A TOOL FOR VISUALIZATION OF RISK INFORMATION: THE RISK BOX

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ABSTRACT

A TOOL FOR VISUALIZATION OF RISK INFORMATION: THE RISK BOX

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Visualization is an effective way to represent data that mainly aims to make the data easier to be understood, analyzed, and processed by the users. In literature, there exist many studies focusing on the necessity and effectiveness of visualization in decision-making processes. Risk, on the other hand, is an important topic that needs to be considered for decision-makers in the project to decide on the further pathways to follow and need to be visualized in such a way to aid the decision-makers in these procedures. Hence, this thesis aims to understand the performance of the existing risk visualization techniques and form new ways to visualize the risk analysis outputs and risk information. In this manner, an initial needs assessment study has been conducted using the traditional outputs of Monte Carlo Simulation and found out that the visuals are not easy to understand by decision-makers. Hence, a “Risk Box” idea has been proposed and tested with decision-makers via semi-structured interviews using a case project. The proposed concept of Risk Box aimed to be designed as in the shape of a box having different faces while acquiring different and complementary risk information. At the end of the study, it has been found out that

Risk Box is a useful and promising tool to be used in practice. Therefore, this study has shown that construction professionals can use Risk Box during risk assessment for a more effective communication of probabilistic information.

Keywords: Risk Management, Risk Communication, Risk Information Visualization

ÖZ

BİR RİSK BİLGİSİ GÖRSELLEŞTİRME ARACI: RİSK KUTUSU

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Görselleştirme, temel olarak verilerin kullanıcılar tarafından anlaşılmasını, analiz edilmesini ve işlenmesini kolaylaştırmayı amaçlayan etkili bir yoldur. Literatürde karar verme süreçlerinde veri görselleştirmesinin gerekliliği ve etkinliğine odaklanan birçok çalışma bulunmaktadır. Risk ise projedeki karar vericilerin ileride izleyecekleri yollara karar vermeleri için dikkate alınması ve karar vericilere bu prosedürlerde yardımcı olacak şekilde görselleştirilmesi gereken önemli bir konudur. Dolayısıyla işbu tez, mevcut risk görselleştirme tekniklerinin performansını anlamayı ve risk analizi çıktılarını ve risk bilgilerini görselleştirmek için yeni yollar oluşturmayı amaçlamaktadır. Bu doğrultuda, Monte Carlo Benzetiminin geleneksel çıktıları kullanılarak bir ön ihtiyaç değerlendirme çalışması yapılmış ve görsellerin karar vericiler tarafından anlaşılmasının kolay olmadığı tespit edilmiştir. Bu nedenle, bir "Risk Kutusu" fikri önerilmiş ve örnek bir vaka projesi kullanılarak yarı yapılandırılmış görüşmeler yoluyla karar vericilerle ve test edilmiştir. Önerilen Risk Kutusu konsepti, farklı ve tamamlayıcı risk bilgileri içeren farklı yüzlere sahip bir kutu şeklinde tasarlanmayı amaçlamıştır. Bu tez çalışmasının sonunda Risk

Kutusu'nun pratikte kullanılabilecek faydalı ve gelecek vaat eden bir araç olduğu ortaya çıkmıştır. Bu nedenle, bu çalışma, inşaat sektöründeki profesyonellerin, olasılık bilgilerinin daha etkili bir şekilde iletilmesi için risk değerlendirmesi sırasında Risk Kutusu'nu kullanabileceğini göstermiştir.

Anahtar Kelimeler: Risk Yönetimi, Risk İletişimi, Risk Bilgisi Görselleştirme

To my beloved father…

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I have dedicated this thesis to my father, Kemal Karakoçak, who cannot be physically with me to see the ending and who always be the idol of power to me. By knowing that there are not enough thanks to make, but I am genuinely grateful for my dearest family, Filiz Karakoçak, Ceyda Knöbel, Martin Knöbel, and Eren Knöbel, for enabling me to come this far, for their never-ending love, support, patience and energy and for making me who I am at this day.

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ABBREVIATIONS

ANP	Analytical Network Process
APM	Association for Project Management
CoV	Coefficient of Variation
DD	Duration of Design
EXP	Expert
F	Familiar
OCP	Operational Cost Percentage
P	Participant
PMBOK	Project Management Body of Knowledge
Q	Question
U	Unfamiliar
UCA	Unit cost of aggregate
UCC	Unit cost of cement

CHAPTER 1

INTRODUCTION

"*If you know the enemy and know yourself, you need not fear the result of a hundred battles. If you know yourself but not the enemy, for every victory gained, you will also suffer a defeat. If you know neither the enemy nor yourself, you will succumb in every battle.*" (Sun Tzu, 2000) is a famous quote on the well-known book of Art of War by Sun Tzu written almost 2,500 years ago, which actually has many things to say about project management and risk management. In this sense, if "enemies" can be considered as "risks", this quote can be interpreted such that knowing your risks is "vital", but "yourself" or your experiences are also necessary to be combined with to win the "hundred battles".

For the concept that has been established well before in history, many other attributions have been done for project management and project risk management concepts. As a more recent reference, Project Management Body of Knowledge (PMBOK) (2017) mentions the aim of project risk management as "*to identify and manage risks that are not addressed by the other project management processes.*" Therefore, this definition addresses project risk management as a direct influencer on project objectives and success, alongside project management procedures.

Within project risk management procedures, expert knowledge has been included in many steps as the main actor throughout (Project Management Institute, 2017). Hence, risk management requires an extensive understanding of the risks in a project in order to be correctly managed. As mentioned by Dikmen et al. (2018), risk assessment is executed based on the existing past data on risk and expert judgment. Although this may create subjectivity (Dikmen et al., 2018), (Kontio et al., 2004), it can be considered as the heart of the risk management process.

Risk management interests and contains many different stakeholders in the project. Hence, it is of vital importance that risk is correctly and efficiently communicated to enable the decision-makers to have more informed decisions. Thamhain (2013) has also stated that when dealing with risks, gaining knowledge on the uncertainties shall come first before efforts of managing. Therefore, the importance of acknowledgment of extensive information by managers of risk is undeniable.

Among methods for supporting the understanding procedures, visualization plays an important role (Moore, 2017), (Eppler & Aeschimann, 2009). As Huang et al. (2008) stated, visualization is a support for cognitive procedures in understanding data. Moreover, it provides a more coherent and structured picture for analyzing if a vast data set exist (Kimiagari & Keivanpour, 2019), (Grainger et al., 2016), (Chandra et al., 2008).

Therefore, visualization can be used and is actually used for risk management, especially for risk communication. At this point, risk communication shall be defined and is defined as the exchange of information between the stakeholders from risk experts to decision-makers (Bostrom et al., 2008). Hence, visualization is an actor in the creation of a bridge between different stakeholders in the communication of risk.

In this study, the objective is to understand and examine the cognition of the existing visualization approaches of risk management and find ways to enhance in order to assist in decision-making procedures as well as risk management. In this manner, the following section will focus on the review of literature on understanding risk management, decision making, and the necessity of visualization. Before starting, it is also mandatory to state that within this thesis, the “risk visualization” term has been used in the intention of defining visualization of the risk-related information, i.e. risk information visualization, it has been used interchangeably.

CHAPTER 2

LITERATURE REVIEW

This chapter overviews the literature that forms the background of this research. Firstly, the risk management and decision-making process will be briefly introduced. Then the communication of risk and the role of visualization in this purpose will be discussed. Finally, the existing methods of risk assessment and their visual outputs will be examined.

2.1 Risk Management and Decision Making

It is essential to start by understanding "risk management" in projects and state the existence of many definitions for the term. For instance, it has been defined by PMBOK as "*the systematic process of identifying, analyzing, and responding to project risks*" (2017), where Association for Project Management (APM) Body of Knowledge (2019) has the definition of "*process that allows individual risk events and overall risk to be understood and managed proactively, optimizing success by minimizing threats and maximizing opportunities and outcomes*" for the same term. Similarly, there are various explanations made in the literature. To exemplify, Kang et al. (2013) has used the term as the "*work that classifies, analyzes and responds to unpredictable risks that exist in the processes of project implementation.*" Willumsen et al. (2019) mention project risk management as a value-adding activity. Alternatively, Qazi et al. (2020) assert that it is "*the process of identifying, analyzing and then responding to risks over the life cycle of a project to meet its objectives.*" Therefore, by utilization of these definitions, it can be said that risk management is the "process", meaning that it is a long-running activity

throughout a project and comprised of comprehending, analysis and reacting to the risks, in the end achieving goals such as success, benefits, outputs.

As in nearly every aspect of life, decision-making is a significant activity in projects' risk management procedures. Choosing between alternatives exists not only in people's daily lives, such as the decision of changing one's job or what to eat, but also frequently happens in projects in the areas such as the decision for investing in a project or working with a specific subcontractor. In this manner, having the necessary knowledge on the alternatives, the "enemies" and "yourself" as defined by Tzu, will bring one to the informed decisions.

To enable an effective and efficient risk management procedure, integrating the existing sources with risk knowledge among the organization is essential (Thamhain, 2013), which addresses efficient communication of risk. At this point, the general practice of identification and analysis of risks shall be mentioned. These processes require the intervention of human where information sharing within parties is mostly preferred (Bostrom et al., 2008), (Kontio et al., 2004), (Vrouwenvelder et al., 2001) in which the risk communication shall be an "*interactive process*" (Roth, 2016). Therefore, communication and sharing of the risks become a must for the risk management procedures.

2.2 Communication of Risk

As discussed briefly above, risk management procedure involves extensive communication that occurs between stakeholders of a project where a commonly acknowledged characteristic is increasing the awareness on risks (Eppler & Aeschimann, 2009), (Bostrom et al., 2008), (Bier, 2001). As also stated by Roth (2016), the aim of risk visualization shall not be to "*educate or persuade*" but to "*empower*".

Moreover, Aven (2016) has established a visual for representation of links in the procedure of decision making under risks:

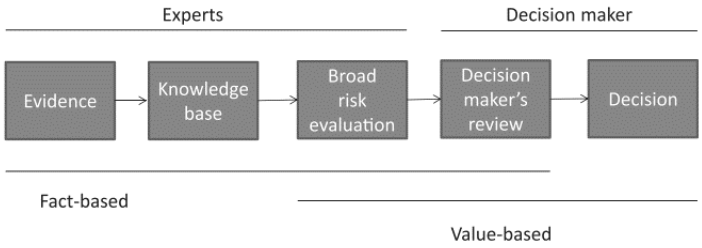


Figure 2.1. Model Established for Risk-Informed Decision Making (Aven, 2016)

By looking at this figure, it is possible to say that in order to have an "informed decision", experts and decision-makers should be in close communication. Another point to focus on here shall also be the emphasis on "knowledge" of the experts that forms the basis for decisions to be communicated to decision-makers.

Moreover, risk communication is not a one-time activity in project risk management but rather a process. As also can be seen in the aforementioned studies, Rowan's (1991) study can also be referred to here where he defines risk communication as a "*problem-solving process*". Therefore, just like project risk management, risk communication is executed throughout the lifecycle of a project.

Finally, Vrouwenvelder et al. (2001) has also discussed in his study that risk communication is a "*complex subject involving highly technical information, psychology, presentational skills etc.*", drawing attention to the many components of risk communication, where "presentational skills" can be interpreted as the visual representation of data. Therefore, by considering all the views, it is possible to conclude that risk communication is an essential part of risk management, and it can be accomplished through accurate and efficient gathering, flow, and presentation of information.

2.3 Visualization

Understanding and processing information can be challenging, especially if the information is complex itself. In this manner, visualization can serve as a tool for enhancing these procedures and enhancing the understanding and eventually decision-making process in the end (Kimiagari & Keivanpour, 2019), (Moore, 2017), (Huang et al., 2008), (Bostrom et al., 2008), (Vrouwenvelder et al., 2001). As explained further by Kumar (2016), "*visualization techniques present complex data in concise and precise manner in visual form in less time that can be very helpful to users to deal with their domain-specific problems.*"

Therefore, it is possible to say that visualization is a way for simplification and decreasing the time to understand presented data. In this subject, Grainger et al. (2016) have mentioned the aspect of visual representations on the provision of aid to reach the explicit information rapidly, eliminating the text-based information. Alternatively, Londsdale and Londsdale (2019) have also expressed visualization's capability to represent a vast amount of data and wordy documents provided at a brief look. Again, the authors have stated the ability of visualization on clear data representation.

In addition, visualization can create the opportunity to compare data as well as identification of the outliers, relationships, and pattern, which in the end enhances understanding and processing (Bica et al., 2020), (Lonsdale & Lonsdale, 2019), (Lurie & Mason, 2007). In addition, it is also necessary to mention the ability of visualization, which is "*storytelling*" (Lonsdale & Lonsdale, 2019), and that the user can see the story behind data such as their relations, correlations, changes, patterns etc. Therefore, visualization not only presents data but forms a unity and coherence between data points to come up with meaningful results, assisting the decision-making process.

In this manner, with the help of visuals, the decision-making procedures of users will be improved in terms of comprehension capability by seeing many data tied around a concept.

Moreover, Chandra et al. (2008) approach visualization as a "*process of helping the decision-maker form a mental model of the problem*", hence emphasizing the existence from beginning to the end rather than solely representing the final product. In addition, the authors have brought the attention to support visualization in the creation of a model in the brain of the decision-maker, mentioning a complex structure and putting visualization into a position of support. Another point of view regarding risk visualization has been presented in the same study where the authors demonstrate the iterative nature of risk visualization. They have stated that decision-makers acquire information through an iterative process and can use and adapt this for future iterations since visualization of risk creates a more "*structured process*".

Although risk visualization is subject that is less focused on (Kimiagari & Keivanpour, 2019), (Eppler & Aeschimann, 2009) an increasing number of studies exist in the literature on this subject. For instance, Kimiagari and Keivanpour (2019) have developed a visualization tool for risk management in the visualization of Fuzzy Analytical Network Process (ANP) results and applied it on a real case project. Alternatively, Eppler & Aeschimann (2009) have developed a conceptual framework for a systematic visualization approach in risk management. Moreover, Kang et al. (2013) have established a 4D CAD system that includes the schedule and risk information via the utilization of colors for risk levels.

It is also necessary to provide remarks about the results of studies on risk visualization. For example, Dikmen et al. (2018) have conducted an experimental study using a case study of a construction project and come up with results such that the confidence level of the participants has increased after visualization of data. Chua et al. (2006) have mentioned that graphical representation of risk information encourages the intellectual impact. Kontio et al. (2004) have focused on the visual

representation approach of risk information via comparison of different methods and concluded that it enhances users' willingness to conduct detailed conversations about risks, and visualization can present more information if used efficiently. Moreover, Visschers et al. (2009) have conducted a literature review on the existing studies regarding risk communication and representation and found out that visualized risk information (such as graphs) can enhance comprehension compared to textual and numerical data.

Alternatively, Matos Costano et al. (2017) have introduced a 3D visualization tool, named as dilemma cube, experimenting with the effectiveness of this tool as a visualization to aid users in their decision-making procedures where the visual for the tool has been presented in Figure 2.2 below. The study has resulted in this visualization having intensified users' cognitive abilities.

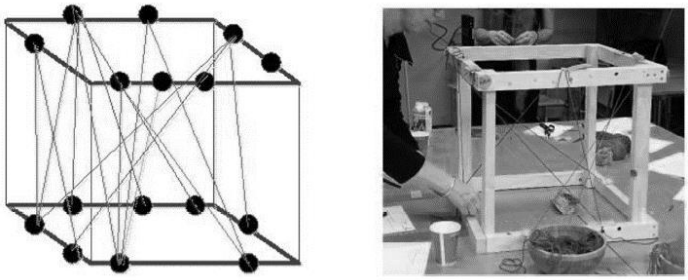


Figure 2.2 Dilemma Cube by Matos Costano et al. (2017)

In the end, it can be seen that visualization of risk results in supported cognition abilities as well as improved understanding and ability of analysis.

2.4 Critical Success Factors for Visualization

The practical and enhancing effects of visualization have been vastly studied in the literature and already briefly introduced above. However, it must also be reminded that visualization of risk information shall be carefully handled since it may affect the perception of risk and approach to risk judgments (Kumar, 2016),

(Bostrom et al., 2008), (Lurie & Mason, 2007), (Chua et al., 2006). The opportunity created by visuals on the representation of vast data may pose a danger if the visual is not established in an efficient manner which may end up with losing the data, losing the meaning, over-simplification, bias, and ignorance of some points (Engin & Vetschera, 2017), (Kumar, 2016), (Chandra et al., 2008), (Lurie & Mason, 2007), (Bier, 2001).

Moreover, as much important as the representation, the comprehension capability and knowledge of decision-maker is also a point to focus on (Engin & Vetschera, 2017), (Lurie & Mason, 2007), (Bier, 2001), (Lipkus & Hollands, 1999). The visual shall be shaped in coherence with the audience, in this case, decision-makers, to serve its purpose. As also asserted by Broekmaat and Brilakis (2019), expertise is an essential aspect of the participant that will support him in the decisions "*based on disconnected data inputs*", requiring skills to make meaningful outcomes from the inputs.

Chandra et al. (2008) have also mentioned the decision-making process under risk and established the map provided below in Figure 2.3, where the authors have defined the process of forming risk strategies as an aspect affected by "risk tolerance" and "risk perception" of the decision-maker. In other words, decision-making has been influenced by the risk attitude of the decision-maker.

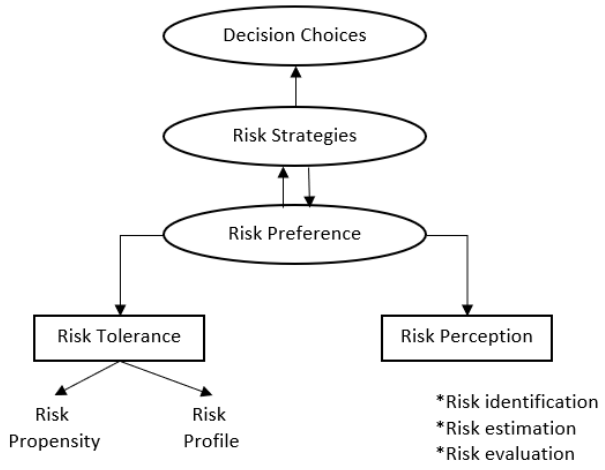


Figure 2.3 Model of Risk Hierarchy by (Chandra et al., 2008)

In this sense, one must pay attention to forming the visuals for risk information to end up with the desired results.

2.5 Visualization of Risk in Construction

Although many studies show that the construction industry is subjected to the risks essentially (Erol et al., 2020), (Kang et al., 2013), it can be seen that risk visualization is less of a focal point for the literature when compared to identification and analysis of risks (Lonsdale & Lonsdale, 2019), (Eppler & Aeschimann, 2009).

In the construction industry, risk information can be seen as information that may require the aid of visualization to be better understood and analyzed (Kang et al., 2013), (Schirillo & Stone, 2005), (Rowan, 1991); hence visualization has a significant role in risk assessment procedures (Eppler & Aeschimann, 2009). As mentioned by Kumar (2016), visualization can be used as a tool to enhance risk communication, where its importance has been explained in the former sections.

There are many risk assessment methods that have been used in construction risk management that involve the visualization of information. Many structures have

been used for the communication of risk information, such as risk ladders, statistical graphs, stick and facial figures, line graphs, dots, pie charts, and histograms (Bostrom et al., 2008). An example can be given from Cai et al.'s (2013) study, where the authors have focused on Bayesian networks as a way of risk assessment method in the offshore oil and gas industry. Alternatively, Bucovetchi et al. (2017) have prepared radar diagrams to visualize risk information and expert perception. Moreover, Turner et al. (2017) have used bow-tie to represent risk and present this as an effective communication tool. In addition, Vianello et al. (2016) has utilized risk matrices and commented on the fact that risk matrices are effective for communication without the existence of numbers.

Moreover, if one is to talk about risk assessment and risk visualization, Monte Carlo Simulation shall also be mentioned. It can be given as one of the most commonly used techniques in risk analysis and visualization (Jepson et al., 2020), (Kwak & Ingall, 2009), (Rezaie et al., 2007) where it has been used in many industries and areas. A more detailed discussion has been done in the following section.

2.6 Closer Look on Monte Carlo Simulation and Visual Outputs

Monte Carlo Simulation considers the uncertainty of variables that are reflected as distributions for the representation of inputs. Hence, the output has been established in the form of a probability distribution demonstrating the possible outcomes. It is important to remember that this simulation has then been iteratively computed to reach the results (Avlijas, 2019). Therefore, the analyst will end up with a range of outcomes and probabilities.

In the construction industry, this simulation has been used in various areas such as cost estimation, schedule analysis but generally focused on the area of risk management (Koulinas et al., 2020), (Kwak & Ingall, 2009). As also stated by Kwak & Ingall (2009), Monte Carlo Simulation serves as a way of understanding

the risks and their effects. Authors have also mentioned that the method can be challenging due to its characteristic of statistics to be used by project managers.

This probabilistic analysis and the outcomes have been visualized traditionally by a frequency chart (Visschers et al., 2009), where different charts can also be obtained (Avlijas, 2019). In addition, sensitivity analysis is generally conducted alongside, and as also mentioned by Medeiros et al. (2017) and Borgonovo & Peccati (2008), sensitivity analysis is of significant importance during decision-making procedures. The outcomes of this analysis are also visually presented in many different ways, where Tornado Chart is a common way (Koulinas et al., 2020), (Borgonovo & Peccati, 2008). Many studies utilize both visualization methods together. For instance, Kremljak and Kafol (2014) have used software to assess and visualize risks conducted under Monte Carlo Simulation and obtained frequency chart and tornado chart. Hence, it is possible to say that this is a common practice in risk analysis executed in the construction industry.

2.7 Point of Departure and Aim of Study

Throughout the literature review provided above, the inevitable existence of decision-making procedures in project risk management has been explained. In the end, it is possible to summarize that decision-makers, who are the actors in decision-making processes, need to be informed of the project risks to end up with informed decisions. As also seen in the existing studies, during these steps, communication of the risk information is vital since risk assessment itself is said to be based on communication between parties. To enhance this communication, academics have conducted investigations and analyses briefed above, ending with the undeniable effect of the visualization on serving the purpose. When utilized correctly, visualization is found to be a very beneficial tool for data transfer and analysis. In addition, the traditional risk assessment method of Monte Carlo Simulation has been

introduced together with the common visual outputs to demonstrate the results of risk analysis. Finally, visualization approaches of different authors have been presented in the above sections, where studies have shown that a deficiency exists on the adequate research in this area. In other words, during literature review, it has been found out that although there exist studies on risk visualization, there still is a gap for studies of evaluation of risk visualization and effect of these visualizations of decision-making procedures.

Therefore, this research aims to provide a point of view on the existing visuals of Monte Carlo Simulation (i.e. frequency chart and tornado chart), which considered to be one of the most common risk assessment methods and proposes a tool for better visualization of probabilistic information.

CHAPTER 3

RESEARCH METHODOLOGY

This section will focus on the methodology followed during the study explaining the reasons for choosing the steps and aims of conducting.

3.1 Research Objectives

This study's objective is to find answers to the questions below:

Question 1: How effective and useful are the existing visuals (i.e. frequency chart and tornado chart) obtained from the widely used risk analysis method of Monte Carlo Simulation?

In the beginning, prior to the results of the literature research, it has been decided to study the effectiveness of the traditional outputs of risk analysis which are frequency chart and tornado chart, and understand the points of view of the decision-makers towards the visuals and the data presented.

Question 2: How can a tool enhance the understanding and interpretation of probabilistic results of Monte Carlo Simulation via visualization?

As the efficiency of visualization on the enhancement of decision-making process in risk management has been seen from the literature review, the study has tried to come up with new means of arriving in the visualization of Monte Carlo Simulation results and evaluate the approaches of decision-makers to provide as an insight.

3.2 Research Approach

For the aforementioned objectives proposed in the questions, a qualitative approach has decided to be followed via surveys and interviews. As also followed by Tory and Möller (2005), expert reviews have determined to be considered for evaluation of the visualizations since they can end up with reliable results (Isenberg et al., 2013), (Jackson et al., 2003),(Freitas et al., 2002). In addition, one can hereby mention the study by Flick et al. (2018), where the authors have commented that interviews with experts can shorten the time necessary for data gathering providing a more efficient solution.

Regarding the number of experts adequate for reaching results in the qualitative approach, it is possible to say that there are many studies exist investigating the number and findings stating that a significant variation exists (Saunders & Townsend, 2016), (Baker & Edwards, 2012). For instance, in the study of Baker and Edwards (2012), authors have communicated with various researchers and asked the adequate number of experts to include in qualitative research, and it has been seen that the answer "*it depends*" has been given by many of the researchers. Moreover, as mentioned by Suhr et al. (2020), there is a lack of standardization for the size of samples in qualitative methods, making a challenging activity to choose the number. In the end, as a result of the many studies in the literature, it can be said that the selection shall be made in a deliberate way in accordance with the aim of the study (Saunders & Townsend, 2016), (Bengtsson, 2016), (Guest et al., 2006).

Carpendale (2008) asserted that the primary goal of qualitative research is to be more focused on acquiring deeper explanations instead of obtaining statistical results, hence naturally requiring lesser groups of samples compared to quantitative research. The author has also pointed out that for observation purposes, sometimes studies can be conducted by two-three people, where this can prove the existence of utilization

of an idea in those instances, and in the worst case, these cases may exemplify the outliers that are also useful in research procedures. Moreover, Baker and Edwards (2012) have compared qualitative and quantitative research in terms of sample sizes, emphasizing that the quantitative approach will try to make meaningful data from a wide variety of samples. In contrast, qualitative research will focus on deeper meanings, "*hoping to generate a subjective understanding.*"

Therefore, in the literature, the adequacy of a smaller group in qualitative research has been discussed and found efficient, based on the fact that the study objective shall be paid attention. In other words, many existing studies favor that if the aim is "*not to claim a generality*" (Isenberg et al., 2013), but to "*obtain a few widely held ideas*" (Weller et al., 2018), then a minor group of participants can be considered to be enough.

When the concept of visualization and its evaluation is examined, Elmqvist and Yi (2015) mention the nature of visualization as "*open-ended*" resulting in a challenge to approach as quantitative manners, and claiming this as the reason for studies in the literature of visualization is more qualitatively approached. In addition, the authors have also supported the idea of smaller groups of reviewer experts in visualization validation studies since expert review can "*significantly reduce the time and cost investment of evaluation while still exposing the system to human subjects for validation.*" However, they also have paid attention to the fact that the results may not always be in consistence since the validation is human-centric.

In terms of qualitative research, interviews are a common method where Young et al. (2018) mention that 49.9%, they are used for "*understanding knowledge, values, beliefs or decision-making processes of stakeholder*." In addition, Lester et al. (2020) mention the semi-structured interviews among the popular qualitative analysis method.

Moreover, Carpendale (2008) has conducted a review on the types of interviews used and found out that a significant majority has preferred semi-structured interviews:

Conduct	Structure				
	Not stated	Structured	Semi- structured	Unstructured	All[a]
Not stated	32	0	11	1	44
One-to-one	42	1	46	3	92
One-to-one face-to-face	73	2	48	5	128
One-to-one telephone	14	1	0	0	15
One-to-one online	1	0	0	0	1
Group	5	0	3	0	8
Focus group	15	0	0	0	15
All[a]	182	4	108	9	303

[a] 197 studies used one type, 47 studies used two different types and four studies used three different types of qualitative interviews.

Figure 3.1. Types of interviews (Carpendale, 2008)

As also mentioned during the literature review, it has been seen that the semi-structured interview method has been widely used. For instance, Low et al. (2018) have conducted a study on the risk-taking aspect of construction workers, and semi-structured interview has been used for the gathering of expert review for 16 safety experts. Alternatively, Wu et al. (2015) have used semi-structured interviews for gaining information on the views of experts regarding the critical factors in offshore pipeline projects. Moreover, Willumsen et al. (2019) have also used this method for the collection of data on the value creation ability of project risk management with 16 participants. Finally, Jepson et al. (2020) also adopted the method for understanding the approaches of project managers on risks with 25 participants.

On the other hand, Döringer (2021) has mentioned in her study that "expert interview" is also a widely-followed method preferred by researchers, where the definition of "expert" being as the person knowledgeable on a subject has been emphasized. Furthermore, the author, via also utilization of other studies, asserts that there are three categories of expert interviews: *exploratory expert interview, systematizing expert interview*, and *theory-generating expert interview;* where the first category is explained as the method used more frequently to obtain the knowledge of experts on a subject to generate a hypothesis. Hence, it is possible to

say that interviews with experts in the subject can be a path to follow for the gathering of data to establish an initial understanding of a subject.

By using these samples and studies in literature, it can be concluded that semi-structured interview is a common methodology for data collection and feedback, and this method has been chosen as the research methodology for this thesis study as well which is to be conducted by the inclusion of experts having the knowledge on project management.

Additionally, during the study, the data collection has been done via semi-structured interviews, followed by transcription of the interviews and analysis of data primarily via content analysis, coding experts' comments to understand the common points, and reviews of experts involved in the studies. This method can also be considered a widely used method for the analysis of interviews in the literature. For instance, in the study of Shergadwala et al. (2020), the authors have executed semi-structured interviews with four industry professionals for the provision of understanding and their "states of belief" followed by content analysis and coding and data analysis method. Alternatively, Willumsen et al. (2019) have also executed interviews, transcribed, and followed an approach of content analysis to understand the outcomes through iterative steps. Furthermore, the study of Erol et al. (2020) has also preferred interviews as a data collection method, followed by coding of the results for identification of common points, categorization, and emphasize points. Therefore, for analysis of the results of this study has also been determined to be executed in the same manner.

3.3 Research Design and Steps

First of all, the literature review has been conducted to analyze the existing studies and their related findings. Later, an initial study (needs analysis) has been undertaken and executed in a qualitative way to understand the visions of decision-makers on

the traditional outputs of risk analysis by Monte Carlo Simulation. Followingly, by utilizing the results of the literature review and initial study, a visual tool is to be developed to represent the outcomes. Last but not least, the evaluation of this new tool has again been done via qualitative methods, finally coming up with an enhanced visual tool.

In other words, the steps followed have been presented in the figure below:

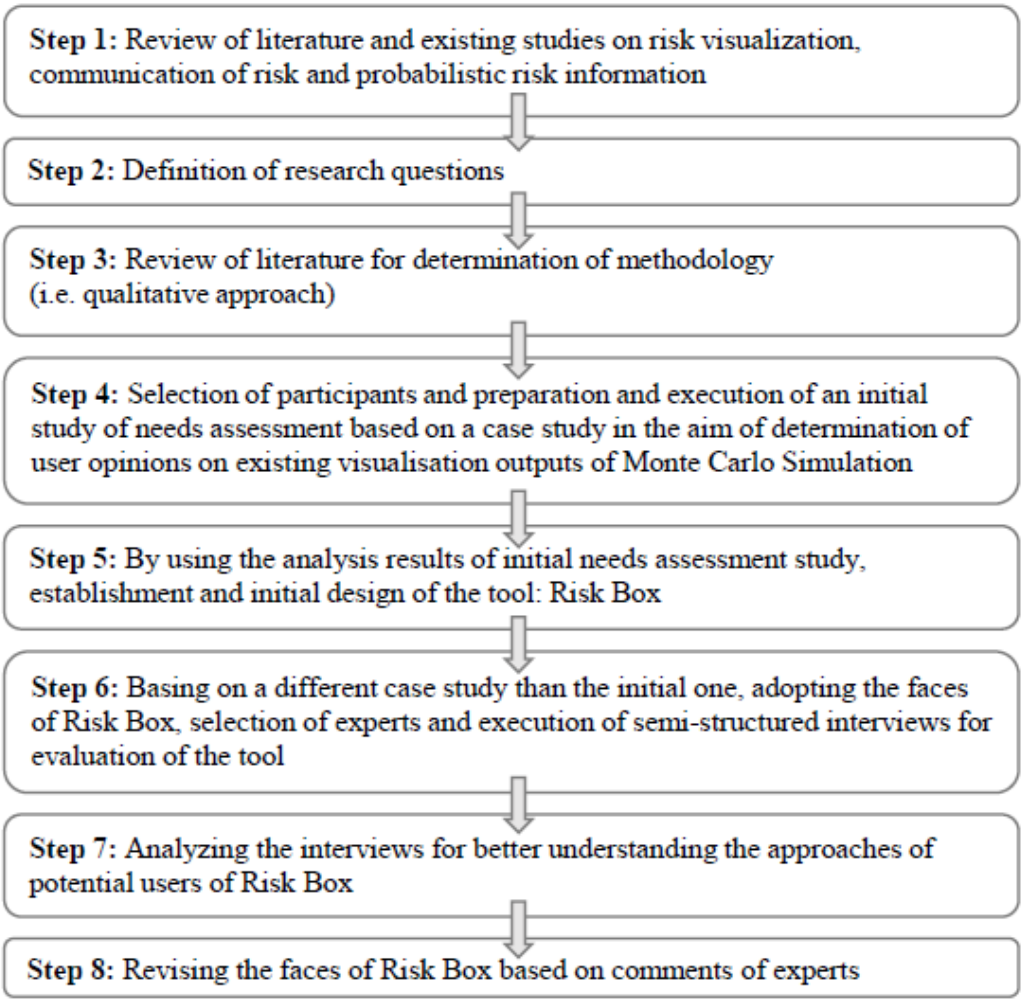


Figure 3.2 Research Steps

CHAPTER 4

RESEARCH FINDINGS

This section summarizes the findings of the research, which are executed as two steps for the evaluation of visualization formed as a result of risk analysis.

4.1 Initial Study on Needs of Decision-Makers about Risk Visualization

By looking at the sample studies in literature, where some of them have been briefly explained in the previous sections, the initial study of this thesis has decided to be conducted as an online survey based on a case study for assessment of the needs. In this initial study, 15 participants have been selected according to their knowledge and experience in the construction industry as well as their experience in decision making. In this group, a mixture of experts has aimed to be selected in terms of risk management knowledge.

As can be seen in Table 4.1 below, the experts have chosen to have experience in industry with more than 10 years in management positions while having various risk knowledge.

In addition, the notation of “F” for “Familiar” and “U” for “Unfamiliar” has been used to define the familiarity of the participants with risk and risk management and will continue to be used in the following sections.

The information on participants have been provided below:

Table 4.1 Participants in Initial Study (*F= Familiar, U= Unfamiliar)

ID	Education	Years of Experience in Industry	Current Title	Familiarity with Risk*
P1	MSc, MBA, PMP	26	Project Director	F
P2	MSc	26	Project Planning and Control Man.	F
P3	MSc	24	Company Manager	U
P4	MSc	31	Company Manager	U
P5	MSc, MBA	26	Contracts Manager	F
P6	MSc	26	Chief Executive Officer	U
P7	MSc, Global Finance	26	Deputy CEO	F
P8	BSc	14	Project Coordinator	U
P9	BSc	11	Project Coordinator	U
P10	BSc	14	Project Coordinator	U
P11	PhD	10	Head of Tendering	F
P12	MSc	26	Project Director	U
P13	PhD, PMP, FCIArb, LLM	12	Senior Planning and Claims Eng.	F
P14	PhD, PMP, EIT	20	Senior Project Scheduler	F
P15	BSc	19	Project Coordinator	U

4.1.1 Execution of the Initial Needs Assessment Study

The initial study for needs assessment has been executed based on a case study which is the report for the results of a schedule risk assessment belonging to a mega construction project conducted in Turkey. However, the details of this project cannot be disclosed due to confidentiality.

In this regard, a questionnaire established from the parts of the schedule risk analysis report for the case study has been prepared and distributed to the participants, also provided in Appendix A. In the questionnaire, the participants have been briefly informed on the project, the steps of risk assessment done, some assumptions and risks, and the aims of the risk assessment; which are to evaluate the likelihood of the project achieving the target schedule and the most sensitive activities/risk events for the schedule. For the questionnaire, open-ended questions have been used to learn about the risk-related information the participants have understood and/or willing to learn. Followingly, the traditional outputs (i.e. frequency chart and tornado chart) have been provided which are also presented in Figure 4.1, and the information gained from these visuals has been asked. In the end, participants' comments on the visuals are also taken, together with their wishes in terms of visualization of such risk information. Since the report belongs to a schedule risk assessment, participants have also been asked to focus on the schedule aspect for their comments.

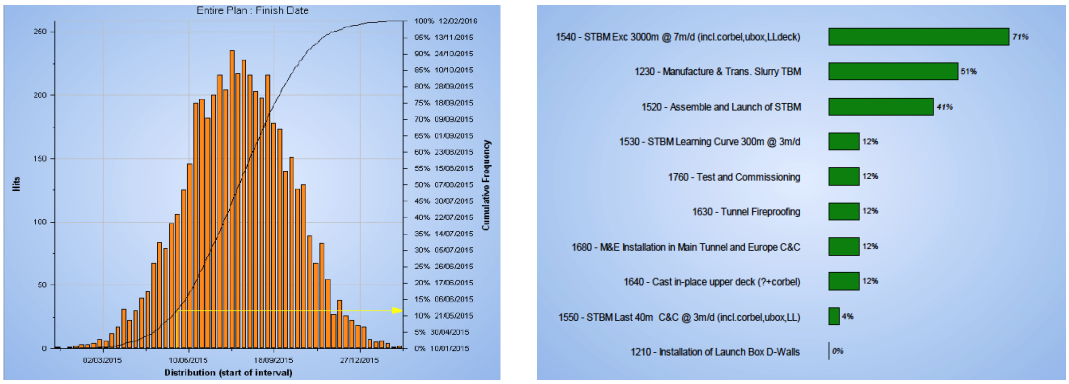


Figure 4.1 Visuals Provided to Experts in Initial Needs Assessment Study

4.1.2 Results of the Initial Study

For the presentation and analysis of results, summary tables have been prepared. The tables are established based on participants' comments to the questionnaire, primarily including numerical data. Therefore, before beginning, it is vital to emphasize that the aim is to understand the participants' points of view and to form a basis on the general common points of understanding. Therefore, the obtainment of a statistical result is not within the objectives of this study. Hence, one can interpret the numerical values in this section as the representation of the reviews and comments of a group of experts on the risk analysis visualization taken from a real-life schedule risk analysis report to be further used in the improvement of risk information visualization.

Firstly, in the questionnaire, participants have been asked about their requests and expectations from a schedule risk analysis report before seeing the results of risk analysis. The items have been stated as:

Table 4.2 Comments of Participants Regarding the Items Requested to be in a Schedule Risk Report

Items requested to be in a schedule risk analysis report
Overall impact (cost-schedule & interrelations)
Individual risks (key risks, risk register etc.)
Mitigation strategies and costs
Probability of risks
Best-Worst Case Scenarios
Sensitivity info
Mitigated vs. unmitigated risk impacts
Timing of risks
Key assumptions
Residual risks

As can be seen from the figure, there have been common answers given to this question. Participants have requested to see the combined cost effect, strategies to

mitigate or strategies already applied to mitigate the risks, and comparison as before-after in addition to probabilities of risks, the best- and worst-case scenarios, information on sensitivity.

Later, participants have been provided the probability distribution chart (i.e. frequency chart), and tornado chart prepared for the case project, and asked to analyze the information presented. For instance, participants have been requested to provide numerical data they understand from the charts, such as the probability of finishing before a specific date.

Table 4.3 Results of Comments on Probability Distribution Chart and Tornado Chart in Initial Needs Assessment Study

Distribution Chart			
	TOTAL	**F**	**U**
Correct interpretations about chart	80%	86%	75%
No correct answer / satisfactory answer	20%	14%	25%
Finds the visual hard to read / understand	47%	14%	75%

Sensitivity Chart			
	TOTAL	**F**	**U**
Correct interpretations about chart	60%	71%	50%
No correct answer / satisfactory answer	40%	29%	50%
Finds the visual hard to read / understand	53%	29%	75%

In the end, it has been seen that participants have given more correct answers for the distribution chart than the sensitivity chart. Upon this, 47% of respondents have found the distribution chart hard to read/understand, where this percentage is 53% for the sensitivity chart (i.e. tornado chart). These percentages have even become 75% when only “Unfamiliar” respondents are considered. In the end, it is possible to evaluate the results such that a great majority of the respondents have found these two charts to be challenging to comprehend, especially those who are unfamiliar with

risk. In addition, it has also been seen that the sensitivity chart has been less understood than the frequency chart, which is believed to be an important finding.

Next, participants have been asked to comment on the level of information they gained on the charts considering some aspects such as their level of uncertainty of project completion date or the significant risk factors and events.

By looking at the figure in Table 4.4 showing the results, one can conclude that although respondents have indicated their level of information as “strong” about possible completion dates and probabilities, the level of information about “level of uncertainty” is low-medium. In other words, although participants have “acquired” enough information on the possible completion dates and probabilities, they evaluated their level of knowledge as low-medium on the level of uncertainty which the variance can be visually seen from the charts.

These results may further be interpreted such that the respondents may experience difficulties in understanding what they “see” in the charts; hence they may need additional tables and information. Participants have also indicated their level of information on significant risk factors as “low”, and mostly “undecided” about their impacts. This finding may reveal why they need a risk matrix/register accompanied by Monte Carlo Simulation outputs.

Table 4.4 Results for Level of Information Acquired by the Charts in Initial Needs Assessment Study

Level of information acquired by the charts	**Undecided**	**Low**	**Medium**	**Strong**
Level of uncertainty (risk level) of project completion date	0%	47%	47%	7%
All possible project completion dates and their probabilities	7%	27%	7%	60%
Confidence level regarding the contract/tender duration	13%	33%	33%	20%
Significant risk factors/events	13%	40%	13%	33%
Most likely, optimistic and pessimistic scenarios	27%	20%	47%	7%
Impact of individual risk factors on project completion date	20%	27%	27%	27%

Furthermore, participants have further been requested to evaluate the schedule risk of the project basing on the provided charts. The probabilities calculated by Monte Carlo Simulation show that given the milestone dates, schedule risk is “low” in this project. However, as can be seen from the figure of the results, 47% of respondents are undecided, and this ratio is even higher for “U” respondents. In addition, in this initial study, 43% of F respondents have evaluated as “low risk” whereas only 13% of U respondents have evaluated the project as “low risk”. By looking at all this data, one may interpret that these results may be because respondents do not believe in the outputs of Monte Carlo Simulation or cannot understand the outputs and trust their judgments.

Table 4.5 Results of Evaluations by Participants of Project Schedule Risk in Initial Needs Assessment Study

Evaluation of project schedule risk	TOTAL	F	U
High	27%	14%	38%
Low	27%	43%	13%
Unknown/undecided	47%	43%	50%

Furthermore, when the participants have been asked to comment on the existing visuals (frequency chart and tornado chart), the results below in Figure 4.2 have been obtained. As can be seen, nearly all participants have requested different/improved/more detailed visuals finding the existing visuals as confusing / not sufficient. Finally, participants have also been asked to state their "ideal risk pictures" for such a risk analysis report. Some common answers such as risk matrix have been taken for the additional information and quantitative data and tables, summarized information, and executive summaries have been taken for representation of data.

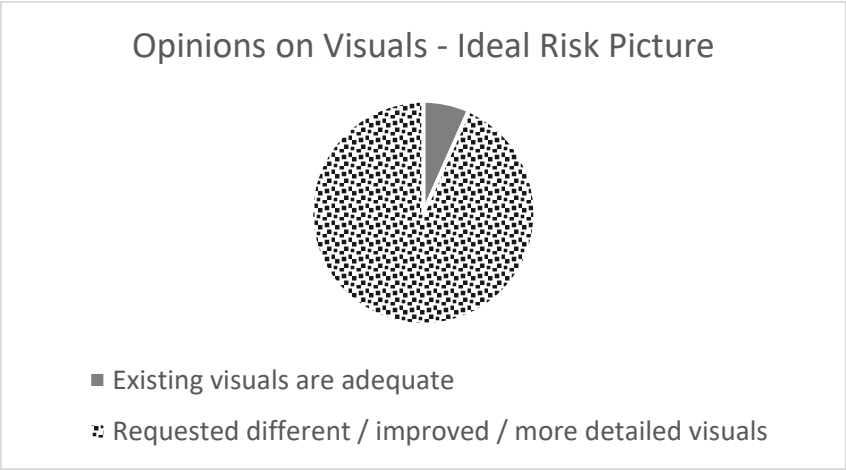


Figure 4.2 Results of Opinions of Participants on the Visuals in Initial Needs Assessment Study

To summarize, it has been identified from this initial needs assessment study that participants have been examining difficulties in the information they have seen on the visuals formed traditionally for Monte Carlo Simulation, and this is regardless of their familiarity with risk knowledge. Although some of the respondents has come up with comments on the data on visuals, they still had difficulties on understanding of overall riskiness (in terms of schedule) of the case project requesting more information. However, for a report that aimed to give enough information to managers so that they can understand the level of schedule risk in this project, having these results may point to a problem that needs to be solved on visualization of the risk-related information. At this point, it shall be once again reminded that the aim is not to have a statistical basis but to gain insights for the understanding achieved by a group of experts experienced in the industry.

4.2 Why Risk Box?

Using the results of this initial study, it has been believed that a different visualization approach of risk outputs is necessary. Hence, a tool, “Risk Box” has decided to be developed.

Risk Box is intended and designed as a “box” having different and complementing data at different faces regarding the results of risk analysis and risk-related information. This way, the aim has been to support decision-makers in understanding the risk analysis results via assisting them in ending up with informed decisions.

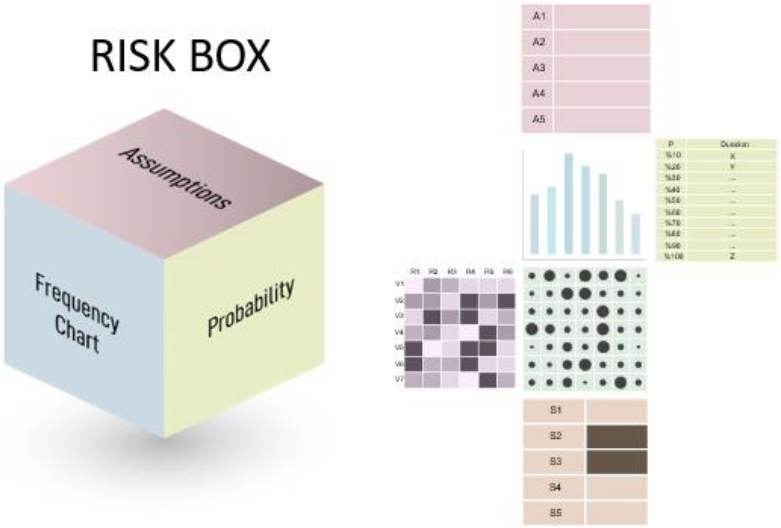


Figure 4.3 Initial Risk Box Idea

It is necessary to explain the main aim of choice for the “box” shape. Initially, the shape offers the option of a vast visualization area via its six faces; hence, it may integrate different sources of information about risk (individual risk factors, scenarios, probabilities, strategies, assumptions, etc.) and other visual representations. In addition, while providing many risk data in one place, it helps to reveal the hidden information in Monte Carlo outputs such as the risk and risk-prone variables for each scenario in the frequency chart that is not seen in the chart itself). Finally, it creates a solid image on users’ minds while representing the required information in a simpler way. Hence, this common geometrical shape of “box” can be mentally visualized in an easy way while creating the basis for the concept of “unfolding the box” via actually unfolding each face to get risk-related information to reach or support a decision.

Furthermore, Risk Box is designed as an interactive tool since the user can change aspects and see the results to compare. With this option, it can be used during the project at different stages.

4.3 Selection of Risk Information to be Visualized in Risk Box

For the selection of the information to be visualized on the faces of Risk Box, the results of the literature survey and the findings of initial needs assessment study have been used.

First of all, since the participants of the initial survey do not negatively comment on the data presented but the representation of it, frequency chart and tornado chart results have decided to be kept but decided to be demonstrated in different ways in the faces of Risk Box. Another reason is that the outputs are already in the nature of the simulation, hence the information provided in both charts have decided to be kept.

In addition, risk-matrix has planned to be included for the establishment of a basis for decision-makers in better understanding of the risks and the variables. The reasons behind are that it is a commonly used way for risk identification and analysis procedures (Duijm, 2015), (Thomas et al., 2013) and participants in the initial needs assessment study have requested to see such information.

Next, by utilizing the requests of participants in the first study to represent the assumptions behind the analysis, a face dedicated to assumptions has planned to be included.

Finally, a face for risk prone variables and their corresponding values obtained at the end of risk analysis has been designed for the provision of a connection between risks, variables, and the results of analysis, which is again aimed to be provided for support in the understanding processes of decision-makers.

4.4 Design of Faces of Risk Box via a Case Study

Upon the initial idea of the Risk Box, a case study has decided to be used for the establishment of the sample faces. A case study has been selected as the feasibility of a ready-mix concrete plant where the main criterion for the investor has been the payback period of this investment. The target of 6 years has also been chosen for the desired payback period in order for the participants to establish a base for easier commenting and utilization of the Risk Box.

The risks and variables defined for the case study have been demonstrated below:

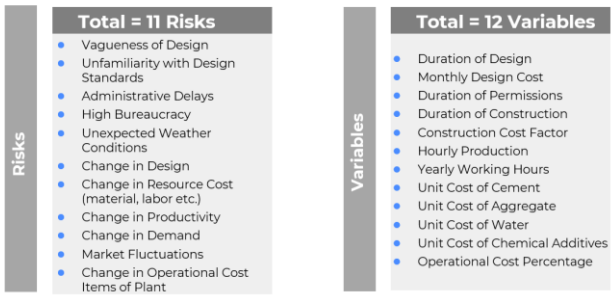


Figure 4.4 Risks and Variables Defined for the Case Study

Later, a risk matrix has been established, distributions have been given to the variables, and Monte Carlo Simulation has been conducted by using @Risk software. Via utilization of the results, the faces of Risk Box have been formed.

Before the presentation of each face of the box, an initial vision can be provided as below in Figure 4.5.

Figure 4.5 Risk Box for Case Study

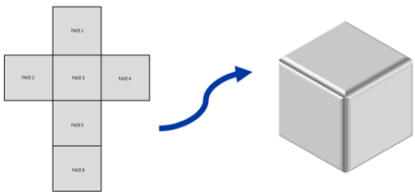


Figure 4.6 Visual Representation for the Concept of "Unfolding the Risk Box"

To begin with, the Figure 4.7 demonstrates the first face of the Risk Box, Face-1 (Frequency Chart), which is the frequency of the scenarios for the payback periods (i.e. less than 6 years, 6 - 7 years, 7 - 8 years, 8 - 9 years and more than 9 years) found as a result of Monte Carlo Analysis. A 10x10 figure has been utilized to represent a 100% overall where for each scenario, the probability of occurrence has been shown as the colored circles within the visual. For instance, if a scenario has a probability of occurrence of 35%, 35 out of 100 circles have been colored. In addition, as the color choice, red color has been selected for the target (i.e. 6 years of payback period) for ease of differentiation from other scenarios. For the others, shades of a selected color, i.e. grey, have been used. Finally, a legend has been provided showing the corresponding color and scenario.

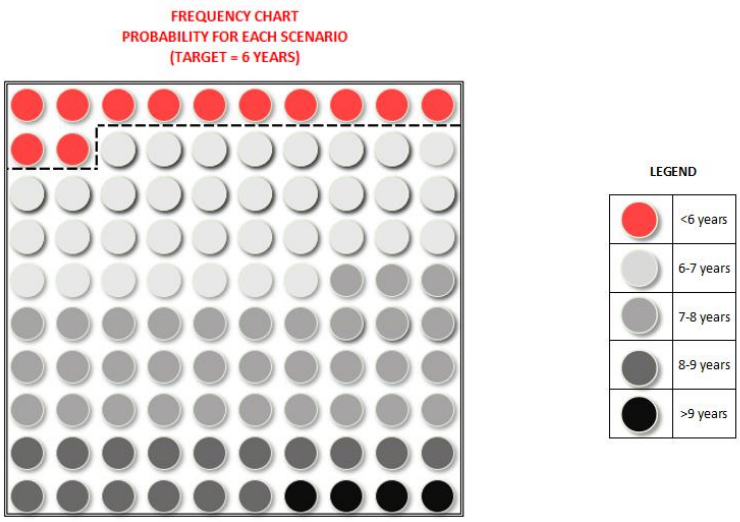


Figure 4.7 Face - 1 Frequency Chart

Moreover, the Figure 4.8 demonstrates the second face, Face-2 (Statistical Information), that has tabular information on again the results of Monte Carlo Analysis. This face includes the best-case scenario (years), worst-case scenario (years), mean (years), median (years), standard deviation (years), coefficient of variation, %90 percentile (years) as well as the target and its probability.

Information on Scenarios	
Best Case	4,64 years
Worst Case	10,69 years
Mean	7,14 years
Median	7,07 years
St. Dev.	0,96 years
Coef. of Var. (St. Dev. / Mean)	0,13
90% Percentile	8,0-8,5 years
Target	**6,00 years**
Cum. Prob. to Reach Target	**12,0%**

Figure 4.8 Face 2 - Statistical Information

In addition, the Figure 4.9 demonstrates the third face, Face-3 (Sensitivity Analysis), which is a representation of the results of sensitivity analysis for the variables. The abbreviations, variable names and related units have been included in the visual where a final column exists for the results of the analysis. Here, a color scheme has been used from red to green and their shades which implies the order of sensitivity. In addition, red color has been used for the most sensitive five variables and green for the remaining. For instance, the variable that is the most sensitive (i.e. UCC-unit cost of cement) has been shown in a darker shade of red and a greater magnitude of a bar, where the least sensitive variable (i.e. OCP- operational cost percentage) has been shown in a lighter shade of green and a smaller magnitude of bar.

Variable		Unit	Difference Between Minimum and Maximum Values of Payback Period at the End of Sensitivity Analysis
UCC	Unit Cost of Cement	TL/kg	
UCA	Unit Cost of Aggregate	TL/ton	
DC	Duration of Construction	months	
CCF	Construction Cost Factor	TL	
DD	Duration of Design	months	
UCCA	Unit Cost of Chemical Additives	TL/liter	
YWH	Yearly Working Hours	hr	
HP	Hourly Production	m3/hr	
DP	Duration of Permissions	months	
UCW	Unit Cost of Water	TL/liter	
MDC	Monthly Design Cost	TL	
OCP	Operational Cost Percentage	%	

Figure 4.9 Face 3 - Sensitivity Analysis

Furthermore, Figure 4.10 demonstrates the fourth face, Face-4 (Risk Matrix), a traditional risk matrix formed by only the most sensitive five variables. Here, the columns have been used for the risks and the rows for the five variables. Finally, the color scheme of red-yellow-green has been preferred for high, medium, low, respectively, where a legend in this regard has been provided.

MOST SENSITIVE 5 VARIABLES	Change in Resource Cost (material, labour etc.)	High Bureaucracy	Vagueness of Design	Administrative Delays	Change in Design	Change in Demand	Market Fluctuations	Unfamiliarity with Design Standards	Change in Productivity	Unexpected Weather Conditions	Change in Operational Cost Items of Plant
UCC Unit Cost of Cement	🔴	🟢	🟢	🟢	🟢	🟡	🔴	🟢	🟢	🟢	🟢
UCA Unit Cost of Aggregate	🔴	🟢	🟢	🟢	🟢	🟡	🔴	🟢	🟢	🟢	🟢
DC Duration of Construction	🔴	🟡	🟡	🟡	🟡	🔴	🟡	🟢	🔴	🔴	🟢
DD Duration of Design	🟢	🔴	🔴	🔴	🔴	🔴	🟢	🔴	🟢	🟢	🟢
CCF Construction Cost Factor	🔴	🟡	🟢	🟢	🟡	🟢	🟡	🟢	🟡	🟢	🟡

LEGEND

LEVEL	SYMBOL
HIGH	🔴
MEDIUM	🟡
LOW	🟢

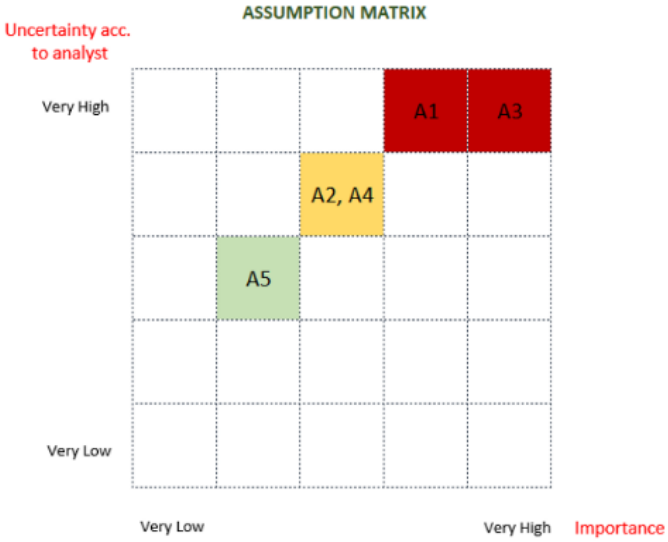
Figure 4.10 Face 4 - Risk Matrix

Last but not least, Figure 4.11 demonstrates the fifth face, Face-5 (Risk Prone Variables), which is a visual for risk prone variables established by the most sensitive five variables as well as their units. Here, the columns represent the scenarios in the first face, where cells include the average value of the variable in the scenario. On the other hand, the two columns on the right-hand side have been formed in the same manner but for the best and worst-case scenario. Moreover, for the columns of scenarios (i.e. columns 3-7 from left), bars have been used for each cell where the magnitude of the bar represents the relative magnitude for the variable. For instance, for variable UCC – unit cost of cement, the largest average has been obtained for the scenario of larger than nine years; therefore the greater magnitude of the bar for the row has been given to the related cell.

VARIABLE	UNIT	AVERAGE VALUE OF MOST SENSITIVE 5 VARIABLES IN EACH SCENARIO					VALUE IN BEST & WORST SCENARIOS	
		<6,0 years	6,0 - 7,0 years	7,0 - 8,0 years	8,0 - 9,0 years	>9,0 years	Best (4,64 years)	Worst (10,69 years)
UCC Unit Cost of Cement	TL/kg	0,286	0,293	0,299	0,303	0,307	0,285	0,309
UCA Unit Cost of Aggregate	TL/ton	47,476	48,628	50,067	51,155	51,739	47,384	51,952
DC Duration of Construction	months	7,91	8,80	9,14	9,52	10,23	7,773	10,902
CCF Construction Cost Factor	TL/ton	29.183.321	29.926.567	30.045.547	30.289.390	30.758.724	27.197.216	31.402.202
DD Duration of Design	months	3,869	3,972	4,013	4,075	4,079	2,767	4,296

Figure 4.11 Face 5 - Risk Prone Variables

Finally, Figure 4.12 demonstrates the final and sixth face, Face-6 (Assumption Matrix), which is a matrix for assumptions filled in by the risk analysts where the vertical axis shows the level of uncertainty of the assumption to the risk analyst and the horizontal axis shows the importance of the assumption. IDs for assumptions have also been given, and a legend has been provided on the right-hand side for this reason. Later, assumption IDs have been placed in the matrix considering the levels on the axes. For instance, if an assumption has been evaluated by the analyst to have a level of uncertainty of high and importance as high, its ID has been placed on the right upper side to the related location. After placement of all assumptions in the matrix, color coding has been used such that for the assumptions having high levels of uncertainty and importance, they are in darker shade of red and the color has been faded to red - yellow for the assumptions having relatively low importance / uncertainty.



LEGEND

ID	Explanation
A1	Extreme conditions such as force majeure events or contractual risks have not been taken into account
A2	Interest rate has not been taken into account
A3	Same contractors are assumed to be providing services / materials until the end of payback period
A4	No change of bureacratical procedures are assumed
A5	Productivity of contractors are assumed to be maintained during payback period

Figure 4.12 Face 6 - Assumption Matrix

In short, the faces of Risk Box have been determined and designed based on the results of the initial needs assessment study and literature review, to in the end fold together to form a “box” which will act as an aid to the decision-maker for ending up with an informed decision by providing rich content of risk data.

For the evaluation of Risk Box, which is presented in this section, a qualitative research step has been followed for a group of experts, which shall be detailed in the following section.

4.5 Methodology of Evaluation of Risk Box

In order to get the feedbacks on the Risk Box, semi-structured interviews have decided to be conducted online with 5 participants selected among experienced experts. Like the initial study, the selection has aimed to be a diverse pool of experts in terms of risk knowledge but making sure that they have been experienced in

project management. In this manner, the information of the experts selected for this second step has been provided below in Table 4.6:

Table 4.6 Expert Information Participated in Evaluation of Risk-Box

	EXP1	**EXP2**	**EXP3**	**EXP4**	**EXP5**
Education Level	PhD	PhD	MSc	PhD	MSc
Total Years of Exp. in Constr. Industry	20+ years	10+ years	20+ years	10+ years	20+ years
Current Job Title	Risk Consultant	Chief Risk Officer	Executive Manager	Project Manager	Executive Manager
Knowledge on Risk Analysis	HIGH	HIGH	MED-LOW	HIGH	MED-LOW
Duration of Interview	47 mins	50 mins	40 mins	50 mins	50 mins

In order to be used in analyses, the interviews have been recorded prior to the consent of participants. The interviews have generally been conducted in Turkish however, since all participants have a good understanding of English, the main terms and concepts have been discussed in the English language. Later, these recordings have been transcribed and translated at times of necessity.

The presentation used during interviews is provided in Appendix B. Interviews have begun by recalling the Monte Carlo Simulation and the logic behind the inputs and outputs for the risk analysis. The aim of this introduction is to briefly remind the experts on Monte Carlo Simulation or to briefly introduce the method to the experts who have less knowledge on risk analysis. Later, the case study of feasibility has been presented, and experts have been asked to place themselves as the investor for this feasibility project to act as a decision-maker. They have also been told that their main target, which is selected as payback period, is six years.

Later, each face of Risk Box formed as a result of risk analysis has been presented. The expert has been given some minutes for review, and the comments on the visual have been taken. After this has been done for each face, the general questions section has begun. Seven questions listed below have been asked regarding the Risk Box itself:

1. Please assign scores from 1-5 (1 if you strongly disagree and 5 if you strongly agree) for the following qualifications regarding the "Risk Box in general":
   a) Easy to understand (clear)
   b) Informative
   c) Efficient (useful for the decision)
   d) Aesthetically appealing
2. Which face is the face (or faces) that has/have remained in your mind? List the most important (critical for your decision) information you get from the Risk Box.
3. Do you think you can generate some strategies to increase feasibility of this Project based on what you learned from Risk Box? Could you please share any of these suggested strategies?
4. As a result, what do you think about feasibility of this investment? Are you confident about your decision? Any missing information that would help you to increase your confidence?
5. Could you please comment on the positive attributes of the Risk Box? (consider potential positive impacts on your decision and decision-making process)
6. Could you please comment on the negative attributes of the Risk Box?
7. As a decision maker, would you want to use this visualization tool in your real-life projects? If yes, where, or for what purposes you can use it?"

At the end of each question, including the questions asked for each face, additional comments of experts, if any, have also been asked to be given, and feedbacks have been taken. The interviews have all been recorded to be further used in the analysis.

4.6 Methodology for Analysis of Semi-Structured Interviews

For analysis of the interviews, MAXQDA software has been used.

Since each interview is recorded, following to consent of experts, transcripts have been established from each record. Due to the fact that interviews have been planned and conducted in a semi-structured manner, questions prepared and defined above have been asked to each participant.

Hence, the answers, other than the personal information, have been grouped in this manner for the analysis such that six questions for each face of Risk Box, and seven general questions at the end, where the first general question have been further divided into 4 subgroups. The grouping and IDs have been provided below in Table 7:

Table 4.7 IDs of Questions for Each Face of Risk Box

No	ID	Question
1	FACE1	All comments of expert on the face 1 – frequency chart
2	FACE2	All comments of expert on the face 2 – statistical information
3	FACE3	All comments of expert on the face 3 – sensitivity analysis
4	FACE4	All comments of expert on the face 4 – risk matrix
5	FACE5	All comments of expert on the face 5 – risk prone variables
6	FACE6	All comments of expert on the face 6 – assumption matrix

Table 4.8 IDs of General Questions on Risk Box

No	ID for Coding	Question
1	Q1a	Scoring of expert for Risk Box in terms of clarity (1-5 scale)
2	Q1b	Scoring of expert for Risk Box in terms of informativeness (1-5 scale)
3	Q1c	Scoring of expert for Risk Box in terms of efficiency (1-5 scale)
4	Q1d	Scoring of expert for Risk Box in terms of aesthetics (1-5 scale)
5	Q2	Face remained in expert's mind
6	Q3	Can the expert generate strategies – if yes, examples
7	Q4	Evaluation of feasibility and necessity of additional information for this decision
8	Q5	Positive attributes of Risk Box
9	Q6	Negative attributes of Risk Box
10	Q7	Wish to use in real-life and purposes

Later, for experts, the following IDs have been used: EXP1, EXP2, EXP3, EXP4, and EXP5 relative to the order in which the interview has been conducted. Followingly, a matrix has been formed with experts' personal information of education level, experience in the industry, familiarity with risk, as well as their answers to the asked 16 questions in total (presented in Table 4.7 and Table 4.8 above). This matrix has been formed to be further utilized as a basis for the software MAXQDA.

After this sorting, the spreadsheet formed by the matrix has been directly imported to MAXQDA. At first, the information in the matrix has been identified and sorted by the software itself where further manual interventions have also done. In the end, the information in Figure 4.13 has been obtained where "imported texts" have been

assigned for experts, “imported codes” for each question answered, and “imported variables” for the personal information of the experts. The fact that “ignored documents” has been found as zero shows that no information has been neglected to be imported.

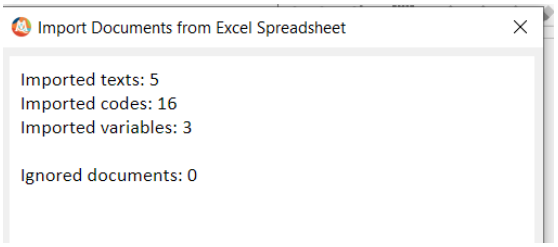


Figure 4.13 Import Information Output from MAXQDA

Hence, by using this methodology, each transcript of the expert has been separated and treated as a separate document by MAXQDA. In addition, the grouping of answers and the assignment of ID for each has been treated as “codes” by the software; therefore, after import, the transcripts have already been “coded” and ready for analysis.

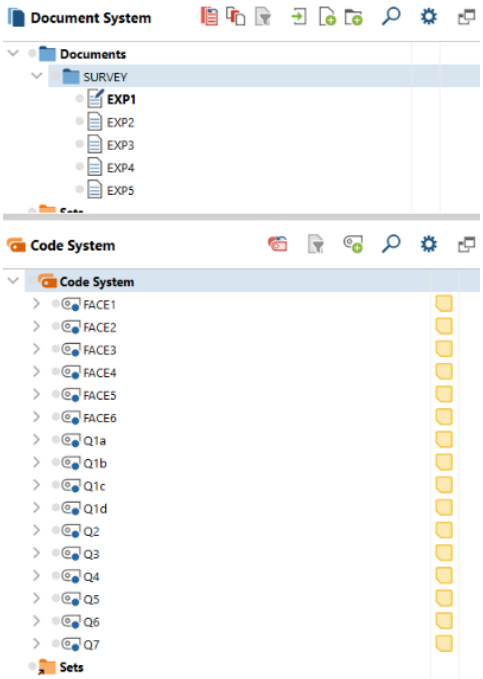


Figure 4.14 First Import to MAXQDA

Then, for each question further subcodes have been formed by analysis of the answers where this will be explained in the following sections.

Initially, as the software already grouped and coded the questions, whole set of documents and the answers for a question has been selected to see all answers to the same question. Later, word cloud analysis has been conducted by using the software by also ignoring some of the words such as “and, the, a” etc. With this initial elimination, it has become possible to see mostly recurred words for each question. Here, subcodes have been formed by these words, and sub-codes have been established to the related question.

Later, the “categorization of the survey data” option of the software has been used by selecting the code of the question. With this option, it has become possible to see once again all answers to the question and the subcodes assigned to the answer. Here, the answers where no subcodes exist have been focused on and assigned under the existing subcode or a new subcode has been created. Following this action, the “complex coding query section” of the software has been used to check if any answer has been left uncoded.

In addition, the words having the common stem have also tried to be detected by the word cloud and assigned to the related subcode. Moreover, in case of detection for a word within the transcripts having a typo, as it does not occur or adds up to the frequency of the specific word, it is manually added to the subcode.

After this semi-automized coding done with the applications provided by the software, manual checks have been done to check if there is any incorrectly assigned answer due to the context. For this reason, answers by all experts for a certain question have been analyzed together and subcodes have been further corrected or added to the question’s code.

For some subcodes, a hierarchical approach has been followed. For instance, comments on aesthetics for faces have been further divided into groups such as comments on colors, comments on dimensions etc. since they are related to aesthetics of the visual but required additional divisions.

One of the initial principles followed during coding has been the coverage. If the established code has found to be deficient in comprising the answer as a whole, either the code has been changed, and items assigned to the code before has been re-reviewed or an additional subcode has been established.

After conducting these steps for each question, the re-checks and reviews have been done in an iterative way to reach the finalized version ready for further comments.

4.7 Analysis of Results

4.7.1 Analysis of Comments on Faces of Risk Box

4.7.1.1 Face 1 – Frequency Chart

As also remembered, the first face of the Risk Box has been prepared inspired by the traditional frequency chart visual of the Monte Carlo Simulation showing the overall frequencies of each scenario of payback period.

For all participants, highly positive feedback has been taken for this face. Regardless of risk knowledge, all participants have stated that they can easily understand this face at first glance, and they all understood that this is a visual showing the probabilities of different scenarios.

> *EXP1: "I see from this visual that someone has done feasibility analysis, his target was 6 years and presents the results in a visual."*

EXP2: "I am looking at the visual and seeing that there are I guess 100 dots colored corresponding to different scenarios."

EXP3: "When I first looked, without even looking at legend, I can see that the different colors will correspond to different outputs. (...) I find the visual very easy to understand."

EXP4: "This visual shows the outputs or scenario like the traditional frequency chart."

EXP5: "I can see that there are 100 circles in the visual, and I have understood that the possibility of a scenario is the number of colored dots."

It has also been detected that all of the participants have successfully identified the probability of the target payback period scenario as %12 percent where some of them commented, without seeing other faces, that this is a low percentage for a target:

EXP1: "If I were to think like I am the investor himself, and this is the information given to me, I can see that it is nearly 12% to reach the target of having a payback period less than 6, where 12% is a small number in case I am the decision maker. I can see that with %88 probability, the payback period will be larger than my target and this is not good since once the payback period is higher, it shows that my investment will pay back to me in a later time."

EXP2: "Approximately 12% is the percentage that I can reach my target. (...) Hence, I understand that I most probably cannot reach my target."

EXP4: "A 6 year of payback period is understood to be 12% from the visual and it is very small compared to other scenarios."

Similarly, participants have also commonly mentioned the scenario of payback being larger than 9 years:

EXP1: "Here, it seems like having a payback period more than 9 years do not seem high."

EXP2: "I see that around 4% of probability, the payback will be 9 years."

EXP5: "I can very clearly see that there is a little probability for being more than 9 years."

Moreover, by looking at this face, all of the participants have commented that the payback period will be most like be between 6-8 years.

EXP1: "If you look at the visual, it can be said that the possibility to be in between 6-8 years seems very high. When I count the circles, I can see that the payback period will be 6-7 years as it is the greatest possibility."

EXP2: "My project, with a higher probability, will end up in 6-8 years of payback period."

EXP3: "We can see that this project will most probably have a payback around 6-7 years or 7-8 years."

EXP4: "More probably, looking at the number of dots, I can say that the payback will be either 6-7 or 7-8, so it can be said that it is 6-8 years."

In addition, all participants stated that in the shoes of an investor, the information given by this face is highly useful for their understanding of the feasibility of the investment project. In addition, the following comments can be given for the usability mentions on this face:

EXP1: "This face shows me the possibilities of different scenarios, which is a good and useful information."

EXP2: "Of course this is a very useful information regarding the feasibility of investment."

EXP3: "The information given in this face is very useful and valuable and we want to see this specifically this information in an investment."

EXP4: "This is of course a very useful information."

EXP5: "A very important information to be used."

Moreover, all participants have stated that they have a positive attitude in terms of aesthetics, especially in understanding and distinguishing the target scenario from the visual.

EXP1: "Existence of different colors have enhanced the comprehensibility of the visual in terms of sorting out the scenarios."

EXP2: "The black and red makes it very easy to distinguish and take my attention."

EXP3: "Aesthetics of this visual is very nice."

EXP4: "I can easily calculate and see the possibility of a scenario directly when I looked at the visual."

EXP5: "The visual is very clear. I can get the information at the first glance without many efforts."

Finally, one of the participants has also mentioned that this visual is better in terms of understanding when compared to the traditional visual.

EXP4: "Considering the traditional visual, I am more easily understanding the probability to reach my target if I was to compare."

However, there also have been some suggestions to the face. For instance, the color choice has been mentioned by a few, stating that although the target can clearly be identified, the shades of grey for other scenarios can be hard to distinguish; hence a different color scheme can be used for each scenario.

EXP2: "Color choices can be different. (...) For the greys, I think it is hard to separate the shades and they are less understandable compared to black and red. They could have been a different color such as blue or green. But of course, if you look at in detail, it is understandable but when the colors are to be changed, it can become easier to understand."

In addition, few experts have also suggested mentioning the percentages in numbers in the legend together with the visual so that one does not have to count each circle but can easily see the number.

EXP1: "Maybe in the legend next to the visual, the exact percentages can be written so that I don't have to count each."

EXP3: "I may prefer the percentages written in the legend rather than counting the circles. But then the circles will not make any sense and the visualization logic behind might be lost."

Other than these mentioned modifications, no negative comment has been received for this face. More comments have also been made by references to this face in the general questions section, where they are more detailly examined in the related section.

4.7.1.2 Face 2 – Statistical Information

The second face of the Risk Box has been prepared in a tabular format showing the statistical information on the results of the Monte Carlo Simulation.

All participants have easily understood the face and commented that it is a common, frequently used visual requiring less effort to understand.

EXP1: "This information is presented as a table which I believe is very explanatory."

EXP5: "The visual is as clear as crystal."

All participants mentioned the usefulness of the information on best- and worst-case scenarios. All of them stated that knowing their best option and their worst option will be useful in their decision of the investment.

EXP1: "On the previous face I could not see for instance the 4,64 years (best-case) information. This face is important in this manner since it demonstrates the values of best and worst-case scenarios."

EXP5: "I can very clearly see my best and worst case options if I want to decide on a business."

EXP2: "It is very important to see the best, worst and the mean."

In addition, only one participant has commented on the %90 percentile information on the visual:

EXP2: "I also think that the information on %90 percentile is very important, with %90 percent probability, the project will have a payback of 8,5 years."

Many mentions about the mean and median information on this face have been made. However, common feedback has been taken from all such that the terms "mean" and "median" are too statistical where one may not remember the difference, and they both can be approached as "mean". Hence, all stated that this division may not be necessary and most probably confusing in understanding. Nonetheless, it is needed to mention that in spite of the experts having more familiarity with the risk analysis procedures have better understood the difference and made comments, they still believed that the existence of both might not be necessary in their evaluation of feasibility and only one may serve in this regard.

Moreover, considering the approach of experts explained above, most of the experts have stated that it is again useful in their decisions to know about the "mean" together with best and worst cases and compare with the target.

EXP2: "In my experiences, for the executive managers as they have limited time, they will most probably don't know the difference between mean and median, and mean or median will most probably do not make such a difference for them. Yes, this information is useful but not directly understandable."

EXP3: "Most of the information in this face is incomprehensible on my end. For instance, yes, I can understand best and the worst. I know mean and median is something like an average but I really do not know the distinction."

However, experts have commented that the information presented in this face is useful overall, especially in terms of seeing best, worst and mean.

EXP1: "This information is useful on my end."

EXP2: "Yes, this information is useful but not directly understandable."

EXP4: "Of course this is very useful, I can see that the possibility of 6 years is very low, and what happens if everything goes right or wrong, therefore this is useful for me."

Furthermore, the information on standard deviation has also been treated as unnecessary by all experts, reasoning that it is again a piece of very statistical information serving very little in their decision procedures. In addition, experts having medium-low knowledge on risk analysis could not understand the "coefficient of variation (CoV)" term and requested the definition having difficulty in understanding and processing in the end. Experts with high-risk knowledge, since they are familiar with the term, evaluated that although it is important information, this does not have a primary role in their decision of feasibility. Hence, this information is overall assessed to be unnecessary.

EXP3: "I am familiar with the term standard deviation but I do not know what 0,96 represents, is it something good or bad. Same with CoV."

EXP2: "In my experiences, for the executive managers as they have limited time, they will most probably don't know the difference between mean and median, and mean or median will most probably do not make such a difference for them. Yes, this information is useful but not directly understandable."

Finally, regarding the target information on this face, most of the experts have mentioned that they have already acknowledged this fact from the previous face (i.e. face 1) and have already evaluated this information to be very valuable. Where most participants think that the recurrence of the target is not fundamental, one expert stated that he would prefer to get this target information repeated at all faces.

EXP2: "I have already seen the target information on the previous face."

EXP4: "The possibility to reach the target has only been shown in one face and once can easily forget this information. I think this information shall be on every face, maybe as a footnote, as a reminder."

In terms of aesthetics, all participants stated that this is a commonly used format; hence nothing aesthetically special has been used; however, no negative comments in this regard have been recorded. Thus, their approach can be defined to be neutral for the aesthetics of this face.

EXP1: "There is no additional aspect of aesthetics in this table, but there also isn't anything disturbing either, it is a normal table."

EXP3: "It is a normal table, there is nothing much special."

4.7.1.3 Face 3 – Sensitivity Analysis

The third face of the Risk Box has been prepared inspired by the tornado chart for the results of the Monte Carlo Simulation.

For all participants, at first look, the visual cannot be directly understood, and participants required time to understand. For the participants having high-risk knowledge, since they are familiar with sensitivity analysis concept, after a quicker time, they could be able to comprehend the visual. In addition, all of them shared that this visual might be hard to read if the person does not know sensitivity analysis.

> *EXP2: "An information should be provided here for people who are not familiar with sensitivity analysis regarding how to read and analyze the information in this face."*

> *EXP3: "I am having difficulties in understanding the visual. Are they the inputs or outputs? I can make some guesses, but I think it will hard for people who do not know what sensitivity is."*

In addition, after time and a reminder on what sensitivity analysis if requested, all experts can be able to identify that this is an order of the variables in terms of sensitivity as well as the most and least sensitive variables.

> *EXP1: "I can see that UCA, UCC and DD are important variables to my payback period. I have to decrease the variation in these parameters if I want my project's feasibility to increase. (...) If I want to see the least sensitive one, it seems like it is monthly design cost."*

> *EXP2: "From this, once can understand that UCC, UCA and DD are the most important 3 variables that will affect the 6-year payback period the most under uncertainty, that are very critical."*

> *EXP5: "At the top, I can see variables such as UCC and UCA, meaning that they are the most sensitive ones. On the other hand, I can guess and see that monthly design is the least sensitive one effecting my payback period the least."*

Moreover, all participants have commented that the information is very beneficial for their decision procedures and has also been addressed in their strategies which will be again be discussed in the further sections.

> *EXP4: "This information is very, very useful. It shows what to focus on. The information on this face is among the ones that will be used in the decision."*

> *EXP3: "A highly valuable information has been shared in this face. These results of the analysis will be highly effecting in the future steps as well as evaluating the analysis itself."*

> *EXP1: "The given information is important because it shows that I need to consider these variables if I wanted to reach my target. (...) This visual provide information for my strategy on what to do."*

> *EXP2: "(....) (on the subject of positive attributes) it shows the sensitivity information, which I believe is very important."*

The color scheme has been found to be appropriate and supporting by all participants; hence the visual is generally evaluated to be good in terms of aesthetics.

> *EXP4: "As a visual, it is aesthetically adequate and clear."*

> *EXP1: "I like the aesthetics of this visual."*

In addition, there are also some suggestions made regarding the visuals. Nearly all participants have suggested that the titles in the visual can be simplified and clarified to assist in understanding.

> *EXP2: "The title is like an explanation rather than a title which might confuse the users."*

> *EXP5: "I do not clearly understand what is meant in the title and I wish it to be simplified."*

EXP4: "If the title is to be something like 'top risk variables' or 'most contributing variables', I believe the visual would be more understandable. In addition, a rating like 1-2-3 from top to bottom can also be done showing that this is an order."

Moreover, the units have been found unnecessary, and most of them commented that knowing the unit will not affect the sensitivity term in their minds.

EXP2: "I do not understand the units, are they necessary?"

4.7.1.4 Face 4 – Risk Matrix

The fourth face of the Risk Box has been prepared in the form of a risk matrix however narrowed down for the most sensitive five variables.

For this face, participants have both positive and negative approaches. Regardless of having high or medium-low risk knowledge, some of the participants commented that the visual is very clear and easily understood. However, there were also participants that felt confused by the visual:

EXP3: "Visual is very easily comprehensible."

EXP5: "I am having some difficulties in understanding this visual. Which one effects the other?"

All participants evaluated that the information is very useful.

EXP3: "This is a very handy visual showing the things affecting the most sensitive 5 variables that affect us the most."

EXP4: "Especially for seeing the risks and how / what they effect on the most 5 sensitive variables are very important."

In addition, by looking at this face, experts with high risk knowledge have mentioned their requests to see more risk information in this visual and believe these additions would be very helpful.

> *EXP1: "This matrix does not show me the magnitudes of risks but their effects. I may prefer to see the risk magnitudes or risk scores on the visual. For example, color codes can be given to the risks, if one of the risks is the most important one, it can be red, if not green etc."*

> *EXP4: "I wanted to see information on the risks in this face, for instance which risk affects which part of my investment?"*

Regarding the aesthetics, no negative feedbacks have been received from the participants.

4.7.1.5 Face 5 – Risk Prone Variables

The fifth face of the Risk Box has been prepared in a tabular form based on the most sensitive variables and their average values in each scenario.

Regardless of the risk knowledge, all participants stated that this visual is very complex and very difficult to understand. In addition, all of them requested further clarifications. However, after the clarifications, all experts have a very positive approach to the visual and find it very valuable not only to see the current situation but for making some comments about the alternatives and options as well:

> *EXP1: "For example, I can see that if I want to decrease the payback period to under 6 years, duration of construction must be near 7. But for instance, at the worst case, I can see that it is 10. This gives a meaningful result. In fact, the most important variable has a variance between 0,2 – 0,3."*

> *EXP5: "I do not understand the face and probably cannot without any help. However, after I have been clarified, I believe that this face gives very*

important and useful information. I can see my other targets, such as which variable shall be made to which value, that becomes my new target."

EXP4: "I think this face summarizes a lot of things. I can take the additional information that I am not able to from other faces. In addition, I can see what happens when the variable has been changed. (...) Basing on my experiences, I think the ability of seeing the most sensitive five variables is the most valuable information out of this Risk Box. This is because, for my previous companies as well as the current one, generally, a fixed contingency amount has been defined for risks during tender procedure according to strategic internal decisions of the company. Hence, once the project starts, the general approach becomes to find out strategies on how to / on what risk should this budget be used. Therefore, we try to come up with risks to reach the contingency amount as a risk analysis like this has not been conducted in the first place during tender. When these analyses are to be done, from the beginning, you know which aspects you should focus on. With this in mind, the face with risk prone variables have become the most important face to me since I am able to see everything from this face, even the values that I should reach, or I could reach once I changed my inputs."

In addition, the existence of units has been found very handy in this visual to help them compare the numbers for a variable. However, due to the nature of the values, the averages for scenarios have resulted as very close for some variables. Hence, some participants have difficulty in understanding the concept but acquired some clues from the units.

EXP3: "As I can recall from previous faces, duration of design (DD) is an important and sensitive variable, however, within these scenarios, an approximately 1-month variance can be seen, which I don't think is a major variance considering the investment. Alternatively for instance, the construction cost factor has changed very little, maybe 3-5 % but a dramatic

difference in payback period scenarios can be seen. I think this is due to the inputs used in the analysis and might change for some other situations, which enable the difference to be seen in a clearer way. (…) I also believe that unit is vital in this visual."

Most comment has been taken regarding the existence of the bars and too many numbers. Participants mentioned that it is the bars that they are mostly confused about.

EXP2: "To my experience, we generally use bars for representing percentages or progresses. For instance, for values greater than 9 years, the bars are full, giving me the sense that something has reached 100%."

EXP3: "I cannot understand what bars are for. I believe they make it hard to understand the visual."

EXP4: "As the numbers are complex and mixed, it is hard to understand."

EXP5: "Bars confused me. Before it has been explained, due to the magnitude of the bars, I have had the feeling that unit cost of cement is more important for scenarios 7-8 then 6-7. In other words, bars make me feel like an important comparison shall be made. However, with the explanations, I have understood that this is not the case."

For the presence of best and worst values, different comments have been received. A majority of participants mentioned that they would expect the best value to be lower than the smallest scenario and the worst to be vice versa. Aforementioned, due to the nature of the values resulted at the end of risk analysis in this case study, the value for best-case scenario and the average value for the minor scenario (i.e. less than six years) have been very close. Therefore, some participants found the existence of best and worst-case scenario values as avoidable.

EXP4: "It is always expected to see the best-case scenario to be the least and the worst case to be the greatest. Hence, I don't think the best and worst-case information is necessary."

Whereas some have found it very useful to see their ultimate best and ultimate worst value for a sensitive variable to see their overall opportunity;

EXP1: "I will prefer the existence of best- and worst-case scenarios in this visual."

Finally, an improvement has been mentioned by one expert:

EXP3: "I think a suggestion can be made at this point. I believe, at the first face, I see that the highest percentages belong to the scenario of 6-7 years, hence, the column of this scenario can be colored in a darker shade and the shade can be changed regarding the percentages. Because I think the comparison shall also be made not only horizontally but by vertically as well."

4.7.1.6 Face 6 – Assumption Matrix

The final and sixth face of the Risk Box has been prepared based on the assumptions made by the risk analysts during the analysis procedures.

All participants have reacted to this face very positively, and all of them mentioned how useful this information at the first time they have seen the visual. In addition, some of the experts noted that making the assumptions comparable is most certainly increased the effectiveness and practicality of the visual.

EXP2: "This is a very important face. In our analyses, we generally forgot to write down our assumptions which actually are a very important part during risk analysis procedures. Hence, not only noting them down but even to classify them is what I believe to be very useful."

EXP5: "I believe this information is one of the most important ones. I can also see how important this assumption is as well."

All participants have noticed the assumption in the top right corner during their initial examinations.

EXP3: "I think this table should represent the data among the ones to be presented on the upper right corner."

Regardless of risk knowledge, all of the participants have easily understood the visual, where they all found it pleasant in terms of aesthetics. However, although understandable, there have been comments that the term "uncertainty to analyst" can be revisited.

EXP2: "I could have understood the visual but I have been kindly affixed to the 'uncertainty to analyst' part. Maybe this term can be written in a different way."

EXP3: "I may prefer a different saying for the 'uncertainty' part."

Moreover, participants have also mentioned that for the next step, they would come and look at this face.

EXP1: "I can later come back to this face and ask the analyst again that what happens after I release an assumption."

As a suggestion, one of the participants have suggested that legend can be removed:

EXP4: "The visual on the left already summarized the whole point, hence rather than going back and forth between legend and visual, the assumptions can be written within the visual, maybe not as full sentences but by keywords maybe."

4.7.2 Analysis of General Comments on Risk Box

4.7.2.1 Question 1: Scoring

Although the aim of this study is not to analyze in a statistical point of view, during interviews, all participants have been asked to score from 1-5 the Risk Box overall for the following items: easy to understand (clear), informative, efficient (useful for the decision), aesthetically appealing. Scores have been summarized in Figure 4.15 below:

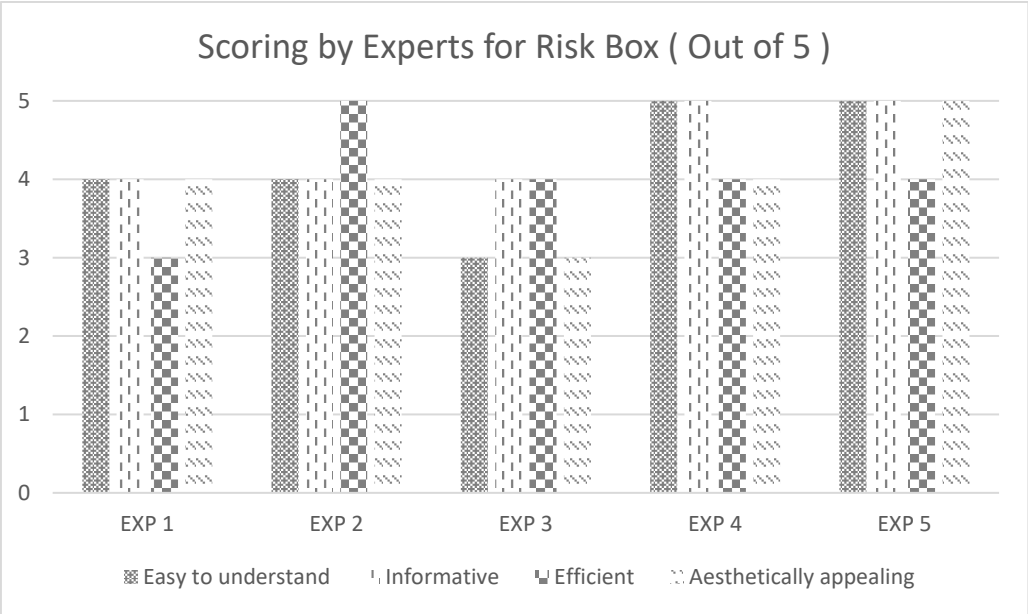


Figure 4.15 Scores of Experts

It can be seen that there are no scores less than 3 for any of the items to be scored; hence it can be said that the Risk Box tool is a promising tool for visualization.

One other point to emphasize is that the scores given to the “informative” aspect of the Risk Box has seemed to be attaining the highest rankings. This might be seen as a support for the idea that the informative quality of the Risk Box is very high.

4.7.2.2 Question 2: Face Remained in Expert's Mind

For this question, the face or faces that have remained in the expert's mind has been asked. It has been seen that all answers of experts have included the first face (i.e. Face 1 Frequency Chart), which generally had positive comments from all of the experts. In addition, the sixth face (i.e. Face 6 Assumption Matrix) and the fifth face (i.e. Face 5 Risk Prone Variables) has also been mentioned commonly by experts. Below can be seen some comments:

> *EXP1: "The face that remained in my mind is the fifth face, the one with risk prone variables. And the first face also provides good and useful information. Of course, the other faces have also been able to provide valuable information, but these have been the ones that remained in my mind."*
>
> *EXP2: "The first face I can think is the Face 1, followed by Face 6 and Face 3."*
>
> *EXP3: "I actually have really liked Face 3 in terms of aesthetics. However, I believe there is only one important face, which is the first one. This face is the face to look at if you want to make decisions, the others are just supports."*
>
> *EXP4: "When I think, at first, the face remained in my mind has been the fifth face. And if you wish to know the face that remained the least, it is the fourth face for me."*
>
> *EXP5: "It is the first face since it has reminded me of abacus. And when I looked at the Risk Box overall, I would say that second face has reminded the least."*

4.7.2.3 Question 3: Strategies

For this question, experts have been asked whether they could establish some strategies basing on the information provided by Risk Box. All of the participants have answered as "yes".

Later, some examples for strategies have been requested by the experts. Many participants have referred to the first face, and by utilization of this knowledge, they have stated that they need to reconsider their target since %12 is a very low percentage, and a larger percentage has been resulted for 7-8 years scenarios.

> *EXP2: "Yes I can decide on some strategies. Initially, I will go back to go-no go decision. I have seen that the project will most probably have a payback period of 7-8 years instead of 6, therefore I will comment that this target should be reviewed. I would ask the analysts to reevaluate that whether the target of 6 years is reasonable? I would ask them to check the calculations and analysis."*

> *EXP4: "Yes. I will reconsider my target of 6 years. I have seen that 6 years of payback period is not probable. If my target is really 6 years, I will abandon this project or look for ways to manage risks. (...) Because, I can see that I can easily manage the risks when my target is around 7 years, this way the probability of me reaching my target becomes more than 50%."*

In addition, the sensitivity information and the most sensitive variables have been addressed by experts where strategies have been formed on decreasing their sensitivity:

> *EXP1: "Yes, this is very useful for me to make some strategies. First of all, I have seen that there is 12% probability that I will reach my target, hence this project is not feasible. I have even seen the possibility of reaching 10 years. I have also seen the most sensitive variables and observed that Unit Cost of*

Concrete is important in this sense. I could make contracts and fix the unit cost for a certain amount of time, to increase the feasibility. Alternatively, I have seen that construction duration is also important. In order to decrease, I can rearrange my contracts with contractors with inclusion of liquated damages to prevent extension of duration."

EXP2: "(...) If there no mistakes found in the analysis, and if there is a strategic importance of the project, I would continue with go decision but will request more detailed analysis on the major issues such as the 5 variables that affect the payback the most. I would ask for the analysts to look for how to manage those risks and rerun the sensitivity analysis."

EXP4: "(...) I would look for ways to manage those 5 risks or variables. If I can find solutions, I may decide to go with my current target of 6 years."

EXP5: "I may request projections on exchange currencies since I have seen that costs are important."

Furthermore, the assumption matrix has also been addressed, mainly for the assumptions located on the upper right corner of the matrix when considering the strategies of experts:

EXP1: "As a decision-maker, I can see which assumption to be challenged. I can later come back to this face and ask the analyst again that what happens after I release an assumption."

EXP2: "(...) I would also ask the analysts to go back reconsider their assumptions."

In addition, both experts with medium-low risk knowledge, risk matrix has been mentioned in their answers to this question:

EXP3: "I would look for decreasing the effects of the red ones. For instance, unfamiliarity with design has seriously affected me, what should I do to

eliminate this risk? Maybe hiring an experienced designer company? So, I would try to come up with strategies by looking at the red dots, basing on my and projects existing conditions, to mitigate the risks."

EXP5: "To see the affecting issues, I would go back to risk matrix and focus on the ones that are marked as high. At the first glance, I see that I need to have a solid design, therefore I would ask my team to do a market research on designers. I would also ask my team to search for bureaucratical concerns such as upcoming elections."

4.7.2.4 Question 4: Feasibility

For this question, experts have been asked whether they think this investment is feasible or they do need additional information.

Like the previous question, all of them referred to the information provided in the first face, and all decided that the target is hard to reach.

EXP1: "First of all, I have seen that there is a 12% probability that I will reach my target, hence this project is not feasible."

EXP2: "I have seen that the project will most probably have a payback period of 7-8 years instead of 6, therefore I will comment that this target should be reviewed."

EXP4: "I have seen that 6 years of payback period is not probable."

EXP5: "%12 is a very low percentage, so it is a low probability that I will have 6 years."

However, some experts have also requested additional information to decide on whether to continue the investment or cancel.

EXP2: "Regardless of how good this analysis and presentation is, I would need more information. Generally, go- no go decisions of such projects have been decided based on results of various analysis and studies. In other words, free of informativeness, with the goods and the bads, decision makers may request 2-3 different studies. The current one is the part with risks. Decision maker may further additionally ask for cost effects or consideration of Employer requests. If we are to base our decisions on one analysis, executives will probably ask for detailed back-up information regarding this analysis. Therefore, studies of many departments within the company will be required to be involved in some number of studies. For instance, by looking at the assumptions, establishment of forecasts and further analysis can be a study to be conducted by related department. Alternatively, for contractual risks, contract department can be consulted on what to do with them or negotiate with Employer. In addition, technical office can be assigned to look for calculations of quantities and research of suppliers for better prices. Therefore, this study can be seen as an alarming one, and acting as an information mechanism to look for your target and your solutions."

EXP3: "I would need additional information to have a healthier decision of investing in this project or not. For instance, I can see the payback period, but I would also need a cash flow to see my profits and losses. I believe the most important thing is the flow of cash until the point where the investment has paid back, I need to see how much of backup financing is required and, in this study, I cannot see this information."

EXP4: "I wish to see information on the manageability of the risks. But I believe it is necessary to re-examine the top 5 variables, manage them and re-run the analysis to see what happens."

EXP5: "Although %12 is a low percentage, I still believe the decision of feasibility depends on the project and project data. If this is to be a real

project that I am responsible for making the decision, since the target is 6 years and the project will most probably have 6-7 years, I have also seen that the mean in around 7, I may say that is rather feasible. However, I may still request more information to continue with the investment. If I have seen that the scenario of 8-9 years has been resulted, then I would most definitely say that the project is not feasible."

4.7.2.5 Question 5: Positive Attributes

For this question, experts have been asked about the positive attributes of the Risk Box. The most mentioned positive attribute has been the property of Risk Box being orderly and compact. Most of the participants, regardless of the level of risk knowledge, have mentioned that a lot of information has been contained within the box in a net and clear way.

EXP1: "It is clean and tidy. It brings together many related information and it makes it easier to tell something to decision-maker with this box."

EXP2: "Since I am actively involved, I am aware of the work that must be conducted behind, before the establishment of this Risk Box. It is a very hard job to demonstrate this much of information without losing the message behind but in a very simplified way, therefore I really like the tool. (...) Although this may differ from person to person, executive managers generally do not have much time to read reports written in pages and pages. They mostly require and request information to be given in a very summarized version. Hence, this tool will answer to this request very well."

EXP3: "Since traditionally I am not used to seeing a range of results but one result, seeing the possibilities impressed me and opened up my horizon. If this feasibility study is to be done by myself without this knowledge, I would end up with a number for payback period and will probably not able to

understand the real logic behind, my other possibilities and the correct strategies to define."

EXP4: "This tool should definitely be used for evaluation of risks. People generally do not like reading wordy reports. If this information is to be presented as pages and pages of reports, people may not be reading it."

Similarly, positive comments have also been made on the visualization of the risk data and how it made the information more attractive.

EXP2: "This is something that needs to be presented to top management. Therefore, it needs to attract attention. And it does, it does this in a very nice way."

In addition, one of the experts have commented on the shape of the Risk Box as an answer to this question:

EXP5: "I am really impressed by the idea that this is a cube. It made me feel like information has been prepared, gathered and closed to form a cube, ready to make some decisions. For instance, if this is designed as a cylinder, it will make me feel like information has been gathered but the tool continues to roll due to its shape, hence leading to nowhere where this seems to me that I will not end up with any decisions in the end."

Participants have also mentioned that the Risk Box shows the points to focus on in the decision process or after the investment is decided to be done. In addition, many of the participants have mentioned their positive feedbacks on the usefulness of the information the Risk Box contains. Therefore, it can be commented that participants are mostly satisfied with the content of Risk Box.

EXP2: "One, the most important benefit, in my opinion, is that it shows the project risks. Two, it shows whether our target can deviate under different

probabilities, to what extent etc. Third, it shows the sensitivity information, which I believe is very important."

EXP3: "If you decide to invest in a project, this Risk Box will also enable you to see the subjects you need to manage."

EXP4: "Risk Box contains all the initial information to be looked at such a decision. (...) I believe the best quality of this Risk Box is that it shows where to focus. (...) It is tailored to analyze your target."

In addition, participants have commented on the iterative attribute of the Risk Box.

EXP1: "This box provides the opportunity for iteration such that if you change anything, information in the box will also change and can be tracked down with the Risk Box."

Among the participants having high risk knowledge, comparisons between the traditional visuals of Monte Carlo Simulation have also been made.

EXP1: "Moreover, there exists information that complements and reveals the relationships (risk matrix and risk prone variable table), different that the traditional Monte Carlo Simulation outputs."

4.7.2.6 Question 6: Negative Attributes and Shortcomings

Similarly, for this question, experts have been asked about the negative attributes of the Risk Box. The most mentioned positive attribute has been the necessity of determination of the target group and the necessity of guidance in this regard.

EXP2: "Who is the target for this Risk Box? If the target is top management and the decision-makers of the company, the Risk Box needs support."

EXP3: "If it is expected that executives are to be informed, it is not very clear. However, if one is to look and understand once to the Risk Box, it will then

be very clear. Maybe some modifications can be made to make it more understandable for the people with less knowledge on risk."

EXP5: "I believe the aspect of the Risk Box that I will mention will be the necessity of some explanation at certain points, but other than that it is very clear and useful, having no other negative attribute."

Comments on the digitalization of the tool have also been made, and participants requested to see the tool in a more digitalized and automatized way:

EXP1: "If this tool is to be a digital one, I think it will be better. For instance, if you could open a touch screen and see the Risk Box interactively. I believe the most important negative attribute is that the tool is not digital. (...) I would also request to use with scheduling, but I don't know if it will work. It will need software connection to a program like Primavera."

EXP5: "If this tool to be used in connection with other software. I believe this tool can already been used for many analyses, but if you integrate with software, it can be used everywhere."

Negative and / or improvable comments regarding the aesthetics have already been mentioned in the sections above. Some participants have also indicated aesthetics as an answer to this question.

EXP1: "Aesthetics can be improved."

EXP4: "Aesthetics is good enough at this stage but can be developed."

One expert with high knowledge of risk commented that the box is more focused on the variables rather than risks, therefore he requests more information on risks.

EXP2: "Risk part seems a little missing, it looks like the box mostly focused on the variables."

One other expert has also made a negative comment on the Risk Box such that the box has to be reviewed in a certain order, based on a well-defined process.

> *EXP4: "This tool is designed as a box, however it looks like it has to be orderly looked at. You may not start at a random face. For example, if I see the fifth face at first, it will not make any sense, I do not know what 5 sensitive variables is and where do they come from. If I see the second face first, the first face nearly loses sense since I already have seen my possibility to reach the target. Therefore, it seems like you need the order. However, the existing order is so good that it prepares you for your decision."*

Another modification request has been taken from one expert regarding the content of Risk Box:

> *EXP2: "I think it can be useful to have an introduction and conclusion face for the decision makers. Introduction may contain information on the methodology and basic information on project where conclusion can contain how to analyze all this information providing a synthesis and options for decision makers to follow. (….) I think a section is needed showing the overall picture, summarizing the critical points and promoting the decision maker to his decision. It can be more guiding in this way."*

Finally, experts have also mentioned that this Risk Box may have difficulties in more complex projects.

> *EXP1: "I could not imagine how this box can be used in more complex projects. There are 11 risks, 12 variables now. Okay it is easily understandable. However, once the project grows, hundreds of risk factors can be defined. Once the risk matrix grows, it may be hard to integrate in this box. This issue is something to examine."*

> *EXP4: "In this case study, we care about one target, which is the payback period. What if for a different and complex project, my target is both having*

a payback period of X and budget under Y at the same time? Real life projects may not always be simple as this case project. I am not sure if this can be used in those cases."

4.7.2.7 Question 7: Utilization in Practice

For this question, experts have been asked about whether they would like to use this tool in their real lives and, if yes, in which areas. All participants have stated that they would utilize Risk Box in their own projects, but different views exist on the areas to be used.

As the case study has chosen to be an investment one, participants have a very positive attitude towards using it in investment projects to see the feasibility:

> *EXP3: "If you decide to invest in a project, this Risk Box will also enable you to see the subjects you need to manage. (...) I have initially thought about utilization on investments since the sample case study was an investment one but the tool can be used for other projects as well."*
>
> *EXP5: "I will again be willing to use in an investment."*

Similarly, one of the experts has mentioned that he will prefer it to use during the initial stages, such as tender, investment etc.

> *EXP4: "Since I currently am on the execution side of projects, I can think about the utilization in execution. However, I believe this should be used, especially in the beginning, like the tender phase of feasibility studies. In execution, you will determine and analyze risks one way or another. However, it will be better if Risk Box is used in the beginning. I think the case study is suited to the Risk Box."*

Another common answer is utilization for the presentation of data.

EXP1: "As a risk consultant, my duties include coordination and moderation of discussions on risks in firms. In the end, these procedures require consolidation and gathering data, summing up of people's ideas and comments and summarizing in the end. This tool will very well serve to this purpose."

EXP3: "Since we are a consulting company, when we do a study like feasibility for an employer, such representation will be very attractive for an employer. Therefore, I believe that this tool is very useful in terms of presenting a qualitative service."

Participants have also mentioned that they can use this tool in cost estimations.

EXP1: "I can use Risk Box in estimations of costs."

EXP2: "I would use this tool to see whether the project can be completed with target profit, therefore will use in cost-related matters. I would use it to see what profit it will bring at what probability."

One comment has also been taken such that the tool can be used in planning.

EXP1: "I would also request to use with scheduling, but I don't know if it will work. It will need software connection to a program like Primavera."

Finally, one of the experts has made a comment on the changes he desires in using it in real life.

EXP2: "I would definitely use this tool, but I may prefer to consolidate some of the data. For instance, I would absolutely use Face 1 and Face 6. I can merge Face 1 and Face 2 since they acquire similar information. I would definitely use Face 3 and Face 6. I would also add some information on the risks together with variables to Face 3 and Face 5. I would avoid Face 4 and include an introduction and conclusion in the end."

4.7.3 Discussion and Comments on Findings

The questions and the answers of experts have been given in the section above regarding the Risk Box in general and its faces. It is essential to emphasize once again that this study aims to understand the approaches of experienced participants towards the tool of Risk Box on the utilization in a case study and for further projects.

4.7.3.1 Overall Approach

To begin with, overall, it can be concluded that all participants have a positive attribute to the Risk Box considering the fact that they use the terms very frequently such as “useful”, “understandable”, “important” etc. The utilization of common positive terms can be provided as a support at this point where MAXQDA software can be used for seeing the frequency of words. In this manner, the built-in properties have been used where the word counts have been filtered such that the meaning is preserved. For instance, if a participant has used “not” and “important” together, then the “important” is not taken into account for the counts. In the end, the following frequencies have resulted:

Table 4.9 Frequencies of Some Positive Terms in the Comments of Participants

Expert ID	Frequency of “important”	Frequency of “useful”	Frequency of “understandable”	Frequency of “nice”
EXP1	18	3	1	8
EXP2	11	12	4	15
EXP3	10	14	3	4
EXP4	8	5	1	9
EXP5	9	4	5	3
Total	**56**	**38**	**14**	**39**

In addition, the fact that all participants have managed to provide strategies on the case study can also be interpreted as a positive approach considering that participants have only been provided brief information on the case study (i.e. solely the type of

project, the criterion, the target and brief introduction on risks and variables). Therefore, with this limited knowledge, it has been seen that participants can have a general comprehension while commenting on the feasibility and the results.

It has also need to be considered that the participants have tried to be selected as a mixture of project management experts but acquiring varying risk knowledge. With this selection in mind, all participants have managed to understand the case study as well as the visuals presented within the Risk Box. In addition, the comments on the solid facts such as the probability of the target, the main logic behind the visuals etc. have shown similarity between the experts having high risk knowledge and medium-low knowledge. For instance, regardless of risk knowledge, all participants have commented that this case study is not feasible, mostly basing on the information of reaching the target being 12%. Again, valid for all participants, they have established strategies mostly based on the sensitivity data. Therefore, this fact can be a support for demonstrating the usability of this tool, i.e. Risk Box.

4.7.3.2 Information Provided by Risk Box

As explained above, Risk Box is treated by participants as being “informative”.

When details have been more closely focused on, considering the case study and the answers of the participants, many references have been made by participants on the probability of reaching the provided target, such that it has been easily understood. In addition, all participants used this information further during evaluation of feasibility of the project, questioning the target and establishing strategies. Therefore, it is possible to say that this information is used by all experts, which is easily comprehended.

Another common point is the attention of all participants on the best case – worst-case scenarios. This information can be mainly gained by Face 2 (Statistical Information), where mentions also exist on Face 1 (Frequency Chart) and Face 5

(Risk Prone Variables). For Face 2, as also mentioned in the previous section, participants have commented on the usefulness of the best- and worst-case scenarios to see what can happen in the best if everything goes right and vice versa. In other words, they have mainly treated these two scenarios as the limits. Moreover, they have seen these scenarios also on the first face in terms of the related probability. This also has been used for comparison purposes for instance, the relativity of probability of target and probability of worst cases.

In addition, the assumption information in Face 6 has been rather positively approached by experts. All experts have seen to be understanding the matrix without many problems, all commenting on the usefulness of the provided information, regardless of the risk knowledge. Moreover, nearly all experts have utilized this information on the establishment of the strategies. Therefore, it can be said that this face is an informative one within the faces of the Risk Box.

4.7.3.3 Difficulties Experienced by Participants

Although many of the comments by participants have been positive, there also exists some points where participants had difficulties in understanding. These items have already been mentioned above but below are some major points discussed again.

To begin with, it has been seen that the visual that nearly all experts have commented on the struggle of understanding has been the Face 5 (Risk Prone Variables). This struggle has understood to be caused initially by the representation of information together with the information itself. When the comments on the visual have been analyzed, it has been seen that the colored bars have created confusion on experts. Most of them have commented that they generally use that kind of bar in demonstration of relative percental/comparison information. In addition, some comments have also been taken as that the bars have made the visual more complex. Furthermore, considering the comments on the data itself, the existence of many

numbers has generally created confusion on experts' minds together with the definitions in the titles. Hence, nearly all participants have needed an explanation on how to read the visual. However, it is also important to emphasize that once the visual is explained, all participants have pointed out that the information provided is beneficial mainly because they can see the different values of the variables in different scenarios. Nonetheless, experts do not have solid comments on the possible modifications.

Secondly, Face 3 (Sensitivity Analysis) has also created some difficulties where it is mainly caused by the term used for the titles. It has been seen that once the participants have understood that this visual is about sensitivity, the rest of the visual has been easily interpreted by the experts. In this manner, some suggestions have been made, such as providing numbers demonstrating the ordering or simply changing the title itself.

Thirdly, another common confusion has been realized for Face -2 (Statistical Information), where the data has been found "too statistical" by all experts. In addition, it has been seen that for the further questions, nearly none of the experts have mentioned the data of standard deviation, coefficient of variation, and %90 percentile, especially when the strategies or the feasibility of the project have been asked. In addition, none of the participants have mentioned this face as the face that reminded their minds. One of the experts has also mentioned that if he were to use this tool in real life, he will integrate Face 1 and Face 2. Hence, it can be said that that information does not serve the experts' decisions and can be avoided.

4.7.3.4 Limitations Addressed by Participants

Throughout the interviews, participants have also stated some limitations of the visuals and Risk Box, where they have been mentioned in the related sections above. More examination can be done on the major comments below.

Although the Risk Box tool has been found highly informative and formed a basis for the decision, some experts have still requested additional information to support their decision-to-make. In other words, by looking at their target and the probability of reaching the target, experts all decided that the project is not feasible, but most of them still needed more support. As understood from approaches of experts, their general method for making decisions of the feasibility of this kind of project include analysis of many items together with risks through their years of experience. Experts' reservations on the sole adequacy of this tool might have resulted from this issue. In addition, the fact that this is a newly presented tool prepared for a project that they are not very familiar with may also have been led them to feel insecure about their overall decision. However, it shall be reminded that this Risk Box can be a supportive tool together with other additional information requested by users, without additions on the faces.

Another point to study shall be the mentions of experts on the limitation of the utilization of this tool for more complex projects. However, it shall be emphasized that for this study, the analysis has been done based on a relatively basic case study with a more limited number of variables and risks to provide an initial tool to visualize such kinds of risk analysis results. Therefore, improvements can be made to have better results basing on the user comments. In addition, as also mentioned by participants, this tool is forecasted to be integrated with digital tools and software for establishment and use. With the help of technological improvements and modifications, this tool is foreseen to be used in many other areas.

Moreover, a comment has also been received such that there must be a certain order to follow for reviewing this Risk Box. Participant has mentioned that if one to see the fifth face (Face 5- Risk Prone Variables), the "most sensitive five variables" may not make sense or if the second face (Face 2-Statistical Information) has been seen first, since the probability of reaching the target has already been seen, first face (Face 1- Frequency Chart) may lose its meaning. However, the intention of making

this tool as a box has been the ability to provide different information that complements and supports each other to in the end, help the decision-maker in the decision. In addition, it also has been chosen for its ability to be easily pictured since a box, or a cube is a common geometric shape and known by anyone. Therefore, all faces of the box have designed to be including different information where common points exist due to the complementing nature.

4.8 Summary of Findings

The major findings can be summarized as below:

Table 4.10 Summary of Major Findings for Each Face

	Face 1 – Frequency Chart	**Face 2 – Statistical Information**	**Face 3 – Sensitivity Analysis**	**Face 4 – Risk Matrix**	**Face 5 – Risk Prone Variables**	**Face 6 – Assumption Matrix**
Information within the face found useful	✓	✓	✓	✓	✓	✓
Achieved a comment such that it is easy to understand (both aesthetics and the information)	✓					✓
Experts experience difficulties in understanding the visual			✓		✓	
Experts experience difficulties in understanding the information within		✓			✓	
Positive comments received for aesthetics of visual	✓					✓
Mentioned in the answer of Q2 (Face Remained in Expert's Mind)	✓				✓	✓
Mentioned in the answer of Q3 (Strategies)	✓		✓	✓		✓

Table 4.11 Summary of Comments on Major Items for Risk Box

	Informative	**Neat Representation of Data / (Better than Reading Pages of Reports)**	**Aesthetics is Good / Appealing**	**Some Explanations Might Be Needed for Top Management**	**Willingness to Use in Real Life**	**Potential Areas of Usage**	**Management Strategies can be Developed by**	**Additional Information that may be Needed for Investment Decision**
EXP1 PhD – 20+years of experience, Risk Management Knowledge is High	✓	✓	✓		✓	*Planning *Cost Estimation *Presentation of Data	*Concentrating on sensitive variables *Reconsidering and relaxing assumptions	*Magnitudes/impacts of individual risks
EXP2 PhD – 10+years of experience, Risk Management Knowledge is High	✓	✓	✓	✓	✓	*Cost Estimation	*Revisiting initial target *Concentrating on sensitive variables *Reconsidering and relaxing assumptions	*Cost effects of individual risks *Information from different departments (such as technical office, contractual etc.) *Separate faces for introduction and conclusion
EXP3 MSc – 20+years of experience, Risk Management Knowledge is Medium-Low	✓	✓	✓	✓	✓	*Investment *Presentation of Data	*Revisiting risk matrix	*Information on Cashflow

Table 4.11 Summary of Comments on Major Items for Risk Box (cont.d)

	Informative	**Neat Representation of Data / (Better than Reading Pages of Reports)**	**Aesthetics is Good / Appealing**	**Some Explanations Might Be Needed for Top Management**	**Willingness to Use in Real Life**	**Potential Areas of Usage**	**Management Strategies can be Developed by**	**Additional Information that may be Needed for Investment Decision**
EXP4 PhD – 10+years of experience, Risk Management Knowledge is High	✓	✓	✓	✓	✓	*Investment *Tendering	*Revisiting initial target *Concentrating on sensitive variables	*Information on manageability of risks
EXP5 MSc – 20+years of experience, Risk Management Knowledge is Medium-Low	✓	✓	✓		✓	*Investment	*Concentrating on sensitive variables *Revisiting risk matrix	*More information on nature / characteristics of the project

4.9 Improvements of Visuals Based on Comments of Experts

After analyzing experts' comments, some improvements have been made on the faces in terms of the coloring, content, and representation where the revised faces have been presented in this section.

For Face 1 – Frequency Chart, the colors have been changed, and the percentages have been written in the legend:

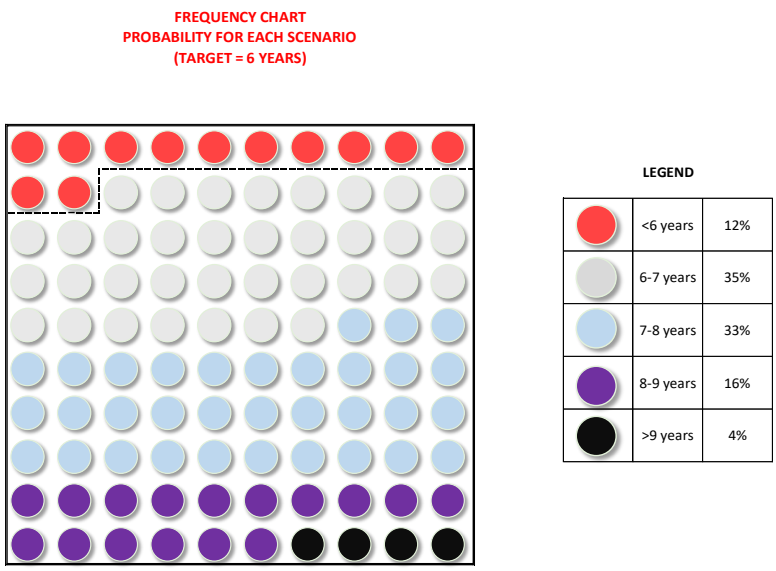


Figure 4.16 Face 1 – Frequency Chart– Revised

For Face 2 – Statistical Information, the information provided has been consolidated and decreased to only best case, worst case, mean, 90% percentile, target, and cumulative probability of reaching the target upon experts' comments.

Information on Scenarios	
Best Case	4,64 years
Worst Case	10,69 years
Mean	7,14 years
90% Percentile	8,0-8,5 years
Target	**6,00 years**
Cum. Prob. to Reach Target	**12,0%**

Figure 4.17 Face 2 – Statistical Information – Revised

For Face 3 – Sensitivity Analysis, the abbreviations and units of variables have been removed, a column for "Order" has been added and the title has been changed for ease the understanding.

Variable	Order	Top Variables in terms of Sensitivity
Unit Cost of Cement	1	
Unit Cost of Aggregate	2	
Duration of Construction	3	
Construction Cost Factor	4	
Duration of Design	5	
Unit Cost of Chemical Additives	6	
Yearly Working Hours	7	
Hourly Production	8	
Duration of Permissions	9	
Unit Cost of Water	10	
Monthly Design Cost	11	
Operational Cost Percentage	12	

Figure 4.18 Face 3 - Sensitivity Analysis – Revised

For Face 4 – Risk Matrix, the risks have been shown and indicated as decreasing risk scores. The same has been applied to the most sensitive five variables as well.

Decreasing Risk Score →

Decreasing Sensitivity ↓

MOST SENSITIVE 5 VARIABLES	RISKS										
	Change in Resource Cost (material, labour etc.)	High Bureaucracy	Vagueness of Design	Administrative Delays	Change in Design	Change in Demand	Market Fluctuations	Unfamiliarity with Design Standards	Change in Productivity	Unexpected Weather Conditions	Change in Operational Cost Items of Plant
UCC Unit Cost of Cement	🔴	🟢	🟢	🟢	🟢	🟡	🔴	🟢	🟢	🟢	🟢
UCA Unit Cost of Aggregate	🔴	🟢	🟢	🟢	🟢	🟡	🔴	🟢	🟢	🟢	🟢
DC Duration of Construction	🔴	🟡	🟡	🟡	🟡	🔴	🟡	🟢	🔴	🔴	🟢
DD Duration of Design	🟢	🔴	🔴	🔴	🔴	🔴	🟢	🔴	🟢	🟢	🟢
CCF Construction Cost Factor	🔴	🟡	🟢	🟢	🟡	🟢	🟡	🟢	🟡	🟢	🟡

LEGEND

LEVEL	SYMBOL
HIGH	🔴
MEDIUM	🟡
LOW	🟢

Figure 4.19 Face 4 - Risk Matrix - Revised

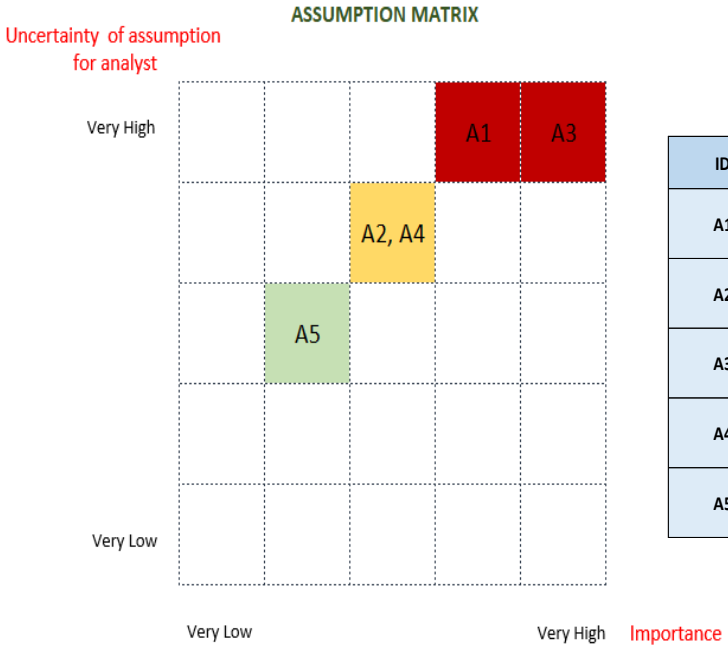
For Face 5 – Risk Prone Variables, the bars have been removed, the colors have been simplified, and an explanatory note has been added to the bottom.

MOST SENSITIVE 5 VARIABLE	UNIT	Value at Best Case (4,64 years)	AVERAGE VALUE OF VARIABLE IN EACH SCENARIO					Value at Worst Case (10,69 years)
			<6,0 years	6,0 - 7,0 years	7,0 - 8,0 years	8,0 - 9,0 years	>9,0 years	
UCC Unit Cost of Cement	TL/kg	0,285	0,286	0,293	0,299	0,303	0,307	0,309
UCA Unit Cost of Aggregate	TL/ton	47,384	47,476	48,628	50,067	51,155	51,739	51,952
DC Duration of Construction	months	7,773	7,908	8,801	9,140	9,517	10,233	10,902
CCF Construction Cost Factor	UCA	27.197.216	29.183.321	29.926.567	30.045.547	30.289.390	30.758.724	31.402.202
DD Duration of Design	months	2,767	3,869	3,972	4,013	4,075	4,079	4,296

**Note: For this visual, each row corresponds to one variable and each column corresponds to the (average) value of the variable at the scenario.*
Example: Duration of Construction (DD) has an average value of 9,517 months for the payback period scenario of 8-9 years.

Figure 4.20 Face 5 - Risk Prone Variables - Revised

Finally, For Face 6 - Assumption Matrix, a minor change in the title of vertical axis has been made.



LEGEND

ID	Explanation
A1	Extreme conditions such as force majeure events or contractual risks have not been taken into account
A2	Interest rate has not been taken into account
A3	Same contractors are assumed to be providing services / materials until the end of payback period
A4	No change of bureacratical procedures are assumed
A5	Productivity of contractors are assumed to be maintained during payback period

Figure 4.21 Face 6 - Assumption Matrix - Revised

With these modifications, the requests of experts in terms of “make-up” of the faces of Risk Box have tried to be fulfilled, ready for the further studies.

CONCLUSION

5.1 Summary

Studies conducted have shown that risk management is an essential part of project management and has vital importance in the construction industry since it is a risk-prone industry. As mentioned in many literature studies, risk communication is necessary to result in informed decisions under risk. Therefore, stakeholders in risk management procedures need to acknowledge the project risks thoroughly to come up with strategies and manage them.

At this point, literature has proved that visualization is an efficient method to communicate data, especially the complex datasets where risk information can also consider to be complex. Therefore, many authors suggest the utilization of visualization during risk management, from risk identification to representation of results of risk analysis.

In this manner, when the most common risk analysis method of Monte Carlo Simulation is considered alongside sensitivity analysis, frequency chart and tornado chart are the traditional ways of representing risk analysis results, widely preferred in practice. Therefore, there exist many approaches to the visualization of such risk data.

However, there still are gaps in the literature on the evaluation of risk visualization and its effectiveness in decision-making procedures, establishing the departure point for this study.

Thus, the objectives of this study are;

1) Trying to understand how the traditional visuals of frequency and tornado chart are acknowledged by decision-makers,

2) Offering a different way to visualize the results to enhance the decision-making procedures in terms of risk management, i.e. Risk Box

Have been determined in order to fill an important gap in construction project management literature on visualization of information.

This thesis, similar to previous studies conducted before, favors the utilization of qualitative methods for comprehension of views of experts/users in order to form a starting point for future studies. Hence, by the target of the establishment of insight, rather than statistical results to generalize findings, a research design having two steps have been conducted; an initial study has been carried out to identify needs of the user, based on these needs, a Risk Box concept has been developed, and performance of Risk Box has been tested with experts by semi-structured interviews. As the audience, experts in project management have been chosen and tried to be selected as a diverse pool in terms of risk knowledge and project management knowledge to have an idea on the different approaches at both steps. The initial study has aimed to learn about the comments of experts on the existing visuals (frequency chart and tornado chart), which have been presented via a real-life project. In the end, it has been found out that regardless of the risk knowledge of the participant, the visuals are not effective and sometimes fail for the low-medium risk-knowledged expert to communicate the results. Therefore, by using these observations, a tool has decided to be proposed, which is a Risk Box. It was simply designed to be a box, having six faces, presenting different and complementary risk information at each face. To evaluate this Risk Box, which is the second step of this thesis, the risk analysis results of a case study have been used to form the visuals. Later, semi-structured interviews have been conducted to learn about the views of the experts.

At the end of the study, highly positive feedbacks have been taken for the Risk Box idea by all participants where all of them has found this representation as useful, wishing to use it in their real-life projects. In addition, another common comment was the representation of such vast and complex data in a clearer way, decreasing

the time to understand risk level in a project via Risk Box. Last but not least, the comments on the risk information, the strategies and decisions established have shown great similarities between participants. This could be interpreted such that this tool is able to address different target groups in terms of risk knowledge, experience, education etc. in communication of risk data and a common ground can be created within a variety of background.

There are various comments made by participants stating that these presentations of risk information via faces of Risk Box are better than the traditional methods and form a greater base for understanding both the risks and risk analysis findings. This finding can be concluded to be an indication of the realization of project objectives; in other words, the Risk Box can be proposed as a tool that could be better in many ways when compared with traditional methods.

In addition, a literature review has been presented in the beginning of this thesis, providing studies on the positive effects of visualization on communication of (risk) data. When the results of this study have been considered, it is possible to say that they are in accordance with the results in literature such that the visualization has practically affected the understanding processes of the users. In other words, these results obtained from this second step of the thesis can also be seen as a support for the other aforementioned studies in the literature proving that visuals are better ways to present information, making it easier to relate, communicate and come up with decisions requiring less effort to comprehend. As a proof, participants during the step of evaluation of the tool, Risk Box, has managed to generally understand the data presented within the faces, and form strategies and made decisions even with just a little information on the case project itself.

However, as every coin has two sides, there also are some modification suggestions of experts for the Risk Box idea. Some of these modifications, such as the ones regarding the “make-up” of the visuals, can be implemented in future studies.

Finally, it is necessary to emphasize once more that the main aim of this study is to come up with an insight in understanding the approach of users experienced in project management toward the visuals formed in terms of their decision-making procedures under risk. Therefore, the aim is not to achieve generalized findings; rather, it is simply to understand some comments of the potential users of the Risk Box.

5.2 Practical Utilization of Risk Box

Initially, when Risk Box is designed, the aim has been to form a different perspective on the representation of risk analysis result data, which is inspired by the traditional visuals combining with other elements and/or steps of risk analysis. In this manner, the Risk Box has been targeted to be used in any stage of a project, act as a support to decision-makers for risk management and project management procedures and have an iterative nature so that it could be comparable to have a before-after picture.

In the second step, where the Risk Box has been formed and evaluated, the participants have also been asked to comment on their willingness to use this tool in real life and the possible areas of usage. They all stated that they want to utilize the Risk Box in the future for their projects.

Regarding the usage areas, a common answer by the participants has been to use it for communication and presentation to executives since Risk Box provides an easier way to present risk data. As also defined in the initial objectives, the results of this study have also shown that the image drawn by Risk Box can be a way of transmission of risk information between stakeholders.

In addition, there were some mentions of participants using the Risk Box in the beginning phases of a project. The phases have further exemplified as such that feasibility studies, determination of realizing the project or not, tendering phase etc.

Moreover, participants have also asserted that cost estimation and planning can be phases to use Risk Box.

The Risk Box is seen to be capable of answering the suggestions and requirements of the participants; hence with improvements, a greater window can still be obtained. For instance, the Risk Box idea is ready for being a digital and interactive tool, considering the technological advancements rapidly realizing around the world. Hence, it could be converted into an online tool where users can easily "play" with it. Later, it is also an opportunity that this tool can be integrated with existing software like risk analysis software, planning software, or presentation software; hence the faces can automatically be formed and further utilized by using computer technology.

Last but not least, Risk Box forms the basis for the presentation of more data due to its nature. For instance, one can prefer to present different information on faces other than the ones established within this study, where it can be easily applied. Alternatively, if one requires more space, this "box" can be transferred to be a different 3D geometrical shape to increase the faces. Alternatively, it is possible to represent information other than risk since it is actually a visualization tool. Hence, Risk Box is a customizable visual gadget that can be tailored to many purposes.

5.3 Limitations and Further Studies

There, of course exist limitations on the study that can be overcome in future studies. Firstly, the group of experts can be considered as a limitation; hence a further step could be to select a greater number of participants for testing the performance of Risk Box. Participants from different backgrounds, having different levels of experience, and working in different positions can be invited to test Risk Box. A high number of user studies can provide better evidence for benefits, shortcomings, and

possible modifications of Risk Box. In order to generalize findings and conduct statistical analysis about its utilization, a higher number of participants is needed.

Moreover, several case studies can be conducted to understand how Risk Box can be utilized in different phases of projects, such as risk assessment workshops at the start, during and after the project. Comparative studies about traditional visualization methods and Risk Box can be carried out on the same case project to see in what ways Risk Box can overcome the traditional methods or vice versa. If a digital tool is developed for the Risk Box concept, its performance can also be tested by usability tests. Moreover, as one of the advantages of Risk Box is proposed to be storing risk information and learning between projects, its performance can be tested within this context. Also, dynamic utilization of Risk Box, in other words, iterative risk assessment-strategy identification process, can be tested in real projects.

Finally, this study can be interpreted as the first step of the development of tools for better risk information visualization as well as communication, and Risk Box has been proved to be a promising concept to be further utilized in construction companies with certain modifications, if needed.

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APPENDICES

A. Questionnaire For The Initial Needs Assessment Study

This appendix presents the questionnaire for the initial needs assessment study prepared by using the results of a real-life mega project. This questionnaire has been provided to participants to answer the questions within.

OPINION SURVEY FORM ON VISUALISATION OF RISK INFORMATION IN CONSTRUCTION PROJECTS

The PMBOK® Guide describes risk as, an uncertain event or condition, that if it occurs, has a positive or negative effect on a project's objective. The key element of this definition is “uncertainty”. Many things are uncertain; risks are by definition only those uncertainties that will affect the project should they occur. In this study, we aim to explore how effectively visuals are used to convey information about project risks (especially probabilistic information) to decision-makers.

In this form you will find four parts. The contents of each part and requirements are summarized below:

Part 1: Summary of a risk report prepared by an international consultancy firm is presented for your information. The aim of this report was to assess schedule risk in a mega tunnel project conducted in Turkey. Can you please read this summary (3 pages) to familiarize with the Project and risk assessment process?

Part 2: After reading this summary, can you please share your ideas about the kind of information you want to see in the quantitative risk assessment part of this report?

Part 3: In this part, findings of quantitative risk assessment are presented. Visuals such as a frequency chart and a tornado/sensitivity graph are given. Can you please tell us what kind of information you get from these visuals? What do you want to learn more?

Part 4: Now, this is the exciting part! Please imagine a picture (visual metaphor, conceptual map, graph, nD model etc.) that can be used by managers to visualise risk in projects. Can you please tell us about your dream risk picture?

Many thanks for your contributions!

Part 1. Summary report

SCHEDULE RISK ASSESSMENT OF A MEGA-TUNNEL PROJECT: ISRC

This report summarizes the findings of the schedule risk assessment of a mega construction project carried out in Turkey. The project is abbreviated as ISRC and its name is withheld due to confidentiality reasons. JV which was responsible for construction, operation and maintenance of the facility for around 25 years, hired an international consultant to carry out a schedule risk analysis for the ISRC Project. "Reasonable assessment of the JV's risk exposure" was conducted by the Consultant with the objective "to assist the JV in a more informed decision-making process".

During risk assessment, first, a qualitative risk assessment was conducted by a risk workshop attended by company experts. Experts identified and evaluated risk factors using Probability-Impact ratings (on a scale of 1-3). Identified risk factors were prioritized according to their ratings and mitigation strategies were formulated. A risk checklist (risk register) that includes all risk factors evaluated by the experts during the risk workshop was presented in the report. The risk checklist includes 84 risk factors/events that may have an impact on cost and/or schedule of the project. High probability and high impact risks cover unrepairable/serious damage to TBM cutterhead and late delivery of TBM affecting advance rate whereas some low probability-high impact risks are earthquake induced liquefaction during construction and environmental constraints. A part of the risk checklist is given below (Figure A.1).

Figure A.1. Part of the risk checklist

	Workshop Risk Register	Probability of Occurring (%)	< 20%	20 - 80%	>80%		
		Cost Impact ($)	<$0.5 m	$0.5m- $5 m	>$5 m		
	Date December 10th & 13th 2010	Time Impact (mths)	< 1 wk	1 -4 wks	1 - 3 mths		
Risk I.D.	Risk Description	Assessment Notes	Probability %	Cost Impact	Schedule Impact	Ranking	Suggested Mitigations
11	Flooding of shaft during construction due to storm surge	Construction shafts, open cut and cover boxes should be protected against maximum possible storm surge likely to occur during construction. This is a cost risk but not a schedule risk.	1	3		3	Raise the height of temporary support of excavation walls or provide berms to protect open excavations against maximum possible storm surge.
12	Earthquake induced liquefaction during construction leads to failure of utilities and power supply and TBM settlement if in sandy lenses.	Considered to be a high impact risk up to 3mths or more but v. low probability <5%	1	3	3	6	Accept the risk and include this possibility in the project insurance.
13	Rejection of muck at final disposal site and owner rejects temporary storage on site, results in modification on the submissions for muck operations, or searching other possible disposal sites.	Low probability if filter press is used with treatment process before disposal. Logistics at construction site will also be impacted as filter press requires considerably more space than centrifuge. No schedule impact but possibly quite high cost impact. Possibly some cost risk if centrifuge is used as separation process is not as effective as the filter press. Stockpiling and additional treatment maybe required before disposal.	1	3		3	Use filter press in the slurry treatment plant

Some of the construction-related risks as identified by the experts are :

- Late delivery, assembly and launch of slurry tunnel boring machine (STBM)
- Serious but repairable damage to the STBM
- Unrepairable damage to the TBM cutterhead
- Delay of construction works on the European side due to environmental constraints
- Earthquake induced liquefaction during construction
- Difficulty of getting power to the site
- Clogging of TBM cutterhead
- Unforeseen geotechnical conditions (dikes, faults)
- Flooding of construction shafts during storm surge
- Flooding due to tsunami
- Wear and tear on slurry treatment palnt, failure of slurry pipeline
- Muck disposal issue if centrifuge is used in slurry separation stage

Administrative and Contractual risks such as ;

- Work being stopped by the Employer for archaeological discoveries
- A major change in the proposed alignment or increase in diameter of the tunnel
- An insistence by the Employer on point extract ventilation
- Stoppage/delay of works due to unavailability of funds
- Public opposition to the Project,

were also identified by the experts during the workshop.

JV requested the consultant to conduct a “quantitative risk analysis” to calculate the impact of risks on project duration. Schedule risk analysis was performed by Monte Carlo Simulation using Primavera Risk Analysis to answer the following questions:

- What is the likelihood of JV achieving the tender schedule (55 months)?
- What are the parameters, activities and risk events that schedule is most sensitive to?

According to the decision given by the Consultant, quantitative schedule risk assessment did not include administrative and contractual risks. It included only the critical construction-related risk factors under the responsibility of JV. Catastrophic risk events were also not included in the analysis as their inclusion may not give a realistic risk scenario. Moreover, it was assumed that approvals by the Employer and 3rd party stakeholders will be obtained on a timely manner and will not delay design and construction works.

The tender schedule was based on a design and construction duration from award of a contract to operations of 55 months.

The construction schedule without considering risk and uncertainty found by Primavera showed that duration is 49 months (based on several assumptions about release of funds from the lender, development of ad-hoc design, agreement with the TBM supplier for early design procurement for the TBM etc.). Thus, the risk-free duration was calculated as 49 months.

Then, the Consultant conducted Monte Carlo Simulation to calculate probabilities associated with alternative risk occurrence scenarios. Probabilities associated with risk events and probability distributions showing the impact of risks on project duration were determined based on expert opinions. Simulation results were presented as frequency charts (probability distribution curves). Sensitivity analysis was also utilized to find out contribution of uncertain parameters to overall

uncertainty of completion date. Report included further analysis results showing how the results/completion dates would change if some risk mitigation strategies were implemented.

Part 2

As the decision-maker/top manager who is responsible to formulate project management strategies, what kind of information would you like to see in this report? Please list some critical risk-related information you would like to learn as a result of schedule risk analysis. (Note: You can list them as questions you would ask to your Consultant).

Response:

Part 3

1. Please find below the output of Monte Carlo Simulation, a frequency chart (Figure 2). Please write down what kind of "specific" information you see/learn from this frequency chart (Please list your observations such as: there is x% probability that project can be completed before a given date, most likely completion date is ….)

   Please note that the chart assumes that contract award is on 1.5.2011. If you consider 49 months (risk-free) duration, project completion date is on 26.5.2015. 55 months contract duration coincides with a completion date of 30.11.2015.

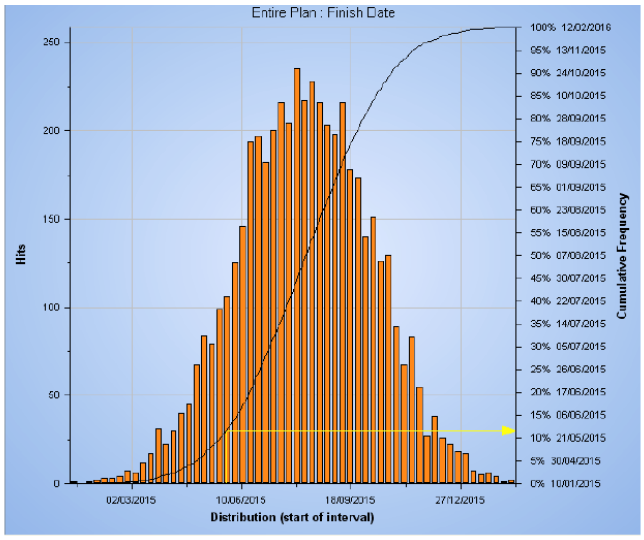


Figure A.2. Frequency chart of project completion date

<u>Response:</u>

2. Please find below a tornado/sensitivity chart (Figure 3) found as a result of sensitivity analysis. Please write down what you were able to see /learn from this graph.

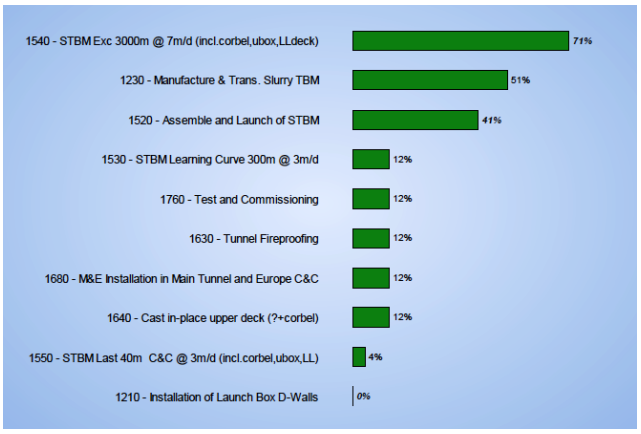


Figure A.3. Sensitivity chart

<u>Response:</u>

3. By looking at the simulation outputs (probability chart and sensitivity chart), can you please evaluate "the level of information" you get from Monte Carlo results? (0-undecided, 1-weak, 2-medium, 3-strong)

Information	**Evaluation (0, 1, 2 or 3)**
Level of uncertainty (risk level) of project completion date	
All possible project completion dates and their probabilities	
Confidence level regarding the contract/tender duration	
Significant risk factors/events	
Most likely, optimistic and pessimistic scenarios	
Impact of individual risk factors on project completion date	

4. Do you think schedule risk is high in this project? Why/why not? If you are undecided, what kind of extra information would you need to give your decision?

Response:

5. Do you think frequency chart and sensitivity chart provide a reliable and effective (easy-to-understand) visual representation about risk level of a project? Can you please comment on their benefits/shortcomings?

Response:

Part 4.

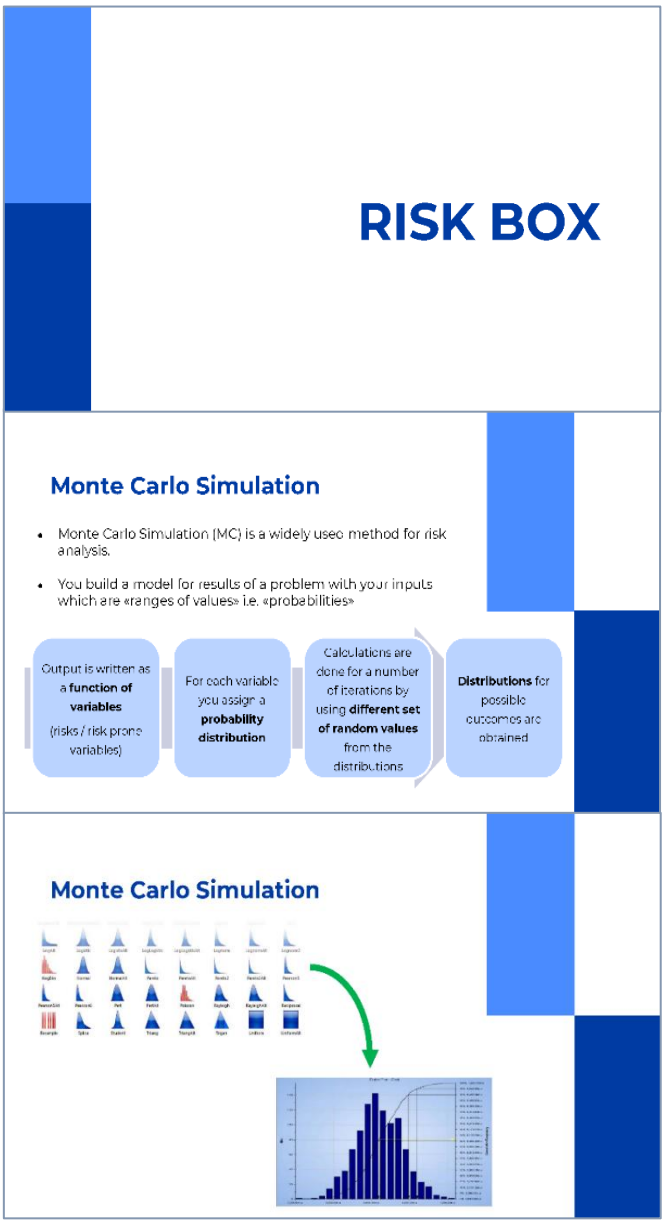
In risk reports, a couple of visualizations such as risk matrices, checklists, frequency charts, tornado graphs, spider diagrams are usually used together to demonstrate uncertainty about project outcomes, risks and their impacts.

Think of a perfect "risk picture" of the project, and please describe it. What would you like to "see" in this picture? This is your dream risk picture; it can be anything visual! (visual metaphor, conceptual graph, 3D model, an interactive tool etc.). Hand drawings and sketches are most welcome.

Response:

B. Presentation Used For Evaluation Of Risk Box

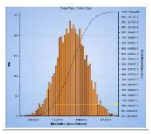
This appendix will present the screenshots for the presentation that has been used during interviews for evaluation of faces of Risk Box.

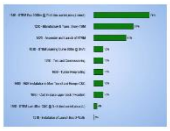


01
Initial Study

Findings From Initial Study

- Existing visuals (frequency chart – sensitivity chart) have been presented to 15 participants formed based on a real-life Project.

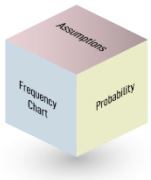


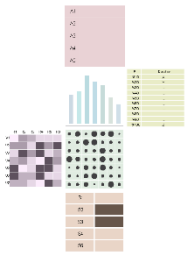


- Results:
  - Visuals are evaluated as being not effective and hard to interpret for most of the participants.

02
Risk Box

Risk Box





Case Study

- Ready mix concrete plant feasibility study
- Decision criterion for the investor = Payback Period (return on investment as early as possible)
- Target for payback period: **6 years**

Risk Analysis Procedure

Phase 1

- Risk analysts define risks, variables and assign related distributions
- Risk analysts represent the output (payback period) as a function of these variables

Phase 2

- Monte Carlo Simulation conducted (e.g. @Risk software)

Phase 3

- Faces of Risk Box is formed and presented to decision-makers

Case Study – Risk Analysis

Risks

Total = 11 Risks

- Vagueness of Design
- Unfamiliarity with Design Standards
- Administrative Delays
- High Bureaucracy
- Unexpected Weather Conditions
- Change in Design
- Change in Resource Cost (material, labour etc.)
- Change in Productivity
- Change in Demand
- Market Fluctuations
- Change in Operational Cost Items of Plant

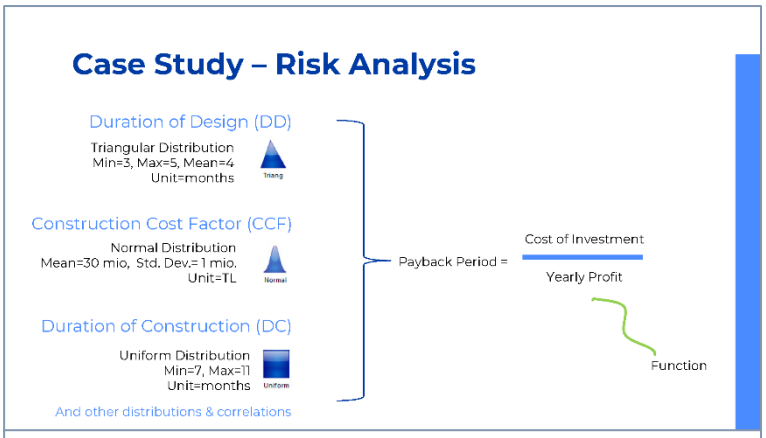
Variables

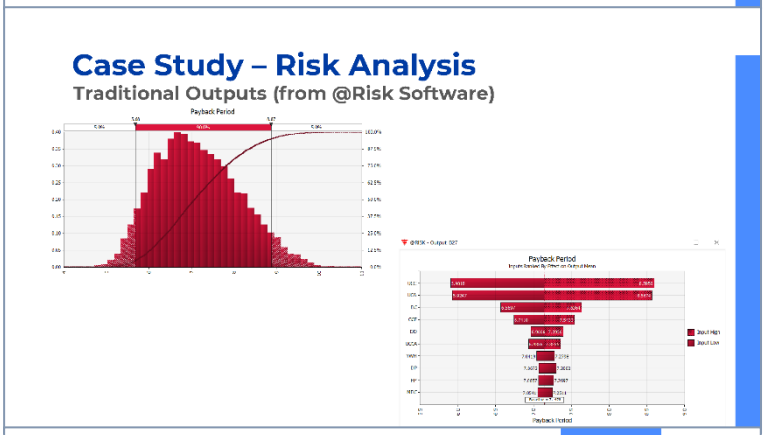
Total = 12 Variables

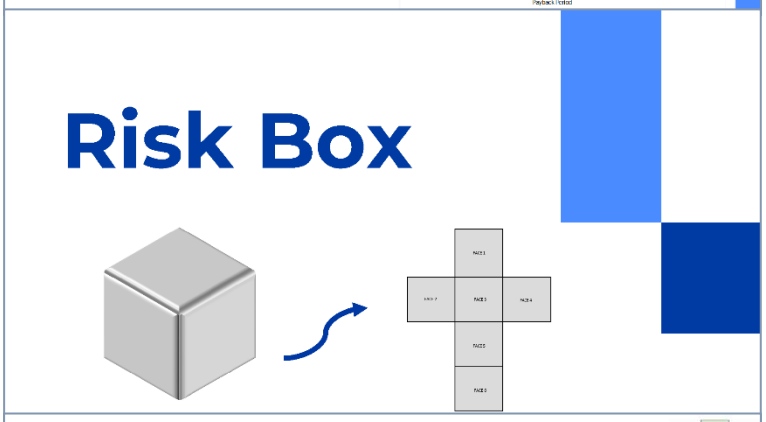
- Duration of Design
- Monthly Design Cost
- Duration of Permissions
- Duration of Construction
- Construction Cost Factor
- Hourly Production
- Yearly Working Hours
- Unit Cost of Cement
- Unit Cost of Aggregate
- Unit Cost of Water
- Unit Cost of Chemical Additives
- Operational Cost Percentage

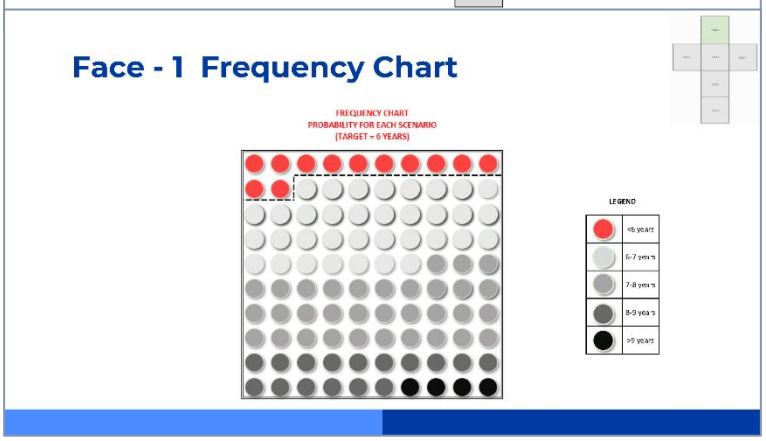
Probabilities & Impacts for Risks

Risks	Probability of Occurrence	Impact on Payback Period	Risk Score (Impact x Probability)
Vagueness of Design	2	4	**8**
Unfamiliarity with Design Standards	2	3	**6**
Administrative Delays	2	4	**8**
High Bureaucracy	3	3	**9**
Unexpected Weather Conditions	1	4	**4**
Change in Design	2	4	**8**
Change in Resource Cost (material, labour etc.)	2	5	**10**
Change in Productivity	1	5	**5**
Change in Demand	2	4	**8**
Market Fluctuations	2	4	**8**
Change in Operational Cost Items of Plant	1	4	**4**


Case Study – Risk Analysis
Duration of Design (DD)
Triangular Distribution
Min=3, Max=5, Mean=4
Unit=months
Triang
Construction Cost Factor (CCF)
Normal Distribution
Mean=30 mio, Std. Dev.=1 mio.
Unit=TL
Normal
Duration of Construction (DC)
Uniform Distribution
Min=7, Max=11
Unit=months
Uniform
And other distributions & correlations
Payback Period =
Cost of Investment
Yearly Profit
Function


Case Study – Risk Analysis
Traditional Outputs (from @Risk Software)
Payback Period
Payback Period


Risk Box


Face - 1 Frequency Chart
FREQUENCY CHART
PROBABILITY FOR EACH SCENARIO
(TARGET = 6 YEARS)
LEGEND
<6 years
6-7 years
7-8 years
8-9 years
>9 years

Face - 2 Information on Scenarios

Information on Scenarios	
Best Case	4,64 years
Worst Case	10,69 years
Mean	7,14 years
Median	7,07 years
St. Dev.	0,96 years
Coef. of Var. (St. Dev. / Mean)	0,13
90% Percentile	8,0-8,5 years
Target	**6,00 years**
Cum. Prob. to Reach Target	**12,0%**

Face - 3 Sensitivity Analysis

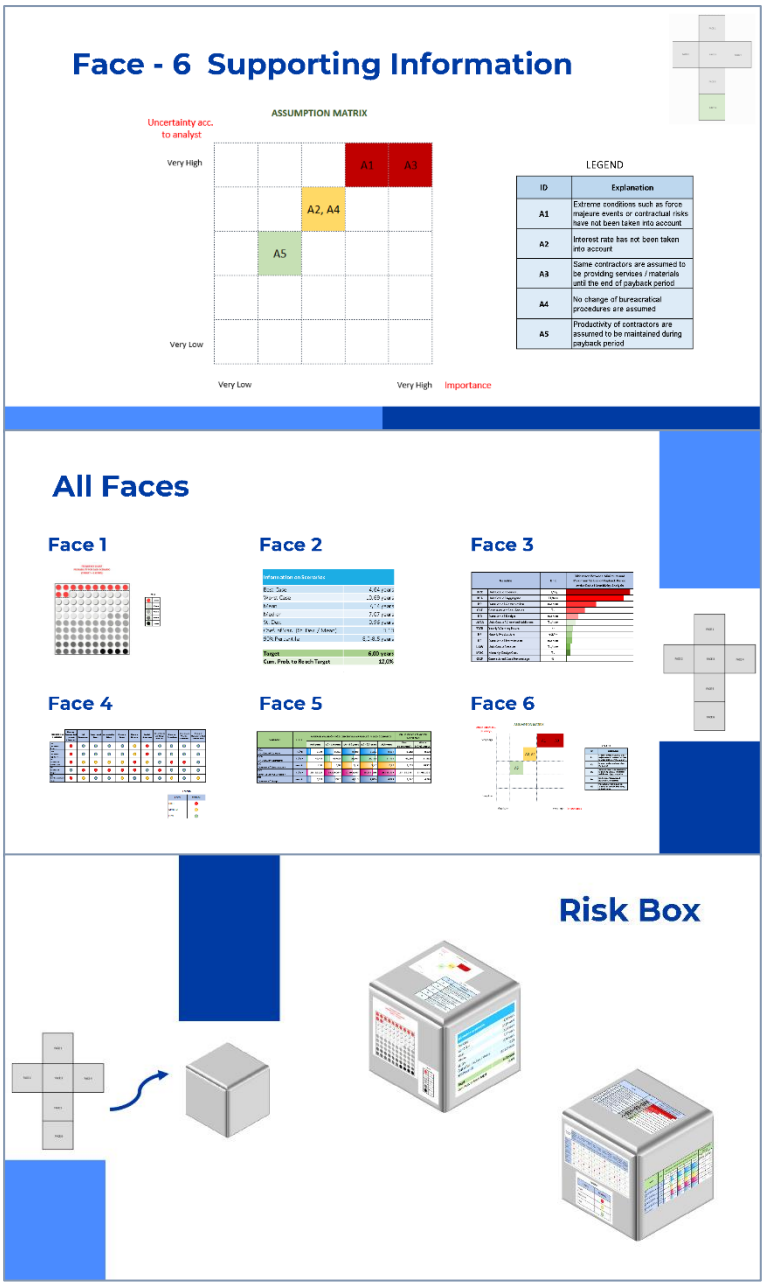
Variable		Unit	Difference Between Minimum and Maximum Values of Payback Period at the End of Sensitivity Analysis
UCC	Unit Cost of Cement	TL/kg	
UCA	Unit Cost of Aggregate	TL/ton	
DC	Duration of Construction	months	
CCF	Construction Cost Factor	TL	
DD	Duration of Design	months	
UCCA	Unit Cost of Chemical Additives	TL/liter	
YWH	Yearly Working Hours	hr	
HP	Hourly Production	m3/hr	
DP	Duration of Permissions	months	
UCW	Unit Cost of Water	TL/liter	
MDC	Monthly Design Cost	TL	
OCP	Operational Cost Percentage	%	

Face - 4 Risk Matrix

MOST SENSITIVE 5 VARIABLES	Change in Resource Cost (material, labour etc.)	High Bureaucracy	Vagueness of Design	Administrative Delays	Change in Design	Change in Demand	Market Fluctuations	Unfamiliarity with Design Standards	Change in Productivity	Unexpected Weather Conditions	Change in Operational Cost Items of Plant
UCC Unit Cost of Cement											
UCA Unit Cost of Aggregate											
DC Duration of Construction											
DD Duration of Design											
CCF Construction Cost Factor											

Face - 5 Risk Prone Variables

VARIABLE	UNIT	AVERAGE VALUE OF MOST SENSITIVE 5 VARIABLES IN EACH SCENARIO					VALUE IN BEST & WORST SCENARIOS	
		<6,0 years	6,0 - 7,0 years	7,0 - 8,0 years	8,0 - 9,0 years	>9,0 years	Best (4,64 years)	Worst (10,69 years)
UCC Unit Cost of Cement	TL/kg	0,286	0,293	0,299	0,303	0,307	0,285	0,309
UCA Unit Cost of Aggregate	TL/ton	47,476	48,628	50,067	51,155	51,739	47,384	51,952
DC Duration of Construction	months	7,91	8,80	9,14	9,52	10,23	7,773	10,902
CCF Construction Cost Factor	TL/ton	29.183.321	29.926.567	30.045.547	30.289.390	30.758.724	27.197.216	31.402.202
DD Duration of Design	months	3,869	3,972	4,013	4,075	4,079	2,767	4,296


Face - 6 Supporting Information
ASSUMPTION MATRIX
Uncertainty acc. to analyst
Very High
Very Low
A1
A3
A2, A4
A5
Very Low
Very High
Importance
LEGEND
ID
Explanation
A1
Extreme conditions such as force majeure events or contractual risks have not been taken into account
A2
Interest rate has not been taken into account
A3
Same contractors are assumed to be providing services / materials until the end of payback period
A4
No change of bureacratical procedures are assumed
A5
Productivity of contractors are assumed to be maintained during payback period
All Faces
Face 1
Face 2
Face 3
Face 4
Face 5
Face 6
Risk Box