Productivity Improvement and Resource Optimization for Construction Operation Using Simulation Model

Civil and Environmental Engineering

By

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An undergraduate thesis submitted to the Department of Civil & Environmental Engineering of Islamic University of Technology, Board Bazar, Gazipur in partial fulfillment of the requirements for the degree

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DECLARATION

We hereby declare that the undergraduate project work reported in this thesis has been performed by us and this work has not been submitted elsewhere for any purpose (except for publication).

October, 2013

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Dedicated

To

Our Beloved Parents

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ABSTRACT

A series or parallel completion of different independent or dependent activities carries out a construction operation. These activities sometimes require common resources which make it difficult to schedule the construction operation effectively. Eventually it leads inefficient use of resources which lengthen the project duration and increase cost. Therefore improving construction productivity to reduce duration and cost is very important for a construction project. Total Ineffective Time of a construction project can be minimized through proper planning and scheduling prior to construction. Additionally, it would also help the project manager to choose from different alternative plans on the basis of suitable cost. Manual calculation and planning is complicated and time consuming considering the interaction of different work activities, resources and lengthiness of the project. This situation has motivated the study to figure out the usefulness of simulation models for minimizing project duration and cost. Simulation models can be an efficient tool to generate effective plans and schedules as they consider complex interactions among various units on the jobsite to evaluate the performance of the construction operation.

A simulation model has been developed using STROBOSCOPE simulation language in this study. The model has considered various resource combinations for the analysis. The construction of a real life project has been selected as case project for the study. The construction operation that has been selected for the model development is a **RAMP** of **FLYOVER** which consists of earth excavation and sand filling, construction of base foundation, slab casting. Simulation has been run for different combination of resources. The results show that simulation model is very effective to select the optimum combination of resource that produces minimum project duration and cost. It is hoped that the study will be a guideline for the construction projects to ensure minimum duration and cost.

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CHAPTER 1

INTRODUCTION

1.1 Background

Construction Management is the overall planning, co-ordination and control of a project from inception to completion aimed at meeting a client's requirements in order to produce a functionally and financially viable project that will be completed with minimum possible time and cost and to the required quality standards. Nevertheless, construction projects are somewhat difficult to manage due to the nature of the industry; such as complex and unique projects, mobile workforce, diverse sub-contractors and suppliers.

In order to complete a project with minimum time and cost, one must improve the productivity of construction operation. Productivity is generally a ratio of input to output measuring production efficiency. A resource is an entity that contributes to the accomplishment of project activities such as manpower, material, money, equipment, time or space. Inputs may be considered as the human & non-human resources like labor, materials, equipment, tools, designs, capital etc. Proper combination & utilization of these resources are precondition for obtaining optimum productivity, as the resources are inter-connected with each other. It is very essential to minimize the project duration & cost by improving construction productivity for any kind of construction project.

Construction projects contain numerous inter-dependent and inter-related activities. Projects employ voluminous resources. But they have in-built difficulties, uncertainties and risks. These pose series of problems concerning resources, like how much they are required, 'where they are going to come from', 'when they should be inducted at site', where they should be housed', 'how to optimize their utilization' and 'when to demobilize. Due to the resource-driven nature of construction management, Resource Management is really a difficult task. The construction manager must develop a plan of action for directing and controlling resources of workers, machines and materials in coordinated and timely manner in order to deliver a project within the frame of limited funding and time. The crucial factor in successful implementation of a construction project not only depends on the quality & quantity of work, but also largely depends on availability of resources. All activities involved in the project require certain amount of resources. Each activity is allocated with a specific resource and must be completed within the time limit, otherwise it may adversely affect the overall duration of the project (A. Ray Chaudhuri et al, 2012) .

To prepare the exact plans & schedules simulation models are considered as the most efficient tool. The main advantage of simulation models is that they can analyze different combination of resources & produce the best combination with minimum cost & time. Since the interactions among various units on job sites are complex, computer aided simulation technique is highly recommended in construction industries. Other techniques such as real system experimentation or application of mathematical models including queuing theory, Line of Balance (LOB) are too expensive, time consuming & contain many assumptions. Construction simulation is usually favored with the availability of modern computers that may simulate the operations realistically. It is also inexpensive, flexible, and requires less computational time (Hassan, 2006).

Recently some of the developed countries have already used simulation techniques in the construction industries. However, developing countries like Bangladesh are yet to start using this technique in the construction industries.

1.2 Problem Identification

In context of Bangladesh, the major problem is that the people related with construction work don't have that much courage to keep the records of a project that are necessary for proper productivity calculation. Even they are not used to with different tools for efficient calculation of productivity because of lack of expertise in such simulation software. Apart from this, there are so many problems associated with construction project such as hidden cost (misuse of material, thievery of different materials), incompetency of labor in case of operating, communication gap, unavailability of equipment, most of the equipments are not well functioned, lack of proper maintenance of equipments, distance between the storage facility & construction site. Due to the lack of proper planning, some other problems may arise such as requirement of large number of labors, increase in the quantity of equipment, some equipment may remain idle and duration of a particular activity may increase. All these problems increase the cost & duration of a project & thereby decrease productivity.

In Bangladesh, usual practice is to take decision on the basis of situation. That means in construction field equipments & resources are used based on priority of the work. Normally they prefer this manually decision making process over any kind of computer aided analysis. But this process is time consuming & desired productivity cannot be achieved. On the other hand, simulation technique takes less time, easier to calculate & produces more accurate results.

1.3 Objectives

The main objective of this study is to develop a simulation model to improve productivity through which resource optimization of a construction operation can be obtained. The specific objectives are:

- To improve productivity by minimizing time & cost through resource optimization using a simulation model.
- To find out the optimum combination of resource for minimizing time & cost

1.4 Scope of the study

The study will focus on resource optimization of a particular construction project in order to increase productivity. Though the analysis of the whole construction project will give the overall picture of productivity improvement, this will be very complicated to model at this stage. However, modeling a particular construction operation considering the interactions between sub-activities and resource sharing is complex enough to understand the productivity improvement. The proposed model will focus on both time & cost analysis through resource optimization. STROBOSCOPE will be used for developing the simulation model.

1.5 Thesis Organization

The rest of the thesis has been organized as follows:

Chapter two contains literature review which includes different studies related to construction productivity, short comings of construction productivity in Bangladesh, some suggestions to overcome these short comings. Finally, research direction of this study has been mentioned in the summary.

Chapter three includes identification of problems related with improving construction productivity. It also describes the basis of model development for this study and brief description of data collection and data input process in the model.

Chapter four contains a detail description of the process and the elements we used to develop the model; a short description of the project is also included. This chapter contains the detailed data analysis process and the results we found are shown with necessary explanation. At the end a brief summary of the results and our suggestion to improve productivity is given.

Chapter five is the conclusion the thesis. This chapter summarizes the whole study and describes the effectiveness of this study. It also states some limitation of this study and provides some recommendations about future study on this topic.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses about the importance of construction productivity and resource optimization. What is construction productivity, why resource optimization is important to improve construction productivity and how it can be improved are also described in detail. At the end of this chapter how simulation modeling can help to improve productivity and a short description of different types of simulation software are mentioned.

2.2 Construction Productivity

Productivity has been widely used as a performance indicator to evaluate construction operation through the entire construction phase. Construction companies have to track productivity continuously to gauge their performance capacity to maintain profitability and to prepare for future biddings. (Kim et al. 2011)

Productivity is a ratio between input & output.It is important to indicate the input & output to be considered when calculating productivity because there are many inputs,such as labour,materials,equipments,tools,capital & design relating to a construction system. Transforming input into outputs is also complex.This process is influenced by technology used , by many externalities such as government regulations,weather,unions,economic conditions & management. Nevertheless productivity is often associated to only a particular input (e.g. worker hour) & a particular output(e.g. floor area in m2). It has been assumed as a closed system with all factors held invariable except for the identified input & output.(Centeno,2004)

Measures of productivity include:

- Work place per person
- Value-added per person

- Value-added per combined unit of labor & capital inputs, expressed as an index
- Econometric measures using production functions (Page, 2010)

2.3 Improving construction productivity

When construction management is worried, good planning, scheduling & controlling can improve productivity on a construction project. Several other components associated to construction management must also be considered when a persistent effort is made to increase productivity (Fisk, 2000). Some of these components are as follows:

- Allocate or recruit the right people to do the job or provide training to improve worker's capability & skill.
- Adopt motivational or personnel management measures to increase worker's moral. For example, tie compensation to performance, guarantee that pay, fringe benefits, safety & working conditions are all at least plenty;& enlarge the jobs to include challenge, variety, wholeness & self-regulation.
- Use project scheduling techniques such as computer-aided construction project management (CPM) to optimize the times of connected activities & make sure that works, tools & materials let continuous task performance so as to reduce the joblessness of the labor force to a minimum.
- Remain simple & efficient the communication among employees as well as with linked parties.
- Make the workers know that they are important to the organization & engage them in the making of decisions affecting their jobs such as technique improvements.
- Conduct productivity/performance study at the activity/operation level to create benchmarks & to develop scientific models.

According to Alfold (1988). Three categories of measurements encompassing six dimensions are enough to describe every aspect of construction performance. These dimensions are as follows:

- Quality

1. Accuracy: Measures how narrowly the job conforms to plans, specifications, code requirements & established industry standards for workmanship.
2. Workmanship: Measures important differences in the worth of the finishes job shaped by master-craftsmanship skills.

- Quantity

3. Productivity: Measures differences in the rate at which the work is accomplished over time.
4. Schedule: Measures how closely the job adheres to a best possible construction schedule.

- Resources

5. Manpower: Measures differences in labor cost not reflected in the measurement of productivity.
6. Material, tools, & equipments: Collect measurements of construction resources other than manpower (Centeno, 2004).

Considering every aspect of construction performance and measuring dimensions, following top areas can be found where improvement can be worked out.

1. Labor Management, Conditions and Relations

This category can be divided into some divisions. Such as:

1.1 Incentive programs

1.2 Remote Locations

1.3 Access to job-site

1.4 Labor management and relations

1.5 Resource scheduling (shifts and overtime)

1.6 Training and certification of workforce

2. Project Front-end Planning (Loading) and Work Face Planning

Front end planning is the process of developing sufficient strategic information with which the project team can address project scope and requirements that allows the project to be executed successfully.

3. Management of Construction and Support

In this category, industry professionals have identified many areas for improvement and suggested the proper management of:

- Tools.
- Equipment.
- Access to site and site layout
- Camp facilities
- Travel
- Health programs**.**
- Scaffolding
- Safety

- Management of change and rework minimization
- Material management and Supply Chain Management
- Quality
- Contract administration
- Progress measurement

4. Engineering Management

- Be ready before starting the project. Incomplete engineering leads to delays and rework.
- 80% of engineering complete before mobilizing to site.
- 100% of “Issued For Construction” (IFC) drawings and specifications issued on time and must be completed before construction

5. Effective Supervision and Leadership

- Oversight with experience and authority.
- Accountability of scope, time and cost
- Make key decisions on time in all phases of construction
- Adequate and experienced supervision
- Effective team based for frontline supervision.
- Ensure adequate field supervision and management of workforce.
- Competent management
- Empower project managers to control all aspects of the project

6. Communication

- Clear lines of communications
- Minimize levels of communication
- Give labor force clearer and more direct instructions
- Good communication between owner and contractor.

7. Contractual Strategy and Contractor Selection

- Use Construction Management approach, cost reimbursement with maximum upset and bonus scale.
- Break the project into smaller projects (smaller /and areas). Use multi phase approach.
- Hold the contractor accountable and impose liquidated damages
- Use lump sum contracts.
- Use contractors that have history of dealing with problems efficiently.

8. Constructability in Engineering Design

- Involve operation and construction in detailed engineering
- Provide adequate time & resources to complete constructability reviews and allow early contractor involvement.
- Limit exposure of personnel to elements by maximizing the work under controlled environment. Productivity in a controlled atmosphere (workshop) is higher than field.

9. Government Influence

The factors that influence productivity in projects do not end at the responsibilities of the owner company managers, labor and EPC firms. It extends to include the Government. Industry provided the following suggestions regarding the Government influence.

- Government and industry needs to plan work together to ensure projects flow together and there are no peaks and valleys in work force.
- Remove cross provincial barriers and trade barriers on skilled labor and professional qualifications or make them consistent. Federal responsibilities to allow for easier access to labor forces from all regions of the country to ease labor availability issues.

- Ensure sustainable development (both economically and environmentally) i.e., less development and with more effort on each development.

10. Modularization, Prefabrication, Pre-build in Shops

- Use standardization where possible in plant design and construction and do not reinvent the wheel each time.
- Modularize as much as possible
- Do as much work in vendor's shops to avoid field work (pre-wiring, modularized skids).
- Use consistent construction crews
- Use more prefabricated units

As we discussed the top 10 areas of improvement we can say that proper planning before starting the project and management along the construction period is the key to improve productivity. Among the different sectors we are willing to plan on the proper supply and management of resources and their optimum utilization. We discussed about the resource optimization in the following part.

2.4 Resource Optimization

Resources management is one of the most important aspects of construction project management in today's economy because the construction industry is resource-intensive and the costs of construction resources have steadily risen over the last several decades. Often the

Project planner utilizes the time and precedence based schedule as a basis for the management of resources for the project, (Patrick, 2004).

A Construction Resource Management system automates and dramatically simplifies the process of tracking and managing a construction company's business-critical resources. Combining asset and materials data into one, easily accessible, centralized database, these systems provide detailed information every department needs to ensure that physical construction resources—not just tools and equipment—yield the maximum value possible.

It is essential to prepare feasible resource plans based on schedule plans and budgetary limitations for construction projects. In practice, additional temporary resources are typically purchased to support resource plans, shorten project duration or possibly decrease total cost. That is, this practice is sometimes referred to as "project duration compression". Therefore, outsourcing actions such as temporary subcontracting are generally considered and executed to eliminate deficiencies in the initial resource plan. For example, adding crews and construction equipment can be regarded as outsourcing actions for improving project performance. (Liu & Wang, 2007)

Every project schedule has its own precedence constraints, which means that each activity can be processed when all its predecessors are finished. In general the purpose of project scheduler is to minimize its completion time or make span, subject to precedence constraints.

A more general version assumes that to develop one or more activities, resources such as tools, equipment, machines, or human resources are needed. Each resource has limited capacity; consequently at a certain moments one activity may not begin their processing due to resource constraints even if all their predecessors are finished, (Franco et al, 2006). (Tahreer Mohammed Fayyad, IUG, 2010**)**

2.5 Simulation Modeling To Improve Productivity

Decision- making process is an essential part of any construction operations. (Hassan, 2007) Simulation is important and useful techniques that can help users understand and model real life systems. Once built, the models can be run to give realistic results. This provides a valuable support in making decisions on a more logical and scientific basis. It is the imitative representation of the functioning of one system or process by means of the functioning of another, such as a computer simulation of a construction project. With simulation, one can examine a problem that is often not subject to direct experimentation.

Simulation models can also be used as a tool to assist construction managers in making informed decisions. This approach offers a fast and inexpensive means of studying the performance of the operation and the response of the system to change in resources and equipment allocations. (Hassan, 2007)
Simulation can be a very effective tool to plan for productivity. Moreover, simulation studies have been conducted to understand better the effect of various factors on productivity. Simulation can also be used to support claims due to loss of productivity from bad weather, unexpected delays, changed conditions, changes in the contract, and other factors. Similar studies can be conducted to analyze the effect of particular human factors on productivity. (Dozzi and AbouRizk ,1993)

Many researchers have developed different computer software to evaluate the productivity of any construction operation. Hassan, 2006 some of the most commonly used software are described below:

1. CYCLONE was the earliest simulation program developed to measure performance of construction activities (Halpin, 1977). Many repetitive construction operations have been studied using CYCLONE yet the method is not able to address the properties of resources and needs significant time to maximize productivity. Thus, it is very difficult to model processes at a detailed level.

2. RESQUE is a methodology developed with resource handling capabilities (Chang, 1987). The methodology is an improvement to CYCLONE since it defines resource distinction and enhances simulation control

3. CIPROS characterizes resources by representing activities through a common resource pool. It also allows real properties for resources presented at the pool (Odeh, 1992).

4. RISim simplifies the construction modeling method by considering resources as modeling elements and focuses on their interaction (Chua & Li, 2002). It simulates the interaction as operation logic and categorizes resources depending upon their inherent function.

5. More recent enhancements in the applications of construction simulation like STROBOSCOPE have considered diversity of resources and model resource selection schemes that resemble actual construction operations (Martinez & Ioannou, 1999).

6. SIMPHONY is an advanced simulation tool that provides an intelligent environment through the utilization of construction Special Purpose Simulation (SPS) tools (AbouRizk and Hajjar, 1999). It has also facilitated the construction simulation process by creating standard templates that can be directly used. Tommelein (1998) has shown the application of construction simulation in lean construction incorporating concepts like workflow variability and supply chain management.

The State and Resource Based Simulation of Construction Processes (STROBOSCOPE) software product is an advanced simulation tool that can dynamically determine the state of the simulation and the properties of the resources involved in an operation (Martinez 1996). The state of the simulation defines parameters such as number of trucks waiting to be serviced, the repetition of an activity, and the time of the simulation as related to the system being modeled. This software product was specifically designed to simulate construction operations and makes use of concepts found in Structured Query Language (SQL) to select resources for operations and aggregate their properties. The flexible and object oriented C++ language was used as the simulation language to implement the design objectives and to consider the diversity of resources and their characteristics, allow simulation to control the sequence of tasks, show resource and material, utilization, consumption and production.(Hassan,2007)

2.6 Summary

In this chapter, productivity & ways of improving productivity through resource optimization are discussed briefly. In our country resource optimization is not practiced properly due to lack of proper planning which results in increase of time & cost and decrease of productivity. On the other hand amount of resources is not adequate in our country. In context of Bangladesh resource management is usually done as per the plan made manually by the project managers on the sites. Generally, they don’t adopt any computer aided plan for resource utilization. Interactions among the various resources used in construction sites are too complex to be modeled using classical queuing models. For any construction operation, decision-making is a very essential part. Simulation technique can be used as a tool to make the model of interconnected resources and thus helps to make decision. In Bangladesh simulation model based work is not introduced widely or even not done yet. Our aim is to introduce the effectiveness of simulation modeling in construction work in Bangladesh to optimize the resources.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

The chapter discusses about the procedure that has been followed to conduct the study. It describes about how problem is formulated and data was collected, by which means the model will be developed and analysis will be conducted.

3.2 METHODOLOGY

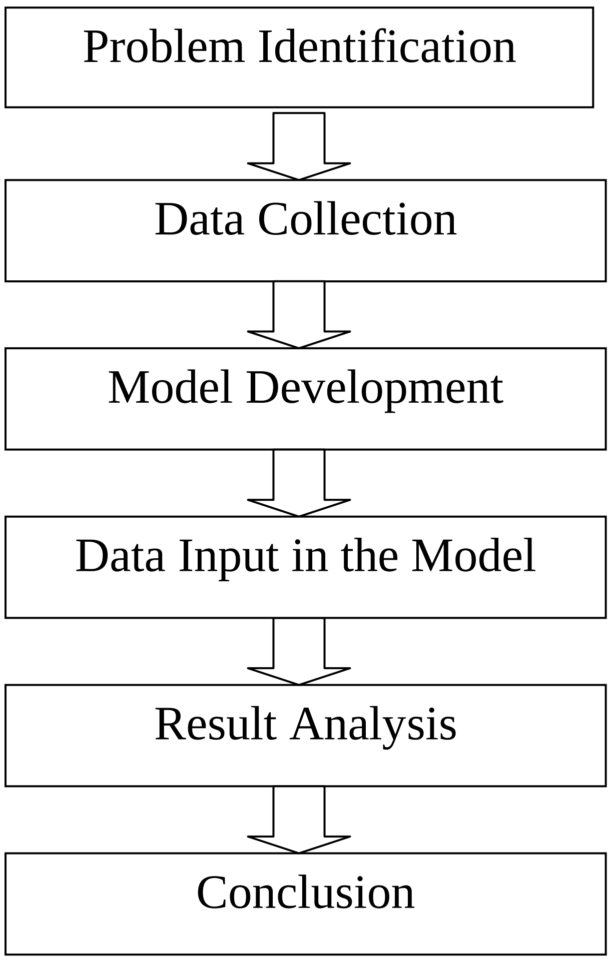


Figure 3.1: Flowchart of the methodology of the study

Figure shows the methodological flowchart of the study which includes problem identification, data collection, model development, data input in the model, result analysis, conclusion. The topics are described in detail below –

3.2.1 Problem Identification

The study will focus on resource optimization of a particular construction project to minimize the time & cost of the project in order to increase productivity. The best combination of resources and activity interaction that will result minimum duration & cost will be chosen.

A simple example is shown below to clarify how the best alternative will be chosen amongst various alternatives. Here the calculation is done manually. In this study a software based analysis will be conducted.

A subcontractor has to install an 1800 m waterline. The trench to be excavated will be 2 m deep and 1.3 m wide. A 1 m3 excavator is used with several 10 m3 dump trucks. The soil at the site is lean clay with a swell of 25%. The excavated material must be hauled 5 km from the trenching site. Assume 50-min hour for efficiency, speed of truck (full) is 30 km/hr, its speed is 50 km/hr when it is empty and the dumping time is 2 minute. The amount of dump trucks for which maximum productivity within a shorter time & lower cost can be achieved has to be determined (Chua D., 2006).

The problem can be solved manually in the following way –

Combination 1: Using 1 truck and 1 excavator

Excavator cycle:

Dig = 30 s

Swing = 20 s

Dump = 15 s

Swing = 20 s

Cycle time, $t_{excavator}$ = 30 + 20 + 15 + 20 = 85 s

Accounting 50-min hour efficiency, $t_{excavator}$= 85 × 60/50 = 102 s

Truck cycle:

1 excavator = 1 m3 and 1 truck = 10 m3;

Then, time to load 1 truck = 10/1 × 102 = 1020 s = 17 mins

Haul (full) = 5/30 × 60 = 10 mins

Dump = 2 mins

Return = 5/50 × 60 = 6 mins

t_{truck} = 17 + 10 + 2 + 6 = 35 mins

Accounting for job efficiency

t_{truck} = 35/50 × 60 = 42 mins

So, the cycle time of a truck (= 42 mins) is much higher than the time required by the excavator to load a truck (= 17 mins).

Therefore, excavator remains idle for some time.

Daily production:

If working shift is 7 hr/day.

P_{daily} = 7 × 60 / 42 = 10 truckloads = 100 m3 or 100/1.25 m3 = 80 m3

[Here, swelling = 25%]

Total duration:

Total excavation = 1800 × 2 × 1.3 = 4680 m3

Total duration = 4680/80 = 58.5 days

Cost:

Let’s assume daily cost for

Foreman, spotter = $230

Excavator with operator = $1200

Truck with operator = $700

Then, Daily cost = 230 + 1200 + 700 = $2130

Unit cost = 2130/80 = $26.6/m3

Total cost = 58.5 × 2130 = $124,605

Combination 2: Using 2 trucks and 1 excavator

Excavator cycle:

17 × 2 = 34 mins

Truck cycle:

42 mins

So, Excavator remains idle.

Thus 2 trucks are loaded in 42 mins

Daily production:

P_{daily} = 2 × 7 × 60/42 = 20 truckloads = 200 m3 or 200/1.25 m3 = 160 m3

Total duration:

4680/160 = 29.25 days

Cost:

Daily cost = 230 + 1200 + 2 × 700 = $2830

Unit cost = 2830/80 = $17.7/m3

Total cost = 29.25 × 2830 = $82,778

Combination 3: Using 3 trucks and 1 excavator

Excavator cycle:

17 × 3 = 51 mins

Truck cycle:

42 mins

So, Trucks remain idle.

Thus 3 trucks are loaded in 51 mins

Daily production:

P_{daily} = 3 × 7 × 60 / 51 = 24.7 truckloads = 247 m3 or 247/1.25 m3 =197.6 m3

Total duration:

Total duration = 4680 / 197.6 = 23.7 days

Cost:

Daily cost = 230 + 1200 + 3 × 700 = $3530

Unit cost = 3530/197.6 = $17.9/m3

Total cost = 23.7 × 3530 = $83,661

From the above results Combination 3 can be chosen as the productivity is higher and required time is less, although the total cost is higher than that of Combination 2.

Similarly for further precision the results for 4, 5 or more trucks can be checked or the number of excavators can be increased but the process will be very much lengthy, time consuming and the analysis will be ambiguous.

Above example consists of only one cycle. That’s why manual calculation is possible. But if the combination consists of more than one cycle then more equipments & resources will be used & the model will be more complex. In such case analysis can be done in an easier way and more precisely by developing a simulation model. It also helps in decision making in a simpler manner.

3.2.2 Data collection

Data was collected from " Mirpur-Airport Road Flyover" project. Its length is 1.79km & the flyover has both two-lanes and four-lanes roadways. The flyover was constructed using 68 piers.

Different information were collected in order to develop a model and analyze productivity; such as equipment type and capacity, number of equipment and labor associated with each activity, labor cost per day, equipment cost, daily work-shift, total work volume, estimated duration of each activity and the entire project. The site engineers and the project manager were consulted to know about the operation of the activities, selected for this study. For developing final model all the necessary data will be collected from the project site as per necessity.

3.2.3 Model Development

STROBOSCOPE will be used to develop simulation model in this study. There are different modeling elements in order to model a construction operation such as NORMAL, COMBI, LINK, QUEUE etc. which will be described in detail in chapter 4. Different combinations of resources and activity interactions will be considered for the model development. All type of activity & equipments used in the project will be included in the model.

3.2.4 Data input in the model

After developing the model in STROBOSCOPE different combinations of resources & activity interactions will be used to obtain results for different combinations. All the corresponding information of cost will be included in the final model.

3.2.5 Result Analysis

The results obtained from using different combinations in STROBOSCOPE model will be explained in detail. The combination that will result in minimum duration &

cost through optimum use of resources will be considered as the optimum combination.

3.2.6 Conclusion

The effectiveness of the model will be described in conclusion. How people can be benefited using the simulation model to improve productivity and manage the construction project in a better way will be discussed in detail. Possible enhancement of this study or future research guideline will also be recommended.

CHAPTER 4

MODEL DEVELOPMENT AND DATA ANALYSIS

4.1 GENERAL

This chapter discusses how the model has been developed in detail. Analysis of different combination of resources and activity interactions to obtain optimum combination of time and cost of the project is also discussed broadly.

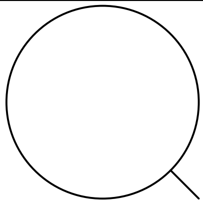
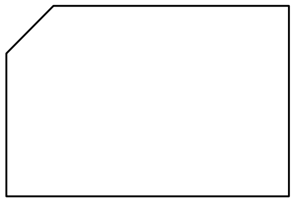
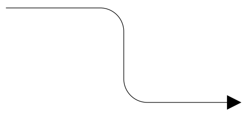
4.2 MODEL DEVELOPMENT

From the example shown in the section 3.2.1 it can be seen that if the calculation is done manually it will be tedious and time consuming. A construction project usually contains many activities and these activities may have different complex interactions among them. Moreover, some resources may be shared in different activities. So a simulation model has been developed in this study to represent a construction project and to analyze the result found from the simulation model.

A construction operation has been modeled by STROBOSCOPE and visualized by Microsoft Visio 2003. The model has been developed using different modeling elements such as NORMAL, COMBI, LINK, QUEUE etc. Resources have been represented by QUEUE. Each activity of the operation has been represented either by COMBI or by NORMAL in the simulation model. When an action is followed by a QUEUE then only COMBI is used, otherwise NORMAL is used. LINK has been used to connect network nodes. It indicates the direction in which a type of resource flows.

The symbols of different modeling elements used in this study for the model development are shown in table 4.1 and the detail of the model is shown in figure 4.1.

Table 4.1: Modeling Elements

Element Name	Symbol
QUEUE	
COMBI	
NORMAL	
LINK	

4.2.1 PROJECT DESCRIPTION

For the case study we have selected the construction of " Mirpur-Airport Road Flyover" project. The construction site is located at the Zia colony, Banani . It is a joint construction project of Mir Akhter construction co. and Bangladesh army.

The construction operation that has been selected for the model development is the construction of the ramp. The estimated duration of this ramp construction was around four months. Construction of the ramp consists a series of combination of different activities. After the pre-work had been done in the project area excavation was done. The volume of excavation was approximately 127x5x8 m^3. Then the excavated site was filled with sand and compaction was done. Then C.C.work and base foundation was done. After that setting of r.c.c. panel, sand fill, compaction, geo-grid setting and finally again compaction was done. This step was done in 4 layers. After that top capping onto panel was done following again C.C work and base foundation was completed. Then slab casting & all railing works up to the end are completed.For excavation truck, loader, excavator. For C.C. work and base foundation mixer truck was used. Body crane was used for setting of r.c.c. panel. For the compaction process roller was used. The construction company had all the equipment of their own except the roller. Their daily work hour was 20 hours. A generator was used for 12 hours per day period. We did not consider any labor cost, only the machinery cost was considered. We considered a partial amount of cost for buying each of the machinery, approximately comparing with the total lifetime of the machinery. Additional daily maintenance cost was also considered.

The construction operation can be divided into three phases. These are:

1. Earth excavation
2. Construction of Base Foundation
3. Slab casting

Again, the earth excavation involves the following sub-activities:

1. Pre-work
2. Excavation
3. Post-work

The construction of base foundation involves the following activities:

1. Sand fill
2. Compaction
3. C.C. work
4. Setting of RCC panel
5. Geo-grid setting
6. Top capping onto panel

And slab casting involves the following activities:

1. Slab casting preparation
2. All railing works up to end

Following resources were used for the project:

Table 4.2: Different Resources and Activities to be performed by these resources

Resources (equipments)	Related activities
Excavator	Excavation
Loader	Loading, carrying sand
Roller	Compaction
Mixer truck	Carrying & delivering ready-mixed concrete
Body crane	Setting of RCC panel
Truck	Hauling & dumping

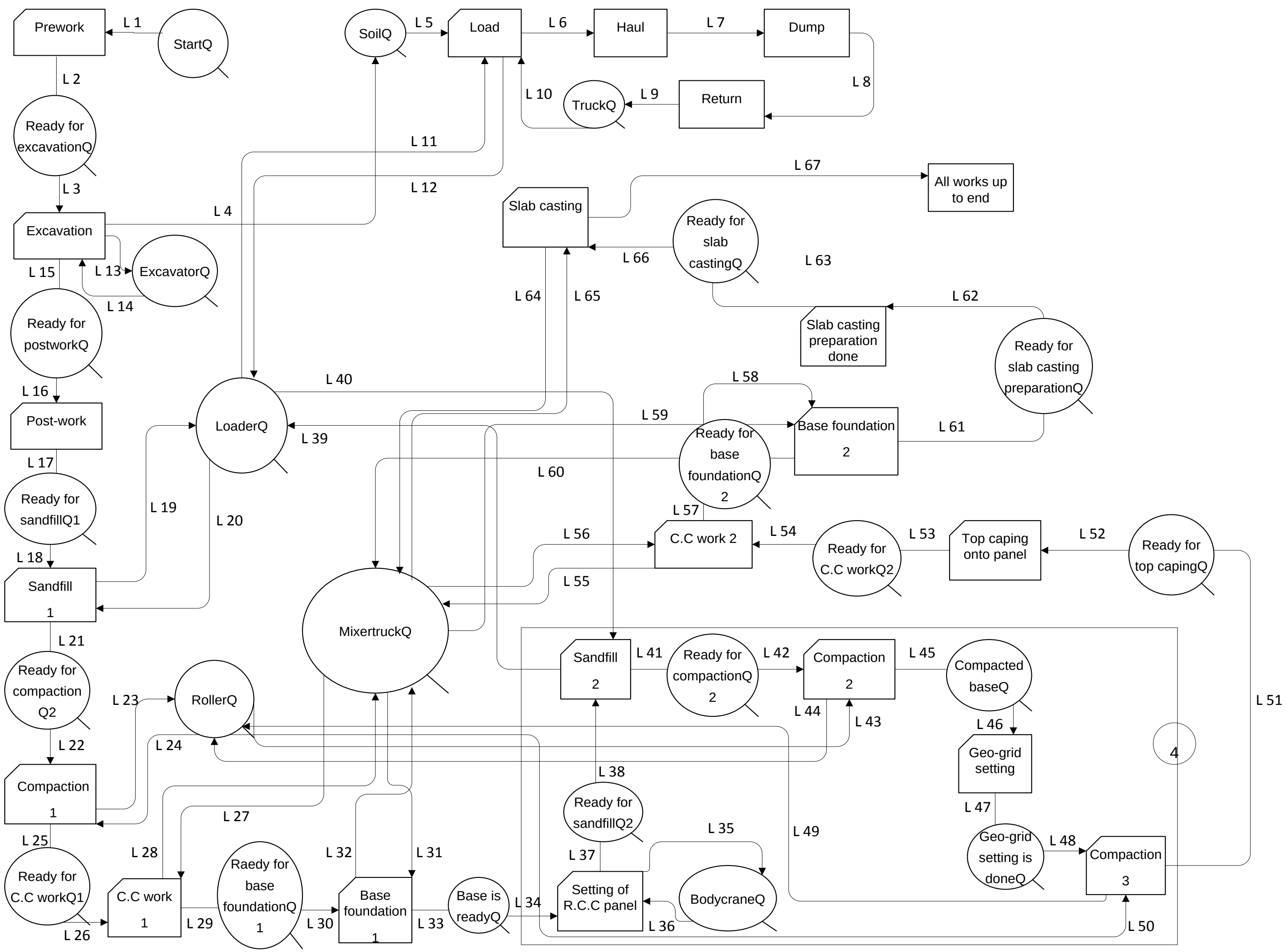


Figure 4.1: Model of construction operation

The model shown in the figure 4.1 is a simulation model in which we have used COMBI for representing different activities which are using different resources like excavation, post work, sand fill etc. QUEUE is used to represent different resources like roller, mixer truck, loader etc. Other activities are represented by NORMAL. LINKS are used to show the activity sequence and to connect the resources and activities. Some additional QUEUE are also included in the model to maintain the sequence of the model. If we follow LINK L5 we can see that for loading resource soil a QUEUE loader is used. Following LINK L6, L7, L8 shows that soil is being hauled, dumped and returned to the previous activity COMBI load.

Durations for each activity of the sub-structure works are shown in table 4.2. The durations provided here have been collected by interviewing project engineer and relevant workers on the site. Those who have been interviewed were experienced in their respective fields.

Table 4.3: Different activities & their duration

Activities	Duration (minutes)
Pre-work	1200
Excavation	18000
Post-work	1200
Sandfill 1	16800
Compaction 1	8400
C.C. work 1	7200
Base foundation 1	7200
Setting of RCC panel	4800
Sandfill 1	2400
Compaction 2	1200
Geo-grid setting	3600
Compaction 3	2400
Top capping onto panel	3600
C.C. work 2	2400
Base foundation 2	2400
Slab casting preparation	14400
All railing work up to end	12000

In our model the whole project proceeds in a sequential manner but in case of other projects or operations the activities may run parallel. The project starts with earth excavation & the first activity of earth excavation is excavation, so without starting excavation following sub-activities cannot be started. Excavator is required only for excavation. On the other hand loader required for both sand fill 1 & loading of excavated earth. Therefore, if a single loader is used for the whole project, sand fill 1 & loading of excavated earth cannot be started simultaneously. Now the time required for excavation is less comparing total time required for sand fill 1 & loading of excavated earth. So, when one loader is used excavator may sit idle. On the other hand if two loaders are used it will speed up the construction operation as sand fill 1 & loading of excavated earth can be completed concurrently. Eventually idle time for excavator will reduce. If more loaders are used then some loaders may sit idle as excavation may not be completed by using a single excavator. In that case, more excavators may be required in order to cope with the number of loaders. So an optimal combination of excavator & loader is to be determined in order to minimize the idle time of resources.

Similar scenario can be seen in case of the resources (truck and excavator) of the excavation phase.

Optimal combination of resources should be selected based on duration of the operation and cost of the project which includes initial cost of the equipments as well as the maintenance cost of the equipments and overhead cost of the project. A detail analysis for different combination of resources is necessary in order to select an optimal combination of resources.

4.3 Data analysis & result:

The simulation model is incorporated with the e following activities.

a) Earth excavation

b) Construction of Base Foundation

c) Slab casting

Each activity is linked to each other as we cannot start one activity without completing the previous one. Again different kinds of resources are required to carry out these activities. We considered the whole project together in the simulation model. We need excavator for the excavation part of the activity. For all the sand filling work of the project loader was required. For all kind of compaction work roller was used. For every kind of C.C. work and base foundation activity mixer truck was used. Mixer truck was also used in the slab casting part of the project. Body crane was needed only for setting of r.c.c panel.

We considered different combination of four resources which include loader, mixer truck, roller, body crane. The project was carried out using 1 loader, 4 mixer trucks, 1 roller, 1 body crane and duration of the project was 126 days.

But we have assumed different number of resource to analysis the project with a view to finding out a combination that will provide optimum cost as well as optimum duration. Although it is required to consider different number of resource, unlimited number couldn't be chosen. Because, the more the number of resource, the more the cost will be without significant change in project duration after a certain level. Moreover, if unlimited number of resource is taken, the site of the project may become congested and thus resource allocation will be complex. So, we have taken a maximum as well as minimum number of resources into consideration.

The maximum and minimum number of resource that we have taken into account is shown in the following table:

Table 4.4: Different Resources and their Maximum and Minimum Number

Name of the Resource	Maximum number	Minimum number
Loader	6	1
Mixer Truck	7	4
Roller	4	1
Body crane	4	2

Here maximum number of mixer truck is 7 and minimum number is 4. When we ran different combinations of resources in the simulation model we found maximum acceptable amount of cost for using highest 7 mixer trucks. On the other hand, if we use less than 4 mixer trucks than the duration does not decrease significantly. With this same consideration we have chosen the maximum and minimum numbers of the other resources.

Initial cost of the resources was taken as the percentage of the fixed cost of the relative resources depending on the use of that particular resource throughout the construction of the **RAMP**.

For each resources, used in the construction project there is a resource acquisition cost. There could be two types of resource acquisition cost. One is the buying cost and the other is the rent cost of the resource. Since all the resources were owned by the company, we considered a fixed cost for every resource as resource acquisition cost. Resource acquisition cost is separated from the operating cost of the equipments. Resource acquisition cost depends on the type of resources. If the number of resources is increased, resource acquisition cost will also be increased.

As we did not have any actual data regarding the cost of the resources, we assumed different fixed cost for each resource as the resource acquisition cost. We also assumed different daily operating cost for each resource. In some case we chose higher cost. Again in some case we assumed lower cost. No moderate cost was taken into account.

We adopted 8 combinations of costs related to the resources of the project to find out different results using simulation model. The results found will be compared to get an optimum combination that might be suitable for the project.

The combinations of costs are shown below:

Table 4.5: Combination of Cost for different Cases

Cases	Resource acquisition cost (taka)	Operating cost (taka)	Overhead cost (taka)
Case 1	High	High	High
Case 2	High	High	Low
Case 3	High	Low	Low
Case 4	High	Low	High
Case 5	Low	Low	High
Case 6	Low	High	High
Case 7	Low	High	Low
Case 8	Low	Low	Low

For case 1 (H-H-H), we took into account following Resource acquisition cost, overhead cost and daily operating cost for these resources:-

Table 4.6: Resource acquisition and operation cost Case-1 (H-H-H)

Resource name	Resource acquisition cost (taka)	Operating cost (taka/day)
Loader	200000	2500
Mixer truck	200000	3500
Roller	70000	2500
Body crane	230000	2500

Overhead cost was assumed to be 8000 taka per day.

Considering Case 1, we ran analysis by simulation and got the following graph using the result.

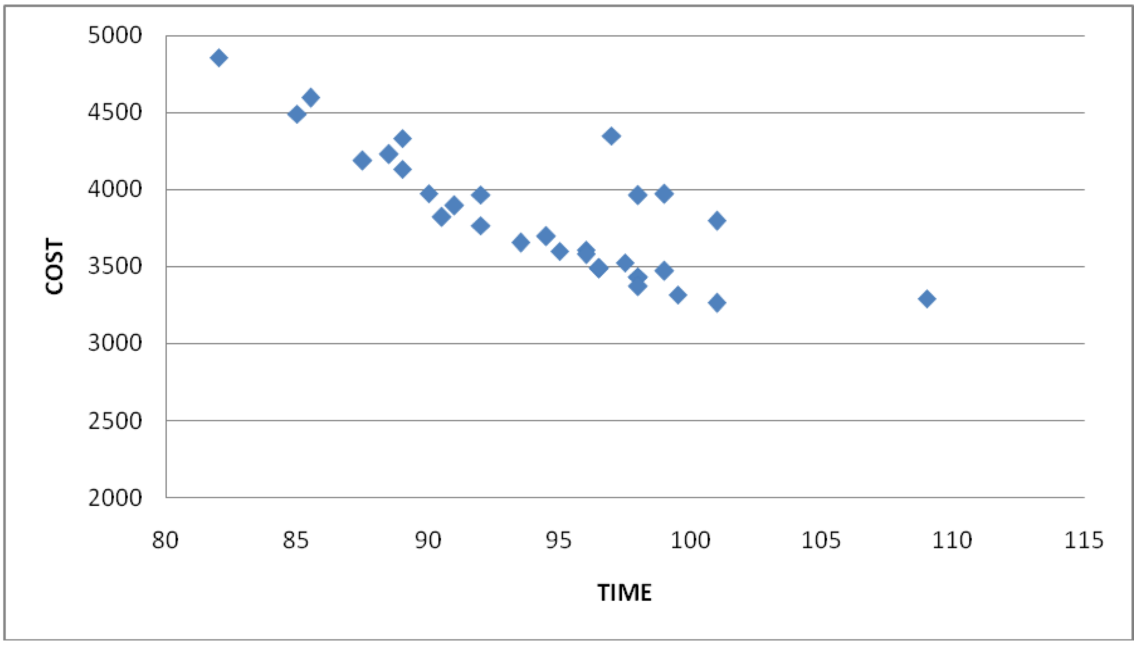


Fig 4.2: Cost vs. time graph for Case 1 (H-H-H)

From the above graph it can be seen that as the day increases for most of the combinations cost decrease comparing to the other combinations. For some combinations like 2 loaders, 4 mixer trucks, 2 rollers, 2 body cranes & 5 loaders, 4 mixer trucks, 1 roller, 2 body cranes though the duration is same i.e. 101 days, the cost varies (3265 and 3795 thousands taka respectively). It is seen that the cost increases by 16.3 %.

From the graph shown above we got a curve of optimum combinations which are shown in the following table:

Table 4.7: Combination of resources for optimum results (Case 1-HHH)

Loader	Mixer Truck	Roller	Body Crain	Duration(Days)	Cost(Thousand Tk)
1	4	1	1	126	3039.8
6	6	4	4	82	4856.9
5	5	4	4	85	4489.8
5	6	3	2	87.5	4187
3	6	3	2	90.5	3820
2	4	4	2	98	3372.5
2	4	2	2	101	3265
1	4	4	2	109	3293

The actual combination of resources was 1 loader, 4 mixer trucks, 1 roller & 1 body crane. For case 1, we found by simulation that it took 126 days & 3030.8 thousands taka to carry out the project. From the above table (Table 4.7) it can be observed that the combination of 3 loaders, 6 mixer trucks, 3 rollers, 2 body cranes could be the optimum combination as the duration decreases 39.22% from the actual one and the cost increases by 25.67%. Again 2 loaders, 4 mixer trucks, 4 rollers & 2 body cranes could be another suitable combination as the duration becomes 98 days (22.22% reduction) and the cost is increased by 332.7 thousands taka (10.94% increase).

For case 2 (H-H-L), Following Resource acquisition cost, overhead cost and daily operating cost for these resources is assumed:

Table 4.8: Resource acquisition and operation cost Case-2 (H-H-L)

Resource name	Resource acquisition cost (taka)	Operating cost (taka/day)
Loader	200000	2500
Mixer truck	200000	3500
Roller	70000	2500
Body crane	230000	2500

Overhead cost was considered to be 5000 taka per day.

Considering Case 2, we ran analysis by simulation and got the following graph using the result:

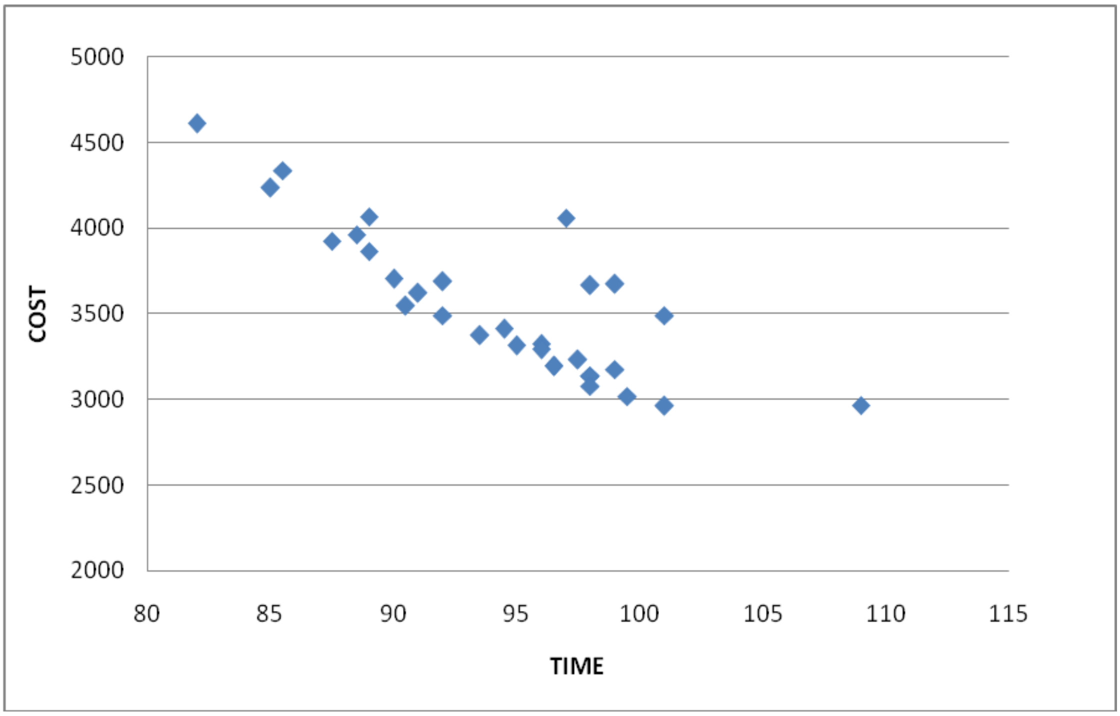


Fig 4.3: Cost vs. time graph for Case 2 (H-H-L)

From the above graph it can be seen that the rate of decreasing cost is higher comparing to the previous graph as the overhead cost used in this case is less than the previous. It can be also observed that if 5 loaders, 5 mixer trucks, 1 roller and 2 body crane are used, the duration is 99 days and the cost is 3676.5 thousands taka. Again if 2 loaders, 4 mixer trucks, 2 rollers and 3 body cranes are used, the duration remains the same i.e. 99 days but the cost is reduced by 13.6%.

From the graph shown above we got a curve of optimum combinations which are shown in the following table:

Table 4.9: Combination of resources for optimum results (Case 2-HHL)

Loader	Mixer Truck	Roller	Body Crain	Duration(Days)	Cost(Thousand Tk)
1	4	1	1	126	2661.8
6	6	4	4	82	4610.9
5	5	4	4	85	4234.8
5	6	3	2	87.5	3924.7
3	6	3	2	90.5	3548.6
2	4	4	2	98	3078.6
2	4	2	2	101	2962
1	4	4	2	109	2966

For case 2, we found from the simulation analysis that 126 days and 2661.8 thousands taka is required to complete the project if the actual combination of resources is used. Comparing the results shown in the table, it is seen that if 2 loaders, 4 mixer trucks, 4 rollers and 2 body cranes are used the duration is reduced by 28 days that is almost 1 month of reduction and the cost is increased by 15.7% (416.8 thousands taka). Change in cost may not be high but the duration is significantly changed. So, this combination of resources might be suitable for the project.

For case 3 (H-L-L), we chose following resource acquisition cost, overhead cost and daily operating cost for these resources:-

Table 4.10: Resource acquisition and operation cost Case-3 (H-L-L)

Resource name	Resource acquisition cost (taka)	Operating cost (taka/day)
Loader	200000	2000
Mixer truck	200000	3000
Roller	70000	2000
Body crane	230000	2000

Overhead cost was considered to be 5000 taka per day.

Considering Case 3, we ran analysis by simulation and got the following graph using the result.

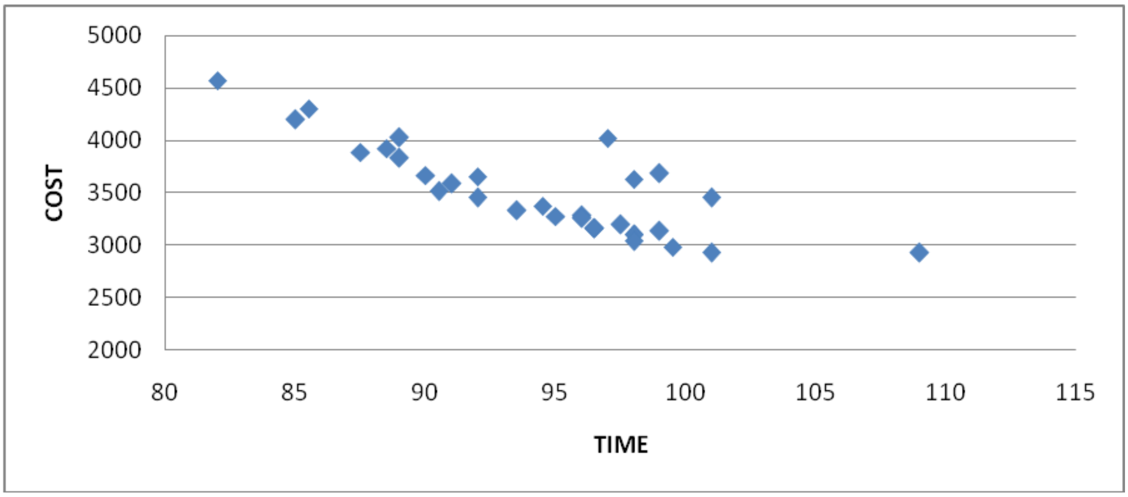


Fig 4.4: Cost vs. time graph for Case 3 (H-L-L)

From the graph it is seen that if 2 loaders, 5 mixer trucks, 3 rollers and 2 body cranes are used the duration is 96.5 days and the cost is 3158 thousands taka. On the other hand if 6 loaders, 6 mixer trucks, 1 roller and 2 body cranes are used the duration is increased by 0.52% which is negligible but the cost is increased by 27.4% which is a remarkable change.

From the graph shown above we got a curve of optimum combinations which are shown in the following table:

Table 4.11: Combination of resources for optimum results (Case 3-HLL)

Loader	Mixer Truck	Roller	Body Crain	Duration(Days)	Cost(Thousand Tk)
1	4	1	1	126	2623.6
6	6	4	4	82	4572.7
5	5	4	4	85	4196.6
5	6	3	2	87.5	3886.6
3	6	3	2	90.5	3510.5
2	4	4	2	98	3040
2	4	2	2	101	2924
1	4	4	2	109	2928

For case 3, 126 days and 2623.6 thousands taka is needed in case of the actual combination of resources. Comparing the results shown in the table, it is seen that if 2 loaders, 4 mixer trucks, 4 rollers and 2 body cranes are used the duration is reduced by 22.2% (28 days of reduction) and the cost is increased by 15.76% (416.4 thousands taka increase) which may not be a significant change in cost but the duration is significantly changed. So, this combination of resources might be suitable for the project.

For case 4 (H-L-H), we considered following Resource acquisition cost, overhead cost and daily operating cost for these resources:-

Table 4.12: Resource acquisition and operation cost Case-4 (H-L-H)

Resource name	Resource acquisition cost (taka)	Operating cost (taka/day)
Loader	200000	2000
Mixer truck	200000	3000
Roller	70000	2000
Body crane	230000	2000

Overhead cost was considered to be 8000 taka per day.

Considering Case 4, we ran analysis by simulation and got the following graph using the result.

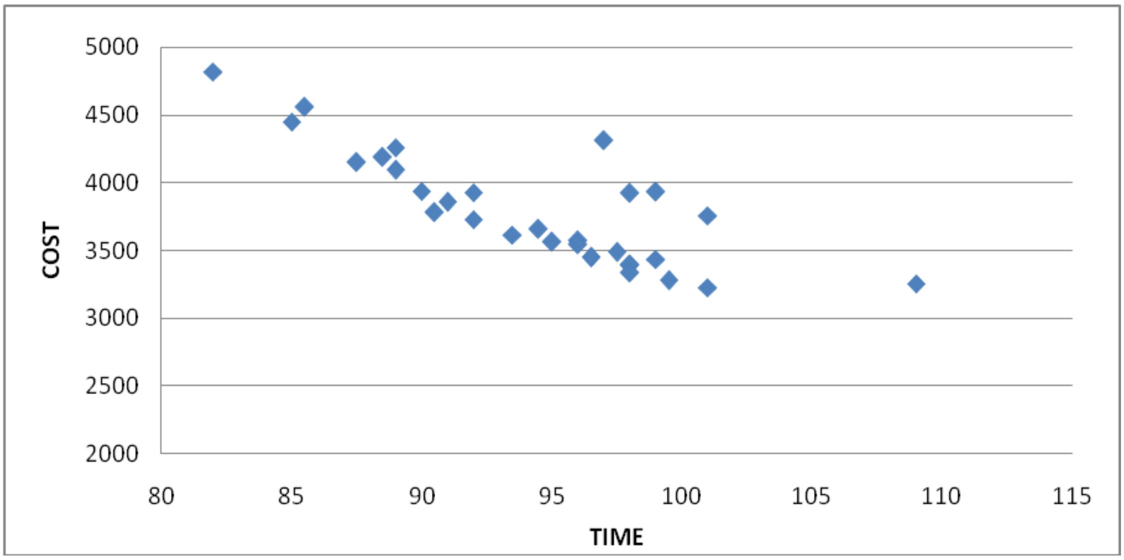


Fig 4.5: Cost vs. time graph for Case 4 (H-L-H)

From the graph it is seen that if 6 loaders, 6 mixer trucks, 1 rollers and 2 body cranes are used the duration is 97 days and the cost is 4313 thousands taka. On the other hand if 2 loaders, 4 mixer trucks, 4 roller and 2 body cranes are used the duration is increased by 1% which is negligible but the cost is reduced by 22.67% (979 thousands taka reduction) which is a significant change.

From the graph shown above we got a curve of optimum combinations which are shown in the following table:

Table 4.13: Combination of resources for optimum results (Case 4-HLH)

Loader	Mixer Truck	Roller	Body Crain	Duration(Days)	Cost(Thou sand Tk)
1	4	1	1	126	3001.6
6	6	4	4	82	4818.7
5	5	4	4	85	4451.6
5	6	3	2	87.5	4149
3	6	3	2	90.5	3781.9
2	4	4	2	98	3334
2	4	2	2	101	3227
1	4	4	2	109	3255

For actual combination of resources, 126 days and 3001.6 thousands taka are needed if case 4 is adopted. Comparing the results shown in the table (table 4.13), it is seen that if 2 loaders, 4 mixer trucks, 4 rollers and 2 body cranes are used the duration is reduced by 22.2% (28 days reduction) and the cost is increased by 11.07%. Change in cost may not be remarkable but the change in duration is high. So, this combination of resources might be suitable for the project.

For case 5 (L-L-H), we considered following Resource acquisition cost, overhead cost and daily operating cost for these resources:-

Table 4.14: Resource acquisition and operation cost Case-5 (L-L-H)

Resource name	Resource acquisition cost (taka)	Operating cost (taka)
Loader	150000	2000
Mixer truck	150000	3000
Roller	40000	2000
Body crane	170000	2000

Overhead cost was considered to be 8000 taka per day.

Considering Case 5, we ran analysis by simulation and got the following graph using the result:

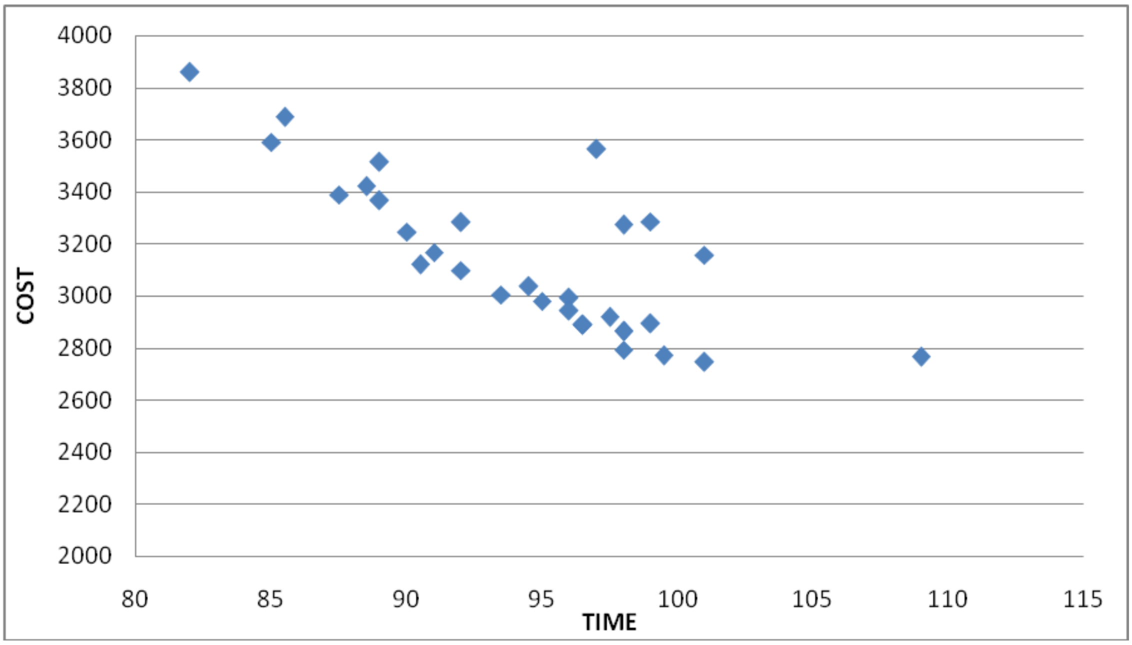


Fig 4.6: Cost vs. time graph for case 5 (L-L-H)

From the graph it is seen that if 6 loaders, 6 mixer trucks, 1 rollers and 2 body cranes are used the duration is 97 days and the cost is 3563 thousands taka. On the other hand if 3 loaders, 4 mixer trucks, 3roller and 2 body cranes are used the duration is increased by 0.5% which is negligible but the cost is reduced by 18.95% which is a significant change.

From the graph shown above we got a curve of optimum combinations which are shown in the following table:

Table 4.15: Combination of resources for optimum results (Case 5-LLH)

Loader	Mixer Truck	Roller	Body Crain	Duration(Days)	Cost(Thousand Tk)
1	4	1	1	126	2661.6
6	6	4	4	82	3858.7
5	5	4	4	85	3591.6
5	6	3	2	87.5	3389
3	6	3	2	90.5	3121.9
2	4	4	2	98	2794
2	4	2	2	101	2747
1	4	4	2	109	2765

For actual combination the duration is 126 days and the cost is 2661.6 thousands taka if case 5 is taken into account. Comparing the results shown in the table, it is seen that if 2 loaders, 4 mixer trucks, 4 rollers and 2 body cranes are used the duration is reduced by 22.2% (28 days reduction) and the cost is increased by 11% (132.4 thousands taka increased) which may not be a significant change in cost but the duration is significantly changed. So, this combination of resources might be suitable for the project.

For case 6 (L-H-H), we considered following Resource acquisition cost, overhead cost and daily operating cost for these resources:-

Table 4.16: Resource acquisition and operation cost Case-6 (L-H-H)

Resource name	Resource acquisition cost (taka)	Operating cost (taka/day)
Loader	150000	2500
Mixer truck	150000	3500
Roller	40000	2500
Body crane	170000	2500

Overhead cost was considered to be 8000 taka per day.

Considering Case 6, we ran analysis by simulation and got the following graph using the result.

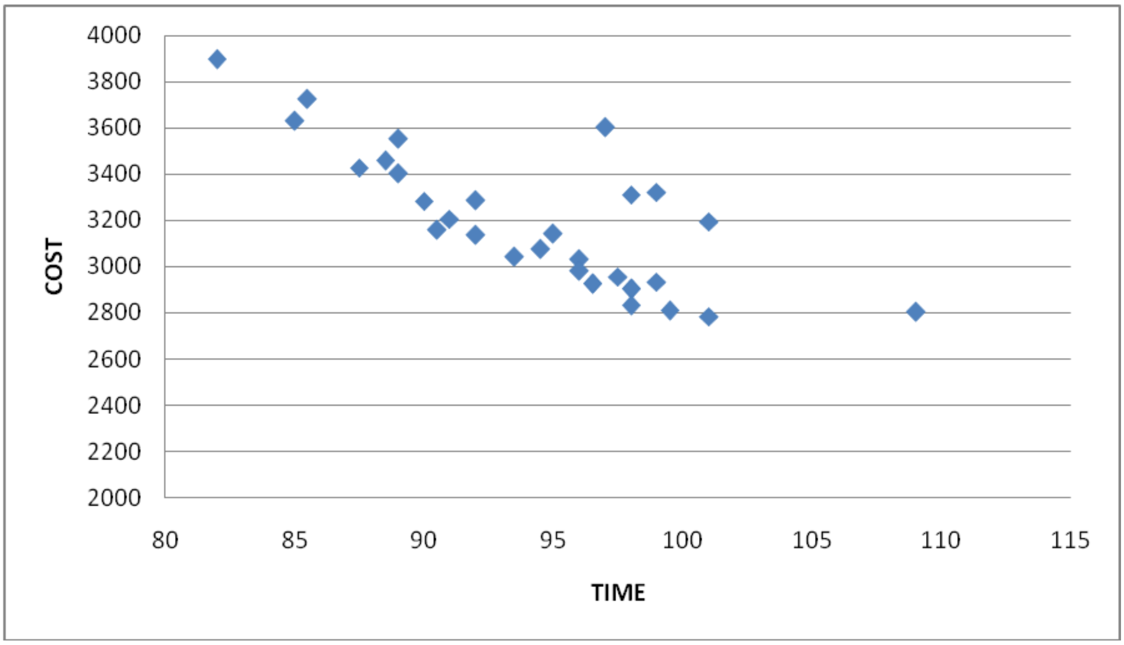


Fig 4.7: Cost vs. time graph for Case 6 (L-H-H)

From the graph it is seen that if 5 loaders, 5 mixer trucks, 1 rollers and 2 body cranes are used the duration is 99 days and the cost is 3323.5 thousands taka. On the other hand if 2 loaders, 4 mixer trucks, 3 roller and 2 body cranes are used the duration is increased by 0.5% which is negligible but the cost is reduced by 15.48% which may be a significant change.

From the graph shown above we got a curve of optimum combinations which are shown in the following table:

Table 4.17: Combination of resources for optimum results (Case 6-LHH)

Loader	Mixer Truck	Roller	Body Crain	Duration(Days)	Cost(Thousand Tk)
1	4	1	1	126	2699.8
6	6	4	4	82	3896.9
5	5	4	4	85	3629.8
5	6	3	2	87.5	3427
3	6	3	2	90.5	3160
2	6	3	2	93.5	3043
2	4	2	2	101	2785
1	4	4	2	109	2803.2
2	4	4	2	98	2832.5

126 days & 2699.8 thousands taka is required in case of actual combination if case 6 is taken to be considered. Comparing the results shown in the table, it is seen that if 2 loaders, 6 mixer trucks, 3 rollers and 2 body cranes are used the duration is reduced by 32.5 days (25.8% reduction) and the cost is increased by 343.2 thousands taka (12.7% increase) which may not be a higher change in cost but the duration is highly changed. So, this combination of resources might be suitable for the project.

For case 7 (L-H-L), we considered following Resource acquisition cost, overhead cost and daily operating cost for these resources:-

Table 4.18: Resource acquisition and operation cost Case-7 (L-H-L)

Resource name	Resource acquisition cost (taka)	Operating cost (taka)
Loader	150000	2500
Mixer truck	150000	3500
Roller	40000	2500
Body crane	170000	2500

Overhead cost was considered to be 5000 taka per day.

Considering Case 7, we ran analysis by simulation and got the following graph using the result.

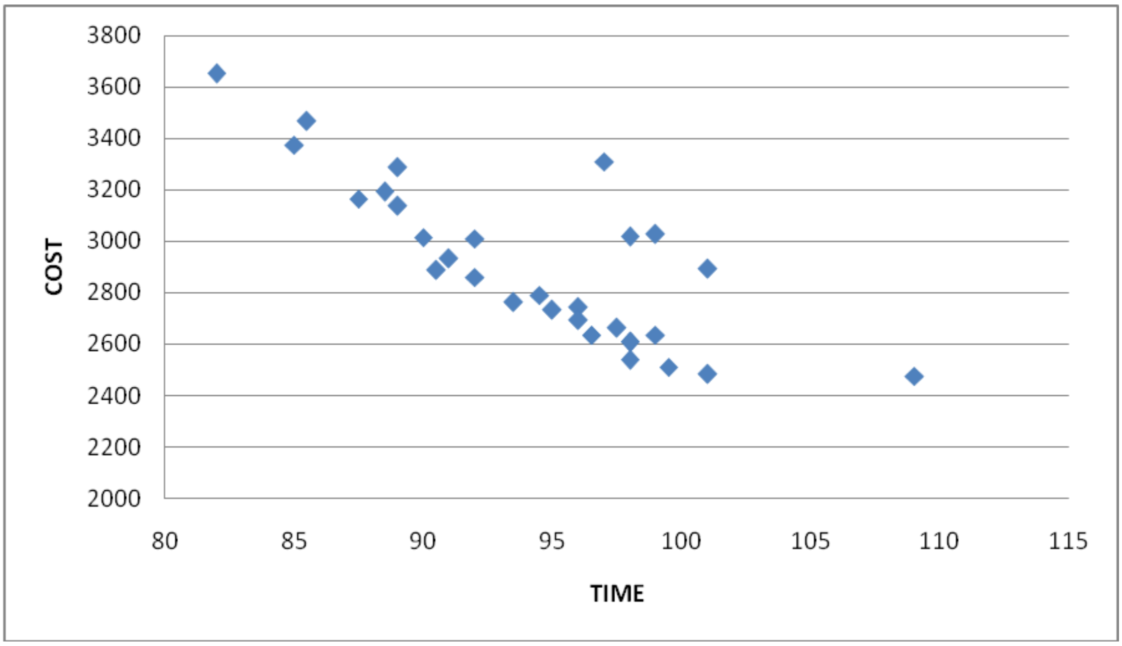


Fig 4.8: Cost vs. time graph for Case 7 (L-H-L)

From the graph it is seen that if 2 loaders, 4 mixer trucks, 4 rollers and 2 body cranes are used the duration is 98 days and the cost is 2538.5 thousands taka. On the other hand if 4 loaders, 6 mixer trucks, 1 roller and 2 body cranes are used the duration remains the same but the cost is increased by 18.9% which is a significant change.

From the graph shown above we got a curve of optimum combinations which are shown in the following table:

Table 4.19: Combination of resources for optimum results (Case 7-LHL)

Loader	Mixer Truck	Roller	Body Crain	Duration(Days)	Cost(Thousand Tk)
1	4	1	1	126	2321.8
6	6	4	4	82	3650.9
5	5	4	4	85	3374.8
5	6	3	2	87.5	3164.7
3	6	3	2	90.5	2888.7
2	6	3	2	93.5	2762.6
3	4	3	2	96.5	2636.5
2	4	4	2	98	2538.5
2	4	2	2	101	2482
1	4	4	2	109	2476

For case 7, it is found from the analysis that 126 and 2321.8 thousands taka is required in case of original combination of resources. Comparing the results shown in the table, it is seen that if 3 loaders, 4 mixer trucks, 3 rollers and 2 body cranes are used the duration is reduced by 29.5 days (23.4% reduction) and the cost is increased by 314.7 thousands taka (13.5% increase). Here, it can be observed that there is almost 1 month reduction in duration which is a remarkable change but the change in cost may not be that much higher. So, this combination of resources might be suitable for the project.

For case 8 (L-L-L), we took following Resource acquisition cost, overhead cost and daily operating cost for these resources:-

Table 4.20: Resource acquisition and operation cost Case-8 (L-L-L)

Resource name	Resource acquisition cost (taka)	Operating cost (taka)
Loader	150000	2000
Mixer truck	150000	3000
Roller	40000	2000
Body crane	170000	2000

Overhead cost was considered to be 5000 taka per day.

Considering Case 8, we ran analysis by simulation and got the following graph using the result.

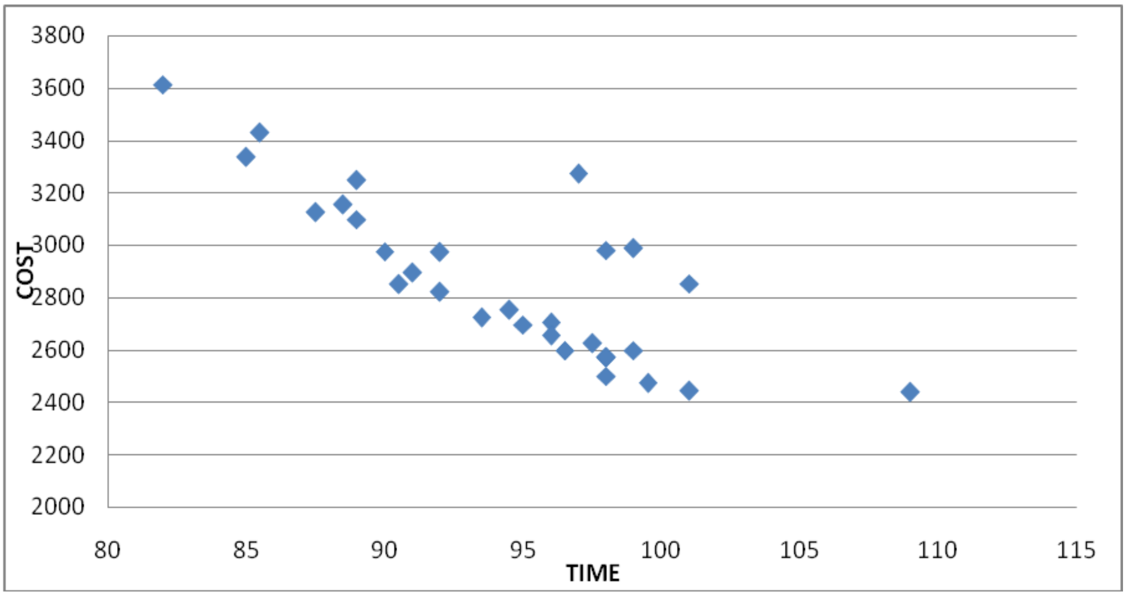


Fig 4.9: Cost vs. time graph for Case 8 (L-L-L)

From the graph shown above we got a curve of optimum combinations which are shown in the following table:

Table 4.21: Combination of resources for optimum results (Case 8-LLL)

Loader	Mixer Truck	Roller	Body Crain	Duration(Days)	Cost(Thousand Tk)
1	4	1	1	126	2283.6
6	6	4	4	82	3612.7
5	5	4	4	85	3336.6
5	6	3	2	87.5	3126.6
3	6	3	2	90.5	2850.6
2	6	3	2	93.5	2724
3	4	3	2	96.5	2598
2	4	4	2	98	2500
2	4	2	2	101	2444
1	4	4	2	109	2438

For case 8 if original combination of resources is used for analysis, 126 days and 2283.6 thousands taka is found to be needed for the project to be completed. Comparing the results shown in the table, it is seen that if 3 loaders, 4 mixer trucks9, 3 rollers and 2 body cranes are used the duration is reduced by 29.5 days which is almost 1 month of reduction and the cost is increased by 314.4 thousands taka. It is seen that change in duration is satisfactory as well as the change in cost may be acceptable. So, this combination of resources might be suitable for the project.

Comparing all the graphs it can be seen that in different cases the number of probable optimum results we got from different combinations of resources varies. From Fig 4.7 the combination of 3 loaders, 4 mixer trucks, 3 rollers, 2 body cranes seemed probable optimum result comparing the duration & cost but it was not a optimum point in other cases like graph 4.6 (Low resource acquisition cost, high overhead cost though operating cost is high), graph 4.5 (Low resource acquisition cost, Low operating cost though high overhead cost), graph 4.4 (High resource acquisition cost, low operating cost, high overhead cost), graph 4.3 (high resource acquisition cost, low operating cost, low overhead cost), graph 4.2 (high resource acquisition cost, high operating cost, low overhead cost), graph 4.1(high resource acquisition cost, high operating cost, high overhead cost). Again in case of graph 4.6 & graph 4.7 for combination of 2 loaders, 6 mixer trucks, 3 rollers, 2 body cranes the result could be optimum but this combination is not optimum for other cases. For some combinations the results are optimum for all the cases like combinations like 2 loaders, 4 mixer trucks, 4 rollers, 2 body cranes the results are optimum for all the cases. There are also some combinations, for example in graph 4.1 we can see that if 2 loaders, 5 mixer truck, 2 rollers, 2 body cranes or 3 loaders, 4 mixer trucks, 2 rollers, 2 body cranes or 2 loaders, 4 mixer trucks, 4 rollers, 2 body cranes are used we get the same duration (98 days) but the result of the cost varies 3432.5, 3432.5, 3372.5 thousand taka respectively. Among these combinations we can choose the third one as the cost has reduced relatively. Similar type of result can be observed in other cases (graphs) too. For case 8 & case 7, a particular change can be mentioned. For a combination of 1 loader, 4 mixer trucks, 4 rollers & 4 body cranes the cost decreases comparing to the closest point in the graph. But in all other cases for the same combination the cost increases comparing to the closest point of the combination of 2 loaders, 4 mixer trucks, 2 rollers & 2 body cranes. For case 6, the combination of 2 loaders, 6 mixer trucks, 2 rollers & 2 body cranes is not optimum as the cost increases comparing to the other cases. Again for case 5, 5 loaders, 5 mixer trucks, 2 rollers & 2 body cranes the combination is not optimum but it could be optimum for other cases as in this case 5 we considered low resource acquisition cost, low operating cost & high overhead cost.

4.4 SUMMARY

From section **4.3** it can be seen that different combination of resources influences the duration as well as the overall cost of the construction operation. As the number of resources are increased the duration of the construction operation decreases. But it also affects the cost of the construction operation. As the number of resources are increased the cost of the construction operation increases also. But for every construction project resources is limited (for this study the maximum available number of loaders has been set to 6, maximum available number of mixer trucks has been set to 7, maximum available number of rollers has been set to 4 & maximum available number of body cranes has been set to 4). Again if the number of certain type of resource is increased than the cost increase is much higher compare to the reduction in total duration. It can be also seen that for various types of cases one certain kind of combination of resources may not give the optimum result for all other cases. Moreover, different combination of cost for different types of expense for the operation (resource acquisition cost, operating cost, overhead cost) also affect the project overall cost. Sometimes it takes more money to complete the project using the same combination for a particular case of cost consideration comparing to the other cases. So it is important to sort out the best combination of resources to obtain minimum duration of a construction operation as well as an acceptable construction cost.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 General

This chapter summarizes the outcome of the study. The effectiveness of the study and how people can be benefited from this study are discussed in short. Possible enhancement of this study and future research guideline are also mentioned in the recommendation part.

5.2 Improving construction productivity

To compete in today's market people are always in need of completing their project with minimum duration and cost. To do so, productivity must be improved. However, construction companies hardly focus on improving productivity. Companies do not invest necessary time on planning for improving productivity. Without a proper plan for improving productivity the project sometimes need more time for completion as a result the cost increases. Sometimes the company has to pay certain penalty for late finishing. Taking this fact into consideration, the study has focused on how construction productivity can be improved. The main purpose of this study were- to improve the productivity of a construction operation by reducing duration and cost of the construction operation; to develop a simulation model for developing a proper schedule that will minimize the duration of the operation as well as keep the expense of the project in an acceptable limit; and to find out the optimum combination of resources for minimum duration and cost.

A simulation model has been developed for a RAMP construction of "Mirpur-Airport Road Flyover". The model has considered different construction activities interaction and combination of resources. From the analysis, best possible combinations have been sorted comparing the duration and cost. It can be found from the results that optimum combination of resource can be significantly shortened along with minimizing total cost of the RAMP construction.

5.3 Effectiveness of the study

The simulation that has been developed for this study can effectively be used to prepare proper schedule, thereby it can be helpful to finish the construction operation within limited time and increased productivity. Optimum combination of resources can be selected by observing the respective duration & cost of the combinations, which will maximize the productivity. As it can provide a proper combination of resources at the beginning of the construction project, resource acquisition can be made at the beginning; thereby delay of operation can be avoided. Again it can help the project manager to allocate the resources efficiently. Therefore misuse of different resources can be minimized which will reduce cost. As the resource needed onsite for maximizing productivity can be known beforehand, smooth working condition can be ensured. In general, this type of simulation model can be an effective tool for reducing construction duration & cost, thereby improving construction productivity.

This study has focused on minimizing the duration and keeping the cost within an acceptable limit. From the analysis it has been observed that if the number of resources is increased, the cost of a project may increase but the duration is decreased. Again if the number of resources is decreased, the cost may go down but the duration will be increased. Moreover using an optimum number of resources may result in minimum duration with acceptable cost. Decision making is actually dependent on the choice of the owner. If it is important for the project to minimize the duration, the number of resources should be increased that may cause higher cost. Again if it is needed to decrease the cost, the number of resources should be lessened that may result in higher duration. On the other hand, if it is required to minimize the cost as well as the duration, optimum number of resources could be used that may provide with a balanced duration and cost. That’s why we have studied this analysis considering both cost and duration. Thus consideration of both duration and cost for the analysis may result in more alternatives.

In case of Bangladesh, usually simulation model is not adopted to prepare scheduling. In most cases decisions are made onsite based on the priority of work to be done. As a result sometimes problems associated with resource scheduling, resource allocation, etc. arise. These types of problems can be solved if simulation model can be done properly.

5.4 Recommendations for future studies

Our study has only dealt with a particular construction operation of a project to develop the model. Detailed study can be performed taking the whole project into consideration. If simulation model is developed for the whole project, there will be more interactions among different activities as well as among the resource sharing.

The activities related to our analysis were mostly sequential. If the activities were parallel, the model would have been more versatile and this analysis would be more useful. In our country, most of the construction works are labor dependent and thus labor is considered as a useful resource. But in our analysis we have ignored labor resource. Moreover, if large numbers of resources are used, the site may become congested and thus the productivity will be dropped. But in our study we didn't consider this fact and chose the number of resources randomly.

Considering aforementioned limitations, future study can be done for improving construction productivity more effectively.

REFERENCES

SK. Nagaraju, B. Sivakonda Reddy, Prof. A. Ray Chaudhuri (2012) "Resource Management in Construction Projects- a case study." *IRACST- Engineering Science and Technology: An International Journal (ESTIJ), ISSN: 2250-3498, Vol.2, No.4.*

Centeno, Javier E. (2004) "How Does Management Impact Construction Productivity?". The Graduate college: University of Wisconsin-Stout.

Seonghoon Kim, Yong Bai, Yang-Ki Jung, and Dukgeun Yun. (2011) "Highway Construction Productivity Measurement with a Wireless Real-Time Productivity Measurement system." Transportation Research Record: Journal of the Transportation Research Board, No.2228, Transportation Research Board of the National Academies, Washington, D.C., pp. 26-33, DOI: 10.3141/2228-04.

Arnorsson, Haraldur. (January, 2012.)"Optimizing the Information Flow on the Construction Site.", Master’s Thesis. Faculty of engineering and science: Aalborg University.

Hassan, M. M., Ph.D. "Estimation of Concrete Paving Construction Productivity Using Discrete Event Simulation." Bradley University.

Page, I.C. (2010)"Construction Industry Productivity." Study Report.

S.P. Dozzi, P.Eng. and S.M. AbouRizk, Ph.D., P.Eng. (December, 1993)"Productivity in Construction."

Shu-Shun Liu, Chang-Jung Wang. (August, 2006)"*Optimization for Resource Assignment Problems of Linear Construction projescts*,". ELSEVIER: Automation in Construction 16 (2007) 460-473.

The Modular Building Institute, USA. "Improving Construction Effeciency & Productivity With Modular Construction ."

Zaneldin, E. K. (June, 2008)"*Resource Optimization of Construction Operations Using AOA-Based Simulation*". Int j simul model 7 (2008) 3, 146-157.

Muthuramalingam, Jayakumar. (November, 2008)"Effective Resource Management in Construction Industries for Success." Vol.2, No.6. School of Engineering and Science, Curtin University Technology.

Fayyed, Tahreer Mohammed. (2010)"Optimizing the Schedule of Resource-Constrained Construction Projects Using Genetic Algorithms." Islamic University of Gaja.

PEng, Dr. George Jergeas. (May, 2009)"Improving Construction Productivity on Alberta Oil and Gas capital Projects." University of Calgary, Alberta, Canada.

Team, CEFRIO Project. (September, 2011)"Improving Effeciency and Productivity in the Construction Sector Through the Use of Information Technologies."