TIME AND COST OVERRUN IN PUBLIC CONSTRUCTION PROJECTS IN QATAR

A Project Report Submitted in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Engineering Management

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Remark

The term delay might be replaced with time overrun in the report.
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Abstract

This study aims to investigate time delays and cost overruns in public construction projects in the State of Qatar by developing statistical relations between projects’ contracted costs or durations and other variables. An extensive review of regional and international case studies was conducted to get a better understanding of the phenomena and of the various methodologies used to analyze it. The data of the study, which was collected from the public work authority ASHGHAL, covered 122 public roads, buildings, and drainage projects. Statistical techniques such as analysis of variances ANOVA and linear regression were used for the data analysis and inference. Four models were developed based on project type and its duration and cost. However, the models were limited in scope. Therefore, future work will involve adding more variables into the current models.
Chapter 1 : Introduction

1.1 Background and Need

Changes are facts of the construction process. The changes are issued to respond to newly developed circumstances. The changes can be small, well managed, and with little effects. However, changes are most likely large, poorly managed, and have tremendous negative impacts on project time and cost performances.

According to studies and reports, one of the major problems of the construction industry is project frequent delays and cost overruns. In today’s economic boom times and highly competitive business environment, the need for achieving construction projects within the stipulated cost, time frame and performance expectations is becoming increasingly important. Delays and cost overruns extend the duration of a project, inflate the budget, reduce revenues, and degrade productivity.

In the state of Qatar, ASHGHAL’s projects performed during the period between 2000 and 2013 had a cost overrun of 54% and a time delay of 72%. On the other hand, ASHGHAL’s maintenance projects during the same period had both cost overrun and time delay of 50%.

There is a real need to investigate the time delay and cost overrun in construction projects because of their criticality to the Qatari industry and the limited number of published studies in this area.
1.2 Problem Statement

The aim of this project is to study time delays and cost overruns in Qatari public construction projects. This project with obtained results is expected to help in understanding the time and cost overrun phenomena and guide project owners and construction managers to effectively plan for construction projects. The study is expected to lay the foundation for further research on the subject.

1.3 Objective of the Study

The main objectives of this project are to:

- Determine and analyze the time delays and cost overruns commonly found in Qatari public projects.
- Develop prediction models helps in calculating a project cost or schedule variation percentages based on the contract bidding value. Hence distinguishing projects with possible massive cost or time overrun by the time of selecting the winning bidder and signing the contract.

1.4 Scope and Limitations

The scope of the research is limited to public construction projects data obtained from public work authority - ASHGHAL. Data was used to investigate figures of delays and cost overruns in executed projects, prior to statistical analysis and model development.
1.5 Originality and Value

This document presents the first study, as far as the knowledge of the author and relevant literature, conducted in Qatar that investigate public new and maintenance construction projects carried out by Public Work Authority-ASHGHAL.
Chapter 2: Literature Review

Introduction

Historically, a construction boom triggers an upsurge in other sectors propelling other booms. Haseeb, Lu, Bibi, Dyian and Rabbani (2011) quoted an old French proverb in their analysis of delay effects on the construction industry of Pakistan: “When the construction industry prospers everything prospers”. While this statement is often true, construction delays have sometimes major negative impacts on the economy, which may affect many other sectors so that prosperity declines and economic distresses follow.

Major problems are inevitable in the construction industry because it is extremely complex, fragmented, and schedule and resource-driven. These problems can be cost overruns, deadline delays, delivery delays, poor quality of materials, poor workmanship, and low productivity, etc.

Nowadays many countries, including developing ones, are heavily investing in the construction industry and its affiliated support sectors. This massive investment is often a major part and even the back bone of the country national economy. The construction sector plays a major role in providing employment opportunities, and as such, its rise and decline strongly impact the national income (Sweis, 2013).

One major problem with the construction industry is the frequent delays of projects. In today’s booming economy and highly competitive business environment, the need to achieve construction projects within the stipulated cost, time frame and
performance expectations is becoming increasingly important. These time delays and cost overruns have negative effects and can lead to adverse effects on the growth of national economies, contribute to major financial losses, and hold back the development of the industry. A long-term study of a number of public works projects, which was conducted in the state of Nevada in the United States showed the negative and costly impacts of time delays. The study investigated several design-bid-built state projects from 1991 to 2008. It was concluded that large and long-duration projects had significantly higher cost and schedule overruns than smaller and short-duration projects (Shrestha et al., 2013). Similarly, infrastructure construction projects in Abu Dhabi, UAE showed 93% cost overrun averaging about 8.7% over original budget. Additionally, more than 90% of projects recorded an average delay of 8.3%. Halloum and Bajracharya (2012) concluded that project aspects such as scope definition, coordination of roles and responsibilities among involved parties, initial estimation and contingency planning, and monitoring and control systems are the main factors for time delays and cost overruns. Thus, it is important to determine the main factors causing construction time delays and cost overruns. This chapter investigates some the main causes of construction time delays and cost overruns and suggests few solutions to mitigate and reduce them.

2.1 Delays in Construction Industry

Most construction projects in developing countries are characterized by time delays (Sweis, 2013). Assaf and Al-Hejji (2006) recorded that approximately 70% of public construction projects in KSA suffered from delays caused by a number of factors.
Despite the fact that delay in the construction industry is a global phenomenon, the seriousness of this problem raises with ongoing development plans of massive investments. Thus, working to reduce time overrun is a common target.

A construction project comprises two phases: the pre-construction phase and the construction phase. The preconstruction phase represents the period from the project initial conception to its award. On the other hand, The project construction phase starts from contract awarding to its actual completion. Although they are expected to take place in both phases, delays mostly occur during the construction phase, where unforeseen factors likely arise.

**Construction Delays: Definitions and Effects**

There are several standard definitions of construction delays. According to Zack (2003), a delay can be defined as “… an act or event which extends required time to perform or complete work of the contract manifests itself as additional days of work”. Chan and Kumaraswamy (1995) stated that a delay is “an execution later than intended planned, or particular period, or letter than specific time that all the concerned parties agreed for construction projects.” Aibinu and Jagboro (2002) defined a delay as “… a situation when the contractor and the project owner jointly or severally contribute to the non-completion of the project within the original or the stipulated or agreed contract period”.

When delayed, projects are either accelerated or time extended. Delays extend the duration of a project, inflate the budget, reduce revenues, and degrade productivity.
Such delays usually cause legal problems between the owner, the contractor, and the consultant. Alavifar and Motamedi (2014) reported that projects with extensive delays may end up losing their economic justification, which in turn may result in the termination of the project.

Mahamid (2011) reported the following complications due to delays increase in governmental projects: 1) confusion regarding public development plans, 2) disturbance of the budget execution plan, and 3) public inconvenience resulting from project delays.

For a contractor, delays are additional liability, as the construction period becomes longer; this leads to higher overhead expenses, higher material costs due to inflation, and a possible increase in labor costs. An additional pitfall is the entrepreneur or client becoming trapped by one project if the entire working capital is needed for other concepts or projects.

Delays negatively affect all parties involved in a project: the client, the consultant, the contractor, the builders, the laborers, the suppliers, the users, etc. Although the causes of certain delays can sometimes be difficult to distinguish and may overlap, and it could be hard to determine who is responsible for what, delay problems are frequently the cause of dispute, negotiation, lawsuit, total desertion litigation and abandonment of projects.
Casual Factors of Construction Delays

Earlier papers were investigating possible causes of construction delays; many of these were then identified into various categories based on certain factors; according to frequency, severity and importance. Some of the studies included in the literature search were conducted in Iran, the KSA, the UAE, Jordan, Palestine, East Asia, Malaysia and Nigeria. Alavifar and Motamedi (2014) investigated number of delay causes in public projects in Iran, examining the perspectives from the owner, the consultant and the contractor. The causal factors were prioritized as to their importance, their frequency and severity of effect. Additional factors with respect to project management responsibility scale were queried and identified. Findings resulted in several recommendations and managerial solution to eliminate the causes of such delays. The major cause of construction - delivery delays are outlined below:

- Owner’s viewpoint: insufficient data collection and survey before design.
- Consultant’s viewpoint: a higher than expected increase in costs due to inflation.
- Contractor’s viewpoint: repair/reconstruction work due to errors during construction.

Sweis (2013) conducted a study to determine the cause of time overrun in public projects in Jordan. By examining the responses from engineers working in the public work authority and after reviewing actual projects data, Sweis identified the top major causes as:
• Poorly qualified staff assigned to the project; including consultants and engineers.
• Poor planning and scheduling by contractors.
• Adverse weather conditions.
• Delays caused by late/delayed governmental approval.
• Design changes.

Another study, conducted in Egypt by Marzouk and El-Rasas (2012) identified three main parties as responsible for construction delays: the owner, the consultant and the contractor. In addition, they cited other causes: these were material related, labor and equipment related, project related and other external factors. The study covered construction projects and was not restricted to any specific type of project. Data was analyzed according to time overrun significance of each group. Major causes were identified and ranked. Top significant causes are outlined below:

• Very high significance: Owner-related causes due to financing and payment of completed work, followed by changes in orders or of scope during construction.
• High significance: Contractor-related causes due to ineffective planning and scheduling of projects, followed by contractor difficulties in financing projects.
• Medium significance: Other external factors such as inflation, fluctuations in cost/currency, etc.
Time delay in road construction projects in the West Bank (Palestine) was studied by Mahamid (2011). The aim was to devise a risk matrix for factors affecting road projects from owner’s perspective. The most severe factors noted were:

- Poor communication among construction parties.
- Poor resources management.
- Delays in commencement
- Insufficient site inspection.
- Modifications and reconstruction work due to poor material quality and poor workmanship.
- Payment/salary delay.
- Political issues and West Bank segmentation and Israeli settlements

A study of Malaysian construction industry by Sambasivan and Soon (2006) identified the most important causes of delay. Different factors were grouped into eight categories: client-related, contractor-related, consultant-related, material, labor and equipment related, contract-related and contract relationship, and other external factors. In addition, delays were noted as more common in the traditional type of contracts in which the lowest bidder is awarded the contract. The three most important causes for construction delay were noted as contractor-related. These included:

- Improper planning:
• Poor site management;
• Inadequate and/or limited experience.

2.2 Cost Overrun in Construction Industry

The construction industry is well-known for its continual escalation in cost and going over anticipated budgets. This is partially due to ever increasing labor costs, material costs, inflation, delays and general economic situations and/or crises. As Flyvbjerg (2003b) noted, “Cost escalation has not decreased over the past 70 years.” In the construction industry, money is the basic component to initiate and fund projects, from schematic ideas to the accomplishment of a physical entity. However, cost overrun represents one of the most frequent issues and problems in construction projects worldwide; it is far more severe in developing countries, often with costs exceeding 100% of anticipated figures. In brief, cost overrun is a chronic and endemic problem that hinders project progress. Research findings note that are more cases of cost overrun than time overrun, making the problem of great significance, whose effects can drastically impact on those not even connected with the industry, i.e. the user and the buyer. There is, therefore, an overriding need to study these situations and examine the findings in order to come up with appropriate solutions that can alleviate these negative phenomena and help reduce their adverse financial manifestations and effects.

One sector often plagued by delays is the transport sector. Investments in transport infrastructure projects are very expensive. Cost overruns are common and
result in making these projects much expensive than originally planned; often they require an additional budget for completion. Because infrastructure investments are dependent on a fix budget, cost overrun in one project will cause financial consequences not only for the particular project under construction, but also for other projects; thereby resulting in a insufficient funds and a budget deficit. One example of an enormous escalation occurred in Netherlands, wherein 55% of Dutch transport infrastructure projects completed between 1980 and 2010 showed cost overrun with an average of 16.5% (Cantarelli, Molin, Wee and Flyvbjerg, 2012).

Another sector that frequently demonstrates delays and cost overrun is the construction of waste water projects. Aziz (2012) investigated this problem in his analysis of Egyptian wastewater projects, with the attempt to determine factors causing cost variation. He reported that some projects involved a 30% to 50% cost increase of the total estimated costs. Defined factors were ascribed to four main groups; owner-oriented, designer-oriented, contractor-oriented and miscellaneous. The main causes were found to be owner oriented; including:

- Lowest bidding procurement method;
- Additional unanticipated work requested by owner;
- Bureaucracy in bidding/tendering methods.
According to Park and Papadopoulou (2012) and other researchers, the majority of cost overruns are encountered in lump sum contracts, fewer occur in measurements contracts and even less in reimbursement contracts.

**Construction Cost Overrun: Definitions and Effects**

Cost overrun can simply be defined as an occurrence when the final cost of the project exceeds its original estimates (Avots, 1983). Cost overrun has several synonyms; examples of cost variation, cost escalation and budget overrun which are differences between the actual construction costs at completion and the contract price agreed between the client and the awarded contractor. In essence, cost overrun is a variation of initially budgeted cost in relation to the finalized actual cost.

All stakeholders are adversely affected by cost overrun. For instance, owners receive less return in investments; which leads to an increase in charges for end-users so the owner can recover this loss. End-users often bear the brunt of cost-overrun as they have to pay much more than originally anticipated. The consultant and design team may lose client confidence due to negative publicity of design and management and delays in the project, additionally, contractors suffer a significant reduction in profit margin. With regard to public sector projects, a government with cost overrun projects will need to act upon this predicament and scrutinize plans and plans and estimations more carefully; this may result in limiting investments in new projects temporarily.
Causal Factors of Cost Overrun

One of the most common factors influencing cost overrun in public sector is due to having a bid price based on current prices obtained at the tender time. This is not realistic as prices for materials and goods constantly increase and such increases should be factored into the anticipated cost. Delays from any or both parties, unstable markets and rising inflation with insufficient contingency percentage can all result in significant cost overrun. Additionally, cost overrun is strongly dependent on the length of implementation phase as reported by Flyvbjerg, Holm and Buhl (2003). Delays and long implementation phases represent significant risks of continuing and substantial cost escalations.

It is of note to mention that in most cases, delays caused by the contractor are often not excused, while delays might be excusable and compensable when the owner or the consultant is responsible. However, when the delay is the responsibility of the government, by mean approval processes, it's always excusable and compensable (Sweis 2013). Park and Papadopoulou (2012) conducted a study within the Asian Pacific region to identify the most significant causes of cost overrun in the construction industry. These are outlined as:

- Awarding contracts to the lowest bidder;
- Site conditions;
- Incompetent subcontractors and poor site management;
- Inaccurate estimates and client-led change orders.
As mentioned earlier, Aziz (2011) identified the top causative factors of cost overrun in the study of a waste management project in Egypt. Blame was put primarily on the owner, the designer and the contractor, although some miscellaneous causes were also cited. The cost overrun factors included poor design and delays in design; unrealistic contract time-frames, additional work requested by the owner/client and inexperience or lack of experience as well as late delivery of materials and equipment.

A study conducted by Kasimu (2012), noted that cost overrun factors arise in building projects construction in Nigeria included: financial factors, factors related to construction parties, factors related to construction items, environmental factors, and political factors. In his study, Kasimu identified the most significant impacts of each factor. The major cause of cost overrun are outlined as follows:

- Market conditions.
- Personal experience in the contract work.
- Insufficient estimated time for construction items.
- Material fluctuation.
- Political situations.

Based on the above illustrated studies, some recommendations to mitigate time delays in construction projects are:
• Accelerating the approval process in the governmental authorities by reviewing forms and modifying and improving regulations.

• Reducing design changes and change orders respectively, more accurate and complementary efforts must be implemented in the design stage.

• Providing training programs to achieve effective workforces and site supervision bodies.

• Preparing a comprehensive financial plan and cash flow.

• Maintaining payments to contractor for completed work and finished items according to terms specified in the contract.

Also, the increase in project size necessitates an improved planning process, though additional institutional set ups for infrastructure development and management. These are designed to alleviate some of the problems caused by cost overrun and limit delays.

Reducing cost overruns effects can be as:

• Contractors are to include material fluctuation rates once preparing time schedules for delivering material to site.

• Contractors should prepare method statements for projects undertaken.

• Consultants must avoid centralization of decisions related to consultant work to avoid delay.
Overall, mitigating cost and time overruns can be achieved by:

- Maintaining clear scope definition at early stages and to share this information with stakeholders and executing team.
- Improving initial cost and time estimates for accurate results.
- Adopting and enhancing monitoring and controlling systems.

To sum up, it is therefore crucial to emphasize on the fact that factors cause time delay and cost overrun are location and project type oriented. The major causes of overruns differ from country to country and cannot be generalized, although many share certain common denominators.

2.3 Delays and Cost Overruns in the Qatari Construction Industry

Qatar represents one of the most fastest growing economies nowadays. GDP growth was reported at 2013 to 6.5%, which equivalent to $202.5 billion. Adding to this, Qatar was announced as the highest saving rate in the world, with a percentage of saving recorded to 60.8% of GDP.

This open the door to further development through domestic investments in the non-hydrocarbon sector. Resulting in shifting major investments from oil and gas to construction and transportation sectors.

Construction industry showed the second largest growth in 2013 by contributing 2.7% to the non-hydrocarbon GDP growth. Construction activities are expanding rapidly
on the implementation of infrastructure projects, which are expected to be accomplished ahead of FIFA World Cup in 2022. The rapid growth was also reflected into sharp acceleration in contractors credit from 2% in 2012 to 41% by the end of 2013, as for performing major projects underway.

Major projects are mainly transportation and real estate developments. The significant Doha metro which expands along 216 KM, and is planned as an underground system supported with several metro stations. Public work authority ASHGHAL is ongoing of building a network of expressways comprises 30 major projects along 900 KM of roads. ASHGHAL has newly announced the Sharq crossing, a chain of tunnels and bridges, crossing Doha bay, to link new airport to west bay district and Luical city. that is In addition to new local roads and upgrading existing roads projects. Also, mega under construction projects are new port, the second phase of Hamad International Airport. A number of large under construction real estate projects are Lusail city, to the north of Doha and will include business, commercial and residential districts and Doha downtown Msherib. Figure 1. (Qatar Economic Insight April 2014, QNB group,2014)
Despite the optimistic figures, experts reported that the construction industry in Qatar is carrying a high level of risk to all stakeholders involved, and of consequences on project itself. The key risk are related to time, quality and cost.

A matter of fact, the construction sector, is suffering delay and cost overrun from contracted values. According to data collected from ASHGHAL, new projects are rating 54% cost overrun and 72% delay, on the other hand, maintenance projects achieve 50% for both cost overrun and delay. Newspaper articles and technical journals discussed number of high-profile delayed projects. Common names include the opening of Ezdan Mall and IKEA Doha festival city. Other public projects were also criticized.

The $1.7 billion Salwa road project, which aims to convert a jammed traffic road into a new layout of junctions, underpasses and bridges were a nightmare for vehicle movement and shops running along since construction began in 2010. The initial target was due to the end of 2012. However, the date was pushed to the third quarter of 2013.
The long-awaited Hamad International Airport, $15.5 billion planned investment $15.5bn was delayed four years. It was partially opened in April 2014, with a later phase expected to finish by year 2017-2018.

Sidra medical and research center represents the most ambitious medical research initiative to date, with the globally largest fund given to a medical center recorded as $7.9 billion. The construction phase was planned to achieve during 2009-2013. Early this year, the management team decided to delay the full operation of the facility to year 2015, although it was originally slated to receive patients in 2011, to follow a postponed date at the end of 2012.

Along with facts, Possible justifications to projects delay were mentioned as poor managing and controlling systems, manpower, construction material and equipments shortage, inappropriate estimation of massive scale of projects, harsh summer, funding constraints of private projects. Public projects are also suffering from different authorities interests clashing, imposed changes and unclear scopes and objectives.

While High costs are delivered from delays occurred, it could reflect some factors, as land values, defined quality and technical complexities, which are not considered in initial estimates due to data limitations.

Common recommendation was to handle significant projects by splitting deliverables into smaller phases to reduce the risk of overcapacity and mitigate time and cost overruns. The country could delay some development plans while directing resources as workers, materials and equipment to support critical infrastructure projects.
Besides articles, many research papers studied this phenomena among several countries, including the GCC as Kuwait, KSA and UAE, by investigating causes, examining results and conducting statistical relations among causing factors. However, only two published papers considering the booming Qatari construction market were found by the time of preparing this report.

The First paper by Al Jurf (2012) investigated factors affecting cost and schedule of private investments of residential compound projects. The study showed that 85% of the projects suffered cost or schedule overrun. The main reason was material delay and prices escalations. The second paper by Hussain (2012) aimed in defining causes of scope creep in governmental construction projects; defined as departments headquarters and small public service points. His paper confirmed an inverse relation between project size and direct cost of the scope creep While identified the main cause as poor identification of project scope among stakeholders and project team, leading to expensive changes.

The severity of delays and cost overrun come from high investments, this recall the need for building solid knowledge of possible factors, and developing procedures to use prior to extensive loss.
Chapter 3 : Research Methodology

The methodology followed in this research is similar to what was conducted in previous papers. Starting with data collecting, data mining, performing statistical analysis and building conclusions based on statistical findings.

For the purpose of investigating time and cost overruns in the construction of public projects in Qatar, data was requested from Public Work Authority- ASHGHAL, the only body representing and performing the role of the Qatari government.

A total of 122 projects were studied with a focus on the construction phase only. Constructions were to be completed between the year 2000 to year 2013 and all claims have to be settled by year 2013. Projects are lump sum contracts, while unit price is used for preparing tender documents. Also, projects are following the traditional delivery method design-bid-built, in which the lowest bidder is awarded.

Data collected include project category, project type, contract cost, contract duration, cost at completion and duration at completion. Time and cost overrun percentages had been calculated, using this data.

The data was studied using Analysis of Variance (ANOVA) and regression analysis. MS Excel 2007 software was used for both analyses. Details of data collection and analysis are described in next chapters.
Chapter 4 : Empirical Work

This chapter explains the gathering of needed data and statistical analysis performed.

4.1. Data Collection and Description

Proposing, tendering, awarding, construction supervising of public projects is under the responsibility of the Public Work Authority ASHGHAL. Any technical or financial information related to public projects is archived each into the concerned departments.

A formal letter from the graduate department had issued, reporting the objective of the research undertaken, and asking for possible collaboration to help the author in her task. Several meetings with head of departments were conducted, to discuss the project and get needed approvals. Other meetings with project managers and planning engineers were set up to discuss the topic and get more clarifications through discussing some cases and followed procedures at ASHGHAL. Once the approval was gained, proposed data had been sent to the student.

According to ASHGHAL, public projects are classified into roads, buildings and drainage projects, and being categorized as new construction or maintenance projects.

Road projects include the design, construction, delivery and maintenance of all expressways, major and minor roads all over the country. The same role applies to
buildings projects of public buildings and amenities for a number of government entities, including schools, hospitals, parks and cultural centers. Drainage projects represent storm and rain water, waste water and sewerage drainage and treatment projects across Qatar.

Data for 122 projects was received from ASHGHAL. Projects for analysis follow special criteria;

1. All projects should have started in or after the year 2000,
2. Finish date should be between 2000 to 2013,
3. Claims had to be settled by 2013,
4. All projects are lump sum contracts, 
5. Projects delivery method is design-bid-built, and award goes to lowest bidder, as per ASHGHAL procedure.

<table>
<thead>
<tr>
<th>Type</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>21</td>
<td>14</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>83</td>
</tr>
<tr>
<td>Buildings</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Drainage</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>14</td>
</tr>
</tbody>
</table>

Data collected covered project category, project type, contract cost, contract duration, cost at completion and duration at completion. Durations were for construction phase only. Durations were measured in calendar days, and costs in Qatari Riyals. Road projects constitute 67% of total received data, 21% are building projects and 12% drainage projects. Drainage projects are only new construction projects.
Numerical formulas were used in calculating cost and time overrun percentages as follows:

$$Cost\text{Overrun}(\%) = \frac{Project\ Actual\ Cost - Project\ Contract\ Cost}{Project\ Contract\ Cost} \times 100$$

$$Time\ Overrun\ (\%) = \frac{Project\ Actual\ Duration - Project\ Contract\ Duration}{Project\ Contract\ Duration} \times 100$$

Where project contract cost is the estimated cost at contract signing and includes all major works, overheads and contingencies.

Project contract duration represents the baseline estimated duration, which covers only the construction phase.

4.2. Data Analysis

To start investigating collected data, ANOVA was used to help in determining the statistical difference between multiple defined groups. Data provided several criteria to compare among in relation to delay and cost overrun. The next step was to check possible relations linking cost overrun or time overrun to each variable. This had been performed
using linear regression analysis. Both analyses were implemented using MS-Excel 2007 software.

### 4.2.1. Single Factor ANOVA Test

Statistical analysis was used to compare samples. ANOVA was used to determine if differences were statistically significant. The confidence level selected for the analysis was set to 95%.

ANOVA assumed a null hypothesis, assuming that means of compared samples are to be statistically equal. For the null hypothesis to be false, the p-value must be less than or equal to 0.05. Given that the null hypothesis is true, the p-value represents the probability of observing a random sample that is at least as large as the observed sample. If the p-value is below 0.05, the difference in means is considered to be statistically significant (Weinstein, 2007).

This study covered the three projects types, road, building and drainage construction projects, in which, cost and time overrun percentages were compared based on five categories as follows:

- **Project Type**
  - Road
  - Building
  - Drainage.

- **Project Category**
  - New construction
  - Maintenance construction
• Project Size; defined as the final construction cost.
  ▪ Final cost less than or equal QR10 million
  ▪ Final cost between QR10–QR100 million
  ▪ Final cost between QR100 –QR1000 million
  ▪ Final cost greater than QR1 billion.

• Project Duration; defined as the actual duration after completion.
  ▪ Duration less than or equal 1 year
  ▪ Duration between 1-2 years
  ▪ Duration between 2-3 years
  ▪ Duration between 3-4 years
  ▪ Duration greater than 4 years

• Project Year of Completion
  ▪ Projects completed from 2000-2006
  ▪ Projects completed from 2007-2013

Projects of positive cost and time overrun percentages were only considered for the analysis. Negative and zero percentages were eliminated, as the interest of this study defined by the author is to tackle the issue of costs increase and time delays.

Once multiple groups were identified, single factor ANOVA test was carried between the two groups of highest and lowest means.

4.2.2 Regression Analysis

To identify possible relations between cost or time overrun and project variables, regression analysis was employed. Regression analysis is used to ascertain the statistical relationship between two variables; an independent and a hypothesized dependent variable. In order to measure the strength of such obtained relationship, coefficient of
correlation $R$ and coefficient of determinations $R^2$ are reported. $R^2$ value ranges between 0-1; the higher value, the stronger correlation between variables.

Cost and time overrun were set as the dependent variables, while contract cost and contract duration were assumed to be the independent variables. A matrix; table 4.2, was developed to define which parameters are to be tested at each run. Projects were classified as projects type and project category for better understanding.

Table 4.2 Regression analysis matrix

<table>
<thead>
<tr>
<th></th>
<th>All Projects</th>
<th>New Projects</th>
<th>Maintenance Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All Project</strong></td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td><strong>Building Projects</strong></td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td><strong>Road Projects</strong></td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>****</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td><strong>Drainage Projects</strong></td>
<td>NA</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>****</td>
<td></td>
</tr>
</tbody>
</table>

* Cost overrun with respect to contract cost
** Cost overrun with respect to contract duration
*** Time overrun with respect to contract cost
**** Time overrun with respect to contract duration
Cost and time overrun of non-zero positive percentages were only considered for the analysis.

Points corresponding to a matrix relation were plotted into a scatter diagram. Best fit line, $R^2$ value and line equation were added. When data scattered in a substantial random way that prevented indicating a definite relation which satisfied all data, several intervals were defined, for intensive analysis.

Sample under the analysis went through four consequent steps, aiming to approach a satisfying $R^2$ value. Steps are:

1. Plotting all data in one chart.
2. Plotting data into several charts by defining the contract cost / contract duration into multiple intervals.
3. Examining the chart without eliminating outliers.
4. Examining the enhanced chart, after removing the outliers.

Due to the nature of data, author’s assumptions of accepted $R^2$ value to be 30% or above and obtained from a sample sized of more than four points, excluding the outliers, if any.
Chapter 5: Results and Discussion

Statistical tests were used to determine the descriptive statistics of dependent variables. The first test was to investigate whether sample means of various groups were statistically different or of equal variances. For this goal, MS-Excel 2007 ANOVA tool had been used.

Then, aiming to explore possible relationships between different variables, MS-Excel 2007 regression analysis tool had been performed. This helps in constructing a predict model to estimate cost and time overrun percentages in early stages, which represent the main purpose of the project.

5.1. Single Factor ANOVA Test

Results of testing the statistical differences between cost and time overrun percentages for projects as per different classification methods are tabulated in this section. It is important to mentioned that when multiple groups were identified, single factor ANOVA test was carried between the two groups of highest and lowest means, which are highlighted in each table.

Project Type

Project Type classified project in to Road, Building, and drainage.
Table 5.1. ANOVA project type

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Mean</th>
<th>F Value</th>
<th>P Value</th>
<th>F critical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Overrun % mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building</td>
<td>0.703341</td>
<td>0.596</td>
<td>0.449</td>
<td>4.351</td>
</tr>
<tr>
<td>Road</td>
<td>0.182</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage</td>
<td>0.108</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>4.645</td>
<td></td>
<td></td>
<td>Not significant</td>
</tr>
<tr>
<td>Number of projects</td>
<td>14</td>
<td>40</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Time Overrun % mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building</td>
<td>2.616</td>
<td>0.322</td>
<td>0.576</td>
<td>4.260</td>
</tr>
<tr>
<td>Road</td>
<td>0.815</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage</td>
<td>0.782</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>81.720</td>
<td>0.255</td>
<td></td>
<td>Not significant</td>
</tr>
<tr>
<td>Number of projects</td>
<td>18</td>
<td>51</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Where shaded cells define highest and lowest mean values.

Table 5.1 shows the mean value of construction cost and time overrun for different type of projects, along with F Value, P Value and F critical calculated from lowest and highest means.

The means of cost and time overrun were **not statistically significant** at alpha level, as the P value of both metrics are larger than 0.05 (0.05<0.449 and 0.05<0.576). It is concluded, statistically, that sample means were not different. Cost overrun of building projects was higher, then road projects and finally for drainage. The same sequence was for time overrun.

**Project Category**

Project Category was to compare between new construction projects and maintenance construction projects. Under this comparison, all project types were examined together. Then, building project and road projects were examined separately.
All Projects Comparison

Table 5.2. ANOVA project category

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Mean</th>
<th>F Value</th>
<th>P Value</th>
<th>F critical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New</td>
<td>Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Overrun % mean</td>
<td>0.365</td>
<td>0.170</td>
<td>0.521</td>
<td>0.473</td>
</tr>
<tr>
<td>Variance</td>
<td>1.724</td>
<td>0.024</td>
<td>Not significant</td>
<td></td>
</tr>
<tr>
<td>Number of projects</td>
<td>38</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Overrun % mean</td>
<td>1.560</td>
<td>0.590</td>
<td>0.837</td>
<td>0.363</td>
</tr>
<tr>
<td>Variance</td>
<td>28.835</td>
<td>0.369</td>
<td>Not significant</td>
<td></td>
</tr>
<tr>
<td>Number of projects</td>
<td>51</td>
<td>26</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2 shows the mean value of construction cost and time overrun for different projects category, along with F Value, P Value and F critical.

Although the cost overrun and time overrun was higher in new projects than in maintenance projects, the means were statistically equal and could be treated the same way. In another expression, new and maintenance projects were not statistically significant at alpha level 0.05 (0.05 <0.473 and 0.05<0.363).
Building Projects Comparison

Table 5.3 ANOVA building projects category

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Mean</th>
<th>F Value</th>
<th>P Value</th>
<th>F critical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New</td>
<td>Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Overrun % mean</td>
<td>0.953</td>
<td>0.078</td>
<td>0.451</td>
<td>0.515</td>
</tr>
<tr>
<td>Variance</td>
<td>6.465</td>
<td>0.003</td>
<td>Not significant</td>
<td></td>
</tr>
<tr>
<td>Number of projects</td>
<td>10</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Overrun % mean</td>
<td>3.057</td>
<td>0.412</td>
<td>0.204</td>
<td>0.658</td>
</tr>
<tr>
<td>Variance</td>
<td>97.978</td>
<td>0.028</td>
<td>Not significant</td>
<td></td>
</tr>
<tr>
<td>Number of projects</td>
<td>15</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.3 shows the mean value of construction cost and time overrun for building projects category, along with F Value, P Value and F critical.

Cost and time overrun means of new building projects were higher than maintenance projects. However, in both cases, both were not statistically significant at alpha level (0.05 <0.515 and 0.05<0.658).

Road Projects Comparison

Table 5.4 ANOVA road projects category

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Mean</th>
<th>F Value</th>
<th>P Value</th>
<th>F critical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New</td>
<td>Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Overrun % mean</td>
<td>0.174</td>
<td>0.189</td>
<td>0.062</td>
<td>0.805</td>
</tr>
<tr>
<td>Variance</td>
<td>0.042</td>
<td>0.027</td>
<td>Not significant</td>
<td></td>
</tr>
<tr>
<td>Number of projects</td>
<td>20</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Overrun % mean</td>
<td>0.980</td>
<td>0.614</td>
<td>2.821</td>
<td>0.099</td>
</tr>
<tr>
<td>Variance</td>
<td>0.756</td>
<td>0.412</td>
<td>Not significant</td>
<td></td>
</tr>
<tr>
<td>Number of projects</td>
<td>28</td>
<td>23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5.4 shows the mean value of construction cost and time overrun for Road projects category, along with F Value, P Value and F critical.

Maintenance road projects had higher cost overrun mean, while new road projects had higher time overrun mean. However they were not statistically significant at alpha level (0.05 <0.805 and 0.05<0.099)

**Project Size**

Project Size classified projects as the final construction cost. This had been applied to all projects regarding the type.

**Table 5.5. ANOVA project size**

| Metrics | Mean |  |  |  |  |  |  |
|---------|------|------|------|------|------|------|------|------|------|------|------|------|
|         |      | Less than 1 QR million | 10-100 QR million | 100-1000 QR million | Greater than 1 QR billion | F Value | P Value | F critical |
| Cost Overrun % mean | 0.148 | 0.387 | 0.193 | 0.120 | 0.072 | 0.790 | 4.130 |
| Variance | 0.034 | 1.922 | 0.029 | 0.022 |  |  |  |
| Number of projects | 10 | 34 | 16 | 2 |  |  |  |
| Time overrun % mean | 0.778 | 1.591 | 0.845 | 0.659 | 0.073 | 0.789 | 4.067 |
| Variance | 0.778 | 1.591 | 0.845 | 0.659 |  |  |  |
| Number of projects | 14 | 42 | 18 | 3 |  |  |  |

Where shaded cells define highest and lowest mean values.

Table 5.5 shows the mean value of construction cost and time overrun for projects sizes, along with F Value, P Value and F critical, calculated from lowest and highest means.
Means of cost and time overrun for project size ranges between QR10 million to QR100 million are the highest among, however, means are not statistically significant at alpha level 0.05 (0.05< 0.790 and 0.05<0.789).

**Project Duration**

Project Duration classified projects into five groups as shown. Durations of a project is defined as the actual duration spent on construction phase.

Table 5.6 ANOVA project duration

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Cost Overrun % mean mean</th>
<th>Variance</th>
<th>Number of projects</th>
<th>Time Overrun % mean</th>
<th>Variance</th>
<th>Number of projects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>less than 1 year</td>
<td>1-2 years</td>
<td>2-3 years</td>
<td>3-4 years</td>
<td>greater than 4 years</td>
<td></td>
</tr>
<tr>
<td>Cost Overrun %</td>
<td>0.140</td>
<td>0.518</td>
<td>0.143</td>
<td>0.238</td>
<td>0.150</td>
<td>0.569, 0.456</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.149</td>
</tr>
<tr>
<td>F Value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F critical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>0.03</td>
<td>2.964</td>
<td>0.01</td>
<td>0.035</td>
<td>0.019</td>
<td>Not significant</td>
</tr>
<tr>
<td>Number of projects</td>
<td>12</td>
<td>22</td>
<td>13</td>
<td>9</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Time Overrun %</td>
<td>0.554</td>
<td>1.648</td>
<td>0.907</td>
<td>0.902</td>
<td>1.662</td>
<td>11.652, 0.004</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.494</td>
</tr>
<tr>
<td>F Value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F critical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>0.221</td>
<td>46.205</td>
<td>0.576</td>
<td>0.403</td>
<td>0.834</td>
<td>Significant</td>
</tr>
<tr>
<td>Number of projects</td>
<td>11</td>
<td>32</td>
<td>17</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Where shaded cells define highest and lowest mean values.

Table 5.6 shows the mean value of construction cost and time overrun for projects of different durations, along with F Value, P Value and F critical, calculated from lowest and highest means.

Construction cost overrun mean for projects with duration ranges between 1-2 years and time overrun duration for projects of greater than 4 years were the highest, with
a noticeable difference recognized among cost overrun percentages of other durations. For cost overrun comparison, no statistical difference is obtained at alpha level 0.05 (0.05<0.456). on the other hand, P value calculated of time overrun percentages means showed that means are statistically significant at alpha level 0.05 (0.05>0.004).

Project Year of Completion

Project Year of Completion was to classify projects in to two time intervals, projects completed between 2000-2006 and projects completed between 2007-2013.

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Mean</th>
<th>F Value</th>
<th>P Value</th>
<th>F critical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000-2006</td>
<td>2007-2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Overrun % mean</td>
<td>0.900</td>
<td>0.143</td>
<td>5.606</td>
<td>0.021</td>
</tr>
<tr>
<td>Variance</td>
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</tr>
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<td>0.099</td>
</tr>
<tr>
<td>Time overrun % mean</td>
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<td>0.759</td>
<td>2.792</td>
<td>0.099</td>
</tr>
<tr>
<td>Variance</td>
<td>77.219</td>
<td>0.431</td>
<td></td>
<td>Not significant</td>
</tr>
<tr>
<td>Number of projects</td>
<td>19</td>
<td>58</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.7 shows the mean value of construction cost and time overrun for different completion year of projects, along with F Value, P Value and F critical.

The significant test performed on construction cost overrun showed that P value was less than the alpha level (0.05>0.021), confirming a difference in sample means. In addition to this, mean of projects completed in period 2007-2013 was higher than mean of projects completed in period 2000-2006.
For construction time overrun means, mean of projects completed in period 2000-2006 was higher than mean of projects completed in period 2007-2013. Yet, means were not statistically significant at alpha level 0.05 (0.05<0.099).

To conclude this part, it is found that as per all comparisons performed, only construction cost overrun of projects compared as per year of completion and construction time overrun of projects compared according to project duration were statistically significant, and did not have equal variances.

5.2 Regression Analysis

Results obtained by regression analysis were presented as follows:

Cost Overrun with Respect to Contract Cost

The statistical relationship was examined for each case study group as follows:

All Projects Group

This group comprised of 65 new and maintenance projects, with contract costs varied between QR3 million to QR2.2 billion. No significant correlation was found between cost overrun percentages and contract cost, as figure 5.1 showed scattered data, that produced $R^2 = 0$. 

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Figure 5.108. Project value and cost overrun correlation- all case study

To gain a better understanding, the massive scale of contract cost interval was divided three intervals as follows.

49 projects of contract costs less than QR100 million was plotted. After eliminating 4 outliers points, figure 5.2 indicated that cost overrun was moderately dependent on contract cost of projects within this interval. A positive correlation resulted in $R^2 = 0.377$.

Figure 5.2. Project value and cost overrun correlation- all case study less than QR100 million
Projects with contract costs between QR100 million to QR280 million showed a weak negative correlation. Figure 5.3 illustrated that data of 13 projects were very scattered and so, no outliers could be defined. $R^2$ was found to be 0.007.

![Figure 5.3](image)

Figure 5.3. Project value and cost overrun correlation— all case study QR100<X<QR280 million

Data collected showed a gap between QR280 million to QR750 million, QR750 million to QR1.3 billion and QR1.3 billion to QR2.2 billion. Thus, no clear conclusion could be obtained and a need of more data is raised.

Contract cost interval ranging between QR750 million to QR2.2 billion resulted in $R^2 = 0.728$, however, this result was not acceptable recalling the small size of the interval, being only 3 projects, as illustrated in Figure 5.4.
All New Projects Group

All new projects group included 39 projects. A Scatter diagram was plotted, figure 5.5. Yet, $R^2 = 0$ indicating no correlation between investigated variables.

Data was divided into 3 intervals, for deeper analysis. Projects with contract cost between QR3 million to QR45 millions were plotted, figure 5.6. Data of 19 projects were considered for this interval. After removing 2 outliers, the best value of $R^2$ was 0.199.
This low value of $R^2$ demonstrated weak negative relation, which was not accepted according to the authors’ assumption mentioned in chapter 4.

Along an interval of contract costs ranged between QR51 million to QR300 millions, 17 projects were distributed. Figure 5.7 showed that by removing 1 outlier, a negative correlation was confirmed supported with $R^2=0.409$.

A third interval ranges between QR750 million to QR2.2 billion and resulted in $R^2=0.728$, however, it was rejected due to inadequate sample size, and is shown in Figure 5.8.
All Maintenance Projects Group

All maintenance projects group showed a strong statistical relationship between cost overrun percentage and contract cost of projects. As illustrated in figure 5.9, a sample size of 23 projects and a defined outlier showed positive correlation with $R^2 = 0.448$.

All Building Projects Group

This sample showed a notable significant correlation between cost overrun and contract price. For building type projects, contract costs ranged between QR12 million to...
QR220 million and comprised of 15 projects. Figure 5. 10 showed strong positive relation of $R^2 = 0.674$.

![Graph showing project value and cost overrun correlation for building projects](image)

Although this result is satisfying for this type of projects, it was intended to investigate possible trends among different categories, that is to say, new construction building projects and maintenance building projects.

**New Building Projects Group**

Figure 5. 11 showed an increasing regression line, which represent a very strong correlation justified by high value of $R^2 = 0.753$. New building projects group gathered 11 projects.
Maintenance Building Projects Group

Although figure 5.12 showed a moderate relationship with $R^2 = 0.377$, this relation was not accepted due to small size of the study sample.

Drainage Projects Group

Despite the small number of projects included in this data set, a decreasing regression line and $R^2 = 0.694$ depicted in figure 5.13 confirmed a negative correlation.
between cost overrun and contract cost. This relation was obtained from a total sample of 8 drainage projects, but, after removing 2 outliers. This helped in focusing on projects with contract costs range between QR50 million to QR280 million.

Project of contract cost QR1.3 billion was eliminated due to the gape in the cost interval, which suggested requesting more data for comprehensive analysis.

**All Road Projects Group**

This group combined data from 42 road projects with contract costs between QR2 million up to QR2.2 billion. As represented in figure 5.14, scattered data showed no relation as $R^2 = 0$, and a need for intensive review was called for.

Tackling projects within contract cost interval of QR2 million to QR100 million as figure 5.15, 33 projected were included. With the elimination of 2 outliers, a
satisfying $R^2 = 0.416$ indicated a positive significant correlation between cost overrun and contract cost.

In contrast to the previous interval, projects with contract costs range between QR100 million to QR2.2 billion showed no correlation. Figure 5.16 showed an attempt to enhance the value of $R^2$. Yet, the obtained value showed a weak relation as $R^2 = 0.224$. Thus, it was not accepted due to the assumption of accepted $R^2$ value mentioned in chapter 4.

Figure 5.14. Project value and cost overrun correlation- Road projects

Figure 5.15. Project value and cost overrun correlation- Road projects less than QR100 million
Figure 5.16. Project value and cost overrun correlation- Road projects greater than QR100 million

**New Road Projects Group**

As shown in figure 5.17, data showed no correlation with $R^2 = 3 \times 10^{-6}$. This sample combined 21 projects along an interval of QR3 million to QR2.2 billion. Data were divided in to 2 set for better understanding.

Figure 5.17. Project value and cost overrun correlation- New road projects

Projects of contract costs less than QR100 million were plotted in figure 5.18. 11 points after eliminating an outlier point showed a significant strong correlation with $R^2 = 0.522$. 

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Figure 5.18. Project value and cost overrun correlation- New road projects less than QR100 million

Furthermore, projects with contract cost exceeding QR100 million showed a weak relation. Figure 5.19 illustrated a decreasing regression line with $R^2 = 0.224$, which was not considered for a reliable result.

Figure 5.19. Project value and cost overrun correlation- New road projects greater than QR100 million
**Maintenance Road Projects Group**

A notable strong relation is obtained from this group. 20 maintenance road projects with contract costs ranged between QR4 million to QR200 million were plotted, as shown in figure 5.20. \( R^2 = 0.511 \) represented a significant positive correlation.

![Figure 5.20: Project value and cost overrun correlation - New road projects greater than QR100 million](image)

To sum up this part, cost overrun percentage of new building projects, drainage projects, maintenance road projects, and new road projects with contract costs between QR3 million to QR100 million could be estimated using models discussed above. Projects from other contract costs and different classifications required more parameters for investigation. Table 5.8 summarize the analysis of this part.
Table 5.8 Cost overrun due to contract cost – Analysis summary

<table>
<thead>
<tr>
<th></th>
<th>All Projects Cost Deviation</th>
<th>New Projects Cost Deviation</th>
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<tbody>
<tr>
<td></td>
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<td>Several Interval</td>
</tr>
<tr>
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<td></td>
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<tr>
<td>$R^2=0%$</td>
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<td>65</td>
</tr>
<tr>
<td>int 1: $R^2=5.8%$</td>
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<td>49</td>
</tr>
<tr>
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<td>45</td>
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<td>13</td>
</tr>
<tr>
<td>int 3: $R^2=72.8%$</td>
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<td>3</td>
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<tr>
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</tr>
<tr>
<td><strong>Road</strong></td>
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<td></td>
</tr>
<tr>
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<td>42</td>
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<tr>
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<td>33</td>
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<tr>
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<td>9</td>
</tr>
<tr>
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<td>8</td>
</tr>
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<td>$R^2=75.3%$</td>
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<td><strong>Drainage</strong></td>
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</tr>
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<td>30&lt;X&lt;1310</td>
<td>8</td>
</tr>
<tr>
<td>$R^2=21.3%$</td>
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<td>7</td>
</tr>
<tr>
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<tr>
<td>Road</td>
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</tr>
<tr>
<td>---------</td>
<td>---------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td></td>
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</tr>
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</tr>
<tr>
<td></td>
<td>int 2: ( R^2 = 12.6% )</td>
<td>100&lt;X&lt;750</td>
</tr>
<tr>
<td></td>
<td>int 2: ( R^2 = 22.4% )</td>
<td>100&lt;X&lt;750</td>
</tr>
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</table>

### Improvement Projects Cost deviation

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<tr>
<th>One Interval</th>
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<th>interval M QR</th>
<th>Sample size</th>
<th>Include Outliers</th>
<th>Removed Outliers</th>
<th>Comments</th>
</tr>
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<td>( R^2 = 19.3% )</td>
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<td>X</td>
<td>(+ve) relation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( R^2 = 48.8% )</td>
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<td>22</td>
<td>1 point</td>
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<td></td>
</tr>
<tr>
<td>Building</td>
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<td>4</td>
<td>X</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Road</td>
<td>( R^2 = 19.1% )</td>
<td>3&lt;X&lt;200</td>
<td>21</td>
<td>X</td>
<td>(+ve) relation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( R^2 = 51.1% )</td>
<td>4&lt;X&lt;200</td>
<td>20</td>
<td>1 point</td>
<td>(+ve) relation</td>
<td></td>
</tr>
</tbody>
</table>

Where shaded cells highlight reliable outcomes

**Cost Overrun with Respect to Contract Duration**

The statistical relationship was investigated as following:

**All Projects group**

Figure 5. 21 showed all 64 projects data, with contract duration 149 days to 914 days. Data scattered randomly within the diagram, with a difficulty of representing a definite relation. \( R^2 = 0.004 \), concluding that no significant correlation was confirmed.
Five intervals were introduced, for better understanding.

For projects with contract duration 149 days to 179 days, low value $R^2 = 0.147$ indicated a weak correlation, yet with positive trend was illustrated in figure 5.22.

A high $R^2 = 0.664$, reflected a strong statistical relationship between cost overrun and contract duration. Figure 5.23 showed an increasing regression line for contract duration 297 days to 359 days.

Projects of contract durations range from 424 days to 547 days were plotted as figure 5.24. A satisfying relation was difficult to conduct, but a negative trend could be read with $R^2 = 0.138$.

A positive trend in cost overrun was demonstrated in figure 5.25, for projects with contract duration 607 days to 729 days. However, $R^2 = 0.045$ reflected a weak relation among variables.
Contract duration from 822 days to 914 days were showing a considered negative correlation between cost overrun and contract duration, justified with $R^2 = 0.749$. figure 5.26.

Figure 5.22. Project duration and cost overrun correlation- All projects 149<X<179 days

Figure 5.23. Project duration and cost overrun correlation- All projects 297<X<359 days

Figure 5.24. Project duration and cost overrun correlation- All projects 424<X<547 days
All New Projects Group

35 projects were classified as new construction projects, with contract duration of 149 days to 914 days. The case study showed random scattered points, that prevented defining a satisfying relation to all data. $R^2 = 0.031$ with negative tendency represented in figure 5.27.
Contract duration was divided into smaller intervals, aimed for a comprehensive analysis. 4 projects were defined within contract duration of 149 days to 179 days. Due to small sample size, assumption defined in chapter 4, this interval was not considered.

Projects with contract duration of 297 days to 363 days showed a moderate positive relation, with $R^2 = 0.359$. Figure 5.28.

A low value of $R^2 = 0.097$ indicated a weak relation among projects. Data of contract duration of 424 days to 547 days showed positive trend as in figure 5.29.
Projects with contract duration of 607 days to 729 days reflected an increasing regression line, yet of $R^2 = 0.084$, which is not considered. Figure 5.30.

Following the same increasing trend, and as depicted in figure 5.31, projects with contract duration of 899 days to 914 days resulted in $R^2 = 0.142$, specifying weak correlation.

![Graph 5.29](image)

Figure 5.29. Project duration and cost overrun correlation - All New projects 424<X<547 days

![Graph 5.30](image)

Figure 5.30. Project duration and cost overrun correlation - All New projects 607<X<729 days
Figure 5.31. Project duration and cost overrun correlation- All New projects $899<X<914$ days

**All Maintenance Projects Group**

This group comprised of 25 projects along an interval of contract duration of 149 days to 822 days. Figure 5.32 showed increasing of cost overrun percentages as the contract costs increased. A satisfying relation was difficult to conduct, and $R^2 = 0.046$ was obtained.

Figure 5.32. Project duration and cost overrun correlation- All maintenance projects $149<X<822$ days

Contract duration was defined in to 2 intervals. This helped in obtaining reliable models for each specified intervals.
Projects with contract duration of 149 days to 354 days illustrated in figure 5.33, showed a significant positive correlation. Data plotted resulted in high value of $R^2 = 0.553$.

![Figure 5.33](image)

**Figure 5.33. Project duration and cost overrun correlation- All Maintenance projects 149<X<328 days**

The same increasing tendency was carried on the interval 449 days to 882 days, with $R^2 = 0.340$, reflected a positive moderate correlation between variables. figure 5.34.

![Figure 5.34](image)

**Figure 5.34. Project duration and cost overrun correlation- All Maintenance projects 449<X<822 days**

**All Building Projects Group**

This group included 14 projects, with contract duration of 179 days to 607 days. Data was difficult to analyze using linear regression techniques, as $R^2 = 0.093$. Yet it
showed increasing of cost overrun percentages as the contract duration increased, which illustrated in figure 5.35.

Concentrating on data along contract duration of 179 days to 365 days, a notable strong correlation of positive trend was achieved, with $R^2 = 0.569$. Figure 5.36.

In contrast to results of previous interval, projects with contract duration of 438 days to 607 days demonstrated a weak correlation, with decreasing regression line and $R^2 = 0.005$. Figure 5.37.
New Building Projects Group

Projects with contract duration of 297days to 607days showed positive correlation between variables as depicted in figure 5.38. Yet, low value of $R^2 = 0.121$ demonstrated a weak correlation.

Despite the small size of the data set, with contract duration of 297days to 364days, the increasing regression line in the scatter plot and high value of $R^2 = 0.890$ showed in figure 5.39 confirmed a positive correlation between cost overrun and contract duration.

On the other hand, projects with durations greater than 438days showed no relation. Figure 5.40
**Maintenance Building Projects Group**

This Projects sample was not considered for the analysis, due to assumption of accepted sample size mentioned in chapter 4.
Drainage Projects Group

8 drainage projects were analyzed, with contract duration of 539 days to 914 days. A satisfying relation was difficult to conduct, and $R^2=0.056$ was gotten. However, a negative trend could be read, as illustrated in figure 5.41.

![Figure 5.41. Project duration and cost overrun correlation - Drainage projects 539<X<914 days](image)

All Road Projects Group

This group included 42 road projects along an interval of contract duration of 149 days to 912 days. Data was scattered randomly within the diagram, causing a difficulty in defining a relation among, with $R^2=0.003$ being produced. Figure 5.42.

Moreover, projects with contract duration less than 730 days demonstrated that no significant correlation was applicable, supported with $R^2=0.025$. Figure 5.43.

In contrast to previous data, figure 5.44 showed projects with contract duration of 822 days to 912 days, and represented a strong negative correlation. High $R^2$ value equal to 0.767 was obtained. Yet it wasn’t accepted because of small sample size.
Figure 5.42. Project duration and cost overrun correlation- All road projects 149<X<912 days

Figure 5.43. Project duration and cost overrun correlation- Road projects 149<X<730 days

Figure 5.44. Project duration and cost overrun correlation- Road projects 822<X<912 days

New Road Projects Group

21 new projects data along contract duration of 149 days to 912 days were plotted, as figure 5.45. sample was difficult to analyze using linear regression
techniques, due to randomly scattered data. Yet it showed a decreasing of cost overrun percentages as the contract duration increased. $R^2 = 0.045$, which is not considered.

![Figure 5.45. Project duration and cost overrun correlation- New road projects 149<X<912 days](image1)

**Maintenance Road Projects Group**

21 of road projects were classified as maintenance projects, with contract duration between 149 days to 882 days. The low value of $R^2 = 0.031$ demonstrated a weak correlation. However, figure 5. 46 showed an increasing of cost overrun percentages as the contract duration increased.

![Figure 5.46. Project duration and cost overrun correlation- Road projects 149<X<730 days](image2)
It had been concluded that correlation linking cost overrun percentage and contract duration was not adequate. Projects, with the exception of new building projects of contract duration 297 days to 364 days, show no or poor relations. This required more parameters for reliable results. Table 5.8 summarize the above analysis.

Table 5.9 Cost overrun due to contract duration - Analysis summary

<table>
<thead>
<tr>
<th>One Interval</th>
<th>Several Interval</th>
<th>interval day</th>
<th>Sample size</th>
<th>Include Outliers</th>
<th>Removed Outliers</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²=0.4%</td>
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<td>149&lt;X&lt;914</td>
<td>64</td>
<td>X</td>
<td></td>
<td>no relation</td>
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<td>X</td>
<td></td>
<td></td>
<td>(+ve) relation</td>
</tr>
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<td>X</td>
<td></td>
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</tr>
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<td>X</td>
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<td>X</td>
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<td>(+ve) relation</td>
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<td>X</td>
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<td>(-ve) relation</td>
</tr>
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<td>X</td>
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<td>(+ve) relation</td>
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<td>299&lt;X&lt;364</td>
<td>16</td>
<td>X</td>
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<tr>
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<td>13</td>
<td>X</td>
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</tr>
<tr>
<td>int 5: R²=2%</td>
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<td>5</td>
<td>X</td>
<td></td>
<td></td>
<td>(+ve) relation</td>
</tr>
<tr>
<td>int 6: R²=46.6%</td>
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<td>3</td>
<td>X</td>
<td></td>
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<td>X</td>
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<td></td>
<td>(+ve) relation</td>
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<tr>
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<td>X</td>
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<td>(+ve) relation</td>
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<td>int 5: R²=14.2%</td>
<td>899&lt;X&lt;914</td>
<td>5</td>
<td>X</td>
<td></td>
<td></td>
<td>(+ve) relation</td>
</tr>
</tbody>
</table>
Time Overrun with Respect to Contract Cost

The statistical relationship was examined for each case study group as following:

All Projects group

This group included 79 projects with contract costs varied between QR2 million to QR2.2 billion. No significant correlation was found and $R^2=0$ as illustrated in figure 5. 47. This resulted from fluctuating behavior of data along the cost interval. Further analysis was conducted as follows.

Where, shaded cells highlight reliable outcomes.
The first interval included projects with contract costs varied between QR2 million to QR5 million, shown in figure 5. 48, and illustrating a weak increasing relation with low $R^2=0.136$.

Following the same positive trend, a significant correlation was obtained for projects with contract costs varied between QR5 million to QR10 million. A high value of $R^2=0.553$ was obtained of 7 projects, and after removing an outlier, as figure 5. 49 illustrated.

No correlation was shown between projects of contract costs from QR10 million to QR30 million and time overrun. Figure 5. 50 shown the regression line with $R^2=0$.

Projects with contract costs varied between QR30 million to QR100 million confirmed a positive correlation, with $R^2=0.477$, depicted in figure 5. 51.

For projects greater than QR100 million, a satisfying relation was difficult to conduct, reflected by low value of $R^2=0.002$.Figure 5. 52
Figure 5.48. Project cost and time overrun correlation - All projects \( QR2 < X < QR5 \) million

\[
y = 0.355x - 0.234 \\
R^2 = 0.136
\]

Figure 5.49. Project cost and time overrun correlation - All projects \( QR5 < X < QR10 \) million

\[
y = 0.248x - 1.299 \\
R^2 = 0.553
\]

Figure 5.50. Project cost and time overrun correlation - All projects \( QR10 < X < QR30 \) million

\[
y = 0.001x + 0.543 \\
R^2 = 9E-05
\]
All New Projects Group

New construction projects comprise a sample of 53 projects, with contract costs between QR2 million to QR2.2 billion. Figure 5.53 showed data scattered randomly within the diagram, with a difficulty of representing a definite relation among, resulting in $R^2 = 0.001$. 
Projects of contract costs between QR2 million to QR20 million showed no correlation between variables of $R^2=0.008$, as indicated in figure 5.54.

In contrast to that, projects with contract costs between QR22 million to QR100 million confirmed a positive relation with $R^2=0.517$. figure 5.55.

A negative trend could be read for projects with contract costs between QR100 million to QR280 million, yet no satisfying correlation could be confirmed as $R^2=0.011$. Figure 5.56.

Projects with contract cost greater than 750 million were difficult to analyze using linear regression techniques, and came out with low $R^2=0.179$. But an increasing of time overrun percentages showed, as the contract costs increased, illustrated in figure 5.57.
Figure 5.54. Project cost and time overrun correlation - New projects QR2<X<QR22 million

Figure 5.55. Project cost and time overrun correlation - New projects QR22<X<QR100 million

Figure 5.56. Project cost and time overrun correlation - New projects QR104<X<QR280 million
All Maintenance Projects Group

This group included 26 projects, with contract costs between QR3 million to QR280 million. However, data was scattered in a random way with $R^2 = 0.012$, that prevent defining a relation to satisfy all data. Several intervals were defined to examine possible relations. Yet, all indicated the same conclusion as for the total interval. Figure 5. 58.
All Building Projects Group

In all building projects group, data of 19 projects were carried in the investigations, with contract costs between QR2 million to QR220 million. Figure 5. 59 showed that data was scattered randomly within the diagram, leading to a difficulty of representing a definite relation among all data, which were defined and studied. Data indicated no correlation, while $R^2 = 0.002$.

![Graph showing project cost and time overrun correlation for All Building Projects Group QR2<X<QR220 million](image)

Figure 5.59. Project cost and time overrun correlation- All building projects QR2<X<QR220 million

Interval of contract costs between QR25 million to QR120 million showed a strong positive correlation with $R^2 = 0.912$. Figure 5. 60. Interval of contract costs between QR2 million to QR25 million showed no correlation and had not mentioned in this part.
New Building Projects Group

This group contained the majority of projects studied in the previous group. Contract costs varied between QR2 million to QR280 million and concluded with no correlation, as for all building group. $R^2 = 0$ and data was illustrated in figure 5.61.

A reliable relation could be read for projects with contract costs between QR25 million to QR120 million, with $R^2 = 0.936$. Figure 5.62.
**Maintenance Building Projects Group**

Due to the size of this study sample, being less than the assumption followed by the author, the result was not accepted nor represented.

**Drainage Projects Group**

Despite the small size of the study sample, consisted of 6 projects, a decreasing regression line was plotted of $R^2 = 0.409$. Figure 5.63 confirmed a negative correlation between time overrun percentage and contract cost. This result applied to projects with contract cost between QR50 million to QR280 million.
When including more points, as in figure 5.64, the same negative relation is maintained. But a weak relation is expressed as \( R^2 = 0.174 \).

A need for more data was required, to cover the gap between QR280 million and QR1.3 billion, to obtain a clear accurate results.

**All Road Projects Group**

To study possible correlation between time overrun and contract costs among road projects, 52 projects were analyzed. Although the interval of contract cost covered
values between QR2 million to QR2.2 billion, the majority of projects were less than QR300 million.

Figure 5.65 showed random scattered data, which accumulated within the interval between QR2 million to QR300 million. This accumulation of data prevented defining a trend among the entire interval.

To perform a detail analysis, projects were plotted in 2 diagrams, for less than QR100 million and above QR100 million. Both diagrams resulted in unreliable correlation as $R^2 = 0.084$ and $R^2 = 0.020$ respectively. But, best fit line reflected a positive trend, that could be read, and perhaps, enhanced with more variables included. Figure 5.66 and 5.67.
New Road Projects Group

29 new road projects were analyzed. As for all road projects group, figure 5. 68 showed scattered data with contract costs between QR2 million to QR2.2 billion, Similarly, accumulation occurred between QR2 million to QR300 million.

No significant correlation was confirmed for the entire interval with \( R^2 = 0 \). the same result was obtained for projects with contract cost greater than QR100 million with \( R^2 = 0.010 \), figure 5. 69.
For projects with contract cost less than QR100 million, it indicated an increase in time overrun as the contract cost of the project increased. The low value of $R^2=0.262$ demonstrate weak correlation between variables. Yet, eliminating 1 outlier resulted in reliable relation with $R^2=0.442$, for the same set of data. Figure 5.70
Maintenance Road Projects Group

This group included 23 maintenance road projects, with contract costs between QR3 million to QR275 million. Most of the projects are of costs less than QR50 million.

As illustrated in figure 5.71, a satisfying relation was unable to conduct, due to the random scattering of data, and the gap between projects with costs exceeding QR50 million. It was found that $R^2 = 0.015$, and detailed analyses was carried on.
For projects with contract costs between QR3 million to QR15 million, moderate negative correlation was confirmed, while $R^2 = 0.356$, as shown in figure 5.72.

![Figure 5.72. Project cost and time overrun correlation- Maintenance road projects QR3<X<QR15 million](image)

The same behavior was confirmed for projects with contract costs between QR50 million to QR275 million, however, the low value of $R^2 = 0.298$ demonstrated weak correlation, figure 5.73.

Projects with contract costs between QR15 million to QR50 million, illustrated in figure 5.74, showed random scattered data, and no significant correlation.

![Figure 5.73. Project cost and time overrun correlation- Maintenance road projects QR50<X<QR275 million](image)
Results of this part concluded that time overrun percentage of new building projects of 25 million to QR120 million, drainage projects, new road projects with contract cost of QR30 million to QR100 million, and maintenance road projects with contract of QR3 million to QR15 million could be estimated using models discussed above.

Building projects and road projects with other contract durations required more parameters for investigations. Table 5.10 summarize discussion above.

Table 5.10 Time overrun due to contract cost – Analysis summary

<table>
<thead>
<tr>
<th>All Projects</th>
<th>Cost Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One Interval</td>
</tr>
<tr>
<td>R²=0</td>
<td>2&lt;X&lt;2200</td>
</tr>
<tr>
<td>int 1: R²=13.6%</td>
<td>2&lt;X&lt;5</td>
</tr>
<tr>
<td>int 2: R²=14.6%</td>
<td>5&lt;X&lt;10</td>
</tr>
<tr>
<td>int 2: R²=55.3%</td>
<td>5&lt;X&lt;10</td>
</tr>
<tr>
<td>int 3: R²=9*10⁻³%</td>
<td>10&lt;X&lt;30</td>
</tr>
<tr>
<td>int 4: R²=24.0%</td>
<td>30&lt;X&lt;100</td>
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<tr>
<td>int 4: R²=47.7%</td>
<td>30&lt;X&lt;100</td>
</tr>
<tr>
<td>int 5: R²=0.2%</td>
<td>100&lt;X&lt;2200</td>
</tr>
<tr>
<td></td>
<td>Building</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>int 1:</td>
</tr>
<tr>
<td></td>
<td>int 1:</td>
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<td>int 2:</td>
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<table>
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<th>X</th>
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<td></td>
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<td>41</td>
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<td>int 1:</td>
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<td>38</td>
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<td>(+ve) relation</td>
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<td></td>
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### New Projects Cost Deviation

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<th>Several Interval</th>
<th>interval M QR</th>
<th>Sample size</th>
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<th>Removed Outliers</th>
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<td>X</td>
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<td></td>
<td>int 1: R²=0.80%</td>
<td>2&lt;X&lt;20</td>
<td>21</td>
<td>X</td>
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<td>No relation</td>
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<tr>
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<td>int 2: R²=51.7%</td>
<td>22&lt;X&lt;100</td>
<td>15</td>
<td>X</td>
<td></td>
<td>(+ve) relation</td>
</tr>
<tr>
<td></td>
<td>int 3: R²=1.1%</td>
<td>104&lt;X&lt;280</td>
<td>13</td>
<td>X</td>
<td></td>
<td>(-ve) relation</td>
</tr>
<tr>
<td></td>
<td>int 4: R²=17.9%</td>
<td>750&lt;X&lt;2200</td>
<td>4</td>
<td>X</td>
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</tbody>
</table>

| Building     | R²=3*10⁻⁵%      | 2<X<220       | 16          | X                | (+ve) relation   |
|--------------|-----------------|---------------|-------------|------------------|------------------|-----------------|
|              | int 1: R²=3.7%  | 2<X<20        | 16          | X                | (+ve) relation   |
|              | int 2: R²=8.2%  | 25<X<218      | 6           | X                | (+ve) relation   |
|              | int 2: R²=93.6% | 25<X<218      | 5           | 1 point          | (+ve) relation   |

<table>
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<td>int 2: R²=1.0%</td>
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### Improvement Projects Cost deviation

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<th>Include Outliers</th>
<th>Removed Outliers</th>
<th>Comments</th>
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</thead>
<tbody>
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<td>R²=1.2%</td>
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<td>3&lt;X&lt;280</td>
<td>26</td>
<td>X</td>
<td>(-ve) relation</td>
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</tr>
<tr>
<td></td>
<td>int 1: R²=9.0%</td>
<td>3&lt;X&lt;50</td>
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<td>X</td>
<td>(-ve) relation</td>
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<td>2 points</td>
<td>(+ve) relation</td>
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<td></td>
<td>int 2: R²=29.8%</td>
<td>52&lt;X&lt;280</td>
<td>5</td>
<td>X</td>
<td>(-ve) relation</td>
<td></td>
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</table>
Time Overrun with Respect to Contract Duration

The statistical relationship was carried out as follows:

All Projects Group

Within this group, 77 projects were included, which combined both new and maintenance projects. Contract duration varied between 74 days to 1094 days. A weak correlation between time overrun percentages and contract duration, as figure 5.75 showed scattered data with a decreased trend, leading to low value of $R^2 = 0.009$.

Where shaded cells highlight reliable outcomes.

<table>
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<th>$R^2=37.2%$</th>
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<th>X</th>
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<td>X</td>
<td>No relation</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>int 2: $R^2=29.8%$ $50&lt;X&lt;280$ 5 X No relation</td>
</tr>
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Figure 5.75. Project duration and time overrun correlation- All projects
An attempt to enhance this weak correlation, duration was divided into 4 time intervals. As followed. Yet, no satisfying relation was considered.

Projects with Contract duration varied between 74 days to 179 days were plotted. Figure 5.76 illustrated negative relation obtained from 13 projects after removing 1 outlier. The low value of $R^2 = 0.285$ demonstrated a weak correlation between time overrun percentages and contract duration.

For contract durations between 240 days to 364 days, data of 31 projects were plotted as shown in figure 5.77. Negative weak relation was obtained with $R^2 = 0.044$.

A value of $R^2 = 0.128$ was achieved from 26 projects with contract durations between 424 days to 729 days, indicated a weak decreasing regression line, shown in figure 5.78.

Contract duration between 822 days to 1094 days were plotted, figure 5.79. However, data obtained from 7 projects confirmed a weak correlation with $R^2 = 0.181$.

![Figure 5.76. Project duration and time overrun correlation- All projects duration X<180 days](image)
All New Projects Group

This group included 51 projects spread along contract duration varied between 74 days to 1094 days. Although a decreasing regression line had fit the well scattered points,
low value of $R^2 = 0.009$ was calculated, demonstrated a weak relation, which not be considered. Figure 5. 80.

The same definition of intervals introduced in investigating all projects group was used here.

Figure 5.80. Project duration and time overrun correlation- New projects

Figure 5.81 showed projects of contract duration between 74 days to 179 days. Sample size of 6 projects, in addition to 1 outlier point removed, confirmed a strong negative relation between time overrun and contract duration, represented by $R^2 = 0.570$.

For projects of contract duration between 297 days to 364 days, figure 5.82 showed 6 projects with positive correlation. Yet, $R^2 = 0.194$ indicated a weak relation, which was not accepted.

Data from 20 projects with contract duration between 424 days to 729 days were plotted as figure 5. 83. A negative trend of the regression line is presented with $R^2 = 0.102$ reflecting weak relation between variable.
In contrast to previously mentioned intervals, a significant correlation of $R^2 = 0.478$ was obtained. This result was got from 6 projects of contract duration between 899 days to 1094 days. Figure 5.84.

Figure 5.81. Project duration and time overrun correlation- New projects duration less than X<180 days

Figure 5.82. Project duration and time overrun correlation- All projects duration 180<X<365 days

Figure 5.83. Project duration and time overrun correlation- All projects duration 365<X<730 days
All Maintenance Projects Group

All maintenance projects group gathered 26 projects of contract duration between 149 days to 822 days, Figure 5.85. Regression line showed negative relation between variable. Yet, low value of \( R^2 = 0.052 \) indicated weak relation and not accepted.

Figure 5.85. Project duration and time overrun correlation- All maintenance projects

Figure 5.86 represents data illustrated from 6 projects with contract duration between 149 days to 180 days resulted in \( R^2 = 0.161 \). Data points behaved with increasing trend, but weak correlation.
A notable strong statistical relationship between time overrun and project duration was illustrated in figure 5. 87.13 projects of contract duration between 240 days to 364 days represented a negative trend, supported with high $R^2$ value equal to 0.862.

The same trend was carried out during contract duration between 449 days to 822 days. Figure 5. 88 illustrated 7 projects with $R^2 = 0.420$, reflected significant correlation.

Figure 5.86. Project duration and time overrun correlation- All maintenance projects duration less than X<180 days

Figure 5.87. Project duration and time overrun correlation- All maintenance projects duration 180<X<365 days
All Building Projects Group

Data of 18 projects were classified as building projects. Data of contract duration between 170 days to 610 days was plotted into scattered randomly within the diagram, as shown in figure 5.89. With a difficulty of representing a definite relation among data, no correlations were indicated, as $R^2 = 0$.

Figure 5.90 showed the same data after removing 4 outlier points. A satisfying relation was difficult to conduct, but a positive trend could be read with $R^2 = 0.244$. 
**New Building Projects Group**

This group included 15 projects with contract duration between 170 days to 610 days. Figure 5.91 was difficult to analyze using linear regression techniques. \( R^2 = 0.010 \), yet it showed a decreasing of time overrun percentages as the contract duration increased.

Moreover, 3 points are defined to be outliers were removed. Sample showed a slightly increasing trend, but not accepted as \( R^2 = 0.098 \), figure 5.92.
Maintenance Building Projects Group

The small sample size being less than 4, was not accepted due to the assumption followed by the author, although resulted in $R^2 = 0.619$.

Drainage Projects Group

Despite the small size of the data set, decreasing in time overrun was directly proportioned to the increase of project contract duration, reflected in high value of $R^2 = 0.651$ and depicted in figure 5.93. This group included 8 projects with contract durations of 530 days to 1100 days.

Figure 5.92. Project duration and time overrun correlation- New building projects

Figure 5.93. Project duration and time overrun correlation- Drainage projects
All Road Projects Group

This group comprised of both new and maintenance road projects. A study case included 51 road projects along contract duration between 74 days to 593 days. Figure 5.94 illustrated data being scattered randomly, in a way that prevent defining a satisfying relation, to include all data, but a negative trend could be read. $R^2=0.015$.

![Figure 5.94. Project duration and time overrun correlation - All road projects]

Data was analyzed as per smaller contract durations. For projects of contract durations between 74 days to 179 days, a satisfying relation was difficult to conduct, but a negative trend was shown in figure 5.95 with $R^2=0.029$.

Also, a low value of $R^2=0.207$ demonstrated weak negative correlation between time overrun and contract durations for projects of contract durations between 180 days to 365 days. Data was illustrated in figure 5.96.

A strong statistical relationship was illustrated in figure 5.97, for projects with contract duration between 424 days to 547 days. High value of $R^2=0.466$ was obtained.
from data of 12 projects. A time overrun is inversely proportioned to contract duration of this sample.

In contrast to the previously mentioned interval, a positive regression line with $R^2=0.593$ was achieved for 8 projects along contract duration between 669 days to 912 days. Figure 5.98.
Figure 5.97. Project duration and time overrun correlation - All road projects duration 365<X<600days

Figure 5.98. Project duration and time overrun correlation - All road projects duration X>600days

**New Road Projects Group**

A sample of 28 road projects were classified into new construction projects, with contract duration between 669 days to 912 days. Data were scattered and difficult to analyze using linear regression techniques, $R^2=0.010$. Yet, best fit line showed a decreasing tendency, as figure 5.99 confirmed.
An attempt to get significant correlation between variables, 4 intervals were defined.

Time overrun of projects with contract duration between 74 days to 180 days were strongly decreasing as the contract duration increase. $R^2=0.848$ was obtained out of 5 projects, after eliminating 1 outlier point, as showing in figure 5. 100.

A weak positive correlation was indicated for projects with contract duration between 180 days to 365 day, and $R^2=0.112$, thus, not considered relation. Figure 5. 101.

For projects with contract duration between 365 days to 547 days, 9 projects showed a decrease in time overrun to the increasing of project duration, figure 5. 102. $R^2 =0.486$, which indicated a significant correlation.

A notable strong statistical relationship was illustrated in figure 5. 103. Projects of contract durations between 547 days to 912 days confirmed a positive correlation with high value of $R^2$ equal 0.744.
Figure 5.100. Project duration and time overrun correlation: New road projects duration X<180 days

Figure 5.101. Project duration and time overrun correlation: New road projects duration 180<X<365 days

Figure 5.102. Project duration and time overrun correlation: New road projects duration 365< X <547 days
**Maintenance Road Projects Group**

This group gathered 23 maintenance road projects with contract duration between 149 days to 882 days. It was difficult to analyze data using linear regression techniques. Yet, the low value of $R^2 = 0.071$ demonstrated a weak correlation between investigated variables. Figure 5.104.

Although this case study showed unconsidered result, plotting data into smaller intervals helped in producing reliable models.
Figure 5.105 indicated that time overrun was moderately depending on contract duration, with accepted $R^2 = 0.391$. A positive relation was found for projects with contract duration between 149 days to 179 days.

A notable strong statistical relationship was confirmed between time overrun and contract duration between 240 days to 365 days. Negative relation with significant $R^2 = 0.900$ as depicted in figure 5.106.

For contract duration between 449 days to 822 days, projects showed a satisfying decreasing relation with $R^2 = 0.438$, as illustrated in figure 5.107.
To conclude this part, time overrun percentage of drainage projects, new road projects with contract duration between 74 days to 180 days, 365 days to 547 days, and 547 days to 912 days, and maintenance road projects with contract durations greater than or equal to 149 days could be estimated using models discussed above.

Building projects and road projects with other contract durations required more parameters for investigations. Table 5.11 summarize the analysis of this part.

Table 5.11 Time overrun due to contract duration – Analysis summary

<table>
<thead>
<tr>
<th>Interval</th>
<th>Sample size</th>
<th>Schedule Deviation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All Projects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²=0.90%</td>
<td>74&lt;X&lt;1094</td>
<td>77</td>
<td>X</td>
</tr>
<tr>
<td>int 1: R²=3.5%</td>
<td>74&lt;X&lt;179</td>
<td>13</td>
<td>X</td>
</tr>
<tr>
<td>int 1: R²=28.5%</td>
<td>74&lt;X&lt;179</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>int 2: R²=4.4%</td>
<td>240&lt;X&lt;364</td>
<td>31</td>
<td>X</td>
</tr>
<tr>
<td>int 3: R²=12.8%</td>
<td>424&lt;X&lt;729</td>
<td>26</td>
<td>X</td>
</tr>
<tr>
<td>int 4: R²=18.1%</td>
<td>822&lt;X&lt;1094</td>
<td>7</td>
<td>X</td>
</tr>
<tr>
<td>R²=0.0%</td>
<td>170&lt;X&lt;610</td>
<td>18</td>
<td>X</td>
</tr>
<tr>
<td>R²=24.4%</td>
<td>170&lt;X&lt;611</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>
### Road

<table>
<thead>
<tr>
<th>R² = 1.5%</th>
<th>74 &lt; X ≤ 593</th>
<th>51</th>
<th>X</th>
<th>(−ve) relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>int 1: R² = 2.9%</td>
<td>74 &lt; X ≤ 179</td>
<td>11</td>
<td>X</td>
<td>(−ve) relation</td>
</tr>
<tr>
<td>int 2: R² = 20.7%</td>
<td>180 &lt; X ≤ 365</td>
<td>20</td>
<td>X</td>
<td>(−ve) relation</td>
</tr>
<tr>
<td>int 3: R² = 46.6%</td>
<td>424 &lt; X ≤ 547</td>
<td>12</td>
<td>X</td>
<td>(−ve) relation</td>
</tr>
<tr>
<td>int 4: R² = 59.3%</td>
<td>669 &lt; X ≤ 912</td>
<td>8</td>
<td>X</td>
<td>(+ve) relation</td>
</tr>
</tbody>
</table>

### All Projects

<table>
<thead>
<tr>
<th>New Projects</th>
<th>Schedule Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One Interval</td>
</tr>
<tr>
<td>R² = 0.9%</td>
<td>74 &lt; X ≤ 1094</td>
</tr>
<tr>
<td>int 1: R² = 3.5%</td>
<td>74 &lt; X ≤ 179</td>
</tr>
<tr>
<td>int 1: R² = 57.0%</td>
<td>74 &lt; X ≤ 179</td>
</tr>
<tr>
<td>int 2: R² = 19.4%</td>
<td>297 &lt; X ≤ 364</td>
</tr>
<tr>
<td>int 2: R² = 23.7%</td>
<td>297 &lt; X ≤ 364</td>
</tr>
<tr>
<td>int 3: R² = 10.2%</td>
<td>424 &lt; X ≤ 729</td>
</tr>
<tr>
<td>int 3: R² = 23.6%</td>
<td>424 &lt; X ≤ 729</td>
</tr>
<tr>
<td>int 4: R² = 47.8%</td>
<td>899 &lt; X ≤ 1094</td>
</tr>
</tbody>
</table>

### Drainage

| R² = 65.1% | 530 < X ≤ 1100 | 8 | X | (−ve) relation |

### Improvement Projects

<table>
<thead>
<tr>
<th>Improvement Projects</th>
<th>Schedule deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One Interval</td>
</tr>
<tr>
<td>R² = 5.2%</td>
<td>149 &lt; X ≤ 822</td>
</tr>
<tr>
<td>int 1: R² = 16.1%</td>
<td>149 &lt; X ≤ 179</td>
</tr>
<tr>
<td>int 2: R² = 86.2%</td>
<td>240 &lt; X ≤ 364</td>
</tr>
<tr>
<td>int 3: R² = 42.0%</td>
<td>449 &lt; X ≤ 822</td>
</tr>
<tr>
<td>Building</td>
<td>$R^2=61.9%$</td>
</tr>
<tr>
<td>----------</td>
<td>--------------</td>
</tr>
<tr>
<td>Road</td>
<td>$R^2=7.1%$</td>
</tr>
<tr>
<td>int 1:</td>
<td>$R^2=39.1%$</td>
</tr>
<tr>
<td>int 2:</td>
<td>$R^2=90.0%$</td>
</tr>
<tr>
<td>int 3:</td>
<td>$R^2=43.8%$</td>
</tr>
</tbody>
</table>

Where shaded cells highlight reliable outcomes.
Table 5.12 summarize reliable outcomes for each relation.

<table>
<thead>
<tr>
<th>Group Projects</th>
<th>Cost Overrun with respect to Contract Cost X</th>
<th>Cost Overrun with respect to Contract Duration D</th>
<th>Time Overrun with respect to Contract Cost X</th>
<th>Time Overrun with respect to Contract Duration D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New Buildings</strong></td>
<td>Applied to 12&lt;X&lt;220 million Positive correlation $R^2 = 75.3%$ Y = 0.002X+0.022</td>
<td>Applied to 297&lt;D&lt;364 day Positive correlation $R^2 = 89.0%$ Y = 0.001X-0.530</td>
<td>Applied to 25&lt;X&lt;220 million Positive correlation $R^2 = 93.6%$ Y = 0.018X-0.292</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Maintenance Buildings</strong></td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Drainage</strong></td>
<td>Applied to 50&lt;X&lt;280 million Negative correlation $R^2 = 69.4%$ Y = -0.001X+0.321</td>
<td>NA</td>
<td>Applied to 50&lt;X&lt;270 million Negative correlation $R^2 = 40.9%$ Y = -0.003X+1.468</td>
<td>Applied to 530&lt;D&lt;1100 day Negative correlation $R^2 = 65.1%$ Y = -0.002X+2.743</td>
</tr>
<tr>
<td><strong>New Roads</strong></td>
<td>Applied to 3&lt;X&lt;100 million Positive correlation $R^2 = 52.2%$ Y = 0.003X+0.039</td>
<td>NA</td>
<td>Applied to 3&lt;X&lt;100 million Positive correlation $R^2 = 44.2%$ Y = 0.024X+0.223</td>
<td>Applied to 74&lt;D&lt;180 day Negative correlation $R^2 = 84.8%$ Y = -0.012X+2.606</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>365&lt;D&lt;547 day Negative correlation $R^2 = 48.6%$ Y = -0.014X+7.965</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>547&lt;D&lt;912 day Positive correlation $R^2 = 74.4%$ Y = 0.003X-1.563</td>
</tr>
</tbody>
</table>
Values of contract costs were represented in maximum of three digits for simplicity of chart plotting and model equation representation. This should be considered for model application.

**Discussion of Findings**

The purpose of the regression analysis applied was, first, to study the trend of each project type, as for cost and time overrun, and how percentages depends on initial cost and estimated construction phase duration. A second goal was to provide a predict model, as a linear equation of a reliable correlation among studied variable, of $R^2$ greater than or equal to 30% and a sample size greater than 4.

From literature review, some inquiries were raised, and expected to be elaborated after analysis.
Cost overrun was investigated with respect to contract cost and estimated duration. Results varied according to project type and category. Cost overrun percentages showed an increasing trend as project size increase, while an opposite approach for drainage projects. Larger duration also affected cost overrun percentages. Both findings are enlightened as following.

For cost overrun with respect to original budget, data collected confirmed that, the increase in contract costs lead to higher cost overrun percentages. This was true for new building constructions with contract cost varied between QR12 to QR220 million. It also applied to new road construction of contract cost between QR3 to QR100 million ,and to maintenance road constructions of contract cost between QR4 to QR200 million. It could be justified as the higher the contract cost the higher the risk associated to the project; being more complex or of large scale. On the other hand, drainage projects showed the opposite result, where cost overrun percentages decreased as the contract cost increased for projects with contract cost between QR50 to QR280 million. It could be explained as such projects were of special requirements and needed specialized contractors to achieve the deliverables. Calling from that, big projects would go to employ well managing and controlling system, which help in mitigating factors causing cost overrun.

When tackling cost overrun and projects contract durations, it was of interest to question whether projects of longer durations were more susceptible to cost overrun. This was agreed only for new building construction projects of contract durations varied between 200 days to one year. This had been explained as the longer the duration the
higher the risk for price inflations and market conditions. Other projects showed no relation to confirm and required additional variables for the investigations.

Delays; expressed as time overruns, were also questioned with respect to the size of projects and estimated construction duration. Although time overrun figures with respect to contract cost confirmed a common trend as per the project type, i.e. new projects versus maintenance projects, it was difficult to read a common behavior among projects once comparing time overrun with estimated durations. Results are explained as following.

Time overrun with respect to contract cost analysis was investigating if project size, expressed by as its contract cost, helps in raising time overrun percentages. This was found to be true for new constructions of both building projects of contract cost between QR25 to QR220 million and road projects of contract cost between QR3 to QR100 million. While maintenance building projects of contract cost between QR50 to QR270 million and road projects of contract cost between QR3 to QR15 million confirmed an opposite result, in which larger contract cost projects were less affected to time overrun comparing to small size projects. It could be explained as new projects with larger size were more vulnerable to construction risks and scope/tasks ambiguity comparing to smaller projects. However, the complexity raised with large size projects would enhanced controlling and monitoring processes, which might enhance project performance according to planned schedules.
Time overrun was also examined with respect to contract duration. New road projects of contract duration exceeded 547 days and road maintenance projects of contract duration less than 180 days expressed higher time overrun percentages as the contract duration increased. New road projects of durations less than 547 days and maintenance projects of durations greater than 240 days showed decreasing time overrun behavior as the project duration increased. With this conflict in result, it is observed that this model is not adequate for such purpose, and a need of more variables involvements is called.

It is initial to mention that several projects, mostly of the same type and category, were given the same contract duration. However, cost and time overrun recorded various figures, reflected in point accumulation vertically at some points, while causing gaps along the diagrams.

Results could also be read according to project category. New building and drainage projects showed a common trend of overruns for cost and schedule. On the other hand, road projects results did not reflect a similar behavior and should include more variables for better understanding.

Although contract duration were studied for cost ad time overruns, contract fiscal figures were considered to be of higher accuracy than estimated duration figures, which should be enriched with price inflation forecasts.

To sum up, findings represent a preliminary predicting models with reliable results that help in forecast overrun percentages based on contract figures.
Chapter 6: Conclusion

This present study pursued the following objectives. First, was investigating time and cost overrun in state construction projects in the State of Qatar, then, was to use data and regression analysis for establishing some statistical relations of projects’ contracted costs and durations, prior to introducing a predicting model, which help in estimating a project cost or schedule variation percentages based on contract data. Intensive literature review was conducted to regional and international case studies, leading to a better understanding of the phenomena while inspecting various methodologies performed for different goals. Data on the study variables was collected directly from the Public work authority ASHGHAL. Statistical tools such as analysis of variances ANOVA and Linear Regression were applied for data analysis and inference. According to best of knowledge, this study is pioneering as neither any international research nor Qatari papers applied such data analysis techniques to identify statistical relations among variables, that might cause delay and cost overrun in construction projects.

The objective of the study aims to explore significant variables with its possible statistical correlation, of delay and cost overrun in the construction industry of Qatari government projects, which was achieved successfully. It is concluded that only construction cost overrun of projects compared as per year of completion, were statistically significant, and did not have equal variances.
The results of the study revealed four models, developed according to project type, with respect to duration or cost intervals. Sample data of new building projects showed cost and time overrun increasing as the projects size and duration increased. The same cost overrun performance was true for new road projects. While an opposite performance is found for drainage projects. However, models were of limited scopes and not being wide-ranging applicable.

The main source of limitations of the study is due to confidentiality of projects. Data obtained for the present study was restricted and considered only four independent variables, while different researchers had introduced the use of several other factors; so this study can be extended further by either adding more variables into the current model or by using different variables. Further researches would help in validating and generalizing this report outcomes.
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