CRASHING PROJECT TIME BY LINEAR PROGRAMMING: A CASE STUDY

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DHAKA-1000, BANGLADESH

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BY

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DEPARTMENT OF INDUSTRIAL & PRODUCTION ENGINEERING

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CERTIFICATE OF APPROVAL

The thesis titled "CRASHING PROJECT TIME BY LINEAR PROGRAMMING : A CASE STUDY" submitted by Mohammah Anamul Haque, Roll No. 100508121(P), Session - October 2005 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Advanced Engineering Management on February 02, 2010.

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It is hereby declared that this thesis or any part of this has not been submitted elsewhere for the award of any degree or diploma.

February, 2010

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ABSTRACT

Business and its environment are more complex today than ever before and decision making has become much more complicated than in the past due to increased decision alternatives, uncertainty, and cost of making errors. As a result, it is very difficult to rely on a trial and error approach in decision making. While dealing with projects, to become competitive, sometimes it is required to complete a project within the predetermined deadline to keep cost at lowest possible level. Failure to do so ultimately leads to increase in total cost. Crashing an activity saves time but increases the cost. Thus there must be a time-cost trade-off. This study mainly provides a framework for reducing total project time at the least total cost by crashing the project network using Linear Programming (LP). Then the model is solved with real project data of an installation project by using Solver in Microsoft Excel. In this work real data is used from machine installation projects in Siemens Bangladesh Healthcare. An illustrative example with a project network consisting of 19 nodes and 22 activities is provided. The computational study includes tabulation of the interrelationships among time and cost.

In this work project crashing base on LP real data is used from installation projects in Siemens Bangladesh Healthcare. Siemens Bangladesh Health care deals with different medical equipments in different hospitals of the country. Now Siemens has several projects in hand and to complete those projects in time it is necessary to crash the project time of those projects. One of the projects is AXIOM Artis installation project which is an angiogram machine at Lab Aid Cardiac Haopital. From previous experience it has observed that it took 51 days to complete the full installation. In this project, management decided to crash the project time and set 40 days to complete the installation.

The purpose of this study is to implement the linear programming models outperforms the default algorithm implemented in these packages to minimize total project cost. It appears that the programming in project time-cost trade-off concept has more to offer than the graphical methods and scheduling software packages. A real understanding of this concept leads to improved solutions to large scale systems facing project cost control systems and network compression.

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CHAPTER-1
INTRODUCTION

1.1 Introduction

Nowadays in business world we are undertaking lots of projects ranging from implementing a large scale manufacturing plant to a small sales campaign. But as the managers are working in a very uncertain environment, it is very difficult or sometimes impossible to meet the deadline of a particular project. That is why astute managers always set a time range for a project other than setting a fixed deadline.

Adding more resources to a project to shorten its duration or to complete the remaining tasks of a running project in time is called "crashing”. For crashing project time with CPM, the first task is to identify the normal critical path and the critical activities. CPM uses two sets of time and cost estimates for activities: normal time and normal cost and crash time and crash cost. Normal time is the estimated time and the normal cost is an estimate of how much money it requires to complete a project in its normal time. Crash time of an activity is the shortest possible time and crash cost is the cost for completing an activity on the crash basis. Basically this information will be used along with the CPM solution to crash the project within a deadline with minimal cost.

In order to meet the project due date, sometimes project manager needs to expedite the project. It means that some activities must be done faster than normal. Crashing an activity saves time but increases the cost. Thus there must be a time cost trade-off. How can crash activities ensure or maintain project cost minimum, in this thesis we propose a model. That incorporates the crashing project with minimum cost using project management software and linear programming. This thesis helps project management practitioners to schedule crash activities more realistically.

In the previous time project crashing base on LP use hypothetical data, in this work real data will be used from machine installation projects in Siemens Bangladesh Healthcare. Siemens Bangladesh Health care deals with different medical equipments in different hospitals of the country. Now Siemens has several projects in hand and to complete those projects in time it is necessary to crash the project time of those projects. One of the projects is AXIOM Artis installation project which is an angiogram machine at Lab Aid Cardiac Hospital. From previous experience it has observed that it took 51 days to complete the installation. In this project, management decided to crash the project time and set 40 days to complete the installation. In this project total numbers of activities are 22 which can summarize as room preparation, machine installation, calibrations and hand over.

This practical oriented work will help to crash the project time with least cost and can be used for determining which activities should be crashed, which should be slowed (if the money for crashing has to come from another activity), and for determining which activities need to be most closely monitored. This model will provide us a systematic and logical approach for decision making and ultimately increases the effectiveness of the decision. As the LP solution provides the starting time of the activities, this can be used for monitoring the project. The sensitivity analysis generated from LP solution also provide the upper limit and lower limit of the variable coefficient of the objective function within which solution would remain optimum

1.2 Background

Time-cost trade-off problems for a project network have been studied since the late 1950s and were mostly focused on shortening its duration by crashing the time required for performing an activity. The Critical Path method (CPM) is a common technique to illustrate the time constraint of a project. It is more suitable for deterministic rather than probabilistic applications. Applicable areas of CPM includes various types of projects such as construction, maintenance, retooling programs for high-volume production, new product launching, assembly and testing of production facilities, installation, as well as programming and debugging of computer systems . CPM is used to determine time-cost trade-off for an activity that meets given project completion time at a minimum cost and is useful when having some similar experiences from previous projects.

In the first paper on PERT, Malcolm (1959) presented their well-known method for estimating the probability of completing a project at its scheduled date using the beta distribution. As Elmaghraby (1977) explains, shortcomings in the assumptions behind PERT has lead to other techniques for dealing with uncertainty, including generalized activity networks (GAN) and graphical evaluation and review technique (GERT).

A mathematical model based on CPM is a linear program for calculating the utility of a project. Liberatore (2001) proposed a quadratic mixed integer programming approach for reducing project completion time that considered crashing as well as the removal and modification of precedence relationships. The net benefit in time-cost trade-off of a project can be increased by doing successive scheduling with stochastic effects which a lances time, cost and resources. This successive scheduling is aimed at reducing the uncertainty of a schedule.

Babu and Suresh (1996) developed linear programming models to study the tradeoffs among time, cost, and quality under their judgment that quality might be affected by crashing the project. To this extent they adapted a continuous scale from zero to one to specify the quality attained at each activity. Tareghian (2006) proposed three binary integer programming models for assisting decisions regarding the tradeoffs among cost, duration and quality of a project, where cost and quality were discrete non-increasing functions of project duration.

In a case study on the trade-off among time, cost and quality, Khang (1999)applied the Babu and Suresh's framework to an actual cement factory construction project. Results indicated that the quality measurement for each of the activities was too subjective and inaccurate to be considered as an objective function by a linear programming formulation.

In our country Islam, Nazrul and Rana, Baktiar (2004) provides a framework for reducing total project time at the least total cost by crashing the project network using Linear

Programming (LP). Then the model is solved with hypothetical data of a hypothetical project by using Solver in Microsoft Excel.

1.3 Importance of Executing this Project

Projects are typically defined as successfully if they are completed within their allocated time and budgets. Often actual project completion times exceed the allocated timeframe. A prime example of the above claim is the construction industry. Project delays stem from variability induced when pre-mobilization assumptions do not match reality. More specifically, unforeseen changes in both construction technology and or techniques will likely create budgetary and schedule stress. Ultimately this increases the risk of project failures. The results of a survey on the completion time of different types of construction projects in Saudi Arabia indicated that 45 of 76 (about 60%) projects experienced time delay.

A common technique to alleviate schedule pressure is to 'crash' a particular activity or activities. Crashing an activity is the process of allocating greater than planned resources to accomplish the same task in a shorter duration. The extended resources could consist of capital equipment or direct labor.

It is axiomatic that all projects are constrained by budget, time and scope. Overemphasis on one constraint will be at the expense of the other two. Hence the claim that crashing an activity represents a time-cost trade-off. However, an implicit assumption in crashing is that the scope of the task does not enter the trade-off equation. Therefore, in addition to delivering a timely cost effective project, the project must meet the owner's requirements. Thus project managers need to also balance the possibility of rework or modifications associated with incorrectly completed crashed activities.

The assumption of traditional time-cost trade-off problems is that an activity is completed without any rework as scheduled. But this is not always valid. In the existing literature, some researches have also taken scope quality into account as a significant factor in the time-cost tradeoff problems. In one case, they promote a continuous scale from zero to one for specifying the quality attained from each of all activities. However, in an application of the Babu and Suresh's time-cost-quality trade-off models for a cement factory construction project in Thailand, the manager and engineers involved in that project had difficulty accepting the premises that project quality could be compromised by crashing. Their opinion was that an activity's quality could be decided by their subjective judgment.

Therefore the concept that scope quality must be taken into consideration when making an activity crashing decision is made is not fully accepted. The purpose of this thesis is to present research regarding minimizing cost and project activity crashing. In addition, this proposes a model to account for scope quality in time-cost trade -offs.

1.4: Guideline for Crashing

Some actions are involved in the faster completion of a project. Based on experience with a number of projects, the following actions would lead to faster completion schedules:

- Carry out the activities listed next while preparing a feasibility report or a detailed project report (expenditure on these activities could be in fructuous if the project. is not approved or is abandoned)

  - Soil investigation, site survey, and site selection

  - obtaining clearances on environmental impact assessment report; no objection certificate from the State Pollution Control Board and other agencies

  - Land acquisition and engineering for site grading, site development, roads, boundary wall, drains, culverts, etc.

  - Planning and design of infrastructure and facilities

  - Action on pre-project activities such as selection of licensor and engineering contractor; development of overall plot plan, electrical single line diagram, etc.

  - Finalization of project design book with licensor and engineering contractor (project design book includes design basis, project scope and procedures, project execution methodologies, and philosophies)
- Plan activities in parallel to the extent possible

- Plan on the basis of earliest start
- Take advance action when possible and feasible
- Use with some risk historical data, preliminary information and past experience on similar jobs for:

  - Piling and foundation design

  -ordering for bulk materials such as reinforcement bars, torsteel, cement, structural steel, plates, piping, electrical, and bulk instrument kerns

  - Pipe racks and sleepers size and loadings

  - Road crossings for piping, cables, etc.

  - Road culverts, etc.
- Repeat facilities if possible based on previously executed projects and use the same drawings
- Plan liberally on construction aids, construction site requirements and infrastructure such as cranes, mobile equipment, inspection and testing equipment, de-watering pumps, welding sets, etc.
- Plan for scarce construction materials and consumables
- Plan for standby facilities such as diesel generator sets for construction power
- Negotiate orders and contracts based on item rate, component pricing philosophy, rate contracts, etc.
- Negotiate shorter deliveries for supplies and shorter completion time for erection contracts
- Introduce attractive bonus clause
- Use modular construction approach
- Use faster mode of transportation
- Change from indigenous to imported equipment or vice versa for faster deliveries
- Vigorous follow-up and expediting.

However, each of the above actions will have direct or indirect cost implications. These costs have to be carefully analyzed and compared with the likely savings, keeping always the feasibility of the compressed schedule in view. Otherwise, one may end up with both schedule overruns and cost overruns. Also, reduced durations should not be attempted by sacrificing quality, operability or safety of the plant.

Project planners would do well to explore tradeoffs through a detailed study of different time and cost factors, as it can save project cost considerably. In the field of project management study it is found that advance, timely, and proper action can enable crashing most time schedules by 10 to 15 per cent of normal time duration. In some cases, it may be possible to compress time schedules by 30 to 40 per cent. The costs of crashing time by more than 20 per cent of the normal time increase more rapidly than the anticipated savings from crashing. The following issues must be kept in mind about the time schedule of a project:

• One has to be cautious in analyzing the options for a project time schedule. They have to be realistic within prevalent environment and constraints

• crashing should not be attempted by sacrificing quality, operability, and safety of the plant

• the optimum time schedule should be backed by proper execution strategies and alternative action plans which take into account reasonable assumptions, achievable targets, and practicable execution philosophies and methodologies

Crashing project time is a project management tool and technique which play a critical role in helping to successfully plan, implement and complete projects on time. This work delivers the knowledge to create clear project missions and goals, accurately estimate project time and costs, manage project scope, schedule and allocate time-critical resources, and establish feedback systems to ensure project control in time.

CHAPTER-2
PROJECT CRASHING

2.1 Project Crashing Situation

A project must be sped up to meet a deadline, “crashing” the program or project is to speed up various activities to reduce the total time of the project, by allocating more resources to their completion. To shorten the critical path, it is necessary to increase the resources allocated to activities on it. This increases both the cost per day and the total cost of the activities. The duration of some activities may be very sensitive to changes in the resources allocated to them.

Reasons for imposed project duration dates i.e. project crashing are:

1. Customer requirements and contract commitments
2. Time-to-market pressures
3. Incentive contracts (bonuses for early completion)
4. Unforeseen delays
5. Overhead and goodwill costs
6. Pressure to move resources to other projects

There is agreement with customer that project will be handed over in schedule time. Management suggested that time management involved the process of determinacy of needs, setting goals to achieve the needs, prioritizing and planning the tasks required to achieve these goals.

2.2 Causes of Project Failure

It's true that every project is unique. However, it's also true that all project failures can be assessed using the same generalities. It helps to understand these because then proactive in avoiding the problems to begin with.

1. Poor up-front planning

This is probably the most common problem. If you have ever been on a troubled project, chances are you looked back and said "We should have spent more time planning." Projects that start execution without fully understanding the work to be done (and getting the sponsor to agree) are usually destined for problems. By the time you realize that you are not in synch with your sponsor, it's usually very difficult to get back on track within the allocated budget and timeframe.

2. Incomplete or vague project work plan

Work plan (schedule) is the roadmap that describes how to complete the work. We have problems if work plan is at too high a level, incomplete or not up-to-date. We may get away with it on a small project, but it will be fatal on a larger effort.

3. Weak ongoing project management discipline

Some project managers do a great job in the upfront planning process, but then don't manage the project effectively from that point on. This includes having problems managing scope change, resolving issues, communicating proactively and managing project risks.

4. Inadequate resources

This covers a lot of areas. Manager may not have the right level of resources because he didn't estimate the work correctly. Manager might have estimated the work correctly, but his management has not allocated the proper level of staffing. It's possible that manager has enough bodies, but he doesn’t have people with the right skill mix. All of these may lead to major project failures.

5. People problems

In experience, people tend to get along fine when the project is on track. However, if the project gets into trouble, people start to work longer hours, feel more stress, get more edgy and have more personality conflicts. While it is certainly possible that these problems are actually causing the project to slip, it is also likely that other problems are causing the problem and that the people problems are a later symptom.

6. Lifecycle problems

There are many opportunities for project problems throughout the lifecycle. Many of these will cascade as the project progresses, leading to major trouble. Examples of lifecycle problems include:

- A failure to clearly and completely define the requirements, resulting in building the wrong features or leaving gaps in the features needed.
- New or state of the art technology may cause unanticipated problems.
- A poor technical design is not allowing the solution to be easily modified or is not scalable.
- Requirements are not frozen late in the project and continued change requests start to cause the project to drift.
- Technology components do not fit together as designed.
- Poor initial testing techniques cause repeated errors and rework in later tests.

All of these problems will cause projects to struggle. If problems occur toward the end of the project, manager may have no choice but to do whatever is required to push the project to completion. The problems that appear earlier will cause the most trouble over time and are more likely to be the ones that require a full project rescue.

2.3 Project Failure Prevention

It is now well-known and well-documented that far too many projects fail totally or partially, both in engineering generally and software engineering. Every project manager want his project must completed in schedule time. To prevent project failure here describe some 'Principles for Project Control'
The principles for project control can be summarized as follows:

1. Put Together the Right Team

If project requires a number of people, make sure they are the right people for the job and that they can and will work together as a team, rather than working as a committee. They need the right mix of technical skills, and they need to be a balance of thinkers and doers, starters and finishers. And avoid a group of highly talented prima-donnas - with all that ability (and ego), chances are they won't work as a real team. On the other hand one prima-donna may be the salvation of a project.

2. Clearly Define the Deliverable

Get a clear definition of the functionality of the product you are going to deliver, document it thoroughly and make sure everyone agrees in writing. Once you know what you are going to deliver, get a clear definition of the design - how it is going to work.

3. Manage Change

Even if prroject manager has functional and design specifications that are cast in concrete, there will be changes, both practical and whims. A good change control procedure will allow manager incorporate necessary 'improvements' and avoid the unnecessary 'wishes'.

4. Accurate Estimates

Estimates are critical to a projects success. In the real world they will never be perfect, but they can be the best manager can get with the information he has. Here are some general tips:

- Do own estimating, but balance numbers against those of experts in environment and who have experience delivering the type of product are working on.

- Remember that if the estimate is 16 man-hours to complete a task, the elapsed time will be closer to two and a half days rather than two days.

- Don't put the cart before the horse and base estimates on deadlines, unless managers are allowed to drastically trim the functionality!

- Once work begins, track the actual time to complete a task. Compare the actuals against estimates - if they are wildly off, manager may need to re-estimate everything.

5. Identify Risks, Dependencies and Assumptions

Even if the project looks simple, the unexpected can and will occur. List everything that would have a negative impact on schedule and deliverable, and make sure everyone involved is aware of what can go wrong and what need to be successful.

6. Set Realistic Deadlines

Once project manager has his 'accurate' estimates, base his milestones and deadlines on a realistic schedule. Include contingency to cover the unexpected. Incorporate the information manger has on the risks, dependencies and assumptions - if manager is dependent on delivery from another team; make sure his requirements and their ability to deliver are in sync.

7. KISS (Keep It Simple S-)

Once project manager has a clear idea of what is required, step back and look at the scale of the project. If it's too big to be managed effectively, manager need to rethink his strategy. Projects regularly fail because the team took on too much and/or didn't/couldn't break the effort down into separate areas of functionality which could be developed by coordinated teams.

8. Document Everything

Every meeting, procedure, decision, success and problem should be documented. Weekly status reports are a must. If project manager think his documentation isn't being read, start holding meetings, calling the invitees on the phone if necessary to get them to attend. Meeting minutes should be published too - remember he who writes the minutes rules the meeting, so make sure Project Manager take the notes.

9. Involve the Customer

A good customer will be an ally in getting the resources manager need to achieve his mutual goals, in getting by-in from other teams and as a source of morale support. If project manager is building a product for a customer project manager will never see, involve them indirectly by using the internet to see what people are asking for and what they are complaining about.

10. Make the Tough Calls

If project manager find his project is slipping, it's time to make some tough choices. If a team member isn't working out, they may need to be replaced, even at the cost of getting a new member up-to-speed. If the estimates are proving to be less than 'accurate', re-estimating and re-scheduling is required. If the functionality is proving too much for the time-scales, propose a more phased approach, delivering a core product with enhancements later.

11. Be Proactive

Try to solve situations before they become real problems. If anyone see a problem he can do nothing about, report it to the proper people as soon as possible, along with any alternatives he can identify to keep things on track.

2.4 Different Process of Crashing

To complete a project in time we need to crash the project. This can be done in several ways

- Adding Resources
- Outsourcing Project Work
- Scheduling Overtime
- Establishing a Core Project Team
- Do It First—Fast and Correctly
- Fast-Tracking
- Critical-Chain
- Reducing Project Scope
- Compromise Quality

There are different ways to analysis project crashing, those are:

1. Project Crashing using Linear Programming with least cost.

This approach of project crashing is applicable with Critical Path Method, where both the time to complete each activity and the cost of doing so are known with certainty. CPM uses two sets of time and cost estimates for activities: 1) a normal time and normal cost; 2) a crash time and crash cost. LP (Linear Programming) is used for developing the model to get a solution to minimize the project crashing cost by crashing time of the project activities

2. Activity Resource Elasticity: An Approach to Project Crashing

Here assume the time saved is a linear function of the increase in resources used per day. As a result, it can compute how sensitive an activity's duration is to the resources made available, which we call the "resource elasticity" of the activity, the percentage reduction in time, divided by the percentage increase in resources. This elasticity measure is a practical, easily implemented metric that allows the manager to identify which activities' duration times are more or less sensitive to daily spending rates. This metric can be used for determining which activities should be crashed, which should be slowed (if the money for crashing has to come from another activity), and for determining which activities need to be most closely monitored.

3. Crashing Analysis of a Stochastic Project using GERT

In a stochastic network, a single activity may significantly influence the duration of a project. In this case the graphical evaluation and review technique (GERT) can use to deal with the stochastic project and proposes a formula to measure the importance of an individual activity. Moreover, here present a crashing index for each individual activity to identify the priority of crashing the activity. Based on the crashing indices, decision makers can deal more effectively with such problem.

4. Project crashing by analysis project cost(Time -cost Tradeoff)

- Reducing the time of a critical activity usually incurs additional direct costs
- Cost-time solutions focus on reducing (crashing) activities on the critical path to shorten overall duration of the project

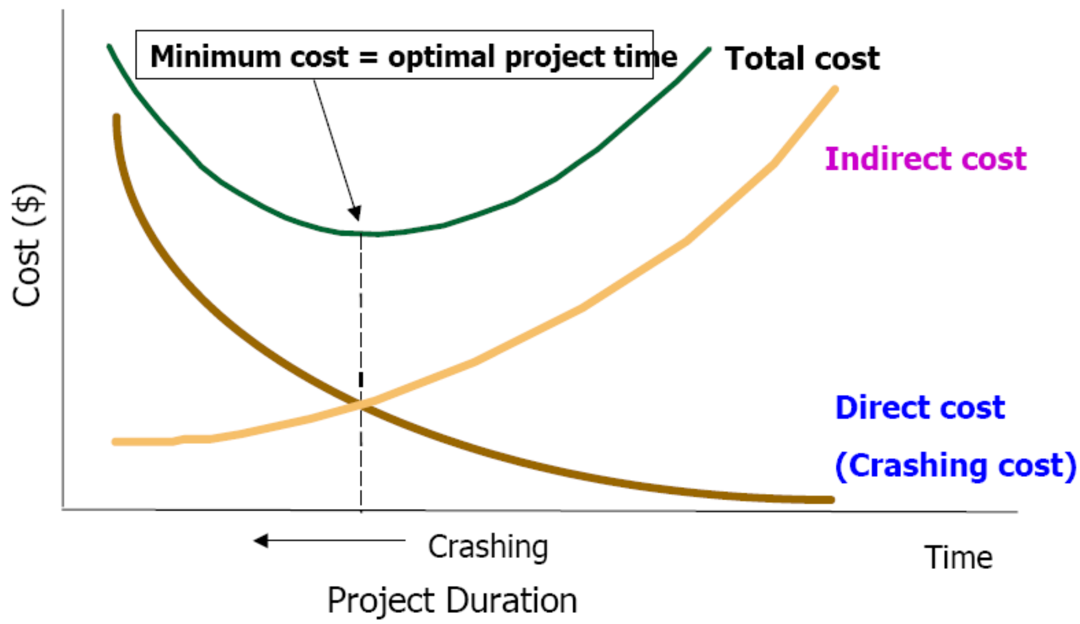

Fig 2.1: Project crashing by analysis project cost (Time-Cost Trade-off)

- Gather information about direct and indirect costs of specific project durations.
- Search critical activities for lowest direct-cost activities to shorten project duration.
- Compute total costs for specific durations and compare to benefits of reducing project time.
- Crashing costs increase as project duration decreases
- Indirect costs decrease as project duration decrease
- Reduce project length as long as crashing costs are less than indirect costs (optimum cost)

2.5 Project Crashing Using LP

LP (Linear Programming) is used to get a solution to minimize the project crashing cost by crashing time of the project activities. Project data has been used to run the model. Solver option of Microsoft Excel has been used to solve and generate report of the problem.

Linear programming is a tool for decision making under certain situation. So, the basic assumption of this approach is that we have to know some relevant data with certainty.

The basic data requirements are as follows:

1) Have to know the project network with activity time, which can be achieved from PERT and CPM.
2) To what extent an activity can be crashed.
3) The crash cost associated with per unit of time for all activities.

Project is the combination of some activities, which are interrelated in a logical sequence in the sense that the starting of some activities is dependent upon the completion of some other activities. These activities are jobs which require time and resources to be completed. The relationship between the activities is specified by using event. As an event represents a point in time that implies the completion of some activities and the beginning of new ones, the beginning and end point of an activity are thus expressed by two events.

Now the variables of the problem are:

X_i = the time when an event i will occur, measured since the beginning of the Project, where i = 1 to m.

Y_j = Amount of times (measured in terms of days, weeks, months or some other units) that each activities j will be crashed where $j = 1$ to n.

C_j = Crash cost per unit of time for activity j.

The objective is to minimize the cost of crashing the total project, LP objective function will be:

Minimize $Z = \sum_{j=1}^{n} C_j . Y_j$

Using Solver in Microsoft Excel minimum crashing cost can be solved. In this thesis for project crashing Linear Programming is used. This gives us the least cost solution in crashing the project.

There is a relationship between a project's time to completion and its cost. For some types of costs, the relationship is in direct proportion; there is an optimal project pace for minimal cost. By understanding the time-cost relationship, one is better able to predict of a schedule change on project cost.

It is difficult to estimate cost for compressed time schedule. They are necessarily subjective. Only a shrewd, experienced and skilled estimator can provide reasonably correct estimates of cost. Schedule crashing costs, therefore, should be accepted only after detailed review and analysis. Project manager has a great responsibility to plan and schedule the project and prevent project failure.

CHAPTER-3
PROJECT DESCRIPTION OF SIEMENS

3.1 Siemens Bangladesh Limited (SBL)

SIEMENS is one of the worlds largest Electrical Engineering and Electronics Company since 1854 in Germany. The company has approximately 47500 employees working in over 190 countries to develop and manufacture products, design and install complex systems and projects

SIEMENS in Bangladesh began in 1956 and since then it has been involved in a number of Bangladesh's major modernization and infrastructure development programs. Since then it has managed to establish its brands as one of the most trusted and sought after. Today Siemens stands for quality, excellence, and class. With her wings spread over such diverse area as health, information technology, power and energy, and home appliances, SBL consistent with its parent company's culture and principles, is looking toward the future- as it has been for the last 40 years.

The company has nine separate divisions for the smooth operations in Bangladesh. The five divisions are directly related with business and rest four are supporting divisions.
The main divisions are:

- Medical Solutions Division / Health Care
- Power Generation & Transportation System Division
- Power Transmission & Distribution System
- Telecom & Information Technology
- Consumer products

Supporting Divisions are:

- Human Resources Division

- Finance & Accounts Division
- Corporate Communication & Business Development Division

Medical solutions division:

Medical engineering is one of the keys to Siemens' success. From the beginning, Siemens has been the market leader in medical equipment in Bangladesh. It is SBL's goal to provide high- performance systems and devices, top-quality diagnostics and treatments, as well as maximum possible protection.

With over 7,000 products, Siemens is the largest manufacturer of medical engineering devices in the world. Two-thirds of its products are less than three years old, and it applies for a new patent almost every day. SBL's responsibility doesn't end right after selling equipments or a solution. It also carry out project planning for the clients that include room-planning, site planning as well counseling about the equipments, before it actually install and commission the necessary Siemens medical equipment for the clients.

SBL also provides after- sales service, which include full maintenance of the equipment and solutions, including providing training on use of the equipments. Here is a list of equipments offered by SBL.

Table 3.1: Medical Equipments Offered by SBL

Medical Equipments offered by SBL	
Angiography Systems/ Angio-cardiogram Machine	Mobile X-Ray Systems
Lithotripsy Systems	Simulator
Magnetic Resonance Imaging (MR!) Systems	Echocardiography
Mammography Systems	OT Table
Mobile C-Arm Systems	Ultra sonogram
Computed Temography (CT) Systems	Anesthesia Machine
Colour Doppler Machine	Patient Monitoring
Gray Scale Digital Ultrasound Systems	Gas Pipeline

Linear Accelerator & Simulator Systems	OPG
Linear Accelerator & Simulator Systems	Dental X-Ray
Nuclear Medicine (Gamma Camera & PET) Systems	Servo Ventilator
X-Ray (Radiography & Fluoroscopy) Systems	Dental Chair
Hearing Solutions	OT Light

3.2 Projects Handle by Siemens Medical Solution

Siemens medical Solution of Bangladesh deals with different medical equipments in different hospitals of the country. Siemens is vendor of all high tech medical diagnosis and treatment equipment like Angiogram Machine, Linear accelerator , MRI, CT Scan, Digital X Ray, 3D Ultrasound, OPG, Mammography machine etc. Basic responsibilities of Siemens Health care are installation of those machines and after sales service. Installation of different type's machine is main project work of medical solution division.

Installation of those machines needs lot of resources, manpower, money and time. On the basis of project, time need for installation from one week to two months. By this time project manager complete room preparation, Installation work and handed over procedure.

3.3 Present Situation of Different Projects

Now Siemens Health care handles several installation projects. Those projects are in private sector and some are in Govt. sector.

3.3.1 Government projects

There are several Government projects now in hand of SBL. In Govt. project there is dead line by which the project should complete other wise there is a plenty for this. That's why those Govt. projects should give special attention. Govt. projects in hand are given in the Table 3.2.

Table 3.2: Government Project in Hand

No	Machine Name	Machine Location
1	Digital X Ray (Iconos R 100)	Medical College Hospital, Sylhet
2	Digital X Ray (Iconos R 100)	Medical College Hospital, Khulna
3	Digital X Ray (Iconos R 100)	Medical College Hospital, Mymensing
4	Digital X Ray (Iconos R 100)	General Hospital, Kishorgong
5	Digital X Ray (Iconos R 100)	Medical College Hospital, Barisal
6	Digital X Ray (Iconos R 100)	General Hospital, Jamalpur
7	Digital X Ray (Iconos R 100)	General Hospital, Kushtia
8	Digital X Ray (Iconos R 100)	General Hospital, Gopalgong
9	Digital X Ray (Iconos R 100)	General Hospital, Jessore
10	Digital X Ray (Iconos R 100)	General Hospital, Potkhaliua
11	Digital X Ray (Iconos R 100)	General Hospital, Norshindy
12	Digital X Ray (Iconos R 100)	General Hospital, Noakhali
13	Digital X Ray (Iconos R 100)	General Hospital, Gaibhanda
14	Digital X Ray (Iconos R 100)	General Hospital, Tanghail
15	Digital X Ray (Iconos R 100)	General Hospital, Bogra
16	Digital X Ray (Iconos R 100)	General Hospital, Pabna
17	Digital X Ray (Iconos R 100)	General Hospital, Cox Bazar
18	Digital X Ray (Iconos R 100)	General Hospital, N-Gong
19	Digital X Ray (Iconos R 100)	General Hospital, B-Baria
20	Digital X Ray (Iconos R 100)	General Hospital, Panchagor
21	Digital X Ray (Iconos R 100)	General Hospital, Feni
22	CT Scan	NICVD
23	CT Scan	SSMC & Mitford Hospital,
24	CT Scan	Medical College Hospital, Dinagpur
25	CT Scan	Medical College Hospital, Sylhet
26	Digital X Ray Axiom Aristros	TB Hospital, Rajshahi
27	Digital X Ray Axiom Aristros	TB Hospital,Chittagong
28	Digital X Ray Axiom Aristros	TB Hospital, Khulna
29	Digital X Ray Axiom Aristros	TB Hospital, Dhaka
30	C Arm Serimobil Compact	DMCH, Dhaka

31	C Arm Serimobil Compact	SSMC, Mitford, Dhaka
32	C Arm Serimobil Compact	CMCH, Chittagong
33	C Arm Serimobil Compact	NICVD, Dhaka

3.3.2 Private Sector Project in Hand

There are several projects of private customer now in hand. Meet the deadline of handed over is very important. It is directly related goodwill of the company. So management always wants to hand over the project in time.

Table 3.3: Private Project

No.	Machine Name	Hospital Name
1	AXIOM Artis dFC (Angiogram machine)	Lab Aid Cardiac Hospital
2	AXIOM Artis dFC (Angiogram machine)	Ibnsina Hospital, Dhaka
3	Lumimons Classic (Digital X Ray)	Ibnsina Hospital, Dhaka
4	Multix Swing (X Ray)	Ibnsina D Lab
5	AXIOM Iconos R 100 (Digital X Ray)	Ibnsina Hospital, Sylhet
6	Multix Swing (X Ray)	Ibnsina Hospital, Sylhet
7	OPG Dental	Ibnsina Hospital, Sylhet
8	Mammography	Ibnsina Hospital, Sylhet
9	CT Scan	Popular Diag, Mymensing
10	CT Scan	Popular Diagnostic, Rangpur
11	OPG Dental	Popular Diagnostic, Dhaka
12	OPG Dental	Popular Diagnostic, N Gong
13	Multix Compact (X Ray)	Ibnsins D Lab, Dhaka
14	MRI	Ibnsins D Lab, Dhaka
15	MRI	Ibnsina Hospital, Sylhet

To complete those projects in time it is necessary to crash the project time of those projects. It is very important for customer satisfaction and good well of the company. In govt. project there is a plenty if company fail to install all machine in schedule time. In this case management takes decision to crash some projects to meet the dead line of all projects. Private customer are very sensitive about time that's why first take decision to crash the installation project time of Angiogram machine at Lab aid Cardiac Hospital. Management has also plan to crash the 21 Govt. X Ray installation project which improve companreak y good will and reliability.

3.4 Analysis the Project Using Project Management Software

Using project management software "Openproj" this installation project can describe. Installation project of 21 Iconos R 100 Digital X-ray machine and one AXIOM Artis dFC Angiography machine are planed by using OpenProj softwere.

First we plane the project, define all sub tasks and precedence task after than schedule all those tasks according to start date, finish date. Allocate the resource for the task. Using Openproj software we find project network diagram from which we find critical path of the project, and project details information.

Iconos R 100 Digital X-Ray installation project is a Govt. project, 21 digital X-Ray machines will be installed in different part of the country. Here installation schedule is done by Openproj where task description, start date, duration, predecessors, resource name and resource cost need to define.

Angiogram machine installation is private project at Lab Aid cardiac Hospital which is our main case study. All task and sub tasks are defined of this project through Openproj software.

		Name	Duration	Start	Finish	Predecessors	Resource Names
1		Installation in Kushtia	20 days	2/5/09 8:...	2/28/09 5...		Engineer 1[50%];Site Engineer;Application Expart;Skill Technician 1;S...
2		Installation in N Gong	17 days	12/21/08...	1/8/09 5:...		Application Expart;Labor;Site Engineer;Skill Labor 3b;Installation Set ...
3		Installation in Jessore	26 days	1/4/09 8:...	1/29/09 5...		Labor;Engineer 3;Engineer 4 ;Site Engineer;Application Expart;Skill La...
4		Installation in Barisal	20 days	1/10/09 ...	1/29/09 5...		Application Expart;Site Engineer;Engineer 1;Skill Technician 1;Skill Lab...
5		Installation in Noakhali	19 days	1/18/09 ...	2/5/09 5:...		Application Expart;Engineer 2;Installation Set Up & Excessories 2;Lab...
6		Installation in Norshindy	23 days	1/31/09 ...	2/19/09 5...		Application Expart;Engineer 3;Engineer 4 ;Installation Set Up & Exces...
7		Installation in Sylhet	20 days	1/31/09 ...	2/19/09 5...		
8		Room Preparation in Sylhet	8 days	1/31/09 ...	2/8/09 5:...		Site Engineer;Labor
9		Room planning	1 day	2/9/09 8:...	2/9/09 5:...	8	Engineer 1
10		Table Base Installation	0.5 days	2/10/09 ...	2/10/09 1...	9	Engineer 1;Skill Labor 1a;Installation Set Up & Excessories 1
11		Transport the Unit in Location	1 day	2/9/09 8:...	2/9/09 5:...	8	Skill Technician 1;Skill Labor 2a;Skill Labor 3a
12		Image Intensifier Installation	1 day	2/10/09 ...	2/10/09 5...	11	Skill Labor 2a[50%];Skill Labor 3a[50%];Engineer 1[50%]
13		Table Installation	1 day	2/11/09 ...	2/11/09 5...	9;12	Engineer 1;Skill Technician 1[50%];Skill Labor 1a;Skill Labor 2a;Skill La...
14		Tube Installation	0.5 days	2/12/09 ...	2/12/09 1...	13	Engineer 1;Skill Labor 1a
15		Table Electronics Installation	0.5 days	2/12/09 ...	2/12/09 5...	14	Engineer 1;Skill Labor 2a;Skill Labor 3a;Skill Labor 1a
16		X Ray Generator Installation	2 days	2/9/09 8:...	2/10/09 5...	8	Skill Labor 1a;Skill Labor 3a[50%]
17		Monitor Trolly Setup	3 days	2/13/09 ...	2/15/09 5...	15	Skill Labor 3a;Skill Technician 1
18		Table Side Cable connection	3 days	2/13/09 ...	2/15/09 5...	15	Engineer 1;Skill Labor 2a
19		Bucky Wall stand Position	1 day	2/11/09 ...	2/11/09 5...	16	Skill Technician 1[150%];Skill Labor 1a[50%]
20		X Ray Generator Cable Connecation	0.5 days	2/12/09 ...	2/12/09 1...	19;16	Engineer 1;Skill Labor 3a
21		Control Console Setup	3 days	2/12/09 ...	2/15/09 1...	20	Skill Technician 1;Skill Labor 1a
22		Stabilizer Installation	1.5 days	2/10/09 ...	2/11/09 1...	9	Skill Labor 1a;Skill Labor 2a
23		Power UP	1 day	2/16/09 ...	2/16/09 5...	18;20;21;22	Engineer 1
24		Calibration and Adjustment	1 day	2/17/09 ...	2/17/09 5...	23	Engineer 1
25		Bucky Wall stand Installation	1.5 days	2/17/09 ...	2/18/09 1...	23	Skill Technician 1;Skill Labor 2a
26		Finishing work step	3 days	2/18/09 ...	2/21/09 1...	24;25	Engineer 1[50%];Skill Technician 1[50%];Skill Labor 1a[50%];Skill Lab...
27		Demonstration	3 days	2/21/09 ...	2/24/09 1...	26	Application Expart
28		Handed over	1 day	2/24/09 ...	2/25/09 1...	27	Application Expart
29		Room Preparation in Mymensing	8 days?	2/22/09 ...	3/1/09 5:...		Labor;Site Engineer
30		Room planning	1 day	3/2/09 8:...	3/2/09 5:...	29	Engineer 2
31		Table Base Installation	0.5 days	3/3/09 8:...	3/3/09 1:...	30	Engineer 2;Skill Labor 2b;Installation Set Up & Excessories 2

Iconos R 100 nstallation - page1

		Name	Duration	Start	Finish	Predecessors	Resource Names
32		Transport the Unit in Location	1 day	3/2/09 8:...	3/2/09 5:...	29	Skill Technician 2;Skill Labor 2b;Skill Labor 3b
33		Image Intensifier Installation	5 days	3/3/09 8:...	3/7/09 5:...	32	Engineer 2;Skill Labor 2b[50%];Skill Labor 3b[50%]
34		Table Installation	2 days	3/8/09 8:...	3/9/09 5:...	30;33	Engineer 2;Skill Technician 2[50%];Skill Labor 1b;Skill Labor 2b;Skill La...
35		Tube Installation	0.5 days	3/10/09 ...	3/10/09 1...	34	Engineer 2;Skill Labor 1b
36		Table Electronics Installation	0.5 days	3/10/09 ...	3/10/09 1...	34	Engineer 2;Skill Labor 1b;Skill Labor 2b;Skill Labor 3b
37		X Ray Generator Installation	2 days	3/2/09 8:...	3/3/09 5:...	29	Skill Labor 1b;Skill Labor 3b[50%]
38		Monitor Trolly Setup	1 day	3/10/09 ...	3/11/09 1...	36	Skill Technician 2;Skill Labor 3b
39		Table Side Cable connection	1 day	3/10/09 ...	3/11/09 1...	36	Engineer 2;Skill Labor 2b
40		Bucky Wall stand Position	1 day	3/4/09 8:...	3/4/09 5:...	37	Skill Technician 2;Skill Labor 1b[50%]
41		X Ray Generator Cable Connecation	0.5 days	3/5/09 8:...	3/5/09 1:...	37;40	Engineer 2;Skill Labor 3b
42		Control Console Setup	3 days	3/5/09 1:...	3/8/09 1:...	41	Skill Technician 2;Skill Labor 1b
43		Stabilizer Installation	1.5 days	3/3/09 1:...	3/4/09 5:...	31	Skill Labor 1b;Skill Labor 2b
44		Power UP	1 day	3/11/09 ...	3/12/09 1...	39;41;42;43	Engineer 2
45		Calibration and Adjustment	3.5 days	3/12/09 ...	3/15/09 5...	44	Engineer 2;Skill Labor 3b
46		Bucky Wall stand Installation	3.5 days	3/12/09 ...	3/15/09 5...	44	Skill Technician 2;Skill Labor 1b
47		Finishing work step	2 days	3/16/09 ...	3/17/09 5...	45;46	Engineer 2[50%];Skill Technician 2;Skill Labor 1b;Skill Labor 3b[50%]
48		Demonstration	3 days	3/18/09 ...	3/21/09 5...	47	Application Expart
49		Handed over	1 day	3/22/09 ...	3/22/09 5...	48	Application Expart
50		Room Preparation Panchogor	8 days?	3/1/09 8:...	3/8/09 5:...		Labor;Site Engineer
51		Room planning	1 day	3/9/09 8:...	3/9/09 5:...	50	Engineer 3
52		Table Base Installation	0.5 days	3/10/09 ...	3/10/09 1...	51	Engineer 3;Skill Labor 2c;Installation Set Up & Excessories 3
53		Transport the Unit in Location	1 day	3/9/09 8:...	3/9/09 5:...	50	Engineer 4 ;Skill Labor 2c;Skill Labor 3c
54		Image Intensifier Installation	7 days	3/10/09 ...	3/16/09 5...	53	Engineer 3;Skill Labor 2c[50%];Skill Labor 3c[50%]
55		Table Installation	2 days	3/17/09 ...	3/18/09 5...	51;54	Engineer 3;Engineer 4 [50%];Installation Set Up & Excessories 3
56		Tube Installation	0.5 days	3/19/09 ...	3/19/09 1...	55	Engineer 3;Skill Labor 1c
57		Table Electronics Installation	0.5 days	3/19/09 ...	3/19/09 5...	56	Engineer 3;Skill Labor 1c;Skill Labor 2c;Skill Labor 3c
58		X Ray Generator Installation	2 days	3/9/09 8:...	3/10/09 5...	50	Skill Labor 1c;Skill Labor 3c[50%]
59		Monitor Trolly Setup	3 days	3/20/09 ...	3/22/09 5...	57	Engineer 4 ;Skill Labor 3c
60		Table Side Cable connection	3 days	3/20/09 ...	3/22/09 5...	57	Engineer 3;Skill Labor 2c
61		Bucky Wall stand Position	1 day	3/11/09 ...	3/11/09 5...	58	Engineer 4 ;Skill Labor 1c[50%]
62		X Ray Generator Cable Connecation	0.5 days	3/12/09 ...	3/12/09 1...	58;61	Engineer 3;Skill Labor 3c
63		Control Console Setup	3 days	3/12/09 ...	3/15/09 1...	62	Engineer 4 ;Skill Labor 1c

		Name	Duration	Start	Finish	Predecessors	Resource Names
64		Stabilizer Installation	1.5 days	3/10/09 ...	3/11/09 1...	51	Skill Labor 1c;Skill Labor 2c
65		Power UP	1 day	3/23/09 ...	3/23/09 5...	60;62;63;64	Engineer 3
66		Calibration and Adjustment	2 days	3/24/09 ...	3/25/09 5...	65	Engineer 3;Skill Labor 3c
67		Bucky Wall stand Installation	1.5 days	3/24/09 ...	3/25/09 1...	65	Engineer 4 ;Skill Labor 1c
68		Finishing work step	4 days	3/26/09 ...	3/29/09 5...	66;67	Engineer 3[50%];Engineer 4 ;Skill Labor 1c;Skill Labor 3c[50%]
69		Demonstration	3 days	3/30/09 ...	4/1/09 5:...	68	Application Expart
70		Handed over	1 day	4/2/09 8:...	4/2/09 5:...	69	Application Expart
71		Installation in Pabna	20 days	3/7/09 8:...	3/26/09 5...		
72		Room Preparation in Pabna	9 days	3/7/09 8:...	3/16/09 5...		Labor;Site Engineer
73		Room planning	1 day	3/17/09 ...	3/17/09 5...	72	Engineer 1
74		Table Base Installation	0.5 days	3/18/09 ...	3/18/09 1...	73	Engineer 1;Installation Set Up & Excessories 1;Skill Labor 1a
75		Transport the Unit in Location	1 day	3/17/09 ...	3/17/09 5...	72	Skill Labor 2a;Skill Labor 3a;Skill Technician 1
76		Image Intensifier Installation	1 day	3/18/09 ...	3/18/09 5...	75	Engineer 1[50%];Skill Labor 2a[50%];Skill Labor 3a[50%]
77		Table Installation	1 day	3/19/09 ...	3/19/09 5...	72;76	Engineer 1;Installation Set Up & Excessories 1;Skill Labor 1a;Skill Labo...
78		Tube Installation	2.5 days	3/20/09 ...	3/22/09 1...	77	Engineer 1;Skill Labor 1a
79		Table Electronics Installation	0.5 days	3/22/09 ...	3/22/09 5...	78	Engineer 1;Skill Labor 1a;Skill Labor 2a;Skill Labor 3a
80		X Ray Generator Installation	0.5 days	3/17/09 ...	3/17/09 1...	72	Skill Labor 1a;Skill Labor 3a[50%]
81		Monitor Trolly Setup	3 days	3/23/09 ...	3/25/09 5...	79	Skill Labor 3a;Skill Technician 1
82		Table Side Cable connection	3 days	3/23/09 ...	3/25/09 5...	79	Engineer 1;Skill Labor 2a
83		Bucky Wall stand Position	1 day	3/17/09 ...	3/18/09 1...	80	Skill Labor 1a[50%];Skill Technician 1[150%]
84		X Ray Generator Cable Connecation	0.5 days	3/18/09 ...	3/18/09 5...	80;83	Engineer 1;Skill Labor 3a
85		Control Console Setup	0.5 days	3/19/09 ...	3/19/09 1...	84	Skill Labor 1a;Skill Technician 1
86		Stabilizer Installation	1.5 days	3/18/09 ...	3/19/09 1...	73	Skill Labor 1a;Skill Labor 2a
87		Power UP	1 day	3/26/09 ...	3/26/09 5...	82;84;85;86	Engineer 1
88		Calibration and Adjustment	1 day	3/27/09 ...	3/28/09 5...	87	Engineer 1
89		Bucky Wall stand Installation	3.5 days	3/27/09 ...	3/30/09 1...	87	Skill Labor 2a;Skill Technician 1
90		Finishing work step	3 days	3/30/09 ...	4/2/09 1:...	88;89	Engineer 1[50%];Skill Labor 1a[50%];Skill Labor 3a[50%];Skill Technic...
91		Demonstration	3 days	4/2/09 1:...	4/6/09 1:...	90	Application Expart
92		Handed over	1 day	4/6/09 1:...	4/7/09 1:...	91	Application Expart
93		Room Preparation in Khulna	8 days?	3/21/09 ...	3/28/09 5...		Labor;Site Engineer
94		Room planning	1 day	3/29/09 ...	3/29/09 5...	93	Engineer 2

		Name	Duration	Start	Finish	Predecessors	Resource Names
95		Table Base Installation	2 days	3/30/09 ...	3/31/09 5...	94	Engineer 2;Installation Set Up & Excessories 2;Skill Labor 2b
96		Transport the Unit in Location	1 day	3/29/09 ...	3/29/09 5...	93	Skill Labor 2b;Skill Labor 3b;Skill Technician 2
97		Image Intensifier Installation	7 days	4/9/09 9:...	4/16/09 9...	96	Engineer 2;Skill Labor 2b[50%];Skill Labor 3b[50%]
98		Table Installation	3 days	4/16/09 ...	4/19/09 9...	94;97	Engineer 2;Installation Set Up & Excessories 2;Skill Labor 1b;Skill Labo...
99		Tube Installation	0.5 days	4/19/09 ...	4/19/09 2...	98	Engineer 2;Skill Labor 1b
100		Table Electronics Installation	7.881 days	4/19/09 ...	4/27/09 1...	99	Engineer 2;Skill Labor 1b;Skill Labor 2b;Skill Labor 3b
101		X Ray Generator Installation	2 days	3/29/09 ...	3/30/09 5...	93	Skill Labor 1b;Skill Labor 3b[50%]
102		Monitor Trolly Setup	1 day	4/27/09 ...	4/28/09 1...	100	Skill Labor 3b;Skill Technician 2
103		Table Side Cable connection	1 day	4/27/09 ...	4/28/09 1...	100	Engineer 2;Skill Labor 2b
104		Bucky Wall stand Position	1 day	3/31/09 ...	3/31/09 5...	101	Skill Labor 1b[50%];Skill Technician 2
105		X Ray Generator Cable Connecation	0.5 days	4/1/09 8:...	4/1/09 1:...	101;104	Engineer 2;Skill Labor 3b
106		Control Console Setup	5 days	4/1/09 1:...	4/6/09 1:...	105	Skill Labor 1b;Skill Technician 2
107		Stabilizer Installation	1.5 days	3/30/09 ...	3/31/09 1...	94	Skill Labor 1b;Skill Labor 2b
108		Power UP	1 day	4/28/09 ...	4/29/09 1...	103;105;1...	Engineer 2
109		Calibration and Adjustment	5.5 days	4/29/09 ...	5/5/09 8:...	108	Engineer 2;Skill Labor 3b
110		Bucky Wall stand Installation	5.5 days	4/29/09 ...	5/5/09 8:...	108	Skill Labor 1b;Skill Technician 2
111		Finishing work step	7.502 days	5/5/09 8:...	5/12/09 1...	109;110	Engineer 2[50%];Skill Labor 1b;Skill Labor 3b[50%];Skill Technician 2
112		Demonstration	3 days	5/12/09 ...	5/16/09 1...	111	Application Expart
113		Handed over	1 day	5/16/09 ...	5/17/09 1...	112	Application Expart

		Name	Duration	Start	Finish	Predecessors	Resource Names
1		Room Preparation	10 days	3/1/09 8:00…	3/12/09 5:…		Site Engineer;Labor
2		Machine Setup planning	1 day	3/15/09 8:0…	3/15/09 5:…	1	Engineer 1;Skill Technician 1
3		MTS Rali Setup	2 days	3/16/09 8:0…	3/17/09 5:…	2	Engineer 2;Skill Technician 1;Skill Labor 1a;Skill Labor 2a;In…
4		C Arm Base Installation	2 days	3/18/09 8:0…	3/19/09 5:…	3	Engineer 1;Skill Labor 1a;Skill Technician 1;Skill Labor 2a
5		Table Base Installation	1 day	3/19/09 8:0…	3/19/09 5:…	3	Engineer 2;Skill Labor 3a;Skill Labor 2a[50%]
6		C Arm Installation	2 days	3/22/09 8:0…	3/23/09 5:…	4	Engineer 1;Skill Technician 1[50%];Skill Labor 1a;Installati…
7		Flat Pannel Detector Inst…	0.5 days	3/24/09 8:0…	3/24/09 12…	6	Engineer 1;Engineer 2;Skill Labor 1a[50%]
8		Table Installation	1.5 days	3/22/09 8:0…	3/23/09 12…	5	Engineer 2;Skill Labor 2a[50%];Skill Labor 3a[50%];Install…
9		Tube Installation	1 day	3/24/09 12:…	3/25/09 12…	7	Engineer 1[50%];Engineer 2
10		Table Electronics Installation	1 day	3/24/09 12:…	3/25/09 12…	8	Engineer 2[50%];Skill Labor 2a[50%];Skill Labor 3a
11		X Ray Generator Installation	1 day	3/24/09 12:…	3/25/09 12…	6	Skill Technician 1;Skill Labor 1a[50%]
12		Monitor Trolly Setup	2 days	3/23/09 12:…	3/25/09 12…	8	Skill Technician 1[50%];Skill Labor 2a;Skill Labor 3a
13		Control Room Setup	1.5 days	3/25/09 8:0…	3/26/09 12…	6;8	Engineer 1;Skill Labor 1a;Skill Labor 2a
14		Exam Room Cable Connec…	2 days	3/25/09 12:…	3/29/09 12…	4;8;9;10;11;12	Engineer 2;Skill Technician 1;Skill Labor 3a;Engineer 1[50%]
15		Control Room Cable Conn…	1 day	3/26/09 12:…	3/29/09 12…	13	Engineer 1;Skill Labor 2a;Skill Labor 3a[50%]
16		Stabilizer & UPS Installation	2 days	3/29/09 12:…	3/31/09 12…	14;15	Skill Technician 1;Skill Labor 1a;Skill Labor 2a;Skill Labor 3a
17		Power Connection & Powe…	1 day	3/31/09 12:…	4/1/09 12:…	16	Engineer 1;Engineer 2
18		Calibration and Adjustment	2 days	4/1/09 12:0…	4/5/09 12:…	17	Engineer 1;Engineer 2
19		Spot light Installation	1 day	4/2/09 12:0…	4/5/09 12:…	12	Skill Technician 1;Skill Labor 1a
20		Final work step	2.5 days	4/5/09 12:0…	4/7/09 5:0…	18;19	Engineer 1;Skill Technician 1;Skill Labor 2a;Skill Labor 3a
21		Demonstration	7 days	4/8/09 8:00…	4/16/09 5:…	20	Application Expart
22		Hand Over	1 day	4/19/09 8:0…	4/19/09 5:…	21	Application Expart

AXIOM Artis dFC Installation

SIEMENS to relay on its commitment to doing business in Bangladesh for the long term, because it has tremendous faith in the country's potential for development as well as to convey its conviction that it can provide whatever technological solutions its customers in Bangladesh will need for their modernization efforts,

To focus on customers through value addition, developing competency, leadership and business excellence for the benefits of the people and economic development of the country.

As a leading global electrical and electronics company, Siemens will be the most preferred partner of choice in all our fields of operations for the infrastructure development and modernization of the country.

CHAPTER-4

CRASHING A MODEL (REAL) PROJECT

4.1 Introduction

This project is AXIOM Artis installation project which is an angiogram machine at Lab Aid Cardiac Hospital. From previous experience it has observed that it took 51 days to complete the installation of Angiogram machine. In this project management decided to crash the project time and set 40 days to complete the installation.

4.2 Methodology of Crashing

Reduction of total project time at the least cost by crashing the project Network can perform two ways: 1. Manual approach 2.Linear programming approach. In this project LP (Linear Programming) is used for developing the model to get a solution to minimize the project crashing cost by crashing time of the project activities. Real project data has been used to run the model. Solver option of Microsoft Excel has been used to solve and generate report of the problem.

4.2.1: Manual approach

For crashing project time with CPM, the first task is to identify the normal critical path and the critical activities. Then it is required to determine the crash cost per time period (cost-time slopes) for various activities. The cost-time slopes can be computed using the following formula:
Slope = (Crash Cost – Normal Cost)/ Normal Time –Crash Time

The next step is to identify the activity on the critical path with the smallest crash cost per time period. This activity will be crashed to the maximum possible extent or to the point at which management's desired deadline has been reached.

Then it should be checked that the critical path that were being crashed is still critical. If the path is still critical then crash the activity that has second lowest cost-time slopes and continue this process until the goal has been reached.

If, a reduction in a critical activity time causes a non-critical path or paths to become critical, then the crash will be continued along with the new critical path based on the lowest cost time slopes of the new path.

4.2.2 Linear programming approach

We know linear programming is a tool for decision making under certain situation. So, the basic assumption of this approach is that we have to know some relevant data with certainty.

The basic data requirements are as follows: 1) We have to know the project network with activity time, which can be achieved from PERT and CPM. 2) To what extent an activity can be crashed. 3) The crash cost associated with per unit of time for all activities.

4.3 Mathematical Equation and Constrains

Before formulating the model, let us define some relevant terms. We know a project is the combination of some activities, which are interrelated in a logical sequence in the sense that the starting of some activities is dependent upon the completion of some other activities. These activities are jobs which require time and resources to be completed. The relationship between the activities is specified by using event. As an event represents a point in time that implies the completion of some activities and the beginning of new ones, the beginning and end point of an activity are thus expressed by two events.

Now let's define the variable of the problem.

X_i = the time when an event i will occur, measured since the beginning of the project, where i = 1 to m.

Y_j = Amount of times (measured in terms of days) that each activities j will be crashed where j = 1 to n.

C_j = Crash cost per unit of time for activity j.

The objective is to minimize the cost of crashing the total project, our LP objective function will be:

Minimize $Z = \sum_{j=1}^{n} C_j . Y_j$

This objective function is subject to some constraints. These constraints can be classified in to three categories.

1. Crash time constraints: We can reduce the time to complete an activity by simply increasing the resources or by improving the productivity which also require the commitment of additional resources. But it is not possible to reduce the time required to complete an activity after a certain threshold limit. Strive for such intention will result in superfluous resources employment which will be an inefficient approach. That is why the allowable time to crash an activity has a limit.
2. Constraints unfolding the network: These set of constraints describe the structure of the network. As we mention earlier that the activities of a project are interrelated, the starting of some activities is dependent upon the completion of some other activities; we must have to establish work sequence of the activities through constraints.
3. Project completion constraints: This constraint will recognize that the last event (completion of last activities) must take place before the project deadline date.

So, the constraints are:

1. Crash time constraints:

$Y_j \leq$ Allowable crashing time for activity *j* measured in terms of days.

2. Constraints unfolding the Network:

There will be one or more constraints for each event depending on the predecessor activities of that event.

As the event 1 will start at the beginning of the project, we begin by setting the occurrence time for event 1 equals to zero. Thus, $X_1 = 0$.

The other events will be expressed as follows:

$X_i \geq$ Times it takes for activity *j* which is related with the occurrence of event *i* - Y_j + Occurrence time for the head event of the predecessor activity of activity *j*.

3. Project completion constraints:

$X_m \leq$ Project deadline date after being crashed, where *m* indicate the last event of that project.

Now, the question arises what will be the extent of crashing project time or what will be the minimum completion date of the project after being crashed. To determine this extent, we have to develop a CPM based on crash time of the activities that will provide us the minimum time beyond which the project cannot be crashed. So, the adjusted deadline of the project must be greater than or equal to the project completion date under crash time basis.

4.4 Project Data Analysis

Now the project crashing will be tested against model project data. Project activities, analysis the table, network diagram, calculation the critical time and project summery will be described now.

4.4.1 Project Activities Table

Project activities table represent all activities of project, different predecessor activities, normal completion time, crash completion time, normal cost and crash cost. In this project there are 22 activities and its normal completion cost is Tk.419800. by 51 days. Management of this project wants to complete the project within 40 days. Now, the management wants to know how to crash the activities of the project so that total cost will be minimized. In this project starting event is Room Preparation (A) then Machine setup planning (B), MTS Rail Setup (C), C Arm Base Installation (D), Table Base Installation (E), C Arm Installation (F), Flat Panel Detector Installation (G), Table

Installation (H), Tube Installation (I), Table Electronics Installation (J), X Ray Generator Installation (K), Monitor Trolley Setup (L), Control Room Setup (M), Exam Room Cable Connection (N), Control Room Cable Connection (O), Stabilizer & UPS Installation (P), Power Connection & Power up (Q), Calibration and Adjustment (R), Spot light Installation (S), Final work step (T), Demonstration (U) and end event is Hand Over (V).

Table 4.1: Activities of Axiom Artis Installation Project.

ID	Installation Activities	Predecessor	Normal Completion Time(Day)	Crash Completion Time(Day)
A	Room Preparation	__________	15	10
B	Machine Setup planning	A	1	1
C	MTS Rail Setup	B	3	2
D	C Arm Base Installation	C	2	2
E	Table Base Installation	C	2	1
F	C Arm Installation	D	3	2
G	Flat Panel Detector Installation	F	1	1
H	Table Installation	E	2	1.5
I	Tube Installation	G	1	1
J	Table Electronics Installation	H	1	1
K	X Ray Generator Installation	F	1	1
L	Monitor Trolley Setup	H	3	2
M	Control Room Setup	H	2	1.5
N	Exam Room Cable Connection	I, J, K	3	2
O	Control Room Cable Connection	M	2	1
P	Stabilizer & UPS Installation	N,O	4	2
Q	Power Connection & Power up	P	1	1
R	Calibration and Adjustment	Q	3	2
S	Spot light Installation	L	1	1
T	Final work step	R,S	3	2
U	Demonstration	T	10	7
V	Hand Over	U	1	1

4.4.2 Installtion Description

Different installation steps are shown in fig

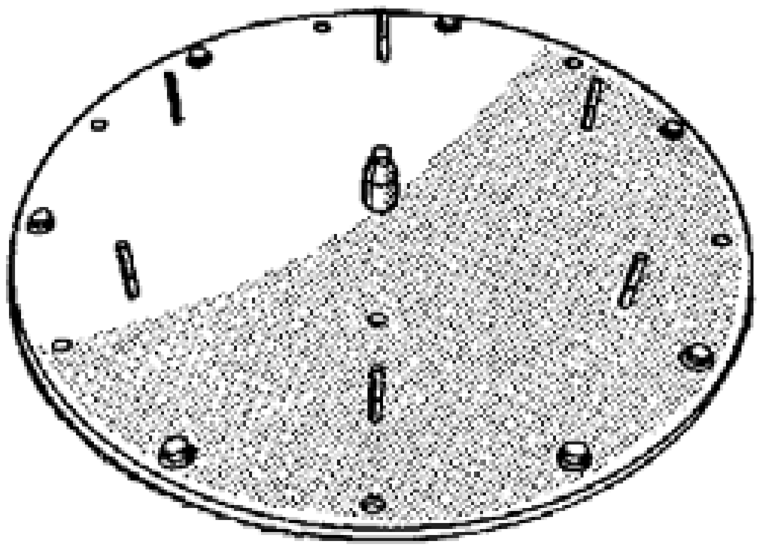

Fig 4.1: Floor Stand Installation Plate

Fig 4.2: C Arm Floor Stand With Tube.

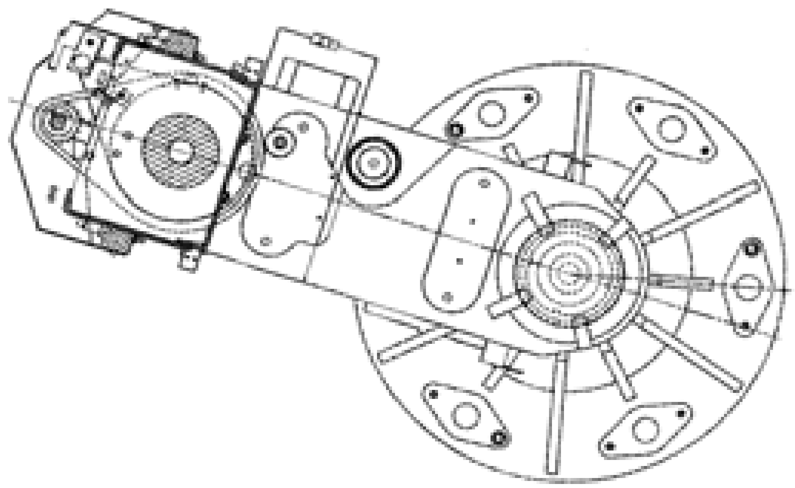

Fig 4.3: Floor Stand with Top Position

Fig 4.4: Ceiling Stand Installation

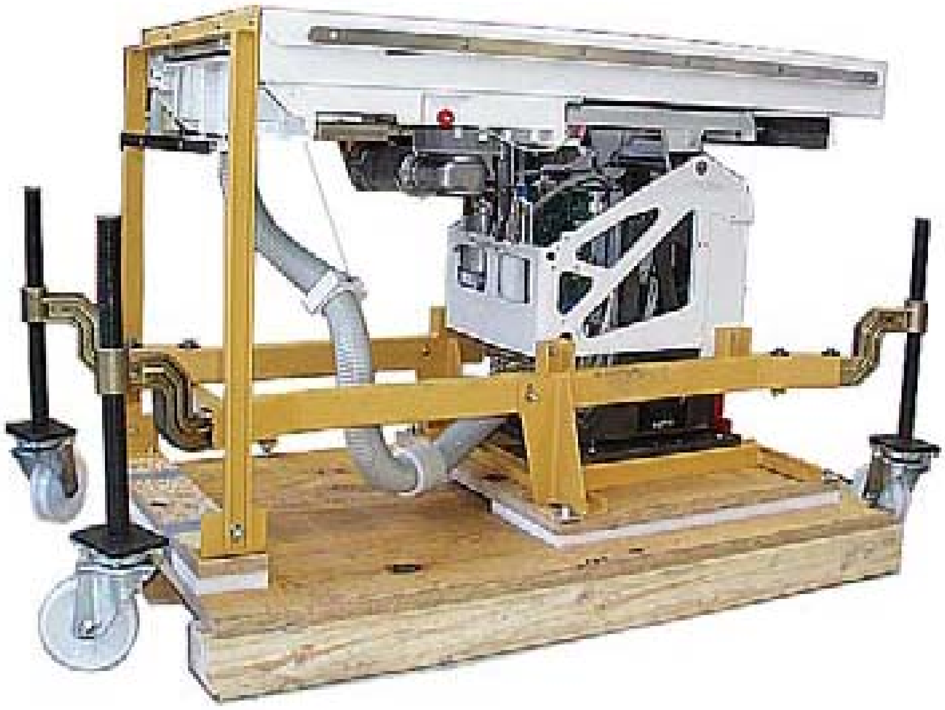

Fig 4.5: Table Base Installation

Fig 4.6: Longitudinal Drive of Table adjustment

Fig 4.7: MTS Installation(Monitor Trolly)

Fig 4.8: MTS Cable LayOut

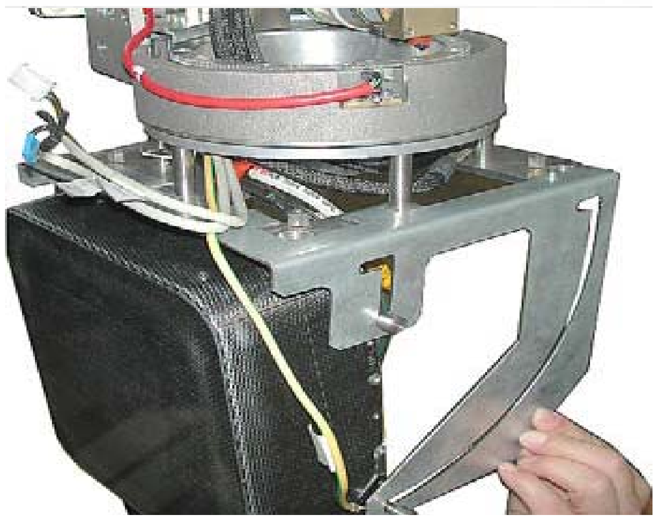

Fig 4.9: Flat Panel Detectro

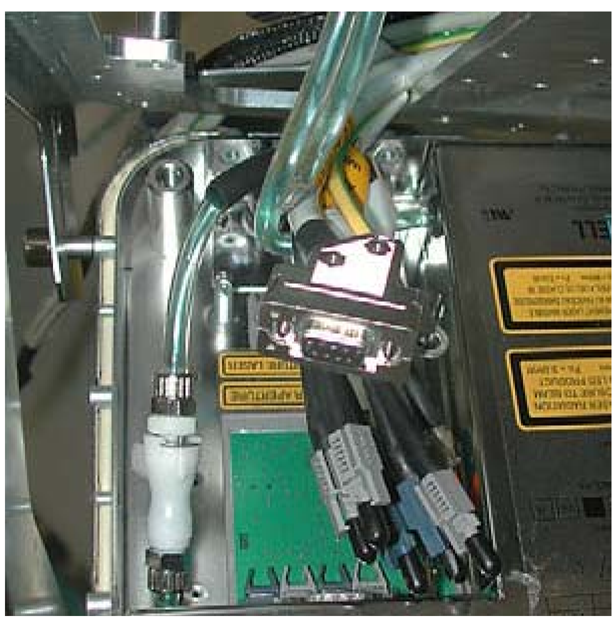

Fig 4.10: Detector Laying the cooling Hoses

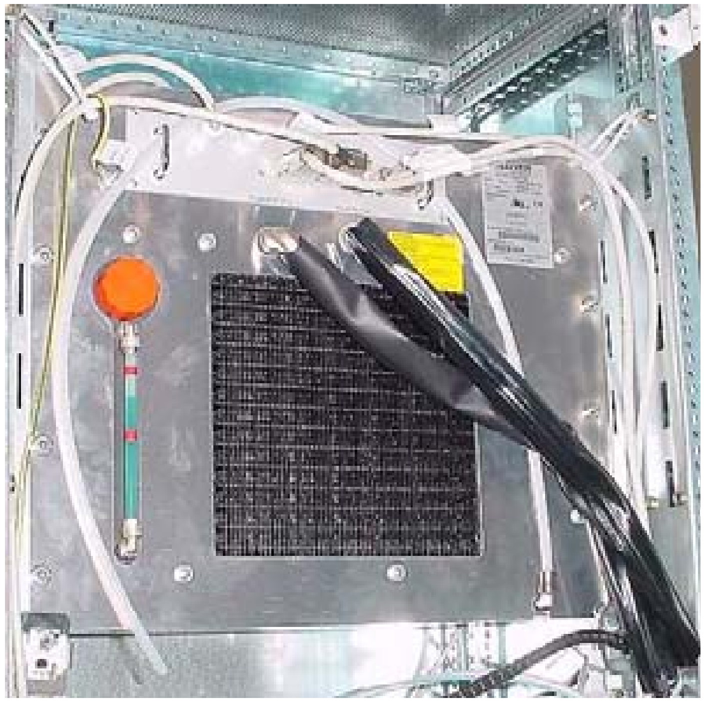

Fig 4.11: Detector cooling Unit

Fig 4.12: Component in the Exam room. ECC, Control module

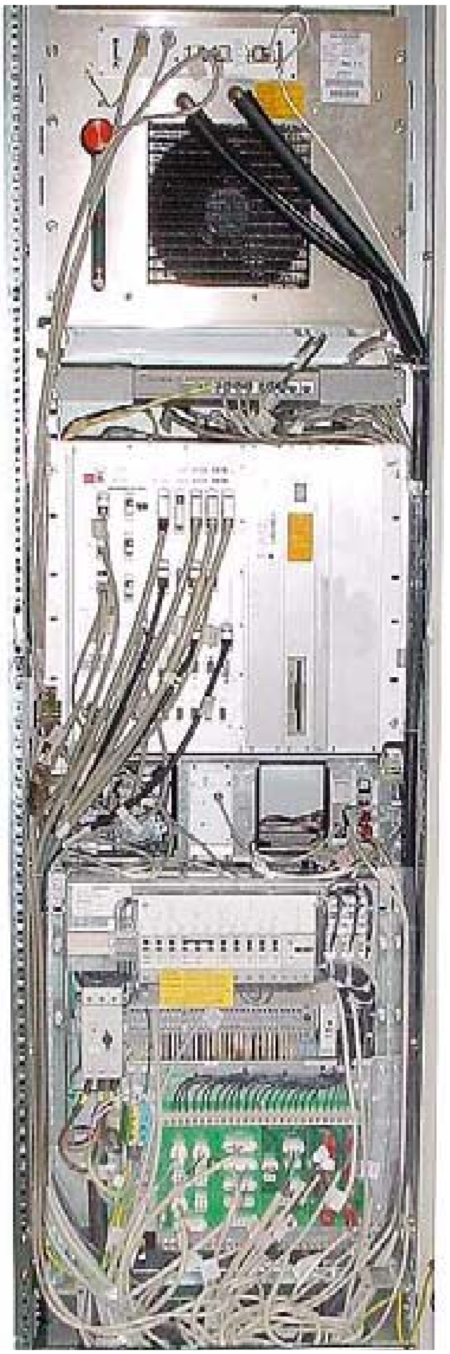

Fig 4.13: System Controller

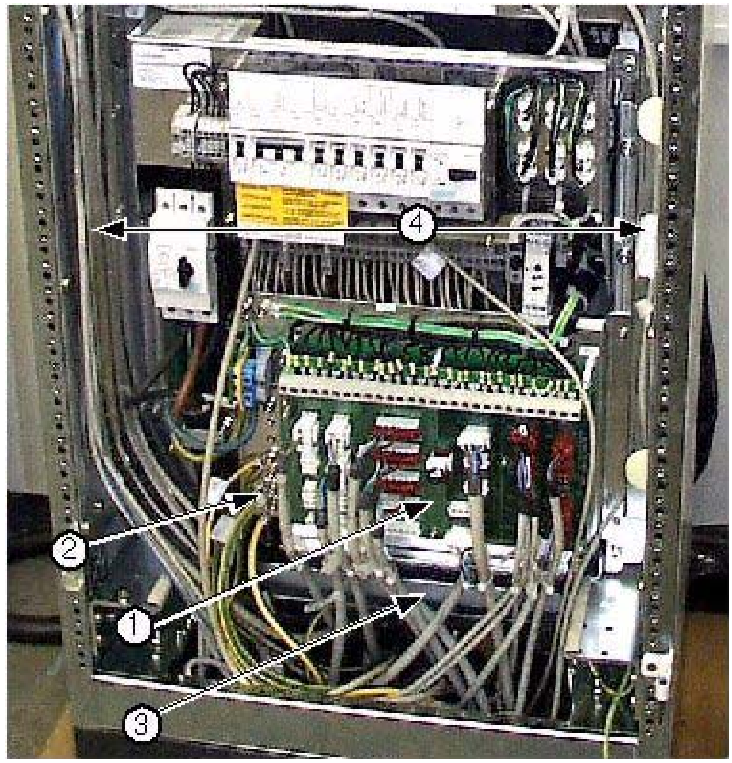

Fig 4.14: Power Distributor

Fig 4.15: Intercom System

According to task, resource and resource cost we find project cost during normal operation and during crashing project time. Table 4.2 gives all sub tasks cost, crashing time cost and all total crash cost. In this project normal cost is Tk. 419800 and cost for crashing all tasks is Tk. 508258 is found from Openproj data.

Table 4.2: Project cost of AXIOM Artis installation

ID	Activities	Predecessor	Normal	Crashing	Normal	Crashing
1	A	__________	15	10	39600	62400
2	B	A	1	1	9600	9600
3	C	B	3	2	32160	38560
4	D	C	2	2	21440	21440
5	E	C	2	1	9120	10160
6	F	D	3	2	28080	30240
7	G	F	1	1	5320	5320
8	H	E	2	1.5	10240	13920
9	I	G	1	1	12000	12000
10	J	H	1	1	4840	4800
11	K	F	1	1	1880	1880
12	L	H	3	2	4920	7248
13	M	H	2	1.5	10240	13650
14	N	I, J, K	3	2	30360	33120
15	O	M	2	1	10240	11760
16	P	N,O	4	2	12840	25760
17	Q	P	1	1	16000	16000
18	R	Q	3	2	30600	35680
19	S	L	1	1	2160	2160
20	T	R,S	3	2	32160	38560
21	U	T	10	7	80000	98000
22	V	U	1	1	16000	16000
					419800	**508258**

4.4.3 Cost time slopes of the activities

Cost time slopes give very important information from which we can decide which activity can be crashed. The activity on the critical path with the smallest crash cost per time period that activity will be crashed to the maximum possible extent

Slope = (Crash Cost – Normal Cost)/ (Normal Time –Crash Time)

The cost-time slopes of the activities are shown in Table 4.3.

Table 4.3: Cost-Time Slope of the Activities

ID	Activities	Reduce Crash Time ΔT(Yj=NT-CT) Day	Additional Crash Cost ΔC(CC-NT) Tk.	Slope= ΔC /ΔT
1	A	5	22800	4560
2	B	0	0	
3	C	1	6400	6400
4	D	0	0	
5	E	1	1040	1040
6	F	1	2160	2160
7	G	0	0	0
8	H	0.5	3680	7360
9	I	0	0	
10	J	0	0	
11	K	0	0	
12	L	1	2328	2328
13	M	0.5	3410	6820
14	N	1	2760	2760
15	O	1	1520	1520
16	P	2	12920	6460
17	Q	0	0	
18	R	1	5080	5080
19	S	0	0	
20	T	1	6400	6400
21	U	3	18000	6000
22	V	0	0	

4.4.4 Network Diagram of the Project

For the purpose of solving the problem, it is necessary to define the activities in terms of starting and ending event. Project network diagram give us overall picture of the project. The total number of events in this project is 22 and 19 node.

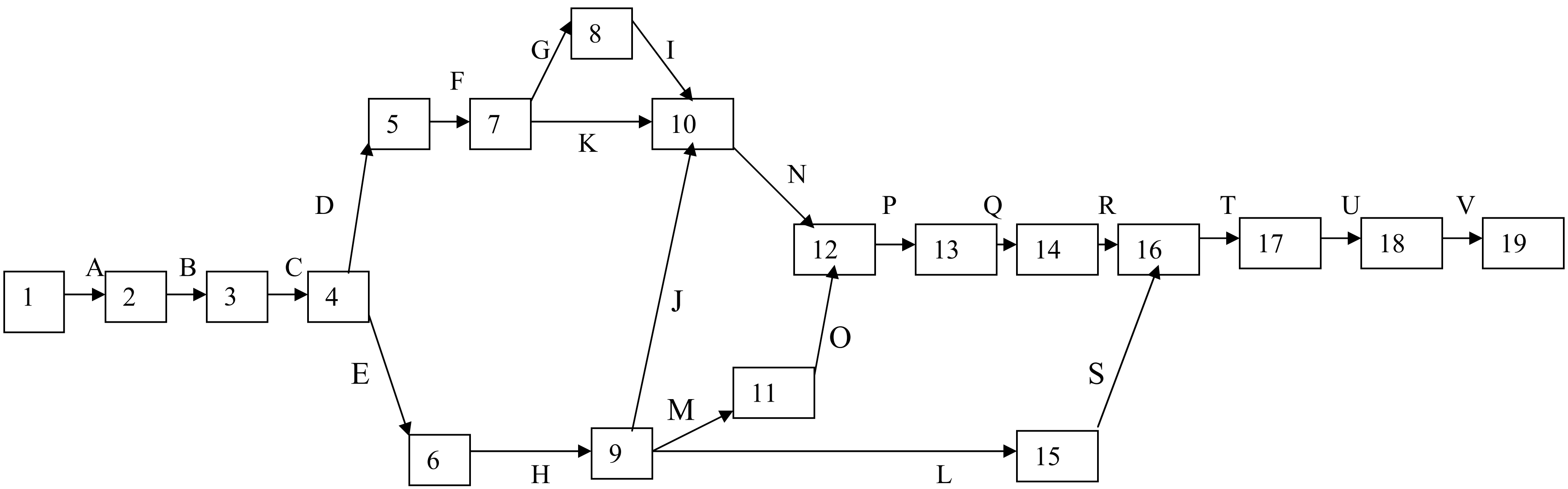

Figure 4.16: Network Diagram of the Project

Project network diagram give us overall picture of the project. Using project management software "Openproj" this network diagram is found

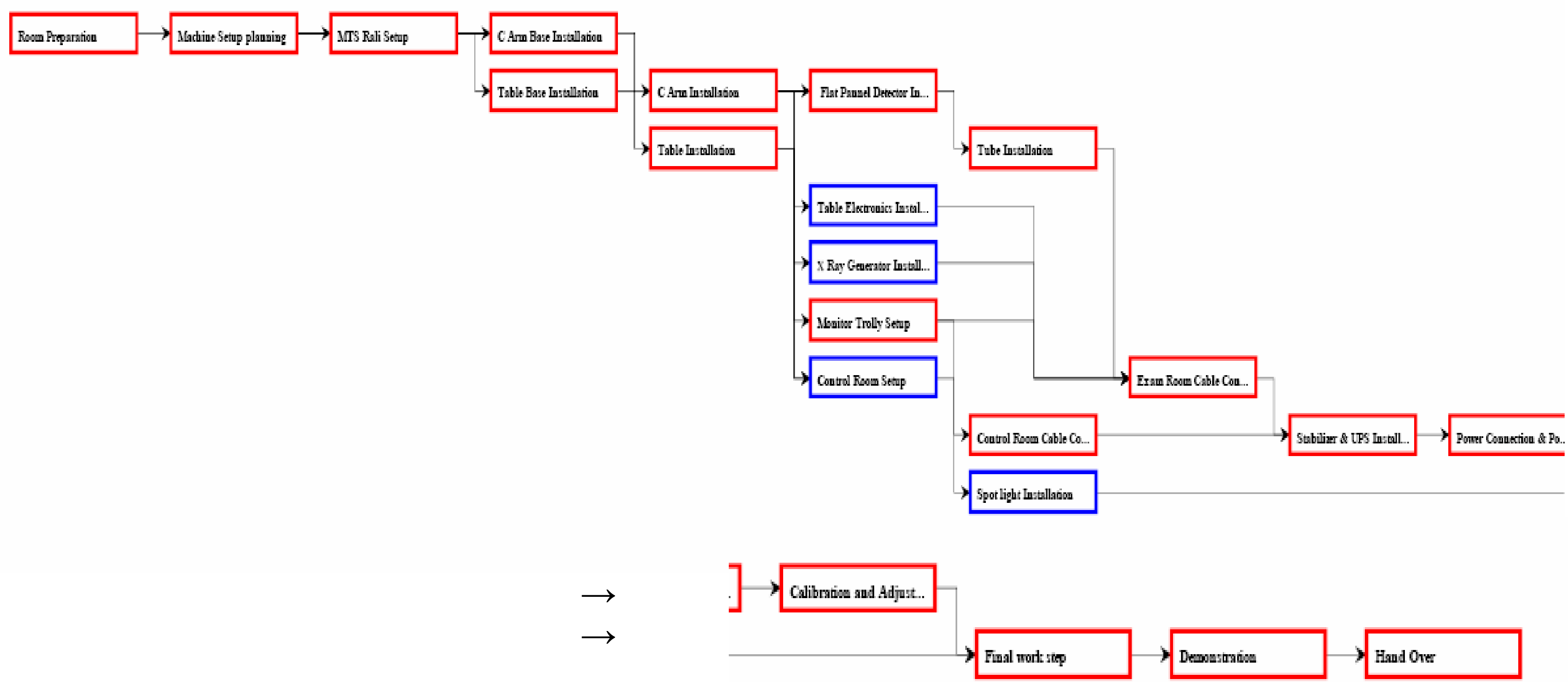

Figure 4.17: Network Diagram of the Project (Openproj)

4.4.5 Calculation of Project Critical Time

We can identify the critical path of the project to determine the project's expected completion time. Based on the calculation by project management software "OpenProj", the sample project will be completed within 51 days. The calculation is shown in Table 4.

Table 4.4: Calculation of Project's Critical Time

ID	Name	Start	Finish	Critica	Late Start	Late Finish	Free Slack	Total Slack
1	Room Preparation	3/1/09 8:00 AM	3/19/09 5:00 PM	true	3/1/09 8:00 AM	3/19/09 5:00 PM	0 days	0 days
2	Machine Setup planning	3/22/09 8:00 AM	3/22/09 5:00 PM	true	3/22/09 8:00 AM	3/22/09 5:00 PM	0 days	0 days
3	MTS Rali Setup	3/23/09 8:00 AM	3/25/09 5:00 PM	true	3/23/09 8:00 AM	3/25/09 5:00 PM	0 days	0 days
4	C Arm Base Installation	3/26/09 8:00 AM	3/29/09 5:00 PM	true	3/26/09 8:00 AM	3/29/09 5:00 PM	0 days	0 days
5	Table Base Installation	3/26/09 8:00 AM	3/29/09 5:00 PM	true	3/26/09 8:00 AM	3/29/09 5:00 PM	0 days	0 days
6	C Arm Installation	3/30/09 8:00 AM	4/1/09 5:00 PM	true	3/30/09 8:00 AM	4/1/09 5:00 PM	0 days	0 days
7	Flat Pannel Detector Installation	4/2/09 8:00 AM	4/2/09 5:00 PM	true	4/2/09 8:00 AM	4/2/09 5:00 PM	0 days	0 days
8	Table Installation	3/30/09 8:00 AM	3/31/09 5:00 PM	true	3/30/09 8:00 AM	3/31/09 5:00 PM	0 days	0 days
9	Tube Installation	4/5/09 8:00 AM	4/5/09 5:00 PM	true	4/5/09 8:00 AM	4/5/09 5:00 PM	0 days	0 days
10	Table Electronics Installation	4/5/09 8:00 AM	4/5/09 5:00 PM	false	4/5/09 8:00 AM	4/5/09 5:00 PM	2 days	2 days
11	X Ray Generator Installation	4/5/09 8:00 AM	4/5/09 5:00 PM	false	4/5/09 8:00 AM	4/5/09 5:00 PM	1 day	1 day
12	Monitor Trolly Setup	4/1/09 8:00 AM	4/5/09 5:00 PM	true	4/1/09 8:00 AM	4/5/09 5:00 PM	0 days	0 days
13	Control Room Setup	4/5/09 8:00 AM	4/6/09 5:00 PM	false	4/5/09 8:00 AM	4/6/09 5:00 PM	1 day	1 day
14	Exam Room Cable Connecation	4/6/09 8:00 AM	4/8/09 5:00 PM	true	4/6/09 8:00 AM	4/8/09 5:00 PM	0 days	0 days
15	Control Room Cable Connection	4/7/09 8:00 AM	4/8/09 5:00 PM	true	4/7/09 8:00 AM	4/8/09 5:00 PM	0 days	0 days
16	Stabilizer & UPS Installation	4/9/09 8:00 AM	4/14/09 5:00 PM	true	4/9/09 8:00 AM	4/14/09 5:00 PM	0 days	0 days
17	Power Connection & Power up	4/15/09 8:00 AM	4/15/09 5:00 PM	true	4/15/09 8:00 AM	4/15/09 5:00 PM	0 days	0 days
18	Calibration and Adjustment	4/16/09 8:00 AM	4/20/09 5:00 PM	true	4/16/09 8:00 AM	4/20/09 5:00 PM	0 days	0 days
19	Spot light Installation	4/20/09 8:00 AM	4/20/09 5:00 PM	false	4/20/09 8:00 AM	4/20/09 5:00 PM	10 days	10 days
20	Final work step	4/21/09 8:00 AM	4/23/09 5:00 PM	true	4/21/09 8:00 AM	4/23/09 5:00 PM	0 days	0 days
21	Demonstration	4/26/09 8:00 AM	5/7/09 5:00 PM	true	4/26/09 8:00 AM	5/7/09 5:00 PM	0 days	0 days
22	Hand Over	5/10/09 8:00 AM	5/10/09 5:00 PM	true	5/10/09 8:00 AM	5/10/09 5:00 PM	0 days	0 days

Activity A, B, C, D, F, G, H, I, J, L, N, O, P, Q, R, T, U and V are the critical activities of the project. If any one of them is delayed for any reason, the entire project will be delayed.

4.4.6 Project Summery

Before applying the model (LP) into this problem, it is required to determine the extent of project crashing time. Using project management software "OpenProj" and developing a CPM based on crash time of the activities (all crash plan) will provide us the same critical path with expected completion date of 36 days. This indicates that this model (LP) will provide feasible result if only adjusted deadline of the project is greater than or equal to 36 days. Management desire to complete the project within 40 days lies in between the all crash and all normal plans.

Table 4.5: Project Summary with normal activities

ID	Name	Duration	Start	Finish	Percent Complete	Cost	Work
1	Room Preparation	15 days	3/1/09 8:00 AM	3/19/09 5:00 PM	0%	$ 39,600.00	240 hours
2	Machine Setup planning	1 day	3/22/09 8:00 AM	3/22/09 5:00 PM	0%	$ 9,600.00	16 hours
3	MTS Rali Setup	3 days	3/23/09 8:00 AM	3/25/09 5:00 PM	0%	$ 32,160.00	96 hours
4	C Arm Base Installation	2 days	3/26/09 8:00 AM	3/29/09 5:00 PM	0%	$ 21,440.00	64 hours
5	Table Base Installation	2 days	3/26/09 8:00 AM	3/29/09 5:00 PM	0%	$ 9,120.00	24 hours
6	C Arm Installation	3 days	3/30/09 8:00 AM	4/1/09 5:00 PM	0%	$ 28,080.00	60 hours
7	Flat Pannel Detector Installation	1 day	4/2/09 8:00 AM	4/2/09 5:00 PM	0%	$ 5,320.00	20 hours
8	Table Installation	2 days	3/30/09 8:00 AM	3/31/09 5:00 PM	0%	$ 10,240.00	40 hours
9	Tube Installation	1 day	4/5/09 8:00 AM	4/5/09 5:00 PM	0%	$ 12,000.00	12 hours
10	Table Electronics Installation	1 day	4/5/09 8:00 AM	4/5/09 5:00 PM	0%	$ 4,840.00	16 hours
11	X Ray Generator Installation	1 day	4/5/09 8:00 AM	4/5/09 5:00 PM	0%	$ 1,880.00	12 hours
12	Monitor Trolly Setup	3 days	4/1/09 8:00 AM	4/5/09 5:00 PM	0%	$ 4,920.00	48 hours
13	Control Room Setup	2 days	4/5/09 8:00 AM	4/6/09 5:00 PM	0%	$ 10,240.00	40 hours
14	Exam Room Cable Connecation	3 days	4/6/09 8:00 AM	4/8/09 5:00 PM	0%	$ 30,360.00	84 hours
15	Control Room Cable Connection	2 days	4/7/09 8:00 AM	4/8/09 5:00 PM	0%	$ 10,240.00	40 hours
16	Stabilizer & UPS Installation	4 days	4/9/09 8:00 AM	4/14/09 5:00 PM	0%	$ 12,840.00	124 hours
17	Power Connection & Power up	1 day	4/15/09 8:00 AM	4/15/09 5:00 PM	0%	$ 16,000.00	16 hours
18	Calibration and Adjustment	3 days	4/16/09 8:00 AM	4/20/09 5:00 PM	0%	$ 30,600.00	50 hours
19	Spot light Installation	1 day	4/20/09 8:00 AM	4/20/09 5:00 PM	0%	$ 2,160.00	16 hours
20	Final work step	3 days	4/21/09 8:00 AM	4/23/09 5:00 PM	0%	$ 32,160.00	96 hours
21	Demonstration	10 days	4/26/09 8:00 AM	5/7/09 5:00 PM	0%	$ 80,000.00	80 hours
22	Hand Over	1 day	5/10/09 8:00 AM	5/10/09 5:00 PM	0%	$ 16,000.00	16 hours
						$ 419,800.00	1,210 hours

Table 4.6: Project Summary with crashing activities

ID	Name	Duration	Start	Finish	Percent Complete	Cost	Work
1	Room Preparation	10 days	3/1/09 8:00 AM	3/12/09 5:00 PM	0%	$ 62,400.00	260 hours
2	Machine Setup planning	1 day	3/15/09 8:00 AM	3/15/09 5:00 PM	0%	$ 9,600.00	16 hours
3	MTS Rali Setup	2 days	3/16/09 8:00 AM	3/17/09 5:00 PM	0%	$ 38,560.00	96 hours
4	C Arm Base Installation	2 days	3/18/09 8:00 AM	3/19/09 5:00 PM	0%	$ 21,440.00	64 hours
5	Table Base Installation	1 day	3/19/09 12:00 PM	3/22/09 12:00 PM	0%	$ 10,160.00	24 hours
6	C Arm Installation	2 days	3/22/09 8:00 AM	3/23/09 5:00 PM	0%	$ 30,240.00	65.6 hours
7	Flat Pannel Detector Installation	1 day	3/24/09 8:00 AM	3/24/09 5:00 PM	0%	$ 5,320.00	20 hours
8	Table Installation	1.5 days	3/22/09 12:00 PM	3/23/09 5:00 PM	0%	$ 13,920.00	50.4 hours
9	Tube Installation	1 day	3/25/09 8:00 AM	3/25/09 5:00 PM	0%	$ 12,000.00	12 hours
10	Table Electronics Installation	1 day	3/25/09 8:00 AM	3/25/09 5:00 PM	0%	$ 4,800.00	20 hours
11	X Ray Generator Installation	1 day	3/25/09 8:00 AM	3/25/09 5:00 PM	0%	$ 1,880.00	12 hours
12	Monitor Trolly Setup	2 days	3/24/09 8:00 AM	3/25/09 5:00 PM	0%	$ 7,248.00	51.2 hours
13	Control Room Setup	1.5 days	3/24/09 12:00 PM	3/25/09 5:00 PM	0%	$ 13,650.00	48.6 hours
14	Exam Room Cable Connecation	2 days	3/26/09 8:00 AM	3/29/09 5:00 PM	0%	$ 33,120.00	73.6 hours
15	Control Room Cable Connection	1 day	3/26/09 8:00 AM	3/26/09 5:00 PM	0%	$ 11,760.00	40 hours
16	Stabilizer & UPS Installation	2 days	3/30/09 8:00 AM	3/31/09 5:00 PM	0%	$ 25,760.00	96 hours
17	Power Connection & Power up	1 day	4/1/09 8:00 AM	4/1/09 5:00 PM	0%	$ 16,000.00	16 hours
18	Calibration and Adjustment	2 days	4/2/09 8:00 AM	4/5/09 5:00 PM	0%	$ 35,680.00	64 hours
19	Spot light Installation	1 day	4/5/09 8:00 AM	4/5/09 5:00 PM	0%	$ 2,160.00	16 hours
20	Final work step	2 days	4/6/09 8:00 AM	4/7/09 5:00 PM	0%	$ 38,560.00	96 hours
21	Demonstration	7 days	4/8/09 8:00 AM	4/16/09 5:00 PM	0%	$ 98,000.00	98 hours
22	Hand Over	1 day	4/19/09 8:00 AM	4/19/09 5:00 PM	0%	$ 16,000.00	16 hours
						$ 508,258.00	1,255.4 hours

4.5 Crashing the Project Using LP

For the purpose of solving the problem, it is necessary to define the activities in terms of starting and ending event. The total number of events in this project is 22 and 19 node.

Table 4.7: Head and Tail Events of Activities

Activities	Tail Event (Starting Event)	Head Event (Ending Event)	Description of Job
A	1	2	Room Preparation
B	2	3	Machine Setup planning
C	3	4	MTS Rail Setup
D	4	5	C Arm Base Installation
E	4	6	Table Base Installation
F	5	7	C Arm Installation
G	7	8	Flat Panel Detector Installation
H	6	9	Table Installation
I	8	10	Tube Installation
J	9	10	Table Electronics Installation
K	7	10	X Ray Generator Installation
L	9	15	Monitor Trolley Setup
M	9	11	Control Room Setup
N	10	12	Exam Room Cable Connection
O	11	12	Control Room Cable Connection
P	12	13	Stabilizer & UPS Installation
Q	13	14	Power Connection & Power up
R	14	16	Calibration and Adjustment
S	15	16	Spot light Installation
T	16	17	Final work step
U	17	18	Demonstration
V	18	19	Hand Over

Defining the variables:

Let, X_1 = Time when event 1 will occur.

X_2 = Time when event 2 will occur.

X_3 = Time when event 3 will occur.

X_4 = Time when event 4 will occur.

X_5 = Time when event 5 will occur.

X_6 = Time when event 6 will occur.

X_7 = Time when event 7 will occur.

X_8 = Time when event 8 will occur.

X_9 = Time when event 9 will occur.

X_{10} = Time when event 10 will occur.

X_{11} = Time when event 11 will occur.

X_{12} = Time when event 12 will occur.

X_{13} = Time when event 13 will occur.

X_{14} = Time when event 14 will occur.

X_{15} = Time when event 15 will occur.

X_{16} = Time when event 16 will occur.

X_{17} = Time when event 17 will occur.

X_{18} = Time when event 18 will occur.

X_{19} = Time when event 19 will occur.

Y_a= Number of days activity A will be crashed.

Y_b= Number of days activity B will be crashed.

Y_c= Number of days activity C will be crashed.

Y_d= Number of days activity D will be crashed.

Y_e= Number of days activity E will be crashed.

Y_f= Number of days activity F will be crashed.

Y_g= Number of days activity G will be crashed.

Y_h= Number of days activity H will be crashed.

Y_i= Number of days activity I will be crashed.

Y_j= Number of days activity J will be crashed.

Y_k= Number of days activity K will be crashed.

Y_l= Number of days activity L will be crashed.

Y_m= Number of days activity M will be crashed.

Y_n= Number of days activity N will be crashed.

Y_o= Number of days activity O will be crashed.

Y_p= Number of days activity P will be crashed.

Y_q= Number of days activity Q will be crashed.

Y_r= Number of days activity R will be crashed.

Y_s= Number of days activity S will be crashed.

Y_t= Number of days activity T will be crashed.

Y_u= Number of days activity U will be crashed.

Y_v= Number of days activity V will be crashed.

Objective Function:

Minimize $Z=\sum_{j=1}^{n} C_j.Y_j$ .... (4.1)

Since activity B, D, G, I, J, K, Q, S and V can not be crashed those activities are not included in the objective function equation.

Minimize $Z = 4560Y_a + 6400Y_c + 1040Y_e + 2160Y_f + 7360Y_h + 2328Y_l + 6820Y_m + 2760Y_n + 1520Y_o + 6460Y_p + 5080Y_r + 6400Y_t + 6000Y_u$ ...... (4.2)

Constraints of the Model:

Crash time constraints:

$Y_a \leq 5$ .... (4.3)

$Y_c \leq 1$ .... (4.4)

$Y_e \leq 1$ .... (4.5)

$Y_f \leq 1$ .... (4.6)

$Y_h \leq 0.5$ ………………………………………………………………. (4.7)

$Y_l \leq 1$ ………………………………………………………………. (4.8)

$Y_m \leq 0.5$ ………………………………………………………………. (4.9)

$Y_n \leq 1$ ……………………………………………………………… (4.10)

$Y_o \leq 1$ ……………………………………………………………… (4.11)

$Y_p \leq 2$ ……………………………………………………………… (4.12)

$Y_r \leq 1$ ……………………………………………………………… (4.13)

$Y_t \leq 1$ ……………………………………………………………… (4.14)

$Y_u \leq 3$ ……………………………………………………………… (4.15)

In this project $Y_b=0$, $Y_d=0$, $Y_g=0$, $Y_i=0$, $Y_j=0$, $Y_k=0$, $Y_q=0$, $Y_s=0$ and $Y_v=0$

<u>Constraints unfolding the Network:</u>

We begin by setting the event occurrence time for event 1 to be $X_1 = 0$. The constraints describe the structure of the network are as follows:

$X_1 = 0$ ………………………….. (4.16)

$X_2 \geq 15 - Y_a + X_1$ *i,e,* $X_2 + Y_a - X_1 \geq 15$ ………………………….. (4.17)

$X_3 \geq 1 - Y_b + X_2$ *i,e,* $X_3 + Y_b - X_2 \geq 1$ ………………………….. (4.18)

$X_4 \geq 3 - Y_c + X_3$ *i,e,* $X_4 + Y_c - X_3 \geq 3$ ………………………… .. (4.19)

$X_5 \geq 2 - Y_d + X_4$ *i,e,* $X_5 + Y_d - X_4 \geq 2$ ………………………….. (4.20)

$X_6 \geq 2 - Y_e + X_4$ *i,e,* $X_6 + Y_e - X_4 \geq 2$ …………………………. (4.21)

$X_7 \geq 3 - Y_f + X_5$ *i,e,* $X_7 + Y_f - X_5 \geq 3$ …………………………. (4.22)

$X_8 \geq 1 - Y_g + X_7$ *i,e,* $X_8 + Y_g - X_7 \geq 1$ …………………………. (4.23)

$X_9 \geq 2 - Y_h + X_6$ *i,e,* $X_9 + Y_k - X_7 \geq 1$ ………………………… (4.24)

$X_{10} \geq 1 - Y_i + X_8$ *i,e,* $X_{10} + Y_i - X_8 \geq 1$ ………………………… (4.25)

Or, $X_{10} \geq 1 - Y_9 + X_7$ *i,e,* $X_{10} + Y_j - X_9 \geq 1$ ………………………… (4.26)

Or, $X_{10} \geq 1 - Y_7 + X_7$ *i,e,* $X_{10} + Y_k - X_7 \geq 1$ ………………………… (4.27)

$X_{11} \geq 2 - Y_m + X_9$ *i,e,* $X_{11} + Y_m - X_9 \geq 2$ ………………………… (4.28)

$X_{12} \geq 3 - Y_n + X_{10}$ *i,e,* $X_{12} + Y_n - X_{10} \geq 3$ ………………………… (4.29)

Or, $X_{12} \geq 2 - Y_o + X_{11}$ *i,e,* $X_{12} + Y_o - X_{11} \geq 2$ ………………………… (4.30)

$X_{13} \geq 4 - Y_p + X_{12}$ *i,e,* $X_{13} + Y_p - X_{12} \geq 4$ ………………………… (4.31)

$X_{14} \geq 1 - Y_q + X_{13}$ *i,e,* $X_{14} + Y_q - X_{13} \geq 1$ ………………………… (4.32)

$X_{15} \geq 3 - Y_l + X_9$ *i,e,* $X_{15} + Y_l - X_9 \geq 3$ ………………………… (4.33)

$X_{16} \geq 3 - Y_r + X_{14}$ *i,e,* $X_{16} + Y_r - X_{14} \geq 3$ ………………………… (4.34)

Or, $X_{16} \geq 1 - Y_s + X_{15}$ *i,e,* $X_{16} + Y_s - X_{15} \geq 1$ ………………………… (4.35)

$X_{17} \geq 3 - Y_t + X_{16}$ *i,e,* $X_{17} + Y_t - X_{16} \geq 3$ ………………………… (4.36)

$X_{18} \geq 10 - Y_u + X_{17}$ *i,e,* $X_{18} + Y_u - X_{17} \geq 10$ ………………………… (4.37)

$X_{19} \geq 1 - Y_v + X_{18}$ *i,e,* $X_{19} + Y_v - X_{18} \geq 1$ ………………………… (4.38)

<u>Project completion constraints:</u>

$X_{19} \leq 40$ ………………………… (4.39)

And, $X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, Y_a, Y_c,$ $Y_e, Y_f, Y_h, Y_l, Y_m, Y_n, Y_o, Y_p, Y_r, Y_t, Y_u$ and $Y_v \geq 0$

As the manager wants to complete the project within 40 days, so the last event should be completed before or on 40th day. By analyzing the project on crash time basis the expected date of completion of the project is 36 days. So, the maximum extent of crashing the project is 36 days. Beyond this time period, the project cannot be crashed.

CHAPTER-5

RESULT (OUTPUT) OF CRASHING

5.1 Result of Crashing the Project

Data found from the project and apply equations (1) to (39) in solver program we found our project crashing solution. Here optimum solution gets least cost for project crashing. From planning calculation by Openpoj we estimate that project normal cost is Tk.419800 and if project crash then cost will be Tk.50800. Estimated total extra cost for crashing the project is Tk.88458. Now we find the optimum result from LP solution.

5.2Analysis and Result

As the manager wants to complete the project within 40 days, so the last event should be completed before or on 40th day. By analyzing the project on crash time basis the expected date of completion of the project is 36 days. So, the maximum extent of crashing the project is 36 days. Beyond this time period, the project cannot be crashed.

Table 5.1: Equations and result of project crashing using Excel Solver

Objective Value (Variable)	**Final Solution**	**Objective Value (Variable)**	**Final Solution**	**Crash time constraints**		**Constraints unfolding the Network**	
Min Z=	50800	Y_a	5	$Y_a \le$	5	$X_1 = 0$	
X_1	0	Y_c	0	$Y_c \le$	1	$X_2 \ge$	$15 - Y_a + X1$
X_2	10	Y_b=Y_d=	0	Y_b=Y_d=	0	$X_3 \ge$	$1 - Y_b + X2$
X_3	11	Y_e	0	$Y_e \le$	1	$X_4 \ge$	$3 - Y_c + X3$
X_4	14	Y_f	1	$Y_f \le$	1	$X_5 \ge$	$2 - Y_d + X4$
X_5	16	Y_g=	0	Y_g=	0	$X_6 \ge$	$2 - Y_e + X4$

X_6	16	Y_h	0	$Y_h \leq$	0.5	$X_7 \geq$	$3 - Y_f + X5$
X_7	18	Y_i=Y_j=	0	Y_i=Y_j=	0	$X_8 \geq$	$1 - Y_g + X7$
X_8	19	Y_k=	0	Y_k=	0	$X_9 \geq$	$2 - Y_h + X6$
X_9	18	Y_l	0	$Y_l \leq$	1	$X_{10} \geq$	$1 - Y_i + X8$
X_{10}	20	Y_m	0	$Y_m \leq$	0.5	$X_{10} \geq$	$1 - Y_j + X9$
X_{11}	20	Y_n	1	$Y_n \leq$	1	$X_{10} \geq$	$1 - Y_k + X7$
X_{12}	22	Y_o	0	$Y_o \leq$	1	$X_{11} \geq$	$2 - Y_m + X9$
X_{13}	26	Y_p	0	$Y_p \leq$	2	$X_{12} \geq$	$3 - Y_n + X10$
X_{14}	27	Y_q=	0	Y_q=	0	$X_{12} \geq$	$2 - Y_o + X11$
X_{15}	21	Y_r	1	$Y_r \leq$	1	$X_{13} \geq$	$4 - Y_p + X12$
X_{16}	29	Y_s=	0	Y_s=	0	$X_{14} \geq$	$1 - Y_q + X13$
X_{17}	32	Y_t	0	$Y_t \leq$	1	$X_{15} \geq$	$3 - Y_l + X9$
X_{18}	39	Y_u	3	$Y_u \leq$	3	$X_{16} \geq$	$3 - Y_r + X14$
X_{19}	40	Y_v=	0	Y_v=	0	$X_{16} \geq$	$1 - Y_s + X15$
						$X_{17} \geq$	$3 - Y_t + X16$
						$X_{18} \geq$	$10- Y_u + X17$
						$X_{19} \geq$	$1- Y_v + X18$

Table 5.2: Limit Range of Project Variables

Name	**Value**				
Min Z= Final Solution	50800				
Adjustable Name	**Value**	**Lower Limit**	**Target Result**	**Upper Limit**	**Target Result**
Ya Final Solution	5	5	50800	5	50800
Yc Final Solution	0	0	50800	1	57200
Yb=Yd= Final solution	0	0	50800	0	50800
Ye Final Solution	0	0	50800	1	51840
Yf Final Solution	1	1	50800	1	50800
Yg= Final Solution	0	0	50800	0	50800

Yh Final Solution	0	0	50800	0.5	54480
Yi=Yj= Final Solution	0	0	50800	0	50800
Yk= Final Solution	0	0	50800	0	50800
Yl Final Solution	0	0	50800	1	53128
Ym Final Solution	0	0	50800	0.5	54210
Yn Final Solution	1	1	50800	1	50800
Yo Final Solution	0	0	50800	1	52320
Yp Final Solution	0	0	50800	2	63720
Yq= Final Solution	0	0	50800	0	50800
Yr Final Solution	1	1	50800	1	50800
Ys= Final Solution	0	0	50800	0	50800
Yt Final Solution	0	0	50800	1	57200
Yu Final Solution	3	3	50800	3	50800
Yv= Final Solution	0	0	50800	0	50800
X1 Final Solution	0	0	50800	0	50800
X2 Final Solution	10	10	50800	10	50800
X3 Final Solution	11	11	50800	11	50800
X4 Final Solution	14	14	50800	14	50800
X5 Final Solution	16	16	50800	16	50800
X6 Final Solution	16	16	50800	16	50800
X7 Final Solution	18	18	50800	18	50800
X8 Final Solution	19	19	50800	19	50800
X9 Final Solution	18	19	50800	19	50800
X10 Final Solution	20	20	50800	20	50800
X11 Final Solution	20	21	50800	21	50800
X12 Final Solution	22	22	50800	22	50800
X13 Final Solution	26	26	50800	26	50800
X14 Final Solution	27	27	50800	27	50800
X15 Final Solution	21	20	50800	20	50800
X16 Final Solution	29	29	50800	29	50800

X17 Final Solution	32	32	50800	32	50800
X18 Final Solution	39	39	50800	39	50800
X19 Final Solution	40	40	50800	40	50800

From result it is found that the project can be completed by 40 days and extra cost for crashing is Tk.50800. It is also found that not all event need not to crash, If management want to complete the project by 36 days that also possible and extra cost for this crashing is Tk.76520. From solver solution we find different crash cost for completing the project by different time. It varies from 36 days to 51 days and crash cost also change up to Tk.76520. From limit range Table 5.2 we find that not necessary to crash the entire task when project completion constrain more than 36 days.

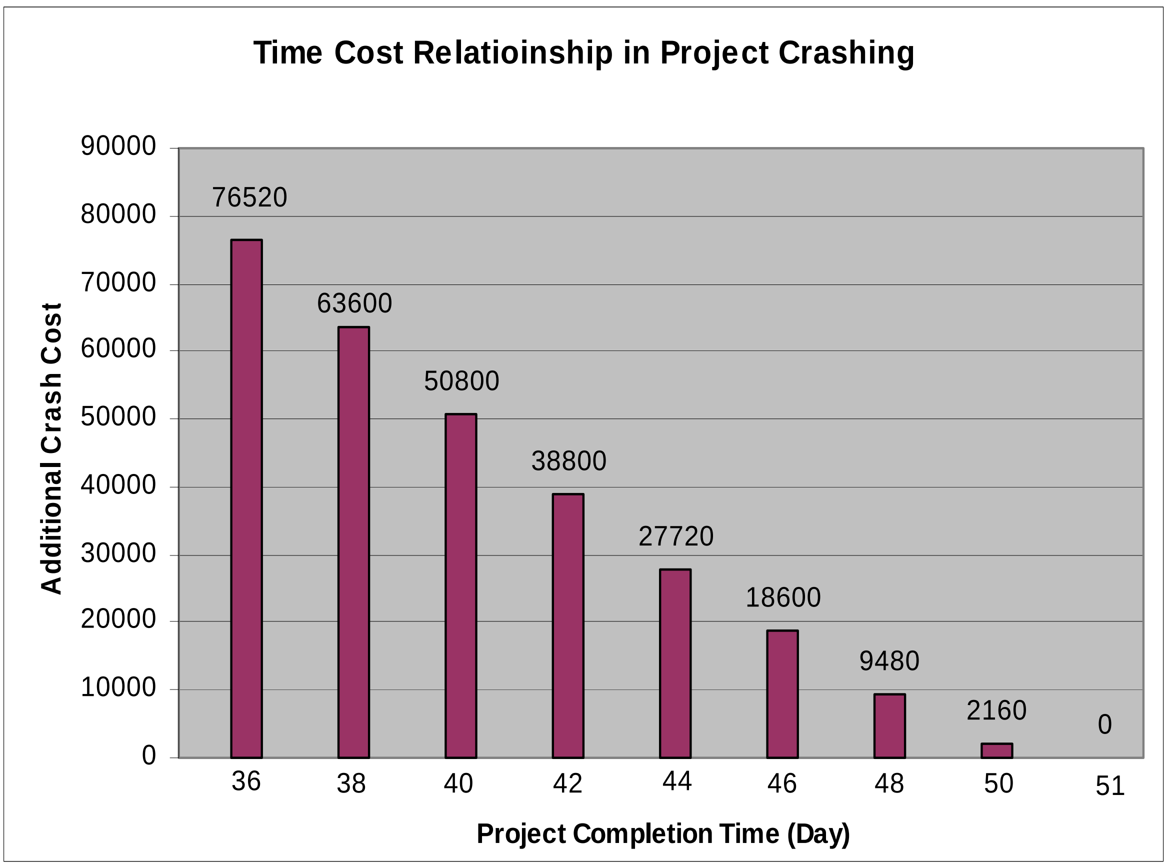

Fig 5.1: Time Cost Relationship in Project Crashing

Project network diagram give us overall picture of the project. The total number of events in this project is 22 and 19 node. Here X_i is node number and it's completion time in day is shown in the box. To complete the project by 50 days we need to crash the activity "F" by one day. Red indicator activities need to crash and crash time shown in parenthesis.

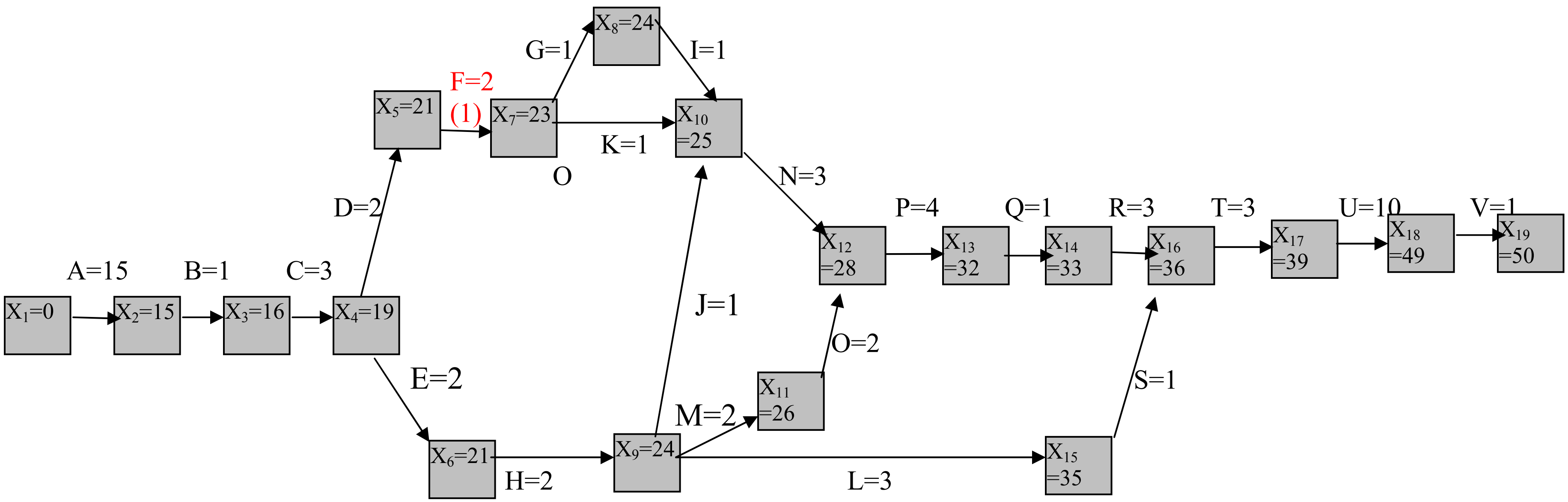

Figure 5.2: Network Diagram of the Project to complete by 50 days.

To compete the project by 40 days we need to crash the activities A, F, N, R and U by five, one, one, one and three days respectively. In this case total extra crash cost is Tk.50800.In the parenthesis crash time is shown.

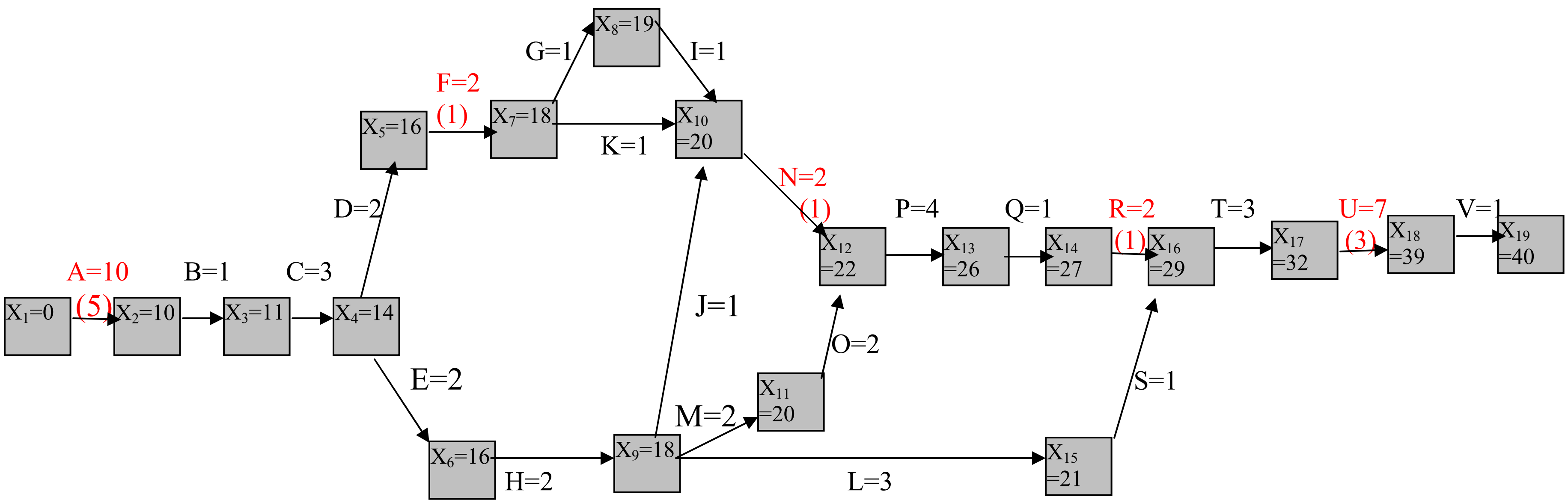

Figure 5.3: Network Diagram of the Project to complete by 40 days.

If we want to compete the project by 36 days we need to crash the activities A, C, F, N, P, R, T and U by five, one, one, one, two, one, one and three days respectively.
In this case total extra crash cost is Tk.76520. In the parenthesis crash time is shown.

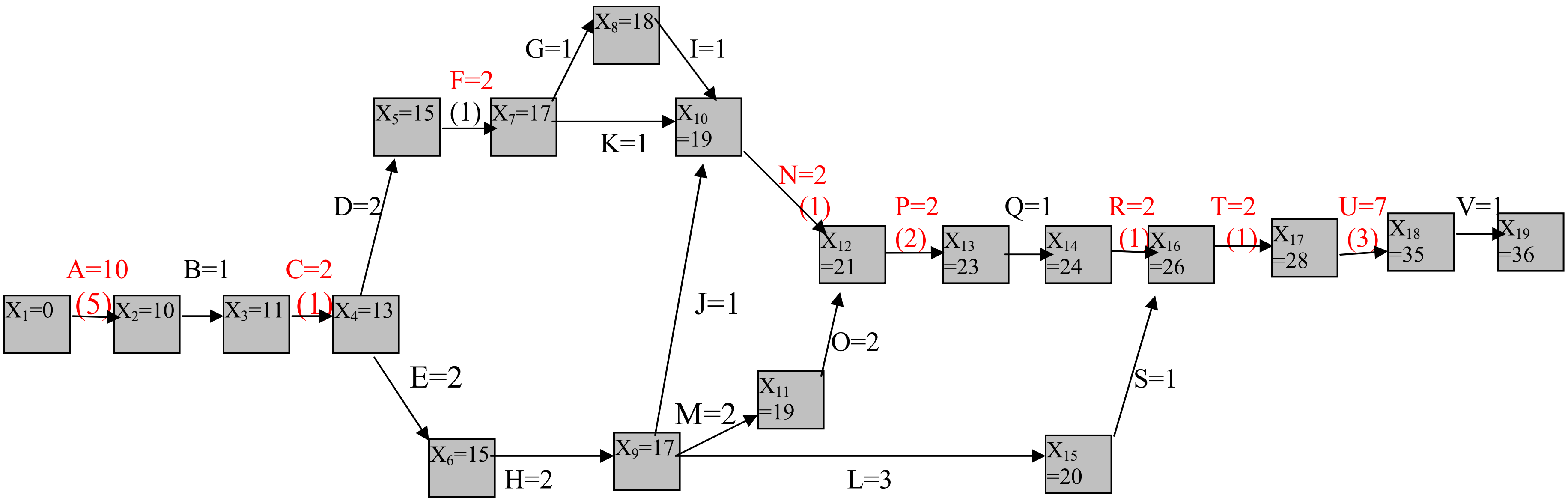

Figure 5.4: Network Diagram of the Project to complete by 36 days.

5.3 Sensitivity Analysis of the Project

We had a plane to complete the project by 40 days and the project have completed by 40 days and extra cost for crashing is Tk.51000 and total project cost is Tk. 471000 which is agree with solver result.

Table 5.3: Sensitivity Analysis of Objective Function

Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
Ya Final Solution	5	-1440	4560	1440	1E+30
Yc Final Solution	0	400.0000001	6400	1E+30	400.0000001
Yb=Yd Final Solution	0	-10960	0	1E+30	10960
Ye Final Solution	5.3E-15	0	1040	480	1040
Yf Final Solution	1	-2800	2160	2800	1E+30
Yg= Final Solution	0	-4960	0	1E+30	4960
Yh Final Solution	0	6320	7360	1E+30	6320
Yi=Yj= Final Solution	0	-4960	0	1E+30	4960
Yk= Final Solution	0	0	0	1E+30	0
Yl Final Solution	0	2328	2328	1E+30	2328
Ym Final Solution	0	5780	6820	1E+30	5780
Yn Final Solution	1	-2200	2760	2200	1E+30
Yo Final Solution	0	480	1520	1E+30	480
Yp Final Solution	0	460.0000001	6460	1E+30	460.0000001
Yq= Final Solution	0	-6000	0	1E+30	6000
Yr Final Solution	1	919.9999999	5080	919.9999999	1E+30
Yt Final Solution	0	400.0000001	6400	1E+30	400.0000001
Yu Final Solution	3	0	6000	400.0000001	919.9999999
Yv= Final Solution	0	6000.000002	0	1E+30	6000.000002
X1 Final Solution	0	6000	0	1E+30	6000
X2 Final Solution	10	0	0	1E+30	1440
X3 Final Solution	11	0	0	10960	1440
X4 Final Solution	14	0	0	400.0000001	1440

X5 Final Solution	16	0	0	400.0000001	1440
X6 Final Solution	16	0	0	400.0000001	480
X7 Final Solution	18	0	0	400.0000001	1440
X8 Final Solution	19	0	0	400.0000001	1440
X9 Final Solution	18	0	0	400.0000001	480
X10 Final Solution	20	0	0	400.0000001	1440
X11 Final Solution	20	0	0	400.0000001	480
X12 Final Solution	22	0	0	400.0000001	1440
X13 Final Solution	26	0	0	400.0000001	1440
X14 Final Solution	27	0	0	400.0000001	1440
X15 Final Solution	28	0	0	0	0
X16 Final Solution	29	0	0	400.0000001	919.9999999
X17 Final Solution	32	0	0	400.0000001	919.9999999
X18 Final Solution	39	0	0	6000	6000
X19 Final Solution	40	-6000	0	6000	1E+30

From limit range Table 5.2 we find that all tasks are not same sensitive, some tasks are more sensitive and some are less sensitive. We should crash the most sensitive tasks first then according to project completion constrain then crash the other less sensitive task.

The sensitivity analysis generated from solver solution also provide us the upper limit and lower limit of the variable coefficient of the objective function within which solution would remain optimum (Table 5.3). In our sample project, the final value of variable Y_A in the objective function is 5. The current coefficient of the variable is 4560, allowable increase is 1440 and allowable decrease is 1E+30. It indicates our current solution would remain optimum if crash cost per unit of time for activity A varies from Tk. 6000 to Tk. -1+E30. The reduced cost of the non basic variables (the variables whose value is zero in the optimum solution) provide us the information about how much objective coefficients of these variables should be reduced to have a positive value of those variables in the optimum solution. In our project reduced cost of a current non-basic variable Y_C is Tk.400. It means the current coefficient of this variable which is now 6400 must reduce 400 (that means the coefficient would be 6000 or below) to get a basic (positive) value of this variable in the optimum solution.

Table 5.4: Sensitivity Analysis of Right Hand Side of the Constraints.

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
X2 Final Solution	10	6000	0	0	3
X3 Final Solution	11	6000	0	0	3
X4 Final Solution	14	6000	0	0	3
X5 Final Solution	16	4960	0	0	1
X6 Final Solution	16	1040	0	1	0
X7 Final Solution	18	4960	0	0	1
X9 Final Solution	18	1040	0	1	0
X8 Final Solution	19	4960	0	0	1
X10 Final Solution	20	0	0	1	1E+30
X10 Final Solution	20	0	0	1	1E+30
X10 Final Solution	20	4960	0	0	1
X11 Final Solution	20	1040	0	1	0
X13 Final Solution	26	6000	0	0	3
X14 Final Solution	27	6000	0	0	3
X15 Final Solution	28	0	0	7	1E+30
X16 Final Solution	29	0	0	7	1E+30
X12 Final Solution	22	4960	0	0	1
X12 Final Solution	22	1040	0	1	0
X16 Final Solution	29	6000	0	0	3
X17 Final Solution	32	6000	0	0	3
X18 Final Solution	39	6000	0	0	3
X19 Final Solution	40	6000	0	0	3

Right hand sensitivity of the constraints provides us information regarding the status of the constraints- which of these constraints are binding (fully utilized) or non-binding. Binding constraints having a value in the shadow price column (Table 5.4) other than zero, means how much contribution these binding constraints will provide individually in the objective function, if the value of the right hand side of these constraints are increased by 1 unit. The allowable increase and allowable decrease column of Table 5.4 indicate the range of increase and decrease of the right hand side value of the binding resources within which the current shadow price would remain unchanged. So, this solution would help management to reach the optimality where sensitivity analysis would provide some flexibility in the project.

CHAPTER-6
CONCLUSION

6.1 Conclusion

In this work, we used an algorithmic model based on linear programming incorporated with a minimal time-cost trade-off in an installation project. The format of the model lends itself to a wide range of variables and considerations. It allows a great number of parameters to simulate project conditions and project manager preference and provides potentially useful tool for decision making on project scheduling.

Use of linear programming models outperforms the default algorithm implemented in these packages to minimize total project cost. It appears that the programming in project time-cost trade-off concept has more to offer than the graphical methods and scheduling software packages. A real understanding of this concept leads to improved solutions to large scale systems facing project cost control systems and network compression.

The cost of the network activities has been optimized for various overall durations. The optimum trade-off of time against cost has been made. This approach is an acceptable tool of management and proving to be not only superior method for planning, scheduling and controlling project progress, but also is very real and valuable assets to project manager in convincing the owner of their potentials and abilities. With the introduction of better and more rigorous methods of planning work, together with cost analysis, the project control will become more systematic. Mathematical models are used more and more for executive planning functions. In all of these, decisions must be made to carry out the operation in the best way possible in light of the restraints that are bound to exist.

The sensitivity analysis can also be helpful for assessing the effects of uncertainties in some of the data items. The further uncertainties in the data may be examined directly by running the program with upper and lower limits on the data to check the sensitivity of the results in different circumstances. The linear programming analysis carried out to determine the optimal policy of investing in extra resources in order to meet the deadline is obtained. It is important for project manager to recognize the flexibility of the system that can be used to explore numerous possible opportunities to the project manager.

6.2 Recommendation

Time-cost trade off problem is one of the main aspects of project scheduling. Due to variations in the real world, usually, risks in estimation of project parameters are considerably high. Therefore, it is necessary to use of uncertain models to solve time-cost trade off problems, and give a scheduling with more stability against environmental variations. On the other hand, crisp decision making in uncertain environment causes loss of some parts of information. In this work we implement an optimal approach to model time-cost trade off problem in the real environment.

The uncertainty of activities will influence the completing duration and cost of a project. For project management, the crashing cost should be considered as well as the importance of each individual activity. The more important of an activity, the larger the influential effect will be for project duration.

Experience gather from the field of project management has convinced that advance, timely, and proper action can enable crashing most time schedules by 10 to 15 per cent of normal time duration.

In some cases, it may be possible to compress time schedules by 30 to 40 per cent. The following issues must be kept in mind about the time schedule of a project:

- One has to be cautious in analyzing the options for a project time schedule. They have to be realistic within prevalent environment and constraints
- Crashing should not be attempted by sacrificing quality, operability, and safety of the plant

- The optimum time schedule should be backed by proper execution strategies and alternative action plans which take into account reasonable assumptions, achievable targets, and practicable execution philosophies and methodologies.
- It is difficult to estimate cost for compressed time schedule. They are necessarily subjective. Only a shrewd, experienced and skilled estimator can provide reasonably correct estimates of cost. Schedule crashing costs, therefore, should be accepted only after detailed review and analysis.

In conclusion, it is believed that the proposed model is valid and represents a practical methodology to prevent potential quality loss cost arising from a crashed activity. Also from this example, it is demonstrated that the quality in the time-cost trade-off problem has a significant impact. Project leader or decision maker can take proper actions to ensure quality for the special care activities while developing the project schedule.

This is a practical model which will help project management practitioners develop accurate project schedules. For further research, the uncertainty of activities during the project crashing needed to consider. Then this model would be a more powerful solution for practical problems.

REFERENCES

[1] Liberatore. J., Bruce and Pollack-Johnson, "Extending Project Time-Cost Analysis by Removing Precedence Relationships and Task Streaming", International Journal of Project Management, 24, (2006), pp. 529-535.

[2] Babu. A. and Suresh, N., "Project Management with Time, Cost, and Quality Cosiderations", Journal of Operational Research, 88,(1996), pp.320-327.

[3] Tareghian. H. and Taheri. S., "On the Discrete Time, Cost and Quality Tradeoff Problem", Applied Mathematics and Computation, 181, (2006), pp.1305-1312.

[4] Khang. D. and Myint. Y., "Time, Cost and Quality Tradeoff in Project Management: A Case Study", International Journal of Project Management, Vol.17, No. 4, (1999), pp. 249-256.

[5] Boctor. F., "A new and efficient heuristic for scheduling projects with resource restrictions and multiple execution modes", European Journal of Operational Research,(1990), pp. 349-361.

[6] Kelly. J., "Critical-path planning and scheduling: Mathematical basis". Operations Re- search, Vol. 9, (1996), pp. 296-320.

[7] Tavares. L., "A review of the contribution of operational research to project management", European Journal of Operational Research, Vol.136, (2002), pp. 1-18.

[8] Yang. I.T., "Performing complex project crashing analysis with aid of particle swarm optimization algorithm", International Journal of Project management, (2007), Vol.25, pp. 637-646.

[9] Islam. N. and Rana. B., "Crashing project time: A Linear Programming Approach", Journal of Business Research, Vol.6, (2004), pp. 12-26.

[10] Kim. J. and Kagn. C., "Ensuring quality in time –cost trade-off problems in crashing a project", Proceedings of SKISE Autumn Conference, November (2008), pp. 14-15.

[11] Ronald. S. and Mitchell. T., "Activity Resource Elasticity: A New Approach to Project Crashing", University of Nevada, Reno, August 2007