University of Genoa
DIME/TEC – Polytechnic School

Ph.D. Thesis
Development of Simulation Based Approaches for Cost Estimation and Effect Analysis in Industrial and Humanitarian projects, Including System Dynamic Model and Monte Carlo Simulation

XXXII Cycle

Course:
Engineering of Machinery and Energy, Environment and Transport Systems

Curriculum:
Mathematical Engineering and Simulation
By:
Fahimeh Allahi

Supervisors:
Prof. Roberto Revetria
Prof. Roberto Mosca
Prof. Lucia Cassettari

Coordinator:
Prof. Roberto Cianci
April 2020

ABSTRACT

Cost management has become an integral part of management fields these days and has acquired great weight in the sector of project management as well. For most beneficiaries in the industry and humanitarian field, the management of projects is synonymous with the management of cost that affects directly the funds they need to mobilize to deliver their scheme. This thesis deals with the development and validation of simulation-based methods in the industry and the humanitarian field. In addition, several novel methods of cost management have been proposed considering the complexity of different factors.

In the industry field, construction projects are characterized by great uncertainty. Appropriate risk analysis techniques are required to estimate the adequate coverage level against the occurrence of extra costs to increase the progress of the project in the tenders. The project margin increases when an excessive provision leads to more comprehensive coverage of the risks. Also, an accurate estimation of the contingency reserve is a crucial subject in construction projects to reduce the risk of overruns' costs to an acceptable level and ensure the competitiveness of the company's bid. To achieve this goal, a Company's traditional approach has been applied to a real railway project and then a stochastic Risk Mode and Effect Analysis (RMEA) methodology base on Monte Carlo Simulation compared with the outcome of the company's traditional approach applied to the same project. Most of the contingency estimation methods are included problems of subjectivity, complex mathematical models, and inaccurate estimation. This research proposes a combination of the Risk Mode and Effect Analysis (RMEA) with Monte Carlo Simulation (MCS) to determine the amount of allocated contingency fund that overcomes other methods' limitations. The output of the analysis is a cumulative distribution function that demonstrates a coverage level related to the contingency amount to control extra cost and reduce the amount of contingency in projects. The developed method is validated by applying a real construction project and the obtained results are compared with the outcomes' of the company's traditional approach, clearly demonstrate the potential and the benefits of the proposed methodology. The result of the proposed method allows the decision-makers to operate with a lower contingency amount and control extra expenses of projects. In addition, a Decision Support System (DSS) approach using Failure Mode Effect Analysis and Monte Carlo Simulation has been discussed in this chapter.

Besides, in the humanitarian field, A System Dynamic (SD) model has been applied to a humanitarian project to study the impact of different levels of financial aid paid to beneficiaries for different impact factors and estimate financial aid variation.

Natural and man-made disasters seem unpredictable every year, increasing a wide range of universal sufferers. Several people are affected by the direct outcomes of these disasters, and their life depends on disaster relief aid administered by humanitarian organizations. Recently, there has been renewed interest in cash distribution in the humanitarian sector during disaster relief to increase access of vulnerable people to supporting services such as health or education and develop their life’s condition while rising the efficiency of humanitarian organizations committed to the program. The research proposes a casual-loop and system dynamic model to assess multi aspects of related impact factors to provide optimal support of beneficiaries. The model provides a decision-making framework with a high-level overview of the interactions between the education and health aspects of the recipient’s life, provides a system dynamics analysis including interactions that could have led to improving the vulnerable people's condition life. This system dynamics approach can be used to study the significant factors on education and health aspects of refugee crises such as the case of Syrian refugees in Turkey. Reviewing the humanitarian management literature, a causal loop is developed to better understand the health and education variables and their interactions. Then a system dynamic model is proposed and validated by historical data of Syrian refugees in Turkey. The result of financial aid sensitivity shows that more financial aid from humanitarian organizations are significantly improved the general health of refugees and also it is caused higher attendance for children in schools. In addition, enhanced financial aid supports can lead to improving access to water and hygiene facilities and also building more schools for their children.

DEDICATION

I dedicate this work to my husband, my father, and my mother, for their parental and family love and care, and for being the foundation and pillars in my whole life. Whatever I have done in my life would never have been accomplished without them. I owe them everything for the past, the present and the future. Their encouragement and unconditional support in all my decisions has always been the power I use to carry on.

“Dad, Mum, Amir, I am grateful for everything, you are my whole life in this world”.

ACKNOWLEDGEMENTS

The completion of this thesis represents the culmination of three years of hard work. I went through lots of challenges, risks and tribulations throughout the period of study that has culminated in this thesis. All these difficulties presented challenges that in the end have made me a better person in my moral standing, and with a better personal ethical code. Over the three years that have gone into completing this work I have been fortunate to be accompanied by an extraordinary range of wonderful people. Each of these people has made the journey easier for their being involved. I would like to take this opportunity to express my sincere gratitude to my Supervisors Professor Roberto Revetria, Roberto Mosca and Lucia Casettari whose trust, support and guidance went far beyond their job requirements. Their support has been unique, and they knew how to manage my situation and how to make me carry on with the research study.

Secondly, I owe special thanks to my supervisor, Professor Roberto Revetria. I could have not completed my PhD without his help and support. His guidance was valuable, which enabled me to develop a strong understanding of the subject and supported me to complete this thesis.

I am also grateful to Dr. Ehsan Sabet who was my co-supervisor in the United Kingdom and offered me a great opportunity to be part of the Loughborough University to advance my knowledge in humanitarian and system dynamics and also extended my network in the research community.

Also, I would like to thank my coordinator, Professor Roberto Cianci who has supported my development, including visiting in UK and arranged facilities and authorizations and always helped me for all these years.

My appreciation and warmest gratitude also go to my husband, Dr. Amirreza Fateh, who has been beside me for his unique support in all aspects of my life and he has always kept me balanced when things were wrong and his support made me put my life back on track. I have absolutely no doubt that without his presence in the background I would never have completed this work.

No set of acknowledgments would be complete without mentioning a family. My mother and father have provided me with over thirty years of support in which they have helped me through a broad variety of challenges.

Table of Contents

List of Figures

LIST OF TABLE

LIST OF ABBREVIATIONS

AACE = American Association of Cost Engineers;

ANN = Artificial Neural Networks;

CC = cost contingency;

DEV = Deviation;

DM = Decision Maker;

DSS = Decision Support System;

FMEA = failure mode and effect analysis;

MCS = Monte Carlo simulation;

MED = Medium;

MSPE = Mean Square Pure Error;

MSPEMED = Mean Square Pure Error of the Mean;

MSPESTDEV = Mean Square Pure Error of the Standard Deviation;

PDF= probability density function;

PERT = Program Evaluation Review and Technique;

PM = project manager;

RA = Regression Analysis;

RMEA = Risk Mode and Effect Analysis;

RR = residual risk;

SD = System Dynamic.

LIST OF PUBLICATIONS

Part of the outcome from this PhD research has been published in four international conferences and three international journals. The rest has been prepared for publication by 2019.

1. Allahi, F., Cassettari, L. and Mosca, M., **2017**. Stochastic risk analysis and cost contingency allocation approach for construction projects applying Monte Carlo simulation. In ***Proceedings of the World Congress on Engineering*** (Vol. 1).
2. Allahi, F., Cassettari, L. and Mosca, M., **2017**. A Stochastic Risk Analysis Through Monte Carlo Simulation Applied To The Construction Phase Of A 600 MW Gas Turbine Plant. In ***Proceeding of MAS 2017, International conference on modelling and applied simulation***, 18-20 September.
3. Allahi, F., Cassettari, L., Mosca, M. and Mosca, R., 2017, July. An Innovative DSS for the Contingency Reserve Estimation in Stochastic Regime. ***In The World Congress on Engineering*** (pp. 43-57). ***Book Chapters published in the Springer***, Singapore.
4. Allahi F., Leeuw S.D., Sabet E., Kian R., Damiani L., Giribone P., Revetria R., Cianci R., (2018). A Review of System Dynamics Models Applied in Social and Humanitarian Researches. In Ao S. I., Gelman L., Hukins D.W.L., Hunter A. & Korsunsky A.M. Lecture Notes in Engineering and Computer Science. Paper presented at the ***Proceedings of the World Congress on Engineering*** **2018**, London, U.K., 4-6 July (pp. 789-794), Newswood Limited International Association of Engineers.
5. Allahi F., Revetria R., Cianci R. (2018). Cash and Voucher Impact Factor in Humanitarian Aid: A System Dynamic Analysis. ***Proceedings of the MAS 2018, 17-19 September, Budapest, Hungary***.
6. Cassettari, L., Allahi, F., and Mosca, M., **2020.** Contingency Cost Estimation Using Stochastic Risk Mode and Effect Analysis based on Monte Carlo Simulation in Construction Projects. ***Under review of Journal of Management in Engineering***

CHAPTER ONE

INTRODUCTION

1 Introduction

This chapter gives a brief introduction to the research background that helps to understand the research necessity from the academic and practical viewpoint. The thesis outline is provided to explain the different simulation based approaches in project management, followed with cost estimation in industry's and humanitarian project. First, the background of the study and statement of the research problem are addressed. The research aim and objectives are also presented. Subsequently, the scope and boundaries of the study are presented followed by a summary of the research methodology adopted. Finally, a statement of the contribution to knowledge and the significance of the research findings are described**.** The chapter ends with a description of the structure of the thesis.

1.1 Research Background

Cost management has become an integral part of management fields these days and has acquired great weight in the sector of project management as well. For most beneficiaries in industry and humanitarian field, the management of projects is synonymous with the management of cost that affect directly on the funds they need to mobilize to deliver their scheme. Cost management is defined as the process of planning and controlling the budget of the projects. It helps in predicting the expenses of the projects so that one can avoid going over budget, thereby being an integral part of project management (Oberlender, 1993). Project cost management can be divided into three main phases: cost estimating, cost budgeting and cost control which the phase of cost estimating takes place in advance of the operational work in the project to evaluate how many costs will occur during the project and the sum of expenses has to be estimated (Guh, 2005)

The cost estimation is especially relevant to construction and humanitarian projects, where the risks and complexity factors are high (Watkins, 2014). On such schemes, project managers often have a huge challenge to deliver operational tasks, as well as forecast probable overruns to change conditions of those complex factors. Effective management of cost in such projects is a key role and often a requirement for achieving successful delivery and is often the advance criterion for key project decisions.

Three case studies have been discussed in this thesis which one of them has presented a system dynamic model for cost estimation of a humanitarian project for the case study of Syrian refugees and two of them comes from the need for a multinational Company operating on construction projects, to develop a new and safe simulation method for assessing and managing cost. Regarding existence of uncertainty and complex factors in construction and humanitarian projects, developed simulation based techniques such as Monte Carlo Simulation and system dynamic have been discussed.

Cost estimating is one of the most important steps in project management since there is always uncertainty in the last predicted price. The evidence suggested that such effective estimation of construction project's cost is often difficult to attain without contingency and management reserves (Gillet, 2015). It is a significant subject in the cost estimation to find out the more accurate cost amount to allocate in the projects)Moselhi, 2015).

The word 'Contingency' is one of the most questionable, misunderstandings and least discovered objects in the estimation and means various units to different people in the several fields of study (Clark and Lorenzoni, 1985; Patrascu, 1988). American Association of Cost Engineers (AACE) in 2012 described contingency as a precise reserve of money in an estimate for the unpredictable or indeterminate cost of components by statistical analysis of ancient data (Clark and Lorenzoni, 1985). Furthermore, the Project Management Institute (PMI) in 2012 defined it as a fund amount to reduce the overrun risks to an acceptable level for the company. Basically, it is a reservation for uncertainties in the projects (Thompson and Perry 1992). Among the projects, construction projects also can be particularly complex because of the risk elements, which may unfavorably affect the result (Flanagan and Norman 1993; Mills 2001; Qazi et al. 2016). To provide for these risks, Contingency Reserve (CR) is allocated into the budget. While Cost Contingency (CC) involve within a cost estimate, the budget describes the total financial commitment for the project manager (Baccarini and Love 2014). The CR and other resources are assembled to guarantee the successful result of a project (Hillson 2002; Uzzafer 2013). Moreover, it is a significant method to control risks in the cost estimation (Project Management Institute 2012). A realistic estimate has a significant effect on the projects since it uses as a baseline in the project controlling for decision-making (Yeo 1990). This method is based on setting apart some amount of budget to cover the project warnings. (Association for Project Management 2008; Eldosouky et al. 2014).

A careful contingency assessment is essential to ensure competitiveness in tenders. The higher the contingency reserve is, the higher the coverage level is. However, at the same time, the allocation of contingency reserve leads to an increase of the overhead costs, impacting on the overall value of the project estimation. This is necessary to support the Company in implementing the new methodology and to manage the random component, typical of all kind of risks, in a statistically correct way (Moselhi, 1997).

Commonly, in the traditional methods, the risk occurrence probability and related percentages were used to estimate the contingency fund (Moselhi, 1997.(Some authors presented reasons such as inaccurate, complex and inordinate allocation of budget to refuse using traditional methods (Baccarini, 2005).

Accurate cost contingency amount can be obtained by probabilistic method)Moselhi, 2015.(Among probabilistic methods, MCS is one of the most common method, which is applied for cost contingency estimation and risk analysis in construction projects (Bakhshi and Touran, 2014). Upon the occurrence of a probabilistic risk event, for some years now there has been a movement to replace classic scenario analysis (based on minimum, maximum and most probable values) with the definition of a PDF that describes the probability of possible occurrences of the economic impact values associated with each individual risk. The output of the analysis based on the Monte Carlo simulation, is a PDF curve, capable of linking the reserve amount with the probability of covering expected global risk. Furthermore, in comparison with other methods, MCS is more impressive because of comprehensible, easy to use and feasible (Eldosouky et al. 2014).

Besides, it can be noted that, developed MCS method for cost estimation has been presents for industrial case studies and also, system dynamic simulation has been used for humanitarian case study.

Regarding numerous aspects of impact factors in humanitarian and the complex relationship among them, the recommended system dynamic model illustrates how the methodology of system dynamics can be useful for understanding the behaviours of complex factors in humanitarian and consider them while project manager make the decision for the costs in the disasters or emergencies situation (Revetria et al. 2008).

Recently, an SD model was applied in humanitarian project management to model distribution of critical supplies during relief procedures in case of a hurricane event to understand aid supply required in accommodation and distribution (Cruz-Cantillo, 2014). In addition, Kunz et al., 2014 suggested a system dynamic model for food transfer during a disaster and established a decision framework on how to allocate budgets in emergencies. The main issue of the developed SD model is lack of measurements and estimation of cost in the long-term refugee crisis.

In this research, a SD approach is applied to simulate key factors in refugees’ life such as health and education.

Generally, Applying and analysis of financial aids to health and education system of refugees are very complicated. In order to making smooth this methods it is better to illustrate all the actions using casual loop diagrams (CLDs).

CLDs are essential tools and visual qualitative models for interpreting the feedback structure of systems by employing feedback loops to show links between the variables that define a system (Briano et al., 2010). They have long been employed in academic studies and frequently applied in organizations to quickly capture assumptions about the causes of dynamics (Revetria et al. 2008). The consequences of relations between the variables can be further simulated by the SD model to evaluate and enhance the perception of this complex system. Hence, this study aims to address this need, first by understanding health and education system and its building elements, by investigating the interaction dynamics between these building elements, by assessing the impact of humanitarian financial aid in changing such interactions, and finally by offering a system dynamics (SD) simulation model verified with Syrian refugees' historical data, as a future guideline for cost estimation. To the best of our knowledge, our study is the first research project which uses a quantitative SD model verified and validated with real data for different factors related to the refugee crisis and the validated model is then used to estimate the amount of financial aid for health and education services and presents the better way of spending money for policy makers in humanitarian organizations.

1.2 Research Structure

This thesis deals with the development and the validation of simulation based methods in industry and humanitarian field and novel methods in order to cost management considering complexity of factors have been proposed. To achieve this goal, a Company's traditional approach has been applied to a real railway project and then a stochastic Risk Mode and Effect Analysis (RMEA) methodology base on Monte Carlo Simulation compared with the outcome of the company's traditional approach applied to the same project. In addition, a Decision Support System (DSS) approach using Failure Mode Effect Analysis and Monte Carlo Simulation has been discussed. Finally, System Dynamic model has been applied to a humanitarian project to study the impact of different levels of financial aid paid to beneficiaries for education and health impact factors and estimate financial aid variation.

Hence, the structure of thesis is described in more details:

- Chapter one:

This chapter deals with the background to the research including justification and the problem statement, aim and objectives and the associated contribution to knowledge emanating from the research and structure of the thesis.

- Chapter two:

This section focuses on estimation of contingency in stochastic regime by MCS. The traditional method of a real life Company applied to an industrial project of railway signaling and integrated transport systems. The proposed method considered the qualitative risk analysis and stochastically quantitative analysis by using the Monte Carlo method and executed for two probability distribution, which presented the cost contingency amount for the risks happening with the determined probability (under 20 percent) to allocate in the project.

The comparison between the results obtained from two different types of probability distributions showed two different coverage level for one contingency amount, which means the contingency value, is not accurate and also the result was influenced by the choices of the decision-maker. Therefore, it is resulted that the method has the problem of subjective and inaccurate.

In the next section, a new methodology will be introduced for which is more accurate and have the feature of objective.

In addition, combination of the Risk Mode and Effect Analysis (RMEA) with Monte Carlo Simulation (MCS) is presented to determine the amount of allocated contingency fund that overcomes other methods' limitations. The output of the analysis is a cumulative distribution function which demonstrates a coverage level related to the contingency amount to control extra cost and reduce the amount of contingency in projects. The developed method is validated by applying to the real construction project and the obtained results are compared with the outcomes' of the company's traditional approach, clearly demonstrate the potential and the benefits of the proposed methodology. The result of the proposed method allows the decision-makers to operate with a lower contingency amount and control extra expenses of projects. Thanks to this method, the calculations carried out in a quick and precise way. In addition, the accuracy of the model is high, and it does not need a specific mathematical expert.

This chapter also addresses an innovative risk analysis method based on Monte Carlo Simulation to the construction phase of a 600 MW gas turbine plant to demonstrate the advantages of a study in a stochastic regime. This proposed methodology for risk management and project control allows working in a stochastic regime that increases the progress of the project. The study aims to highlight the benefits and results obtained through a stochastic analysis compared to traditional deterministic analysis. In Particular, two project phases were considered in this research: the process of bid and the phase of work in progress control; Risk Analysis with Monte Carlo method has been applied to both. The analysis on the first phase has led to the allocation of a contingency equal to 8% of the costs of construction of the plant; this percentage represents a quantitative estimate of all the possible risks that may occur in the pipeline. The MCS analyses in the progress phase identified the project final dates for each critical path calculated at five different time instants, from June 2016 to December 2016; this has allowed to verify the evolution of the program and modify the program to avoid penalties. Finally, it has been possible to note how the variability of the results decreases with the approaching of the implant delivery dates; this aspect is fundamental in order to identify more precisely the final date of the project over time.

- Chapter three:

This chapter is devoted to a system dynamics model applied in social and humanitarian research during the visiting period in the United Kingdom. The model applied to a real project which aims to improve the welfare of Syrian refugees, one of the most distressing tragedies affecting millions of people who had to leave their homeland and live as refugees in Turkey. This comes with many concerns including basic needs of the refugees, planning for a fair and efficient of health and education services and estimate the proper cost for them. The success of the project will be reflected by the increase in the level at which the needs of the refugees are satisfied.
For this purpose, a causal loops to better understand the building-boxes of refugees' need and their interactions have proposed and then an SD model is applied and validated by field data from humanitarian organizations. The result of sensitivity shows the significant contribute to health and education of refugees when considering more financial aid from humanitarian organizations.

- Chapter four:

Finally, in this chapter**,** the fundamental objectives of the research are reviewed and highlighted. Conclusions drawn from the thesis are presented and recommendations are made.

CHAPTER TWO

COST CONTINGENCY ALLOCATION APPROACHES IN CONSTRUCTION PROJECTS

2 Cost Contingency Allocation Approaches in Construction Projects

The cost contingency estimation is an essential phase in the project management, especially when the regime of performance is stochastic. This chapter proposes some methods to estimate project cost contingency by considering the fact that any risk can occur on a variety of values in terms of economic impact. The proposed methods has been applied to construction projects of real life companies.

First of all, a probabilistic model is considered to estimate project cost contingency regarding the fact that any risk can occur on a variety of values in terms of economic impact. The impact of risks on the project is achieved by qualitative analysis through three parameters: schedule, cost, and performance. In addition, a stochastic quantitative analysis has been performed using Monte Carlo Simulation (MCS) with the aim to determine the probability distribution of the contingency cost and the related level of risk coverage. The proposed method has been applied on a construction project of a real life company using @Risk for Excel software. By obtaining the contingency amount for the project, it can be realized that with allocating a determined budget, a specific level of risks can be covered and vice versa. Eventually, the robustness of the result was evaluated by another probability distribution to compare the obtained results.

In the next section, a combination of the Risk Mode and Effect Analysis with Monte Carlo Simulation is proposed to determine the amount of allocated contingency fund that overcomes other methods' limitations like subjectivity, complex mathematical models and inaccurate estimation. The output of the analysis is a cumulative distribution function which demonstrates a coverage level related to the contingency amount to control extra cost and reduce the amount of contingency in projects. The developed method is validated by applying to the mentioned construction project and the obtained results are compared with the outcomes' of the company's traditional approach in the last section, clearly demonstrate the potential and the benefits of the proposed methodology.

In the last section a stochastic risk analysis is applied to the construction phase of a 600 MV gas turbine plant using Monte Carlo Simulation.

2.1 Introduction

A risk is an uncertain event or condition that, if it occurs, has an effect on at least one of the project objectives. Fundamentally, contingency cost is an essential reservation for uncertainties in the projects (Thompson and Perry 1992) and it is demonstrated the total financial obligation for the project manager (Baccarini and Love 2014). Contingency cost is the estimated amount of budget or time setting aside to cover the total risk of projects (Eldosouky et al., 2014).

A critical phase in contract of engineering is when the Decision Maker (DM) must determine the contingency reserve, or the extra cost that should be added to the overall project cost to ensure an adequate coverage level against the risk of cost overruns. The procedure of project risk management consists of identifying, quantitative and qualitative risk analysis, response planning and mitigating risks which are caused the successful of the project (Maytorena, et al., 2007). By applying a risk analysis method such as the Monte Carlo Simulation (MCS), PERT, Failure Models and Effect Analysis (FMEA), decision trees and sensitivity analysis (Baccarini 2005), the estimated contingency amount can be obtained. As an example, while a project contains tasks with risk factors, PERT method can determine the risk of overcoming the estimated time. A careful contingency assessment is essential to ensure competitiveness in tenders. The higher the contingency reserve is, the higher the coverage level is.

Taroun in 2013, focused on the research of new approaches to the risk assessment problem but do not consider the risk impact on the real project development and on the contingency reserve definition. Besides, risk management methodology only applied to engineering design projects and some small business Companies without considering the contingency reserve which have to be consequently allocated (Yim et al., 2014).

It is emphasized that an inaccurate estimation of project contingency costs may result in a drastic reduction in the total profits (Chou et al., 2009).

(Howell et al., 2010) review the different approaches adopted by PMs in the contingency costs estimation, rating each strategy according to five drivers: uncertainty, complexity, urgency, team empowerment and criticality.

Chou et al. in 2011, finally, propose a simulation approach using the Monte Carlo method. In particular, it uses a historic set of projects to create stochastic distributions to be associated with the project costs.

2.2 Literature Review of Methods for Estimation of Cost Contingency

Regularly, applied techniques of contingency estimation are classified into two main groups, namely deterministic and probabilistic techniques (Moselhi 1997, Schneck et al. 2009), but recently, Bakhshi and Touran (2014) supplemented a classification by adding the modern mathematical method to this group. Cost item allocation (Moselhi, 1997) and traditional percentage (Ahmad, 1992; Moselhi, 1997) were proposed as deterministic methods. In addition, expected value method (Hollmann et al., 2012), method of moments (Diekmann, 1983; Yeo, 1990; Moselhi, 1997) and Program Evaluation Review and Technique (PERT) (Aquino, 1992) were presented as probabilistic methods which calculate the contingency amount without using any simulation software which is an advantage for companies to not invest money on purchasing any software package. However, without any simulation, complex models in large-scale projects cannot be solved and these methods are useful solely for the first phase of risk assessment such as the conceptual or planning phase (Bakhshi, 2014).

The most commonly used method to estimate a contingency budget is traditional percentage method, which is deterministic and applied for each cost factor based on their most probable value and predetermined percentages to present a point estimate for the contingency budget (Ahmad, 1992; Moselhi, 1997; Mak et al., 1998). Contingencies are usually evaluated as an all-inclusive percentage addition on the base estimate, according to previous experiences which is arbitrary and difficult to justify or defend because it is an unscientific method (Thompson and Perry, 1992; Hartman, 2000). Moreover, it often leads to excessive allocation of the budget (Hartman, 2000). Cost estimators occasionally avoid using traditional methods respecting the complexity and strong mathematical requirement for contingency estimation (Khalafallah et al., 2005). Furthermore, an inaccurate estimate of project contingency costs may result in an extreme reduction in a project’s profit. It is required to present an approach for estimating the project budget based on heuristic techniques and simulation models in order to provide valuable input such as the likelihood of occurrence and levels of confidence, as a basis for making decisions for Project Manager (PM) (Chou et al., 2009). For this reason, three methods of estimation have supplanted this approach and have therefore taken on a greater importance, namely the Monte Carlo Simulation (MCS) (Chau, 1995), Regression Analysis (RA) (Merrow and Yarossi, 1990) and Artificial Neural Networks (ANN) (Chen and Hartman, 2000). However, regression models and ANN are often difficult to apply for users without any particular skill, MCS presents more opportunities for applicability to projects (Allahi et al. 2017a). Monte Carlo Simulation may consider cost objects independently or with correlation (Sonmez et al., 2007), but the availability of historical data is important to create appropriate probability density functions. The approach based on MCS is formed preferably on the subjective choice by individual decision makers of the probability distributions of each risk’s influence. This choice requires the referent to imagine in addition to the most likely value of the impact, the minimum value, maximum value and a probability profile over the entire range of possible values of the impact (Chau, 1995). This approach would be objective in the case where it is possible to have a database sufficiently rich to extrapolate the probability distributions with sufficient accuracy. Despite this fact, the extrapolation of past behavior into the future should always be handled with great care.

The methods that use the probabilistic approach produce more accurate contingency estimates than the ones that use the deterministic approach (Salah and Moselhi, 2015; Yim et al., 2015). A summary of some of different contingency estimating methods is displayed in Table 1.

Table 1 A summary of contingency estimating methods

Methods	*Explanation*	*Type of Method*	*Proposed by*
Traditional percentage	Percentage addition to the base	Deterministic method	Ahmad, 1992; Moselhi, 1997
Lump sum allowance	Presented sum of money in the contract sum.	Probabilistic method	Otali and Odesola, 2014
Cost item allocation	To each cost item, a percentage is allocated and estimated as a weighted average	Deterministic method	Moselhi, 1997
Probabilistic estimation (Allocation)	A calculation of probability of cost overrun for a given contingency level	Probabilistic method	Moselhi, 1997
Method of moments	Proposes a probability distribution of each cost item in an estimate to reflect the risk of the cost elements.	Probabilistic method (Non-simulation)	Diekmann, 1983; Yeo ,1990; Moselhi, 1997 Chau, 1995; Clark, 2001
Monte Carlo Simulation	A technique uses to develop data through a random number generator or by using a statistical program.	Probabilistic method (Simulation)	Aquino, 1992
PERT	Provided three different cost estimates for each item.	Probabilistic method (Non-simulation)	Curran, 1989
Range estimating	Estimating using risk analysis the determined contingencies by identifying and costing risk events associated with the project.	Probabilistic method (Simulation)	Merrow and Yarossi, 1990; Aibinu and
	A powerful statistical technique for		

Regression Analysis	analytical and predictive purposes in estimating cost.	Probabilistic method (Parametric Estimating)	Jagboro, 2002 Chen and Hartman, 2000
Artificial Neural Networks	An information processing technique that simulates the biological brain and its interconnected neurons.	Modern Mathematical Method	Zadeh, 1965; Shipley et al., 1997
Fuzzy techniques	A mathematical technique for capturing uncertainty attached to human behavior in which words are used instead of numbers in the fuzzy logic calculation.	Modern Mathematical Method	Mak et al., 1998
Individual risks expected value	A technique of multiplying the probability of occurrence and the deterministic risk impact to obtain the expected value of each risk.	Probabilistic method (Non-simulation)	

The problem of determining the allocated amount for covering project contingencies was addressed in research of Idrus et al. (2011), who criticized the allocation of contingency costs as a percentage (based on a historical set of projects) of the total project cost. The drawn method calculated a model based on risk analysis and fuzzy techniques that developed risk factor determination and validation. Although the problem of knowledge of fuzzy logic existed for the project manager, it was within 20 percent accuracy in the result.

Recently, some authors have dealt with the issue of allocating contingency funds despite its relevance in project management. In 2014, Lhee et al. presented a method to estimate the optimal contingency for construction projects. The two-step neural network method was based on statistics such as the mean squared error and correlation that decreased the risk of overcommitting investments and work better in comparison with one-step neural network methods. Furthermore, Salah and Moselhi in 2015 introduced a newly developed fuzzy-set-based model for estimating, allocating, and managing a contingency fund in construction projects. In the same year, Baccarini and Love carried out statistical analysis for the properties of cost contingency in water infrastructure projects. Then, to increase the accuracy of a contingency estimate, the empirical distributions of cost contingency were applied and the best-fit probability distribution was obtained. A number of authors have drew a method to estimate contingency, which employed lump-sum contracts and the log-logistic probability density function to best model the behavior of cost overruns in road construction projects (Love et al., 2015). Much of the previous research have presented different methods to estimate cost contingency, however, some of the methods require special knowledge in ANN, fuzzy techniques and some other mathematical subjects.

In a study conducted by Hammad et al. (2016), a method was supplied based on the activities contribution to the overall project cost variance to estimate the contingency in order to allocate within the project. The project manager does not need special knowledge of complex models with this method, but the problem of subjectivity exists and also the approach did not control for the impact of the error on results. In particular, there was a strong dependence of some key parameters on subjective decisions made by individual decision makers.

Overall, these studies highlight the need to make some substantial changes to the existing methodologies in order to make the results as objective as possible and make the final result more “robust” in terms of reliability.

Therefore, a new method for measuring the amount of the allocated project contingency has been proposed. The approach is innovative because of combining Risk Mode and Effect Analysis (RMEA) technique with MCS and has improved reliability and accuracy compared to other techniques analyzed in the literature. RMEA is a risk assessment tool that mitigates potential failures in systems, processes, designs or services and has been used in a wide range of industries (Hammad et al. 2016). The introduced approach can be used to calculate a correct allocation amount of cost contingency for construction and industrial projects, against the risk of overruns’ cost and cash flow by determining the risk factors. Regarding the structure of this method, it can be applied easily without any mathematical skill, even by non-specialist project managers for making decisions about setting aside the accurate value to cover the approximate total risk of the project. The presented method is based on three risk factors including the risk occurrence probability, severity and detectability. The size of the contingency or the financial reserve produced by proposed new method is more accurate compared with the other approaches. The set aside contingency is protected by the project’s gain and the financial result of the company, without allocating unnecessary costs and as a result, company gains competitiveness in the market, without compromising the level of protection against risk.

In addition, using this approach, managers have been able to deal with the major limitation, which is the subjectivity of assessment in the allocation of weights associated with each risk. The mentioned limitations were inevitable until now and had a significant impact on the risk assessment and estimation. However, problem of subjectivity has been solved by normalizing, weighting and re-evaluating extracted data by assessors (usually chosen by department heads) in this research. The introduced approach is applicable to any company with any size, belonging to any sector. Furthermore, the developed method has improved reliability and speed in estimating of cost contingency in comparison with the common use of the RMEA, adapted by the tender process with clear instructions to use at every stage of the process. Furthermore, it has a low impact on company resources and application speed. RMEA is integrated with Monte Carlo simulation (MCS) in this methodology in order to stochastically evaluate the least expected cost and obtain the cumulative distribution function. Consequently, it presents and ensures an adequate "level of coverage" connected with the estimated contingency amount. The higher level of coverage will be obtained when the set aside contingency fund is high. However, at the same time, the allocation of the high contingency fund provokes an increase in the so-called overhead costs and it affects the overall value of the project estimate. The size of the contingency is much reduced by this approach compared with other methods and limits the overhead costs.

First of all, the traditional method of cost contingency estimation has been applied to an industrial project for a real life company operating in the field of railway signaling and integrated transport systems and then combination of RMEA and MCS is applied to this project and will be compared with the traditional method.

2.3 Stochastic Risk Analysis and Cost Contingency Allocation Approach for Construction Projects Applying Monte Carlo Simulation: Case Study of Railway Project

This section a method is proposed to estimate the contingency in stochastic regime by MCS. The purpose is to support the Companies with the stochastic regime against the risk of cost overruns to win in the tenders.

The early methodological phases of a qualitative and quantitative risk analysis are presented in the next section. Then, the method is applied to a railway project. After a critical risk analysis, the robustness of results is checked by another probability distribution.

2.3.1 Risk identification: qualitative and quantitative analysis

Risk identification is one of the important steps to recognize whole risks, which can affect the project budget. In order to identify these risks, the company uses a checklist guide. It makes possible to identify different kinds of risks: those of a strictly operational nature and those of a legal/financial nature arising from contract terms. The checklist was filled out with some interviews dedicated to members of the company, directly have involved in the management of the project. Qualitative and quantitative assessment are applied after the risk identification. The qualitative analysis determines the significant risks for the step of mitigate action.

At first, the impacts that the risks may have on the project are qualitatively identified through the three parameters: schedule, cost and performance. For each of these, it is necessary to define a scale to be able to identify a high (3), medium (2) or low (1) impact. The indicator used to rank the risks is the "risk factor", which is obtained by the multiplication of the probability occurrence of the mentioned risks by the level of their severity. Regarding the impact on schedule parameter, there are two types of risks, namely operational and legal/financial. Therefore, it is necessary to define two different scales for the two types of risk.

According to operational risks, Table 2 presents the number of delayed days on the project completion, caused by the occurrence of the risk. It proposes for the delay more than 30 days, the severity of risk will be high and influences on the cost of the project.

Table 2 Scale for operational risks

IMPACT ON THE SCHEDULE PARAMETER	
Number of delayed days	**Severity**
≤ 7 days	(1)
7-30 days	(2)
≥ 30 days	(3)

Regarding the legal/financial risks relating to the payment of the penalties for late delivery, the scale of Table 3 is considered.

Table 3 Scale for legal/financial risks

IMPACT ON THE SCHEDULE PARAMETER		
Payment	**Action**	**Severity**
< 15 days	Penalty clauses not applied	(1)
≥ 15 days	Penalty clauses applied for every late day	(3)

This table clearly shows that as long as the request subject to a contract penalty has a delay lower than of 15 days, the associated penalty is not actually applied and hence not considered. Obviously, once 15 days are reached, every day of delay accrued will be paid.

For analyzing the impact on costs, a single scale is considered for both types of risk (Table 4). The assessment is closely related to the fact that the risk occurrence would result in a more or less significant decrease in the cost of the project K or in the Gross Margin. Based on several studies, values x1 and x2 were identified as discriminants between the various levels of impact (not reported due to corporate intellectual property right).

Table 4 Scale for impact on cost

IMPACT ON COSTS		
Cost	Assessment base on x_1 and x_2	Severity
< 57 k €	Job order K decreases less than x_1%	(1)
57 k - 1,000 k €	Job order K decreases between x_1% and x_2%	(2)
> 1,000 k €	Job order K decreases more than x_2%	(3)

Besides, the impact on performance, it is not necessary to apply separate analyses for the two types of risk. The scale used in this case is presented in Table 5.

Table 5 Scale for impact on performance

IMPACT ON PERFORMANCE	
Performance	**Severity**
The system/component does not meet contract specification and operational inefficiency of it exists.	(3)
A specific requirement is not satisfied without negative consequences on system's operational performance (Visible risk to the customer).	(2)
Contract requirements not fully satisfied (Not visible risk to the customer).	(1)

Once the mentioned scales were defined, the scale related to Risk Occurrence Probability (ROP) is determined. In particular, ROP is evaluated according to the followed criteria.

- ROP < 20%: Severity of risk = 1;
- 20% ≤ ROP ≤ 50%: Severity of risk = 2;
- ROP > 50%: Severity of risk = 3.

In order to rank the risks, the risk factor obtains by combining the qualitative assessments of the severity of the risks and its probability of occurrence in a matrix that presents a numeric value. The latter is calculated by multiplying the probability parameter by the impact parameter (in quantifying the impact, the highest value among those recorded for schedule, cost and performance was considered). The possible risk factor values are summarized in Table 6.

Table 6 Risk factors values

probability of occurrence	3	3(●)	6 (*)	9 (*)
	2	2 (◊)	4(●)	6 (*)
	1	1 (◊)	2 (◊)	3(●)
		1	2	3
		Risk Impact		

The obtained risk factor makes it possible to rank the identified risks according to priority. In particular, it was decided to proceed with the next step of analysis only for the risks characterized by a risk factor greater than or equal to three (The symbols of (●) and (*) that are determined in Table 6).

The economic impact of the possible occurrence of the risk will be quantified as the next step. According to the estimation of the risk impact, the procedure varies depending on the type of risk under consideration. If the risk is related to penalties, the maximum impact is estimated as the product of the accrued delay (typically assumed greater than or equal to 15 days) by the sum of the penalties.

Once the values of the impact associated with the individual risks are determined, the possible mitigation actions are implemented by identified precaution for each of them. This activity is based on an analysis of the causes generating the individual risks and aims at reducing/eliminating the impact of the risk.

It should be noted that the implementation of a mitigating action allows the reduction of an uncertain cost with a certain incurred cost (the cost of the action) whose amount is estimated to be lower. In order to ensure the right balance between risk reduction and cost-effectiveness, it is necessary to determine the net benefit of the mitigating actions. This benefit is determined as the difference between the expected value of the risk before and after the risk mitigating action. Clearly only the interventions with a positive net benefit must be implemented, unless there is still an overall benefit for the project and/or the Company.

After the reassessment of the residual risks and their final impact value, the amount of contingency fund will be defined. The set aside amount, makes it possible to "cover" the project if the risk event occurs. The objective is to minimize the occurrence of extra costs associated with the occurrence of the risk while trying at the same time to minimize the impact of the overheads that reduce the competitiveness of the job offer. In particular, the choice of the percentage of contingency to be allocated is a function of the value of the risk occurrence probability, according to the criteria in Table 7.

Table 7 Contingency allocation policy

CONTINGENCY	
Prob ≥50%	Contingency = Whole impact value
20%<Prob<50%	Contingency = 50% of the impact value
Prob ≤ 20%	Contingency = 30% of the impact value

After starting the described process, all the risks that did not occur should be reviewed to possibly re-determine the associated contingency cost.

Finally, when checking the condition that makes it possible to declare the risk "closed", the associated contingency reserve can be:

- "Used": if the risk has occurred, causing economic damage to the project. The contingency is considered "used" to cover the damage suffered up to a maximum value equal to the amount previously allocated. Any part of the damage that is not covered by the contingency is to be considered an "extra cost".
- "Releasable" or "Partially Releasable": in case the risk event does not occur and causing fewer damages compared to the allocated contingency.

In order to monitor the occurrence of the event linked to the risk, specific milestones must be assigned to the activities associated with the risk event. The completion of the milestone indicates that the risk, which has or has not occurred in the past, will not occur in the future. It is clear that a monitoring and a complete and comprehensive review of the risks must necessarily cover the entire project, which hence be constantly updated throughout its life cycle.

2.3.2 Stochastic Quantitative Analysis

The quantitative analysis described above is based on the assumption that the expected value of the risk and calculated as the product of the occurrence probability and the economic impact. It is enough to capture the essential aspects of the overall risk profile of the project.

However, since the regime of normal operations of companies is not deterministic but stochastic, it is necessary to take into account the fact that any risk can occur on a variety of values in terms of economic impact. Precisely for this reason, the methodology described above has been integrated with the steps illustrated below. For each risk, the decision maker identifies a probability distribution associated with the values of severity of the economic impact of the event. Among the most widely used, it suffices to mention uniform distribution, triangular distribution, normal distribution and beta distribution. The @Risk for Excel software is used for quick and easy definition of probability distributions, simply by selecting and customizing templates that is used in the paper.

Using the Monte Carlo method allows for the distribution of the overall likelihood of the contingency fund to be allocated starting from the probability distributions attributed to the individual risks. In the next part, the application to a railway construction project is carried out. Once the simulation runs, the curve of the probability distribution of the contingency and its integral curve is illustrated by means of MCS.

2.3.3 Application to a Construction Project

The obtained results from the application of the methodology described to a construction project in the railway sector are illustrated in Table 8. Once the critical risks were selected in section three (for risk factor > 3), each risk was associated with an appropriate probability distribution.

Table 8 Analyzed risk list

Risk	Occurrence Probability	Most likely impact value
Technological maturity	20%	€20,872.07
Low quality supply	20%	€251,841.41
Reworks	5%	€174,311.15
Plant software bugs	10%	€176,216.38
Wrong structural calculation	10%	€37,733.33
Wrong geotechnical calculation	10%	€37,733.33
Not consolidated experience of the subcontractor	10%	€226,400.00

Not consolidated experience of the subcontractor	10%	€226,400.00
Failure to define supply boundaries among subcontractors	10%	€75,466.67
Passing the maximum number of acceptable breakdowns.	5%	€550,996.39
Possible breakdowns	20%	€402,488.89

In particular, the project engineers selected the beta distribution (Figure 1). By means of the selected beta probability distribution, it was possible to assign a greater occurrence probability to the most likely considered impact value. At the same time, it was possible to assign a greater occurrence probability to those values lower than the estimated impact compared to those with higher values (decision deemed correct by the Company following an accurate a prior estimate of the impact itself). The need to use this type of distribution was determined to have a more accurate estimation.

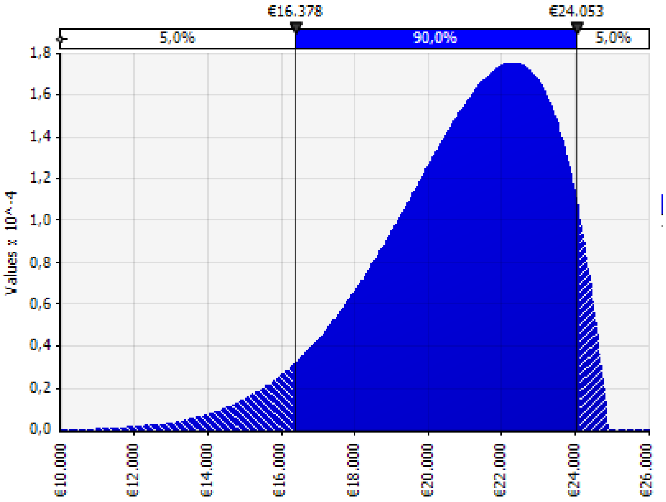


Figure 1 Beta distribution used for the "technological maturity" risk

At this step of the methodological analysis, it is important to carry out a number of experimental runs on the model such that it is possible to obtain an output of statistically reliable results with a known confidence level. For this purpose, the methodology of the Mean Square Pure Error in repeated run which was developed by Cassettari et al. 2010 and Cassettari et al. 2012 was used to determine the correct number of simulation runs. The proposed approach is based on the analysis of the curves illustrating the trend of the quantities Mean Square Pure Error of the Mean (MSPEMED) and Mean Square Pure Error of the Standard Deviation (MSPESTDEV). This methodology was created by the Authors as a conceptual extension for the Monte Carlo simulators evolving over time (Mosca et al., 2010). In addition, significantly by using the MSPE method, the experimental error in the results was controlled (Bendato et al., 2015). To this end, an experimental campaign of 5 simulations, each representing a sample of 20,000 elements, was set. The trend curves of the Mean Square Pure Error of the Mean and Standard Deviation shown in Figure 2 put in evidence that both curves stabilized at around 20,000 runs. It presents for this number of runs the mean value of the output will be very stable and the contribution of these two variables on the confidence interval of the contingency fund will be almost negligible.

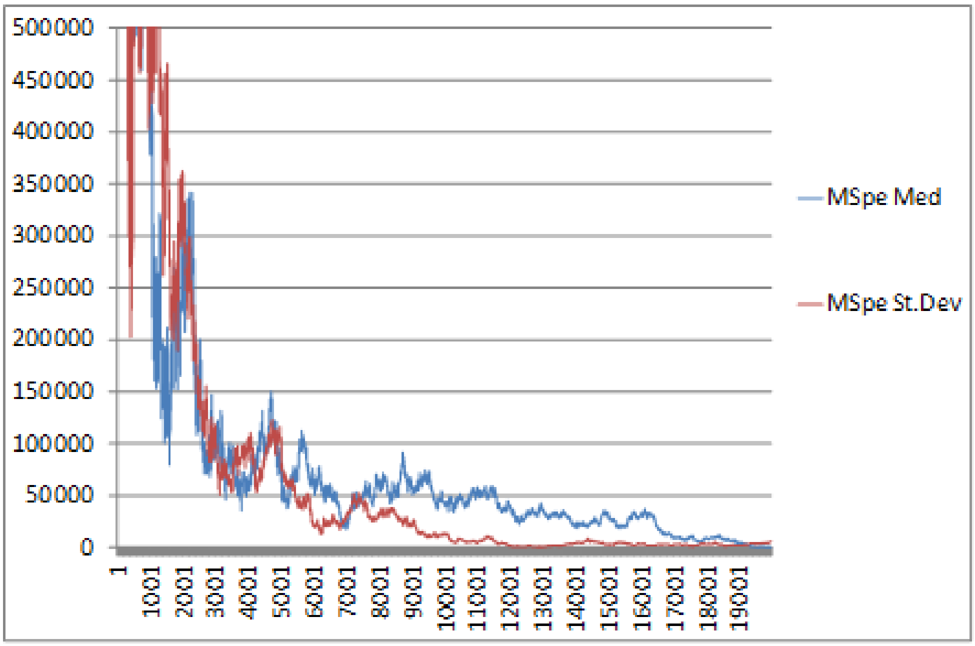


Figure 2 Trend of the quantities MSPEMED and MSPESTDEV depending on the number of runs

Once 20,000 is set as the number of repeated simulation runs, the curve of the probability distribution of the contingency and its integral curve, shown in Figure 3 and Figure 4were obtained.

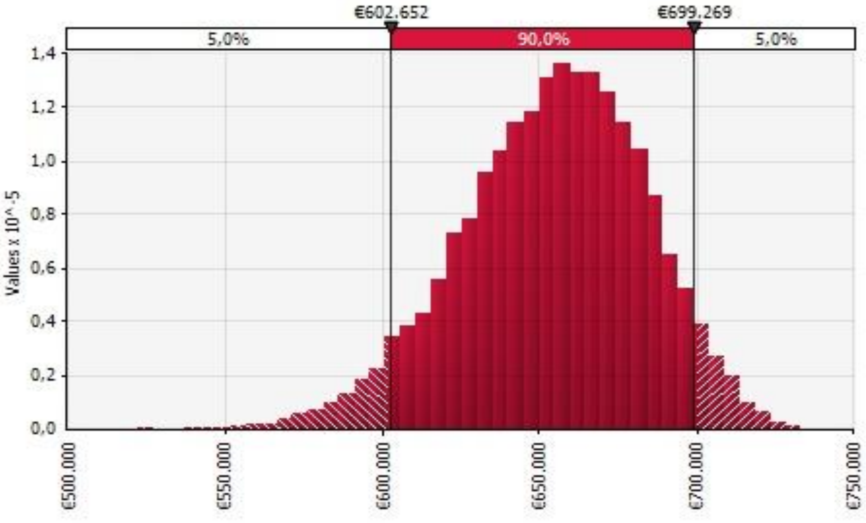


Figure 3 Probability distribution of contingency cost

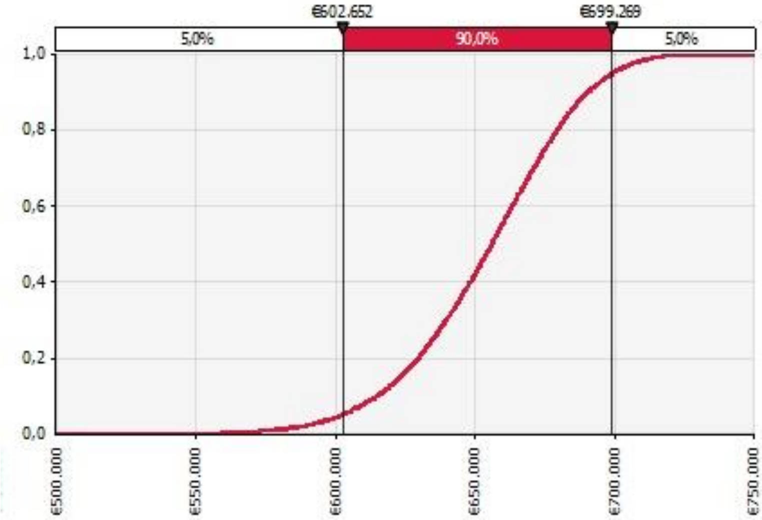


Figure 4 Cumulative probability curve of contingency cost

This Monte Carlo analysis makes it possible to determine the probability distribution of the contingency cost and allows identifying the degree of coverage corresponding to each value of the total allocated contingency fund. The curve is obtained by integration of the probability distribution from Figure 3 and features the possible contingency values on the X axis and the "Level of Coverage" on the Y axis (Figure 4). Hence, The Level of Coverage is the probability of being able to cover completely the costs arising from the occurrence of the risks using a set total amount of allocated contingency reserve.

The probability distribution in Figure 3 presents the contingency tends to spread according to a normal pattern. In addition, the most probable value of the distribution by a confidence level of (1 - α) % with $\alpha = 0.05$ is between the 600,000 and 700,000 €. Consequently, the data can be considered highly stable. In the Table 8, the occurrence probability values are lower than or equal to 20 and according to Table 7, contingency for Prob ≤ 20% equals to 30% of the impact value. Hence, the estimated contingency under a deterministic system was equivalent to 654,138 € (the sum of the most likely impact values of the individual risks multiplying by 0.3). By analyzing the cumulative probability curve (Figure 4), it may be noted that by a coverage level of 90 %, the contingency cost is equal to 690 € which totally covers the risks. In particular, entering the contingency value resulted from Table 8 (654,138 €), it can be obtained a risk coverage probability of about 40%. It presents that this graph does not provide information concerning the value of the extra costs but only concerning the level of risk coverage implemented with a 30% of contingency set aside for risks with a probability of occurrence of no more than 20% (see Table 8). Furthermore, allocating € 500,000 would be equal to take on a level of coverage of zero against the risk of extra costs. The same level of risk coverage would be obtained also by setting aside a contingency equal to zero, but it is clear that, in both cases, the extra costs incurred would be significantly different.

2.3.4 Robustness Analysis of the Methodology

In order to evaluate the robustness of the identified results, it was decided to use other probability distributions for the characterization of the risks and then compare the obtained results.

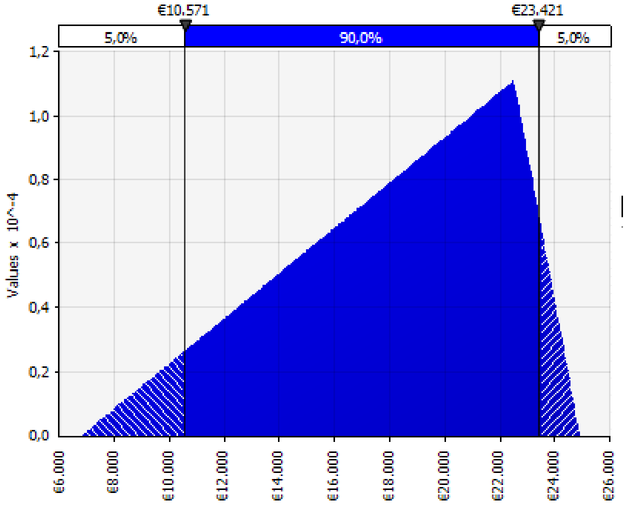


Figure 5 Triangular distribution used for the "technological maturity" risk

Therefore, triangular distributions were chosen (Figure 5) instead of the beta distributions (Figure 1), because of maintaining the min, max and most likely values as the supposed data. According to the proposed method, five simulations were performed, each having a number of 20,000 repeated runs, and the trend curves of MSPEMED and MSPESTDEV were built.

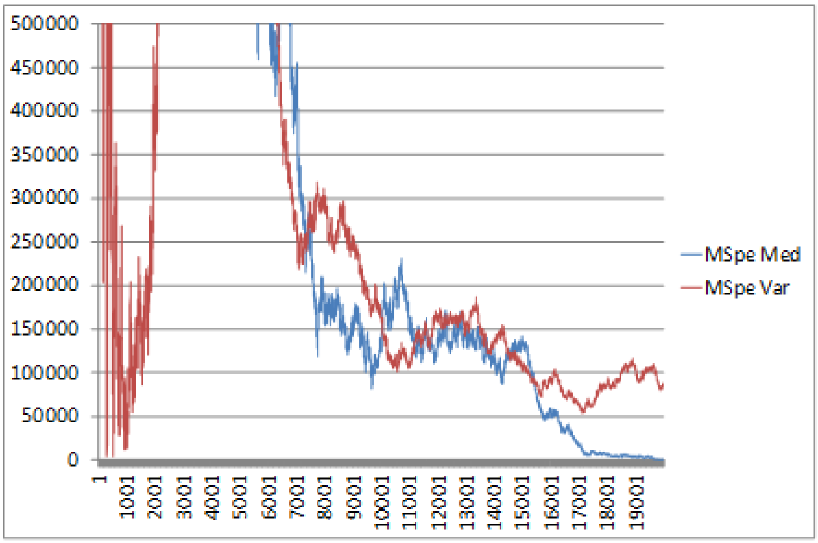


Figure 6 Trend of the quantities MSPEMED and MSPESTDEV depending on the number of runs

As the graph in Figure 6 shows, while the curve of MSPEMED stabilizes at 15,000 runs, the curve relating to MSPESTDEV still shows phenomena of instability so that it would be necessary to increase the number of Monte Carlo runs, namely the sample size.

By using a sample of 20,000 runs, the probability distribution and probability curve of the contingency cost (Figure 7 and Figure 8) were obtained. Figure 7 shows how the mean value of the distribution drops to € 565,403, with a confidence band of (1-α)% with α = 0.05.

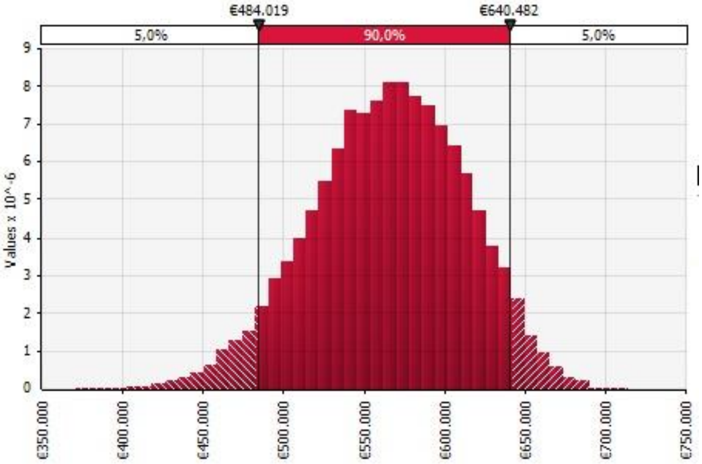


Figure 7 Probability distribution contingency with triangular distributions

The analysis of the cumulative probability curve is shown in Figure 8. By the contingency amount of 654,138 € (the obtained result from the deterministic analysis), a level of risk coverage of 90% is obtained which is higher than the determined amount using beta distribution.

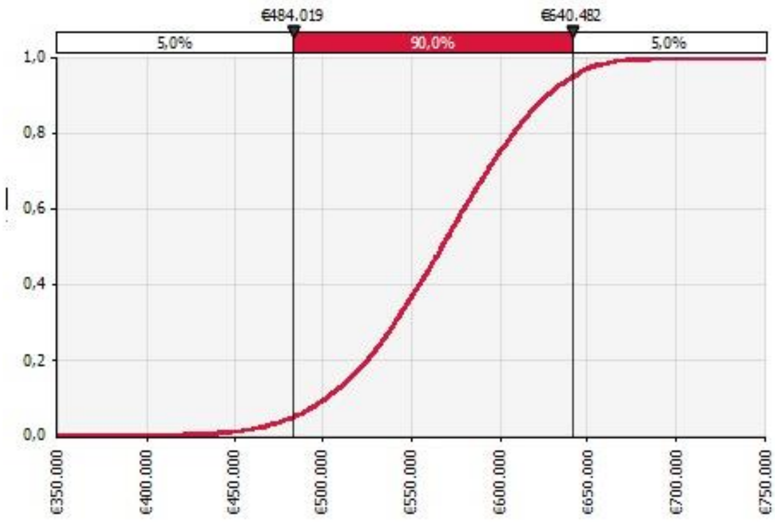


Figure 8 cumulative probability curve of contingency with triangular distributions

The comparison between the captured results by two different types of probability distributions, while maintaining the min, max and most likely values unchanged, shows the obtained contingency amount covers the determined risks up to 40% probability. Hence, by analysing both of Figure 4 and Figure 8 the contingency amount of 690 € covers the total obtained risk with the coverage level up to 90%.

The proposed method considered the qualitative risk analysis and stochastically quantitative analysis by using the Monte Carlo method. In addition, the application for a real life company executed for two probability distribution, which presented the cost contingency amount to allocate in the project. The presented method is not powerful and accurate as it can show the contingency amount just for the risks happening with the determined probability (under 20 percent) and estimates the contingency value to cover all the possible risks and also comparison between the results obtained from two different types of probability distributions showed two different coverage level for one contingency amount, which means the contingency value, is not accurate. In addition, the result was influenced by the choices of the decision-maker which is resulted that the method has the problem of subjective and inaccurate.

In the next section, the proposed method can be more accurate and have the feature of objective by assigning the risk assessment to another project managers in order to estimate carefully and using combination of MCS and RMEA.

2.4 Contingency Cost Estimation Using Stochastic Risk Mode and Effect Analysis based on Monte Carlo Simulation in Construction Projects: Case study of Railway Project

While carrying out the study, following Company guidelines, lack of an objective base in the used approach has been found. In particular, there was a strong dependence of some key parameters on subjective decisions made by the individual decision-makers. Consequently, it was decided to make some substantial changes to the methodology in order to make the results as objective as possible.

2.4.1 Methodology

RMEA technique is used to identify the associated risks and carry on the qualitative risk analysis; it consists of identification of relative causes and possible mitigation action. The steps for performing a RMEA analysis have a similar structure with the FMEA, but are re-defined both in the application mode and in contents.

Project risk analysis is a significant part of a project which is used to increase the likelihood of success. For carrying out a complete project risk management, the analysis should be structured as follows:

- Risk Identification: Determining a list of risks that could affect the project or its outcomes.
- Qualitative risk analysis: This phase includes a part of risk assessment that recognizes the risk priority and classifies them by their probability of occurrence and impact. In this research, qualitative risk analysis is carried out by the adjustment of the RMEA method.
- Quantitative risk analysis: Quantitative risk assessment naturally relates to risk modeling (Taroun, 2013) and analyzes the effect of identified risks on overall project objectives (cost impact, schedule impact, etc.) by combining RMEA and MCS in this new methodology. Quantitative and qualitative phases are performed together to stochastically evaluate the least expected cost and allocate accurate contingencies to the project.
- Risk response planning: Improvement of risk mitigation and actions to decrease threats to project aims (Skorupka, 2008).

- Risk monitoring: Risk should be monitored, and if the desired result of risk management is not achieved, then follow the identified risks and control the residual risks. Next, all steps should be reviewed, and where a problem occurs, implementation of the risk mitigation plan should be applied.

The framework of the contingency reserve management proposed by authors includes all of the abovementioned risk analysis steps and is structured as follows (Figure 9):

- The first step of RMEA: preliminary data collection and evaluation
- Normalization and weighting
- The second step of RMEA: mitigation scenarios of the main risks identified and sensitivity analysis
- MCS for contingency reserve identification

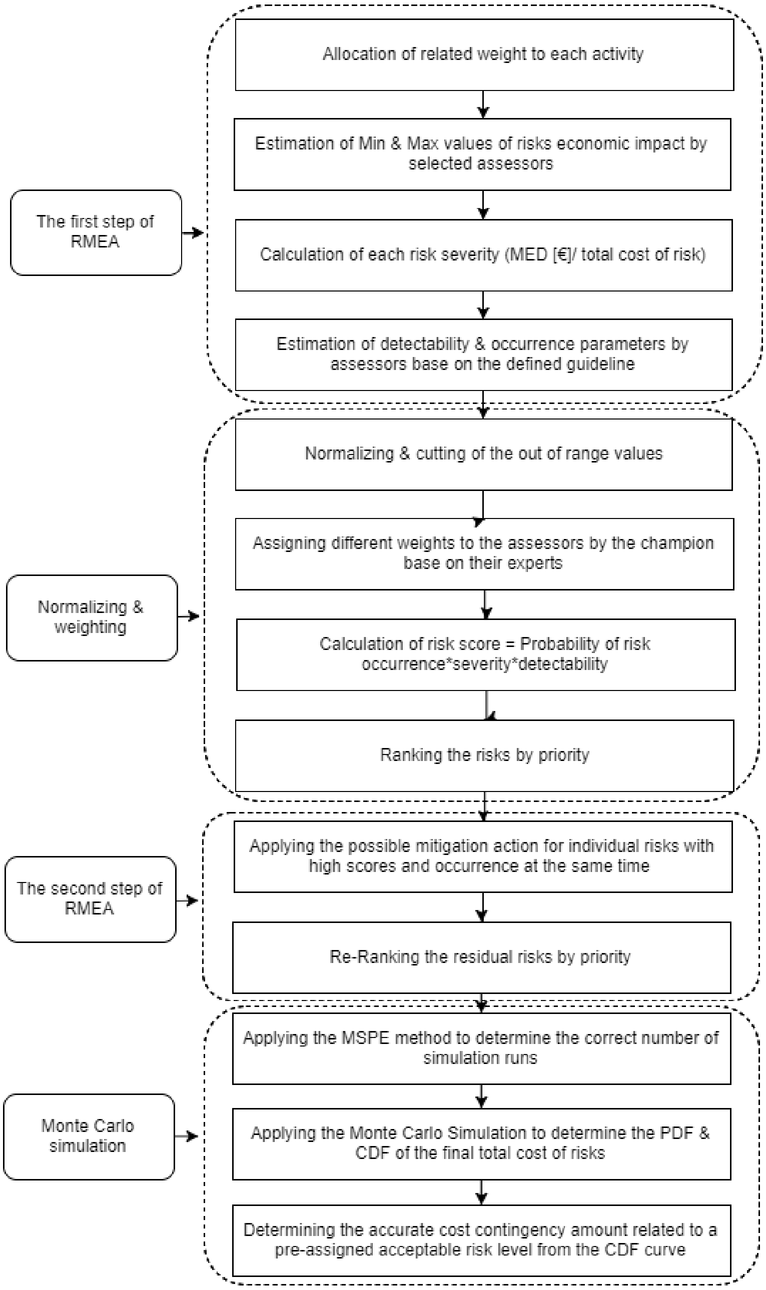


Figure 9 Framework for contingency reserve management

2.4.1.1 The First Step of RMEA

The objective of the first phase is to identify all possible risks that could affect the project. It can be carried out by using checklists, nominal grouping, mind mapping, Delphi technique, interviews or brainstorming sessions (Garrido et al., 2011).

One of the major limitations presented by the risk analysis is allocation of associated weights to each risk which it has a significant impact on the risk assessment. Assigning scores for the risk assessment to parameters such as detectability, severity and probability of occurrence is challenging work. The final evaluation depends on several subjective factors such as type of selected evaluator, his biorhythm, mood, attention level, tiredness, and various kinds of constraints and events of the surrounding environment. Consequently, it is necessary to minimize the influence of the listed factors. For this purpose, a first phase of risk assessment based on multiple interviews is proposed. It is a parallel data collection method involving different competence centers in the organization to extract a wide range of unconditional information. Once the most significant risks are identified, qualitative and quantitative assessment are carried out.

The qualitative survey consists of determining the main risks in order to prioritize them and to understand which one needs a mitigation action.

The first action in this phase is identification of an internal or external person to whom the role of "Champion" in the evaluation process is assigned. The Champion then selects the proper assessors and carries out interviews. In this phase, all of the possible risks are identified and evaluated in order to customize the specifically designed RMEA template (Table 9). The minimum and maximum values of the financial impact of each risk are estimated by assessors and is placed in the related columns in order to determine the medium financial impact. Then, the risks effect (MED%) are automatically calculated (effect of each risk = medium value of the financial impact (MED [€])/total cost of risk) and used by the Champion in order to set a proper 10 score scale for estimating the severity of each risk (last column) based on the values reported in Table 10 (an example of severity score assignment).

Table 9 The first step of RMEA

ID	First Step									
	Prepared by Champion, Following preliminary discussions with the Management and the interview with department heads									
	Phase of project		Risks							
	Function	Task	Potential risk	Potential Causes	Risk Economic Impact					
					Quality assessment	MIN [€]	MAX [€]	MED [€]	MED [%]	SEV
1	purchasing Office	Watertight doors	Delay	Difficult to identify Suppliers	Low	€ 25,000	€ 90,000	€ 57,500	3%	3
2	Project management	Hull construction	Delay	Delays Deliver (subcontractors)	Medium	€ 100,000	€ 120,000	€ 110,000	7%	7
3	purchasing Office	Deck hatches	Cost	Monopolists Suppliers, off Mkt	High	€ 100,000	€ 140,000	€ 120,000	7%	7
4	Assembly	Tender hatches	Defects	Testing conducted on a sample	Low	€ 60,000	€ 70,000	€ 65,000	4%	4
5	purchasing Office	Underwater lights	Cost	Difficult to identify Suppliers	Low	€ 30,000	€ 50,000	€ 40,000	2%	2
6	Assembly	Hull construction	Delay	Problems during assembly	Medium	€ 180,000	€ 200,000	€ 190,000	11%	10
7	Project management	Chain plates	Delay	Delays Deliver (subcontractors)	Medium	€ 160,000	€ 180,000	€ 170,000	10%	9
8	Project management	Ballast and storage	Delay	Delays Deliver (subcontractors)	High	€ 170,000	€ 180,000	€ 175,000	10%	9
9	HQSE	Portholes	Defects	Raw materials of poor quality	Low	€ 90,000	€ 130,000	€ 110,000	7%	7
10	HR	Transom door	Delay	Unavailability of labor	High	€ 25,000	€ 65,000	€ 45,000	3%	3
11	HQSE	Shell door	Delay	Rework	Medium	€ 160,000	€ 175,000	€ 167,500	10%	9
12	purchasing Office	SVR hatches	Delay	Delays in supply deliveries	Medium	€ 30,000	€ 35,000	€ 32,500	2%	2
13	Engineering	SVR commercial doors	Rework	Redesign	Medium	€ 60,000	€ 90,000	€ 75,000	4%	4
14	HR	SVR commercial doors	Delay	Problems during assembly	Medium	€ 75,000	€ 100,000	€ 87,500	5%	5
15	Project management	SVR construction	Delay	Delays Deliver (subcontractors)	Medium	€ 20,000	€ 40,000	€ 30,000	2%	2
16	Customer Care	Fly bridge pool	Cost	Customer requests modifications	High	€ 20,000	€ 25,000	€ 22,500	1%	1
17	HR	Fly bridge pool	Delay	Delays in assemblies	Low	€ 22,000	€ 26,000	€ 24,000	1%	1
18	Assembly	SVR windows	Delay	Rework	Medium	€ 70,000	€ 90,000	€ 80,000	5%	5
19	HQSE	Fly bridge	Defects	Raw materials of poor quality	Medium	€ 20,000	€ 23,000	€ 21,500	1%	1
20	HR	Windows frames	Delay	Delays in the assembly phase	Medium	€ 50,000	€ 80,000	€ 65,000	4%	4
				Total Risk Estimated		€ 1,467,000	€ 1,909,000	€ 1,688,000		

Table 10 An example of severity assignment

SEVERITY SCALE	MED %
1	1.00%
2	2.00%
3	3.00%
4	4.00%
5	5.00%
6	6.00%
7	7.00%
8	8.00%
9	10.00%
10	11.00%

The detectability and the probability of risk occurrence are obtained by author to provide the group of assessors with the guidelines presented in Table 11. Operating in this way, the final evaluation should be more objective than assigning the assessment to a single decision maker. Regarding the guideline of Table 11, for different control level, detectability and occurrence are introduced and the assessors determine the correct risk parameter level by the defined features.

Table 11 Guidelines of detectability and occurrence of risks

Level of Control	*Detectability*		*Occurrence*	
Deterministic	Deterministic (cause / effect)	1	0%	5%
	Identification does not require experience	2	6%	10%
	Identification does not require experience, but needs attention	3	11%	20%
	Identification requires experience and special care	4	21%	30%
Stochastic	External causes are easily identifiable and controllable	5	31%	40%
	External causes are difficult to identify but they are controllable	6	41%	50%
	External causes are difficult to identify, but they are manageable and uncontrollable	7	51%	60%
Completely Random	Causes are uncontrollable and targeted normal competition actions	8	61%	70%
	Causes are uncontrollable and targeted competitive actions	9	71%	80%
	Causes are uncontrollable and targeted competitive actions	10	81%	100%

A pre-compiled work sheet of the three risk parameters by one assessor are demonstrated in Table 12. According to Table 11, the assessor defined the detectability and occurrence and by considering Table 9, the severity is determined.

Table 12 Pre-compiled work sheet

	Detectabilty	*Severity*	*occurrency*
1	2	3	8
2	4	7	9
3	5	7	7
4	2	4	3
5	4	2	4
6	7	10	7
7	7	9	6
8	4	9	8
9	7	7	8
10	2	3	8
11	4	9	6
12	2	2	5
13	7	4	5
14	1	5	10
15	7	2	10
16	6	1	8
17	5	1	5
18	7	5	6
19	5	1	5
20	6	4	7

Figure 10 summarizes the procedure of the first step of RMEA to the next level, which applies normalization and weighting and will be described in detail in the next pat.

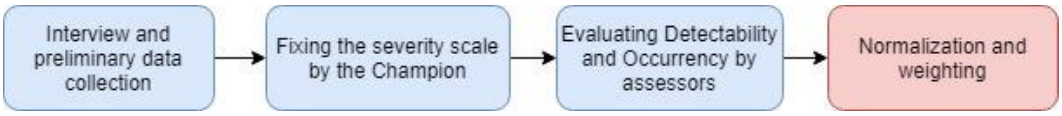


Figure 10 Conceptual brief of the first step of RMEA to the next level

2.4.1.2 Normalization and weighting

To provide a proper analysis, the methodology is carried out a normalization of the collected data according to a suitably designed algorithm. The method provides up to a maximum of 10 assessors, whose ratings are collected into a single spreadsheet, as illustrated in Table 13.

Table 13 Normalization and weighting of the data

	Detectability											Severity											Occurrency										
ID	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10		V1	V2	V3	V4	V5	V6	V7	V8	V9	V10		V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	
1	2	4	7	3	5	2	6	3	9	9	5	2	2	2	2	2	2	2	2	2	2	2.0	8	4	8	7	5	4	8	6	3	6	5.9
2	4	4	2	1	2	4	6	2	6	8	3.9	4	4	4	4	4	4	4	4	4	4	4.0	9	7	4	2	5	6	2	6	9	9	5.9
3	5	7	5	7	7	8	7	10	6	5	6.7	4	5	2	3	3	3	3	4	2	2	3.1	7	7	7	7	5	7	4	4	7	7	6.2
4	2	9	6	8	4	4	7	5	8	6	5.9	3	3	3	3	3	3	3	3	3	3	3.0	3	9	7	9	1	4	7	7	4	9	6.0
5	4	6	1	1	3	1	5	3	9	3	3.6	1	1	1	1	1	1	1	1	1	1	1.0	4	9	5	2	1	8	2	4	8	1	4.4
6	7	5	8	8	5	7	4	5	9	10	6.8	4	5	4	4	4	4	6	6	6	6	4.9	7	5	6	7	7	6	9	6	6	5	6.4
7	7	2	3	2	4	10	7	4	7	9	5.5	6	6	6	4	6	6	6	6	6	6	5.8	6	6	2	9	5	4	10	10	1	9	6.2
8	4	10	8	9	4	7	3	2	4	3	5.4	6	6	6	6	6	5	6	6	6	5	5.8	8	10	5	6	8	8	3	4	3	3	5.8
9	7	6	6	9	7	7	7	4	1	1	5.5	3	4	2	4	3	2	2	2	4	4	3.0	8	7	4	8	4	4	4	5	8	9	6.1
10	2	6	7	1	8	4	6	4	3	5	4.6	2	4	2	2	2	2	2	2	2	2	2.2	8	6	7	4	1	4	4	10	5	8	5.7
11	4	6	6	7	8	6	5	3	7	10	6.2	5	6	6	6	4	4	6	6	6	4	5.3	6	10	8	6	8	5	1	2	9	3	5.8
12	2	5	9	3	10	6	10	4	2	2	5.3	1	1	1	1	1	1	1	1	1	1	1.0	5	8	9	10	3	5	3	10	1	6	6.0
13	7	4	4	2	5	6	7	5	7	4	5.1	3	3	2	3	3	3	4	3	3	3	3.0	5	8	7	6	5	7	2	9	3	8	6.0
14	1	7	4	3	9	10	7	4	7	3	5.5	4	4	4	4	4	4	4	4	4	4	4.0	10	8	5	6	6	7	7	8	1	2	6.0
15	7	2	4	9	2	2	10	8	4	9	5.7	1	1	1	1	1	1	1	1	1	1	1.0	10	9	10	9	4	1	3	3	5	6	6.0
16	6	3	5	6	5	6	3	5	9	5	5.3	1	1	1	1	1	1	1	1	1	1	1.0	8	7	7	7	4	9	8	9	5	9	7.3
17	5	4	6	5	8	8	6	6	6	7	6.1	1	1	1	1	1	1	1	1	1	1	1.0	5	5	5	6	9	6	6	9	6	8	6.5
18	7	5	3	4	6	6	7	8	8	8	6.2	3	3	3	3	3	3	3	3	3	3	3.0	6	6	9	5	6	8	7	6	9	5	6.7
19	5	6	1	6	7	4	8	6	6	8	5.7	1	1	1	1	1	1	1	1	1	1	1.0	5	2	8	2	7	6	9	7	9	7	6.2
20	6	4	2	2	8	5	6	5	7	9	5.4	3	3	3	3	3	3	3	3	3	3	3.0	7	4	6	3	8	9	5	6	8	7	6.3
	DEV	4								MED	5.47										MED	2.9										MED	6.1

To normalize the collected data, the arithmetic average for each risk and the global averages (MED) for each of the three parameters are calculated. Furthermore, the Champion fixes a proper standard deviation (DEV) by his/her experience in order to determine the lower (MED - DEV) and upper bounds (MED + DEV) from the global average value. The methodology makes a cut off of the scores that are not within the range. For example, for the second risk (ID 2) and the detectability parameter, the score that are not in the bound (0.1 - 7.9) such as “8” is eliminated.

Furthermore, the methodology allows for delegating a stronger duty on evaluators who are recognized by the Champion as particular process experts. This could be obtained by assigning different weights to the ten assessors for the three risk parameters (Detectability, Severity and Occurrence) (Table 14).

Table 14 Assigning different weights to the ten assessors for the three risk parameters

	Detectability										Severity										Occurrency										DET	SEV	OCC	RISK SCORE
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	Average weight (NV)		Multiply	
ID/Weight	**1**	**1**	**2**	**1**	**1**	**3**	**1**	**1**	**1**	**1**	**1**	**3**	**1**	**2**	**2**	**1**	**1**	**1**	**3**	**2**	**1**	**1**	**1**	**2**	**1**	**3**	**1**	**1**	**1**	**1**				
1	2	4	7	3	5	2	6	3	9	9	2	2	2	2	2	2	2	2	2	2	8	4	8	7	5	4	8	6	3	6	5	2	6	60
2	4	4	2	1	2	4	6	2	6		4	4	4	4	4	4	4	4	4	4	9	7	4	2	5	6	2	6	9	9	3	4	6	72
3	5	7	5	7	7	8	7	10	6	5	4	5	2	3	3	3	3	4	2	2	7	7	7	7	5	7	4	4	7	7	7	3	6	126
4	2	9	6	8	4	4	7	5	8	6	3	3	3	3	3	3	3	3	3	3	3	9	7	9		4	7	7	4	9	6	3	6	108
5	4	6	1	1	3	1	5	3		3	1	1	1	1	1	1	1	1	1	1	4		5	2	1	8	2	4	8	1	2	1	4	8
6	7	5	8	8	5	7	4	5	9	10	4	5	4	4	4	4	6	6	6	6	7	5	6	7	7	6	9	6	6	5	7	5	6	210
7	7	2	3	2	4		7	4	7	9	6	6	6	4	6	6	6	6	6	6	6	6		9	5	4	10	10		9	4	6	6	144
8	4		8	9	4	7	3	2	4	3	6	6	6	6	6	5	6	6	6	5	8		5	6	8	8	3	4	3	3	5	6	5	150
9	7	6	6	9	7	7	7	4			3	4	2	4	3	2	2	2	4	4	8	7	4	8	4	4	4	5	8	9	6	3	6	108
10	2	6	7	1	8	4	6	4	3	5	2	4	2	2	2	2	2	2	2	2	8	6	7	4		4	4		5	8	5	2	4	40
11	4	6	6	7	8	6	5	3	7	10	5	6	6	6	4	4	6	6	6	4	6		8	6	8	5		2	9	3	6	5	5	150
12	2	5	9	3		6		4	2	2	1	1	1	1	1	1	1	1	1	1	5	8	9	10	3	5	3	10		6	4	1	6	24
13	7	4	4	2	5	6	7	5	7	4	3	3	2	3	3	3	4	3	3	3	5	8	7	6	5	7	2	9	3	8	5	3	6	90
14		7	4	3	9		7	4	7	3	4	4	4	4	4	4	4	4	4	4	10	8	5	6	6	7	7	8		2	4	4	6	96
15	7	2	4	9	2	2		8	4	9	1	1	1	1	1	1	1	1	1	1	10	9	10	9	4		3	3	5	6	4	1	5	20
16	6	3	5	6	5	6	3	5	9	5	1	1	1	1	1	1	1	1	1	1	8	7	7	7	4	9	8	9	5	9	5	1	8	40
17	5	4	6	5	8	8	6	6	6	7	1	1	1	1	1	1	1	1	1	1	5	5	5	6	9	6	6	9	6	8	6	1	6	36
18	7	5	3	4	6	6	7	8	8	8	3	3	3	3	3	3	3	3	3	3	6	6	9	5	6	8	7	6	9	5	6	3	7	126
19	5	6		6	7	4	8	6	6	8	1	1	1	1	1	1	1	1	1	1	5		8		7	6	9	7	9	7	5	1	5	25
20	6	4	2	2	8	5	6	5	7	9	3	3	3	3	3	3	3	3	3	3	7	4	6	3	8	9	5	6	8	7	5	3	6	90

Moreover, in spite of the fact that the risk factor is described the quantitative translation of a risk measure, is regularly based on the traditional multiplication of the three parameters which is expressed by

Risk score = Probability of risk occurrence*severity*detectability

Failure modes with a high risk score are more critical and given a higher priority than ones with a lower score. In order to rank the risks, the "risk score" is determined and rank them by priority (Table 15).

Table 15 Ranking of the risks

ID	DET	SEV	OCC	RISK SCORE
6	7	5	6	210
8	5	6	5	150
11	6	5	5	150
7	4	6	6	144
3	7	3	6	126
18	6	3	7	126
4	6	3	6	108
9	6	3	6	108
14	4	4	6	96
13	5	3	6	90
20	5	3	6	90
2	3	4	6	72
1	5	2	6	60
10	5	2	4	40
16	5	1	8	40
17	6	1	6	36
19	5	1	5	25
12	4	1	6	24
15	4	1	5	20
5	2	1	4	8

This phase of normalization and weighting have provided a ranking of the risk on the basis of the final score. The conceptual scheme of this phase is displayed in Figure 11.

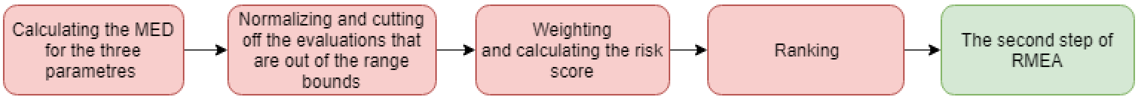


Figure 11 The conceptual scheme of normalization and weighting

2.4.1.3 The Second Step of RMEA

It is now necessary to perform the quantitative analysis that exists to quantify the economic impact of the possible risks on project costs. According to Table 16, once the values of the risk scores associated with the individual risks are determined, for those risks that present high total scores and a high probability of occurrence at the same time, the possible mitigation actions are identified by the assessors. The accomplishment of a mitigating action allows for the reduction of an uncertain cost with a certainly acquired cost (the cost of the action) to obtain a lower contingency estimation.

Table 16 The possible identified mitigation actions

ID	MIN	MAX	MED	MED (%)	Det	Sev	Occ	Score	Mitigation action (MA)	Respansibility	Cost of MA	Residual	Det	Sev	Occ	Score
6	€ 180,000	€ 200,000	€ 190,000	11%	7	5	6	210	Training staff	RESP HR	€ 75,000	€ 100,000	7	4	6	168
8	€ 170,000	€ 180,000	€ 175,000	10%	5	6	5	150	SLA binding	DIR PROCUR	€ 35,000	€ 50,000	5	2	5	50
11	€ 160,000	€ 175,000	€ 167,500	10%	6	5	5	150	Training staff	RESP HR	€ 60,000	€ 80,000	6	3	5	90
7	€ 160,000	€ 180,000	€ 170,000	10%	4	6	6	144	Insert penalties	PRJ MGMT	€ 50,000	€ 60,000	4	2	6	48
3	€ 100,000	€ 140,000	€ 120,000	7%	7	3	6	126	specialist consultancies	DIR PROCUR	€ 30,000	€ 50,000	7	2	6	84
18	€ 70,000	€ 90,000	€ 80,000	5%	6	3	7	126	Extra labor Search	RESP HR	€ 15,000	€ 40,000	6	1	7	42
FIRST=	**€ 840,000**	**€ 965,000**	**€ 902,500**								**€ 265,000**	**€ 380,000**				
4	€ 60,000	€ 70,000	€ 65,000	4%	6	3	6	108	Survey on suppliers	DIR QA	€ 10,000	€ 40,000	6	1	6	36
9	€ 90,000	€ 130,000	€ 110,000	7%	6	3	6	108	SLA binding	DIR PROCUR	€ 20,000	€ 60,000	6	2	6	72
14	€ 75,000	€ 100,000	€ 87,500	5%	4	4	6	96	Training staff	RESP HR	€ 30,000	€ 35,000	4	1	6	24
13	€ 60,000	€ 90,000	€ 75,000	4%	5	3	6	90	R & D - flexible design	RESP HR	€ 30,000	€ 35,000	5	1	6	30
20	€ 50,000	€ 80,000	€ 65,000	4%	5	3	6	90	Training staff	RESP HR	€ 30,000	€ 20,000	5	1	6	30
2	€ 100,000	€ 120,000	€ 110,000	7%	3	4	6	72	Insert penalties	PRJ MGMT	€ 15,000	€ 55,000	3	2	6	36
1	€ 25,000	€ 90,000	€ 57,500	3%	5	2	6	60	specialist consultancies	DIR PROCUR	€ 15,000	€ 25,000	5	1	6	30
SECOND=	**€ 460,000**	**€ 680,000**	**€ 570,000**								**€ 150,000**	**€ 270,000**				
10	€ 25,000	€ 65,000	€ 45,000	3%	5	2	4	40	NA	NA	NA	NA				
16	€ 20,000	€ 25,000	€ 22,500	1%	5	1	8	40	NA	NA	NA	NA				
17	€ 22,000	€ 26,000	€ 24,000	1%	6	1	6	36	NA	NA	NA	NA				
19	€ 20,000	€ 23,000	€ 21,500	1%	5	1	5	25	NA	NA	NA	NA				
12	€ 30,000	€ 35,000	€ 32,500	2%	4	1	6	24	NA	NA	NA	NA				
15	€ 20,000	€ 40,000	€ 30,000	2%	4	1	5	20	NA	NA	NA	NA				
5	€ 30,000	€ 50,000	€ 40,000	2%	2	1	4	8	NA	NA	NA	NA				
THIRD=	**€ 167,000**	**€ 264,000**	**€ 215,500**													

In this phase, the risks are classified into three categories (first, second and third class) based on the overall normalized ranking. For the third class risks, a mitigation action is not considered because the impact value does not justify the cost of mitigation. In the example in Table 16, the total cost of risk before the mitigation actions for the first and the second class is approximately 1500 k€. After the appropriate mitigation actions have been identified (risk of first and second class), the estimated mitigation cost equals 415,000 € and estimated economic impact of the residual risks becomes 650 k€. After supporting the mitigation cost, for each mitigated risk, the severity and the occurrence parameters can decrease, and consequently, the risk scores also decrease. Now it is possible to re-rank the residual risks on the basis of the new final scores and to associate a variability range conservatively as large as the previous one (Table 17).

As displayed in Table 17, the occurrences of the first and second categories, as well as the severity parameters, are changed. Additionally, the risk scores are calculated again and residual risks have been sorted according to the priority. The residual risks are the input for the next simulation step.

Table 17 The final re-ranking of the risks

ID	RR	Min	Max	%	Det	Sev	Occ	Score
6	€ 100.000	€ 94.737	€ 105.263	12,2%	7	4	6	**168**
11	€ 80.000	€ 76.418	€ 83.582	9,8%	6	3	4	**72**
9	€ 60.000	€ 49.091	€ 70.909	7,3%	6	2	6	**72**
3	€ 50.000	€ 41.667	€ 58.333	6,1%	7	2	4	**56**
8	€ 50.000	€ 48.571	€ 51.429	6,1%	5	2	5	**50**
7	€ 60.000	€ 56.471	€ 63.529	7,3%	4	2	6	**48**
16	€ 20.000	€ 25.000	€ 22.500	2,4%	5	1	8	**40**
10	€ 25.000	€ 65.000	€ 45.000	3,1%	5	2	4	**40**
17	€ 22.000	€ 26.000	€ 24.000	2,7%	6	1	6	**36**
4	€ 40.000	€ 36.923	€ 43.077	4,9%	6	1	6	**36**
18	€ 40.000	€ 35.000	€ 45.000	4,9%	6	1	5	**30**
13	€ 35.000	€ 28.000	€ 42.000	4,3%	5	1	6	**30**
1	€ 25.000	€ 10.870	€ 39.130	3,1%	5	1	6	**30**
20	€ 20.000	€ 15.385	€ 24.615	2,4%	5	1	5	**25**
19	€ 20.000	€ 23.000	€ 21.500	2,4%	5	1	5	**25**
12	€ 30.000	€ 35.000	€ 32.500	3,7%	4	1	6	**24**
2	€ 55.000	€ 50.000	€ 60.000	6,7%	3	2	4	**24**
15	€ 20.000	€ 40.000	€ 30.000	2,4%	4	1	5	**20**
14	€ 35.000	€ 30.000	€ 40.000	4,3%	4	1	4	**16**
5	€ 30.000	€ 50.000	€ 40.000	3,7%	2	1	4	**8**
	€ 817.000							

2.4.1.4 Monte Carlo Simulation for contingency reserve identification

Based on the residual impact values of the mitigated risks and their variability intervals, a Monte Carlo analysis is performed to determine the probability density function (PDF) of the final total cost of risk. The knowledge of the PDF allows selecting the proper contingency amount according to the risk attitude of the decision maker. The Monte Carlo analysis is carried out using the two parameters that influence the total cost, occurrency and severity, and proper statistical distributions, according to the literature of risk analysis (Kotz and van Dorp, 2004; Johnson, 1997):

- Occurrency: the probability is correlated with a uniform distribution with a lower and upper bound (Table 11);
- Severity: the economic impact of residual risk (RR) is associated with a triangular distribution defined by a lower, an upper and a most likely value (Table 17)

A simulation software package, @Risk for Excel by Palisade Corporation, has been used. Figure 12 shows the simulation steps.

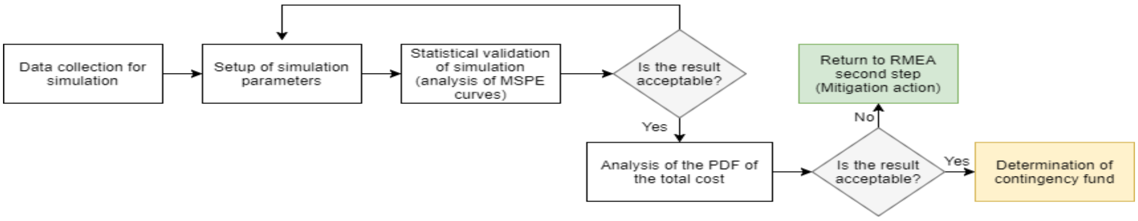


Figure 12 Simulation steps

At first, the program automatically picks up the input parameters, and then it is necessary to set the simulation parameters such as the number of replications for each simulation run and the number of parallel simulations to perform.

To determine the minimum number of replications for each simulation run, the authors carried out the methodology of the Mean Square Pure Error (MSPE) in the repeated runs (Cassettari et al., 2010; Mosca et al., 2010; Cassettari et al., 2012) to control the assessment of the mean and the variance of the replications sample, as well as to determine the pure error entity.

The achievement of statistic stabilization is essential because a lower number of runs would provide results that are also extremely different from each experimental campaign. If the initial number of replications is not able to guarantee a proper error, the entity is sufficient to increase the sample size re-setting the simulation parameters. The Monte Carlo analysis makes it possible to determine the probability distribution of the total cost of risk and allows for identifying the degree of coverage corresponding to each value of the allocated contingency fund (Figure 14).

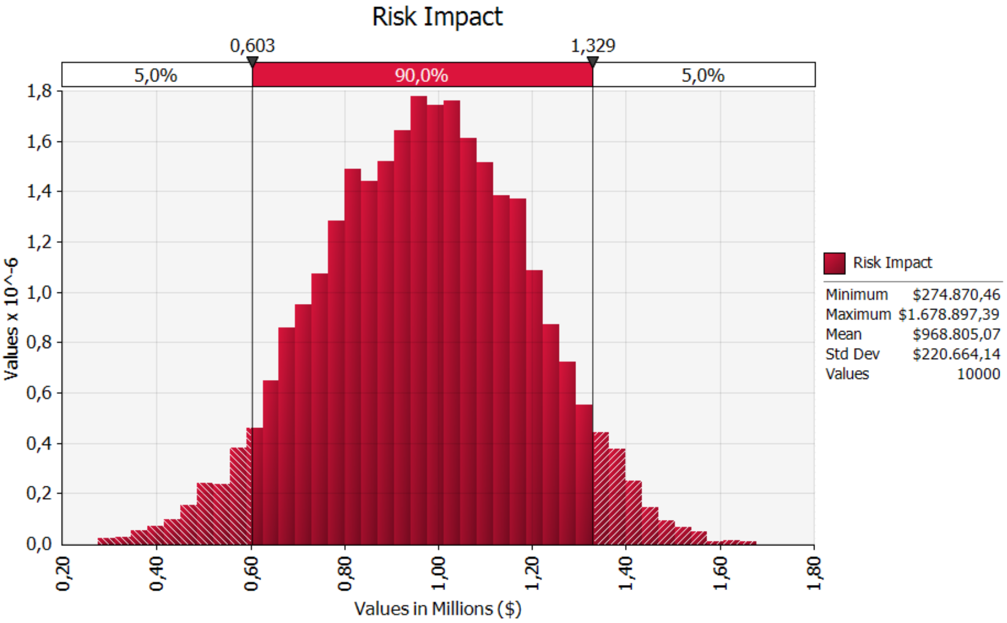


Figure 13 Probability distribution function of contingency

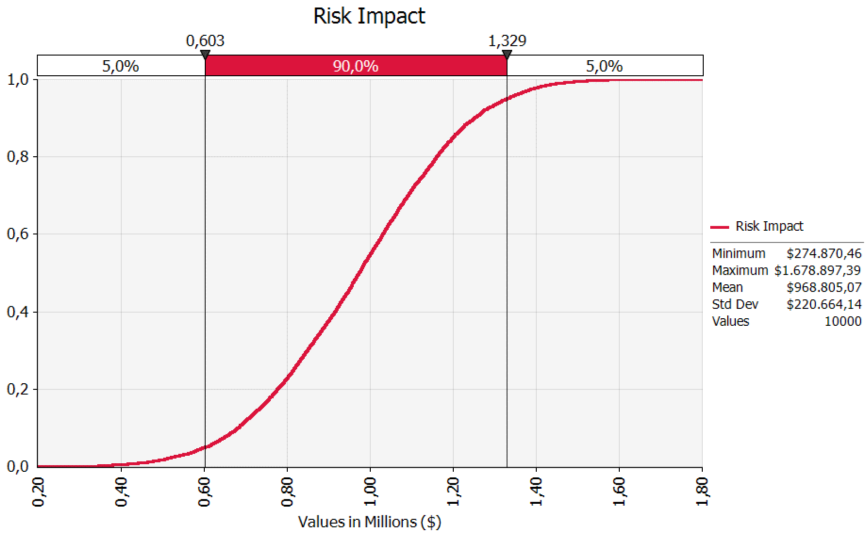


Figure 14 Cumulative distribution function of contingency

The graph of PDF Figure 13) represents the probability distribution of the expected cost of the residual risks. The CDF curve (Figure 14) is obtained by integration of the probability distribution and reports the possible contingency values on the X-axis and the "Level of Coverage" on the Y-axis. The Level of Coverage represents the probability of covering the extra costs of risk using the amount of the allocated contingency fund.

The probability curve allows for entering with a given amount of contingency to assess the level of residual protection and to quantify the extra cost. The amount of extra cost is exposed to the effect of contingency set aside for the company. Additionally, the value of the contingency to be set aside can be determined from a pre-assigned accepted risk level. If the total cost is considered to be too high, the process can be repeated from the mitigation actions step. For instance, with a contingency amount of 1.30 million, the coverage level is about 100%.

2.4.2 Comparison with Traditional Company's Approach

The application to a leading company operating in the sector of high technology for railway and urban transport that designs and produces integrated transport systems is presented. It operates in the design, implementation and management of systems and services for signaling and supervision of railway and urban traffic, as well as the lead contractor. The company has over 3,772 employees in 28 different countries.

The method used by the company for contingency fund estimation, described in detail in section 2.3, is based on the following:

- Predetermined contingency provision linked to the probability of occurrence of the associated risk, following the rules in Table 7.

The subjective choice of probability distributions of the impact of individual risks by the project manager. The approach considered a most likely value of the impact, a minimum value, a maximum value and a probability profile over the entire range of possible values of the impact. It makes the approach objective only in a project with a large database to extrapolate the distributions with an adequate degree of reliability.

Figure 8 shows the cumulative distribution function of the contingency for the previous method that is obtained from the PDF graph (Figure 7), set off to allow a comparison with the curve of the expected total cost of the risk obtained following the implementation of the RMEA methodology proposed in the paper.

The curve represents the possible values of the contingency amount, deriving from the policy described in Table 7. For each contingency value, the cumulative curve gives the probability value of incurring extra costs. By setting a contingency value of 1.30 m€, the probability of incurring extra costs is practically 100%, while with a provision of 1.40 m€, the curve indicates total protection. It should be noted that this curve does not provide information on the value of the extra costs but only on the level of risk coverage implemented.

Allocating indeed 1.30 m€ would be equal to take on a level of coverage of zero against the risk of extra costs. The same level of risk coverage would be obtained also by setting aside a contingency equal to zero, but it is clear that, in both cases, the extra costs incurred would be significantly different.

The application of the proposed RMEA method to the initial phase of risk analysis and mitigation leads instead to determining an expected risk cost distribution shown in Table 16.

By applying the Monte Carlo Simulation as suggested by the methodology proposed by the author, all possible scenarios of the project are created and it is possible to stochastically determine the final expected total cost of risk and the related occurrence probabilities (Figure 13).

An examination of the cumulative distribution function of the final expected cost (Figure 14) objectively presents the level of protection corresponding to each value of contingency set aside.

At a contingency amount of 1.30 m€ on the X-axis, we can see that, unlike the previous approach, the level of risk coverage rises to over 90% with a residual potential additional cost of 900 k€, which in the previous approach provided coverage almost zero.

The proposed methodology guarantees that the company will have more complete and reliable information. In the new method, the coverage level is more reliable and accurate because the cumulative curve is obtained by RMEA and a different use of MCS and is not conditioned by the choice of a unique decision maker.

Using the presented methodology, the decision maker will be able to make a choice regarding the contingency amount based on a level of coverage of known risk with decisive security higher than the previous case.

It will be depends on project manager, based on risk appetite, to determine what level of coverage intends to take, bearing in mind that the final contingency amount has a direct impact on the competitiveness and profitability of the project.

2.4.3 Discussion

The RMEA analysis is a good tool for risk analysis; however, application may sometimes be problematic and also deliver results strongly dependent on the subjectiveness of each evaluator.

Multiple factors impact evaluators during the score assignment, such as rendering inconsistent, from one evaluator to the other or, worse, to the same evaluator, both the evaluation criteria and the assigned scores. Some of the main factors responsible for inconsistency include the following:

- perception of the instrument by the Evaluator
- biorhythm, nutrition
- compilation time
- mood
- level of attention, distraction or interruption
- progressive fatigue
- various types of conditioning
- events of the surrounding environment

Another problem encountered is the passive resistance to the compilation by some Functional Leaders due to causes mainly related to:

- renunciation to accept a project leadership outside the company

- refusal of additional activities, assigned by outsiders, who are to create indirect perceived work
- compilation times take time away from other binding tasks
- protection of its sphere of action, associated with the fear of potential changes
- misgiving that outsiders can introduce methodologies that can lead the Management to potential errors

The issues highlighted have been addressed by the author through the revision of the RMEA methodology and the development of spreadsheets on the excel platform, which make the compilation simple and effective:

- limitation of discretion in the assessment of the detectability, severity and occurrence by using pre-assigned evaluation scales
- clear breakdown into occurrence classes (occurrences)
- postponing the evaluation of mitigation actions after an initial round of RMEA in order to limit this assessment to only priority risks
- collecting, processing, standardizing and analyzing data from the Champion to ensure objectivity of evaluation and minimization of the workload of the evaluators
- skimming off-scale values by standardization
- ability to evaluate different weights for evaluators to take into account specific project experience or their functional role
- weighted average of ratings

The key aspects for a successful implementation of the methodology proposed by the authors include the following:

- clear objective sharing with Management
- a strong level of empowerment
- identification of a Champion with outstanding leadership skills
- adequate training phase for the Assessors

- ad hoc preparation of the RMEA compilation template
- high motivation by the evaluators

2.4.4 Conclusions and future research

This research developed a stochastic Risk Mode and Effect Analysis methodology base on Monte Carlo Simulation for the management of cost contingency amount. A stochastic risk model has been developed to support decision makers in determination of more accurate amount of contingency fund according to a pre-set coverage level to reduce the risk of extra costs in industrial projects. Combining of RMEA with MCS makes the proposed method objective, fast and easy to apply which overcomes other methods limitation. This approach reduced, despite the presented methodologies in the literature, the influence on the risk analysis of the subjective choices of decision makers by a RMEA analysis extended to multiple evaluators (up to 10 evaluators depending on the project complexity) and a stochastic quantitative risk analysis by MCS. It stochastically evaluated the project costs and presented the cumulative distribution function to demonstrate “level of coverage” related to the contingency amount to have the power of controlling overhead costs and diminish size of contingency in projects.

The developed method has been validated by applying a real construction project. The obtained results with RMEA and MCS approach were compared with the outcome of the company’s traditional approach in a study to a real railway project. The proposed approach allows the decision makers to operate with a lower contingency amount thanks to the fact that for each contingency value, the coverage level is known above all the calculated extra cost. The obtained outcomes with Monte Carlo Simulation, without an initial RMEA analysis, are presented an excessive dependence on decision makers in assessing risk, both in terms of impact and probability of occurrence. A single decision maker, generally the project manager, might change his/her judgment in progress, becoming more or less strict, depending on the circumstances (mood, fatigue, motivation, etc.). The aim of the proposed approach is to solve these problems carrying out an initial phase of risk assessment based on a revised RMEA.

2.5 Stochastic Risk Analysis through Monte Carlo Simulation Applied to the Construction Phase of a 600 MW Gas Turbine Plant

This proposed methodology for risk management and project control allows working in a stochastic regime that increases the progress of the project.

This subsection is structured in the following steps: the next part illustrates a description of the company and the different phases of the project. In addition the MCS analysis is applied for the contingency provision. In the last part, the analysis and the obtained results from the application of the methodology to an installation of four gas turbines 600MW are described.

2.5.1 Risk Analysis Method for the Case Study

The proposed method is applied in the EPC project (turnkey system) of an international Construction Company with over 30,000 employees in seven plants. The organizational structure of the Company is quite complex, considering the high number of employees, 2,937 units and the wide range of functions which require an ordering and management on many different correlated levels. In the recent years, the Company has taken steps to strengthen the operational methodologies and tools to support the management. The EPC contract had involved the design and construction of a power plant in open cycle "turnkey" 600 MW in Egypt. The control unit is composed of four equipped units with four gas turbines that are totally designed and constructed by the Company.

The Company usually carried out a Risk Analysis so structured:

1. Identification of the activities needed to complete the job order, thus creating a list of tasks and their dependencies (prior and subsequent activities) and the necessary resources (in the construction phase are the work hours to complete that particular task);
2. Analysis of environmental conditions that may affect the site's activities (socio-political situation, type of customer, logistical constraints, local workforce specialization);
3. Mitigation of the risk of delayed timing and consequently the risk of overcoming the cost of the site budget by increasing the percentage of time and therefore the resources planned in the initial ideal program. The ideal program is modified by finding suitable multipliers “K” that vary according to the environmental analysis result. This step allowed the Company to have a more realistic forecast (Figure 15).

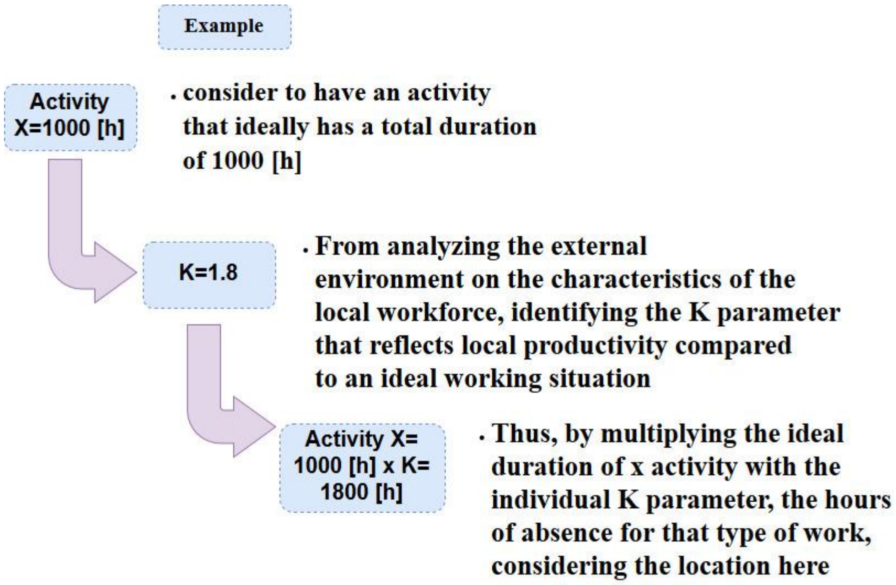


Figure 15 Example of the Company's risk management approach

The Authors applied MCS to manage the phase of development of the project, which is stochastic, with the aim of reducing the risks of delay of the contractual delivery date. In particular, risk analysis has been applied to two different phases of the project:

1. The phase of bid
2. The work progress control

2.5.1.1 The Phase of Bid

This phase is a fundamental activity to estimate the price of the order to success in the project. It is important to note that the methodology will be applied only to the construction phase, which it is allocated about 30% of the total project budget.

In the following, the main steps of the methodology for the bid phase, entitle:

- Identification of necessary data to the model;
- Applying Monte Carlo analysis for the contingency provision.

2.5.1.1.1 Identification of Necessary Data to the Model

When the total required budget for the construction phase is determined, it should be split into the different program activities. Allocation budget to the individual activities is done by taking into account the specific characteristics of each activity such as the duration, the type of processing, the fixed costs and the variable costs. Table 18 presents the identified weight percentage of the total required budget for each activity.

Table 18 Weight percentage of the total required budget for some tasks

Task	Weight	Task	Weight
Excavation for turbine Hall unit 1-4	0.86%	Fuel oil plumps shelter install.	0.81%
Foundation Hall including half of unit 1-4	1.95%	Compressor install	1.00%
Stack unit 1-4 foundations	0.59%	Fogging system install	1.38%
G.T. 1-4 foundations	3.11 %	Underground instrument	7.36%
Steel struct. turbine hall 1-4	2.05%	Cable ways and install	2.93%
Local control system (half) elevation 1-4	1.70%	Yard area and finishing HVAC	8.05%
Main transformer G.T. 1-4 foundations	3.42%	GIS subs. and cable connection	2.31%

In order to obtain the necessary input data for the simulator and acquire an accurate estimation, it has been switched from a deterministic analysis to a stochastic one.

Each activity was then associated with a probability distribution taking into account both the optimistic case, in which the allocated budget is not fully spent, and the bad case, where the execution of the activity requires the allocation of an extra budget .

The most suitable probability density function starting from a 3-point-estimate containing minimum value, maximum and most likely value, is the Triangular Distribution. Therefore, each activity is then assigned with a triangular distribution and the Table 19 is obtained.

Table 19 Applying the Triangular Distribution to Each Task

Weight of single task	Triangular Distribution		
	Min	Real	Max
0.86%	0.77%	0.86%	1.16%
1.95%	1.76%	1.95%	2.63%
0.59%	0.53%	0.59%	0.80%
3.11 %	2.80%	3.11%	4.20%
2.05%	1.85%	2.05%	2.77%
1.70%	1.53%	1.70%	2.30%
3.42%	3.08%	3.42%	4.62%
1.38%	1.24%	1.38%	1.86%
6.04%	5.44%	6.04%	8.23%

2.39%	2.15%	2.39%	3.23%
2.95%	2.66%	2.95%	3.98%
2.21%	1.99%	2.21%	2.98%
1.28%	1.15%	1.28%	1.73%
1.97%	1.67%	1.97%	2.71%

2.5.1.1.2 Applying Monte Carlo Analysis for the Provision Contingency

By using described input data, it is possible to apply the Monte Carlo method. In addition, to apply a number of experimental runs on the model to obtain the valid results, the method of the Mean Square Pure Error (MSPE) in the repeated run (Cassettari et al., 2010) should be done. Furthermore, Figure 16 presents the MSPE curves necessary to identify the sample size in order to obtain the statistical stabilization both of Mean Square Pure Error of the Mean (MSPEMED) and Mean Square Pure Error of the Standard Deviation (MSPESTDEV). It occurs at around 1000 runs. Therefore, the MCS results obtained using @RISK with the features of 5 reps and 10,000 runs are shown in Figure 17.

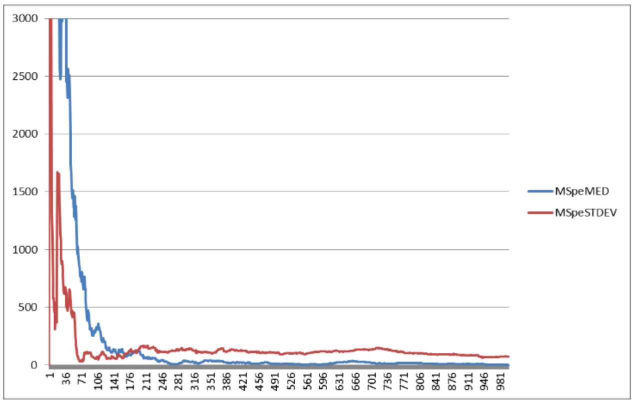


Figure 16 MSPE Curve for the Input Data

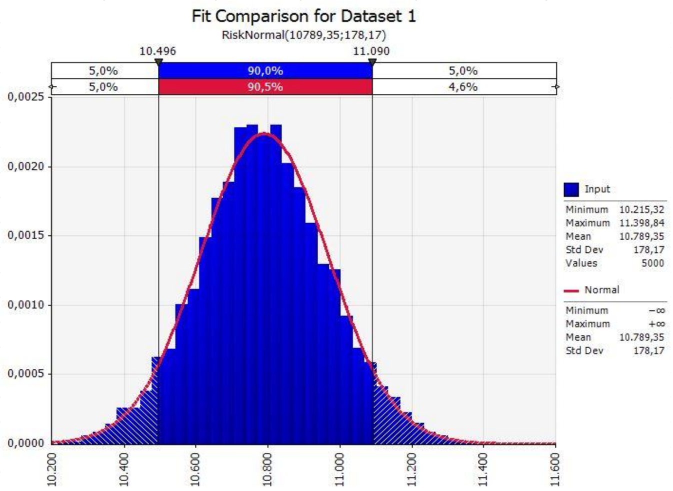


Figure 17 Monte Carlo Simulation by @ Risk Software

The obtained probability distribution curve covers a range of between € 10.2mn and € 11.6mn. In order to have an 80% coverage probability, the Company should therefore allocate an amount of not less than 11m euros, representing about 8% of the total value of the order.

2.5.1.2 The Phase of the Work in Progress Control

The main risk of this phase are the delays that may be the result of various reasons. Following are cited some of the main causes involving delays in the pipeline:

- Equipment failures;
- Errors on the part of employees;
- Weather conditions;
- Delays in the procurement of materials

The objective of the proposed risk analysis to the phase of the progress management is to identify the likelihood of unexpected upstream in order to have the possibility to make changes to the program and the construction budget to complete the project within the deadline. This is crucial as the excess of the end date of the project involves huge penalties from the customer.
The main steps of the applied methodology to the phase of the advancements management are:

- Study of the Construction program and data identification
- Identification of the critical path

2.5.1.2.1 Study of Construction Program and Data Identification

To define the necessary input date for the simulator, each activity should be associated with a real deterministic time. As mentioned above the Company was used to augment the actual time with an incremental time by means of a standard percentage of increase K. Therefore, the first step was to eliminate the effect of the coefficient K and consequently to identify the most likely duration "TM" (an average duration that does not take account of external factors (Figure 18). Once the average time is obtained it is possible to transform the duration of each activity from deterministic to stochastic. The next step is to decide what type of probability distribution to use. It has opted for a non-symmetrical triangular distribution for all activities.

However, the variability of the duration of the activity was differentiated according to the characteristics of the project task.

In particular, for all civil works to take into account the impacting weather variability on outdoor works, it is considered intervals as follows:

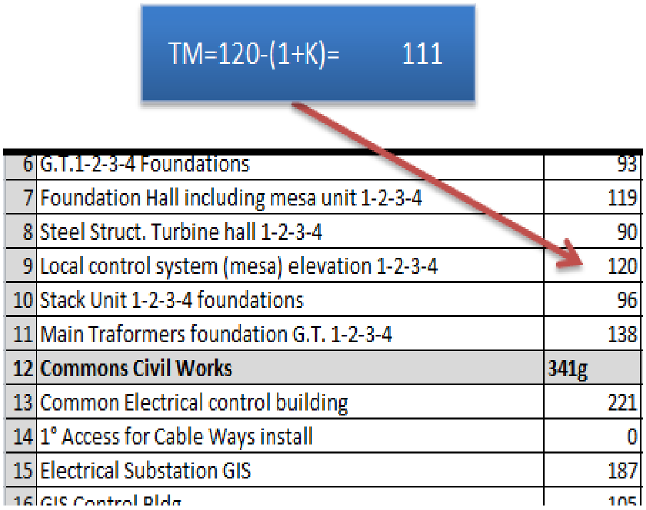
Max duration = TM * 1.4

Min duration = TM * 0.8

As for the electro-mechanical assemblies, the following extreme values are considered:

Max duration = TM * 1.2

Min duration = TM * 0.9



6	G.T.1-2-3-4 Foundations	93
7	Foundation Hall including mesa unit 1-2-3-4	119
8	Steel Struct. Turbine hall 1-2-3-4	90
9	Local control system (mesa) elevation 1-2-3-4	120
10	Stack Unit 1-2-3-4 foundations	96
11	Main Traformers foundation G.T. 1-2-3-4	138
12	**Commons Civil Works**	**341g**
13	Common Electrical control building	221
14	1° Access for Cable Ways install	0
15	Electrical Substation GIS	187
16	GIS Control Bldg	105

Figure 18 Example of the Most Likely Duration Estimation

2.5.1.2.2 Applying Monte Carlo Analysis to Predict the Final Date of the Project

In this phase, the described input data and MCS should apply in the @RISK software with features of 5 reps and 1,000 runs corresponding to the MSPE curves in Figure 19. The MCS has been applied to each of the four critical paths (one for each gas turbine) in order to evaluate the duration of the four units construction.

The MCS risk analysis has been repeated at 5 different instants of time in order to take into account during the progress of the project of the activities which already completed. In addition it recalculates with an increasing level of reliability of the expected date of delivery of the four gas turbines.

- T = 0: from June 1, 2016
- T = 1: from August 31, 2016
- T = 2: from September 30, 2016
- T = 3: from October 31, 2016
- T = 4: from November 30, 2016

Some of the MSPE Curves and MCS results on the different critical path associated with these instants of time are reported in the following.

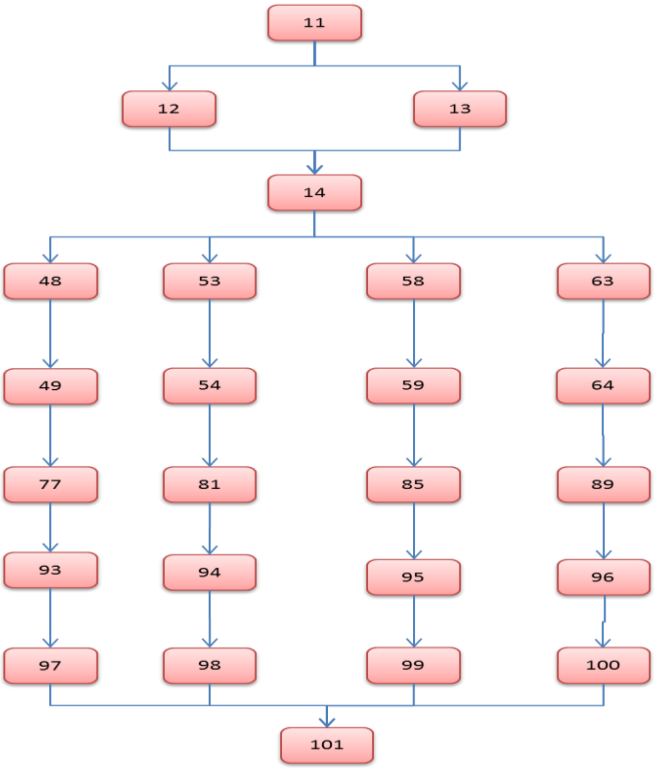


Figure 19 Critical Paths for Each Gas Turbine

Critical path 1 (T=0):

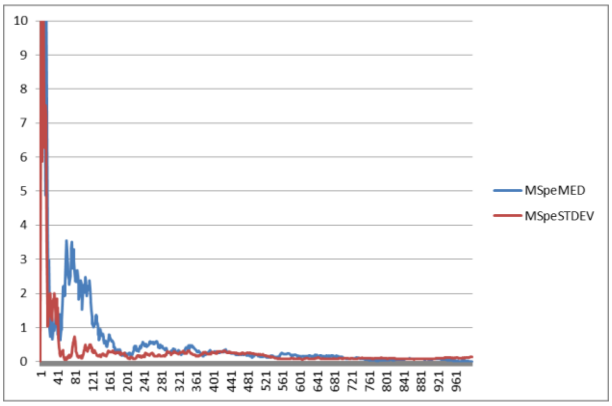


Figure 20 MSPE Curve for Critical Path 1 (T=0)

From T = 0 to T = 1, which is from June to August 2016, the first civil works were completed. There were no major problems or delays and some of activities had been concluded in advance with a positive impact on the overall project duration. In Figure 20 and Figure 21 the results of MSPE and Monte Carlo analysis for Critical path 1 for T = 0 and Figure 22 and Figure 23 for critical path=1 for T=1 are illustrated.

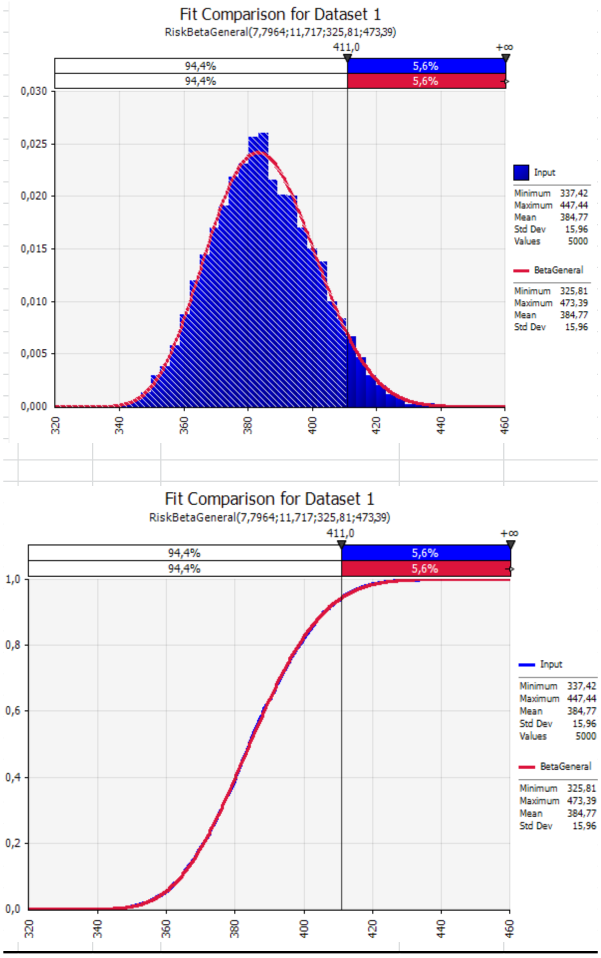


Figure 21 Monte Carlo Simulation for Critical path 1 (T=0)

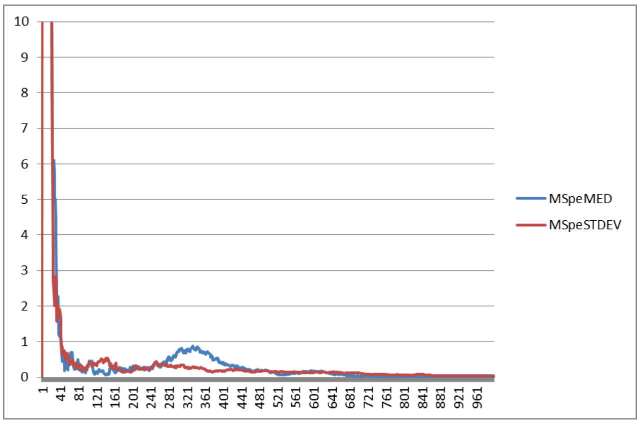


Figure 22 MSPE Curve for Critical Path 1 (T=1)

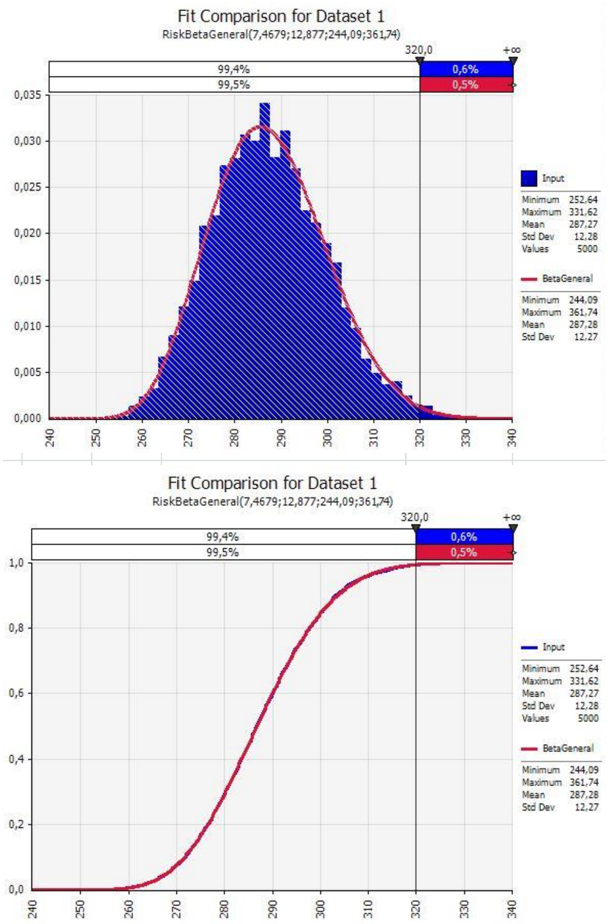


Figure 23 Monte Carlo Simulation for Critical Path 1 (T=1)

From the instant T = 1 to the instant T = 2, i.e. from September to October 2016, the realization of civil works continued. There were no particular problems or delays during the implementation of the program activities.

From the instant T = 2 to T = 3, i.e. from October to November 2016, almost all civil works were completed without any unexpected details, but the obtained time advantage in the first phase of the order had a slight decrease, as shown in the curve of project total cost (Figure 24).

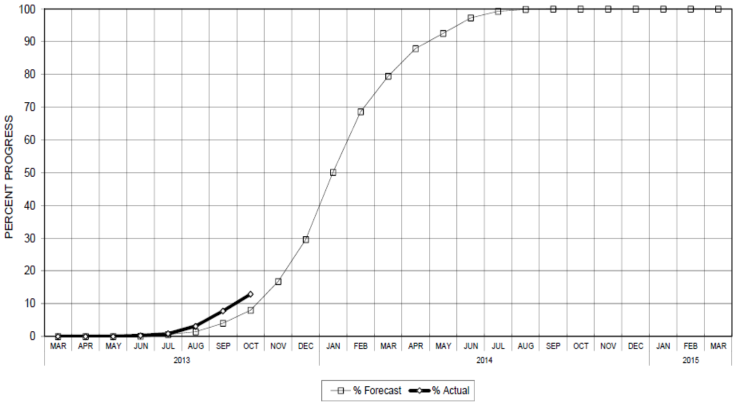


Figure 24 Project Total Cost

From time T = 3 to T = 4 i.e. from November to December 2016 continued the civil works and construction of steel structures of the four gas turbines has started. Although the overall situation of the construction phase has to be in advance of the program yet, the previously accumulated advantage has been greatly reduced.

The progress in the pipeline and the total order curves progress updated at T=4 are illustrated in Figure 25.

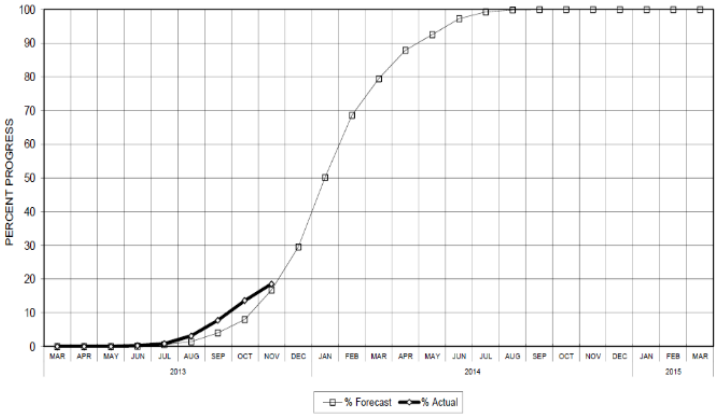


Figure 25 Total Order Curve of Progress

The objective of the proposed risk analysis was to identify for each critical path and each instant of time, the probable date of delivery of the plant and also the respective percentages of risk that the effective date would exceed.

In Particular, the obtained data from the carried out analysis are:

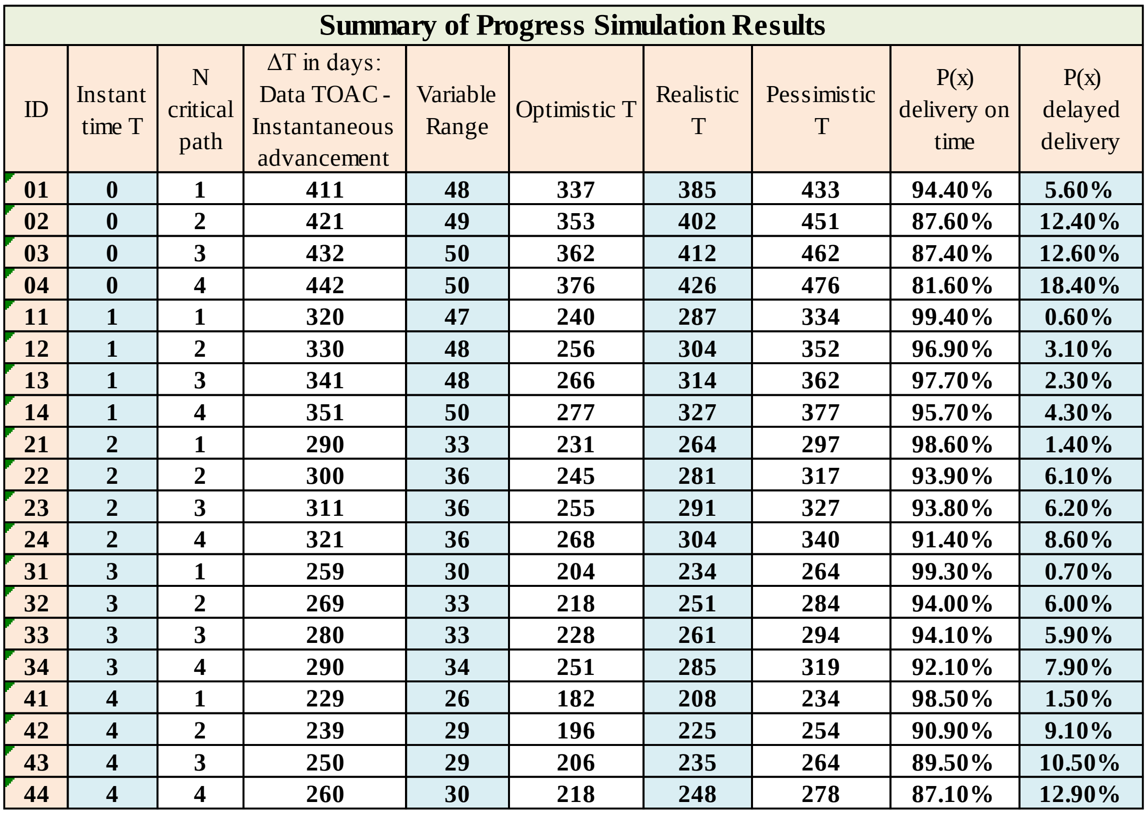
- ΔT: this data indicates the duration in days that divides the current date and the delivery date of the plant (for example, if you consider the time instant T = 2 of the first critical path the ΔT will equal 290 because the days are passing from late September 2016 to August 2017).
- Variability Range

This data indicates the variability of project final date determined by the analysis:

- Optimistic, realistic and pessimistic time
- P(x) delivery on time
- P(x) delayed delivery

Table 20 summarizes all the results just described.
At this point to understand when it would be appropriate to make changes to the program it is necessary to identify an additional element named P(x) threshold.
The P(x) introduces the probability of delay threshold that shows whether or not to make changes to the program of activities. For instance when P(x) threshold > P(x) delayed delivery, the advancements in the pipeline are under control then it will not allowed to make changes to the program. In addition, when P(x) threshold < P(x) delayed delivery, the construction site of the advancements are having significant delays so it is appropriate to begin to change the program by allocating additional resources to make up for lost time.

Table 20 Summary of Progress Simulation Results



Summary of Progress Simulation Results									
ID	Instant time T	N critical path	ΔT in days: Data TOAC - Instantaneous advancement	Variable Range	Optimistic T	Realistic T	Pessimistic T	P(x) delivery on time	P(x) delayed delivery
01	**0**	**1**	**411**	**48**	**337**	**385**	**433**	**94.40%**	**5.60%**
02	**0**	**2**	**421**	**49**	**353**	**402**	**451**	**87.60%**	**12.40%**
03	**0**	**3**	**432**	**50**	**362**	**412**	**462**	**87.40%**	**12.60%**
04	**0**	**4**	**442**	**50**	**376**	**426**	**476**	**81.60%**	**18.40%**
11	**1**	**1**	**320**	**47**	**240**	**287**	**334**	**99.40%**	**0.60%**
12	**1**	**2**	**330**	**48**	**256**	**304**	**352**	**96.90%**	**3.10%**
13	**1**	**3**	**341**	**48**	**266**	**314**	**362**	**97.70%**	**2.30%**
14	**1**	**4**	**351**	**50**	**277**	**327**	**377**	**95.70%**	**4.30%**
21	**2**	**1**	**290**	**33**	**231**	**264**	**297**	**98.60%**	**1.40%**
22	**2**	**2**	**300**	**36**	**245**	**281**	**317**	**93.90%**	**6.10%**
23	**2**	**3**	**311**	**36**	**255**	**291**	**327**	**93.80%**	**6.20%**
24	**2**	**4**	**321**	**36**	**268**	**304**	**340**	**91.40%**	**8.60%**
31	**3**	**1**	**259**	**30**	**204**	**234**	**264**	**99.30%**	**0.70%**
32	**3**	**2**	**269**	**33**	**218**	**251**	**284**	**94.00%**	**6.00%**
33	**3**	**3**	**280**	**33**	**228**	**261**	**294**	**94.10%**	**5.90%**
34	**3**	**4**	**290**	**34**	**251**	**285**	**319**	**92.10%**	**7.90%**
41	**4**	**1**	**229**	**26**	**182**	**208**	**234**	**98.50%**	**1.50%**
42	**4**	**2**	**239**	**29**	**196**	**225**	**254**	**90.90%**	**9.10%**
43	**4**	**3**	**250**	**29**	**206**	**235**	**264**	**89.50%**	**10.50%**
44	**4**	**4**	**260**	**30**	**218**	**248**	**278**	**87.10%**	**12.90%**

The Figure 26 illustrates an example comparing for each instant of time and any critical path with the threshold P(x) delayed delivery:

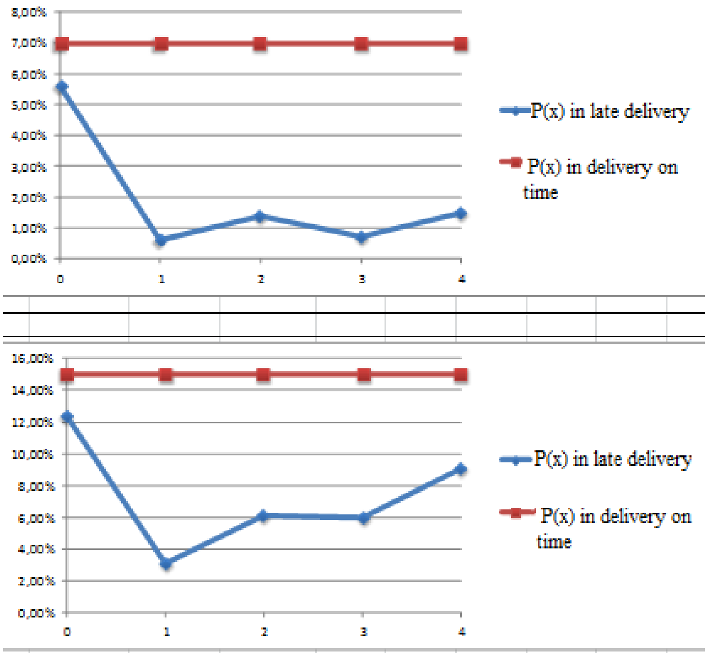


Figure 26 Comparison with the Threshold P(x) for Critical Path 1 (top chart) and Critical Path 2 (bottom chart)

As can be seen from the charts, for the analyzed time period it was not necessary to make changes to the program for any critical path at each instant of time. So it has been concluded that the advances in the pipeline in the period from June 2016 to December 2016 mirrored the predictions made at the

Finally, by the Figure 27, it is understood that how the variability of results decreases with the approaching of the delivery dates. This is very important because it allows the passing of time to identify more accurately the project end date.

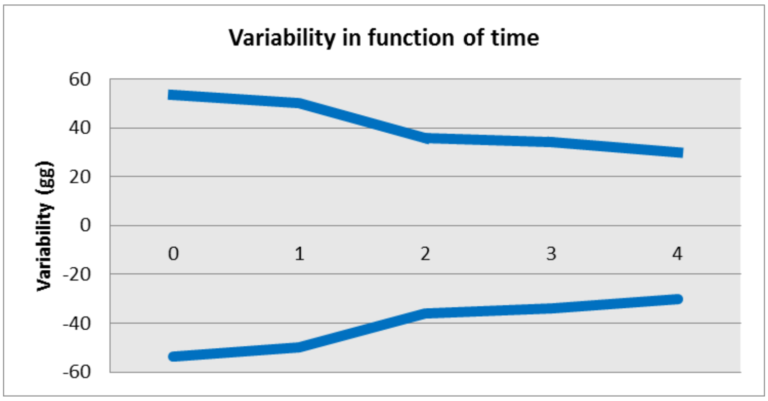


Figure 27 Range of Variability

2.5.2 Conclusion

The proposed study illustrate the application of a stochastic risk analysis based on Monte Carlo method to a real case study. The study aims to highlight the benefits and results obtained through a stochastic analysis compared to traditional deterministic analysis.

In Particular, two project phases were considered in this research: the process of bid and the phase of work in progress control; Risk Analysis with Monte Carlo method has been applied to both.

The analysis on the first phase has led to the allocation of a contingency equal to 8% of the costs of construction of the plant; this percentage represents a quantitative estimate of all the possible risks that may occur in the pipeline.

The MCS analyzes in the progress phase identified the project final dates for each critical path calculated at five different time instants, from June 2016 to December 2016; This has allowed to verify the evolution of the program and modify the program to avoid penalties. Moreover, it can be understand from the months analyzed showed that was not necessary to change the program of activities.

Finally, it has been possible to note how the variability of the results decreases with the approaching of the implant delivery dates; this aspect is fundamental in order to identify more precisely the final date of the project over time.

CHAPTER THREE

SYSTEM DYNAMIC MODEL IN HUMANITARIAN PROJECT

3 System Dynamic Model in Humanitarian Project

Over the past decades, the number of disasters has been on the rise, including earthquakes, war, flood and other incidents that cause destruction of society, such as education and health services. Forecasts show that over the next 50 years, natural and manmade disasters are expected to increase five-folds both in the number and impact. Therefore, there is a need for effective and efficient disaster support actions during emergencies. This compels humanitarian organizations to improve the effectiveness and efficiency of their approaches and facilitate decision making in resolving such complicated problems characterized by numerous parameters. Besides, humanitarian organizations face situations with multiple critical events, inadequate funding, limited time to plan and react, and operating in increasingly challenging circumstances. Useful approaches for tackling problems in such dynamic conditions require methods and tools that take into account uncertainty and enable managers to evaluate the dynamic complexity of such systems, to facilitate decision making. Among the large amount of decision-aid tools for humanitarian organizations, System Dynamic (SD) is a method used for the evaluation of complex system behavior and for presenting the effect of decisions over time in an easy-to-use model. This chapter proposes a system dynamics (SD) approach to study health and education aspects of the beneficiaries' life in longstanding refugee crises such as the case of Syrian refugees in Turkey and find out the best estimation of financial aid from humanitarian organizations in each part of services to improve them. At first a causal loop is developed to better understand the building-boxes of health and education of refugees and their interactions and then a system dynamic model is proposed and validated by field data from humanitarian organizations. The finding of this research can be used to facilitate further research in developing the system dynamic methodology for humanitarian organizations to present the essential impact factors for modeling complex environments including and feedback loops between the performance variables in the humanitarian supply chain that could have led to improving the vulnerable people's condition life by more aid from humanitarian organizations.

3.1 Introduction

Since 1990, natural disasters have influenced more than 200 million people every year (Leaning & Guha-Sapir, 2013). With the frequent occurrence of disasters in the past decades, there has been a rise in the number of disasters and cause the disruption of cities and facilities, famine, illnesses, poverty and health of people around the world CRED (2014). Therefore, there is a necessity for efficient disaster support efforts quickly after the occurrence of disasters in various ways like affording cash and voucher assistance or food aid and demand humanitarian organizations to help the affected region, reducing the impacts and initiating the improvement of operational skill to better face disasters (Allahi et al. 2018).

Financial aid strategies have been used for advancement goals for a number of decades, especially in social protection scheme in underdeveloped countries (Arnold, 2011). Lately, aid plans have been frequently employed in humanitarian contexts with the intention of assisting crisis-affected people in meeting their basic needs and also implementing support for livelihoods improvement by providing more financial aid. Cash-aid programs have been applied by humanitarian organizations, donor's, governments, and national local organizations for delivering people's aid beyond all regions. (Gairdner et al. 2011).

Cash assistance in humanitarian perspectives has been described as “the provision of money to individuals or households, either as emergency relief intended to meet basic needs for food and non-food items or to buy essential items to make better livelihoods” (ECHO, 2009). Stakeholders consider money aid to be a useful process of meeting recipient's requirements because it enhances access to fundamental demands and services like education and health and combines humanitarian support and rehabilitation of the local economy (Gairdner et al. 2011). The origins of cash-based methods in emergencies come from research which interpreting famine as a result of the war (de Waal, 1990). While reliable supply and markets are available and qualified to respond to gains in demand occurring from cash infusions without inflation or other negative factors, the cash program can be a preferable alternative to the in-kind provision of goods or services for populations affected by emergencies for some significant reasons such as cost-effectiveness of cash and voucher program for the emergency aid of humanitarian organizations, creation of a greater sense of empowerment in recipients, donor's organizations assistance to beneficiaries to consume appropriate food in greater quantity, variety and increasing their diet’s variety (Gairdner et al. 2011). Since 2004, cash programs in emergencies has gradually raised in humanitarian sectors to facilitate crisis- affected peoples to develop food security and access to water, health equipment, and basic services. (Harvey et al., 2010).

Nonetheless, while there have been theoretical and empirical studies about cash and voucher aid program in the humanitarian supply chain, little attention has been devoted to the consideration of all the impact factors in different aspects together and illustration the casual-loop model for efficient use of financial aid. Previous works on system dynamic models of cash assistance program did not cover all range of beneficiaries need simultaneous with the local economy, government and humanitarian organization's preferences, feedback loops and dynamic complexities of all factors after the disaster relief performance . There is a lack of research on the consideration of such complicate factors, time delays, and nonlinear relations between the all parts of parties in the humanitarian cash aid (Allahi et al. 2018b). Many researchers have highlighted the significance of feedback in the decision-making process and mentioned that the causal relations between complex variables provide an appropriate visual by which managers can clearly understand the causal model of a humanitarian organization. (Sousa et al., 2005; Grosswiele et al., 2013; Shaik and Abdul-Kader, 2014; Mitchell et al., 2014). Regarding numerous aspects of impact factors and the complex relationship among them, there is a need to casual loop model to illustrate how the methodology of system dynamics can be useful for understanding the behaviors of complex factors and consider them before the cash transfer. This paper, therefore, makes a contribution in addressing this gap in the knowledge. To achieve this purpose, a developed casual- loop has been proposed to the disaster relief operation and the impact factors related to different beneficiaries are extracted from several studies and the recommended casual loop model illustrate how the methodology of system dynamics can be useful for understanding the behaviors of complex factors and consider them while humanitarian organizations make the decision for the cash transfer program in the disasters or emergencies situation (Allahi et al. 2018b, Revetria et al. 2008). System dynamics is used to formulate the feedback loops structures between all the impact factors. The causal relationships between the performance variables have been discussed and a conceptual casual-loop model has illustrated in the disaster relief operation. The model provides an integrated view of the feedback loops between varies variables and may improve to future view for comprehensive all needs following the financial aid program.

In this research, it is essential to identify the impact factors that consider in the program of the humanitarian organizations and their ability to provide a safe and secure essential services for the individuals and develop health and education services for refugees. This effort takes place in four steps: 1) describing impact factors of health and education in a way that leads to the understanding of its characteristics and the relation between them, 2) diagramming Casual Loop model that lead to understanding the interactions and dependencies, 3) proposing the SD model of health and education system for Syrian refugees in Turkey and present the financial aid impact and 4) Validation of SD model with historical data and shows with more financial aid, refugee can have better health and more attending in school.

The remainder of this article is structured as follows. The next section presents system dynamic review and findings on the aforementioned factors within the existing body of literature. Then the sub factors by causal loop models will be analyzed to see the relations and interactions between them. The impacts of financial aid will also be displayed by SD and then it is validated by historical data of Syrian refugees in Turkey and finally, our conclusions are presented in the last section.

3.2 System Dynamic Review

System dynamics is a modeling and simulation methodology that has be introduced for the first time by Jay. W. Forrester in 1958 at the Massachusetts Institute of Technology (Forrester, 1958), which emphasized the multi-loop, multistate, and nonlinear features of the feedback systems in human life. The SD model can be displayed graphically by applying a mixture of simulation and circumstances modeling to develop both perception and modeling (Briano et al., 2010). Furthermore, it can be applied to systems with several factors, high range of uncertainty, casual obscurity, and complexity adjusted with the requirement of humanitarian organizations.

The SD approach presents administrators with a collection of tools that can support their knowledge in complex environments including causal mapping to think systemically and interpreting the dynamic complexity, and simulation modeling (Revetria et al. 2008) to evaluate the outcomes of interactions between variables and improve comprehension of complex systems (Sterman, 2000).

In the field of system dynamics, (Sterman, 1994) and (Hsiao and Richardson, 1999) have provided two robust literature reviews on the present simulators. Complex dynamic systems have been reviewed by (Sterman, 2000) and 33 empirical studies in the view of dependent and independent variables have been evaluated by (Hsiao and Richardson, 1999). The investigation of problems involving interacting feedback loops has presented that it is required to solve them by system dynamic (Sterman, 19991).

Some of the benefits of dynamic modeling (McGarvey and Hannon, 2004)

- Discover probable emergent characteristics of a system: dynamic models provide a way to investigate emergent behavior because such models can cover these real-time spans at the time of model runs.

- Prepare quantitative assessments of qualitative ideas: system dynamic models allow the user to convert qualitative understanding into a quantitative style which most systems are just recognized at a qualitative level.
- The most important parameters can be identified in a system dynamic: a lot of inputs should be recognized to understand their impact on the output; however, it's really difficult to monitor all of them. SD model allows evaluation of the impact of each input on the output and ranking them, then by sensitivity analysis, it can be decided to choose high ranked input.
- By means of SD models, the long-term effects of decisions on a defined humanitarian system can be predicted.
- SD tool can be effectively used to assist humanitarian decision making and provides managers with a set of tools that can help them learn in complex environments (Briano et al., 2010).

In particular, SD is a method to improve learning in complex systems within humanitarian-related projects, especially large infrastructure projects. However, learning about complex dynamic systems requires more than only technical tools to create mathematical models. Because these tools are applied to the behavior of human as well as physical and technical systems

According to (Forrester, 1961) models can be considered and used as a basis for experimental investigations at lower expenses and in less time than trying changes in actual systems.

3.2.1 Humanitarian and System Dynamics

When a disaster affects population and people's vulnerability (Strömberg, 2007), the sequence force people to handle damages, and an assistance demand from humanitarian organizations, public agents, and other donor's is asked for the affected region and reduce impacts (UNISDR, 2009). Recently, disasters and any occurrence that produces the disruption in the environment happen increasingly (CRED, 2014) and cause serious effects on different aspects of human life. Beside, related humanitarian support expected much more as well due to unplanned famine, poverty, diseases, climate change (IFRC, 2014) which generate more migration-related crises such as refugees, internally displaced people and PoC camps. Accordingly, a universal demand of disaster assistance procedures raised during emergencies which are incited donors and humanitarian organizations to develop the benefits of their methods and decision making in modifying such complex problems. These findings have forced managers of humanitarian organizations to recognize the complexity of these parameters, understand the demand and desired response to a disaster (De Leeuw et al. 2010) and discover how to manage complex aid performances. Beneficial knowledge in such dynamic situations needs convenient tools that empower managers to demonstrate the dynamic complexity in a system and to develop decision making. System dynamic is a strength tool in the evaluation of complex system behavior and demonstrating the effect of donor's decisions on humanitarian subjects in developing an easy-to-use model. Furthermore, the interrelations among the observed and reviewed phenomena could be visualized by means of appropriate tools such as SD (Remida, 2015). When system dynamic and modeling the complex situation are properly understood, humanitarian organizations can extract the maximum benefits from their available resources in their efforts to attend to victim demand (IFRC, 2014). Modeling the organizational dynamics in emergency situations would enable better understanding of the human behaviors to improve humanitarian's performance. Therefore, SD enables the causal relationships to be quantified and tested more explicitly and rigorously donors could improve their systems analyzing skills allowing them to better learn the dynamic complexity of humanitarian systems in SD modeling. Furthermore, SD models can be developed by the accurate collection of variables and factors and as a result, the effects of current decisions can be observed clearly.

The beneficiary of system dynamic has been discussed on analyze of humanitarian assistance as a complex and dynamic system involving multiple 'actors' which could manage to improved comprehension, better implantation in the humanitarian organization and useful in understanding the system behavior (Bjerneld and et al., 2004). In addition, humanitarian assistance has been suggested as a complex and dynamic system, rather than analyzing problems in a piecemeal way or exploring solutions concerning single characters, may present magnificent insight into efficient ways.

To prove reliability of database source of presented research, online databases by implementing various related subjects and different journals have been considered. Two broadly used electronic databases such as Scopus and Science Direct have been involved. These databases exist between the largest in terms of the set of published papers with multiple subjects, including SD in humanitarian. In addition, the forward and backward search has been applied to the captured papers and consideration of well-known journals published by Springer, Wiley, and Thompson has been regarded. Furthermore, the time horizon of the search is from 2003 to 2018, because of the lack of using SD in the humanitarian subject before 2003 (Cooke, 2003). To search for papers, multiple search terms and keywords such as "system dynamic in humanitarian logistics", "system dynamic in disaster", "system dynamic in emergencies", and "system dynamic in social researches" have been implemented. Regarding papers which applied system dynamics in the humanitarian subject, all papers that were not related to humanitarian filed have been excluded such as papers in health, hospital or construction management subject. Following eliminating unrelated papers, the search resulted in 20 papers (Table 21).

It should be considered that in recent years, several attempts are proposing to investigate the application possibilities of Systems Dynamics in various humanitarian fields (e.g. (Besiou et al., 2007) and (Gonçalves, 2011)). This distinction is further exemplified in (Cooke, 2003) which has developed an SD model to provide insights into the complex web of causes included feedback loops and non-linear relationships and can lead to disaster and valuable lessons for organizational learning.

Reference (Simonovic and Ahmad, 2005) captured human behavior during flood emergency evacuation process and the dynamic interactions among model components using a computer-based model by SD approach. Furthermore, in 2005, Survey such as that conducted by Tucker et al. has presented the need for a system dynamics in humanitarian and discussed properties of complex systems. It mentioned that dynamic modeling is a relatively new technology that is little known in the academic, business, and nonprofit communities. The presented SD method in the research, simulated the impact of the strategic business decisions on the financial well-being of the Social Purpose Organization (SPO). Two limitations have been concerned in the research; first, the results are unique to the specific context of SPO, second, the process for managing this type of research might be different for a large Non-Profit Organization (NPO) or for a for-profit organization.

In 2008, Gonçalves has demonstrated an improvement of complex system's features and declared that it allows a fundamental knowledge of the different factors capable for producing the dynamic complexity in humanitarian relief systems and is a significant step in the management of the complex crisis. Besides, the proposed SD method describes an opportunity to model various phenomena in humanitarian relief and to support manager’s design more effective policy interventions in the long run. Also, (Li et al., 2009) have presented a system simulation of coal mine safety, a complex socio-technical system, by system dynamic approach and analyzed the kinds of hazards and unsafe behavior of employees in the coal mine accidents. In the following, reference Gonçalves in 2011, declared that system dynamics can capture the complexity of humanitarian systems and can improve humanitarian decision makers to predict the effect of their decisions on the system performance over time. The well-defined issue of field vehicle fleet management in humanitarian organizations is used to illustrate an application of SD for humanitarian operations. Although, the authors present an example of over three years of research, but less well-defined subsystem in the humanitarian sector which can be analyzed using SD method to the benefit of the overall humanitarian relief operation.

To obtain a relevant and dynamic decision-support in 2013, Rongier et al. proposed an SD method for decision-makers to resolve the crisis based on performance evaluation, in addition to the essential experience they undergo. The research included limitation such as focusing on general crisis management and performance assessment concepts, mainly on humanitarian applications.

Besides, Kunz et al. in 2014 modeled the delivery process of ready-to-use remedial food items by system dynamic method during the immediate response phase of a disaster and find that pre-positioning inventory provides positive outcomes for the beneficiaries, but at extremely high costs. However, neglected various parameters which are relevant to the overall process of providing humanitarian relief in reality and focusing on a single disaster, single country, and single organization are supposed to some of the research's limitation.

In 2014, Peng et al. proposed a system dynamics model to analyze the behaviors of disrupted disaster relief supply chain by simulating the uncertainties. The author has presented the system dynamics as a popular approach to study such problems for its ability to deal with high levels of uncertainty, causal ambiguity, and complexity. Nevertheless, questionnaire has not been used to collect expert's opinion for logistic planning.

In addition, preliminary, the marketing activities in the nonprofit sector has been modeled by system dynamic in the research of Najev in 2014. The research illustrated potential benefits provided to nonprofit organizations by the application of the system dynamics approach in the field of strategic planning. Also, the proposed SD model created an awareness of circular relationships between the observed variables - starting with the problem, leading to solutions and returning to the problem itself. Though, the dynamic relationship between thee constructs should be further analyzed taking into account the non-linear relationship between the variables in the system and time lags in mutual influences.

Furthermore, reference Cruz-Cantillo in 2014, applied the SD model for the forecasting, prioritization, and distribution of critical supplies during relief operations in case of a hurricane event.

In 2015, a considerable amount of papers has been published on system dynamic in humanitarian. The effectiveness of the system dynamic technique has been exemplified in a report by Suarez that enable stakeholders to experience playable system dynamic models linking geoinformation which is an innovative approach to immerse disaster managers to be more effective and providing innovative ways to accelerate learning to better design and implement humanitarian work.

The systems thinking paradigm can be seen in the case of the (Voyer et al., 2015) and (Octavia et al., 2016) which presented in a manner that emphasizes its adequateness and applicability in Humanitarian Logistics (HL) research. The presented systems thinking paradigm in the case of (Remida, 2015), making the logistics systems in general and HL-systems in particular more sustainable. The method has been included suggestion of taking into account interdependent research questions at once by regarding the uncertain relationships among the system' components, which could be different items, belonging to various levels such as objects, organizations and natural. This could offer a hopeful starting point for dealing with the increased complexity of these days' knowledge management in humanitarian.

Reference (Octavia et al., 2016) allows analysis of complex problems in decisions and information effects on capacity and the role of the media and donors in humanitarian process. But, the paper hold some limitation such as the selected variables and the presented simulation were drawn from the literature, and just one type of disaster was investigated.

In addition, reference (Costa et al., 2015) aimed to enhance the range of examples of system dynamics applications in humanitarian logistics with the objective of minimizing the response time during disaster emergency response. The faster the response time of each humanitarian logistic stakeholder, reduce the risk of fatalities. Reference (Diedrichs et al., 2016) attempted to propose an SD model to study the role of communication and logistical coordination between actors in an emergency disaster which breaks down a complex problem into a set of variables and parameters that can be easily modified as needed. Although, the effects have been studied qualitatively, and the proposed original SD model provides a first attempt to quantify them. Beside, training of decision-makers on flood response by means of SD model has been seen in the case of Berariu et al. in 2016. This case study confirms the capability of system dynamics (SD) model to capture the complex components. However, the research limitation is all influencing variables has not been considered due to the variety of flood events. In the following, Anjomshoae et al. in 2017 developed a dynamic balanced scorecard model for humanitarian relief organizations' performance management. The developed model attempts to describe the relationships between strategic resources and how these resources relate to the humanitarian organizations' goal in providing an appropriate response to the beneficiaries. Although, the research comprises the limitation which is solely based on relevant existing literature, therefore further practical research is needed to validate the interdependencies of performance indicators.

Finally, Kim in 2018 has suggested an SD model for effective debris management under different disaster scenarios to develop better disaster planning for recovery.

Table 21 presents most of the relevant reviews about humanitarian publications associated with system dynamics and explained the purpose of each publication about system dynamic as well.

Table 21 Review of system dynamic paper in humanitarian

No	*Year*	Author(s)	Title	Applied system dynamic in humanitarian
1	*2003*	David L. Cooke	A system dynamics analysis of the Westray mine disaster	Presents a system dynamics analysis of the 1992 Westray mine disaster in Nova Scotia, Canada. The value of simulation is its ability to capture a ‘‘mental model’’ of the safety system, which can stimulate discussion among safety experts as to the systemic causes of a disaster.
2	*2005*	Jennifer S. Tucker et al.	Dynamic Systems and Organizational Decision-Making Processes in Non-profits	Propose a system dynamic modelling process which facilitates organizational learning as leaders and use the insight gained from adopting a systems approach to make effective strategic decisions. The SD simulated the impact of the strategic business decisions on the financial well-being of the SPO.
3	*2005*	Slobodan P. Simonovic and Sajjad Ahmad	Computer-based Model for Flood Evacuation Emergency Planning	Develop a computer-based model for capturing human behaviour during flood emergency evacuation process (movement of people from the region under the threat to safety) using an SD approach.
4	*2008*	Paulo Gonçalves	System Dynamics Modelling of Humanitarian Relief Operations	Presents an SD methodology to represents an opportunity to model different phenomena in humanitarian relief and to help managers design more effective policy interventions in the long run.
5	*2009*	LI Xian-gong et al.	System Dynamics Simulation of Coal Mine Accident System Cause	Analyse the kinds of hazards and unsafe behaviour of employees in the coal mine accidents of China by system dynamics simulation method from organizational and management perspective.
6	*2011*	Maria Besiou et al.	System dynamics for humanitarian operations	Present the preliminary findings of an applied SD model to analyse a well-defined subsystem of humanitarian operations, field vehicle fleet management.

7	*2013*	Carine Rongier et al.	Towards a crisis performance measurement system	Propose a dynamic decision-support system to support the stakeholders in making accurate decisions while carrying out a performance evaluation of the activities that run during the crisis-response process.
8	*2013*	Nathan Kunz et al.	Investing in disaster management capabilities versus pre-positioning inventory: A new approach to disaster preparedness	Evaluate the effects of investing in disaster management capabilities through system dynamics modelling. The delivery process of ready-to-use therapeutic food items has modelled during the immediate response phase of a disaster.
9	*2014*	Min Peng et al.	Post-seismic supply chain risk management: a system dynamics disruption analysis approach for inventory and logistics planning	Apply a system dynamics model to analyse the behaviours of disrupted disaster relief supply chain by simulating the uncertainties associated with predicting post-seismic road network and delayed information.
10	*2014*	Ljiljana Najev Čačija	Preliminary empirical analysis of the relationship dynamics between marketing activities and fundraising success in non-profit organizations	Presents the initial results of the application of a system dynamics methodology to modelling the marketing activities in the non-profit sector.
11	*2014*	Y. Cruz-Cantillo	A system dynamics approach to humanitarian logistics and the transportation of relief supplies	Develops an SD model for the forecasting, prioritization, and distribution of critical supplies during relief operations in case of a hurricane event.
12	*2015*	Pablo Suarez	Rethinking engagement: innovations in how humanitarians explore geoinformation	Offers an innovative approach to immerse disaster managers in geoinformation: participatory games that enable stakeholders to experience playable system dynamic models, decisions and consequences in a way that is both serious and fun.
13	*2015*	A. Remida	A Systemic Approach to Sustainable Humanitarian Logistics	Presents a systemic approach, which take into account the economic and social dimensions of sustainability and the increasing complexity of logistics systems within disaster relief operations that emphasizes its applicability in Humanitarian Logistics (HL) research.
14	*2015*	Otávio Costa et al.	A system dynamics analysis of humanitarian logistics coordination	Demonstrate an SD simulation to analyse the interactions between media, donors and humanitarian organizations in response to an abrupt natural disaster, such as tsunamis and earthquakes.

15	*2015*	J. Voyer et al.	Understanding Humanitarian Supply Chain Logistics with System Dynamics Modelling	Present an SD model referring to humanitarian response to a natural hazard, but they do not focus on conflicting needs resulting from the stockpiling behaviour of the population and the needs for conducting relief operations.
16	*2015*	Danilo R. Diedrichs et al.	Quantifying communication effects in disaster response logistics, A multiple network system dynamics model	Propose a discrete mathematical SD model to study the role of communication and logistical coordination between actors in an emergency disaster response operation, and to measure their impact on the number of lives saved and dollars spent.
17	*2015*	Romana Berariu et al.	Training decision-makers in flood response with system dynamics	Present an SD model to train decision-makers on flood response by providing them the possibility to analyse and evaluate different scenarios.
18	*2016*	Tanti Octavia et al.	Coordination of Humanitarian Logistic Model Plan for Natural Disaster in East Java, Indonesia	Develop a detail coordination SD model in humanitarian logistic in Indonesia.
19	*2017*	Ali Anjomshoae et al.	Toward a dynamic balanced scorecard model for humanitarian relief organizations' performance management.	Propose a conceptual framework for the development of a Dynamic Balanced Scorecard (DBSC) for humanitarian organizations, with a focus on cause-and-effect relationships among KPIs of the humanitarian supply chain.
20	*2018*	Jooho Kim et al.	A framework for assessing the resilience of a disaster debris management system	Apply a system dynamics approach to evaluate the debris removal performance for a resilient community.

In this study we use SD approach to simulate health and education system of refugees and its building elements and understand the cost estimation for each category. Financial aid for refugees are by nature systemic and complex, influencing many interconnected subsystems (eg. level of refugee health), which can be demonstrated by Causal Loop Diagrams (CLDs) to systemically demonstrate and interpret the dynamic complexity. CLDs are essential tools and visual qualitative models for interpreting the feedback structure of systems by employing feedback loops to show links between the variables that define a system (Briano et al., 2010). They have long been employed in academic studies and frequently applied in organizations to quickly capture assumptions about the causes of dynamics. The consequences of relations between the variables can be further simulated via the model to evaluate and enhance the perception of this complex system.

3.3 Causal Loop Model

Reviewing crisis management and humanitarian aid literature, this section studies the building boxes of refugee's health and education. A causal loop diagram will be developed as a result of this section, as the discussion progresses.

3.3.1 Causal Loop Model of Refugees' Health and Education System

Causal loop diagrams (CLDs) are an essential tool for interpreting the feedback structure of systems. It has been used in academic achievement for a long time and frequently overused in organizations to quickly capturing assumptions about the causes of dynamics. The presented causal loop diagram in Figure 28, primarily interactions between the most important factors have been regarded, which is largely effect on other variables. It is a good illustration of social behavior in the disaster over time (the dynamics of the system) and can be interpreted by the interaction of positive and negative feedback loops. Six basic structure blocks; positive feedback or reinforcing loops (Positive loops), and balancing loops (negative feedback) are constructed the model. A causal diagram including of variables connected by arrows indicating the causal impacts amongst the variables. The significant feedback loops are also distinguished in the diagram. Link polarities represent the structure of the system and explain what would happen if there was a change. The details and behavior of the variables will not describe (Sterman 2000).

School Access to healthcare services is a basic human right which humanitarian organizations aim to provide (Rees et al. 2016). Field research on the Syrian refugee crisis in Turkey (Battistin 2016) reports that approximately 60 percent of all financial support by humanitarian agencies aims at ensuring primary assistance to refugees, which in particular means supporting them in their healthcare requirements.

Healthcare needs are categorized in six measures of access to healthcare service: access to clean water, access to hygiene/sanitation facilities, health expenditure, general health, mental health, and violence (Doocy and Tappis 2017). Financial have been reportedly described as one of the most effective means of enhancing access to services they need most (Schule et al. 2017). The high costs of healthcare is one of the most commonly reported factors for refugees which should solve by financial aid (Rees et al. 2016). Furthermore, financial aid are reported to positively impact on access to clean water and hygiene facilities, which all enhance the general health of refugees (Bailey et al. 2008). Reviving money often plays a significant role in the violence and depression feeling (WFP 2017; Bailey et al. 2008). As discussed before, it reduce violence in refugee communities and hence improve the mental health of the community in general, and in particular for the women who experienced different kinds of abuse due to the absence of cash resources and increased mental health in their community (Berg et al. 2013).

Figure 28 demonstrates the effects of financial aid on health and social security and behavior, and their interactions. Financial aid empower beneficiaries to spend more on their health and cause more health rate, thus improve the overall health (Pega et al. 2015) (loop R5). Enhanced overall health state of refugees positively affects their well-being and reduces stress levels to refine mental health level (Abu Hamad et al. 2017) (loop R6). This can reduce the level of violence (Crisp et al. 2009), which in turn reinforces the health loop (loop R2). In addition, increased health expenditure is associated with improvement of access to health services and thus enhanced overall health of the beneficiaries (Devereux and Jere 2008). Enhanced levels of general health, cause reducing in number of death and thus more children and attendance in school which are shown in loop B2. More financial aid help more spending money in education and more attending in school (loop R3). Also birth rate and death rate impact on population and the number of children which will impact on child labor (loop R1 and B1).

General studies of low-income communities highlight that households have on average 2 to 3 children of school age (5 to 17 years old), although more than half of these children often do not attend school (Giordano et al. 2017). More than half of all Syrian refugees are under the age of 18, with over 75% not enrolled in any school in Turkey (UNHCR 2017). Financial aid help to reduce the number of children missing school by covering a large proportion of their education costs (Abu Hamad et al. 2017; Devereux and Jere 2008). Moreover, covering the cost of attending schools, enhance the children's education level by up to 40% (UNHCR 2011). Improvements in school enrolment rates as well as a decreased rate of child labor (DFID 2005). In other research, the World Food Program reported 38% of cash recipients spent cash on education costs for their children (WFP 2017). As a result the causal loop and the relations between variables emphasizes the positive effect of financial aid on the health and education status of refugees.

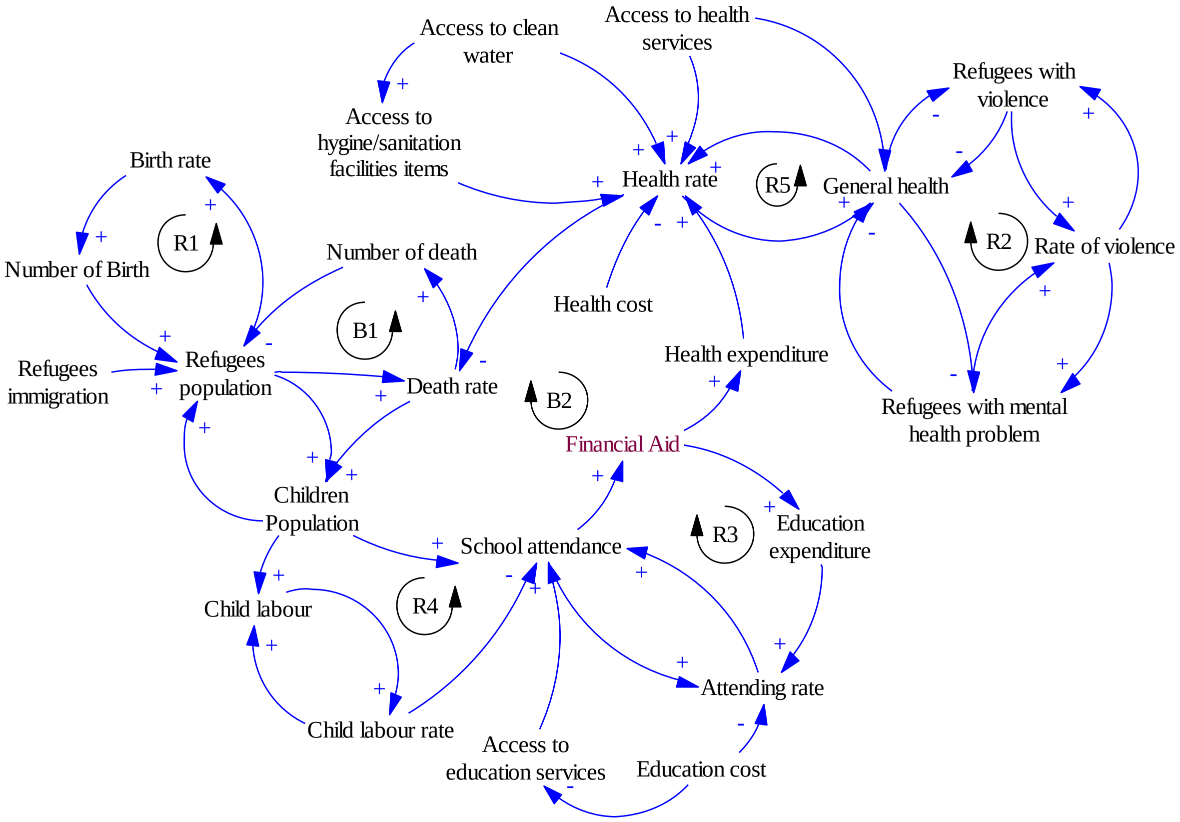


Figure 28 Causal loop diagram of health and education

In the next subsection, a stock and flow simulation model is provided, and numerical verification and validation are presented.

3.4 Quantitative analysis: Stock and Flow simulation model

In this part, the previous developed CLDs model is applied to create a SD model using @Vensim. The quantitative model is designed around the concept of financial aid variable. Total financial aid paid by the humanitarian organizations for education and health system of refugees, which is modeled as a constant currently sums up to US$156000000 per year per refugee (http://reporting.unhcr.org/turkey). Due to historical data, number of child labor, number of refugees access to clean water, number of refugees access to hygiene facilities, number of Syrian refuges immigrate every year, number of refugees have access to education and health are from real historical data series and defined by look up function in the model.

Although financial aid for education is US$48000000 and for health is US$108000000. It

The model overview is illustrated in Figure 29.

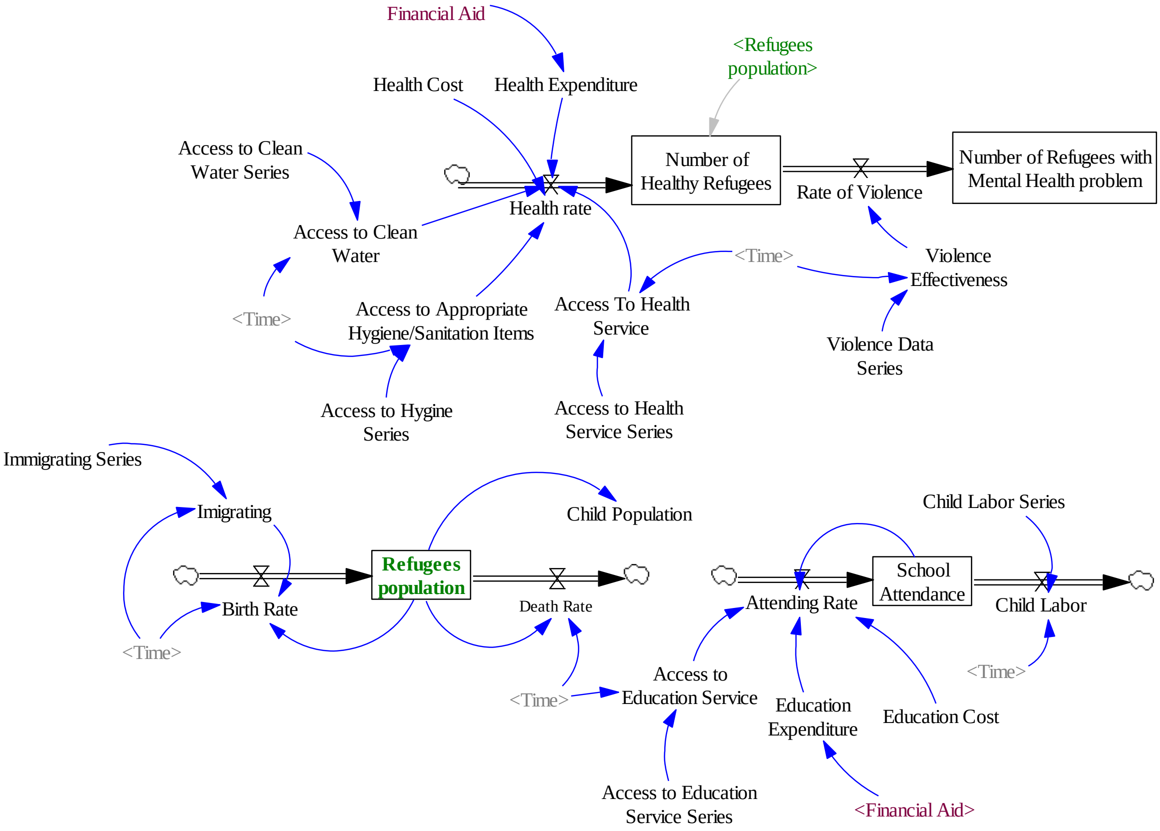


Figure 29 Overview of the Stock-Flow model structure related to health and education factors

3.5 Model verification and related data

The model is validated using different validity methods which is illustrated in Figure 30. The results show a very good agreement between simulation and historical data which is show how the simulation model is reliable and possibility of applying several different scenarios and policies. In addition, the other validation method is applied via using dimensional check. The model estimation fit well to the real time-series data related to Syrian refugees in Turkey in a time horizon of seven years (2012-2019) which applied data are presented in Table 22 and Table 23.

No.	Variable	Explain	Value	Units	References
1	Financial Aid	156000000 $ humanitarian aid per year for education and health services	43	$/Person/year	http://reporting.unhcr.org/turkey
3	Education cost	Average education cost is 6.5 $ per month	75	$/Person/year	UNHCR, 2015

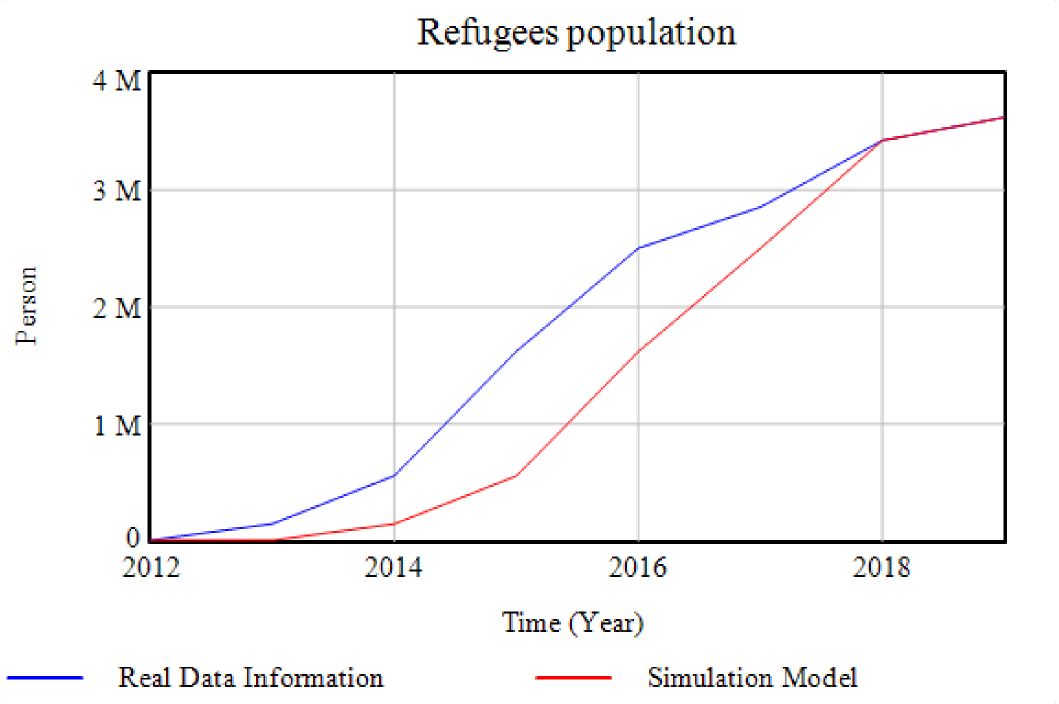
4	Education expenditure	Households spend US$12.5 per months for education cost (30% of Financial aid is for education)	12.9	$/Person/year	Doocy et al. 2016; UNHCR, WFP; Unicef, 2015
5	Health expenditure	Households spend US$24.5 per months for medicine (70% of Financial aid (108000000$)is for health)	18-40	$/Person/year	UNHCR, WFP, and Unicef, 2015
2	Health cost	Average health cost is 20.8 $ per month	250	$/Person/year	Saleh et al., 2018

Table 22 Input parameters: values and units

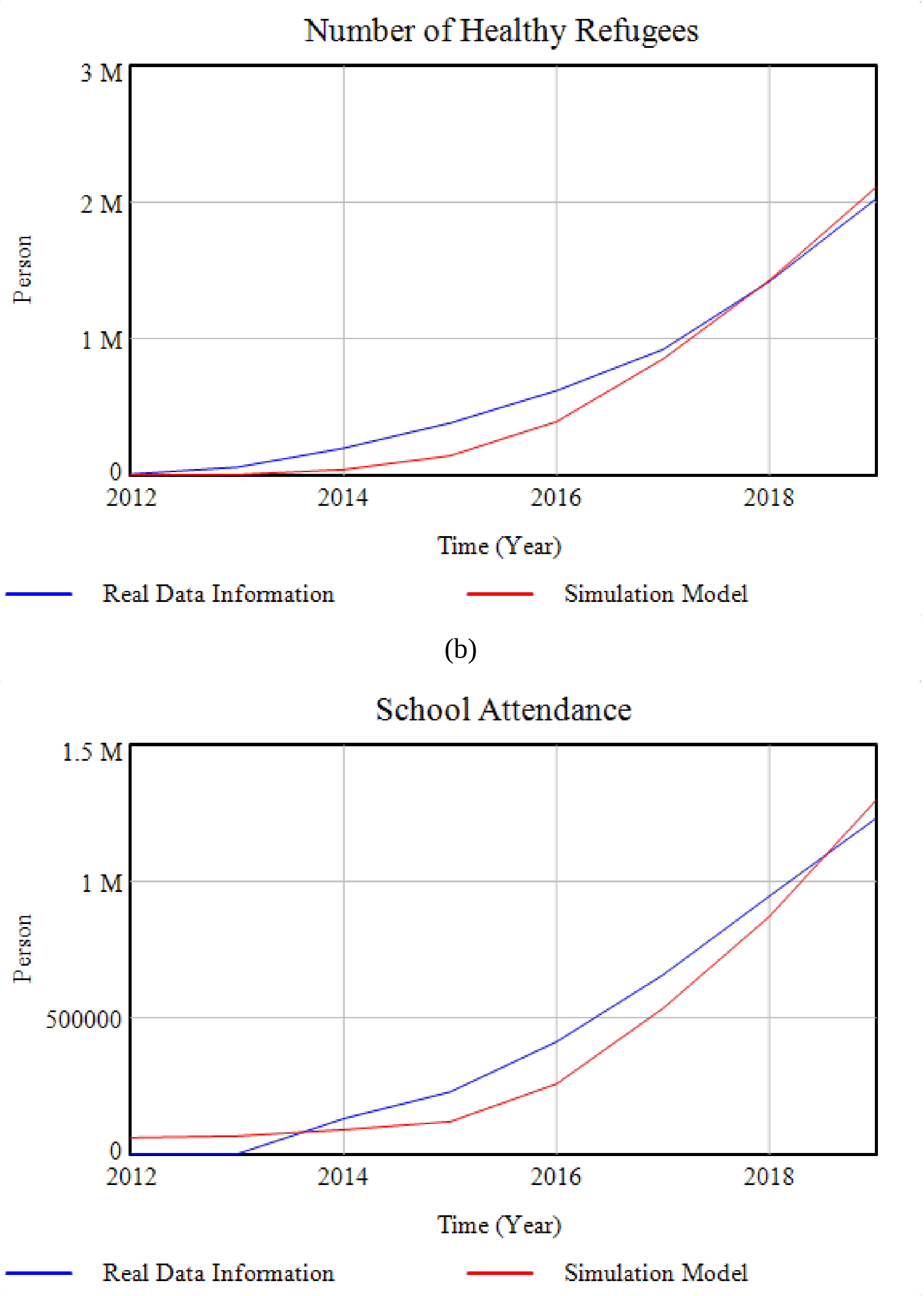
N	**Variable**	**Explanation**	**Data Series of Syrian Refugees in Turkey**								**Reference**
			2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	
1	Refugees Population	Number of registered Syrian refugee in Turkey	9,500	148,441	559,994	1,622,839	2,503,549	2,854,968	3,424,237	3,622,366	Saleh et al. 2018; Carlier, 2018
2	Refugees Children Population	Number of registered refugee children (age 5-17)	4,000	74,220	279,997	811,419	1,138,992	1,239,866	1,746,160	1,811,183	Saleh et al. 2018; Carlier, 2018
3	Number of child labor	The number of Syrian child laborers	0	19,225	59,587	94,845	125,000	150,051	170,000	195,000	UNHCR, 2019
4	School attendance	Number of Syrian students enrolled in school (7-15 years)	0	0	130,000	511,259	710,489	872,536	1109453	1,232,114	UNHCR, 2018
5	Access to Education Services	Number of Syrian refugees access to education services	0	20,000	148,000	591,259	780,489	980,000	1,489,000	1,652,000	UNHCR, 2018; Saleh et al. 2018; Carlier, 2018
6	Access to health care services	Number of Syrian refugees access to health care services	0	0	224,000	960,000	2,178,000	2,595,664	3,013,328	3,260,129	Armstrong and K. Jacobsen, 2015; Doocy et al, 2016
7	Access to Clean Water	Number of Syrian in Turkey having access to clean water	7,000	118,752	531,000	1,379,000	2,002,000	2,340,000	3,253,000	3,431,000	Armstrong and K. Jacobsen
8	Access to Hygiene/Sanitation Facilities	Number of Syrian refuges benefitting from gender appropriate hygiene or sanitation items	4,200	83,200	193,266	249,000	326,000	406,734	587,630	689,000	Doocy et al, 2016; UNHCR, 2018

9	Number of Healthy Refugees	Number of Syrian refugees with good condition of health	4,800	56,000	195,997	381,000	618,000	921,000	1,421,000	2,026,000	Doocy et al, 2016; UNHCR, 2018
10	Refugees with Mental Health problem	Number of Syrian refuges with mental health problem (like depression and violence)	4300	90,891	159,585	180000	235,000	600000	860000	1100000	UNHCR, 2018
11	Violence	Violence between Syrian refugees (Conflict)	600	*2500*	9000	26000	40,000	90000	250000	850000	Doocy et al, 2016

Table 23 Historical data for the identified impact factors



(a)



(b)

(c)

Figure 30 Model verification using real data; (a) Refugee Population ;(b)Number of Healthy Refugee; (c) School Attendance

3.6 Discussion and Conclusion

Refugees in Turkey have faced several problems almost every day and they have had a terrible time in their life in Syria and decided to emigrate from their born country and leave all of their wishes. So they become depress and homesick and violence increase among them which create some mental health problem. Mental health problems affect their general health levels and they should spend money to buy medicines to improve it. Besides, they need to spend some money on the education of their children to improve their education level.

As mentioned before, humanitarian organizations aid just paid $43 for the health and education of each refugee each year which 30% of this money ($12.9) is used for education and the other 70% ($30.1) is spent through the health part. Researches show that the minimum cost for education and health is $75 and $250 representatively which are almost 4 times bigger than the current aid. Obviously, humanitarian organizations should increase their financial aid to improve refugees' health and education.

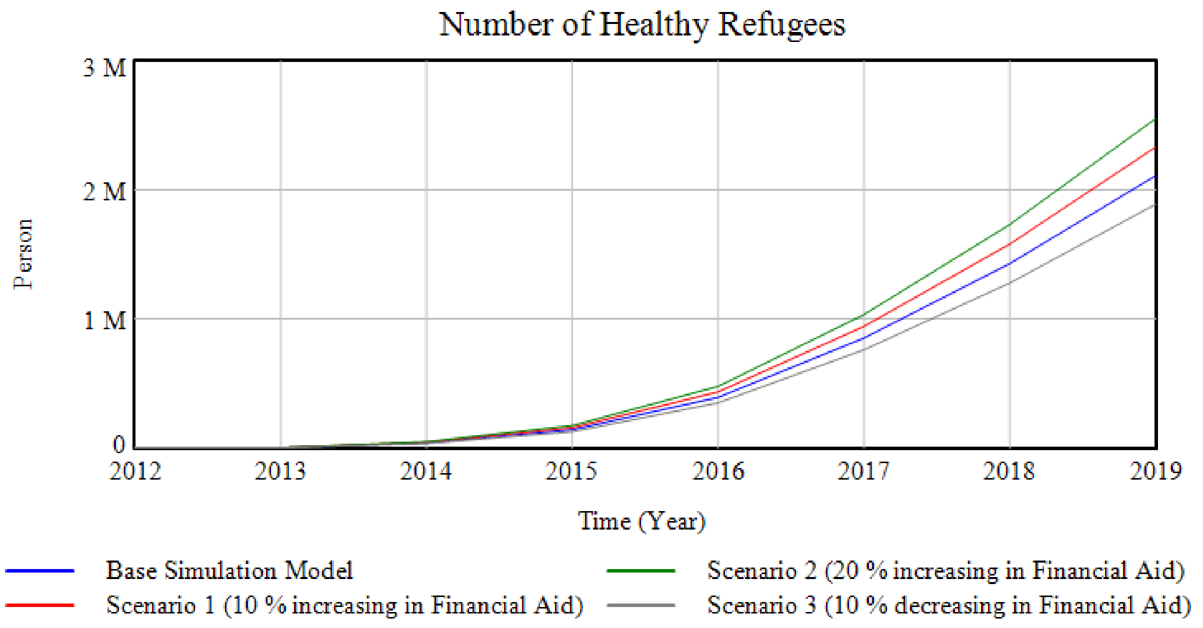
In this section, three different scenarios have been applied to figure out the impact of increasing or decreasing the financial aid in health and education expenditure to see its effects on their general health level and the number of attendance in school.

Figure 31 (a) shows the impact of financial aid in the number of healthy refugees from 2012 to 2019. As it is mentioned in Table 23, about 56 % of the refugees are under health issues both mental and physical which is most of these problems are because of; war, being away from their family, limitation access in education and health system, and finally immigration. Every small problem for non-refugees people are usually very big for the refugees and in this case, all of the humanitarian organizations have tried to manage and inject more money to improve their life. The 3 different scenarios show that the number of healthy refugees will moderately increase each year with increasing about 10% and 20% (Scenarios 1 and 2) in financial aid. In addition, a 10% reduction of financial (Scenario 3) causes to reduction the heath impact on them.

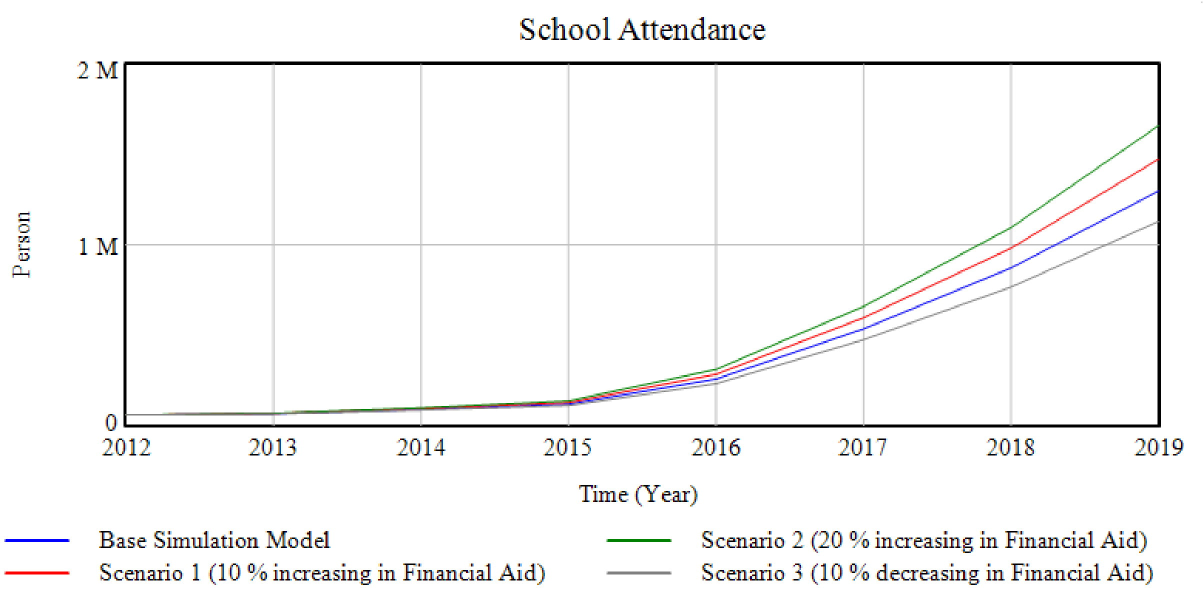
According to this graph, the number of healthy refugees are sensitive to the changes in the financial aid level where the trends of it change with almost a linear multiplier offset for each change. Financial aid only contributes up to 20% of beneficiaries' total health expenditure, but the number of healthy refugees increase by about half a million in 2019.

In addition, there is not any differences in the magnitude of sensitivity between different variables are observed. For instance, the confidence intervals are the same for education Figure 31 (graph (b)). Considering the long-term importance of education in refugee's children level of education and also reducing the child labour, this result should raise a red flag to policy makers. Thus, health service (graph (a)) and education (graph (b)) are less sensitive to financial aid changes in the short term while become more sensitive in the longer term which might be because of lack of capacity availability. As a result, these stock variables behave more sensitive to the financial aid level and just by increasing the financial aid up to $8 to each refugee per year, the number of healthy refugees and the number of attendance of their children can increase to half a million people which is really significant change and thus can empower them to avoid exercising their negative coping strategies such child labour.

This study shows humanitarian financial aid, in moderate amounts, can be well effective in mid and long-term after refugees are settled in a host country. Thus, a more active and direct aid roles by the humanitarian organizations can enhance the effectiveness and sustainability of their cash aid programs in longer terms.



(a)



(b)

Figure 31 Sensitivity Analysis of Financial Aid; (a) Health; (b) Education System

CHAPTER FOUR

CONCLUSION

4 Conclusion

The main purpose of this study was to develop different simulation based approaches in project management, followed with cost estimation in industry's and humanitarian project in order to cost management considering complexity of factors have been proposed.

The results of each chapter are summarized in detail separately, as follow:

- **Chapter One: Introduction and summary**

The first chapter described a general description of the subjects of the thesis.

- **Chapter Two: Cost contingency allocation approaches in construction projects**

This section focuses on estimation of contingency in stochastic regime by MCS. The traditional method of a real life Company applied to an industrial project of railway signaling and integrated transport systems. The proposed method considered the qualitative risk analysis and stochastically quantitative analysis by using the Monte Carlo method and executed for two probability distribution, which presented the cost contingency amount for the risks happening with the determined probability (under 20 percent) to allocate in the project.

The comparison between the results obtained from two different types of probability distributions showed two different coverage level for one contingency amount, which means the contingency value, is not accurate and also the result was influenced by the choices of the decision-maker. Therefore, it is resulted that the method has the problem of subjective and inaccurate. So, a new methodology has been introduced for which is more accurate and have the feature of objective. In addition, combination of the Risk Mode and Effect Analysis (RMEA) with Monte Carlo Simulation (MCS) has been presented to determine the amount of allocated contingency fund that overcomes other methods' limitations. The output of the analysis was a cumulative distribution function which demonstrates a coverage level related to the contingency amount to control extra cost and reduce the amount of contingency in projects.

The developed method has been validated by applying to the real construction project and the obtained results are compared with the outcomes' of the company's traditional approach, clearly demonstrate the potential and the benefits of the proposed methodology. The result of the proposed method allows the decision-makers to operate with a lower contingency amount and control extra expenses of projects. Thanks to this method, the calculations carried out in a quick and precise way. In addition, the accuracy of the model is high, and it does not need specific mathematical expert.

In addition an innovative risk analysis method based on Monte Carlo Simulation has been developed to the construction phase of a 600 MW gas turbine plant to demonstrate the advantages of a study in a stochastic regime. This proposed methodology for risk management and project control allows working in a stochastic regime that increases the progress of the project. In Particular, two project phases were considered in this research: the process of bid and the phase of work in progress control; Risk Analysis with Monte Carlo method has been applied to both. The analysis on the first phase has led to the allocation of a contingency equal to 8% of the costs of construction of the plant; this percentage represents a quantitative estimate of all the possible risks that may occur in the pipeline. The MCS analyses in the progress phase identified the project final dates for each critical path calculated at five different time instants, from June 2016 to December 2016. Finally, it has been possible to note how the variability of the results decreases with the approaching of the implant delivery dates; this aspect is fundamental in order to identify more precisely the final date of the project over time.

Besides, in this study a stochastic Risk Mode and Effect Analysis methodology base on Monte Carlo Simulation has been developed for the management of cost contingency amount. The stochastic risk model proposed to support decision makers in determination of more accurate amount of contingency fund according to a pre-set coverage level to reduce the risk of extra costs in industrial projects. Combining of RMEA with MCS makes the proposed method objective, fast and easy to apply which overcomes other methods limitation. This approach reduced, despite the presented methodologies in the literature, the influence on the risk analysis of the subjective choices of decision makers by a RMEA analysis extended to multiple evaluators (up to 10 evaluators depending on the project complexity) and a stochastic quantitative risk analysis by MCS. It stochastically evaluated the project costs and presented the cumulative distribution function to demonstrate “level of coverage” related to the contingency amount to have the power of controlling overhead costs and diminish size of contingency in projects.

The developed method has been validated by applying a real construction project. The obtained results with RMEA and MCS approach were compared with the outcome of the company’s traditional approach in a study to a real railway project. The proposed approach allows the decision makers to operate with a lower contingency amount thanks to the fact that for each contingency value, the coverage level is known above all the calculated extra cost. The obtained outcomes with Monte Carlo Simulation, without an initial RMEA analysis, are presented an excessive dependence on decision makers in assessing risk, both in terms of impact and probability of occurrence. A single decision maker, generally the project manager, might change his/her judgment in progress, becoming more or less strict, depending on the circumstances (mood, fatigue, motivation, etc.). The aim of the proposed approach is to solve these problems carrying out an initial phase of risk assessment based on a revisited RMEA. Besides

➢ Chapter Three: System dynamic model in humanitarian project

This chapter is devoted to a System Dynamics model applied in social and humanitarian research during the visiting period in the United Kingdom. The model applied to a real project which aims to improve the welfare of Syrian refugees, one of the most distressing tragedies affecting millions of people who had to leave their homeland and live as refugees in Turkey. This comes with many concerns including assessing their health and education demands and estimate the proper cost for them. The success of the project will be reflected by the increase in the level at which the needs of the refugees are satisfied.

For this purpose, a causal loop model has been proposed to better understand the building-boxes of refugees' health and education variables and their interactions have proposed and then an SD model is applied and validates by historical data from humanitarian organizations. The result of the sensitivity and payment of more money from humanitarian organizations shows a significant contribution to improve health and education levels together.

To study the impact of different levels of financial aid to beneficiaries on the impact factors, we have examined a -10%, +10%, and +20% of financial aid variation, and the results are illustrated in the study. It presented, health and education levels of refugees are sensitive to the changes in the financial aid level and will increase by half-million in 2019 when they get more $8 from humanitarian organizations. Considering the long-term importance of education and health in refugees and its contribution to the hosting community in a long run persistent crisis, this result should raise a red flag to policymakers.

Also paying about $4 less money to refugees, decrease the number of healthy refugees, and the number of attendance in school about 100,000 which is a significant change.

Thus, a more active and direct capacity-building role by the humanitarian organizations can enhance the effectiveness and sustainability of their financial aid programs in longer terms and increase the number of healthy refugees and also more educated children.

Recommendations for future

The following tasks are suggested for future works:

- Applying RMEA and MCS model on different projects
- Improving of simulation models for project management
- Collecting real data of Syrian refuges by providing questionnaire
- Adding more factors to the model of SD
- Applying SD model to other refugees around the world and see the result
- Investigate more negative impact factors for SD model
- Applying COVID-19 factor to the SD model and see the virus impact on their health and education

References

Abu Hamad, B., Jones, N., Samuels, F., Gercama, I., Presler-Marshall, E. and Plank, G., 2017 A promise of tomorrow: The effects of unhcr and unicef cash assistance. Overseas Development Institute, London.

Ahmad, I., (1992). “Contingency allocation: a computer-aided approach”, AACE Transactions, 28 June - 1 July, Orlando, F.4.1-7.

Aibinu, A. A., Jagboro, G. O. (2002). “The effects of construction delays on project delivery in Nigerian construction industry”, International Journal of Project Management, 20, 593-599.

Allahi$_a$, F., Cassettari, L., Mosca, M. (2017). “A Stochastic Risk Analysis through Monte Carlo Simulation to the Construction Phase of a 600 MW Gas Turbine Plant”, Proceedings of the MAS 2017, 18-20 September, Barcelona, Spain.

Allahi$_c$, F., De Leeuw, S., Sabet, E., Kian, R., Damiani, L., Revetria R. Giribone, P., and Cianci, R., (2018). A review of system dynamics models applied in social and humanitarian researches. Proceedings of the World Congress on Engineering, pages 4–6.

Allahi$_d$, F., Revetria R. and Cianci, R., (2018). Cash and voucher impact factor in humanitarian aid: A system dynamic analysis. Proceedings of the International conference on Modeling and Simulation (MAS), pages 17–19.

Anderson, R., Gordon, G., Mansingh S., (2014). An assessment of the potential impacts of knowledge-driven decision support in social welfare. Pages 499–505.

Anjomshoae, A., Hassan, A., Kunz, N., Wong, K.Y., de Leeuw, S., 2017. “Toward a dynamic balanced scorecard model for humanitarian relief organizations’ performance management”, Journal of Humanitarian Logistics and Supply Chain Management, Aug 7, 7(2), pp. 194-218.

Aquino-Pedro, V. (1992). “A PERT Approach to Cost Risk Analysis”, Transactions of AACE International, Morgantown WV.

Armstrong, P. and Jacobsen, K., 2015. Addressing Vulnerability? Cash Transfer Programming and Protection Outcomes for Out-of-Camp Syrian Refugees: An analysis of the Danish Refugee Council's e-card programming in southern Turkey. Danish Refugee Council, Copenhagen.

Association for Project Management (2008). “Interfacing Risk and Earned Value Management”, Association for Project Management, UK.

Association for the Advancement of Cost Engineering International (AACE) (2012). “Risk Analysis and Contingency Determination Using Expected Value”, AACE, Morgantown, WV, pp. 1-14.

Baccarini, D., 2005. “Estimating Project Cost Contingency – Beyond the 10% syndrome”, Australian Institute of Project Management National Conferenec, Victoria: Australian Institute of Project Management.

Baccarini, D., Love, P. E. D. (2014). “Statistical Characteristics of Cost Contingency in Water Infrastructure Projects”, Journal of Construction Engineering and Management, 140(3), 10.1061/(ASCE)CO.1943-7862.0000820, 04013063.

Bailey, S. and Harvey, P., 2015. State of evidence on humanitarian cash transfers. Overseas Development Institute Background Note.

Bailey, S., Savage, K. and O’Callaghan, S., 2008. Cash transfers in emergencies: A synthesis of World Vision’s experience and learning. A report commissioned by World Vision International.

Bakhshi, P., Touran, A., 2014. "An overview of budget contingency calculation methods in construction industry." Proceed Engineering Journal, vol. 85, pp. 52-60.

Bastagli, F., Hagen-Zanker, J., Harman, L., Barca, V., Sturge, G., Schmidt, T., and Pellerano, L., (2016). Cash transfers: what does the evidence say? A rigorous review of programme impact and the role of design and implementation features. ODI, London.

Battistin, F., 2016. Lebanon Cash Consortium (LCC) Impact Evaluation of the Multipurpose Cash Assistance Programme January 26th, 2016.

Belardo S., and Harrald J., (1992).A framework for the application of group decision support systems to the problem of planning for catastrophic events. IEEE transactions on Engineering Management, 39(4):400–411.

Bendato, I., Cassettari, L., Giribone, P.G., Mosca, R., (2015). Monte Carlo method for pricing complex financial derivatives: An innovative approach to the control of convergence, J. of Applied Mathematical Sciences, vol. 9, no. 124, pp. 6167-6188.

Besiou, M., Stapleton, O., Van Wassen hove, L.N., 2011. “System dynamics for humanitarian operations”, J. Humanitarian Logistics Supply Chain Manage, 2011, 1, pp. 78–103.

Berariu, R., Fikar, C., Gronalt, M., Hirsch, P., 2016. “Training decision-makers in flood response with system dynamics”, Disaster Prevention and Management, 2016 Apr 4, 25(2), pp. 118-36.

Briano, E., Caballini, C., Giribone, P., Revetria, R., (2010). “Using a system dynamics approach for designing and simulation of short life-cycle products supply chain”, InProceedings of the 4th WSEAS international conference on Computer engineering and applications 2010 Jan 27, pp. 143-149, World Scientific and Engineering Academy and Society (WSEAS).

Bjerneld, M., Lindmark, G., Diskett, P., and Garrett, M.J., 2004. “Perceptions of work in humanitarian assistance: interviews with returning Swedish health professionals”. Disaster Management & Response, 2004, 2(4), pp.101-108.

Cassettari, L., Giribone, P.G., Mosca, M., Mosca, R., (2010). The stochastic analysis of investments in industrial plants by simulation models with control of experimental error: Theory and application to a real business case” Journal of Applied Mathematical Sciences, vol. 4, no.76, pp. 3823–3840.

Cassettari, L., Mosca, R., Revetria, R., (2012). Monte Carlo Simulation Models Evolving in Replicated Runs: A Methodology to Choose the Optimal Experimental Sample Size, Journal of Mathematical Problems in Engineering, Vol. 2012, pp. 0-17.

Carlier, W., 2018. The widening educational gap for Syrian refugee children, 2018.

Centre for Research on the Epidemiology of Disasters (CRED), 2014. The international disaster database. <http://www.emdat.be/database>.

Chau, K. W. (1995). Monte Carlo simulation of construction costs using subjective data. Construction Management and Economics, 13(5), 369-383, http://dx.doi.org/10.1080/01446199500000042.

Chen, D. and Hartman, F. T. (2000). “A neural network approach to risk assessment and contingency allocation”, AACE Transactions, 24-27th June, Risk, 07, 1-6.

Chou, J. S. (2011). “Cost simulation in an item-based project involving construction engineering and management”, International Journal of Project Management, 29, 706-717.

Chou, J. S., Yang, I. T., Chong, W.K. (2009). “Probabilistic simulation for developing likelihood distribution of engineering”, Automation in Construction, 18, 570–577.

Cihan Kızıl, 2016. Turkey’s policy on employment of Syrian refugees and its impact on the Turkish labor market. Turkish Migration 2016 Selected Papers, page 164.

Clark, D. E. (2001). “Monte Carlo Analysis: ten years of experience”. Cost Engineering, 43(6), 40-45.

Clark, F. D., Lorenzoni, A. B. (1985). “Applied Cost Engineering”, M. Dekker, New York.

Cooke, D.L., 2003. “A system dynamics analysis of the Westray mine disaster”, System Dynamics Review, 2003 Jun 1, 19(2), pp. 139-66.

Costa, O., Santos, J., Martins, M., Yoshizaki, H., 2015. “A system dynamics analysis of humanitarian logistics coordination”.

Crisp, J., Janz, J., Riera, J., and Samy, S., 2009. Surviving in the city: A review of UNHCR0 s operation for Iraqi refugees in urban areas of Jordan, Lebanon and. UNHCR, Syria. Geneva, 2009.

Cruz-Cantillo, Y., 2014. “A System Dynamics Approach to Humanitarian Logistics and the Transportation of Relief Supplies”, International Journal of System Dynamics Applications (IJSDA), 2014, 3(3), pp. 96-126.

Curran, M. W. (1989). “Range Estimating”, Cost Engineering, 31(3), 18-26.

Dadouch, S., 2019. Despite talk of returns, turkey quietly works to integrate Syrian refugees. Accessed: https://uk.reuters.com/article/uk-mideast-crisis-syria-turkey-insight/despite-talk-of-returns-turkey-quietly-works-to-integrate-syrian-refugees-idUKKCN1RA0FJ.

De Leeuw, S., Kopczak, L.R., Blansjaar, M., 2010. “What really matters in locating shared humanitarian stockpiles: evidence from the WASH cluster”, In Working Conference on Virtual Enterprises, Springer, Berlin, Heidelberg, pp. 166-172.

Devereux, S. and Jere, P., 2008. Choice, dignity and empowerment? Cash and food transfers in Swaziland. An evaluation of save the children0 s emergency drought response.

DFID, U., 2005. Social transfers and chronic poverty: emerging evidence and the challenge ahead. DFID, London.

Diedrichs, D.R., Phelps, K., Isihara, P.A., 2016. “Quantifying communication effects in disaster response logistics: A multiple network system dynamics model”, Journal of Humanitarian Logistics and Supply Chain Management, 2016 Apr 4, 6(1), pp. 24-45.

Diekmann, J. E. (1983). “Probabilistic estimating: Mathematics and applications.” J. Construct. Eng. Management, 3(297), 297–308.

Doocy, S., Lyles, E., Akhu-Zaheya, L., Burton, A. and Burnham, G., 2016. Health service access and utilization among Syrian refugees in Jordan. International journal for equity in health, 15(1), p.108.

ECHO, D., (2009). The use of cash and vouchers in humanitarian crises.

Eldosouky, I.A., Ibrahim, A.H., Mohammed, H.E., 2014. “Management of construction cost contingency covering upside and downside risks.” Alexandria Eng. J., vol.53, no. 4, pp. 863–881.

Flanagan, R., Norman, G. (1993). “Risk management and construction”, Wiley, Hoboken, NJ.

Forrester, J.W., (1958), “Industrial dynamics: a major breakthrough for decision makers”. Harvard business review, 36(4), pp. 37-66.

Forrester, J.W., 1961 “Industrial dynamics”, MIT press, 1961, Cambridge.

Garrido, M. C., Ruottolo, M. C. A., Ribeiro, F. M. L., Naked, H. A. (2011) “Risk identification techniques knowledge and application in the Brazilian construction”, Journal of Civil Engineering and Construction Technology, 2(11), 242-252.

Gillet, M., 2015. Effective Cost Estimating Strategy in Construction Project Management, In: Blog, [Viewed: 15 December, 2016]. Available: http://www.aproplan.com/blog/news/effective-cost-estimating-strategy-inconstruction-project-management.

Giordano, N., Dunlop, K, Sardiwal, D. and Gabay, T., 2017. Evaluation synthesis of unhcr0 s cash based interventions in Jordan.

Goh, E. (2005). A systematic approach to effective project cost management. Paper presented at PMI® Global Congress 2005—Asia Pacific, Singapore. Newtown Square, PA: Project Management Institute.

Gonçalves, P., 2008. "System Dynamics Modeling of Humanitarian Relief Operations", MIT Sloan School of Management: Cambridge, MA, USA.

Gonçalves, P., 2011. "Balancing provision of relief and recovery with capacity building in humanitarian operations", Oper Manage Res OMR Advancing Pract Theory, 2011, 4(1/2), pp. 39–50.

Government of Turkey UNHCR (2019). Operational portal refugee situation, 2019. Accessed: February, https://data2.unhcr.org/en/situations/syria/location/113.

Hagen-Zanker, J., Ulrichs, M., and Holmes, R., (2017). Cash transfers for refugees, an opportunity to bridge the gap between humanitarian assistance and social protection.

Hall, S., (2013). Cash program review for idps in the Kabul informal settlements.

Hammad, M. W., Abbasi, A., Ryan, M. J. (2016). "Allocation and Management of Cost Contingency in Projects", Journal of Management in Engineering, 32(6), http://dx.doi.org/10.1061/(ASCE)ME.1943-5479.0000447#sthash.S41c2T8x.dpuf.

Harvey, P., and Bailey, S., (2011). Good practice. In Review 11: Cash Transfer Programming in Emergencies. ODI/CaLP.

Hays W.W. (1998). Reduction of earthquake risk in the United States: bridging the gap between research and practice. IEEE Transactions on Engineering Management, 45(2):176–180.

Howell, D., Windahl, C., Seidel, R. (2010). "A project contingency framework based on uncertainty and its consequences", International Journal of Project Management, 28, 256–264.

Hsiao, N., Richardson, GP., (1999). "In search of theories of dynamic decision making: a literature review In Systems Thinking for the Next Millennium" Proceedings of the 17th International Conference of the System Dynamics Society, 1999, Cavana RY et al. (eds). CD-ROM.

Johnson, D. (1997). "The triangular distribution as a proxy for the beta distribution in risk analysis", Journal of the Royal Statistical Society: Series D (The Statistician), 46(3), 387-398.

Idrus, A., Nuruddin, M.F., Rohman, M.A. (2011). "Development of project cost contingency estimation model using risk analysis and fuzzy expert system", Expert Systems with Applications, 38, 1501–1508.

Khalafallah, A. M. G., Taha, El-Said, M. (2005). "Estimating Residential Projects Cost Contingencies Using a Belief Network", Proceeding of a Conference on Project Management: Vision for Better Future, 2005, Cairo, Egypt, see http://people.cecs.ucf.edu /khalafal/ publications /publications_files /Estimating Contingencies.pdf, accessed 30/12/2007.

Kotz, S. and van Dorp, J. R. (2004). Beyond Beta: Other Continuous Families of Distributions with Bounded Support and Applications, World Scientific Publishing Co. Pte.

Kunz, N., Reiner, G., and Gold, S., 2014. Investing in disaster management capabilities versus prepositioning inventory: A new approach to disaster preparedness. International Journal of Production Economics, 157:261–272.

Lhee, S. C., Flood, I., Issa, R. R. A. (2014). "Development of a twostep neural network-based model to predict construction cost contingency", Journal of Inf. Technol. Constr., 19, 399–411.

Love, P. E. D, Sing, C. P., Carey, B., Kim, J. T. (2015). "Estimating Construction Contingency: Accommodating the Potential for Cost Overruns in Road Construction Projects", Journal of Infrastructure Systems, 21(2).

McGarvey B., and Hannon, B., 2004. "Dynamic modeling for business management: An introduction", Springer Science & Business Media.

Mosca, R., Cassettari, L., Revetria, R., (2010). Experimental Error Measurement in Monte Carlo Simulation, Abu-Taieh, E.M.O, El Sheikh, A.A.R., Handbook of Research on Discrete Event Simulation Environments: Technologies and Applications, Information Science Reference, Hershey, New York, USA.

Peppiatt, D., Mitchell, J., and Holzmann, P., (2001). Cash transfers in emergencies: evaluating benefits and assessing risks. Overseas development institute (odi). Humanitarian practice network (hpn).

Hadcroft A.M., 2004. Lessons learned: Humanitarian response in haiti−food security and sanitation component.

Hartman, F. T. 2000. Don't park your brain outside: A practical guide to improving shareholder value with SMART management. Project Management journal, https://doi.org/10.1177/875697280003100410Hillson, D. (2002). “Extending the risk process to manage opportunities.” International Journal of Project Management, 20(3), 235–240.

Harvey, P., 2005. Cash and vouchers in emergencies. Humanitarian Policy Group. Overseas Development Institute.

Harvey, P. and Bailey, S., 2011. Cash transfer programming in emergencies. Humanitarian Practice Network, Overseas Development Institute.

IFRC, Disaster risk reduction makes development sustainable, IFRC, UNDP, UNICEF, Oxfam, GFDRR, UNISDR, 8 Apr 2014a.

International Crisis Group et al. Turkey’s Syrian refugees: Defusing metropolitan tensions. Report No. 241, 2018. Accessed: https://www.crisisgroup.org/europe-central-asia/western-europemediterranean/turkey/248-turkeys-syrian-refugees-defusing-metropolitan-tensions.

I.L.O., 2014. Child labour in the urban informal sector in three governorates of Jordan, Geneva.

IRCR, 2007. Guidelines for cash transfer programming.

Jacobsen, K., and Fratzke, S., 2016. Building livelihoods opportunities for refugees populations. Migration Policy Institute, Washington, DC.

Kane J.C. and Greene, M.C., 2018. Addressing alcohol and substance use disorders among refugees: A desk review of intervention approaches.

Kim, J., Deshmukh, M., Hastak, A., 2018. “A Framework for Assessing the Resilience of a Disaster Debris Management System”, International Journal of Disaster Risk Reduction, Jan 31.

Kunz, N., Reiner, G., & Gold, S., 2014. "Investing in disaster management capabilities versus pre-positioning inventory: a new approach to disaster preparedness." International Journal of Production Economics 157, pp. 261-272.

Lehmann, C. and Masterson, D., 2014. Emergency economies: The impact of cash assistance.

Li, X.G., Song, X.F., Meng, X.F., 2009. “System dynamics simulation of coal mine accident system cause”, In Management Science and Engineering, ICMSE 2009, International Conference on Sep 14, IEEE, pp. 2137-2142.

Mak, S, Wong, J, & Picken, D. (1998). “The effect on contingency allowances of using risk analysis in capital cost estimating: a Hong Kong case study”, Construction Management and Economics, 16, 615-619.

Maytorena, E., Winch, G. M., Freeman, J., Kiely, T. (2007). ”The influence of experience and information search styles on project risk identification performance”, IEEE Trans. Eng. Manag. 54 (2), 315–326.

Merrow E., W., and Yarossi M., E. (1990). “Assessing project cost and schedule risk”, AACE Transactions, H, 6, 2-7.

Mills, A. (2001). “A systematic approach to risk management for construction.” Struct. Surv., 19(5), 245–252.

Mohydin, R., 2019. The economic benefits of having an inclusive refugee policy. Accessed: https://www.trtworld.com/turkey/the-economic-benefits-of-having-an-inclusive-refugee-policy-27636.

Moselhi, O., 1997. “Risk assessment and contingency estimating”, American Association of Cost Engineers (AACE) Transactions Conf., 13-16th July, Dallas, pp. 1-6.

Najev Čačija, L., 2014. Preliminary empirical analysis of the relationship dynamics between marketing activities and fundraising success in nonprofit organizations. Management: journal of contemporary management issues, 19(2), pp.137-155.

Naqvi, A. and Rehm, M., 2014, March. Simulating natural disasters—a complex systems framework. In 2014 IEEE Conference on Computational Intelligence for Financial Engineering & Economics (CIFEr) (pp. 414-421).

Oberlender, G.D., 1993. Project management for engineering and construction (Vol. 2). New York: McGraw-Hill.

Octavia, T., Halim, C.A., Widyadana, I.G., & Palit, H., 2016. "Coordination of humanitarian logistic model plan for natural disaster in East Java, Indonesia." International Journal of Supply Chain Management, 5(4), pp. 52-60.

Oliva, R., 2003. Model calibration as a testing strategy for system dynamics models. European Journal of Operational Research, 151(3):552–568.

Otali, M., & Odesola, I. A. (2014). Effectiveness evaluation of contingency sum as a risk management tool for construction projects in Niger Delta, Ethiopian Journal of Environmental Studies and Management, 7(6), 588-598, http://dx.doi.org/10.4314/ejesm.v7i6.1.

Parvan, K., Rahmandad, H. and Haghani, A., 2015. Inter-phase feedbacks in construction projects. Journal of Operations Management, 39, pp.48-62.

Patrascu, A. (1988). ”Construction cost engineering handbook” Marcel Dekker, New York.

Pega, F., Liu, S.Y., Walter, S. and Lhachimi, S.K., 2015. Unconditional cash transfers for assistance in humanitarian disasters: Effect on use of health services and health outcomes in low-and middle-income countries. Cochrane Database of Systematic Reviews, (9).

Peng, M., Peng, Y., Chen, H., 2014. “Post-seismic supply chain risk management: A system dynamics disruption analysis approach for inventory and logistics planning”, Computers & Operations Research, 2014 Feb 1, 42, pp. 14-24.

Pozarny P. and Davis, B., 2015.The impact of social cash transfer programmes on community dynamics in sub-saharan africa, 2015.

Project Management Institute (PMI). (2012). “A guide to the project management body of knowledge”, fifth Ed., PMI, Newtown Square, PA.

Qazi A., Quigley J., Dickson A., Kirytopoulos K. (2016). “Project Complexity and Risk Management (ProCRiM): Towards modelling project complexity is driven risk paths in construction projects” International Journal of Project Management, 34(7), 1183–1198.

Rees, C.P., Hawkesworth, S., Moore, S.E., Dondeh, B.L. and Unger, S.A., 2016. Factors affecting access to healthcare: an observational study of children under 5 years of age presenting to a rural Gambian Primary Healthcare Centre. PloS one, 11(6), p.e0157790.

Remida, A., 2015. “A Systemic Approach to Sustainable Humanitarian Logistics”, In Humanitarian Logistics and Sustainability, 2015, pp. 11-29. Springer, Cham.

Revetria R., Oliva F., Mosca M., 2008. Modelling of Voltri terminal Europe in Genoa using system dynamic model simulation. In Proceedings of the 7th WSEAS international conference on System science and simulation in engineering, Nov 21, pp. 411-417. World Scientific and Engineering Academy and Society (WSEAS).

Rongier, C., Lauras, M., Galasso, F., and Gourc, D., 2013. “Towards a crisis performance-measurement system”, International Journal of Computer Integrated Manufacturing, 26(11), pp.1087-1102.

Saleh, A., Aydın, S. and Koçak, O., 2018. A comparative Study of Syrian Refugees in Turkey, Lebanon, and Jordan: Healthcare Access and Delivery. OPUS Uluslararası Toplum Araştırmaları Dergisi, 8(14), pp.448-464.

Salah, A., .Moselhi, O., 2015. “Contingency modelling for construction projects using fuzzy-set theory”, Journal of Engineering, Construction and Architectural Management, vol. 22, no. 2, pp. 214-241.

Simonovic, S.P., Ahmad, S., 2005. “Computer-based model for flood evacuation emergency planning”, Natural Hazards, Jan 1, 34(1), pp. 25-51.

Schneck, D., Laver, R., O’Connor, M. (2009). “Cost Contingencies, Development Basis, and Project Application.” Journal of the Transportation Research Board (TRB), No. 2111, Washington, D.C., 109-124.

Schule, F., Bitar, J., Uekermann, F., Taki, M. and Saidi, M., al Omran, S., Choufari, B., and Meerkatt, H., 2017. Food-restricted voucher or unrestricted cash? How to best support Syrian refugees in Jordan and Lebanon.

Shipley, M.F., de Korvin, A. and Omer, K., (1997). BIFPET methodology versus PERT in project management: fuzzy probability instead of the beta distribution. Journal of Engineering and Technology management, 14(1), pp.49-65, https://doi.org/10.1016/S0923-4748(97)00001-5.4

Sloane, E., 2014. The Impact of Oxfam’s Cash Distributions on Syrian refugee households in Host Communities and Informal Settlements in Jordan.

Skorupka D. (2008). “Identification and Initial Risk Assessment of Construction Projects in Poland” Journal of Management in Engineering, 24(3), 120-127.

Sonmez, R., Ergin, A. and Birgonul, T. M. (2007). “Quantitative methodology for determination of cost contingency in international projects”, Journal of Management and Engineering, 23(1), 35-39.

Starr, S., 2018. Syrians in turkey face anger and violence. Accessed: https://www.irishtimes.com/news/world/europe/syrians-in-turkey-face-anger-and-violence-1.3688674.

Sterman, J.D., (1991). "A skeptic’s guide to computer models." Managing a nation: The microcomputer software catalog, 2, 1991, pp. 209-229.

Sterman, J.D., (1994). “Learning in and about complex systems”, System Dynamics Review, 1994, 10(2/3), pp. 291–330.

Sterman, J.D., (2000). “Business Dynamics: systems thinking and modeling for a complex world”, 2000, McGraw-Hill, Boston.

Strömberg, D., 2007. "Natural disasters, economic development, and humanitarian aid." Journal of Economic perspectives, 21(3), pp. 199-222.

Suarez, P., 2015. “Rethinking engagement: innovations in how humanitarians explore geoinformation”, ISPRS International Journal of Geo-Information, 4(3), pp.1729-1749.

Tabor, S.R., (2002). Assisting the poor with cash: Design and implementation of social transfer programs. In World Bank Social Protection Discussion Paper, pages 79–97.

Taroun, A., 2013.Towards a better modeling and assessment of construction risk: insights from a literature review. International Journal of Project Management, 32 (1), 101–115, https://doi.org/10.1016/j.ijproman.2013.03.004.

Thompson, P.A., Perry, J.G., 1992. Engineering construction risks: A guide to project risk analysis and assessment implications for project clients and project managers. Thomas Telford, https://www.icevirtuallibrary.com/doi/full/10.1680/ecragtpraarm.16651.bm01

Tomasini, R.M., and Wassenhove, L.V., (2004). A framework to unravel, prioritize and coordinate vulner-ability and complexity factors affecting a humanitarian response operation. INSEAD, Faculty and Research, pages 1–15, Fontainebleau, France.

Tören, T., 2018. Syrian refugees in the Turkish labor market. ICDD Working Papers.

Tucker, S.J., Cullen, J.C., Sinclair, R.R., & Wakeland, W.W., 2005. "Dynamic systems and organizational decision-making processes in nonprofits." The Journal of Applied Behavioral Science, 41(4), pp. 482-502.

UNHCR, 2018. Turkey education sector achievements.

U.N.H.C.R., 2019. Child labor within the Syrian refugee response: A regional strategic framework for action.

U.N.H.C.R. Global Trends: Forced Displacement in 2016. United Nations High Commissioner for Refugees, 2017.

UNHCR, U.N., Toolkit for Practical Cooperation on Resettlement. Community Outreach–Outreach to Host Communities: Definitions and FAQs, 2011.

UNHCR, WFP, and Unicef. Vulnerability assessment of Syrian refugees in Lebanon 2015 report.: Beirut, Lebanon.

UNISDR, M., 2009. “UNISDR Terminology for Disaster Risk Redution”, United Nations International Strategy for Disaster Reduction (UNISDR) Geneva, Switzerland.

Uzzafer, M. (2013). “A contingency estimation model for software projects.” International Journal of Project Management, 31(7), 981–993.

Voyer, J., Dean, M., Pickles, C., 2015. “Understanding Humanitarian Supply Chain Logistics with System Dynamics Modeling”, Portland, ME.

Watkins, D., 2014. Cost Control and Management, RIBA Part 3 Course Material [Online]. [Viewed: 20/11/2016] Available: https://www.architecture.com/RIBA/Assets/Files/Part3docs/April/Spring%20 Lecture%20Notes%20DXBHK/CostManagementandControl-DavidWatkins.pdf

WFP, 2017. Food-restricted voucher or unrestricted cash? How to best support Syrian refugees in Jordan and Lebanon. Conducted by the Boston Consulting Group.

WFP, 2019. Refugees in turkey. Livelihood survey findings. Ankara, Turkey.

Williams, T. P. (2003). “Predicting final cost for competitively bid construction projects using regression models”, International Journal of Project Management, 21, 593-599.

Yalçın, S., 2016. Syrian child workers in turkey. Turkish Policy Quarterly, 15(3):89–98.

Yeo, K. T. (1990). “Risks, Classification of Estimates, and Contingency Management”, Journal of Management in Engineering, 6(4), 458-470.

Yim, R., Castaneda, J., Doolen, T., Tumer, I., Malak, R., 2015. A study of the impact of project classification on project risk indicators. International Journal of Project Management, 33(4), 863-876, http://dx.doi.org/10.1016/j.ijproman.2014.10.005.

Zadeh, L., A. (1965). “Fuzzy sets”, Information and Control, 8, 338–353, Doi: 10.1016/S0019-9958(65)90241-X.