A CASH FLOW AT RISK (CFaR) MODEL FOR MANAGING PAYMENT DELAYS IN CONSTRUCTION PROJECTS

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ABSTRACT

A CASH FLOW AT RISK (CFaR) MODEL FOR MANAGING PAYMENT DELAYS IN CONSTRUCTION PROJECTS

Cash flow management is a vital process for the efficient and effective management of operations and activities in construction firms. Researchers have been involved in developing the cash flow management models for the use of construction firms. The research presented in this thesis address this vital process - cash flow management in construction firms. It proposes a two-step a stochastic cash flow simulation model to manage interim and final payment delays in construction projects. The first step of the proposed model is pattern identification process - identifying the payment patterns of the owner. The second step is financial risk evaluation process based on Cash flow at Risk (CaFR). Three construction projects are used to illustrate the implementation and utility of the proposed stochastic cash flow model. The results of the proposed stochastic simulation model suggest that payment delays in construction projects is common and payment delays not only increase the operating capital requirements of construction firms but also bring significant financial burden to the construction firms. The proposed model enables construction business executives/practitioner to evaluate the financial risks due to the payment delays.

Key Words: Cash Flow, Cash Flow Management, Cash Flow Analysis, Payment Delay, Cash Flow at Risk

ÖZET

İNŞAAT PROJELERİNDE ÖDEME GECİKMELERİNİ YÖNETMEK İÇİN BİR RİSKE MARUZ NAKİT AKIŞ MODELİ (RmNA)

Nakit akışı yönetimi inşaat firmalarındaki operasyonların ve faaliyetlerin etkin ve etkili yönetimi için hayati öneme sahip olan bir süreçtir. İnşaat firmalarının kullanımına sunulmak üzere araştırmacılar pek çok nakit akış yönetim modelleri geliştirmiştir. Bu çalışma da inşaat firmalarında hayati öneme sahip bu sürece, yani nakit akış yönetimini sürecini ele almaktadır. Çalışmada, inşaat projelerinde ara ödemeler ve nihai ödemelerde yaşanan gecikmeleri yönetmek üzere iki aşamalı stokastik bir nakit akışı simülasyon modeli önerilmektedir. Önerilen modelin ilk aşamasını ödeme düzenlerini tanımlama süreci, yani mal sahibinin ödeme düzenlerinin belirlenmesi, oluşturmaktadır. İkinci aşama, Riske Maruz Nakit Akış Modeli'ni (RmNA) temel alan finansal risk değerlendirme süreciyle ilgilidir. Önerilen stokastik simülasyon modelinden elde edilen sonuçlara göre, inşaat projelerinde ödemelerde yaşanan gecikmeler yaygındır ve bu gecikmeler hem inşaat firmalarının işletme sermayesi gereksinimleri arttırmakta hem de inşaat firmalarına finansal açıdan büyük yük olmaktadır. Çalışmada önerilen model, inşaat firmalarının yöneticilerinin/uygulayıcıların ödeme gecikmelerinden dolayı meydana gelen finansal riskleri değerlendirmelerini sağlamaktadır.

Anahtar Kelimeler: Nakit Akışı, Nakit Akış Yönetimi, Nakit Akış Analizi, Ödeme Gecikmeleri, Riske Maruz Nakit Akışı

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CHAPTER 1

INTRODUCTION

Cash flow management is a vital but a challenging managerial task. The primary objective of this managerial task is to ensure the efficient and effective use of limited "financial resources". Cash flow management has been a challenging (e.g., capital intensiveness, limited financial resources, high operating capital requirements, economic crises, currency fluctuations and uncertainty in supply and demand) managerial task. Yet increasing turbulence in the global economy coupled geopolitical developments present additional new challenges to those responsible for this managerial task – construction business executives/practitioners. These old and new managerial challenges facing construction business executives/practitioners can be addressed adopting by identifying, analyzing, evaluating, treating and monitoring financial risks in project cash flow. In this chapter, problems related to the concept of cash flow in the context of the construction industry are presented.

1.1. Problem Definition

One of the major challenges of construction project management is the uncertainty about direct and indirect construction costs. The uncertainties associated with direct and indirect construction costs coupled poor cash flow management can have detrimental impact on the project performance and in turn can risk survivability of the construction firm. The impact of poor cash flow management on the survivability of construction firms have been widely acknowledged in the construction management literature quite long time ago. There has been a growing interest on cash flow estimation in construction projects. Deficiencies in cash flow management (i.e., planning, forecasting and controlling) have more detrimental impact on the financial performance construction firm operating in the construction industry of an emerging economy (e.g. Paul, Devi, and Teh, 2012). Efficient cash flow management plays an important in strategic role at minimizing working capital requirements of construction firms (Yang and Chang, 2013). The main rationale behind using cash flow management in construction projects is to prevent construction firms from experiencing financial difficulties (i.e., high financial costs or even bankruptcy) due late or of irregular payments (Hwee and Tiong, 2002). Cash flow management capability is one of the key success factors for construction firms to survive and prosper in today's competitive business world. It is a critical task for any construction firm to develop a realistic cash flow forecast in tender preparation process or in contract negotiation. A realistic cash flow forecasting prior bidding a construction project or signing a construction contract provides a rough estimate about the amount financial resources is needed to complete the construction project and also developing a cash flow management strategy. The importance of a realistic cash flow forecasting significantly raises in the case of possible delays of payments to the construction firm and inefficient payments made by owner. It is also important to evaluate the payment plan of construction project.

The importance of reliable cash flow forecasting has been widely acknowledged by construction management researchers and construction business practitioners. Construction management researchers have been involved in developing cash flow forecasting models to assist construction business practitioners to manage financial risks in construction projects. Different forecasting models such as deterministic models, probabilistic models, artificial intelligence-based models, possibilistic models (i.e., fuzzy logic) prevail in the literature. Table 1.1. presents a summary cash flow forecasting models. Some researchers use fuzzy set theory proposed by Zadeh (1964) to study cash flow patterns in construction projects. Some others use – S – curve based models to investigate cash flow problems in construction projects (Boussabaine and Elhag, 1999). Khosrowshahi proposes a software, named Advanced S-curve (TASC), to assist construction practitioners to manage cash flow in construction projects (Khosrowshahi, 2000). Furthermore some researchers explore the construction costs and the cost of design error on project costs. Some other researchers study the risk factors associated with a given cash flow forecast.

Table 1.1. A Review of Cash Flow Forecasting in Construction Projects.

Author	**Name of Article/Year**	**Methodology**	**Objective(s)**
A. P. Kaka, A. D. F. Price	Modelling standard cost commitment curves for contractors' cash flow forecasting / 1993	-Collecting data for 150 completed projects -Using logit transformation technique -Using ANOVA test	-Explores the reasons behind the mistakes of S-curves -Suggests use of standard cost commitment approach

(Continued on next page)

Table 1.1. Continued

A. Kaka	Towards more flexible and accurate cash flow forecasting / 1996	-Composing model by using more than fifty variables	-Calculates the cash flow of individual contracts
A.H. Boussabaine, Taha Elhag	Applying fuzzy techniques to cash flow analysis / 1999	-Using fuzzy techniques	-Proposes alternative approaches to cash flow analysis
F. Khosrowshahi	A radical approach to risk in project financial management / 2000	-Using a financial forecasting and management model	-Estimate cash flow of project
N. G. Hwee, R.L.K. Tiong	Model on cash flow forecasting and risk analysis for contracting firms / 2002	-Sensitivity Analysis	-Presents a computer model -Studies the impact of five major risk factors on a project's cash flow
H. Odeyinka, A. Kaka, R. Morledge	An evaluation of construction cash flow management approaches in contracting organizations / 2003	-Questionnaire survey -Using SPSS -Using ANOVA	-Examines different cash flow approaches
H.Chen, W.Brien, J. Herbsman, M. Asce	Assessing the accuracy of cash flow models: The significance of payment conditions / 2005	-Pattern Matching --Logic-Factorial Analysis	-Explores the accuracy of cash flow estimates
Hyung K. Park, Seung H. Han, Jeffrey S. Russel	Cash flow forecasting model for general contractors using moving weights of cost categories / 2005	-Using new algorithm -Using simulation programs	-Develops a cash flow estimation model considering the time delay
H. Odeyinka, J. Lowe, A. Kaka	An evaluation of risk factors impacting construction cash flow forecast / 2008	-Questionnaire survey -Using ANOVA	-Investigates the impact risks factor on planned and actual cash flow
Q. Cui, M. Hastak, D. Halpin	System analysis of project cash flow management strategy (System dynamic model) / 2010	-Using Vensim DSS simulation -Case study -Using linear regression method	-Studies the impact of cash flow strategies on performance
S. Y. Paul, S. S. Devi, C. G. Teh	Impact of late payment on firms' profitability: Empirical evidence from Malaysia / 2012	-Using the Pareto 80:20 rule	-Investigates the effect of late payments on the firm's profitability
C. Markmann, I. Darkow, H. Gracht	Delphi-based risk analysis- Identifying and assessing future challenges for supply chain security in a multi-stakeholder environment / 2012	-A Delphi risk survey analysis	-Explores the risk factors in supply chain management
H. Odeyinka, J. Lowe, A. Kaka	Artificial neural network cost flow risk assessment model / 2013	-Questionnaire survey -Case Study -Artificial neural network algorithm	-Explore the impact of risk factors on cash flow forecasting
M. A. El razek, H. El din Hosny, A. El Beheri	Risk factors in construction projects cash flow analysis / 2014	-Questionnaire survey -Primavera p6 (For -S-curve) -Excel Macro sheet	-Presents a net cash flow prediction model
T. Zayed, Y. Liu	Cash flow modeling for construction projects / 2014	-Questionnaire survey -Using Monte Carlo Simulation	-Examines the effect of various factors on cash flow

(Continued on next page)

Table 1.1. Continued

A. Hoseini, R. Andalib, B. Gatmiri	Stochastic framework for cash flow forecasting considering owner's delay in payment by use of Monte Carlo Simulation / 2015	-Using a beta-distributed random variable -Using Monte Carlo Simulation	-Develops a model to estimate the cash flow at the tender stage of construction project
R. Andalib, A. Hoseini, B. Gatmiri	A stochastic model of cash flow forecasting considering delays in owners' payments / 2018	-Sensitivity Analysis -Using Equations	-Develops a cash flow forecasting model to analyze the , maximum working capital requirement

It is clear from Table 1.1 that there is a rich literature on cash flow forecasting in the construction management literature.

The major challenge facing construction business practitioners responsible from cash flow management is: (1) the lack of information about the project owner's payment habits and (2) the cost of late interim and or final payments. These two challenges can be addressed by developing a cash flow model based on "Cash Flow at Risk" method.

1.2. Study Objective

The main objectives of this thesis are;

(1) to analyze the payment delays in construction projects

(2) to develop statistical model to identify and evaluate the payment patterns of construction owner(s)

(3) to develop a financial risk management model to estimate the cost of late payments to construction firm "based on amount of effective interest payments" that will be paid by the construction firm

1.3. Structure of the Thesis

This thesis consists of five chapters. The first chapter presents a review of the concepts of "cash flow" and "cash flow forecasting". The second chapter, forms a frame for the definition of cash. The position of cash in construction project management was analyzed in detail. The place and importance of cash concept in construction sector is emphasized. At the same time, the stages of construction projects and management of these projects are mentioned. The definition of cash and its prediction, the importance of it in construction projects and the impacts of cash on costs was described. In addition, analysis methods applied for cash flow in construction sector and factors affecting cash flow are referred. In the third chapter, a model has been developed to observe the irregularities in the monthly payments of the projects and the principles of payment of the owner in line with this purpose. At the fourth chapter, the developed model was applied at two different faculty projects and a semi – olympic indoor pool project. Lastly, the fifth chapter contains a short summary of the thesis' main approach with the results obtained and the contribution of cash flow estimation to literature and construction project management.

CHAPTER 2

CASH FLOW CONCEPT IN CONSTRUCTION INDUSTRY

Construction is one of the oldest business activity (Huemann, Keegan, and Turner, 2007). The recent unprecedented developments in information technologies coupled with financial turbulence in global economy have been significantly increasing the complexity level of the construction industry. The construction industry is not only a labor-intensive but also a capital-intensive industry. This unique of combination "intensiveness" (i.e. both labor and capital) assigns construction industry a vital role in the economic development of an economy.

Defining the term of "construction industry" is not an easy task. The main reason behind such argument is the unclear boundary which construction industry has. The construction industry has a complex network of input and output relations with other industries.

Construction firms can be conceptualized as a bundle of resources (i.e., human, physical, financial and organizational). Financial resources has been the most important resource in this bundle. The shortage of this important resource can delay or stop the activities or operations of a construction firm or even in some cases jeopardize its the survivability. Construction firms, like any other firms, exposed to various financial risks. Cash flow management is the key management function to address the financial risks. It enables construction firms to analyze, evaluate and develop action plans to reconcile the differences or conflicts between the planned and actual of cash flow. Cash flow problems in a construction firm can have detrimental impact on not only its survivability but also on the survivability of its partners (i.e., the second parties who work closely with it). In sum, cash flow management function plays key role in construction firm.

2.1. Construction Industry

The construction industry plays an important role in any nation main due to its contribution to economy growth and job creation. Construction industry in Turkey is not an exception to this argument. Construction industry has been playing a key role in Turkey's economy. Intes report suggests that the contribution of construction industry in Turkey to the Gross National Product (GNP) is about 30%. Construction industry in Turkey is commonly termed "leading industry" or "locomotive industry" mainly due to the national and international market share of construction and construction related activities (i.e., more than 200 sub-markets) (İntes, 2018). It is widely mentioned that the structure of construction industry is composed of is heterogenous and fragmented (Vrijhoef and Koskela, 2000).

2.2. Construction Project Management

''A project is a temporary endeavor undertaken to create a unique product, service, or result (Project Cost Management, 2013).'' Each construction project has unique characteristics (i.e., parties involved, location, time, material, cost and climate). Each construction project has its regional differences. The simplest example for this is that every zoning regulation of each city has its own specific legend notes. According to these notes the construction projects take shape. The basis of any construction project is psychical, financial, and human resources. The primary goal of any construction project is to complete the planned project a within the predefined scope, time and budget. Achieving the predefined project objectives requires a good communication among /between the project participators. Project participators are the project owner, designers and engineers shaping the project and the contractor, sub-contractor and workers that build the project. The Oxford English Dictionary defines ''contractor'' as "A person or firm that undertakes a contract to provide materials or labor to perform a service or do a job (Oxford, 2019)''. A sub-contractor is according to the Oxford English Dictionary ''A firm or person that carries out work for a company as part of a larger project (Oxford, 2019)''.

A construction project is commonly completed in stages. It also takes a relatively long durations to complete. The duration of a construction project varies according to its scale and complexity and the availability of financial, physical and human resources. Project Management Institute proposes that a project can decomposed into five main stages (Institute, 2000) (Figure 2.1):

- Initiating Stage: Approval of the project. At this stage the applicability and purpose of the project is analyzed. At the same time preliminary studies are done and project strategies and costs are defined. If this stage is carried out properly, the project needs are clearly determined. At this stage, well and accurate understanding of the framework of project plan is great importance for the project to succeed.

- Planning Stage: It is the foundation of the planning process at the realization of a project. The understanding of the project is ensured and it is defined how the set targets will be aimed.

- Executing Stage: The process where each unit contributing to the continuity of the project is evaluated and the appropriate guidance are done from the beginning of the project execution until its end. This phase involves the efforts to execute the activities suitable to the plan of the project management.

- Controlling Stage: The process where changes that may occur during project period are controlled. If the problems are recognized in time, corrective measures can be applied at this stage. At the same time, this stage is an important level for monitor and measure the performance of the project.

- Closing Stage: It is the final process where all lacks of the project are eliminated and the suitable usage is ensured.

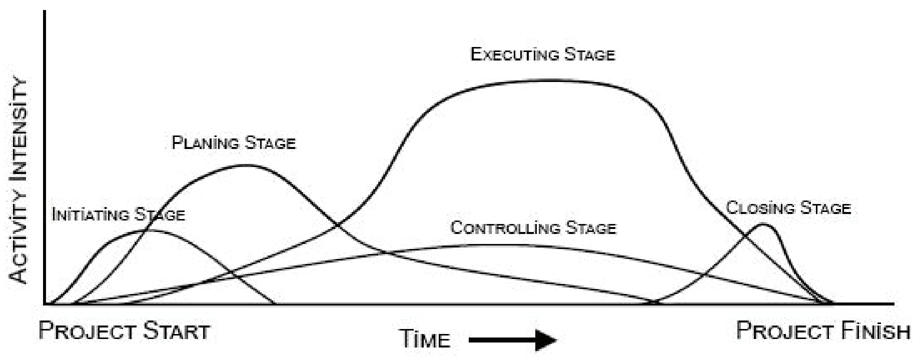

Figure 2.1. Project management process (Source: Project Management Body of Knowledge, 2001)

CMAA is a project management institution at the United States of America. It defines project management as a cluster of many professional teams that manages the design and execution of a project. At the same time, it approached to project management as cost management, time management, quality management, contract management, risk management and safety management (CMAA, 2010).

- Cost Management: ‘‘Project cost management is primarily concerned with the cost of the resources needed to complete project activities (Institute, 2000)’’. It is the main source of the project and one of the most important approaches for the continuation.

- Time Management: ‘‘The word of ‘time’ become a tools for planning, identifying and evaluating the level of achievement in construction projects (Nasir et al., 2016)’’. Time management plays an important role for the finalization of the project at the agreed time.

- Quality Management: The quality of the project stages are managed from the beginning until the end of the project according to the agreement (CMAA, 2010).

- Contract Administration: ‘‘Contract administration means to manage or supervise the execution, use, or conduct of a binding agreement between two or more parties (Creech, 2006)’’.

- Risk Management: It consists of estimation of possible negative occupancies, taking precautions and making right decisions during the project period (Markmann, Darkow, and Gracht, 2013). It is the type of management where the risks of the project and its precautions are defined.

- Safety Management: It is the management that points to the risks of worker’s securities and it provides precautions against the injury of all workers who are contributing to the construction of the project (CMAA, 2010).

Managing construction projects in today's competitive business environment requires construction business practitioners to develop or adopt risk management models or methods to address uncertainty involved in construction activities and operations.

2.4. Cash Flow

Construction firms commonly experience financial difficulties in managing their operations and activities, in particular construction projects those funded by public organizations. The root cause of main financial difficulties experienced in construction firms is the shortage of resource to finance construction operations and activities (Navon, 1996). The low profit margins in the construction industry force construction firms to minimize the cost of their operations and activities (Elazouni and Gab-allah, 2004). Cash flow management is a significant process of any construction project, as construction firms need to know how much a construction project may potentially cost prior to any action or commitment.

Different definition of "cash flow " are proposed in defined in project management literature. Each researcher attempts define cash flow in different ways. Cash flow can be defined as the difference between income and expense (Poskitt and Oxley, 1996). It can be defined as the movement of cash into or out of the company is been the cash flow (Cooke and Jepson, 1986).

Zayed and Liu argue that, as long as the project is in progress, the cash received and spent for the project can termed as cash flow (Zayed and Liu, 2014).

Further, Kenley and Wilson define cash flow as " the flow of cash or commitment from the client to the contractor (Kenley and Wilson, 1986)''.

Smith states that ''cash flow is a financial model necessary to count the demand for money to meet the project cost and the pattern of income it will generate (Smith, 2002)''.

It is clear from the above presented definitions that a cash flow consists of "cash inflow" and "cash outflow". The cash inflow, or also termed the "positive cash flow", includes the advance payments, progress or interim payments and mobilization payments made to the construction firm by the owner. Andalib, Hoseini and Gatmiri suggest that the cash inflow during the project can be is divided into three main groups (Andalib, Hoseini, and Gatmiri, 2018): (1) advance payments, (2) progress payments and (3) retention payments. The main purpose of the advance payments, or also termed mobilization payment, is to enable the construction firm to get access to site, use the facilities and to buy or hire construction equipment and materials when they are needed at the beginning of the construction project. Progress payments is the amount of cash that is paid to the construction firm in return for the productions completed on site. Construction firms prepare invoices as a result of the expenses they make and send a petition to the owner or its representatives. The invoices for the production completed on site may take a relatively long time to be reviewed and approved by the relevant authorities. The rationale behind this review and approval process is to ensure that completed production on site complies with contract documents. The progress payment is made to the construction firm once the completed production on site approved by the relevant authorities. The general terms and conditions of the construction works, the progress payment report shall be accrued by the contractor on the given date in the contract and if there is no record of given date in the contract, it will be accrued within thirty days starting from the day when the contract is signed. Payments are made within fifteen days starting from this date (Yapım İşleri Genel Şartnamesi, 2002). The owners commonly withhold at least 3% as a retainage depending on the terms and conditions of the contract. The retainage, the withholding amount of progress payment, is used to ensure that productions or construction works completed on site are free from any defects and provide a reserve fund to the owner to complete the construction project. According Hughes Hillebrandt, and Murdoch argue that the other function of this reserve fund is to motivate the construction firm to complete the deficiencies (Hughes, Hillebrandt, and Murdoch, 2000).

Cash outflow, also termed "the negative cash flow", consists of operating expenses for human and physical resources and tax and financial payments (Liou and Huang, 2008). "Net cash flow" is the difference between "cash outflow" and "cash inflow" (Odeyinka and Lowe). Figure 2.2. presents a visual representation of the concept of "net cash flow". Public and private clients/owners in Turkey, like in any countries, use different types of construction contracts on procuring construction projects. The type of construction contract has profound implications for cash flow management because a construction contract defines the terms of (e.g., timing of payments, payment processing duration and percent of payment retainage) initial/mobilization, progress and final payments.

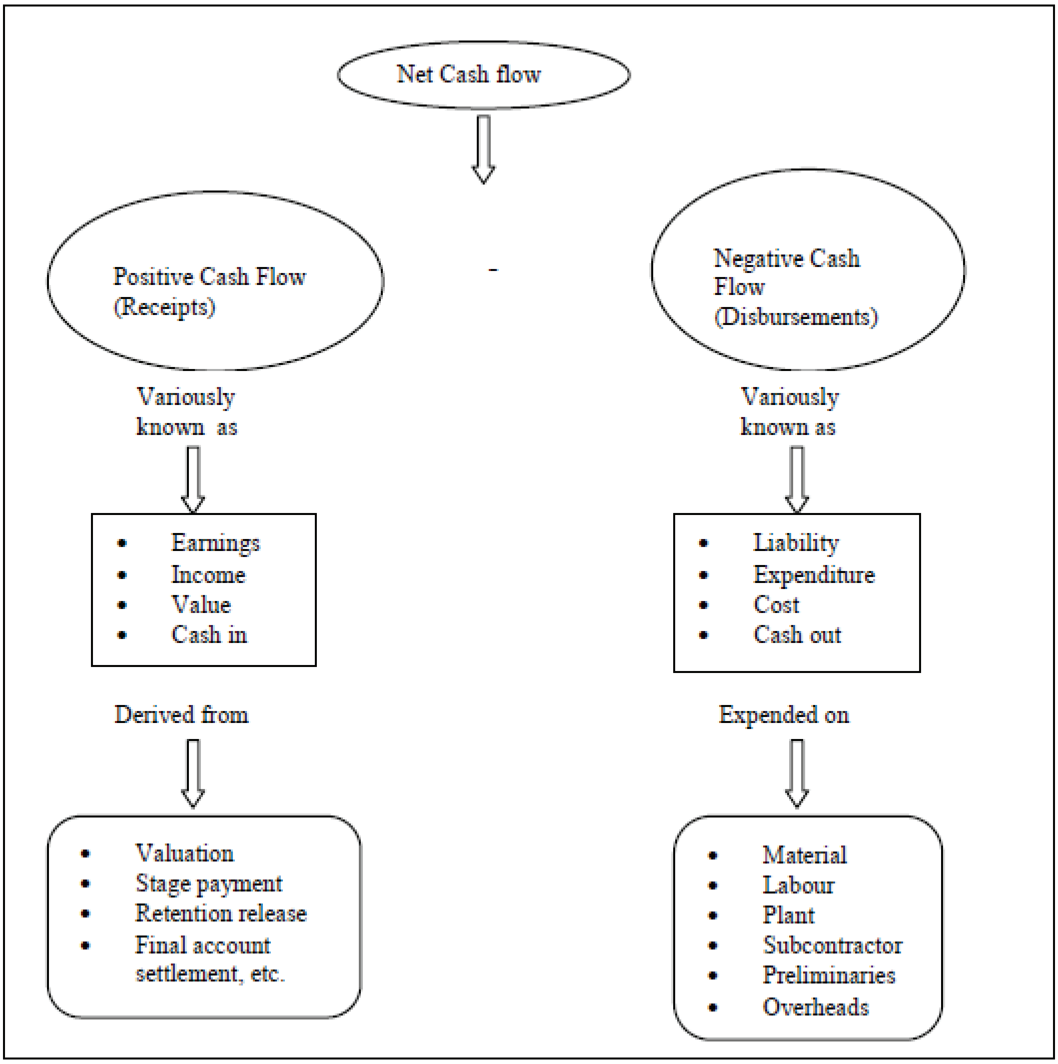

Figure 2.2. The concept of “Net Cash Flow” (Source: Odeyinka and Lowe, 2001).

Figure 2.3. present a general schematic representation the cash flow from start to the end of a construction project.

The cash flow management, which involves planning, forecasting and controlling the movement of financial resources, plays an important role on the survivability of construction firms in the construction industry. A construction firm can use cash flow management models and/or methods to improve its understanding of financial status and minimize the risk of bankruptcy that jeopardize its survivability. Nunnally argues that poor cash flow management is major factor leading the failures of many construction firms (Nunnally, 2011).

Kaka and Price, argue that the main reason of construction companies going bankruptcy is the insufficient working (Kaka and Price, 1991).

Singh and Lokanathan propose a similar claim – the most important factor that leads business failures in construction is “the poor cash flow management” (Singh and Lokanathan, 1992).

Cui, Hastak and Halpin also argue that ineffective cash flow has negative impact on the working capital requirements and can jeopardize the continuity of the project can weaken (Cui, Hastak, and Halpin 2010)

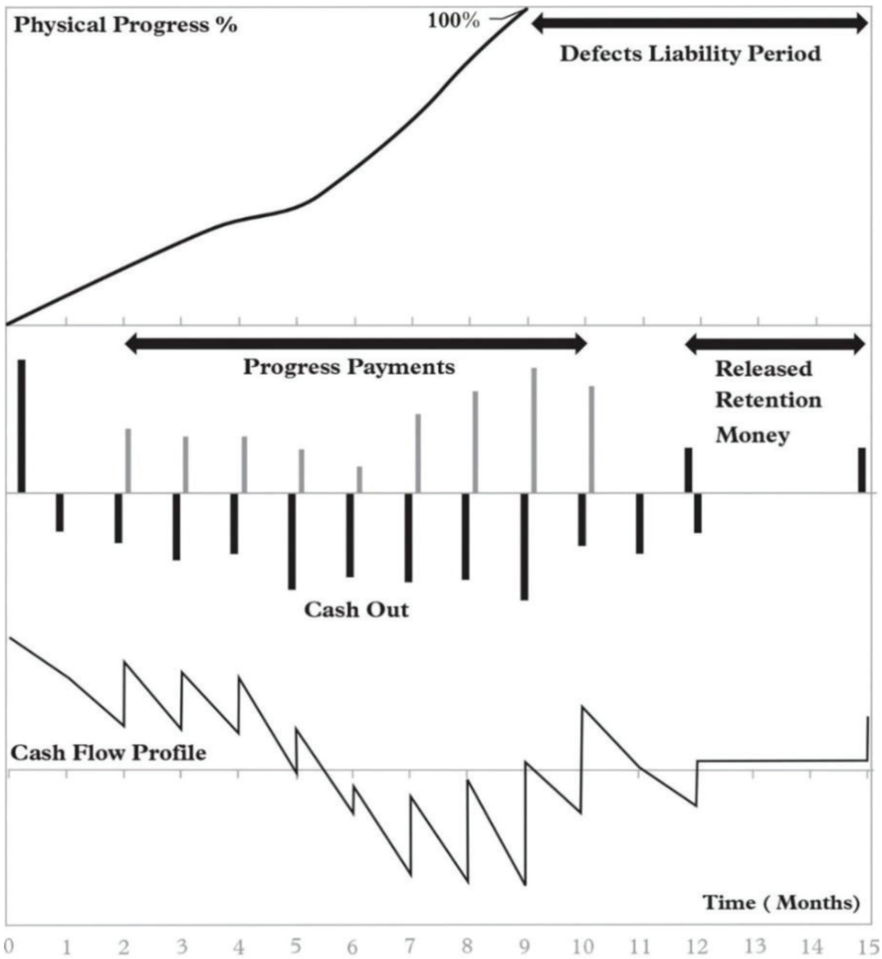

Figure 2.3. Diagram of cash inflow and cash outflow (Source: Andalib, Hoseini and Gatmiri, 2018)

Cash flow management is a proactive approach which requires planning, forecasting and controlling cash-in and cash-out and in turn neutralize the financial threats. Financial institutions prefer to provide financial support to construction firms which have good cash flow management process (Navon, 1995). Therefore, the presence of accurate and appropriate cash flow planning, forecasting and controlling processes in construction firms is a must for financial support when it is needed. Cash flow management may constrain or expand the borders of the project. Therefore, it is vital for construction firms to have prior knowledge on the concept of “cash flow” and its “management”.

The construction industry compared to other industries has the largest bankruptcy. Most of the construction firm report bankruptcy due to poor cash flow management.

2.4.1. Factors of Affecting Cash Flow in Construction Projects

Construction projects are commonly carried out by a number of different parties such as the owner, the contractor and the subcontractor. Each party is be exposed to different types of challenges. Managing these challenges requires “developing” of a risk management plan, “implementing” the risk plan and controlling its implementation process and control. When the risks are not evaluated well, it is not possible to achieve the predefined objective(s) of project (e.g., increase in cost, decrease in quality, delay in projects. It is widely acknowledged that the most important risk facing to those involved in construction projects is “financial risk”.

Failing to complete a construction project at the requested time has financial consequences because delay in delivery date causes additional costs. Delays in construction projects can be categorized into two groups: (1) inexcusable delays and excusable delays (Tumi, Omran, and Pakir, 2009). Inexcusable delays, deriving from contractor and subcontractor. Both sides do not have the option of acting unplanned. Excusable delays are situations occurring out of control which are separated in two categories within itself. Delays in construction projects can be also classified as: (1) non-compensable and (2) non-compensable delays.

The impact of delays on project objectives (e.g., cost, quality and duration) have been an important research issue in construction management literature for quite long time (Herbsman, Chen, and Epstein, 1995). Assaf and his friends state that the primary factors causing the delays in construction projects in Saudi Arabia are irregular payments of the project owner, cash problems due to changes at the design and the deficiency of labor (Assaf and Al-Hejji, 2006).

Toufic's survey of construction business executives/practitioners reveal that the main factors causing delays in construction projects include:

- Delay of material supply or damaged goods
- Inefficiency of workers
- Defect of equipment that will be used at construction
- Payment delay of the project owner effects contractor and subcontractor
- Design mistakes and false estimations
- Long lasting legal procedures
- Lack at planning and deficiency at management
- Location of the construction site and problems with material storages
- Weather conditions
- Missing information at contracts

Mezher and Tawil argue that "lack of funding" and "payment delays" are the most important factors leading delays in construction projects (Mezher and Tawil, 1998).

Realistic planning, accurate forecasting, and a good quality of communication can minimize project risks. Yet it is no surprise to observe that cost and time overruns in construction projects are common in the construction industry (Lo, Fung, and Tung, 2006). Cost and time overruns in construction projects are primarily caused by (1) payment problems, (2) design and material changes and (3) weak contract management (Meng, 2012). Kaming and his friends argue (1) that the lack of planning, (2) changes at design and (3) wrong material choices cause cost overruns (Kaming et al., 1997). Cost and time overruns are common in construction projects (Chang, 2002). Changes in construction projects can increase not only the construction costs but also delay its completion. It should be noted not every change in a construction project directly means negativity. Changes can be grouped as: dysfunctional/harmful and functional/helpful (Hwang and Low, 2012). For example, the change of a material because of aesthetic apprehensions is a harmful change because it has a higher price thus it increased the costs. When thinking about the exact opposite the floor material of the construction is changed from marble to ceramic the costs are decreased and this will be a helpful change.

The cost of a project corresponds to the sum of the items that are obtained by multiplying the quantity of production and the unit price determined for its production. In Turkey, to calculate the project's cost per m^2 is being determined by the use of approximate unit costs those are set by the Ministry of Environment and Urbanism (Çevre Şehircilik Bakanlığı, 2018). Ashworth suggests that it is possible to calculate the cost of the production in advance, since the amount of production in during the construction will not change according to the construction time (Ashworth, 1999). Thus, when the project is still at the design process some regulations can be done at the budget of the project owner. Basically, the cost of a construction changes according to the amount of used materials, its cost and labor. In addition to that following the regulations of the local government, applying the requests of the customer, doing regulations according to environmental conditions and using the appropriate technology for the construction site where the project will be constructed are factors that are affecting construction costs.

Ramachandra and Rotimi state that it is essential to make progress payments in construction projects on time and delay in progress payments may delay the completion of construction projects (Ramachandra and Rotimi, 2015). Abdul-Rahman argues that late or make incomplete progress payments are major factor leading time and cost overruns in construction projects (Abdul-Rahman, Kho, and Wang, 2014).

One of the most important factors contributing to the success of a construction project is to make "progress payments" on time. However, progress payments may not always be made as planned. The economic situation in the countries where the construction is made, the increase in the inflation, and the lack of the financial management of the employer are among the reasons of the delayed progress payments. A recent research by Neveling suggests that delays in payments create domino effect (Neveling, 2005) in an industrial system. For example, while the owner thinks that the construction should be completed at the previously agreed price, the change of material costs along with the unanticipated inflation in the economy is not under the control of the construction firm. If the owner begins to delay payments, the construction firm will continue to provide financial support for the project to continue. Financial resources are used when providing such support, or the construction firm take out loan from the bank.

However, if the owner cannot make a payment for a long time, owner can make an agreement with the construction firm and agree to pay the debts at interest. If the owner and construction firm dissent from about payments, the project may be canceled or terminated. The construction firm is the most affected by the lack of cash during the project, the contractor spends excessive amount of cash during this time. Therefore, the parties which are involved in the construction process should develop some strategies to identify such risks and take necessary measures. In the construction industry, the problems that arise during the construction period are usually caused by the cash shortage. Financial progress in construction projects is ensured by the progress payments and advance payments executed by the owner to the contractor. Regular payment made every month is also important for the contractor to regulate the completion of the planned work. This situation is a great risk for the contractor who cannot receive payment. Also, it is a risk for the contractor that he/she does not have any opinion about the owner's payments plan before he or she accepts the project.

Delays at progress payments are the most common problem facing construction business executives/practitioners. Mbachu points out that increasing lawsuits in the construction industry reveals that "payments are delaying" and "financial risks are rising" (Mbachu, 2011). The terms of payments should be clearly defined in construction contracts.

2.4.2. Cash Flow Management

Cash flow management constitutes the cornerstone of financial management in the construction industry. The accurate cash flow management is not just about delivering the targeted end results. It is also directly proportional to efficient work and staying within budget boundaries. At the same time, the main purpose of cash flow management is to evaluate cash flow properly which is required to sustain the operation of the construction firm. Melik suggests that cash management is a significant to solve the problems encountered in planning, organizing, implementing and controlling the cash flow of the project and delivering it on time (Melik, 2010). A cash flow can be conceptualized as a plan developed to determine the future cash needs of the project. Developing such a plan requires a thorough analysis of (1) possible cash flow strategies and (2) their resource demands/requirements and also (3) the impact cash flow strategies on predefined project objectives. For instance, when the owner and the contractor signed a construction contract, the owner wants to know the estimated costs throughout the construction of the project. Because, the front-loading strategy or back-loading strategy chosen by the contractor for the project will change the cash flow curve to a certain extent.

Cash flow management is about the mobility of financial resources. If a cash flow analysis suggests a construction project has a cash deficit then a number of cash flow strategies can be applied to ensure the continuity of the project. For this reason, it is important to determine cash flow strategies. March states that construction firms can follow some cash flow strategies to prevent the loss of financial resources in projects (March, 2009). Front loading - setting a balance by increasing the work items to be constructed in the first stage and reducing the work done at the end of the work without changing the tender price. Thus, cash flow conditions can be improved. Atallah suggests some other cash flow strategies such as (1) agreeing with the client to ensure fair and reasonable payment terms, (2) customizing scheduling, (3) minimizing unnecessary costs, contracting to receive payments on time and (4) arranging orders (Atallah, 2006). In the construction industry, cash flow management is a key managerial task for making accurate forecast and accurate decisions. Several cash flow analysis models/methods have been developed to provide more accurate and more reliable cash flow.

Given its importance, cash flow models have been at the focus of various research streams in literature. Scholars from these different research streams have been involved in developing cash flow models for construction projects in order to ensure the effective and efficient use of financial resources. Different mathematical techniques, computer models and curve fitting equations have proposed in literature to build an accurate and reliable cash flow model. Despite the abundant number of studies on cash flow management and cash flow models, there is a lack of consensuses on reliable variables/factors that can be used in developing a cash flow model. Each scholar uses different assumptions and focuses on different variables to develop his/her own cash flow model. Navon argues that the estimation of payments during planning/scheduling stage of a project is actually forecasting the cash flow of that project (Navon, 1995). Chen and friends use “the pattern matching logic” and “factor analysis” to develop a cash flow forecasting model for construction projects. The proposed model supports the arguments that a cash flow forecast based on cost – schedule integration (CSI) models can provide accurate results (Chen et al., 2005). Odeyinka and his friends develop an artificial neural network model to explore the impact of financial risks caused by progress payments (Odeyinka, Lowe, and Kaka, 2013). The proposed model is based on the perceptions of construction practitioners about the relative importance of financial risks in construction projects. Kaka proposes a cash flow analysis model which consists of more than 50 variables to reduce uncertainty in payment delays (Kaka, 1996). Russel explores the potential use of quantitative models in cash flow forecasting (Russell, 2003). Boussabaine and Elhag develop a fuzzy logic based model for cash flow forecasting (Boussabaine and Elhag, 1999). Park and his friends proposes a proactive cash flow management model (Park, Han, and Russell, 2005). Jarrah and his friends develop a quantitative model based on fourth degree polynomial regression to forecast the financial resource requirements in construction projects (Park, Han, and Russell, 2005). Zayed and Liu explore the factors that may influence the clash flow of a construction project. They conclude that these factors can grouped under the following major categories: (1) financial issues, (2) subcontractor and supplier related, (3) communications skills (Zayed and Liu, 2014). Hwee and Tiang propose a cash flow model based on -S- curve (Hwee and Tiong, 2002). Kaka and Price argue that cash flow models based on a series of typical -S- curves are very common in the literature. Yet the proposed cash flow models vary with respect to projects characteristics (e.g., size, quality, duration location) (Odeyinka, Kaka, and Morledge, 2003). Cui, Hastak and Halpin report that effective cash flow management involves forecasting, planning, monitoring and controlling of cash receipts and payments. They suggest that an -S- curve represents cash flow changes with respect to time in a construction project (Cui, Hastak, and Halpin, 2010) and an -S- curve is an important cost tracking tool. Using an -S-, enables project managers to track the cash flows in the project over a period of time and to forecast future expenditure trends. In fact, an -S- curve represents the use of materials, labor, equipment, overheads, and subcontractor expenditures – in other words it symbolizes cash-out flow. El razek, El din Hosny and El Beheri argue that the probabilistic -S- curves can be used as an alternative of the Standard -S- curve because the traditional -S- curve method neglects the effect of risk and uncertainties involved in construction projects (El Razek, El Din Hosny, and El Beheri, 2014). The probabilistic -S- curves are used for the probability distribution of the time and cost required to complete the project at a particular time. These curves ensure that the project's cash flow is accurately forecasted. Hwee and Tiong suggest that a cash flow model for construction projects can be developed by the using the following variables:

(1) duration, (2) over/under measurement, (3) variation risk (during work progress), (4) variation risk and (5) material cost variances (Hwee and Tiong, 2002). The performance of a cash flow is operationalized by using two criteria, namely internal rate of return and maximum capital requirements.

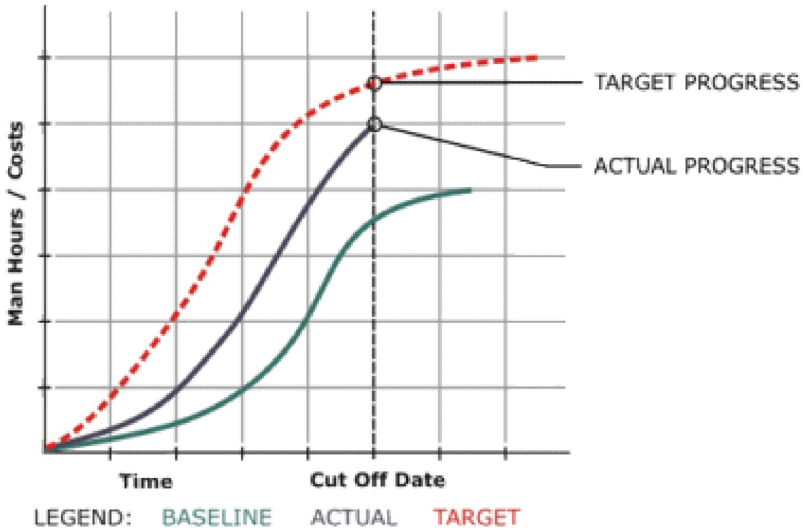

Figure 2.4. Example of S curve (Gendall, 2003)

Abdul Rahman and his friends argue that a contract between public clients and the construction firm defines a general agreement on the planning of works, the measurement and costing of building works and also timing of payment times (Abdul-Rahman, Kho, and Wang, 2014). Yet, payment delays are very common in public construction projects. The main reasons behind payment delays include (1) client's poor financial management, (2) the insufficient financial resources, (3) paymaster's withholding of payment, conflict and poor communication among project participants local and cultural attitude (Abdul-Rahman, Kho, and Wang, 2014). Han and his friends emphasize that a construction firm should use a cash flow management model to forecast the operating capital requirements of construction projects and should ensure that it sufficient operating capital to carry out construction operations and activities (Han et al. 2014). There are numerous models in literature to forecast or estimate the project performance (i.e., cost, quality and schedule). Yet a relative neglected research issue in these previously research studies is to develop a model which enables construction firms (1) to identify the payment patterns of their clients and to quantify the cost of payment delays based on their clients' payment patterns. Only a limited number of research studies focuses on these research areas and develops such a model to address this challenging issues. Hoseni and his friends propose a model for cash flow forecasting model which incorporated payment delays. The proposed model is based Monte Carlo simulation and use Beta distribution function to simulate the payment delays and cash (Hoseini et al., 2015). They argue that if there is not enough data about a project owner's payment patterns expert opinion can be used to build the simulation model.

Delayed payments to the contractor during the project can cause the net cash flow to be negative (Paul, Devi, and Teh, 2012). The execution of daily construction operations and activities and their costs are affected from payment delays. The severity of payment delays varies with respect to the size of construction project. Thus, it essential for construction firms to analyze and evaluate the project owner's payment strategies from previous projects before signing a contractual agreement with the project owner. The negative cash flow caused by payment delays requires construction firm to finance ongoing construction operations and activities using its own financial resources and this in turn increases the financial stress in the construction firm. Information about payment patterns of construction clients is valuable input for construction firms. Smith and his friends argue the payment pattern of project owner (i.e., how long the payments were delayed in previous projects of the project owner) is important factor in determination of fees for services offered by construction firms (Smith and Bohn, 1999).

Payment period has been commonly modeled as a fixed variable. Furthermore, it widely assumed that the payments are done monthly, because of the fact that the invoices are generated monthly at the contracts (Hoseini et al., 2015). The project owner's payment patterns can be "a reliable and valuable information" to forecast the cash flow curve(s) for the next project(s) of this owner.

2.4.3. Cash Flow at Risk (CFaR) in Cash Flow Analysis

Construction projects involves a significant amount of risks such financial, organizational, technical, social, cultural. These different forms of risks must be carefully managed in every stages of construction project in order to minimize their negative impact on the project performance. Risk management has been one of the most important managerial tasks in the construction industry (Iqbal et al., 2015). Risk management in the construction includes a wide range of managerial activities such as identifying, analyzing, evaluating, treating and monitoring the risk. Choudhry argues that the most important risks in the construction industry include economic and financial risks and parties operating in the construction industry try to avoid these risks (Choudhry and Iqbal, 2013). Bufaid suggests that risk involves uncertainties which influence project cost (Bufaid, 1987). The emergence of risk variables and uncertainty are main drivers for increasing construction costs. For example, changing the materials selected for the project, changing the design or the shortage of workforce can have detrimental impact on the cash flow and in turn increase project cost. The primary objective of risk management is reduce the risk to its minimum level and controlling it. The major risk in managing construction projects is the insufficiency of financial resources - cash flows because any type of changes can cause a deviation from the predefined project objectives.

Financial risk management in construction project starts with pointing out the difference between the "concept of risk" and the "concept of uncertainty". Cheng, Ko and Mishra et al. argue that financial uncertainty is non-mathematical because of the lack of financial data or historical information. They also argue that "financial risk" is the probability of an unforeseen financial situation (Chang and Ko, 2016).

Construction firms have strong desire to be proactive to manage financial risks that they may encounter in carrying out their operations and activities. The common objective in those proactive approaches adopted in construction firms is to "identify financial losses" and to "minimize these financial losses". Using effective financial risk management model to accurately forecast cash flow and in turn make the right financial decisions throughout the project have been at the agenda of construction business executives for quite long time. Different financial risk management models have been developed by researchers.

The model developed by Mishra builds on Monte Carlo simulation, the Value-at-Risk (VaR) method and Internal Rate of Rate (IRR) (Mishra, Khasnabis, and Swain, 2015). Mishra and his friends also use the bootstrap method to analyze financial risks in projects. The results of these two models suggest that VaR method can be used for managing financial risks (Mishra, Khasnabis, and Dhingra, 2013).

Chang and Ko propose a model which builds on Monte Carlo simulation to forecast Net Present Value (NPV) of construction projects (Chang and Ko, 2016).

Kale and Yavuz propose a financial risk evaluation model for public private partnership (PPPs) projects. The model is based on the value at risk (VaR). The cash flow of a PPP project is analyzed by using the proposed model (Yavuz and Kale, 2018).

Wang analyzes the issue of liquidity risk by using the value at risk method. And suggests that monte carlo simulation is more effective method to calculate the value at risk.

Andren forecasts the cash flow of a project by using the cash flow at risk (CFaR) method in consideration with macroeconomic problems (Eydeland and Wolyniec, 2003).

Stein and his friends propose a model based on a probability distribution function and cash flow at risk method to evaluate financial risks (Eydeland and Wolyniec, 2003).

Ye and Tiong develop a financial risk management model to forecast the cost of risk exposure by using cost average and risk return methods (Ye and Tiong, 2000).

The value at risk (VaR) is developed by JP Morgan using Risk Metrics. It has been commonly used by financial institutions/firms – parties interested in stocks and bonds. However, as it is commonly used, also it has been used by other firms institutions and private firms (Kaya, 2018). The value at risk (VaR) method which is used in the estimation of financial risks is widely used to observe the maximum loss and to determine the financial risk (Mishra, Khasnabis, and Dhingra, 2013). In other words, it is the method that is used to express the estimated maximum loss in a given time period and in a certain probability. So, this concept contains three different parameters, the time interval, the estimated loss and confidence interval. This method shows that the anticipated profit or loss of distribution.

In calculating the value at risk (VaR), parametric methods and simulation-based methods are used. The parametric method is based on the parameters within the given probability and the results are assumed to have a normal distribution. Simulation method consists of historical simulation and Monte Carlo simulation. When historical data is used in historical simulation, historical data and randomly selected variables are used in Monte Carlo simulation (Kaya, 2018). According to the data that can be obtained from the project, the appropriate method can be determined and the value at risk (VaR) of the construction project can be calculated. Equation 1 is used for calculation of value at risk (Var). At the same time, Figure 2.6. shows the graph of the value at risk. The α symbol defines the confidence interval.

$$\Pr\left[\Delta P\ (N) < VaR\right] = F\left[\Delta P\ (-Var)\right] =$$

$$= \int_{-\infty}^{-VaR} f\big(\Delta P(x)\big)dx = 1 - \alpha \qquad \text{(Equation 1)}$$

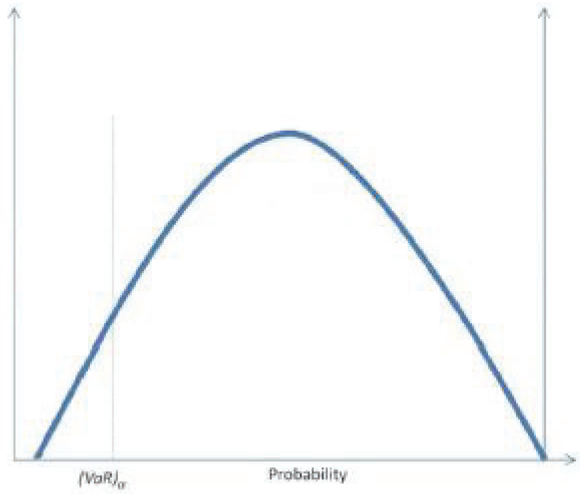

Figure 2.5. Graph of Var (Source: Sharifi and Bagherpour, 2016)

The co-concept of the value-at-risk which is used in financial firms is cash flow at risk (CFaR). The method of calculating the value-at-risk is used mostly by the financial institutions/firms dealing with stocks and securities and focus on asset values. Cash flow at risk method (CFaR) has been used in non-financial firms and it focuses on cash flow. At the same time, cash flow at risk (CFaR) method is used to estimate cash flow which can change according to interest rate and currency fluctuations (Sharifi and Bagherpour, 2016).

Cash flow at risk (CFaR) can be calculated as value at risk(VaR) (Sharifi and Safari, 2016) . In this method, market values are not used, the expected cash flow values are used and cash flow distributions are taken into consideration (Eydeland and Wolyniec, 2003). Cash flow at risk method allows a non-financial firm to determine the financial risks in construction projects.

CHAPTER 3

A SIMULATION MODEL FOR PAYMENT DELAYS IN CONSTRUCTION PROJECTS

In this research, a stochastic simulation model has been developed by considering the delays in the progress payments that the owner has to take into consideration in construction projects. Stochastic approaches are unpredictable models. They show the probability of the occasions (Pidd, 2006). The systematic structure of the developed model is shown in figure 3.1. The main objective is to help contractor out to manage his/her financial status throughout the project by estimating the delay in payments to be received.

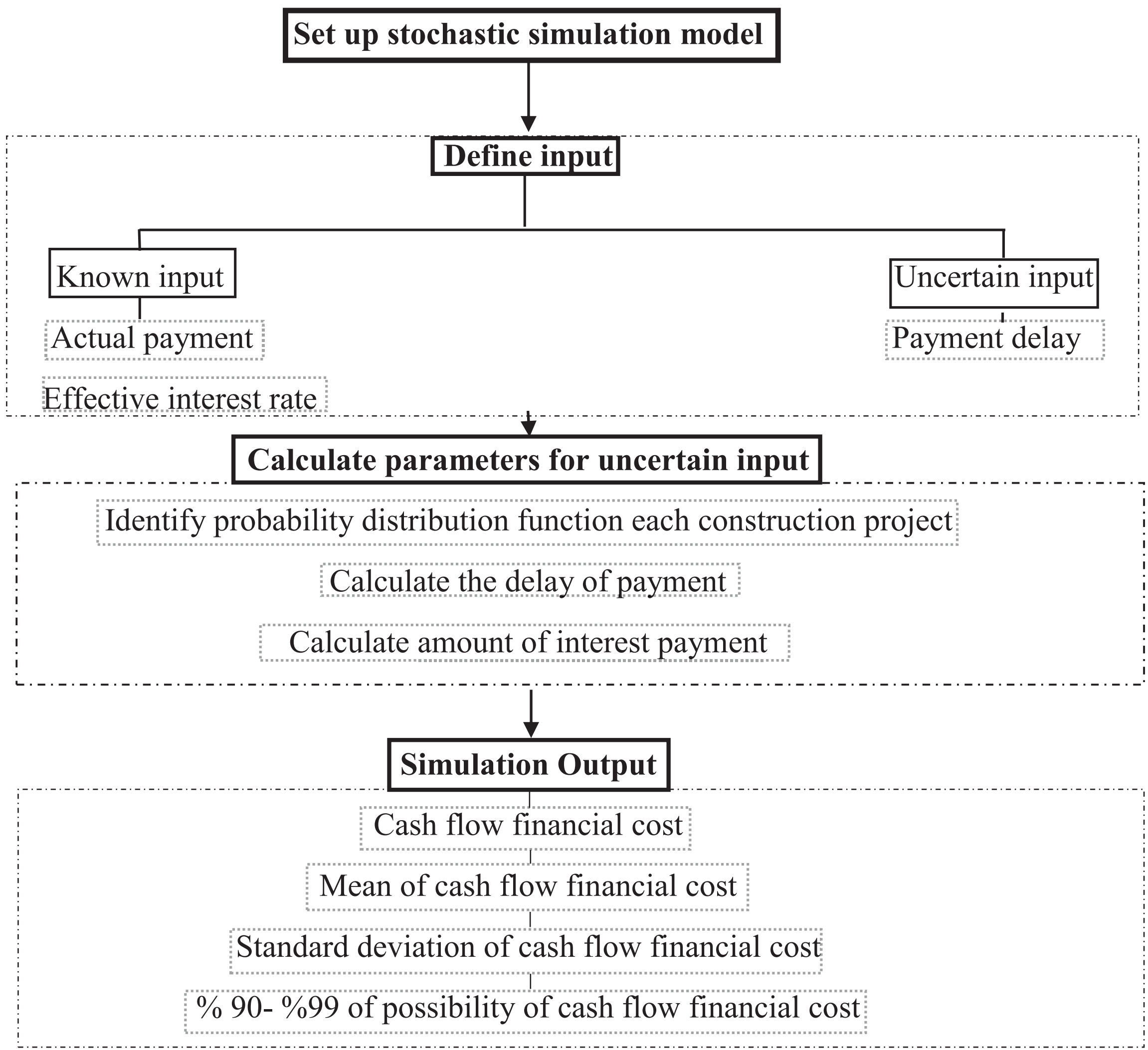

Figure 3.1. Structure of developed model

Firstly, information of the completed projects is obtained from department of construction. The initiation and final dates, the contract prices, the progress payments, the stoppages in these progress payments, the delay periods in the payments received by the contractor and the work program of projects take place in the scope of these information. In the light of these information, cumulative flow graph of planned and actual payments and the graph of planned and actual payments are observed on a monthly basis.

The cost of payments delays are calculated by using the effective of interest rate announced by the Central Bank of The Republic of Turkey. The announced annual interest rates were converted to into the daily effective interest rates by using Equation 6:

$$\text{Daily interest rate} = [(1+r) \wedge (1/m)] - 1 \qquad \text{(Equation 6)}$$

where, r is annual interest rate and m is discounting period.

CHAPTER 4

MODEL IMPLEMENTATION, RESULTS AND DISCUSSION

Three completed construction projects were used as cases to illustrate the implementation and utility of the proposed model. Table 4.1. presents an overview of these three construction projects. The owner of the completed construction projects is the same public agency (i.e., public university). Contract type contract used by the public in procuring these construction projects is “turnkey contract”.

Table 4.1. Project Overview

	Project A	**Project B**	**Project C**
Name of Project	Electrical and Electronic Department	Semi-Olympic Indoor Pool	Civil Engineering Department
Total Area	7.394 m2	3.489 m2	16.253 m2
Type of Contract	Turnkey	Turnkey	Turnkey
Planned Duration	720 days	540 days	604 days
Starting Date	30/07/2015	08/04/2013	22/11/2012
Planned Finish Date	19/07/2017	05/09/2014	19/07/2014
Actual Finish Date	08/08/2017	26/10/2014	15/08/2014
Final Payment	25/09/2017	17/04/2017	25/12/2014
Owner	Public Sector	Public Sector	Public Sector

Table 4.2. Contract Details of the Construction Projects

Items	Project A	Project B	Project C
Contract Amount	11.540.000,00 TL	4.340.000,00 TL	12.600.000,00 TL
Retention Amount	3%	3%	3%
Payment Cycle (months)	1	1	1
Billing Time (months)	1	1	1

4.1. Project A

Project A is the construction of a building for Electric-Electronic Department in a public university. It has a total construction are of 7.394 m². The contract price is 11, 540, 000 TL excluding Value Added Tax (VAT). The last progress payment was made at 25.09.2017. The project was completed with a delay of 20 days (i.e., planned duration is 720 days but completed within 740 days) and a total cost of 12.444.892,99 TL.

- Project Finance: Public Agency
- Contractor Company: X company
- Contract Price: 11.540.000,00 TL
- Tender Date: 13.04.2015
- Contract Date: 30.07.2015
- Substantial Completion: 19.07.2017
- Final Completion (Final Acceptance): 08.08.2017

The progress payment plan for Project A are shown in Table 4.3. Table 4.4. presents the details of actual progress payments (i.e., payment delays, amounts and dates) for Project A. Figure 4.1. presents the planned and actual cash flows of Project A. The cumulative planned and actual cash flows of Project A are presented in Figure 4.2.

Table 4.3. Progress Payment Plan for Project A

Progress Payment Date	Planned Progress Payment (TL)
August 2015	139.317,21
September 2015	139.317,21
October 2015	139.317,21
November 2015	139.317,21
December 2015	139.317,21
January 2016	412.637,60
February 2016	604.840,67
March 2016	520.188,05
April 2016	617.903,83
May 2016	856.902,08
June 2016	917.070,81
July 2016	631.950,01
August 2016	717.755,75
September 2016	683.948,61
October 2016	685.653,98
November 2016	722.032,46
December 2016	795.253,30
January 2017	794.687,78
February 2017	968.553,30
March 2017	755.092,95
April 2017	665.937,20
May 2017	509.023,56
June 2017	368.929,31
July 2017	0,00
August 2017	0,00

Table 4.4. Actual Progress Payments for Project A

Payment Delay (Days)	Date of Application	Date of Payment	Actual Progress Payment (TL)
4	31.08.2015	04.09.2015	516,701.04
8	30.09.2015	08.10.2015	924,871.66
7	30.10.2015	06.11.2015	956,872.67
10	30.11.2015	10.12.2015	299,207.34
25	31.12.2015	25.01.2016	285,454.29
21	31.01.2016	21.02.2016	430,181.21
29	29.02.2016	29.03.2016	540,491,28
12	31.03.2016	12.04.2016	170,598,06
17	30.04.2016	17.05.2016	238,545,22
8	30.05.2016	7.06.2016	449,390,02
1	28.06.2016	29.06.2016	619,929,57
11	29.7.2016	9.8.2016	739,954,17
6	31.8.2016	6.9.2016	542,158,60
10	30.9.2016	10.10.2016	713.244,84
11	31.10.2016	11.11.2016	934.513,42
14	30.11.2016	14.12.2016	729.987,56
37	31.12.2016	6.2.2017	754.004,33
10	31.1.2017	10.2.2017	602.332,36
9	28.2.2017	9.3.2017	1.309.938,84
7	31.3.2017	7.4.2017	968.650,55
9	30.4.2017	9.5.2017	669.309,47
13	31.5.2017	13.6.2017	500.563,13
21	30.6.2017	21.7.2017	785.619,44
56	31.7.2017	25.9.2017	164.169,05

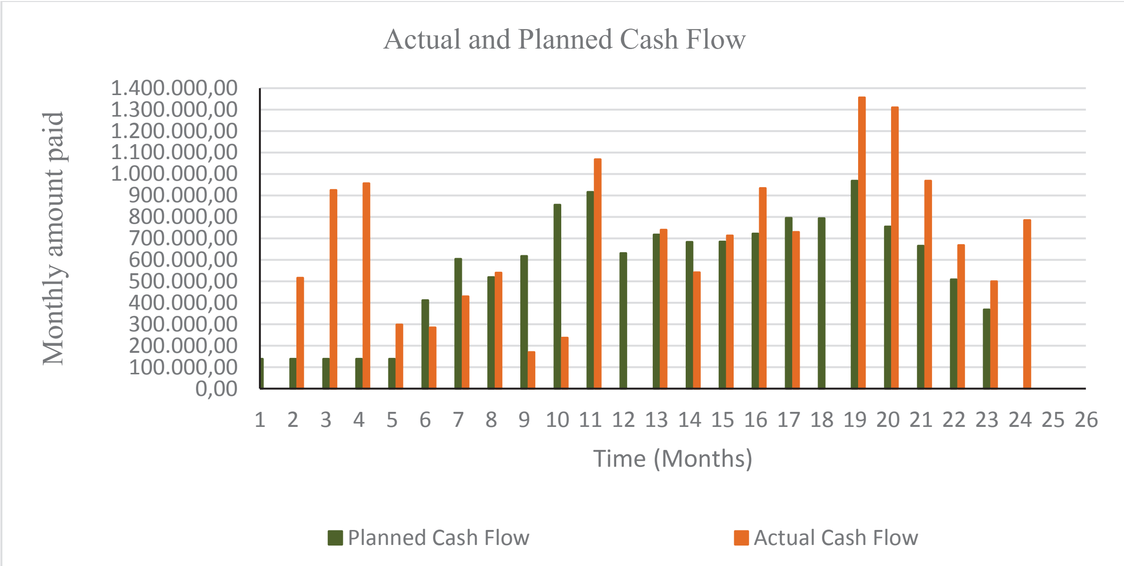

Figure 4.1. Planned and actual cash flows for Project A

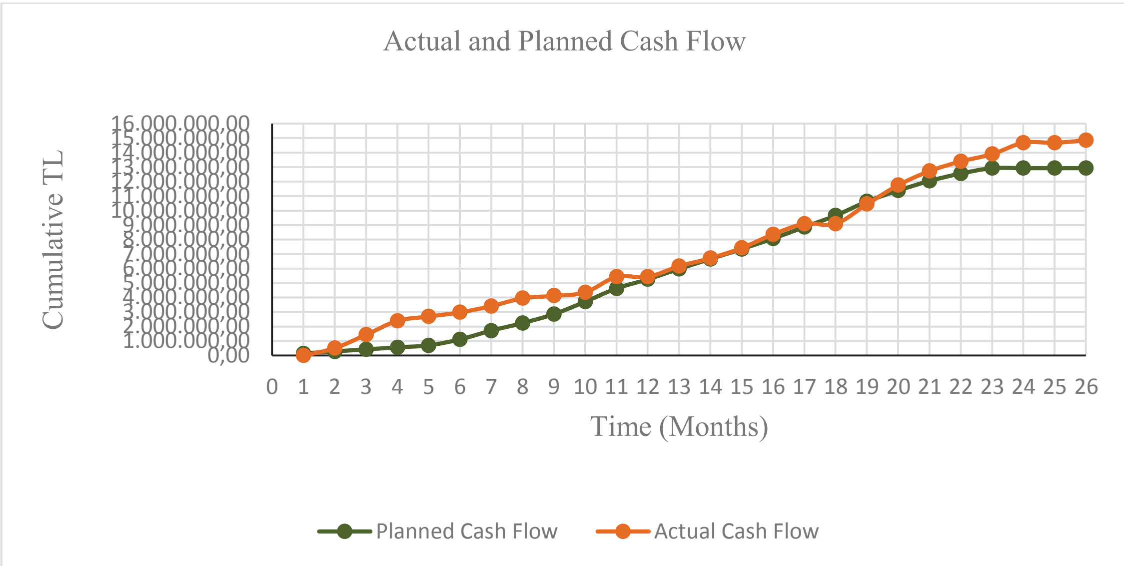

Figure 4.2. Cumulative planned and actual cash flows for project A

The mean and variance of payment delays for Project A are 16.18 days and 13.15 days, respectively. A series of probability distribution fitting process (i.e., Normal distribution (i.e., exponential distribution, gamma distribution, lognormal distribution and Chi-square distribution functions) was used to identify the most appropriate statistical distribution to forecast the frequency of occurrences of payment delays in Project A. Figures 4.4, 4.5, 4.6, 4.7, and 4.8. present the results of statistical distribution fitting processes. It is clear from the results presented in Figures 4.4, 4.5, 4.6, 4.7, and 4.8 that the frequency distribution of payment delays in Project A does not fit to any of the studied statistical distribution function. The significance values (p) of chi-square goodness-of-fit tests of the distribution function investigated are smaller than 0.05 ($p < 0.05$).

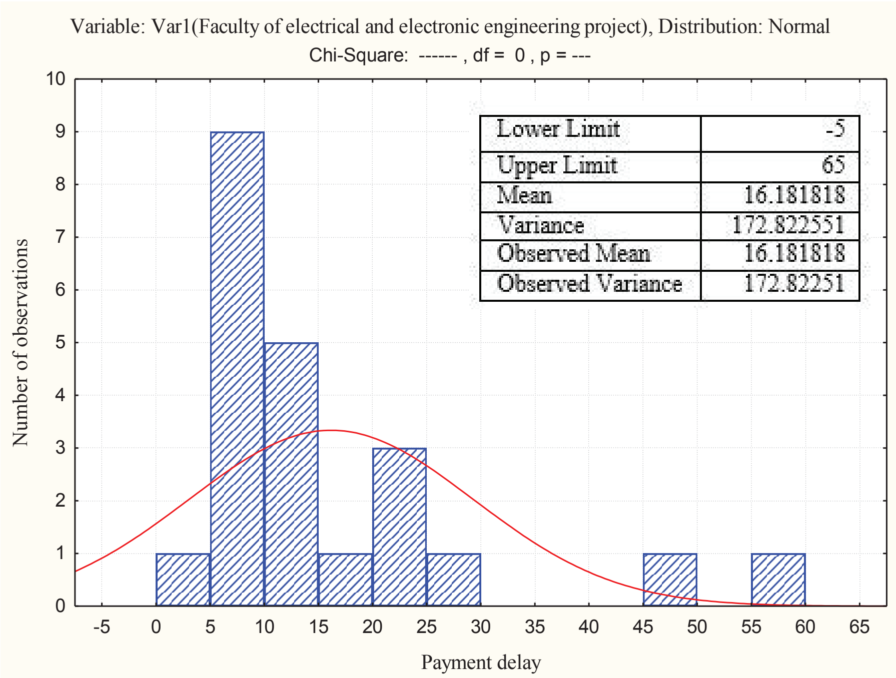

Figure 4.3. Frequency Distribution of Payment Delays for Project A and The Normal Distribution Function

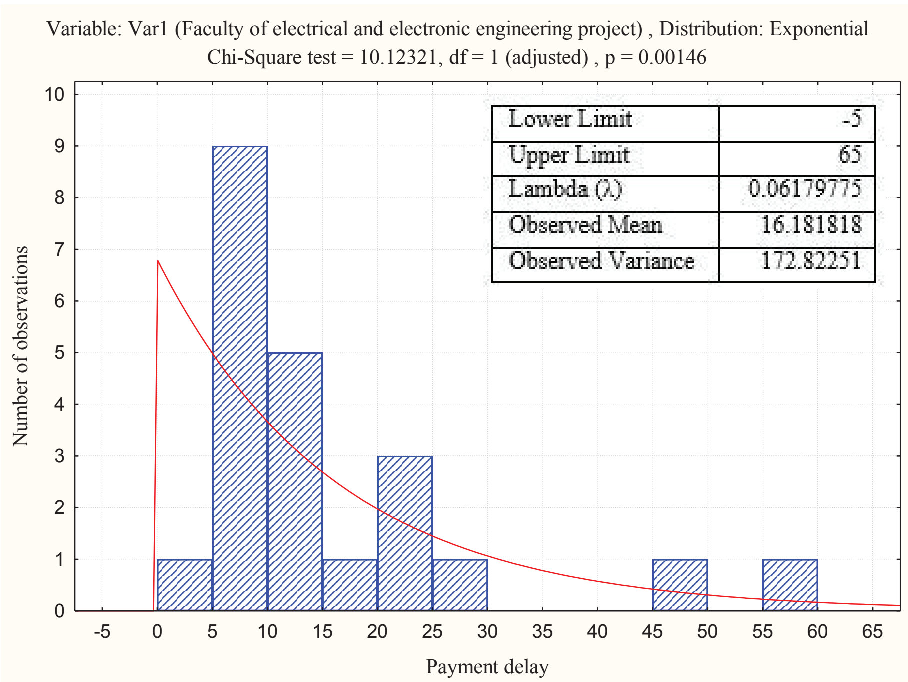

Figure 4.4. Frequency Distribution of Payment Delays for Project A and Exponential Distribution Function

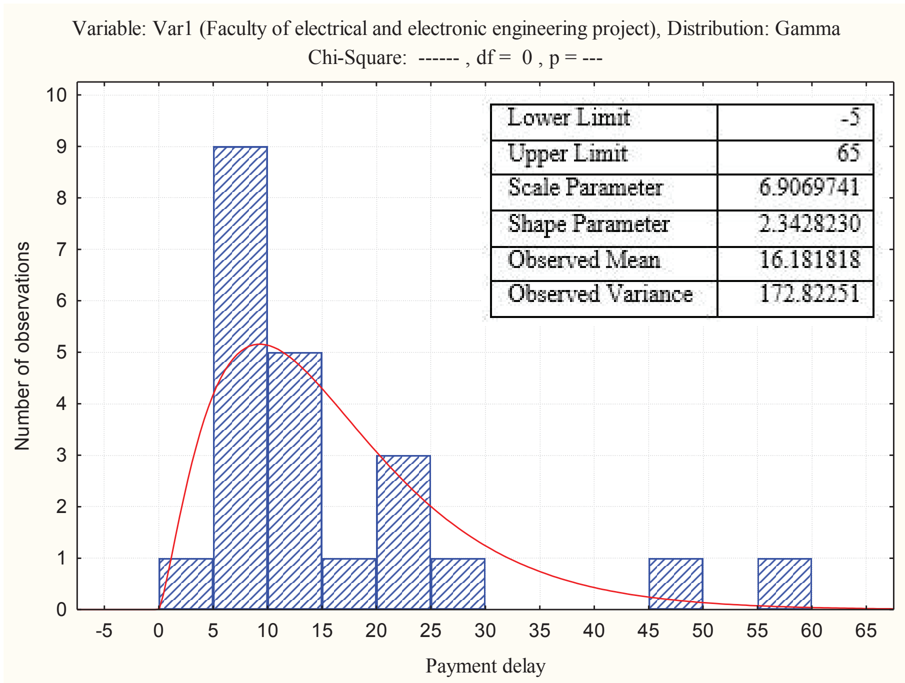

Figure 4.5. Frequency Distribution of Payment Delays for Project A and Gamma Distribution Function

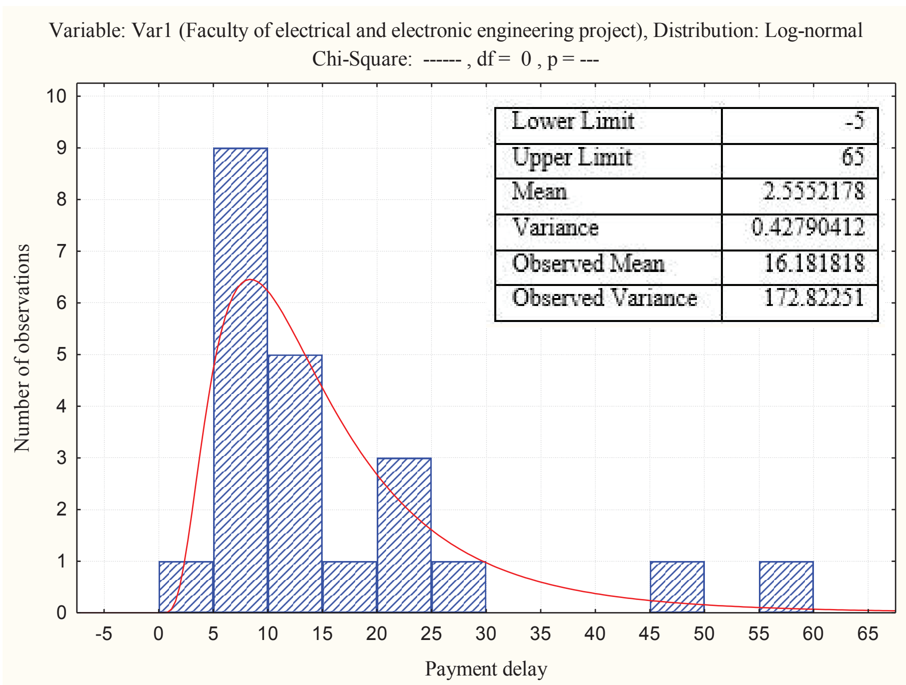

Figure 4.6. Frequency Distribution of Payment Delays for Project A and Lognormal Distribution Function

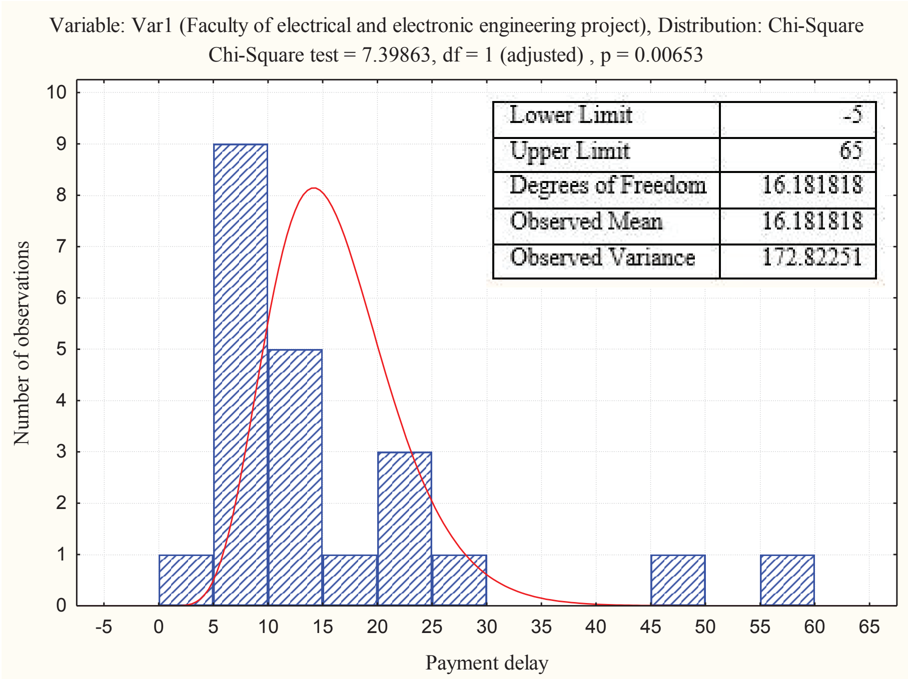

Figure 4.7. Frequency Distribution of Payment Delays for Project A and Chi-Square Distribution Function

4.2. Project B

Project B is the construction of semi Olympic indoor swimming pool in the same public university. The contract information for Project B is presented below. It has a total construction area of 3.489 m². Project B was completed with a delay of 30 days but the final progress payment to the contractor firm was done with a delay of 691 days.

- Project Finance: Public Agency
- Contractor Company: Y company
- Contract Price: 4.340.000,00 TL
- Tender Date: 16.11.2012
- Contract Date: 05.04.2013

- Substantial Completion: 05.09.2014

- Final Completion (Final Acceptance): 26.10.2014

The planned and actual progress payments amounts and payment dates of the project are shown in Tables 4.5. and 4.6.

Table 4.5. Progress Payment Plan for Project B

Planned Progress Payment Date	Planned Progress Payment (TL)
April 2013	153.890,20
May 2013	153.890,20
June 2013	153.890,20
July 2013	153.890,20
August 2013	153.890,20
September 2013	153.890,20
October 2013	153.890,20
November 2013	153.890,20
December 2013	153.890,20
January 2014	41.052,72
February 2014	186.599,81
March 2014	227.651,34
April 2014	136.591,52
May 2014	136.591,52
June 2014	227.652,55
July 2014	455.305,08
August 2014	455.305,08
September 2014	136.591,52
October 2014	182.122,04

Table 4.6. Actual Progress Payments for Project B

Payment Delay (Days)	Application Date	Payment Date	Progress Payment (TL)
8	19.6.2013	27.6.2013	333.347,98
13	14.8.2013	27.8.2013	346.049,97
16	16.9.2013	2.10.2013	264.943,47
30	4.11.2013	4.12.2013	287.757,83
6	18.12.2013	24.12.2013	200.520,25
25	28.2.2014	25.3.2014	336.953,17
13	24.4.2014	7.5.2014	645.444,18
30	26.5.2014	25.6.2014	354.405,05
34	4.7.2014	7.8.2014	506.270,93
23	11.8.2014	3.9.2014	461.523,91
39	11.9.2014	20.10.2014	245.676,60
45	10.11.2014	25.12.2014	62.528,16
19	11.12.2014	30.12.2014	667.452,48
112	30.4.2015	20.8.2015	561.069,68
691	27.5.2015	17.4.2017	86.552,09

The progress payment plan for Project B are shown in Table 4.5. Table 4.6. presents the details of actual progress payments (i.e., payment delays, amounts and dates) for Project B. Figure 4.9. presents the planned and actual cash flows of Project A. The cumulative planned and actual cash flows of Project A are presented in Figure 4.10.

The mean and variance of payment delays for Project B are 27.36 days and 15.95 days, respectively. A series of probability distribution fitting process (i.e., Normal distribution (i.e., exponential distribution, gamma distribution, lognormal distribution and gamma distribution) was used to identify the most appropriate statistical distribution to forecast the frequency of occurrences of payment delays in Project B. Figures 4.12, 4.13, 4.14, 4.15, and 4.16 present the results of statistical distribution fitting processes. It is clear from the results presented in Figures 4.12, 4.13, 4.14, 4.15, and 4.16 that the frequency distribution of payment delays in Project B does not fit to any of the studied statistical distributions because the significance values (p) chi-square goodness-of-fit tests are smaller than 0.05 ($p< 0.05$).

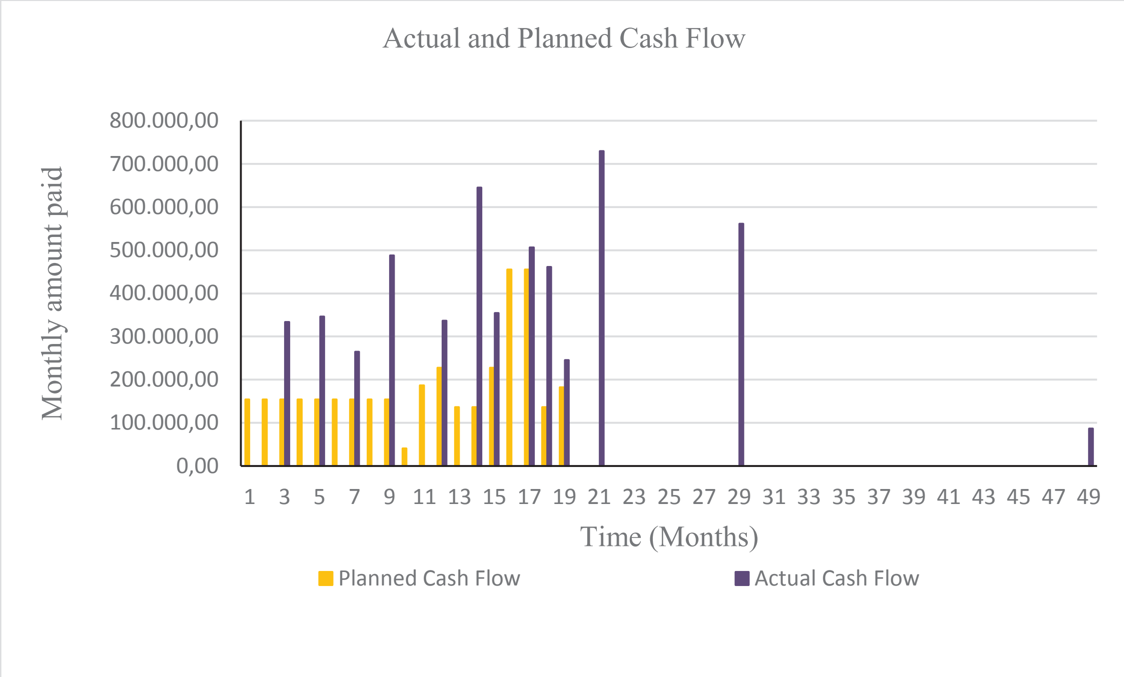

Figure 4.8. Planned and actual cash flows for Project B

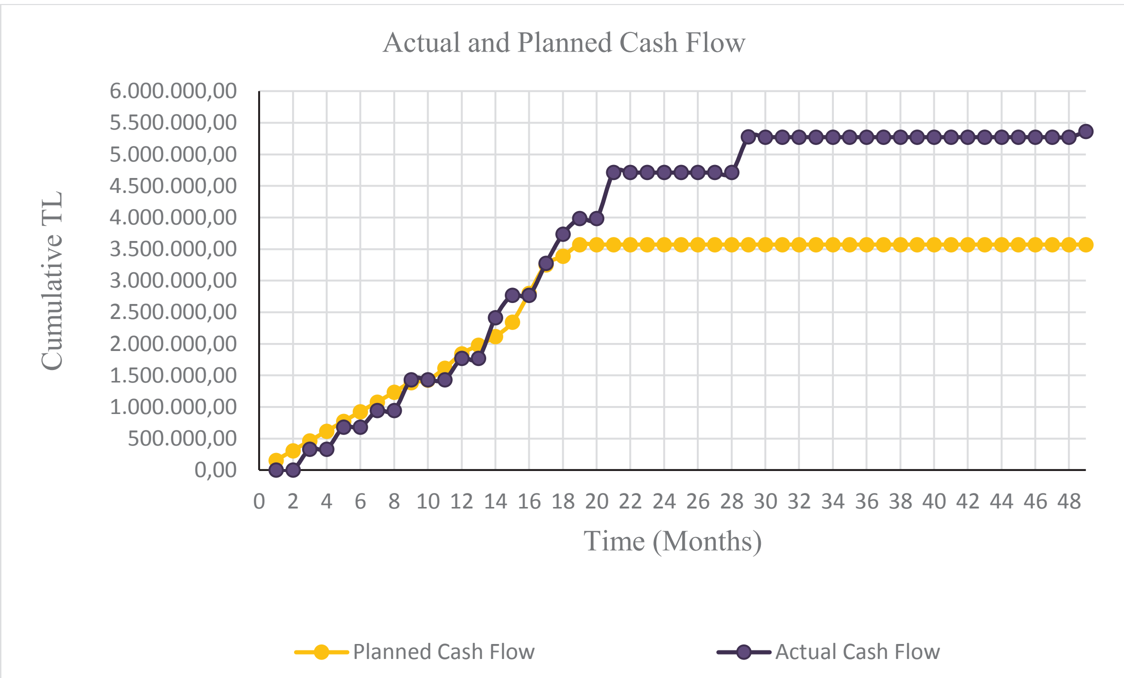

Figure 4.9. Cumulative planned and actual cash flows for Project B

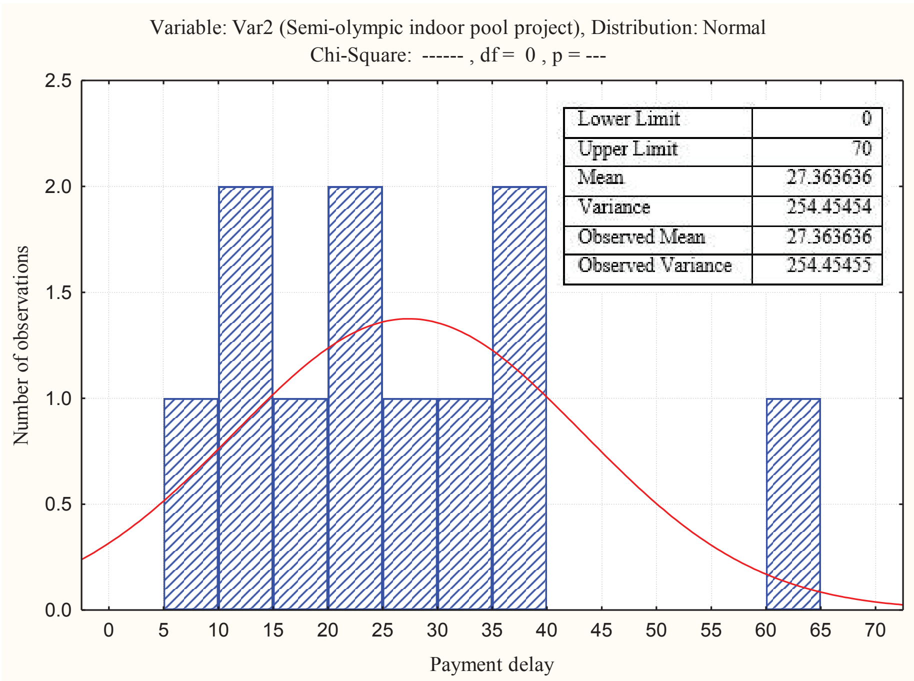

Figure 4.10. Frequency Distribution of Payment Delays for Project B and Normal Distribution Function

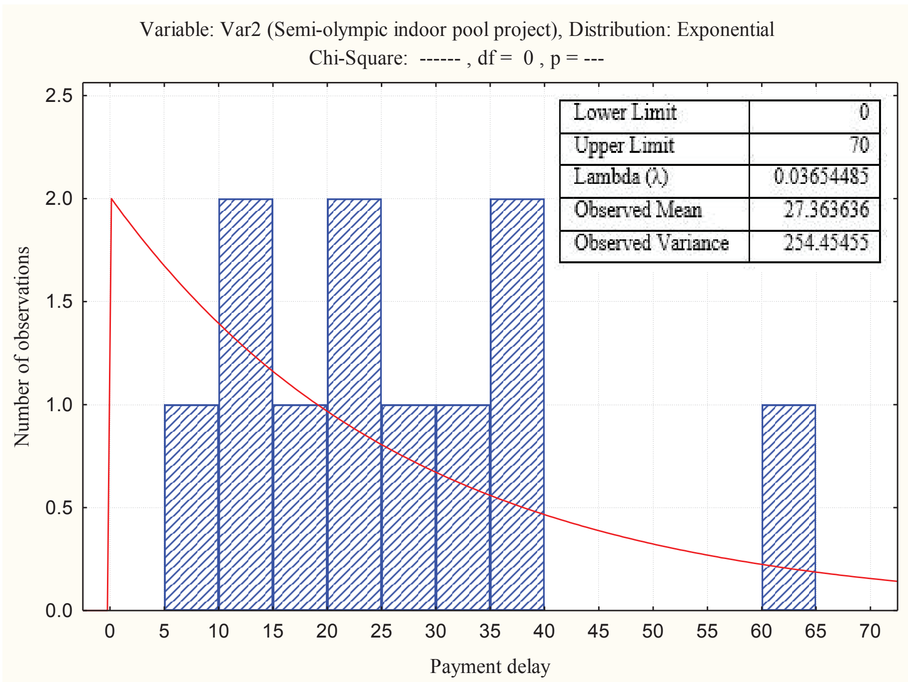

Figure 4.11. Frequency Distribution of Payment Delays for Project B and Exponential Distribution Function

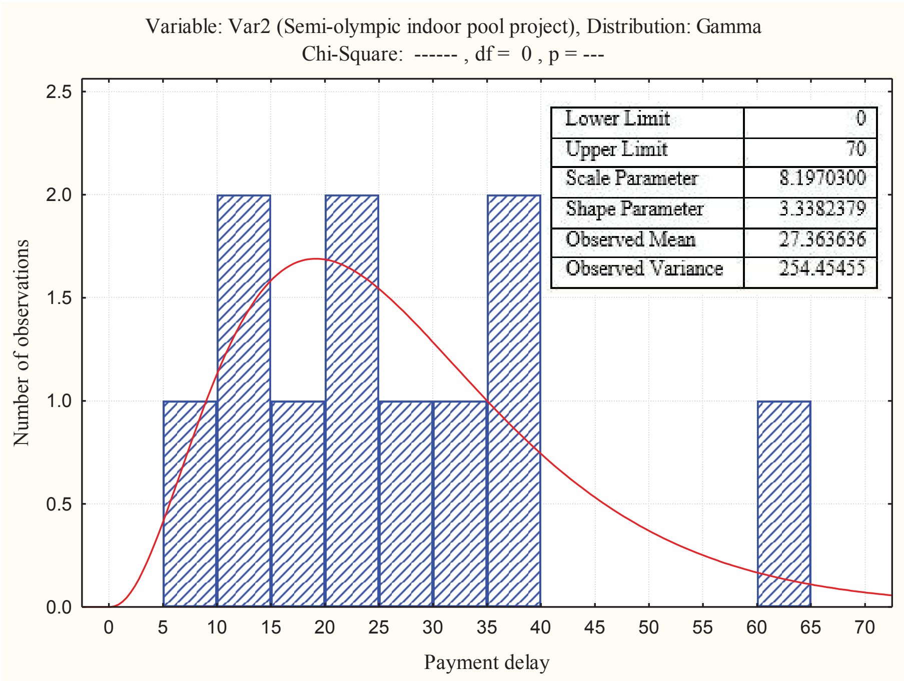

Figure 4.12. Frequency Distribution of Payment Delays for Project B Gamma Distribution Function

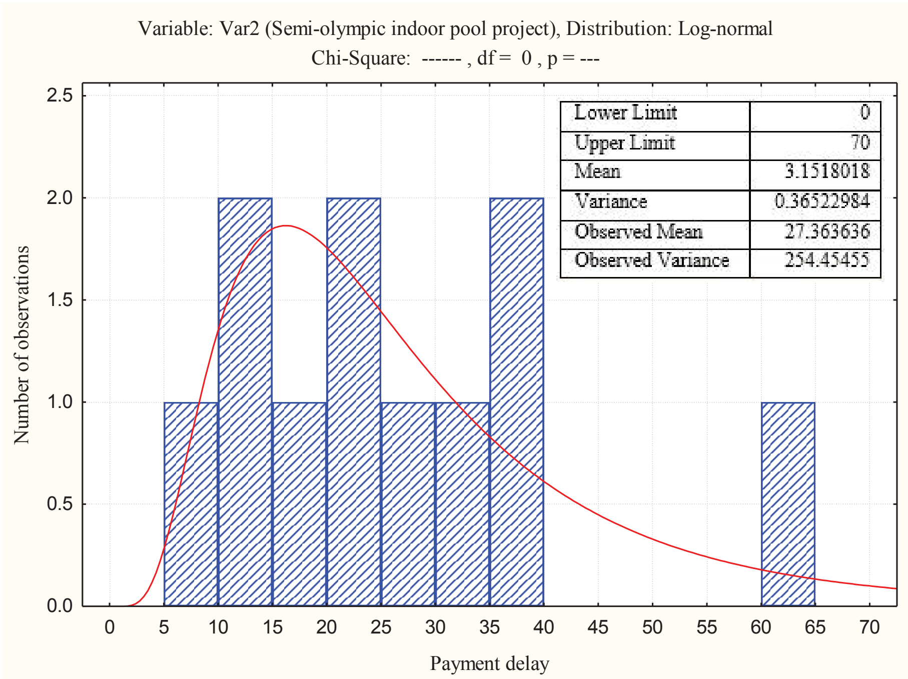

Figure 4.13. Frequency Distribution of Payment Delays for Project B and Lognormal Distribution Function

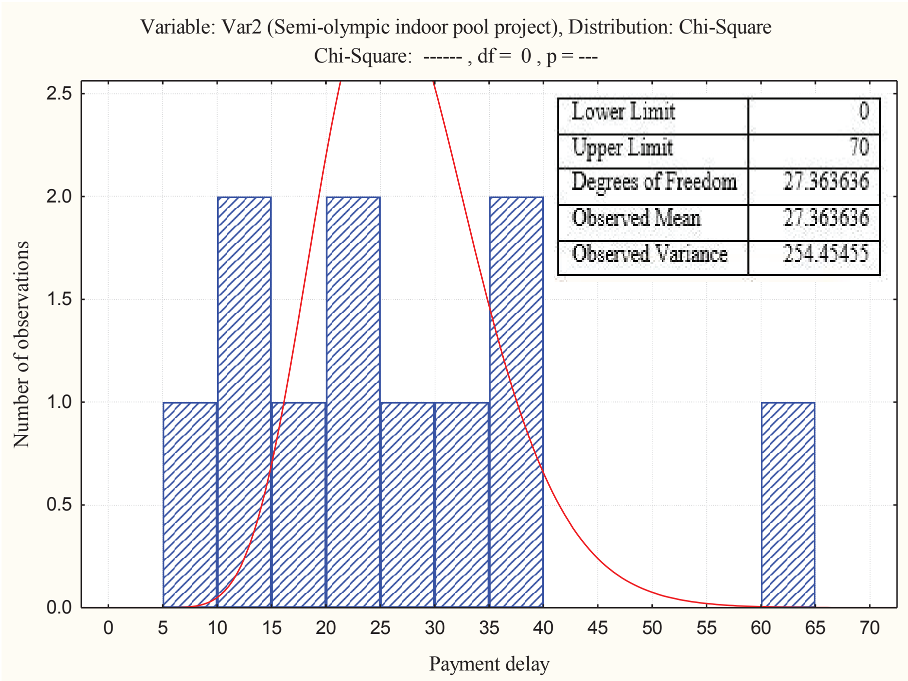

Figure 4.14. Frequency Distribution of Payment Delays for Project B and Chi-Square Distribution Function

4.3. Project C

Project C is the construction of a building for Civil Engineering Department in the same public university. The details of the contract signed between the parties (i.e., construction firm and public university) for Project C is presented below. Project C has a total construction area of 16.253 m² with a contract price of 12,600,000 TL excluding VAT. The project was completed with a delay of 27 days (i.e., planned and actual durations are 604 and 631 days, respectively) and a total cost of 13,135,118.85 TL.

- Project Finance: Public Agency
- Contractor Company: X company
- Contract Price: 12.600.000,00 TL
- Tender Date: 10.10.2012
- Contract Date: 22.11.2012

- Substantial Completion: 19.07.2014

- Final Completion (Final Acceptance): 15.08.2014

The planned and actual progress payments for Project C are shown in Tables 4.7 and 4.8.

Table 4.7. Progress Payments Plan for Project C

Payment Time	Planned Amount Payable for Contractor
November 2012	24.763,39
December 2012	545.454,29
January 2013	609.085,21
February 2013	621.120,91
March 2013	604.225,16
April 2013	614.432,03
May 2013	579.939,93
June 2013	532.585,84
July 2013	600.194,64
August 2013	552.029,28
September 2013	229.087,66
October 2013	263.931,12
November 2013	461.423,60
December 2013	594.753,27
January 2014	751.907,19
February 2014	758.333,89
March 2014	438.121,56
April 2014	962.302,50
May 2014	1.251.260,27
June 2014	1.513.919,17
July 2014	1.014.042,79

Table 4.8. Actual Progress Payments for Project C

Payment Delay (Days)	Filling Date	Payment Date	Progress Payment (TL)
4	24.12.2012	28.12.2012	456.398,17
12	1.2.2013	13.2.2013	810.020,45
19	1.3.2013	20.3.2013	555.664,63
12	4.4.2013	16.4.2013	1.019.016,24
14	1.5.2013	15.5.2013	346.763,59
12	1.6.2013	13.6.2013	912.267,54
16	1.7.2013	17.7.2013	455.321,10
4	1.8.2013	5.8.2013	911.540,11
9	2.9.2013	11.9.2013	455.469,87
9	2.10.2013	11.10.2013	455.032,36
13	2.11.2013	15.11.2013	396.029,75
4	2.12.2013	6.12.2013	514.711,49
13	2.1.2014	15.1.2014	682.801,81
24	3.2.2014	27.2.2014	874.263,84
17	3.3.2014	20.3.2014	697.710,89
0	3.4.2014	3.4.2014	700.937,22
5	3.5.2014	8.5.2014	545.944,45
15	2.6.2014	17.6.2014	1.182.471,34
12	2.7.2014	14.7.2014	1.329.317,43
12	2.8.2014	14.8.2014	1.456.247,51
133	14.8.2014	25.12.2014	451.545,25

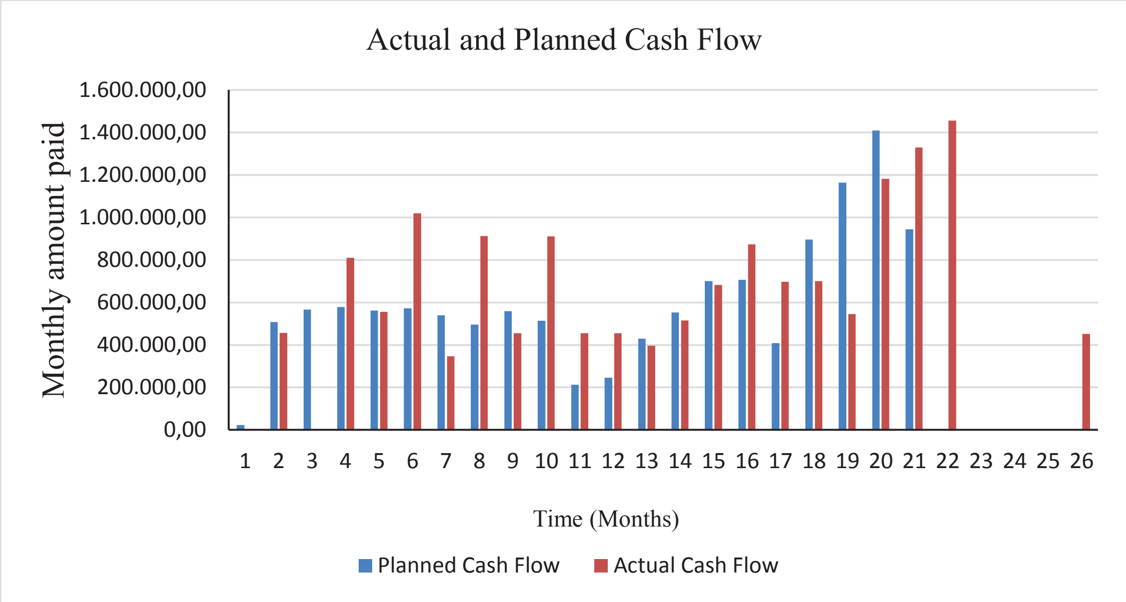

Figure 4.15. Planned and actual cash flows for Project C

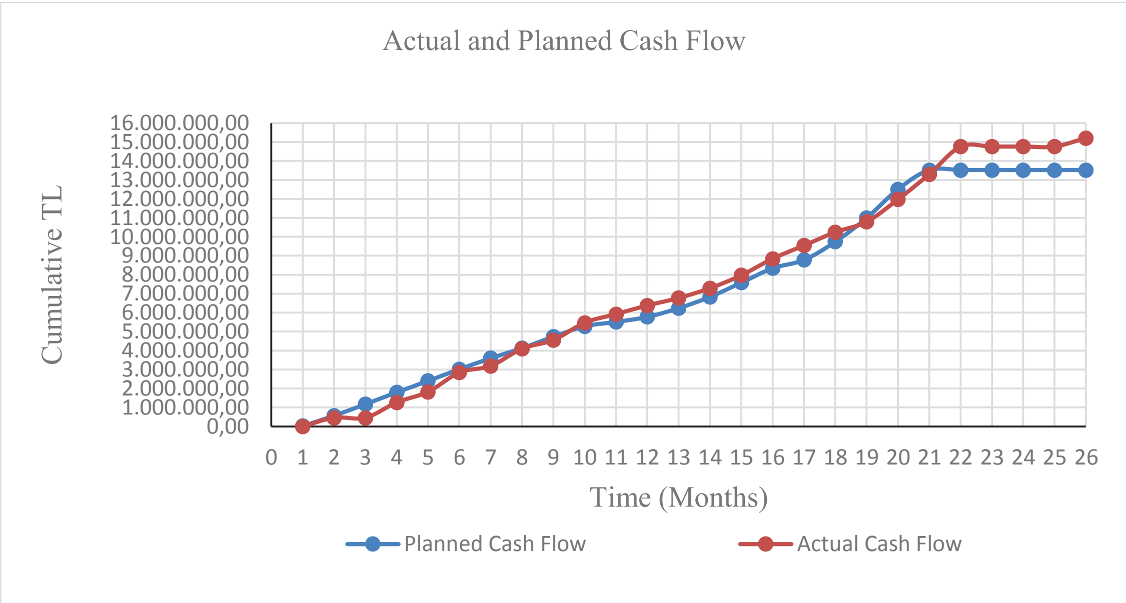

Figure 4.16. Cumulative planned and actual cash flows for Project C

The mean and variance of payment delays for Project C are 11.89 and 5.31 days, respectively. A series of probability distribution fitting process (i.e., Normal distribution, exponential distribution, gamma distribution, lognormal distribution and gamma distribution) was used to identify the most appropriate statistical distribution to forecast the frequency of occurrences of payment delays in Project B.

Figures 4.20, 4.21, 4.22, 4.23, and 4.24 present the results of statistical distribution fitting processes. The significance values (p) of chi-square goodness-of-fit tests for normal (Figure 4.20.), exponential (Figure 4.21.), gamma (Figure 4.22.) or lognormal distribution (Figure 4.23.) functions are smaller than 0.05 ($p < 0.05$). These four distribution functions do fit to the observed data. Yet the significance value (p) of goodness of test for chi-square distribution (Figure 4.25.) is greater than 0.05. Therefore, it is concluded that progress payment delays in Project C can modelled by using chi-square distribution.

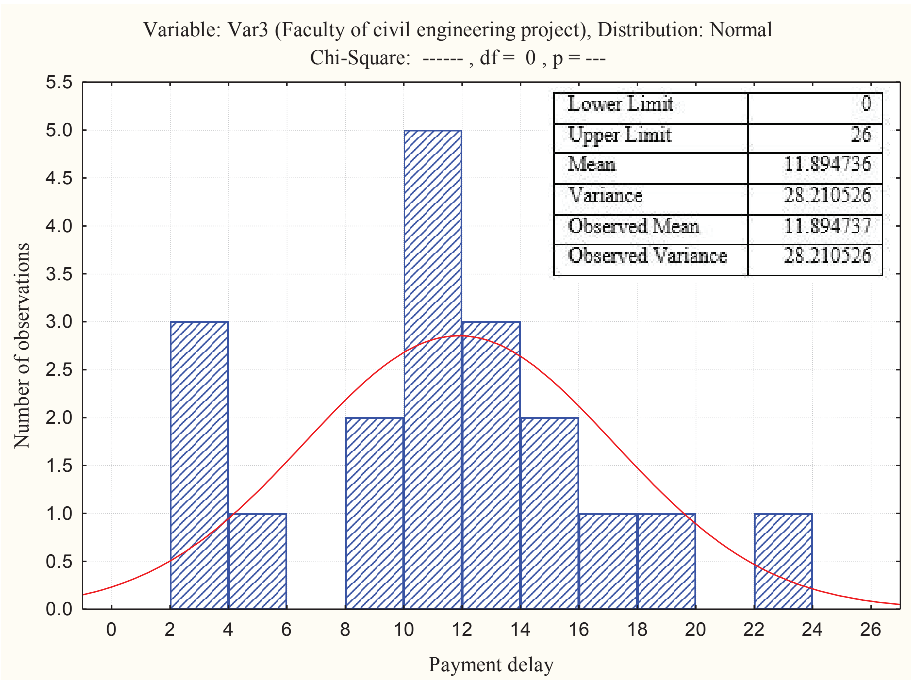

Figure 4.17. Frequency Distribution of Payment Delays for Project C and Normal Distribution Function

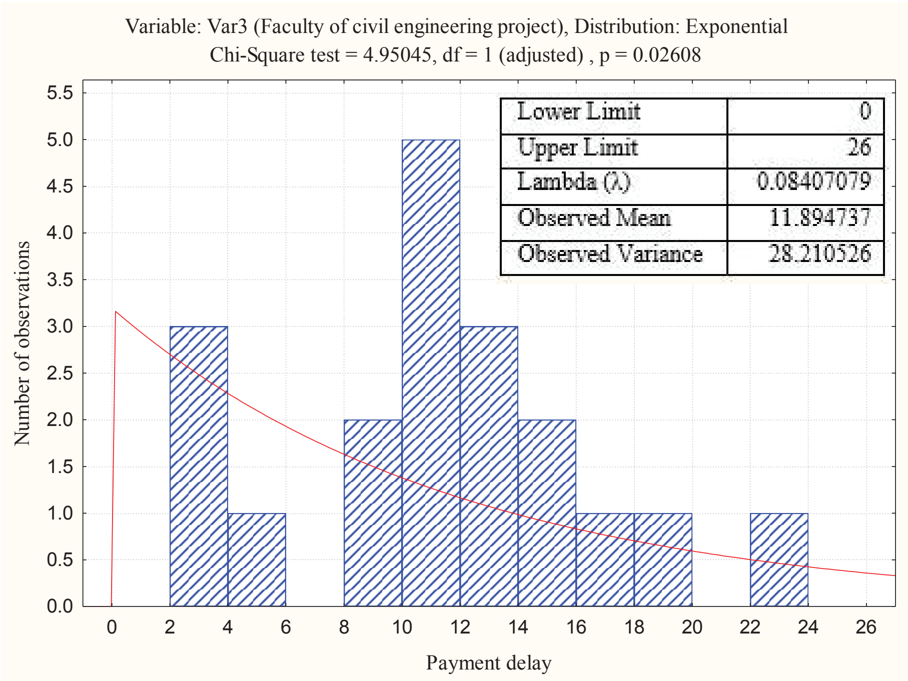

Figure 4.18. Frequency Distribution of Payment Delays for Project C and Exponential Distribution Function

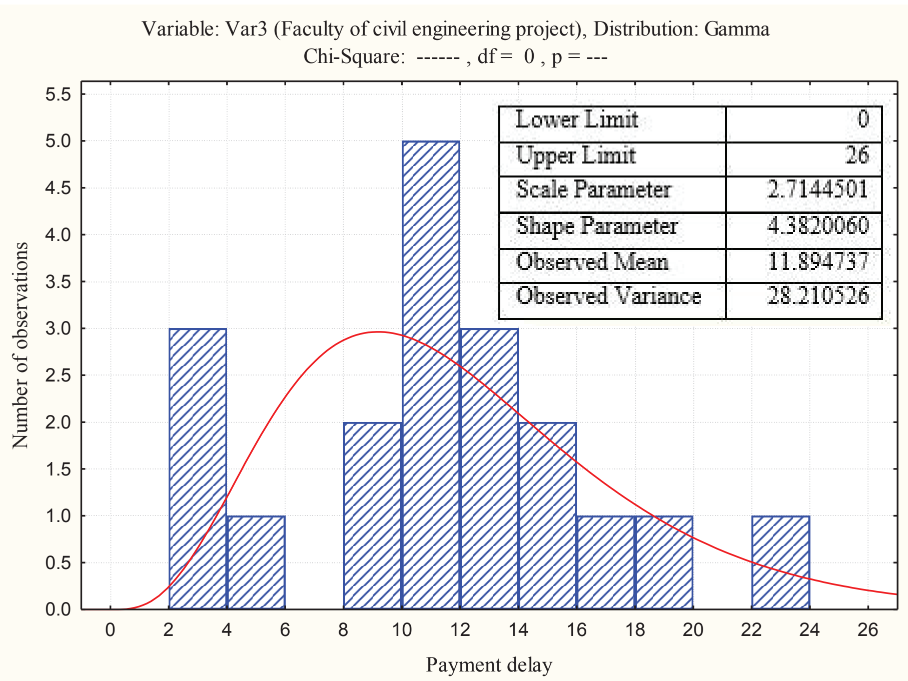

Figure 4.19. Frequency Distribution of Payment Delays for Project C and Gamma Distribution Function

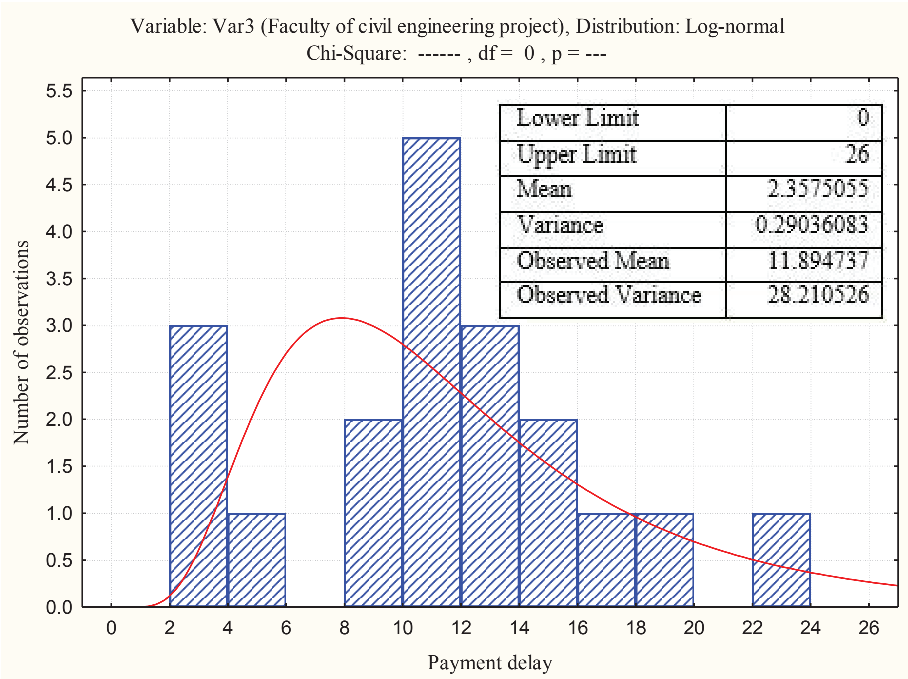

Figure 4.20. Frequency Distribution of Payment Delays for Project C and Lognormal Distribution Function

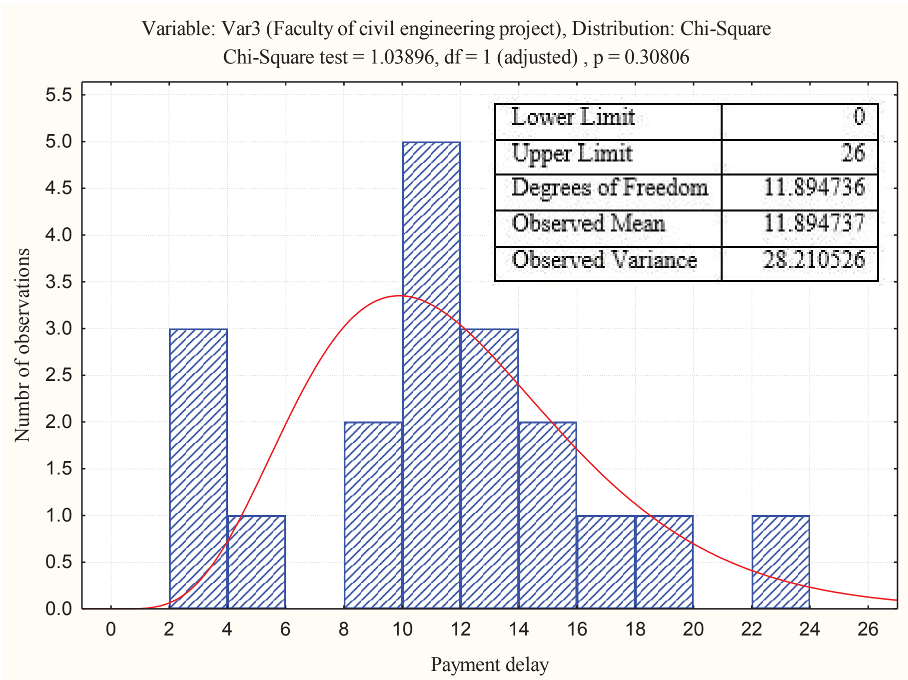

Figure 4.21. Frequency Distribution of Payment Delays for Project C and Chi-Square Distribution Function

Combing the data sets of payment delays observed in the construction projects (i.e., Project A, B and C) which were financed by the same public client presents a promising approach to identify the payment pattern of the public owner. The following section combines the three data sets to accurately forecast the payment pattern of the public owner.

4.4. Progress Payment Delays - Combined Sample of Projects

The mean and variance of payment delays for Project A, B and C are 16.98 and 12.81 days, respectively. A series of probability distribution fitting process (i.e., normal distribution, exponential distribution, gamma distribution, lognormal distribution Chi-square) was used to identify the most appropriate statistical distribution to forecast the frequency of occurrences of payment delays in Project A, B and C.

Figures 4.25, 4.26, 4.27, 4.28, and 4.29 present the results of statistical distribution fitting processes. It is clear from results of distribution fitting processes (i.e., chi-square test and *p* values) presented in Figures 4.20, 4.21, 4.22, 4.23, and 4.16 that the frequency distributions of payment delays for combined sample do follow normal, exponential, gamma or lognormal distribution functions because the significance values (p) of chi-square goodness-of-fit tests are smaller than 0.05 ($p < 0.05$). Yet the significance values (p) of goodness of test for gamma and lognormal distribution functions are 0.10 and 0.26, respectively. Yet the model presented in thesis uses lognormal distribution to forecast the frequency of occurrences of payment delays for the public owner because it has the highest significance value (p) which implies the closest fit to the data (i.e., combined sample of payment delays).

The following section presents simulations of progress payment delays based on lognormal distribution function for Project A, B and C. The mean and variance of lognormal distribution function for the combined sample of projects are 2.60 and 0.44 days, respectively. The mean and variance values are used to simulate the progress payment delays. All simulations used in thesis are based on 500 runs. The cost of payment delays is calculated by using Net Present Value (NPV) method.

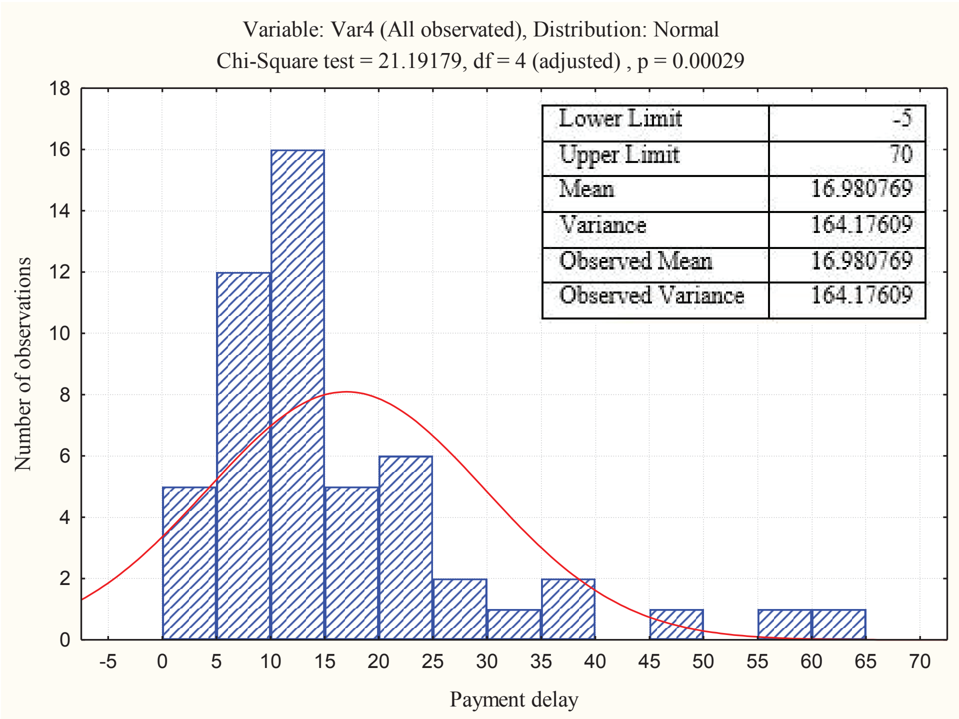

Figure 4.22. Frequency Distribution of Payment Delays for the Combined Sample of Projects and Normal Distribution Function

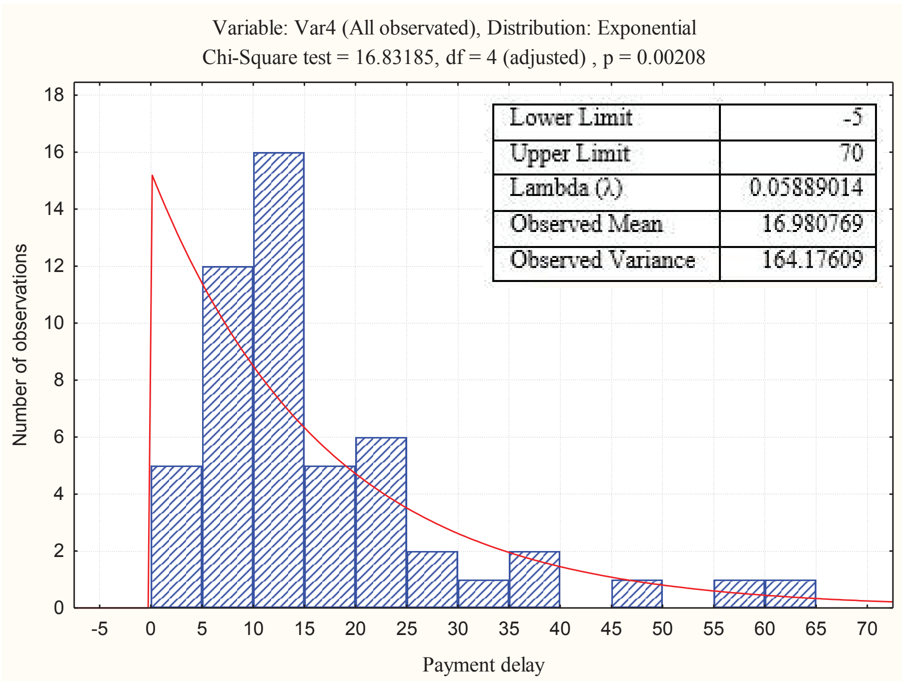

Figure 4.23. Frequency Distribution of Payment Delays for the Combined Sample of Projects and Exponential Distribution Function

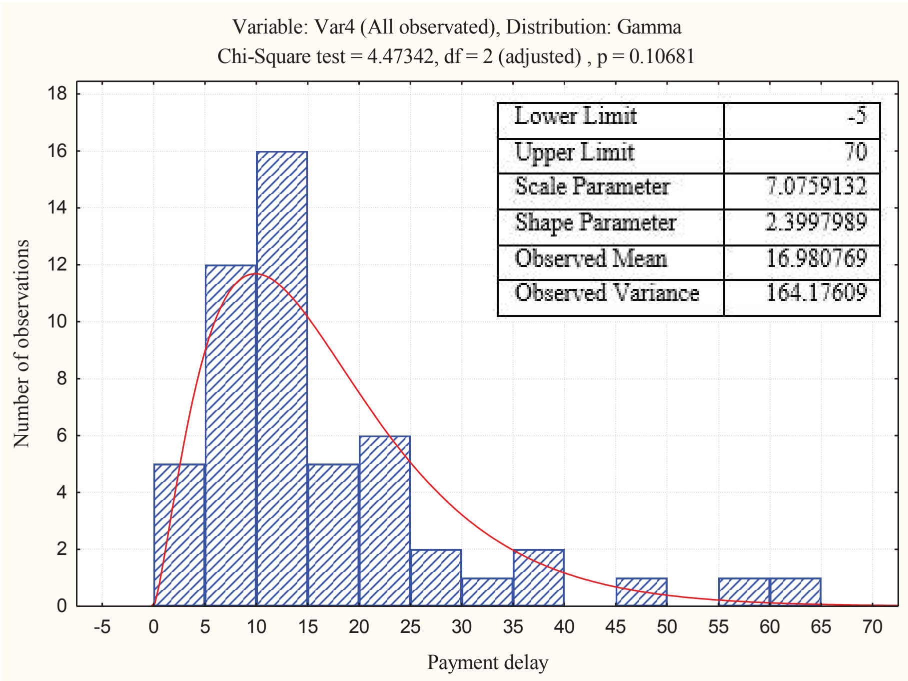

Figure 4.24. Frequency Distribution of Payment Delays for the Combined Sample of Projects and Gamma Distribution Function

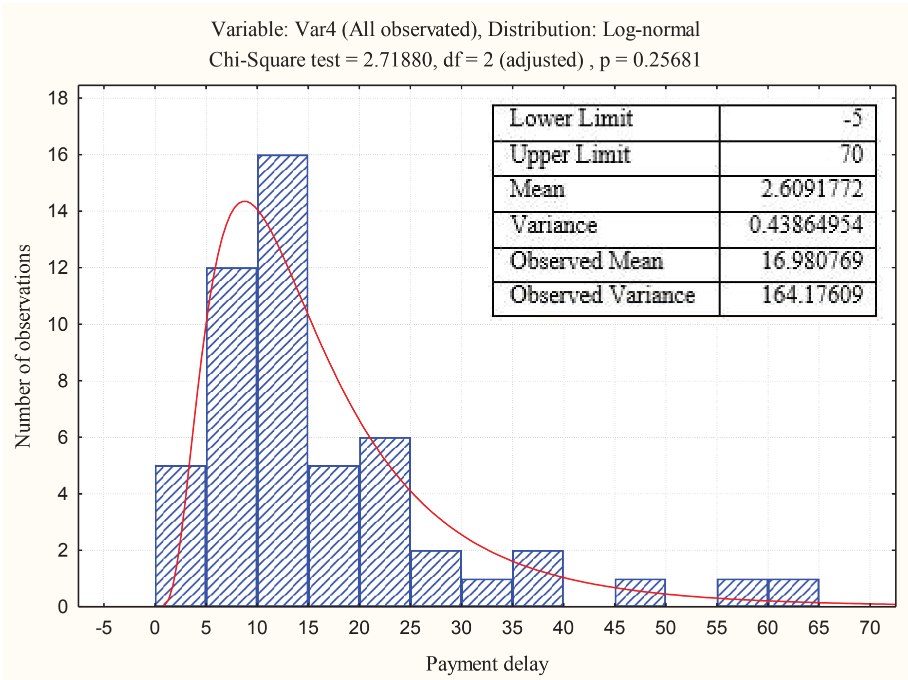

Figure 4.25. Frequency Distribution of Payment Delays for the Combined Sample of Projects and Lognormal Distribution Function

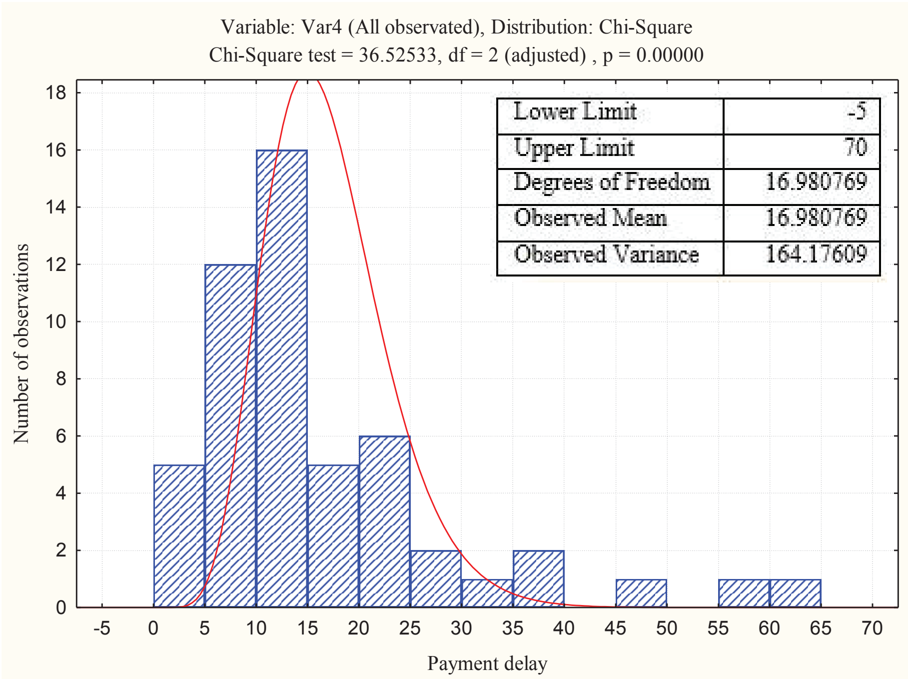

Figure 4.26. Frequency Distribution of Payment Delays for the Combined Sample of Projects and Chi-Square Distribution Function

Table 4.9. Distribution types of all construction projects

	Normal Distribution	Exponential Distribution	Gamma Distribution	Lognormal Distribution	Chi-Square Distribution
Project A	✗	✓	✗	✗	✓
Project B	✗	✗	✗	✗	✗
Project C	✗	✓	✗	✗	✓
Combined Sample	✗	✗	✓	✓	✗

The following sections present a series of comparison of the actual and simulated cost of payment delays and also evaluates the financial risks of payment delays for each project (Project A, B and C) based on Cash Flow at Risk (CFaR) method.

4.4.1. Cash Flow at Risk Analysis for Project A

The simulated frequency distribution of payments delays for Project A is in Figure 4.30.

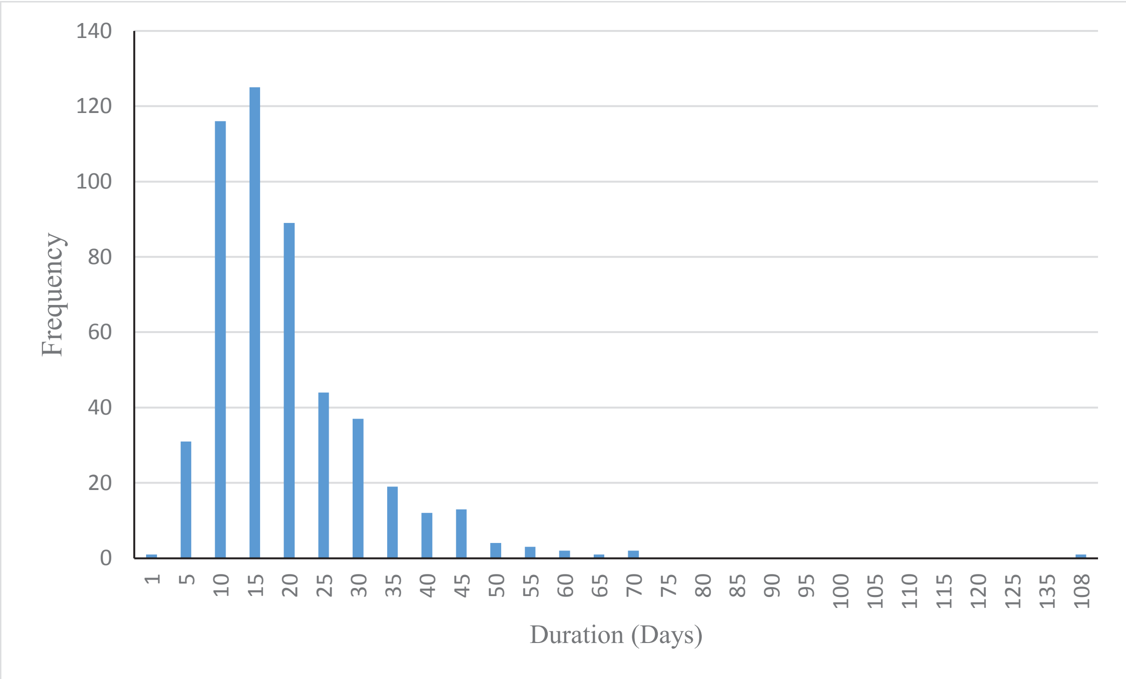

Figure 4.27. Payment Delays for Project A Based on 500 Runs

The mean of cost of payment delays based on 500 runs is 606,052. 03 TL with a minimum of 329,740.73 and with a maximum of 963,066.74 TL. The results of cash flow at risk analysis for Project are shown in Figure 4.32. It is clear from the simulation results present in Figure 4.32 that there is 99 % confidence that the cost of payment delays for Project A will not be greater than 849,612.54 TL. In other words, it is expected that the cost of payment delays for Project A will greater than 849,612.54 TL in one of out of hundred scenarios. The actual cost of late payments for Project A is 493,610. 87 TL. The forecasting accuracy (i.e., measured as percentage error) of the proposed model on 99% confidence interval is 72%.

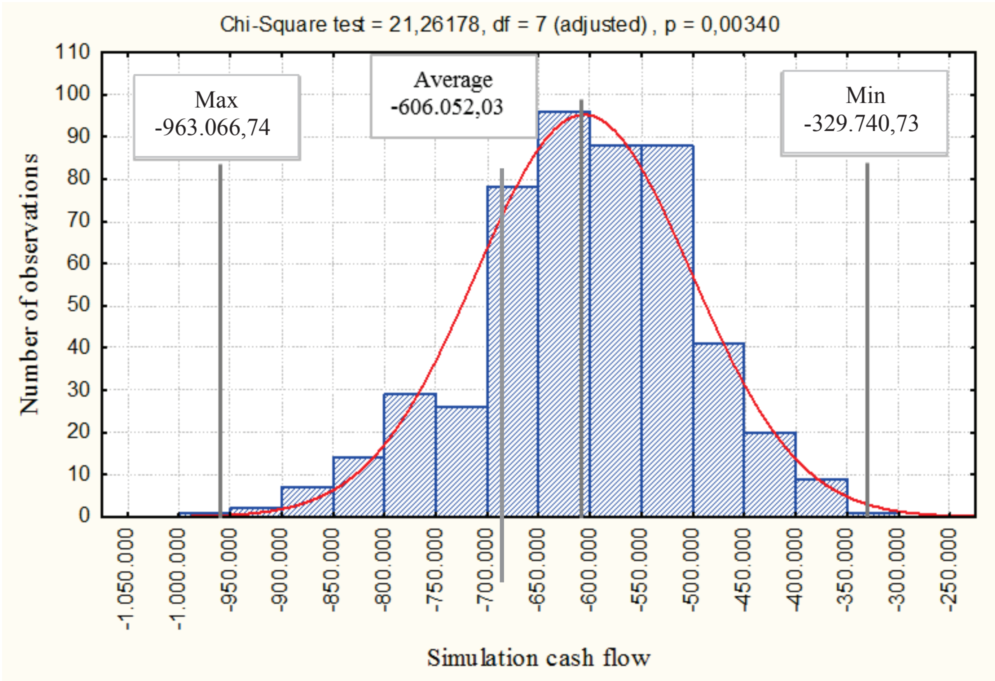

Figure 4.28. Cost of Payment Delays for Project A Based on 500 Runs

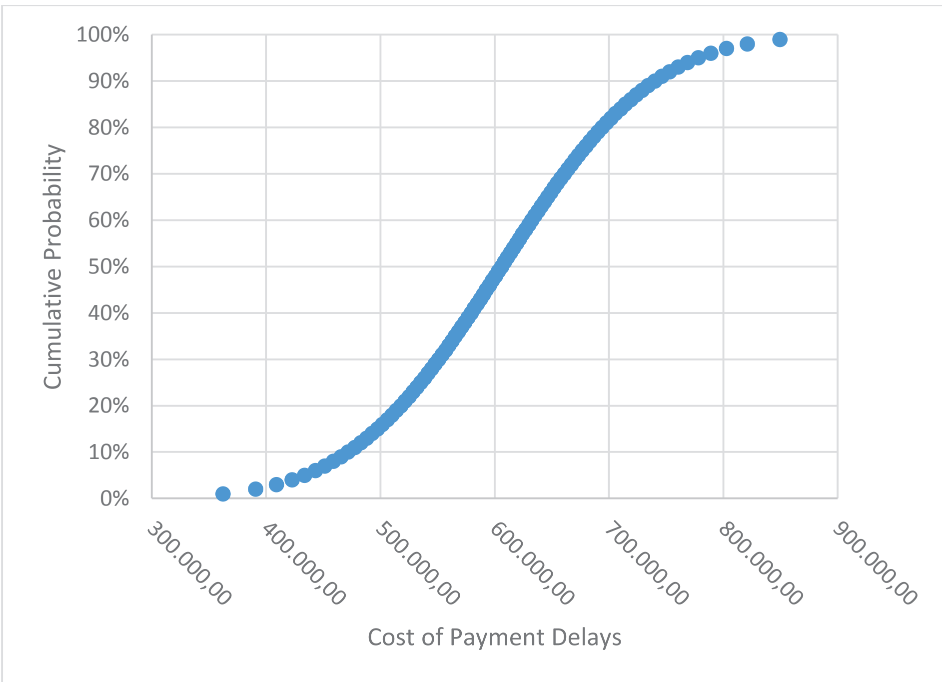

Figure 4.29. Cumulative Probability Distribution for Cost of Payment Delays for Project A

4.4.2. Cash Flow at Risk Analysis for Project B

The simulated frequency distribution of payments delays for Project B is in Figure 4.33. The mean of cost of payment delays based on 500 runs is 192,098.10 TL and with a minimum of 96,073.73 TL and with a maximum of 391, 413.05 TL.

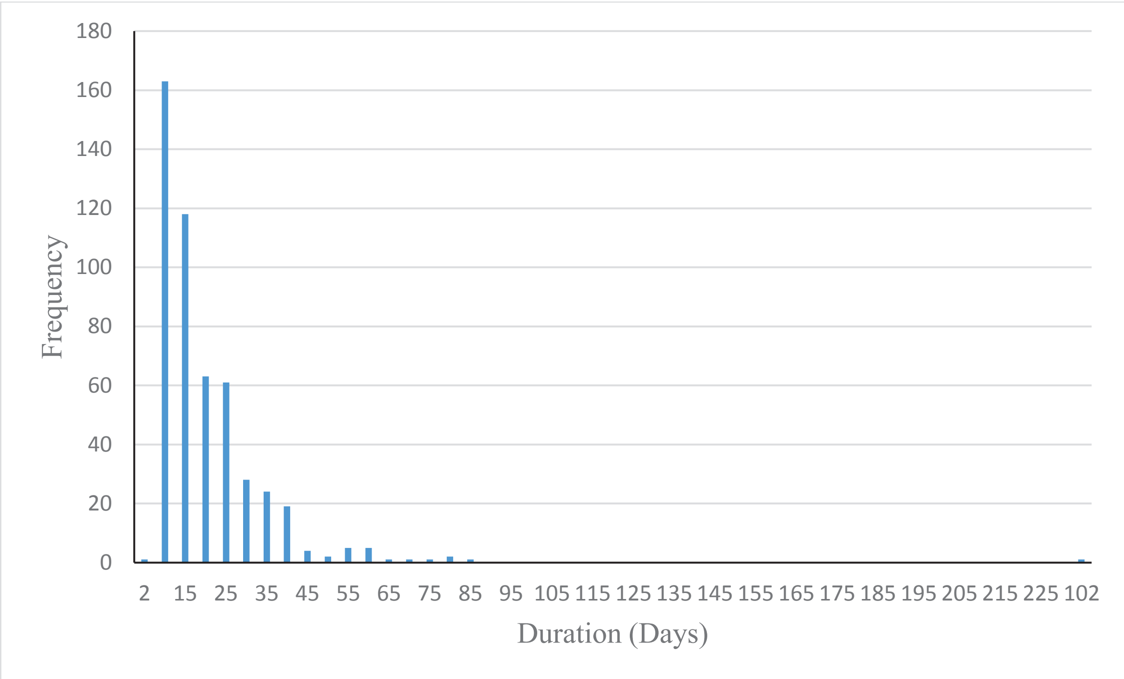

Figure 4.30. Payment Delays for Project B Based on 500 Runs

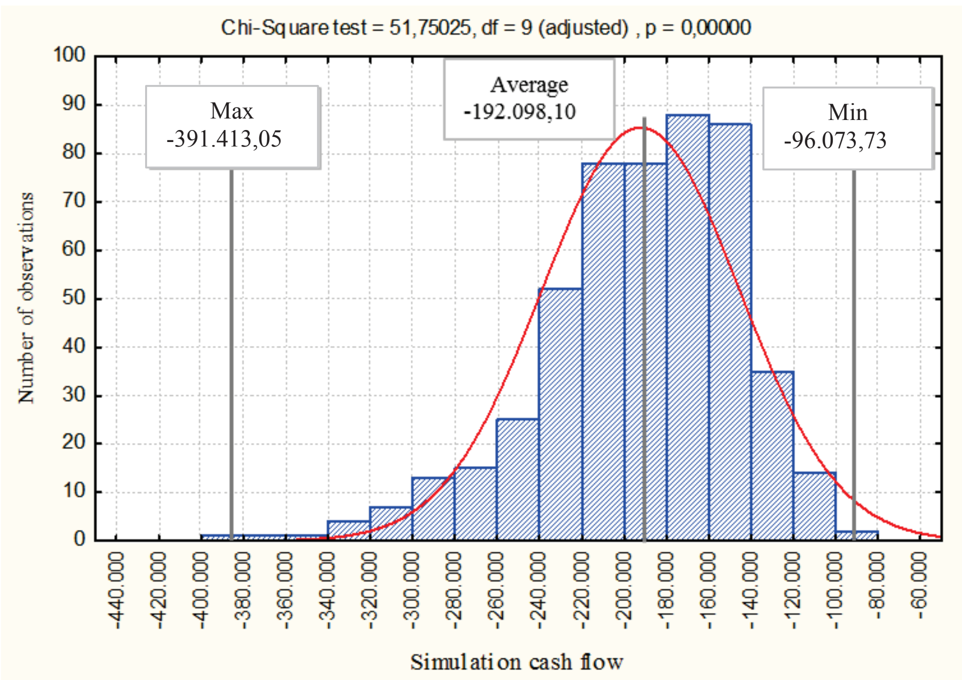

Figure 4.31. Cost of Payment Delays for Project B Based on 500 Runs

Figure 4.32. Cumulative Probability Distribution for Cost of Payment Delays for Project B

The results of cash flow at risk analysis for Project are shown in Figure 4.35. It is clear from the simulation results present in Figure 4.35 that there is 99 % confidence that the cost of payment delays for Project B will not be greater than 300, 788.34 TL. In other words, it is expected that the cost of payment delays for Project A will greater than 300, 788.34 TL in one of out of hundred scenarios. The actual cost of late payments for Project B is 837,113.66 TL. The forecasting accuracy (i.e., measured as percentage error) of the proposed cash flow at risk model on 99% confidence interval is 64%.

4.4.3. Project C

The simulated frequency distribution of payments delays for Project C is in Figure 4.36. The mean of cost of payment delays based on 500 runs is 504,120. 01 TL and with a minimum of 254,043.72 and with a maximum of 1,042,702.82 TL (Figure 4.37). The results of cash flow at risk analysis for Project C are shown in Figure 4.38. It is clear from the simulation results present in Figure 4.38 that there is 99 % confidence that the cost of payment delays for Project C will not be greater than 751,392.27 TL. In other words, it is expected that the cost of payment delays for Project A will greater than 751,392.27 TL in one of out of hundred scenarios.

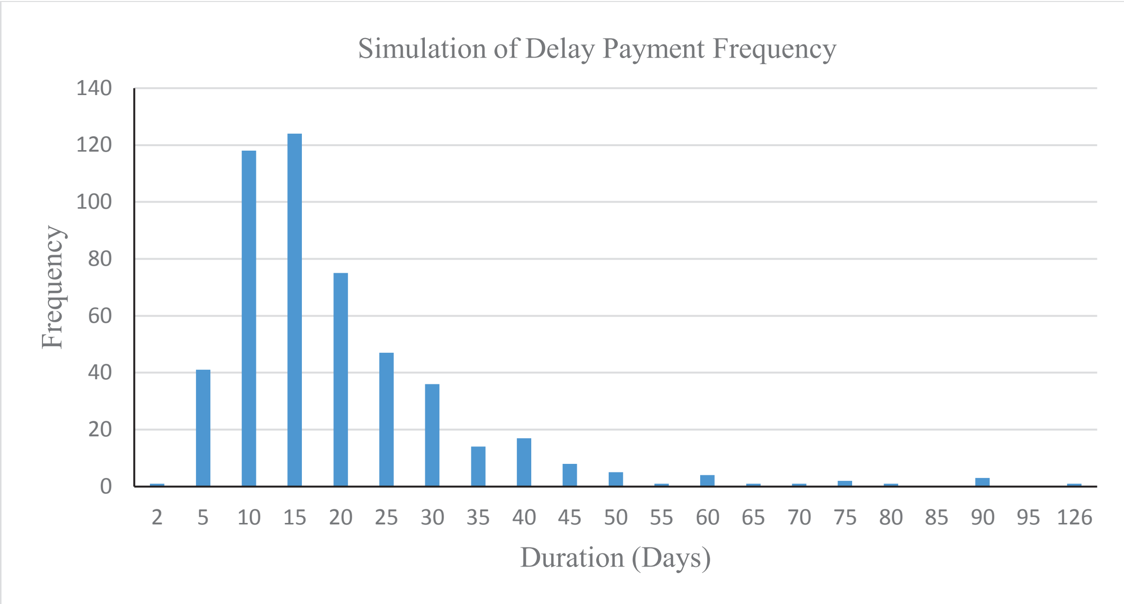

Figure 4.33. Payment delays for Project C Based on 500 Runs

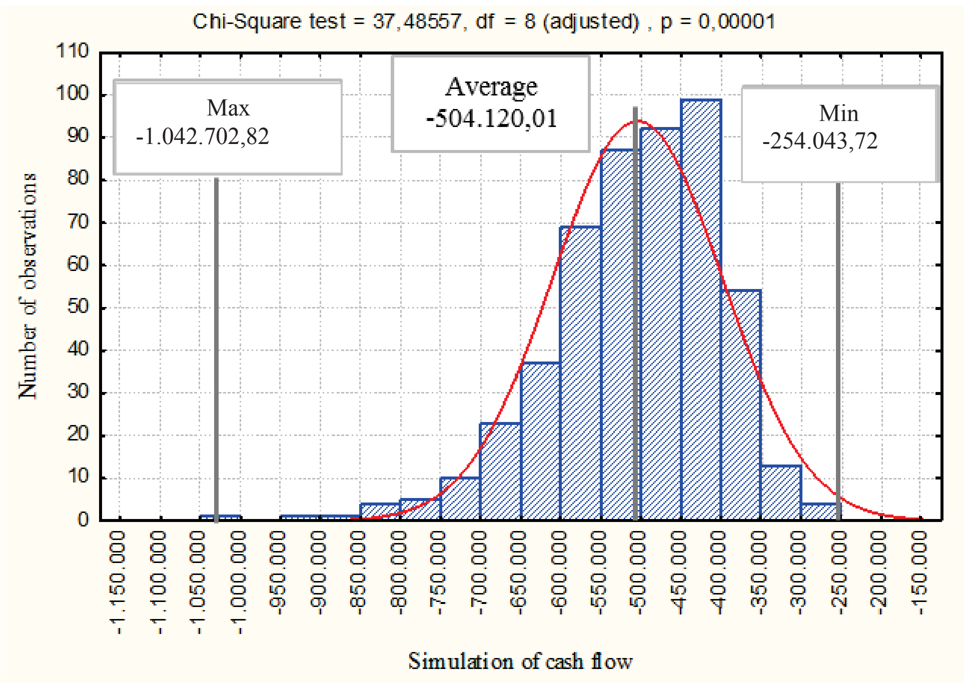

Figure 4.34. Cost of Payment Delays for Project C Based on 500 Runs

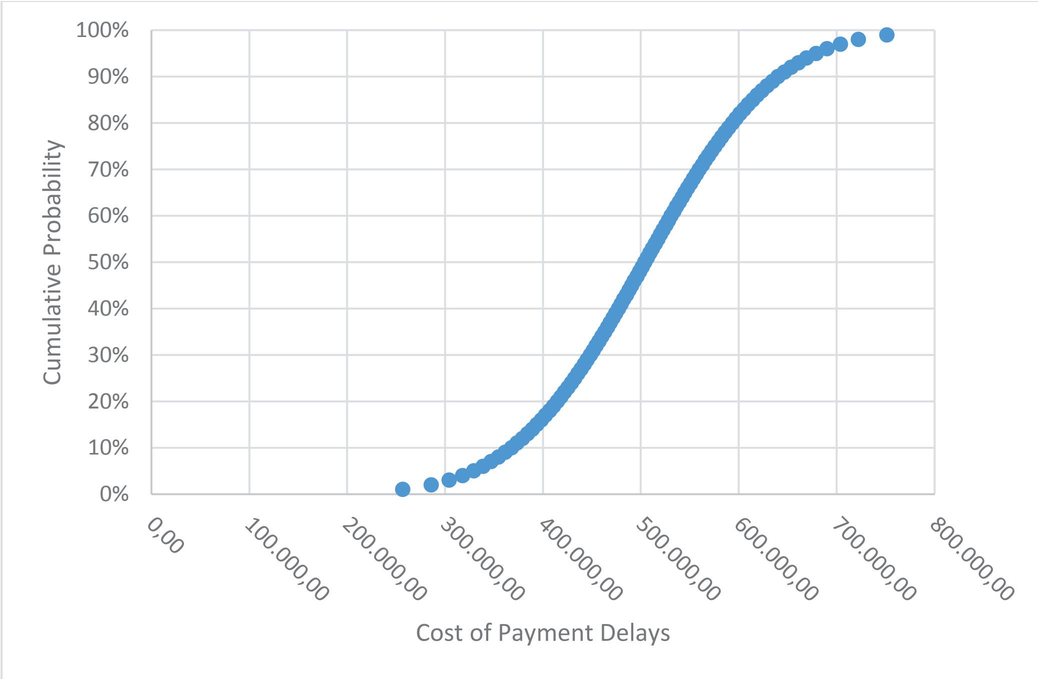

Figure 4.35. Cumulative Probability Distribution for Cost of Payment Delays for Project C

The actual cost of late payments for Project B is 506,967.18 TL. The forecasting accuracy (i.e., measured as percentage error) of the proposed model on 99% confidence interval is 48%.

The actual cost of payment delays used in the preceding sections include extreme payment delays (i.e., outliers). A standard deviation-based model (i.e., the number of

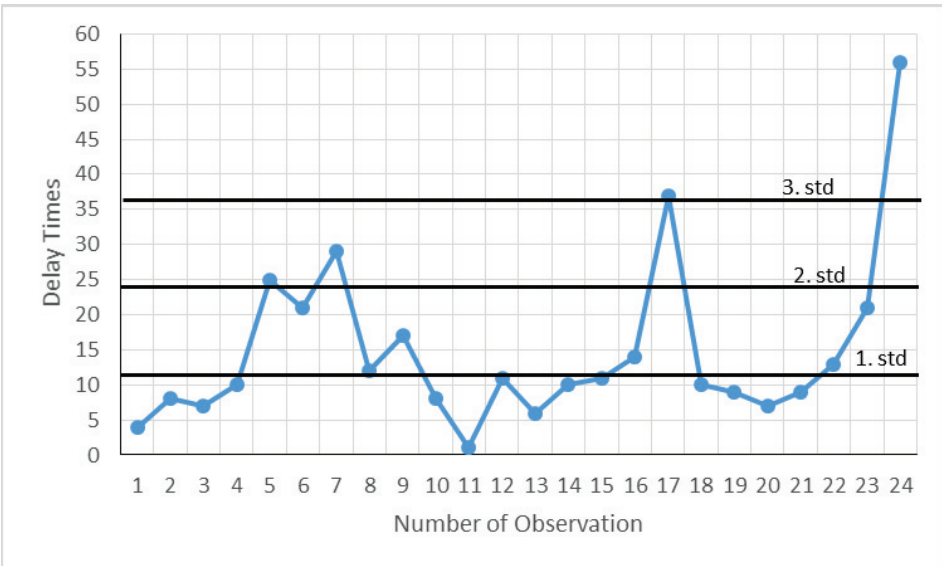

Figure 4.36. Extreme Payment Delay Analysis for Project A

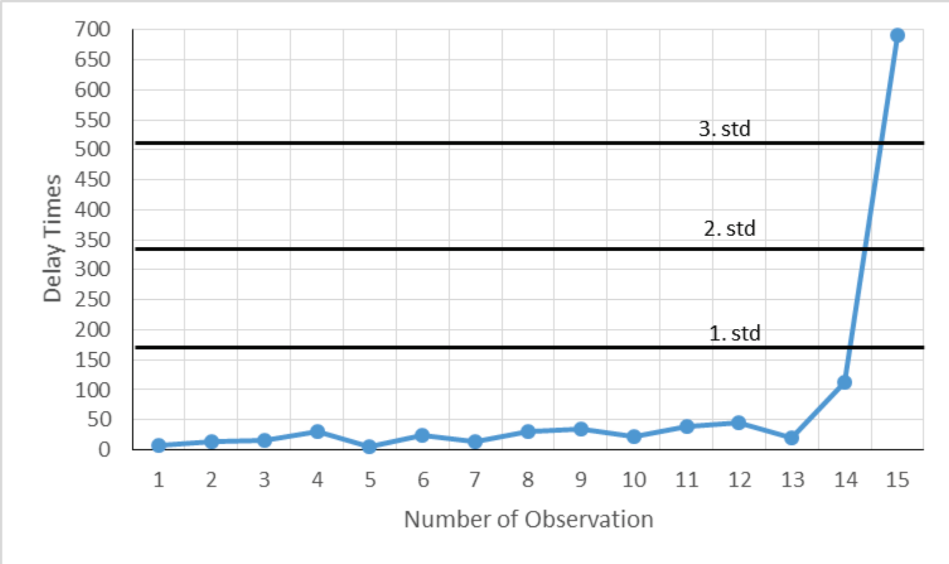

Figure 4.37. Extreme Payment Delay Analysis for Project B

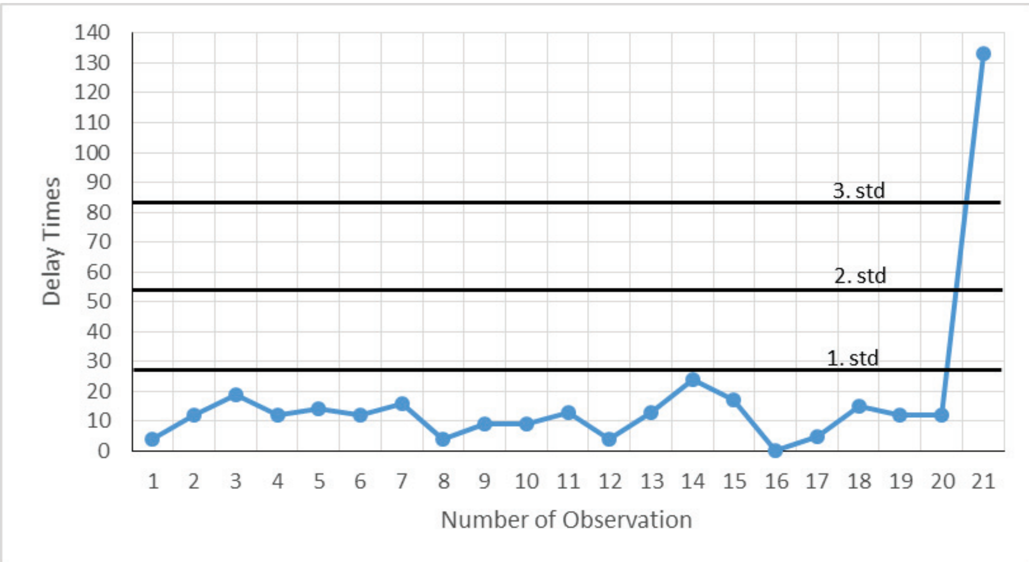

Figure 4.38. Extreme Payment Delay Analysis for Project C

standard deviations away from the mean) was used to detect and exclude outliers in this thesis (Figures 4.39, 4.40 and 4.41). The threshold value used in this outlier detection process was 3 standard deviations from the mean. The actual cost of payment delays based on outlier detection process is presented in Table 4.10.

Table 4.10. A Summary of Cash Flow at Risk Model Results

	Actual Cost of Payment Delays (Including Extreme Payment Delays)	**Actual Cost of Payment Delays** (Excluding Extreme Payment Delays)	**Combined Sample (Confidence Level % 90)**	**Combined Sample (confidence Level % 95)**	**Combined Sample (confidence Level % 99)**
Project A	493,610.87 TL	493,610.87 TL	740,226.01 TL	778,262.47 TL	849,612.54 TL
Project B	837,113.66 TL +	322,178.10 TL +	251,973.99 TL	268,947.97 TL	300,788.34 TL
Project C	506,967.18 TL +	336,290.27 TL +	640,339.03 TL	678,955.23 TL	751,392.79 TL

In sum, the results of CFaR model suggest that;

(1) the construction firm/we can be 90% confident/certain that the cost payment delays will not be greater than 740,226.01 TL for Project A, 251.973,99 TL for Project B and 640.339,03 TL for Project C,

(2) the construction firm/we can be 95% confident/certain that the cost payment delays will not be greater than 778,262.47 TL for Project A, 268,947,97 TL for Project B and 678.955,23 TL for Project C,

(3) the construction firm/we can be 99% confident/certain that the cost payment delays will not be greater than 849,612.54 TL for Project A, 300,788. 34 for Project B and 751,392.79 TL for Project C,

The cost of payment delays can be also defined as a percentage of contract price for a given confidence interval. The results of CFaR model suggest that;

(1) the construction firm/we are 90% confident that the cost of payment delays will not be greater than 6.41% of contract price for Project A, 5.80% of contract price for Project B and 5.08 % of contract price for Project C,

(2) the construction firm/we are 95% confident that the cost of payment delays will not be greater than 6.74% of contract price for Project A, 6.19% of contract price for Project B and 5.39 % of contract price for Project C, and

(3) the construction firm/we are 99% confident that the cost of payment delays will not be greater than 7.36% of contract price for Project A, 6.93% of contract price for Project B and 5.96% of contract price for Project C.

CHAPTER 5

CONCLUSION

Financial risks have been a major issue for the construction firms for quite long time. The main actor of construction industry, namely construction firms, is exposed to a significant amount of financials risks. Therefore, managing financial risks in construction firms has been a primary managerial task. Different financial risk management models have been proposed in literature to support this primary managerial task. Yet identifying the payment patterns of project owners has been a relatively ignored issue in the proposed financial risk management models. The research presented in this thesis presents a stochastic financial risk management model for construction firms. The proposed model builds on Cash Flow at Risk (CFaR) method and stochastic simulation.

Three case projects are used to illustrate the implementation and utility of the proposed model. The results of stochastic simulations point out (1) payment pattern(s) can be identified by using the proposed model and (2) construction firms can use the payment pattern(s) of their clients or project owners to forecast the cost of payment delays in construction projects (3) and the cost of payment delays can be used as an input to their pricing strategy/models and "bidding markup" decisions.

The model presented in this thesis has some limitations. The main limitations of the proposed model are:

(1) Only three construction projects were used to illustrate the utility and validity of the model

(2) All of three construction projects were completed for the use of the same public agency – repeated public project owner.

(3) Only payment delays caused by public agency were considered (i.e., – terms of payments for other parties such as subcontractors and suppliers were ignored),

(4) Value Added Tax (VAT) payments to the government were not used to forecast cost of payment delays

(5) Actual interim payments are known.

The research presented in this thesis can be a source of inspiration for developing financial risk management models based on project owner's payment patterns.

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