examples:

- For instance, door of a room is fixed 10 cm away from the corner. Even though dimension of the room changes, this distance will be kept by the software. Here, the parameter is a number indicating the distance.
- Windows on a frontage is requested to be at equal distance. Even though length of the frontage changes, the distance between the windows will be arranged equally by the software. Here, the parameter is not a number, but a rate.
- Flooring or roof edges are connected with exterior wall. Even though location of the exterior wall changes, flooring and roof are edited accordingly. In this example, the parameter is an association of connection.
- Scale of a plan is changed from 1:100 to 1:200. All writings/typings/letters will relatively enlarge according to drawing elements. In this example, size of writing/typing/letters is a parameter based on scale.
- Four walls forming a rectangular are drawn in the plan. Revit automatically connects them with each other. If location of a wall on the frontage is changed by user, size of other walls change accordingly. Here, the parameter is also an association of connection.

4.5 Associating BIM with OSH

Considering the course of life of structures, it is possible to associate BIM approach with OSH at many phases of the process. However, this association is established from the design process in this study. By doing so, firstly occupational accidents are associated with design. Later, it has become possible to come to a conclusion through fast, easy, safe, flexible and sustainable analysis service BIM provides, which is the backbone, even whole skeleton of the design process.

Chapter 5

DEFINITION OF THE PROBLEM

5.1 Introduction

Problem(s) that are mentioned in this thesis study have been examined in detail and defined in this chapter. Effects of this problem (these problems) in the global scale and their reflection in the TRNC have been given. The subject has been given under two main headlines as fundamental problems at OSH area and the PtD approach that is analyzed in the thesis in particular. Both headlines have been assessed within themselves in terms of their global and territorial effects. The reasons contribute the problem(s) and what additional problems that are created by this problem (these problems) and possible to be created by this problem (these problems) have been mentioned.

5.2 Assessment of General Problems in OSH

5.2.1 Assessment of OSH Problems in Global Scale

OSH problems have reached considerably serious dimensions in all of the service and manufacturing sectors in work life. As it has been stressed many times throughout the study, the situation is the same for the construction sector as well. Despite all of the regulations that have been made in the developed countries for many years, the aimed improvement hasn't been seen in occupational accident rates and that causes the concern on OSH to keep increasing. It is the sad truth that sufficient efficiency still hasn't been received in many subjects from preventive and regulatory system regulations that are made on the basis of legal regulations, projects and businesses and from risk assessments and supervisions. As occupational accidents and OSH problems cannot be taken under control not only in undeveloped or developing countries but also in the most developed countries, it has been compulsory to address this issue in a more serious manner.

The dimensions of occupational accidents in the TRNC, Greek Cypriot Side and Turkey have been briefly summarized in Chapter 2. Similar conclusions are seen when the statistics showing the situation of occupational accidents throughout the world are considered. The 2009 data of the International Labour Organization (ILO) points that approximately 2 million 300 thousand people are killed due to occupational accidents and occupational diseases every year. In addition, it is found that every year 270 million occupational accidents happen and 160 million people suffer from work related diseases (occupational diseases). According to the estimations of ILO (2005), deaths from occupational accidents and diseases constitute 3.9% of all of the deaths. Moreover, it is known that 651000 workers in average die every year due to toxic substances in the Middle East, Southern America, Africa and undeveloped Asian countries (Mahçiçek, 2015). Additionally approximately 10% of skin cancer diseases that occur throughout the world are known to be caused by contacting with toxic substances at work places (ILO, 2009).

5.2.2 Reflections of OSH Problems in the TRNC

A large part of the population living in the TRNC does not have any concern in security not only in work life but also in almost every area in the daily life. Even though they don’t like taking risks, they do not need to question the decisions they give in the daily life and work life for the kinds of risks they posed by their decisions.

A part of the local population living in the country and a large part of the communities, which came to the country as an immigrant from abroad, adopted Muslim culture. Religious beliefs of individuals have become a part of their daily lives and as they lead a fatalist life, they consider hazards and risks at their work environment and daily life as a part of their life and work life. It is inevitable for individuals, who grow up with this culture structure, to perceive considering OSH as an additional responsibility or waste of time. In addition to this fatalist approach of the community, most of the time works are left to chance with the ease given by the mild Mediterranean climate and island life. This approach is the same in OSH issues as well.

Consequently, under the community, shareholders in construction sector carry on their activities in a fatalist and comfortable manner without having the necessary awareness and therefore they are unaware of the necessity to pay the necessary attention to the matter in OSH as in other areas of life.

On account of the education works that are organized in the TRNC in recent years, some employees are being trained to be OSH expert. However, at discussions on OSH, columns and dialogues with the abovementioned experts, it is seen that the priority objective of the candidates is to enter into another area which is new “and whose income is prosperous and easy to gain” and in which they can gain monetary income by integrating their professionalism in a new area. Unfortunately, observations have indicated that the priority objective of public institutions, which organize trainings and which are obliged to execute legislation, is to find an addressee (a responsible) in a possible accident.

Briefly, the objective of public institutions and OSH experts for making rehabilitative contributions in the community and work life are not at the required level. This constitutes a problem in the TRNC..

The priority objective should be in order to increase the efficiency of a regulation or new implementations that will be made in work life and in OSH for the community and employees rather than the experts. Another indicator of the mistake of OSH policy of public institutions is that expertise trainings are accepted as the first and the biggest step that is taken under “regulation in OSH.”

As a result of these serious difficulties that are given above, individuals working at construction sites and around constructions have to work in an unaware manner in OSH and by being exposed to risks at serious levels. The number of individuals that will eliminate these risks and that will provide a safe working environment for employees is very low as a result of the abovementioned reasons again. This is one of the OSH problems in the TRNC.

5.3 Problems at PtD Area

5.3.1 Assessing Problems at PtD Area at Global Scale

It is known that a large part of the hazards that are considered as the resource of occupational accidents at construction stage are created with decisions taken during design (Gambatese, 2008). Accordingly, so as to solve the problem at its source it is necessary to intervene at its design phase. It is deemed that one of the biggest impediments for putting this idea into practice is the approach of designers that manage the process on the subject. Although PtD approach has began to be increasingly accepted, it hasn’t been adopted by a large part of designers. Despite the fact that general framework of this approach is drawn in developed countries such as England and Australia, the approach, which hasn't been included in the sector completely, is exposed to the reaction of designers at some situations in developing countries. Thus, this makes it difficult for this approach to reach larger masses. In fact some designers deem the issue as an additional burden and responsibility and they may insist that having knowledge on OSH and taking these facts into consideration is not their work. Despite that, designers adopting PtD approach foresee the risks that will be created by the design decisions they take and they face some difficulties. This is a situation that may cause the duration of design to extend.

5.3.2 Reflections of PtD Problems in the TRNC

Many sources that were found during literature review have shown that some decisions taken at the design phase make serious contributions on these risks to emerge (Gambatese, 2008). The idea argued by these studies has been accepted at developed countries and has become an approach that began to be applied in training and design works in the sector. The biggest problem, which points that the study is needed to be prepared, is that the mentioned PtD approach hasn't been heard in the TRNC yet. Designers that are aware of this PtD approach and other parties that operate in the design process may avoid accepting this approach sometimes.

It is believed that, the lack of awareness, which is mentioned in the previous sections, and the fact that the community has a structure that lays the foundation for that is another problem that prevents the PtD approach to be understood and accepted in the short term.

When the tension created by planning approval, endorsement and building permit processes, which are applied in the TRNC today and which cause a serious delay for transition to construction phase, on designer and owner are taken into consideration, it is a major work to include OSH subject and PtD approach in this process. It is a separate problem to make designers accept this issue through PtD as a new work in a community structure, in which even contractors and subcontractors that suffer from occupational accidents taking place at work places at first degree don’t want to consider the issue of OSH.

Due to the reasons stressed in the previous paragraphs, the most accurate application that is required to be made for including OSH and PtD approach in the design process is to prevent designers to see them as an additional burden or responsibility. This is possible by expert systems or softwares that include PtD approach in design automatically. However as such an expert system or software hasn’t been developed today is another problem that can be listed with regards to this issue.

Chapter 6

METHODOLOGY

6.1 Introduction

This chapter is comprised of the procedures and methodology within the scope of this thesis. Firstly, the data collection method and features of such data were mentioned. Then, the research methods were indicated accordingly. Finally, this chapter explains the data analysis methods used for this thesis.

6.2 Research Methodology

There are a number of studies conducted to perform the risk assessment, hazard identification etc. in the OSH field through the computer environment with the support of BIM (Taiebat, 2011; Gibb, 2006; Williams, 2006; Suermann et.al, 2009; Sorrensen et.al, 2009; Sulankivi et.al, 2009; Vries et.al, 2004; Vacharapoom & Sdhabhom, 2009; Golparvar-Fard et.al, 2009; Hu et.al, 2008). Such studies are mainly the systems conducting rule-based data check, which means that such studies check the projects with complete design on BIM with regard to certain rules and take necessary measures.

However, this thesis study aims to combine BIM with PtD more than the OSH. Hence, the developed system can be considered as performing the required checks for each design decision at the design phase. Additionally, the system can detect the potential risk situations at the time of occurrence and present it to the designer together with its alternative.

In the first phase of study, the design decisions that the thesis would focus on are determined. For this, the following steps are performed:

- The occupational accidents happened in the TRNC were analysed and construction accidents were focused on accordingly.
- Construction accidents were identified as the most common type of occupational accidents.
- The main activities (work items) that accidents occur during execution were identified.
- The associated design decisions for such activities were detected and to do so, such activities required for the production of building elements were determined. Hence, the associated design decision for the related building element was identified. For instance; where the activity of "exterior walls plastering works" is originated from the design decision of "building the exterior walls with bricks/block materials".

In the second phase of study, by using Fine-Kinney method the risk assessment was perform on the activities identified in the first phase. Consequently, the risk scores for all relevant activities were calculated. The total of risk scores for all activities performed in the construction of design decisions is the risk score of that design decision. Hence, it was possible to make quantitative descriptions concerning the RISK of design decisions.

In the third phase of study, the alternative secondary design decisions were proposed and all of the same procedures conducted on the primary design decisions were also applied on the alternative secondary design decisions. As a result, the quantitative description of secondary design decisions, the risk score, was obtained.

Afterwards, the risk scores of primary and secondary design decisions were compared. As a result, the risk scores of both design decisions were interrelated on Revit Architecture. This was then converted into an automatic code functioning with an algorithm on Revit. The designers would be warned by Revit when they select a model of a less safer design decision.

6.3 Data Collection

6.3.1 Collection of Occupational Accident Records Occurred in TRNC

A comprehensive literature review and a detailed sectoral research were carried out prior to this study in TRNC. Thus, the existence of the above-mentioned problem which tried to solved by this thesis was verified. The initial literature review and sectoral research contributed finding answers to a lot of questions on the subject, and helped to build a strong basis for the study.

The Monthly Activity Reports that are published periodically were attained through the official website of TRNC TRNCLD (TRNCLD). The related “TRNCLD Monthly Activity Reports” that are published since 2006 were reviewed and backed up.

Later the TRNCLD officials were contacted and it is found that the TRNCLD performs the investigations with regard to the Occupational Accidents and Professional Diseases since 1994 and they were regularly archieved. Upon getting the required permission, a total number of 36 folders including investigation reports for 3004 victims were looked at and backed up.

Then the backed up documentation were analysed and transferred on the computer.

Information that are included in the investigation forms and transferred on the analysis program are divided under four headings as:

- Information about accident,
- Information about victim,
- Information about employer and
- Information about the result of accident.

The part with the information about accident covers general information such as date and time of accident, date of investigation, type of occupational accident, archive record number and file number. The part about victim is comprised of details about the name, surname, age, gender, occupation, position, service period in the profession (experience) and educational background of victim. The name of company, activity area (sector) etc. were recorded under the part about employer. With regard to the result of accident, the information whether the accident resulted injury or fatality, number of work days lost for victim, type of injury, place of injury on the body, machinery, equipment, environment etc. caused the accident were recorded. This study comprises all the accidents until 18.02.2015, that the investigations were completed.

As a follow up of the process, sectoral distribution of occupational accidents was identified, working on digital environment. The study especially focused on accidents in the construction sector. During the study, it became essential to re-arrange accident records compatible with the International Classification of Diseases (ICD-10) format.

In the final stage of the study, findings were interpreted and statistical data on occupational accidents, which took place in the construction sector of North Cyprus, were presented for the use of the sector and experts. In addition to this, suggestions for technical and administrative arrangements towards controlling occupational accidents in the construction sector and achieving a sustainable improvement were made, and expert views were also provided. Details of the mentioned section are given in the Chapter 7.

6.4 Method of Analysis

Under the framework of this study, a number of risk assessments were conducted to identify the design related construction accidents, and risk scores were calculated for each activity. The same procedure was also conducted for the alternative design decisions. Finn-Kinney method (Gürcanlı, 2013) that is widely used in the OSH field and construction sector was used in the calculation of risk score. Finn-Kinney method, as an activity based Risk Assessment, generates results that would keep the professional in a safer zone when compared with other risk assessment methods. In order to provide much clear picture with regard to the procedure, the steps that were followed in the procedure are given as bullet points in the further paragraphs. The related Chapters were also given in the parenthesis. Hereunder;

- Occupational accidents that occur in the construction sector were identified and classified (Chapter 7).
- Construction accidents associated with design decisions were determined (Chapter 8 &9)
- Risk Assessment was conducted for primary design decisions (design decisions given by the designers without adopting PtD approach). As indicated above, the risk scores for the construction activities required to construct the design

were calculated. Then the risk scores of related activities were consolidated and the risk score of design were generated with Finn-Kinney method (Chapter 9).

- The same procedures followed for the primary design decisions under Chapter 9 were conducted for the secondary design decisions (design decisions of designers with the adoption of PtD approach). Additionally, the risk scores of Primary Design Decisions and Secondary Design Decisions were compared and it was ensured that the secondary design decisions have lower risk score (Chapter 10).
- Finally, risky primary design decisions and safer secondary design decisions were associated. And this relation were converted into a warning system that function with the support of smart code (Chapter 11).

CHAPTER 7

IDENTIFICATION OF THE MOST COMMON CONSTRUCTION ACCIDENT TYPES IN TRNC

7.1 Introduction

In this chapter, the most common construction accident types and their causing activities have been tried to be identify. For doing this, investigation reports of the TRNCLD on 3004 victims, consisting of 36 folders were all photographed and backed up. This study comprises all the accidents from 01.01.1994 until 18.02.2015. These are accidents which the investigations were completed. After that, the backed up documents were examined in detail, transferred to computer environment, and put to an analysis program. As these documents were saved on a computer, all details were examined one by one, and documents containing missing/false information were excluded from the study.

As a follow up of the process, industrial distribution of occupational accidents was established, working on digital environment. After that, the study focused on accidents in the Construction industry. During the study, it became essential to re-arrange accident records compatible with the International Classification of Diseases (ICD-10) format (ICD,2015).

7.2 Industrial Distribution of Accident Records in TRNC

One of the first findings reached through studies on records is about the industrial distribution of occupational accidents. It can be seen that 793 occupational injuries and deaths of a total of 3004 accidents, investigated by the Directorate of

Labor for the twenty-year period 1994-2014, took place in the Construction industry (Tözer et al.,2018). This figure shows that almost 1/4th of all casualties are construction workers, or from around constructions. The Construction industry is followed by the sector of manufacturing, with 444 casualties (Table 7.1). A total of 722 accidents, of which 12 are deaths and 710 are injuries, are under the heading ‘other industries’, and include agriculture, horticulture, banking, education, public and private industry office work (Tözer et al.,2018). Each industry is also examined for the ratio of deaths originating from work, and the Construction industry was found to have the highest death rate after the quarry industry (Table 7.1).

7.3 Identification of the Most Common Construction Accident Types

The accident records in the study were converted to ICD-10 format, and classified for type of accidents. According to this, ‘falls’ type of accidents take the first place for frequency, and resulting in death and injury. Looking at accidents resulting in injuries, ‘falls’ is followed by ‘struck by thrown’, ‘projected object’, ‘crashed, jammed in or between objects’, ‘sharp object injury’, ‘fall on same level’, ‘falling objects’, ‘traffic accident’, ‘contact with heat or hot substances’, and ‘exposure to electricity’ type accidents, similar to the study by Akboğa and Baradan (2015). In fatal accidents, ‘falls’ is followed by ‘exposure to electricity’, ‘crashed, jammed in or between objects’, ‘traffic accident’, ‘falling objects’, and ‘building and construction collapse’ type accidents, in order (Table 7.2) (Tözer et al.,2018).

Table 7.1: Industrial distribution of occupational accidents in TRNC during 1994-2014, distribution of the number of deaths and injuries, death rates within industries.

Industry	**Death**	**Injured**	**Total**	**(%)**	**Death Rate Within the Industry (%)**
Construction	**42**	**751**	**793**	**26.40**	**5.30**
Carpentry	1	190	191	6.36	0.52
Manufacturing	7	437	444	14.78	1.58
Service	7	350	357	11.88	1.96
Business	5	238	243	8.09	2.06
Costal & harbor works	5	117	122	4.06	4.10
Logistics	2	84	86	2.86	2.33
Quarries	5	41	46	1.53	10.87
Other	12	710	722	24.03	1.66
Total	**86**	**2918**	**3004**	**100.00**	**2.86**

In Table 7.3, falls type accidents are examined in detail and divided into three groups as, ‘falls from scaffolds’, ‘falls from structural elements’, ‘other type of falls’. A total of 86 accidents of falls from scaffolds type (of which 5 died) have been recorded. 59 accidents of falls from structural elements have been recorded, with 7 deaths. In addition, it was observed that 58 accidents of falls from movable ladders, of other type of falls group, were recorded, with 4 deaths. These facts show that the most frequent type of falling is falls from scaffolds, but the most fatal falls are falls from structural elements (Tözer et al.,2018).

Table 7.4 examines other fatal accident types besides falls, in detail. As shown in the table, electric accidents were recorded 19 times, and 10 of these resulted in deaths. These points to the fact that electrical accidents are more deadly that falls from structural elements type of accidents. Again, in Table 7.2, ‘crashed, jammed in or between’ type of accidents are grouped under five sub-headings, and 5 of the 145 victims lost their lives (Tözer et al., 2018).

Table 7.2: Type of Construction accidents with ICD-10 Codes

Causes of Accidents	**ICD-10 Codes**	**Death**		**Injured**		**Total**	
		No.	**%**	**No.**	**%**	**No.**	**%**
Building & Construction Collapse	W20	2	4.76	4	0.5	6	0.757
Cave-in	W20	1	2.38	5	0.7	6	0.757
Contact with Chemical Substances	T52-T59		0	4	0.5	4	0.504
Contact with heat or hot substances	X10-X19		0	23	3.2	23	2.9
Crashed, Jammed in or Between Objects	W23	3	7.15	84	11	87	10.97
Explosives	W36-W40		0	6	0.9	6	0.757
Exposure to Electric	W85, W86	10	23.8	9	1.3	19	2.396
Fall on Same Level	W1, W3, W10		0	62	8.3	62	7.818
Falling Objects	W20	2	4.76	57	7.7	59	7.44
Falls	**W12, W13**	**21**	**50**	**278**	**37**	**299**	**37.7**
Sharp Object İnjury	W25-W29		0	63	8.5	63	7.945
Striking against or struck by objects	W22		0	8	1.1	8	1.009
Struck by thrown, projected object	W20		0	86	11	86	10.84
Traffic Accident	V00-V60	3	7.15	54	7.2	57	7.188
unknown			0	8	1.1	8	1.009
Total		**42**	**100**	**751**	**100**	**793**	**100**

Table 7.3: Detailed analysis of falls

Type of Falls (W12, W13)	**Death**	**Injured**	**Total**
Falls from scaffolds			
Scaffold giving in-breaking-falling	3	24	27
On the scaffold (stepping on air)	1	9	10
On the scaffold (while going up-down)	0	7	7
On the scaffold (setting up-dismantling)	0	5	5
On the scaffold (slipping, loss of balance etc.)	1	36	37
Sub. Total	5	81	86
Falls from structural elements			
Falls from structural element (from the roof)	0	10	10
Falls from structural element (from threshold)	3	28	31
Falls from structural element (flight of stairs)	1	6	7
Falls from structural element giving in	1	1	2
Falling down through opening on the floor	2	7	9
Sub. Total	7	52	59
Other type of falls			
Moving ladder	4	54	58
From the molding system	2	18	20
Into a canal, hole etc.	0	13	13
From a vehicle, machine	2	35	37
Going up on unsuitable object	1	14	15
Other	0	11	11
Sub. Total	9	145	154
Total	**21**	**278**	**299**

Table 7.4: Detailed analysis of other type of fatal accidents

Type of other Fatal Accidents	**Death**	**Injured**	**Total**
Exposure to Electric (W85, W86)			
Contact with object with live electricity	4	3	7
Contacting aerial electric cable	2	3	5
Contacting electric cable in the open	1	2	3
Contacting cable placed in the wall-floor	1	1	2
Electric shock of other types	2	0	2
Sub.Total	10	9	19
Other type of fatal accidents			
Crushed between a stable and a moving object (W23)	2	48	50
Crushed under a fallen object (W20)	2	60	62
Crushed between moving objects (W23)	0	4	4
An organ getting jammed in a machine (W23)	0	15	15
Crushed under a load (W23)	1	13	14
Traffic Accidents (V00-V60)	3	54	57
Building & Construction Collapse (W20)	2	4	6
cave-ins (W20)	1	5	6
other	0	1	1
Sub.Total	11	204	215
Total	**21**	**213**	**234**

Chapter 8

ASSOCIATION OF MOST FREQUENT FALLS-TYPE OCCUPATIONAL ACCIDENTS IN CONSTRUCTION SECTOR WITH DESIGN DECISIONS

8.1 Introduction

In this chapter the studies required for associating the occupational accidents in the construction sector with design decisions was performed. Correspondingly, the most frequent “falls” type occupational accidents in construction was emphasized as determined under Chapter 7. The activities performed at the time of relevant accident type were analysed and the aim was to identify the related design decision for each activity. Hence, the design decisions that cause “falls” type accidents were detected accordingly.

8.2 Association of Fall From Height Type Occupational Accidents with Design

In the previous section, the occupational accidents in construction occurred in the TRNC were classified based on the reasons of accidents and analysed in detail. As a result of analysis, Table 7.2 indicates that the incidence rate of falls comes as first in terms of death and injury. Hence, this study is focused on “falls” type accidents as mentioned before. Later on, the activities performed at the time of relevant accidents were analysed and a related design decision were identified for each one of them.

Therefore, the design and construction processes of typical multi-storey reinforced concrete building project in TRNC. Thus, the design process was analysed step-by-step, which allowed elaborating the material selection and building materials.

Additionally, the accident investigation reports of TRNCLD for “falls” were reviewed as well as the statements of accident victims and eyewitnesses, which reflected the activity performed at the moment of accident.

The aforementioned activities allowed identifying the risk(s) experienced in the use of material selected as a result of design decision or production of building material, and their association with design decision. Such association was shown in Figure 8.1

Within this perspective, the activity at the time of fall from height, building material that the activity was performed for and design decision creating this building material were all identified respectively. The results of such activity are given under Table 8.1 in an order.

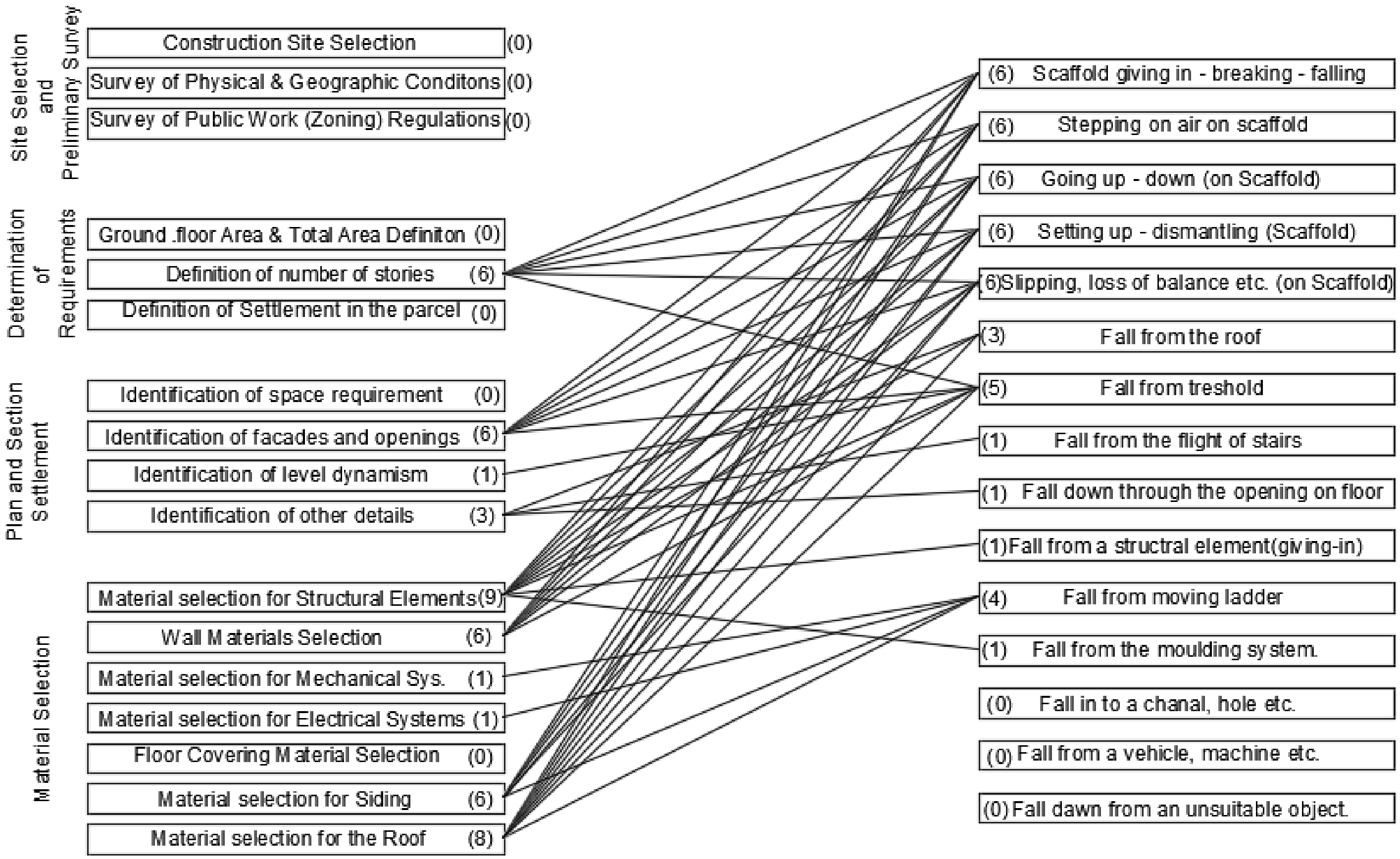


Figure 8.1: Association of the phases of design process with Fall from height incidents

Table 8.1: Activities That Fall From Height, Work Environments and Associated Building Element and Design Decisions *(DD. No: Design Decision Number)*

Activity	**Work Environment**	**Building Element**	**Design Decision**
Exterior Wall Works	Scaffold	Exterior Wall	Design of exterior walls with bricks, blocks etc. (DD.No:1)
Exterior Plastering	Scaffold	Exterior Wall	Design of exterior walls with bricks, blocks etc. (DD.No:1)
Exterior Paint and Maintenance	Scaffold	Exterior Wall	Design of exterior walls with bricks, blocks etc. (DD.No:1)
Exterior Wall Works	Flooring Edge (threshold)	Exterior Wall	Design of exterior walls with bricks, blocks etc. (DD.No:1)
Exterior Coating Works and Maintenance	Scaffold	Exterior coating	Selection of labour intense coating materials for exterior like aluminium panel, pvc panel, ceramic, stone (DD.No:2)
Exterior Insulation and Maintenance	Scaffold	Thermal / Sound Insulation System	Design of thermal / sound insulation system as to be applied from exterior or no design (DD.No:3)
Exterior Installation and Maintenance of Air Conditioning / Ventilation System	Scaffold	Air conditioning, Ventilation System etc.	No central system for air conditioning/ ventilation system etc. (DD.No:4)
Exterior Installation and Maintenance of Air Conditioning / Ventilation System (Flooring edge)	Flooring Edge (threshold)	Air conditioning, Ventilation System etc.	No central system for air conditioning/ ventilation system etc. (DD.No:4)
Roof Insulation Works and Maintenance	Roof edge (threshold)	Water / Thermal Insulation System	Incorrect design of barrier, parapet etc. that would prevent falls from the roof, or no design at all (DD.No:5)
Installation and Maintenance of other Mechanic or Electronic System on the Roof	Roof edge (threshold)	Other mechanical or electronic system on the roof	Incorrect design of barrier, parapet etc. that would prevent falls from the roof, or no design at all (DD.No:5)

Each activity indicated under Table 8.1 had categorised to sub-components and elaborated accordingly in order to understand the sub-activities (or works) that victim was performing at the time of accident. Hence, traditional construction techniques and multi-storey building models in TRNC were taken into consideration and the activities (given in Chapter 7) that falls type accidents happened the most were analysed. Upon this activity, the design decisions given in Table 8.1 that were not observed before or caused some accidents in the TRNC, and activities were marked and reflected in Table 8.2.

In summary, falls is the most frequent type of accidents that might be encountered during a number of construction activities with a total incident rate of 37,7% as 50% fatality and 37% injury rate. Such rates were also elaborated under Table 7.3. Furthermore, Table 8.1 represents the Activities That Fall From Height Occurs Frequently, Work Environment and Associated Building Elements and Design Decisions. In Table 8.2, the design decisions given in the previous table, yet not occur in the TRNC that much, and activities were distinguished. The activities related with the remaining designs were elaborated and divided into sub-activities.

Moreover, due to the association above, risk analysis was conducted on the sub-activities that are identified as causing some of the falls and associated with some design decisions. Considering this risk analysis, primarily the risk score of each sub-activity associated with design was determined and then risk creation impact value for design decisions based on the sub-activities (Table 8.2) was calculated.

Table 8.2: Activities That Falls From Height Accidents and Sub-Activities under Such Activities

Design Decision	Activity	Work Environment	Sub - Activity
Design of exterior walls with bricks, blocks etc. (DD.No:1)	Exterior Wall Works	Scaffold	Carrying brick, blocks
			Carrying mortar-Giving mortar
			Walling
	Exterior Plastering	Scaffold	Carrying plaster materials etc.
			Plastering
	Exterior Paint and Maintenance	Scaffold	Repair of façade cracks etc.
			Preparation of painting area, sandpapering
			Carrying paint, repair materials etc.
			Painting façade
			Post-paint cleaning works
	Exterior Wall Works	Flooring edge (threshold)	Carrying brick, block
			Carrying mortar – Giving mortar
			Walling
Design of exterior walls with bricks, blocks etc. (DD.No:1)	Exterior Coating Works and Maintenance	Scaffold	Carrying and cutting support profiles of system
			Installation and welding works of support profiles
			Carrying coating materials
			Installation of coating materials
			Availability of insulation etc. details on connection points and whole façade
	Exterior Insulation Works and Maintenance	Scaffold	Repair of cracks on façade etc.
			Elimination of burrs on the surfaces where insulation would be applied
			Carrying insulation repair material and insulation material
			Application of insulation material on façade
			Application of protective surfacing and preparation of façade for paint
No central system for air conditioning/ ventilation system etc. (DD.No:4)	Exterior Installation and Maintenance of Air Conditioning / Ventilation System	Scaffold	Preparation of air conditioning infrastructure
			Installation of external unit of air conditioner
	Exterior Installation and Maintenance of Air Conditioning / Ventilation	Flooring edge (threshold)	Preparation of air conditioning infrastructure
			Carrying infrastructure material, air-conditioner etc.

	System (Flooring edge)		Installation of external unit of air conditioner
Incorrect design of barrier, parapet etc. that would prevent falls from the roof, or no design at all (DD.No:5)	Roof Insulation Works and Maintenance	Roof edge (threshold)	Setting up the roof or preparation of existing roof surface for application
			Carrying roof insulation material
			Application of insulation material on the roof
			Placement of protective roof cover
	Installation and Maintenance of other Mechanic or Electronic System on the Roof	Rood edge (threshold)	Carrying mechanic, electronic system materials and infrastructure materials
			Preparation of infrastructure
			Installation and assembly of system elements

Chapter 9

RISK ASSESSMENT FOR THE OCCUPATIONAL ACCIDENTS IN CONSTRUCTION THAT ARE ASSOCIATED WITH THE INITIAL DESIGN

9.1 Introduction

Chapter 9 would perform the risk analyses for the activities that are related with design in the previous chapter. The first step in risk assessment is to identify the risks. Then on the second step, the risks caused by the hazards would be analysed accordingly. The main logic behind risk analysis is to digitise the risks in order to easily make comparisons among them. Where the risks are digitised and their scales are identified, then it is easier to prioritise them. The phase of comparison and prioritisation are very significant for the risk identification process since it is not possible to intervene all of the risks at the same during a project due to the limited budget and labour force (regardless priorities). Therefore, the priority risks are intervened in the first place (İş Sağlığı ve Güvenliği Risk Değerlendirme Yönetmeliği, 2012).

Within the framework of this study, Fine-Kinney method (Fine, 1971; Kinney, 1976) would be utilised in the performance of risk analysis.

9.2 Fine-Kinney Method

Fine Kinney risk analysis method is one of the systematic methods widely used in the risk assessment of occupational health and safety. In this method, three factors as “the probability of an accident occurrence”, “the exposure at risk frequency” and “the gravity" of the induced consequence are analysed for each risk and a risk ranking scale is generated accordingly (Fine, 1971).

Fine Kinney method was developed through the studies conducted by G. F. Kinney for Naval Weapons Centre under the Ministry of Defence, United States of America in 1976. Back then, G. F. Kinney published his study in his article titles "Practical Risk Analysis for Safety Management" (Kinney, 1976). The method, which was introduced by Fine (1971), took its final form with the intervention of Kinney in 1976.

For the threats under each of the works, probability (Table 9.1), exposure (Table 9.2) and impact (Table 9.3) scores should be identified under the Fine Kinney method.

Table 9.1: Likelihood scale for Fine-Kinney method

Value	Category
0.2	Practically impossible
0.5	Plausible, but unlikely
1	Improbable
3	Unusual but possible
6	Possible
10	Predictable

Table 9.2: Exposure (Exposure Frequency for Threat) Scale under Fine-Kinney method

Value	Description	Category
0.2	Very rare	Once or less than once per year
0.5	Quite rare	Several times per year
1	Rare	Once or more per month
3	Occasionally	Once or more per week
6	Regular	Once or more in a day
10	Permanent	Permanent or several times in an hour

Table 9.3: Impact Scale of Fine-Kinney method

Value	Description	Category
1	To be considered	Low-No Harm or Importance
3	Significant	Minor- Low work capacity loss, little damage, first aid
7	Serious	Major – Significant Damage, External Treatment, Loss of Work Day
15	Very Serious	Disability, Loss of Limb, Environmental Impact
40	Too Serious	Fatality, Complete Disability, Severe Environmental Impact
100	Catastrophic	Several fatalities, Significant Environmental Disaster

Table 9.4: Decision and Action Scale Based on the Risk Level under the Fine-Kinney method

Value	Description	Category
R<20	Acceptable	No urgent measure needed
20<R<70	Definite Risk	Action Plan
70<R<200	Significant Risk	Closely monitoring, elimination through action plan
200<R<400	High Risk	Elimination through short term action plan
R>400	Very High Risk	Activity cessation, immediate measures

For instance, the probability in the collapse of a scaffold erected on soil and even muddy surface is certain if no measures are taken. Some of such measures are; erecting the scaffold on an appropriate surface, supporting the scaffold base with large surface plates, fixing on the building from certain points etc. At this point, 10, which is the highest in the probability scale under Table 9.1, should be selected in the determination of accident probability. In terms of exposure value, every moment that the scaffold is in its place introduces such risk once or more per day. Unless measures are taken, 6 should be given through Table 9.2 since 10 would mean the availability of such risk at every moment of each hour, which such level of exposure is experienced during process based production in manufacturing industry. In the calculation of impact for the collapse of scaffold, instead of 100, 40 was given under Table 9.3 as although it might cause fatality, complete disability, and even more than one fatalities at times, it has less impact when compared with big explosions, nuclear leakage, chemical spread on the environment. Therefore, with the value of 40, the risk score was found as 2400 through multiplying these three values, which is equal to very high risk with regard to the Table 9.4. Hence being on the safe, it didn’t go down to low level. The significance of scoring is that it provides data to prioritise in risk mitigation strategies. For instance, the risk for the collapse of scaffold during the construction of nuclear power plant is very high as well as the design mistakes that might cause nuclear substance leakage. However; the score of scaffold collapse is 2400 while the score of other risk might be 6000 or more. Consequently, the decision- making authorities would make a ranking between such scores and the overly high scores would get special attention. On the other hand, this does not mean that the risks under other items would be avoided; yet it means to bring special attention for overly high risks.

Another example would be the disaster that might be caused by any damage on the aerial power lines, notwithstanding that the possibility of such damage is low in general (since such circumstances are considered at the planning stage). From this perspective, the probability score is 1, exposure 2 but impact is 100, which would take it to high-risk category. Another similar example is about the mobile scaffolds in the building. Due to the nature of mobile scaffold, the probability score is 6, exposure 6 and impact 15, which put it under high-risk category with 540 points. The main point here is that both the collapse of scaffold and risks from the mobile scaffold are in the high-risk capacity, while the score of former is 2400 and latter as 540. Such situation indicated risk control hierarchy as underlined under the ordinances and former regulations that should be performed by each civil engineer.

9.3 Assessment of the Risks Causing Fall From Height Associated With Design and Calculation of Risk Score

Table 9.5a and Table 9.5b (Table 9.5 was divided into two as it was a big table) shows the risk analysis, where Fine-Kinney method, which was elaborated above, was used accordingly. Therefore, the first column of Table 9.5a reflects the design decisions that led the frequent occurrence of falls type accidents while the second column shows the construction activities performed in giving the design decisions indicated in the first column. Under the third column of table, the activities were elaborated more and divided into sub-activities. The fourth column of table presents the work places of such activities whereas fifth column shows the risks encountered at the work place of sub-activities. Under the risk analysis table divided into two as Table 9.5a and Table 9.5b, the fifth column was given in both Table 9.5a and 9.5b to emphasize the integrity between two tables. The likelihood values are given under the sixth column of the big Risk Analysis table and the second column of second table. Following the likelihood column, the other parameters as exposure and impact were presented in the tables.

The risk score, which is given in the ninth column of big risk analysis table when counted from left to right and fifth column of Table 9.5b, was calculated through the multiplication of parameters given in the columns prior to risk score as likelihood, exposure and impact. In Table 9.5b, some sort of interpretation of risk score value was performed in the column called as decision column and the level of risk was defined through Table 9.4. The column next to the last column of table describes the level of intervention that should be performed in the conventional risk control systems. For the last column, the risk scores from each sub-activity for the design decisions given in the first column were added and the total risk scores of design decisions were calculated accordingly. The aim in calculating the last column is to compare the primary design decision with alternative design decision.

Table 9.5a Analysis of the risks posed by the design decisions that were identified as causing occupational accidents with the Fine Kinney method (First section of Risk Analysis Table)

(1)	(2)	(3)	(4)	(5)
Initial Design Decision	**Activity**	**Sub – Activity**	**Work Place**	**Definition of Risk**
Design of exterior walls with bricks, blocks etc.	Exterior Wall Works	Carrying brick, blocks	Scaffold	Falling Down To The Ground Upon Losing Balance While Working On Scaffold
		Carrying mortar-Giving mortar		
		Walling		
	Exterior Plastering	Carrying plaster materials etc.		
		Plastering		Falling Due To “Air-Step” While Working On Scaffold
	Exterior Paint and Maintenance	Repair of façade cracks etc.		
		Preparation of painting area, sandpapering		
		Carrying paint, repair materials etc.		Falling Due To Breakage Of Scaffold Element
		Painting façade		
		Post-paint cleaning works		
	Exterior Coating Works and Maintenance	Carrying and cutting support profiles of system		Falling Due to the Rollover of Unfixed Scaffold System
		Installation and welding works of support profiles		
		Carrying coating materials		
		Installation of coating materials		Falling Due to The Heavy Weight of Object in Hand
		Availability of insulation etc. details on connection points and whole façade		
	Exterior Insulation Works and Maintenance	Repair of cracks on façade etc.		
Design of exterior walls with bricks, blocks etc.		Elimination of burrs on the surfaces where insulation would be applied		Dropping Materials Due to Various Reasons While Working On Scaffold
		Carrying insulation repair material and insulation material		
		Application of insulation material on façade		
		Application of protective surfacing and preparation of façade for paint		

	Exterior Wall Works	Carrying brick, blocks	Flooring edge (threshold)	Falling Down To The Ground Upon Losing Balance On the Flooring Edge
		Carrying mortar-Giving mortar		Falling Due To “Air-Step” On The Flooring Edge
		Walling		Falling Due To Breakage Of Protective Barriers on Threshold
No central system for air conditioning/ ventilation system etc.	Exterior Installation and Maintenance of Air Conditioning / Ventilation System	Preparation of air conditioning infrastructure		Falling Due To Complete or Partial Collapse of Flooring
		Carrying infrastructure material, air-conditioner etc.		Falling Due to The Heavy Weight of Object in Hand on the Threshold
	Exterior Installation and Maintenance of Air Conditioning / Ventilation System	Installation of external unit of air conditioner		Dropping Materials While Working on Threshold
		Preparation of air conditioning infrastructure	Scaffold	-
		Installation of external unit of air conditioner		
Incorrect design of barrier, parapet etc. that would prevent falls from the roof, or no design at all	Roof Insulation Works and Maintenance	Setting up the roof or preparation of existing roof surface for application	Roof edge (threshold)	Falling Down To The Ground Upon Losing Balance On the Roof Edge
		Carrying roof insulation material		Falling Due To “Air-Step” On The Roof Edge
		Application of insulation material on the roof		Falling Due To The Breakage of Protective Barriers
		Placement of protective roof cover		Falling Due To Complete or Partial Collapse of Roof
	Installation and Maintenance of other Mechanic or Electronic System on the Roof	Carrying mechanic, electronic system materials and infrastructure materials		Falling Due to The Heavy Weight of Object in Hand on the Threshold
		Preparation of infrastructure		Dropping Materials While Working on Threshold
		Installation and assembly of system elements		

Table 9.5b Analysis of the risks posed by the design decisions that were identified as causing occupational accidents with the Fine Kinney method (Second section of Risk Analysis Table)

(5)	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Definition of Risk	**Likelihood**	**Exposure**	**Impact**	**Risk Score**	**Decision**	**Act**	**Design Decision Risk Score**
Falling Down To The Ground Upon Losing Balance While Working On Scaffold	10	10	40	4000	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	**<u>21620</u>** (Design of exterior walls with bricks, blocks etc.)
Falling Due To “Air-Step” While Working On Scaffold	10	10	40	4000	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
Falling Due To Breakage Of Scaffold Element	6	6	40	1440	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
Falling Due to the Rollover of Unfixed Scaffold System	10	6	100	6000	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
Falling Due to The Heavy Weight of Object in Hand	6	6	40	1440	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
Dropping Materials Due to Various Reasons While Working On Scaffold	10	10	15	1500	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
Falling Down To The Ground Upon Losing Balance On the Flooring Edge	6	6	40	1440	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
Falling Due To “Air-Step” On The Flooring Edge	6	6	40	1440	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
Falling Due To Breakage Of Protective Barriers on Threshold	3	3	40	360	High Risk Risk	Short Term Action Plan For Remedy	
Falling Due To Complete or Partial Collapse of Flooring	1	1	100	100	Significant Risk	Monitoring and Including under Annual Action Plan	**<u>1360</u>** (No central system for air conditioning/ ventilation system etc.)
Falling Due to The Heavy Weight of Object in Hand on the Threshold	3	6	40	720	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
Dropping Materials While Working on Threshold	6	6	15	540	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
-	-	-	-	-	-	-	

Falling Down To The Ground Upon Losing Balance On the Roof Edge	6	6	40	1440	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	**4600** (Incorrect design of barrier, parapet etc. that would prevent falls from the roof, or no design at all)
Falling Due To "Air-Step" On The Roof Edge	6	6	40	1440	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
Falling Due To The Breakage of Protective Barriers	3	3	40	360	High Risk	Short Term Action Plan For Remedy	
Falling Due To Complete or Partial Collapse of Roof	1	1	100	100	Significant Risk	Monitoring and Including under Annual Action Plan	
Falling Due to The Heavy Weight of Object in Hand on the Threshold	3	6	40	720	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	
Dropping Materials While Working on Threshold	6	6	15	540	Very High Risk	To Halt the Works Immediately and Measures To Be Taken	

Chapter 10

DETERMINATION OF SECONDARY (ALTERNATIVE) DESIGN DECISIONS AND RISK ASSESSMENT OF SUCH ALTERNATIVES AND FINANCIAL COMPARISON OF DESIGN ALTERNATIVES

10.1 Introduction

This chapter discusses the design solutions that are considered as alternatives and safer (with lower risk core) with regard to the design decisions. The steps followed for the primary design decisions are applied to the alternative design decisions. As emphasized before, the main logic behind the risk analysis is to digitise the risks so that the comparison among them is possible. When risks are digitised and their sizes are identified, then the prioritisation of risks would be easier. The comparison and prioritisation of risks are crucial since during the projects, all risks cannot be intervened at the same time due to limited budget and labour force (without any priority). Therefore, the priority risks are handled at the first place (İş Sağlığı ve Güvenliği Risk Değerlendirme Yönetmeliği, 2012). Similar to the other chapter, Finn-Kinney method will be performed for the risk analysis.

Additionally, the Total Risk Scores that are calculated separately for primary and alternative design decisions are compared under this chapter. Upon the comparison, the level of lowness for the risk score of Alternative Design Decision against the Primary Design Decision is given with percentage.

10.2 Identification of Safer Design Decisions Considered as Alternative to Primary Design Decisions

In consideration of Table 10.1, many of the risks caused by the primary decisions are explicitly eliminated through the alternative design. Such observations were identified upon considering the work conditions arising from constructing the primary and alternative design decision.

In this chapter the design decisions that are considered as alternative to the primary design decisions were identified. Hence, alternative construction techniques were reviewed in detail by consulting to domain experts. The findings, which were collected from professionals of sector are given in Table 10.2 which . comprises of four columns. The first column includes the building element while the activity related with such element is given in the second column. The third and fourth columns are divided into two. The third column reflects the primary design decision and its associated risk. The fourth column includes the alternative design decision and its associated risk.

For instance; in the primary design, the workers, who would perform the plastering on the brick exterior wall, work on a scaffold and are exposed to the risk of falling from height. However; where panel walls are preferred instead of brick, then there would not be any need for plaster and the workers would not use a scaffold. Consequently, the risks from such activity would be automatically eliminated, as the activity itself would not be applicable. The same example is valid for the exterior insulation. Following the brick exterior wall plastering, the insulation work (known as jaketing) is performed and such work also required the use of scaffold. However, the insulation system is already processed on the panel wall at the time of manufacturing, so an additional insulation is not required. When the wall is assembled, the insulation system would be applied automatically with the wall.

In the next step, the sub-activities from the alternative design decisions are determined accordingly, which are given under Table 10.2. Similar to the previous phase, the sub-activities are determined through assessing the production processes on the site and the professionals were consulted respectively. Finally, a risk analysis was conducted for each one of the sub-activities given in Table 10.2. As indicated in the previous sections, Fine-Kinney method was used for the performance of risk analysis.

Considering Table 10.2, a majority of activities causing the risk of fall from height has been eliminated with the alternative design decisions, while new activities were identified that lead to the risk of Hit by Falling Object.

Table 10.1: Association of primary design decision and alternative design decision that are considered safe

Building Element	**Activity**	**Primary Design**		**Alternative Design**	
		Primary Design Decision	**Type of Risk in the Primary Design**	**Alternative Design Decision**	**Type of Risk in the Alternative Design**
Exterior Wall	Exterior Wall Works	Design of exterior walls with bricks, blocks etc.	Fall From Height	Exterior pre-cast insulated wall system	Hit by Falling Object
Exterior Wall	Exterior Plastering Works	Design of exterior walls with bricks, blocks etc.	Fall From Height	Exterior pre-cast insulated wall system	No Risk
Exterior Wall	Exterior Paint and Maintenance	Design of exterior walls with bricks, blocks etc.	Fall From Height	Exterior pre-cast insulated wall system	Fall From Height
Exterior Coating	Exterior Coating Works and Maintenance	Selection of labour intense coating materials for exterior like ceramic, stone, marble	Fall From Height	Exterior pre-cast insulated wall system	No Risk
Thermal/ Sound Insulation System	Exterior Insulation Works and Maintenance	Design of thermal / sound insulation system as to be applied from exterior or no design	Fall From Height	Exterior pre-cast insulated wall system	No Risk
Air-conditioning, Ventilation System etc.	Exterior Installation and Maintenance of Air Conditioning / Ventilation System	No central system for air conditioning/ ventilation system etc.	Fall From Height	Design of Central Cooling/Heating System	No Risk
Air-conditioning, Ventilation System etc.	Exterior Installation and Maintenance of Air Conditioning / Ventilation System (Flooring Edge)	No central system for air conditioning/ ventilation system etc.	Fall From Height	Design of Central Cooling/Heating System	No Risk
Water/Thermal Insulation System	Roof Insulation Works and Maintenance	Incorrect design of barrier, parapet etc. that would prevent falls from the roof, or no design at all	Fall From Height	Design of parapet of barrier design on the roof	Fall From Height
Other Mechanic or Electronic System on the Roof	Installation and Maintenance of other Mechanic or Electronic System on the Roof	Incorrect design of barrier, parapet etc. that would prevent falls from the roof, or no design at all	Fall From Height	Design of parapet of barrier design on the roof	Fall From Height

10.3 Risk Analysis of Alternative Design Decisions Causing Accidents, and Calculation of Risk Score

Table 10.2a and Table 10.2b (which were divided into two as it was a big table) shows the risk analysis, where the first column reflects the design decisions as alternative to primary design decisions, while the second column shows the construction activities performed in giving the design decisions indicated in the first column. Under the third column of table, the activities were elaborated more and divided into sub-activities. The fourth column of table presents the work places of such activities whereas fifth column shows the risks encountered at the work place of sub-activities. Under the risk analysis table divided into two as Table 10.2a and Table 10.2b, the fifth column was given in both Table 10.2a and 10.2b to emphasize the integrity between two tables. The likelihood values are given under the sixth column of the big Risk Analysis table and the second column of second table. Following the likelihood column, the other parameters as exposure and impact were presented in the tables.

The risk score, which is given in the ninth column of big risk analysis table when counted from left to right and fifth column of Table 10.2b, was calculated through the multiplication of parameters given in the columns prior to risk score as likelihood, exposure and impact. In Table 10.2b, some sort of interpretation of risk score value was performed in the column called as decision column and the level of risk was defined through Table 9.4. The column next to the last column of table describes the level of intervention that should be performed in the conventional risk control systems. For the last column, the risk scores from each sub-activity for the design decisions given in the first column were added and the total risk scores of design decisions were calculated accordingly. The aim in calculating the last column is to compare the primary design decision with alternative design decision.

Table 10.2a: Analysis of Risks from alternative design decisions through Fine-Kinney Method (First section of Risk Analysis Table)

(1) Design Decision	(2) Activity	(3) Sub - Activity	(4) Work Place	(5) Definition of Risk
Exterior pre-cast insulated wall system	Exterior Wall Works	Bringing precast panels to the construction site	Outside Building (Around)	Construction Site Vehicle Machinery Accident
				Jammed To The Gap While Unloading
		Unloading and storing precast panels to the construction site		Hit by the object falling from the crane due to rope breakage
				Hit by the surrounding objects etc. due to the movement of load on the crane
		Lifting and Placing precast panels with a crane		Rollover of crane
				Fall of load on the crane as a result of release
		Fixing the panels placed with the crane	Flooring Edge (Threshold)	Falling Down To The Ground Upon Losing Balance On the Flooring Edge
				Falling Due To “Air-Step” On The Flooring Edge
				Falling Due To Breakage Of Protective Barriers on Threshold
		Finishing and Making the fixed panel ready to use		Falling Due To Complete or Partial Collapse of Flooring
				Falling Due to The Heavy Weight of Object in Hand on the Threshold
				Dropping Materials While Working on Threshold
	Exterior Paint and Maintenance	Repair of façade cracks etc. Preparation of painting area, sandpapering	Scaffold	Falling Down To The Ground Upon Losing Balance While Working On Scaffold
		Carrying paint, repair materials etc. Painting façade		Falling Due To “Air-Step” While Working On Scaffold
		Post-paint cleaning works		Falling Due To Breakage Of Scaffold Element
	Exterior Coating Works and Maintenance	Carrying and cutting support profiles of system		Falling Due to the Rollover of Unfixed Scaffold System
		Installation and welding works of support profiles		Falling Due to The Heavy Weight of Object in Hand
		Carrying coating materials Installation of coating materials		Dropping Materials Due to Various Reasons While Working On Scaffold
	Installation and Maintenance	Preparation of air conditioning infrastructure	In-building Work	No risk detected within the scope of thesis

Central system for air conditioning/ ventilation system etc.	of Air Conditioning / Ventilation System	Carrying infrastructure material, air-conditioner etc.		
		Installation of external unit of air conditioner		
		Preparation of air conditioning infrastructure		
		Installation of external unit of air conditioner		
Design of barrier, parapet etc. that would prevent falls from the roof	Roof Insulation Works and Maintenance	Setting up the roof or preparation of existing roof surface for application	Roof Edge (Threshold)	Falling Down To The Ground Upon Losing Balance On the Roof Edge
		Carrying roof insulation material		Falling Due To “Air-Step” On The Roof Edge
		Application of insulation material on the roof		Falling Due To The Breakage of Protective Barriers
		Placement of protective roof cover		Falling Due To Complete or Partial Collapse of Roof
	Installation and Maintenance of other Mechanic or Electronic System on the Roof	Carrying mechanic, electronic system materials and infrastructure materials		Falling Due to The Heavy Weight of Object in Hand on the Threshold
		Preparation of infrastructure		Dropping Materials While Working on Threshold
		Installation and assembly of system elements		

Table 10.2b: Analysis of Risks from alternative design decisions through Fine-Kinney Method (First section of Risk Analysis Table)

(5)	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Definition of Risk	**Likelihood**	**Exposure**	**Impact**	**Risk Score**	**Decision**	**Act**	**Design Decision Risk Score**
Construction Site Vehicle Machinery Accident	1	0.5	15	7.5	Acceptable Risk	Urgent Measure May Not Be Needed	**2763.1** (Exterior pre-cast insulated wall system)
Jammed To The Gap While Unloading	3	1	15	45	Definite Risk	To Be Included Under Action Plan	
Hit by the object falling from the crane due to rope breakage	0.5	0.5	40	10	Acceptable Risk	Urgent Measure May Not Be Needed	
Hit by the surrounding objects etc. due to the movement of load on the crane	1	1	40	40	Definite Risk	To Be Included Under Action Plan	
Rollover of crane	0.2	0.2	100	4	Acceptable Risk	Urgent Measure May Not Be Needed	
Fall of load on the crane as a result of release	0.5	1	40	20	Acceptable Risk	Urgent Measure May Not Be Needed	
Falling Down To The Ground Upon Losing Balance On the Flooring Edge	3	3	40	360	High Risk	To Be Eliminated Through Short-term Action Plan	
Falling Due To “Air-Step” On The Flooring Edge	3	3	40	360	High Risk	To Be Eliminated Through Short-term Action Plan	
Falling Due To Breakage Of Protective Barriers on Threshold	0.5	1	40	20	Acceptable Risk	Urgent Measure May Not Be Needed	
Falling Due To Complete or Partial Collapse of Flooring	0.2	0.2	40	1.6	Acceptable Risk	Urgent Measure May Not Be Needed	
Falling Due to The Heavy Weight of Object in Hand on the Threshold	3	1	40	120	Significant Risk	Closely Monitored, To Be Taken Under Annual Action Plan	
Dropping Materials While Working on Threshold	3	1	15	45	Definite Risk	To Be Taken Under Action Plan	
Falling Down To The Ground Upon Losing Balance	10	1	40	400	High Risk	To Be Eliminated Through Short-term Action Plan	

While Working On Scaffold							
Falling Due To “Air-Step” While Working On Scaffold	10	1	40	400	High Risk	To Be Eliminated Through Short-term Action Plan	
Falling Due To Breakage Of Scaffold Element	6	1	40	240	High Risk	To Be Eliminated Through Short-term Action Plan	
Falling Due to the Rollover of Unfixed Scaffold System	6	0.5	100	300	High Risk	To Be Eliminated Through Short-term Action Plan	
Falling Due to The Heavy Weight of Object in Hand	6	1	40	240	High Risk	To Be Eliminated Through Short-term Action Plan	
Dropping Materials Due to Various Reasons While Working On Scaffold	10	1	15	150	Significant Risk	Closely Monitored, To Be Taken Under Annual Action Plan	
No risk detected within the scope of thesis	-	-	-	-	-	-	**0** (Central system for air conditioning/ ventilation system etc.)
Falling Down To The Ground Upon Losing Balance On the Roof Edge	0.2	0.2	40	1.6	Acceptable Risk	Urgent Measure May Not Be Needed	**187.2** (Design of barrier, parapet etc. that would prevent falls
Falling Due To “Air-Step” On The Roof Edge	0.2	0.2	40	1.6	Acceptable Risk	Urgent Measure May Not Be Needed	
Falling Due To The Breakage of Protective Barriers	1	0.5	40	20	Acceptable Risk	Urgent Measure May Not Be Needed	

Falling Due To Complete or Partial Collapse of Roof	0.5	0.5	100	25	Definite Risk	To Be Taken Under Action Plan	from the roof)
Falling Due to The Heavy Weight of Object in Hand on the Threshold	0.2	0.5	40	4	Acceptable Risk	Urgent Measure May Not Be Needed	
Dropping Materials While Working on Threshold	3	3	15	135	Significant Risk	Closely Monitored, To Be Taken Under Annual Action Plan	

10.4 Comparison of Risk Scores for Primary Design Decisions and Secondary (Alternative) Design Decisions

In Chapter 9, the activities realized during the performance of Primary Design Decisions were identified, and then the related activities were divided into sub-activities, which a risk analysis was conducted for each of such sub-activities. Finally, the risk scores of sub-activities, which were given under the last column of Table 9.5a and Table 9.5b as the risk analysis table, were summed up and a total risk scores for the design decision were determined accordingly.

In this Chapter, the same procedure was applied to the alternative design decisions and a total risk score is calculated for each alternative design decision and presented under Table 10.2a and Table 10.2b in detail.

Additionally, the total risk scores calculated for each alternative design decisions were compared under Table 10.3. The level of lowness for the risk scores of alternative design decisions compared with primary design decisions are given under Table 10.3.

Table 10.3: Comparison of Risk Scores for Primary Design Decisions and Alternative Design Decisions, Variation Between Two Risk Scores

Primary Design Decision		**Alternative Design Decision**		**Variation in Risk Score (Mitigating Effect of Alternative Design on Risk Score)**
Definition	**Total Risk Score**	**Total Risk Score**	**Definition**	**Rate (%)**
Design of exterior walls with bricks, blocks etc.	21620	2763.1	Exterior pre-cast insulated wall system	87.22
No central system for air conditioning/ ventilation system etc.	1360	0	Central system for air conditioning/ ventilation system etc.	100
Incorrect design of barrier, parapet etc. that would prevent falls from the roof, or no design at all	4600	187.2	Design of parapet of barrier design on the roof	95.93

10.5 Financial Comparison of Primary and Secondary Design Constructions

Activities performed during the construction of Primary Design Decisions of external wall works have been identified. Then their updated unit prices found from the webpage of Department of Planning and Construction of TRNC. After that, the total unit price of construction of Brick External wall has been found (Table 10.4). The same procedure was applied to the secondary design decisions and a total unit price of construction of secondary design has ben found and presented. Table 10.4 demonstrates that the total unit price of panel wall (secondary design) is much more cheaper than the brick wall (primary design).

Table 10.4: Financial Comparison of Primary and Secondary Design Constructions

Design Alternative 1 (Brick Wall 25cm thickness)		**Design Alternative 2 (Pannel Wall 25cm thickness)**	
Definition	**Unit Price (TRY/m^2)**	**Definition**	**Unit Price (TRY/m^2)**
Brick works	122	Pannel Wall	203
Plastering (inside)	45	workmenship	35
Plastering (Outside)	58	-	-
Lintel (Lento)	3	-	-
Jacketing	158	-	-
Total Unit Price	**386**	**Total Unit Price**	**238**

Chapter 11

A BIM BASED SOLUTION PROPOSAL: HAZARD IDENTIFICATION SYSTEM (HIS)

11.1 Introduction

A multi-storey building, which is typical residential apartment projects, was chosen for this section. The selected building was used as a reference and HIS developed over this model. HIS would operate in the way of giving warnings to eliminate falling from height accidents caused due to exterior wall works.

11.2 Development of HIS in Revit Dynamo Environment

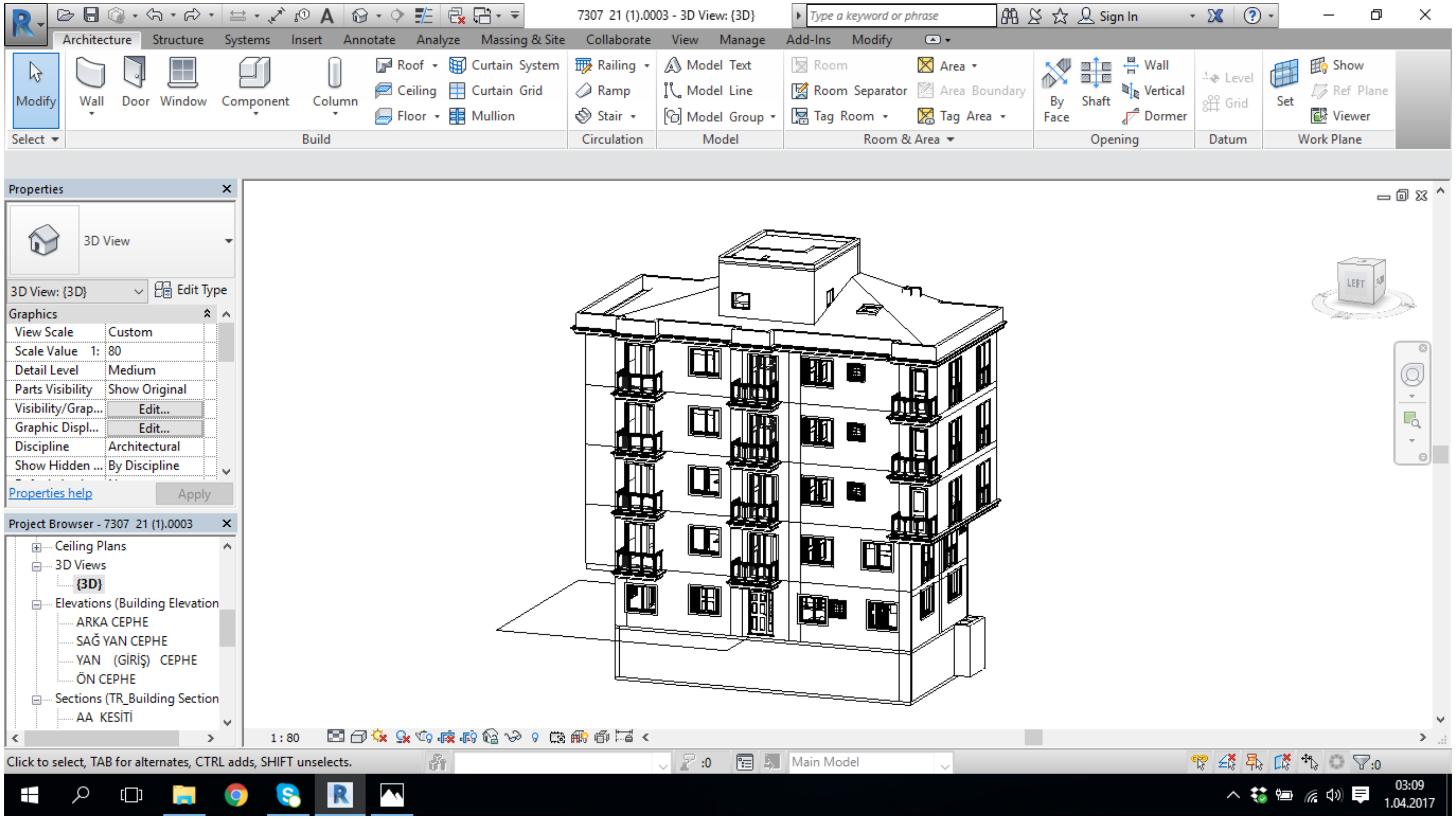
It is important to reiterate the aim of HIS prior to explaining its development. The aim in developing the HIS is to detect the exterior walls built with brick, block, yutong etc. during the construction of multi-storey buildings since a majority of fall from height type of accidents are experienced during the construction of exterior walls with such materials.

Hereunder; a multi-storey reinforced concrete building project modelled in Revit environment was first selected (See. Figure 11).

Then, all interior and exterior walls at each floor were listed on this model, (the walls within the dynamo code are easy to list and there are a total number of 184 wall element on the model).

Furthermore, a filtering parameter was defined on all walls. During this filtering activity, the parameter of “base constraint” was utilised, which indicates where the bottom level of wall starts in terms of floors. Hence, the walls on all floors are selected other than the basement and ground floors since the heights of 2 metre and above are defined as dangerous work height pursuant to the OSH literature.

Afterwards, base constraint parameter is used on the walls at the upper stories (there are a total number of 153 walls at the upper stories) out of basement and ground floor walls (there are 31 walls at the basement and ground floor) as a second filtering. Through this second filtering, “function” parameter is used to split the walls at the upper stories as interior or exterior and we list the exterior walls respectively (there are total 50 exterior walls).



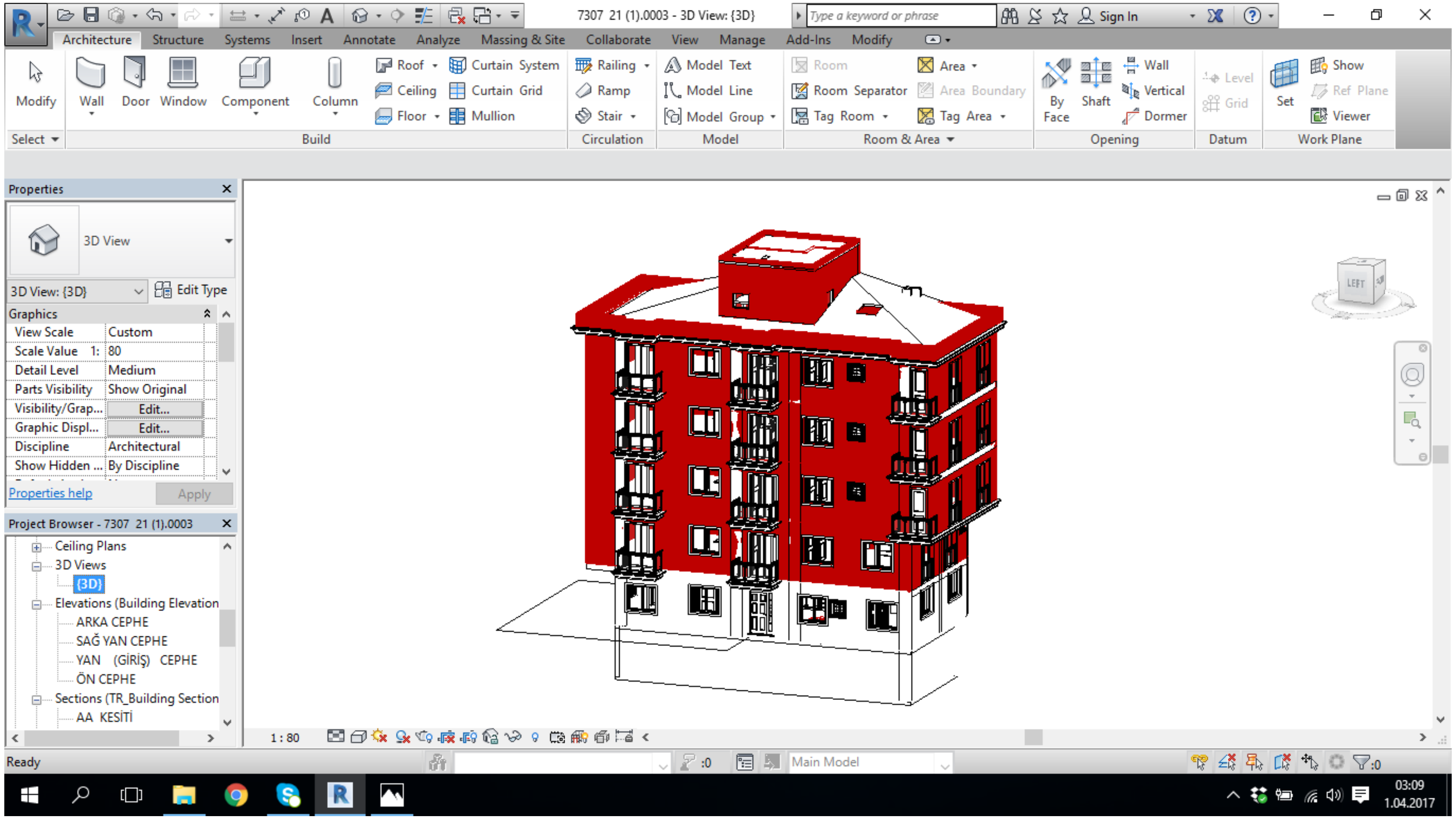
3D View: {3D}	
View Scale	Custom
Scale Value 1:	80
Detail Level	Medium
Parts Visibility	Show Original
Visibility/Grap...	Edit...
Graphic Displ...	Edit...
Discipline	Architectural
Show Hidden ...	By Discipline

Project Browser - 7307 21 (1).0003

- Ceiling Plans
- 3D Views
  - {3D}
- Elevations (Building Elevation
  - ARKA CEPHE
  - SAĞ YAN CEPHE
  - YAN (GİRİŞ) CEPHE
  - ÖN CEPHE
- Sections (TR_Building Section
  - AA KESİTİ

Click to select, TAB for alternates, CTRL adds, SHIFT unselects.

Figure 11.1: 3D model of multi-storey reinforced concrete building project selected as reference on Revit Architecture



7307 21 (1).0003 - 3D View: {3D}

Properties

3D View

3D View: {3D}

Graphics	
View Scale	Custom
Scale Value 1:	80
Detail Level	Medium
Parts Visibility	Show Original
Visibility/Grap...	Edit...
Graphic Displ...	Edit...
Discipline	Architectural
Show Hidden ...	By Discipline

Project Browser - 7307 21 (1).0003

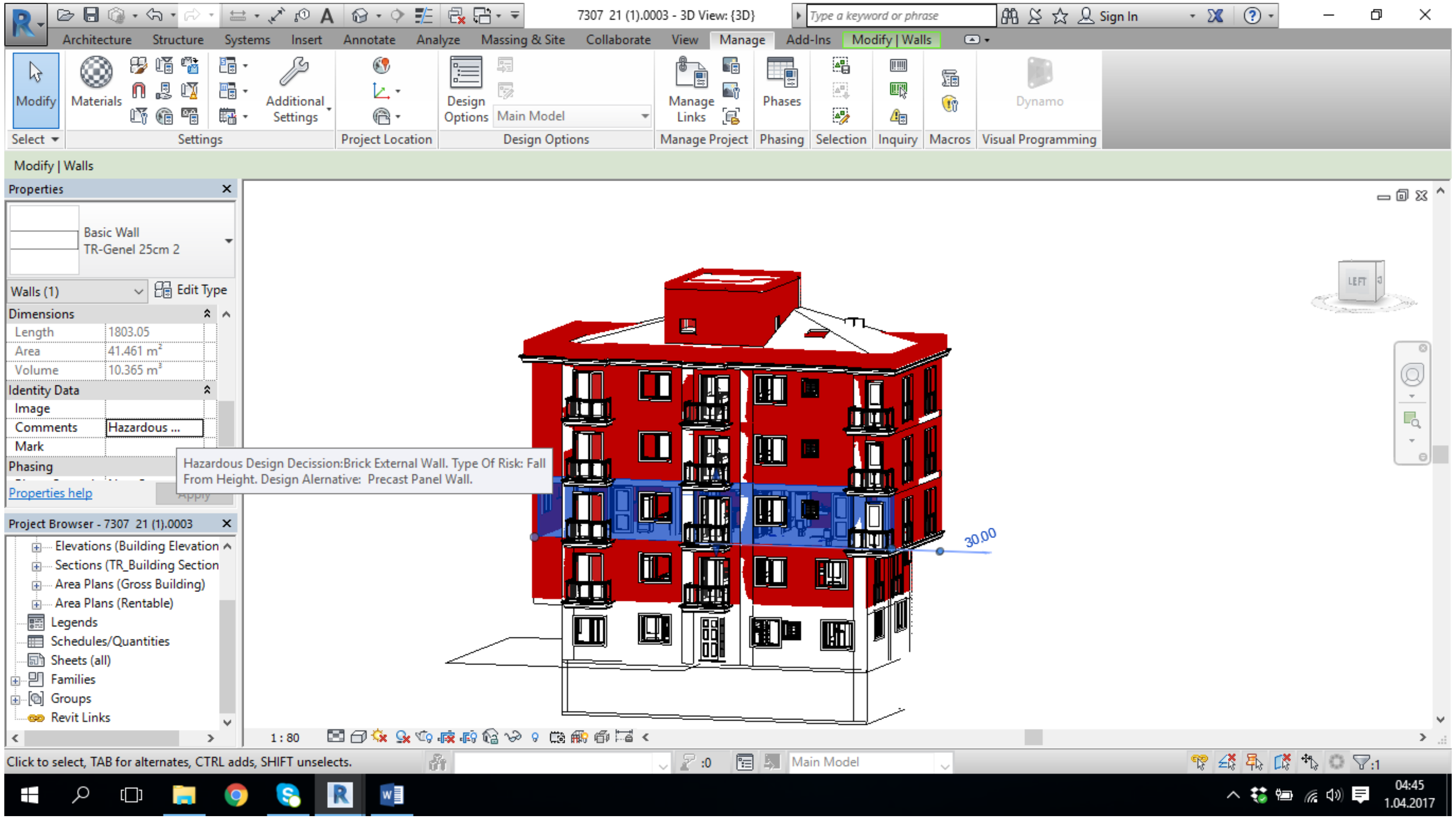
- Ceiling Plans
- 3D Views
  - {3D}
- Elevations (Building Elevation
  - ARKA CEPHE
  - SAĞ YAN CEPHE
  - YAN (GİRİŞ) CEPHE
  - ÖN CEPHE
- Sections (TR_Building Section
  - AA KESİTİ

1 : 80

Ready

Main Model

Figure 11.2: Hazardous building materials (brick exterior walls) detected by dynamo on Revit Architecture are highlighted with red



Basic Wall
TR-Genel 25cm 2

Walls (1) Edit Type

Dimensions
Length 1803.05
Area 41.461 m²
Volume 10.365 m³

Identity Data
Image
Comments Hazardous ...
Mark

Phasing

Properties help Apply

Hazardous Design Decission:Brick External Wall. Type Of Risk: Fall From Height. Design Alernative: Precast Panel Wall.

Click to select, TAB for alternates, CTRL adds, SHIFT unselects.

Figure 11.3: Warning of “Hazardous Design Decision” when one of the elements highlighted with red upon the detection of macro on Revit Architecture environment and the associated alternative design proposal

In the next step, we perform a third filter for 50 exterior walls that was filtered twice. The parameter of “materials” was used for this third filtering, and precast wall materials are filtered and excluded from the list. The list then included materials such as brick, block, yutong. As indicated before, the exterior walls constructed with such materials are the majority of reasons for fall from height accidents. Since the selection for exterior walls on the reference building is brick under “material” parameters, the third filtering eliminated none of the walls. Thus, following the “material” filtering as the third step, there were still 50 exterior walls constructed with brick material. Such walls would be constructed as higher than 2m with brick, block and ytong etc.

The last phase in the development of code is to share the building materials detected on the model and provide the required warning on the screen. There is a two-step way for this. Firstly, the related building elements are highlighted with different colour through the “paint” feature of Dynamo to attract the attention of designer. Such feature allows painting the building materials passed from three filtering phases in the preferred way. The exterior walls with the determined features were asked to be in the colour red (See Figure 11.2). Then as a second phase, we use the “comment” feature of Dynamo to write the warnings on the related building materials in “comment” format. For this application, the text of *“Hazardous Design Decision: Brick Exterior Wall. Type Of Risk: Fall From Height. Design Alternative: Precast Panel Wall”* is added to the properties list of exterior walls at the upper stories and the designer is verbally warned and is directed for change in design (See Figure 11.3). Where the designer selects the specific building material, the warning appears immediately. Figure 11.4 reflects the flowchart describing the development and functioning of aforementioned code.

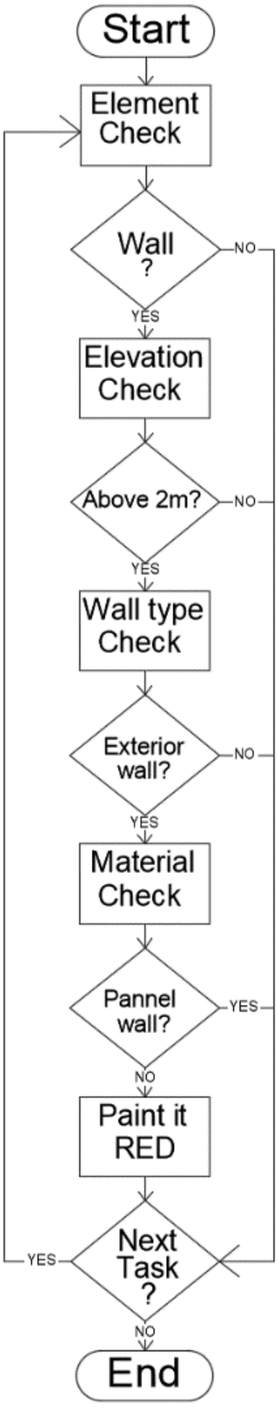


Figure 11.4: Flowchart of HIS prepared to prevent the occupational accidents during the exterior wall works

Chapter 12

RESULTS AND DISCUSSION

12.1 Introduction

The thesis will be concluded by discussing the findings generated as a result of this study, weaknesses, strengths and benefits of this study, on the construction sector and proposals for future studies.

12.2 Assessment of Findings Generated Through the Data Collection

In the data collection process, the work style of TRNC TRNCLD in terms of OSH were investigated. Noticed that, there isn’t any printed reference indicating the background of TRNC TRNCLD and how they accumulated their experience about OSH. The information collected through the face-to-face interviews with the officers at the department was documented for the first time under this study. This is one of the most important finding of this study. Hence, TRNC TRNCLD has started to investigate the notified occupational accidents since 1994 and to archive the investigation reports accordingly. Back in those years, the workers and employers avoided notifying the accident to the TRNC TRNCLD since there is a belief that in addition to the victimisation, the parties would suffer from the legal action. Consequently, the department used to often hear about the occupational accident from the accident notification of employer, press or notice of eyewitnesses to the department. Therefore, the department might not know the majority of occupational accidents. In consideration with the analysis of this study and distribution of accidents per years, the performance of investigations for a couple of major occupational accidents in a year and then the increase in the number of such investigations verify this finding respectively (Tözer and Çelik, 2015). There is an increase in the number of investigations with the years. The awareness of investigation officers about OSH and experience in investigation has improved every year. Such improvement has led making some improvements in the format of investigation forms. The reports between the years of 1994 – 2000 were comprised of investigation form, statements of victims and/or eyewitnesses and in some cases, the photos from the accident scene. However, with the adjustments in 2000, the scope of investigations and reports were improved accordingly. In addition to the standard investigation form, photos and statements, the doctor reports, statements of eyewitnesses, medical board report, if any, the copies of work permit of victim and mastership certificate and supporting documents such as autopsy report in fatal accidents were included as well.

Moreover, as a result of cooperation between the TRNCLD with Social Security Department (SSD) in 2000, the number in the notification of occupational accidents have significantly increased. The primary reason of this is that the victims apply to SSD to compensate their loss of workday and the SSD inform the TRNCLD about the occupational accident. Another reason is that the TRNCLD is informed about the incidents indicating occupational accident under the police investigations for the injuries in the hospital (Çelik and Tözer, 2014). By 2006, investigations have become more scientific. The TRNCLD have begun to back up the data collected from the investigations for the first time in computer environment. Such data has been made available for the information and use of interested parties through the website of Department. In the past, the majority of studies conducted in TRNC concerning OSH mainly used post-2006 data since the “occupational accident register was transferred to the computer environment after 2006”. Master thesis of Amir Azour has been investigated construction accidents between 2006 and 2013. Besides, Çelikağ and Özbilen focus on construction accidents happened in the period of 2000 - 2008. Since the thesis is not limited with 2006 and covers the 12 years before 2006 to include under the literature, which would enhance the importance of thesis. All of these information indicate that the investigations performed for the last about 25 years but particularly for the period of 18 years, have been solemnly conducted and if the existing data is appropriately used, then sound implications can be obtained accordingly.

Considering the yearly distribution of occupational accidents in the TRNC, the dramatic increase in the figures is not that coincidental. The number of accidents has increased in parallel with the work volume through the growth in the sector. However; the aforementioned information given in the related paragraphs noted that another reason of such increase is based on the improvement in the operation of Department in the way of being informed about more accidents. While only the serious accidents resulted with incapacity and fatality were investigated before; now even the most minor accidents known by the hospital or SSD are registered.

In terms of the yearly distribution of OSH in TRNC, the analyses under this thesis might not give good results due to the given reasons. On the other hand, since the basis of this thesis is the analysis of individual accidents rather than the distribution of occupational accidents, this problem is eliminated as well.

The classification and analyses conducted within the scope of this thesis is the most comprehensive study in the field of OSH for the TRNC. The classification and analyses under the study have been introduced to the literature upon their publication in the study by Tözer et al. (2018).

As indicated in the previous chapters, the occupational accidents records that were used within the scope of thesis are the most comprehensive construction occupational accidents classification executed in the northern part of Cyprus. However, two studies stand forward with regard to the previous studies conducted in TRNC. One of such is the study of Çelikağ and Özbilen (2008), which aims to describe the hazards that construction workers are exposed through the assessment of some construction sites in the country. Consequently, the hazards such as dust, toxic substances, sound and high temperature were identified and associated solution proposals were given accordingly. In parallel, the study identified that the fall from height type of accidents. The study also claimed that the scaffolding systems are one of the most dangerous work environments. The findings of Çelikağ and Özbilen (2008) support the findings of this thesis. On the other hand, the master thesis by Amir H. Azour (2014) assessed the construction occupational accidents in TRNC and analysed the occupational accidents occurred between the years of 2006-2013. The study analysing the occupational accidents from different aspects indicated that the fall from height accidents are at the forefront.

12.3 Evaluation of Findings Generated Through Data Analysis

One of the first findings reached through studies on records is about the industrial distribution of occupational accidents. It can be seen that 793 occupational injuries and deaths of a total of 3004 accidents investigated by the TRNCLD for the twenty-year period 1994-2014 happened in the Construction industry (Tözer et al.,2018). This figure shows that almost 1/4th of all casualties are construction workers, or from around constructions. The Construction industry is followed by the industrial industry, with 444 casualties (See Table 7.1). Therefore, focusing on the construction sector within the framework of this study has been an appropriate decision. The situation observed through the detailed analysis of accidents in the sector support the extent of the need for further studies.

Such that, in Construction industry, ‘falls’ type of accidents take the first place for frequency, resulting in death and injury. Looking at accidents resulting in injuries, ‘falls’ is followed by ‘struck by thrown’, ‘projected object’, ‘crashed, jammed in or between objects’, ‘sharp object injury’, ‘fall on same level’, ‘falling objects’, ‘traffic accident’, ‘contact with heat or hot substances’, and ‘exposure to electricity’ type accidents. In fatal accidents, ‘falls’ is followed by ‘exposure to electricity’, ‘crashed, jammed in or between objects’, ‘traffic accident’, ‘falling objects’, and ‘building and construction collapse’ type accidents, in order (Tözer et.al, 2018), (See Table 7.2). Table 7.2 reflects that the focal point would be ‘falls’ type of accidents. In other words, it indicated that focusing on the “falls” type of accidents is relevant. With this approach, falls type accidents are examined in detail and divided into three groups as, ‘falls from scaffolds’, ‘falls from structural elements’, ‘other type of falls’. A total of 86 accidents of falls from scaffolds type (of which 5 died) have been recorded. 59 accidents of falls from structural elements have been recorded, with 7 deaths. In addition, it was observed that 58 accidents of falls from movable ladders, of other type of falls group, were recorded, with 4 deaths. These facts show that the most frequent type of falling is falls from scaffolds, but the most fatal falls are falls from structural elements (See Table 7.3). While elaborating Table 7.2, Table 7.3 underlines that ‘falls from scaffolds' and 'falls from structural elements' type of accidents should be given importance.

It should be reiterated that, the data analysis within the scope of this thesis has been given in Chapter 7, which only includes the thesis-related parts of data set. All outputs from the classification and analysis were delivered under the study by Tözer et.al (2018) published during the thesis process.

The findings generated from the data analyses are in parallel with literature when compared with the studies conducted around the world and TRNC. Consequently, the fall from height accidents are mainly on top of the lists of almost all developing countries in terms of fatality, injury and frequency. One of the reasons that such type of accident ranks first in TRNC is that the scaffolding systems used in the country are significantly primitive and have serious deficiencies in terms of safety (Çelikağ and Özbilen, 2008). Additionally, another factor is that OSH rules are not considered and implemented in the country.

12.4 Evaluation of Findings Generated In Relation To the Association of Accidents with Design

As indicated before, the accident records used during the data analysis, which the results were presented in Chapter 7, were comprised of investigation reports. The relevant reports as the raw data were reviewed one-by-one and added under the related accident class as an accident record upon the analysis of details. Consequently, the 'falls from scaffolds' accidents together with the 'falls from structural elements' accidents were mainly occurred at the time of constructing the structural building elements such as exterior wall or corner columns. Therefore, the consideration of 'falls from scaffold’ and ‘falls from structural elements’ type of accidents as the sub-types of “falls” type of accidents were deemed as appropriate respectively.

Following that, Chapter 8, in the light of investigation reports, verified that the given two accident types are related with the construction of exterior walls and other works on the façade, which led to analyse whether such accidents are related with the design decisions for exterior walls and other works on the façade. The consistency in the findings and statistics generated as a result of Risk Assessment indicated the appropriateness of decision. Consequently, the risk analysis conducted through Fine-Kinney method under Chapte 9 regarding typical multi-storey building model concluded the following results for the primary design decisions. The total risk score for the decision of “Design of exterior walls with bricks, blocks etc.” is 21620, for the decision of “No central system for air conditioning/ ventilation system etc.” as 1360 and for the decision of “Incorrect design of barrier, parapet etc. that would prevent falls from the roof, or no design at all” as 4600. Such risk scores again emphasized the fatality levels of construction sites in the TRNC.

Further on the study, the potential and infrastructure facilities of construction companies in the TRNC were analysed in consideration of building techniques and construction technologies widely used throughout the world. Hence, alternatives suitable for the design decisions reviewed through risk analysis were pursued in order to decrease the higher risk scores generated as a result of risk analysis given in the previous chapter. As indicated in the beginning of paragraph, all of the determined alternative designs can be applicable by almost of all contractor companies in the TRNC. Considering the given information, the results of risk analysis performed on the secondary design decisions foreseen as alternative through the Fine-Kinney method in the Chapter 10 is as follows: the total risk score calculated for the design decision of “Design of exterior walls as precast panel walls” is 2763, for the decision of “Central system for air conditioning/ ventilation system etc.” as 0,00 and for the decision of “Design of parapet or barrier design on the roof” as 187.

Therefore, the results of risk assessment performed with Fine-Kinney Method indicated that the secondary design decisions presented as an alternative to the primary design decisions are successful. Furthermore, the alternative proposal for the design decision about the exterior walls introduced 87,22% improvement, for the air-conditioning system solution (air-condition system) as 100% and for the roof design as 95,93%. Such rates were found as a result of proportioning the total risk scores calculated for the primary and secondary design decisions.

It must be reiterated that the risk analysis and associated risk scores for the primary and secondary design decisions have been generated upon the activities on the selected typical multi-storey reinforced concrete building.

In consideration with the association of occupational accidents with design decision, the professional designers in the sector were also consulted accordingly. The consulted professionals were first informed about PtD and OSH issues. Such professionals pointed out that the procedures with regard to divide the design process into sub-sections and associated results are satisfactory.

12.5 Evaluation of Activities Conducted on Revit

The studies given under Chapter 11 are crucial in order to make the study findings visible and contribute the sector with the study outputs. Under this thesis, the relation between the primary and secondary design decisions were introduced into the real life (real design) following a number of actions under Chapter 11. In order word, a structure that would reflect on the activities in the field in the way to improve the sector was formed respectively. The research findings were put into a software package format to be reflected on the field activities rather than just textual statements hidden in the pages of this thesis. Such situation was possible through the codes developed with the BIM software and Chapter 11 includes all the details with regard to the code development. The choice of Revit for this study was an appropriate decision since it is the most used BIM software in the country and region. On the other hand, Revit, as an AUTODESK product, is compatible with other AUTODESK products in the sector (AutoCAD, NetCAD etc.). And the compatibility between Revit and Windows has no problems.

The code also works without any problem in the Revit. As Chapter 11 describes, the code developed through the DYNAMO application, which is found in the Revit Architecture package as a standard, can function in all versions of Revit and all drawings.

The modelling in Revit is textural and molar (by using materials) rather than linear, and all character of texture type is automatically added on the modelled mass through Revit. For example, if we want to model wall on Revit, we can only do this with the materials that have wall character, and windows with window material. Unlike

AutoCAD or other drawing software, walls would not be drawn with dark red in one project and light red in another. In all Revit models, walls are drawn with wall texture and windows with window texture. Moreover, the designer indispensably determines the top and bottom elevations, left and right boundaries, thickness, whether the material will be brick or block in the correct and complete way. Such standard work structure allows the functioning of DYNAMO software package, developed within the scope of thesis, on all building types **without any problems.**

In the study, the financial assessment of alternatives was very limited. In doing so, the construction costs in the internal market of TRNC were taken into consideration and the cost comparison was only conducted for the exterior walls. However such values are very insufficient in terms of making any analysis about cost since the costs of OSH rules were not reflected into the conducted financial analysis as none of the countries with the conditions of TRNC or similar have OSH unit prices.

Chapter 13

CONCLUSION AND RECOMMENDATIONS

13.1 Conclusion

During the data collection process, the work style of TRNC TRNCLD and the unrecorded development of OSH field of activity has been defined. This thesis is the first study which is correctly indicating the background of TRNC TRNCLD and OSH field of activities. More importantly, all accident records have been collected, ordered and classified according to the standart of ICD-10 Codes.

The relationship between the most critical accidents, design decisions, construction elements and construction activities have been successfully identified. After that, Definition of the activities and sub-activities performed during the construction of mentioned design decisions which create risks for accidents have been done.

The performed a risk analysis for activities and sub-activities for primary and secondary design decisions clearly demonstrate the difference between the alternatives. As a result of comparison of risk levels, secondary design decisions found safer than the primary design decision.

Financial comparison of the construction processes has been done for primary and secondary design decissions. As a result of this, secondary design found much more economical than the primary design. This finding is supporting the consistency of this study.

Performance of HIS has been evaluated by a case study and results shoves that its performance is satisfying. The study mainly focuses on the Exterior Walls, Air-conditioning/Ventilation System and Roof Design and HIS developed on Revit is about the Exterior Walls only. But it is easy to modify the HIS to enlarge its capacity to include Air-conditioning/Ventilation System and Roof Design parameters in it.

13.2 Recommendations

Within this context, period of time of data collected can be extended until today. This will unarguably increase the data set and sensitivity of relation humped between accidents and design decissions indirectly.

A comprehensive financial comparison of the construction process of primary and secondary design may be performed under an independent thesis study.

Besides, limits of HIS can be enlarged as;

- adapt it to diffrent type of structures as higways, tunnel, bridges,
- control and prevent more accident types besides fall from height,
- increase the alternative design suggestions for unit sample.

REFERENCES

Abdelhamid, T. S., Everett, J.G. (2000). Identifying root causes of construction accidents. *J Cons Eng Man* 126, 52–60.

A day in the life: UNDP health and safety expert, Cyprus. (2015, November 25). Retrived from http://europeandcis.undp.org/blog/2012/04/30/a-day-in-the-life-undp-health-and-safety-expert-cyprus/

Akboğa, Ö., Baradan, S. (2015). An Examination of the Characteristics of Fatal Accidents in the Construction industry: Izmir Field Study. *5th Symposium on Worker Health and Work Safety Presentations Booklet* 215-224, Chamber of Civil Engineers Izmir Branch, Turkey. (Published in Turkish).

Andaç, M. (2014). Guide of Risk Assessment Studies. Ministy of labour and Social Security. Turkey. (Published in Turkish).

Aouad, G., Lee, A., Wu, S. (2006). Constructing the Future: nD Modeling. *Taylor and Francis*, London.

Autodesk Inc. (2005). Parametric building modeling: BIM's foundation. (2011, May 2010). Retrived from http://images.autodesk.com/adsk/files/Revit_BIM_Parametric_Building_Modeling_Jun05.pdf

Autodesk Inc. (2007). White paper on bim and cost estimating. (2013, April 28). Retrived from http://www.consortech.com/bim2/doc/BIM_cost_estimating_EN.pdf

Autodesk, Inc. (2008). The Five Fallacies of BIM. White paper. (2013 April 28) Retrived From http://static.ziftsolutions.com/files/8a7c9fef2693aa1e0126d2961da1084b

Azour, A. H. (2014). Analysis of Occupational Construction Accidents in North Cyprus. *(Master thesis*), Eastern Mediterranean University.

Bart, D. N. (2009). Eurostat: Statistics in Focus 63/2009: 8.6% of workers in the EU Experienced work-related health problems. (2015, September 23) Retrived from http://www.adapttech.it/old/files/document/3369EUROSTAT_20_08_2.pdf.

Bruch, E. (2011). Evaluation of the EU Occupational Safety and Health Directives: Construction Sites – 92/57/EEC. *International Safety and Health Construction Co-ordinators Organisation, 11-12, BNP*. Luxenbourg.

Bruch, E. (2014). Evaluation of the EU Occupational Safety and Health Directives: Construction Sites – 92/57/EEC. *International Safety and Health Construction Co-coordinators Organizations, 14-15, BNP*. Luxenbourg.

Bureau of Labor Statistics (BLS). National Census of Fatal Occupational Injuries, January 2002. (2015, May 11) Retrived from www.bls.gov

Bureau of Labor Statistics (BLS). National Census of Nonfatal Occupational Injuries and Illnesses, January 2002. (2015, May 11) Retrived from www.bls.gov

Bureau of Labor Statistics (BLS). Fatal Occupational Injuries and Employment by Industry, January 2002. (2015, May 11) Retrived from www.bls.gov

C. D. M. (2015). Construction (Design and Management) Regulations 2015. (2018, May 15) Retrived from www.hse.gov.uk/construction/cdm/2015/index.htm

C. I. B. (2004). The Construction Sector System Approach: An International Framework, *International Council for Research and Innovation in Building and Construction*, Rotterdam, The Netherlands.

Ceylan, H., Başhelvacı, V. S. (2011). Risk Assessment by using Risk Assessment Table: A Case Study. *International Journal of Engineering Research and Development*. Vol.3, No.2, Sf.25-3.

Construction: a hazardous work. International Labour Organization. (2015, September 29). Retrived from http://www.ilo.org/safework/areasofwork/hazardous-work/WCM S3 56576/lang-en/index.htm

Çelik, T., Tözer K. D., İlter, O., Köseoğlu, O. (2012). Training Work within the scope of Work Safety and Worker Health Administration System and the Effects of this Application on Workers. *PYYK 2012, Izmir Higher Technological Institute*. Turkey. (Published in Turkish).

Çelik, T., Tözer, K.D. (2014). General Analysis of Occupational Accidents in the TRNC, and the Situation in the Construction industry: Effects of the Workers' Level of Education and Culture on Occupational Accidents. *PYYK 2014, Akdeniz University, Antalya. Turkey.* (Published in Turkish).

Çelikağ, M., Özbilen, M. (2008). Health and Safety Matters in Construction Industry in North Cyprus, Proceedings of the 8th International Congress on Advances in Civil Engineering, ACE2008, 15 – 17 September 2008, Gazimagusa, North Cyprus.

Dalcı, A. (2014). An Investigation on Some Benefits of BIM Applications *(Master Thesis).* Department of Civil Engineering. Eastern Mediterranean University.

Doguwa, S. I. (2010). Statistics for National Development. *Journal of Applied Statistics*. Vol.1 (1), 99-106.

Douglas, C. E. (2010). The Effects of Building Information Modeling on Construction. *(Master Thesis).* Faculty of Civil and Environmental Engineering, University of Maryland, Baltimore, MD, USA.

Duman, E., Hamzoğlu, O. (2011). İstanbul'da Bir Şantiyede Çalişanlarin İş Kazalarinin İzlemi. *Mesleki Sağlik ve Güvenlik Dergisi*. 2011;40: 35-42. (Published in Turkish).

Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2008) BIM Handbook: A Guide to Building Information. John Wiley & Sons, Inc. USA.

Eurostat. (2013) European Social Statistics Pocketbooks. 2013 Edition, 94. *Publication of the European Union*, Belgium.

Fang, D. P., Huang, X. Y., Hinze, J. (2004). Benchmarking studies on construction safety management in China. *J Cons Eng Man* 130, 424–32.

Fine, W. T. (1971). Mathematical evaluation for controlling hazards. *Journal of Safety Research*, 3(4), 157-166, 1971.

Gambatese, J. A., Hinze, J., Haas, C. (1997). Tool to design for construction worker safety. *Journal of Architectural Engineering*. 3(1), 32-41.

Gambatese, J. A. (1998). Liability in designing for construction worker safety. *J. of Arch. Eng. ASCE.* 4 (3), 107-112.

Gambatese, J. A. (2000). Owner involvement in construction site safety. *Proceedings of the American Society of Civil Engineers Construction Congress VI*. Orlando, FL, USA, 661–670.

Gambatese, J. A. (2000). Safety Constructability: Designer Involvement in Construction Site Safety. *Proceedings of the American Society of Civil Engineers (ASCE) Construction Congress VI*. Orlando, FL, 650-660.

Gambatese, J. A., Behm, M., and Hinze, J. (2003). Engineering Mandates Stipulated in OSHA Regulations. *Proceedings of the 2003 Construction Research Congress, sponsored by ASCE*, Honolulu, HI.

Gambatese, J. A. (2004). An Overview of Design-for-Safety Tools and Technologies. *Proceedings of the Designing for Safety and Health in Construction Research and Practice Symposium*. Eugene, OR: University of Oregon Press, 109 – 117

Gambatese, J. A., Hinze, J., Behm, M. (2005). Viability of designing for construction worker safety. *Journal of Construction Engineering and Management, ASCE*. 131 (9), 1029- 1036.

Gambatese, J. A., Rajendran, S. (2007). Sustainable Construction Safety and Health Rating System - A Feasibility Study. *Proceedings of the 2007 ASCE Construction Research Congress, ASCE*. Grand Bahama Island, Bahamas.

Gambatese, J. A. (2008). Research Issues in Prevention through Design. *Journal of Safety Research, Special Issue on Prevention through Design*. Elsevier and the National Safety Council, 39(2), 153-156.

Gambatese, J. A. Behm, M., Rajendran, S., (2008). Design's role in construction accident causality and prevention: Perspectives from an expert panel. *Safety Science*. 46 (4), 675-691.

G.C.P. (2011). Global Construction Perspectives, Global Construction 2020, *Global Construction Perspectives and Oxford Economics*, London, UK.

Gee, C. (2010). The Influence of Building Information Modelling On The Quantity Surveying Profession. *(Master Thesis)*. University of Pretoria.

Giaccardi, E., Fischer, G. (2008). Creativity and Evolution: A Metadesign Perspective. *Digital Creativity*. 19(1): 19-32.

Gibb, A. G. (2006). Occupational health: Slow accidents need solutions fast. *Proceedings of CIB International Conference on Global Unity for Health and Safety in Construction, Beijing 28-30 June 2006*. Tsinghua University Press, China, pp. 22-33.

Golparvar-Fard M., Pera-Mora F., Savarese, S. (2009). Application of 4-Dimensional augmented reality model for automating construction progress monitoring data collection, processing and communication. *ITcon. Vol. 14, Special Issue Next Generation Construction IT: Technology Foresight, Future Studies, Roadmapping, and Scenario Planning*. 129-153.

Grilo, A., Jardim-Goncalves, R. (2010). Value Proposition on Interoperability of BIM And Collaborative Working Environments. *Automation in Construction*. 19 (5), 522–530.

Gürcanlı G. E. (2011). Prevention Through Design, *Engineering NEWS of Turkey*. Chamber of Civil Engineering, Ankara. (Published in Turkish).

Gürcanlı, G. E. (2013). Analysis of Fatalities and İnjuries in Construction Industry *Occupational Health and Safety Journal*. April-June 2013. (Published in Turkish).

Gürcanlı, G. E., Müngen, U. (2013). Analysis of Construction Accidents in Turkey and Responsible Parties. *Industrial Health*. Vol.51, 581-595.

Gürcanli, G. E. (2013). An Analysis of Deaths and Injuries in the Construction industry, Turkish Medical Doctors Union. *Journal of Occupational Health and Safety*. Vol. 2013/2, 20-29. (Published in Turkish).

Health and Safety Executive. (2005). Health and Safety Induction for Smaller Construction Companies Site Safety - Scotland, UK.

Health and safety Executive. (2010). 2009/2010 Health and Safety Executive Statistics (INDG345), UK.

Heinrich, H. W. (1959). Industrial accident prevention. *McGraw-Hill*. New York.

Heinrich, H. W., Peterson, D., Roos, N. (1980). Industrial accident prevention. McGraw-Hill, New York.

Hergünsel, M. F. (2011). Benefits of Building Information Modeling for Construction Managers and BIM Based Scheduling. *(Master Thesis)*. Faculty of Civil Engineering. Worcester Polytechnic Institute.

Holness, A., Gordon, V. R. (2008). Building Information Modeling Gaining Momentum. *ASHRAE Journal*. 28-40.

Hunt, C. (2005). eArchitect: Revit Finally Comes of Age. *Building Design*. . (2015, September 29). Retrived from http://global.factiva.com/en/arch/print_results.asp

Hughes, P., Ferrett, E. (2007). Introduction to Health and Safety in Construction, 2nd Ed., 1, *Elsevier Ltd*., UK.

Hu, Z., Zhang, J., Deng, Z. (2008). Construction Process Simulation and Safety Analysis Based on Building Information Model and 4D Technology. *Tsinghua Science and Technology*. 13 (S1, October 2008), pp. 266-272.

I.C.D.-10. International Statistical Classification of Diseases and Related Health Problems. *10th Revision*. (2015, November 23). Retrived from http://apps.who.int/classifications/icd10/browse/2016/en.

I.M.F. (2012). International Monetary Fund, World Economic Outlook-April 2012, IMF, USA.

I.N.T.E.S. (2014). Turkey Construction Industry Employers Union. Construction Industry Report – March 2014. (2015, March 13). Retrived from http://www.intes.org.tr/content/MArt-2014.pdf

I.S.G.I.P. (2016). Health and Sefety Management System Guide for Small or Midium-sized Enterprises: Risk Assessment, Booklet of H&S Risk Monitoring and Control. (2016, November 13). Retrived from http://www3.csgb.gov.tr/csgbPortal/Show_Prop_erty/WLP%20Repository/isggm/dosyalar/isgip_insaat_2 (Published in Turkish).

Jayasena, H.S., Wijayakumar, M. (2013). Automation of BIM Quantity Takeoff to Suit QS’s Requirements. *The Second World Construction Symposium*. University of Moratuwa, Sri Lanka.

Kızılırmak, H. (2010). Understanding Architectural Design Proccess. (Master Thesis). Department of Architecture, Gazi University. Turkey. (Published in Turkish).

Kinney, G. F. (1976). Practical Risk Analysis for Safety Management, Calhoun: The Naval Postgraduate School Institutional Archive DSpace Repository, *China Lake, CA: Naval Weapons Center,* USA.

Lee, C. (2008). BIM: Changing the AEC Industry. *PMI Global Congress 2008. Project Management Institute*, Denver, Colorado, USA.

Leung, C. W., Chow, W. K. (2002). A brief review on construction safety in some Southeast Asian countries. *Architectural Science Review.* Vol.45, 39–49.

Lingard, H., Saunders, L., Pirzadeh, P., Blismas, N., Kleiner, B., Wakefield R. (2015). The relationship between pre-construction decision-making and the effectiveness of risk control: Testing the time-safety influence curve. *Engineering, Construction and Architectural Management*. Vol. 22 Issue: 1, pp.108-124.

Mahçiçek, S. B. (2015). An Activity Based Health and Safety Risk Assessment Method conbined With time Planning Works in Construction Projects. *(PhD. Thesis).* Istanbul Technical University. (Published in Turkish).

Mangan, S. D. (2006). Infrastructure Evaluation on Smart Buildings: Case Study of Istanbul. (Master Thesis). Istanbul Technical University. (Published in Turkish).

Manuele, F. A. (2008). Prevention through design: Addressing occupational risks in the design and redesign processes. *Professional Safety*. 53(10), 28-40.

Manu, P. A., Ankrah, N. A., Proverbs, D. G., Suresh, S. (2012). Investigating the multi-causal and complex nature of the accident causal influence of construction project features. *Accid Anal Prev* 48, 126–33.

Mitchell, W. J. (1999). A Tale of Two Cities: Architecture and The Digital Revolution. *Safety Science*. (285): 839-841.

N.B.L. (2016). National BIM Library. BIM is the future of Construction (2016, December 20). Retrived from http://www.nationalbimlibrary.com/bim-explained

N.I.O.S.H. National Institute of Occupational Safety and Health. Prevention through design: NIOSH Safety and Health Topic. Washington, DC: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Author. (2017, January 06). Retrived from http://www.cdc.gov/niosh/topics/ptd

Occupational Health and Safety Risk Assessment Directive, Official Publication no: 28512, 29 December 2012. Turkey. (Published in Turkish).

Ofluoğlu, G., Doğru, T. (2011). An economical evaluation of Occupational Accidents in Construction Industry in Turkey, *Kamu-İş*. C:11, S:4/2011. (Published in Turkish).

Onat, E. (2006). Face to Face with Architectural Design: A Trip to Architecture. *Yem Yayın*. 111, 119, 134. Turkey. (Published in Turkish).

Özdemir, İ. (2017). Lecture Notes of Working Machinary in Construction. Osmangazi University. Civil Engineering Department. (Published in Turkish).

Özdemir, E., Kılıç. S. (2011). "2008 Global Economic Crises and Construction Industry: A case study on Marketing Activities. *Anadolu Univrsity Social Sciences Journal*. 11(2), 43-68. (Published in Turkish).

Özkılıç, Ö. (2005). Occupational Health and safety Management Systems and Risk Assessment Methods. *TİSK Yayınları*. Turkey. (Published in Turkish).

Özorhon, B. (2012). Construction Industry in Turkey and its Place in the World *Publication of İstanbul Ticaret Odasi Sectoral Development and Research Studies*, 2012-31. Turkey. (Published in Turkish).

Petersen, D. (1982). Human Error-Reduction in Safely Management. *STPM Press*. New York.

Reyes, J. P., San-Jose, J. T., Cuadrado, J., Sancibrian, R. (2014). Health & Safety Criteria for determining the sustainable value of construction projects. *Safety Science*. vol.62, pp 221-232.

Smith, D. K, Tardif, M. (2009). Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Managers. *John Wiley & Sons*. New Jersey.

Smith, S. (2008). Bentley and Autodesk Announce Historic Interoperability Agreement. Bentley.

Song, Y., Chua, D. K. H. (2006). Modeling of Functional Construction Requirements for Constructability Analysis. *J. Constr. Eng. Manage.*, 132 (12), 1314–1326.

Sorensen, K., Christiansson, P., Svidt, K. (2009). Prototype development of an ICT system to support construction management based on virtual models and RFID, *ITcon Vol. 14, Special Issue Next Generation Construction IT: Technology Foresight, Future Studies, Roadmapping, and Scenario Planning*. pg. 263-288.

State Planning Organisation. (2012). Macroeconomic and Industryal Developments in 2009. SPO-MSG 2012-6. *State Printing Office*, TRNC. (2015, December 11). Retrived from http://www.devplan.org/Frame-tr.html (Published in Turkish).

State Planning Organisation. (2015). Macroeconomic and Industryal Developments in 2010 to 2013. SPO-MSG-2013-7. *State Printing Office*. TRNC. (2015, December

11). Retrived from http://www.devplan.org/Frame-eng.html (Published in Turkish).

Suermann, P. C., Issa, R. R. A. (2007). Evaluating the impact of building information Modeling (BIM) on construction. *Proceedings of the 7th International Conference on Construction Applications of Virtual Reality*. The Pennsylvania State University, October 22-23, USA, 10 pp.

Sulankivi K., Makela T., Kiviniemi M. (2009). BIM-based Site Layout and Safety Planning. *Proceedings of the First International Conference on Improving Construction and Use through Integrated Design Solutions,* CIB IDS 2009, 10-12 June 2009 Espoo, Finland.

Szymberski, R. (1997). Construction Project Safety Planning. *TAPPI Journal*. 80(11), 69-74.

Taiebat, M. (2011). Tuning Up BIM fot Safety Analysis Proposing Modelling Logics for Application of BIM in DfS. Virginia Polytechnic Institute and State University.

Taşoluk, D. (2014). Natural Lighting as an input to Architectural Design: An investigation of Office buildings in konya on Natural Lightingin point of view (Master Thesis). Selçuk University. Turkey. (Published in Turkish).

TCSGK Social Insurance Institution Annual Statistics (2014, December 03). Retrived fromhttp://www.sgk.gov.tr/wps/portal/tr/kurumsal/istatistikler/sgkistatistikyillik lari. (Published in Turkish).,

Tözer K. D., Çelik T., Gürcanlı E., (2016). The Analysis of Fatal Health and Safety Accidents of Unskilled workers in North Cyprus Construction Sector. (Published in Turkish). 4rd *Project Construction and Management Conference (PYYK'16)*, Anadolu Universitesi, Eskişehir, Turkey, 3-6 November 2016.

Tözer K. D., Çelik T., Gürcanlı E., (2018). Classification of Construction Accidents in Northern Part of Cyprus. *Teknik Dergi*.Vol.29/2, March'18. PP. 8295-8316. Ankara, Turkey. DOI: 10.18400/tekderg.325546.

TRNC Department Of Meteorology. The Climate of Cyprus. (2015, December 09). Retrived from http://www.moa.gov.cy/moa/ms/ms.nsf/DMLcyclimate_en/DML cyclimate_en (Published in Turkish).

Tunalı, İ. (2009). Design Philosophy Models and Industrial Design. Yem Yayın. 18, 78. Turkey. (Published in Turkish).

Chamber of Contructors in Turkey. (2016). Construction Sector Analysis: 2016 will be a difficult year. Turkey.

Uzun, İ. M. (2012). Health and Safety Risk Assessment on Working Machinary in Construction Industry. (Master Thesis). Istanbul Technical University. (Published in Turkish).

Wang, X., Truijens, M., Hou, L., Wang, Y., Zhou, Y. (2014). Integrating Augmented Reality with Building Information Modeling: Onsite construction process controlling for liquefied natural gas industry. *Automation in Construction* 40, 96-105.

Woo, J. H. (2011). BIM and Pedagogical Challenges. Western Illinois University, Macomb, IL.

Yi, J. S., Kim, Y. W., Kim, K. A., Koo, B. (2012). A suggested color scheme for reducing perception-related accidents on construction work sites. *Accid Anal Prev* 48, 185–92.

Yılmaz, F. (2010). Discussion of Methods in Risk Assessment. *Earthworks Employer Association Journal*. Vol.86, pp.1- 6. (Published in Turkish).

Yorucu, V. (2016). Economical Developments in Southern Cyprus Construction Industry (2015, December 22). Retrived from http://www.Kıbrısgazetesi.com/yazarlar/vedat-yorucu/guney-Kıbrıs-insaat-sektorundeki-ekonomikgelismeler_/215

Vries, B. D., Verhagen, S., Jessurun, A. J. (2004). Building Management Simulation Centre. *Automation in Construction* 13(5). pp: 679-687.

Vacharapoom, B., Sdhabhon, B. (2009). An integrated safety management with construction management using 4D CAD model (2014, October 24). Retrived from http://www.elsevier.com/locate/ssci & http://www.sciencedirect.com

Williams, S. (2006). Tackling your occupational health risk. *presented in the Reducing Occupational Health Risks in Construction conference, May 2006.* Institution of Civil Engineers, London, UK.