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كلية الهندسة
عماده الدراسات العليا

Time Schedule Preparation By Predicting Production Rate Using Simulation

Case Study:- Beach Camp Shore Protection

Ali Abed- El- Fattah Yahia

Supervised by :

Dr. Rifat Rustom
Associate Professor of Civil Engineering, the Islamic University of Gaza

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master in Construction Management

بسم الله الرحمن الرحيم

يقول الله تعالى:

" وقل اعملوا فسيرى الله عملكم و رسوله و المؤمنون".

صدق الله العظيم

Dedication

To my Mother, my Wife and Children

for their unlimited support

Ali Yahia

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Abstract

This study is intended to investigate the problem of scheduling engineering projects utilizing the production rates by the simulation. The main goal of this study is to improve the scheduling of projects and productivity estimation in the construction industry in Gaza Strip.

The present investigation consists of two main parts. The first part is a field survey "questionnaires" accompanied by personal interviews. The Field survey is included to highlight the local factors affecting productivity and the methods used for estimating productivity in Gaza Strip. Forty-five questionnaires were distributed to contractors from which forty questionnaires were received and analyzed. The collected data reflected different size, types, and characteristics of the sample population. The second part is a case study based on an ongoing project in Gaza Strip. The study is intended to demonstrate the use of simulation in estimating productivity based on the actual measurement of the durations of the activities of the project. The observation data were analyzed and fitted to Beta distribution functions.

This study focuses on the application of simulation technique for modeling and simulation an ongoing project in Gaza Strip with the intention to conclude the appropriate project construction production rates and time probabilistic during the planning and implementation the projects. Also, the present investigation shows that there is a need to train the contractors and improve their abilities to use the productivity measurement methods for time scheduling.

الملخص

تحضير الجداول الزمنية عن طريق قياس معدل الإنتاج باستخدام تقنية المحاكاة في قطاع غزة

تتمثل دراسة هذا البحث في معالجة مشكلة جدولة المشاريع الهندسية باستخدام المحاكاة في تقدير معدلات الإنتاج. هذه الدراسة تم تطبيقها على عينة من المقاولين في قطاع غزة، حيث كان الهدف الرئيسي لهذه الدراسة هو تحسين و تطوير جدولة المشاريع و الإنتاجية في صناعة التشييد في قطاع غزة.

آلية تنفيذ البحث تتكون من جزأين رئيسيين، أولهما، عبارة عن مسح ميداني "استبيان" مدعم بالمقابلات الشخصية، حيث تم توزيع خمسة و أربعين استبيانا على المقاولين و تم جمع وتحليل أربعون استبيانا . حيث مثلت المعلومات التي تم جمعها الرؤية الواضحة لحجم و أنواع و سلوك الشركات.
أما الجزء الثاني هو عبارة عن دراسة "مشروع تحت التنفيذ" في قطاع غزة، حيث تم تطبيق الطرق العلمية في دراسة الإنتاجية و الوقت عن طريق الملاحظة اليومية حيث تم معالجة البيانات في هذا الجزء باستخدام تقنية المحاكاة.

لقد أوضحت نتائج هذه الدراسة بأن وسائل وتقنيات دراسة تحليل الإنتاجية لا تستخدم بشكل واسع بين الشركات في قطاع غزة لتحضير الجداول الزمنية و أيضا عدم معرفتهم المطلقة ببرنامج المحاكاة . ولقد بدا واضحا أن نقص المعرفة و عدم الوعي بأهمية طرق دراسة الإنتاجية وجدولة المشاريع لا تزال تشكل عائقا نحو الاستخدام الكفء لهذه الوسائل . من ناحية أخرى أثبتت نتائج الحالة الدراسية بأنه من الممكن استخدام برنامج المحاكاة في دراسة الإنتاجية لجدولة المشاريع الهندسية وذلك عن طريق تصور تنفيذ المشاريع بالكمبيوتر وتطبيق هذا التصور على أرض الواقع .

وعليه فان دراسة هذا البحث يعكس الحاجة الماسة لتوجيه عمليات التدريب نحو تحسين قدرات المقاولين في استخدام طرق قياس الإنتاجية لتحضير الجداول الزمنية و أيضا العمل على تدريب المقاولين باستخدام برنامج المحاكاة لأهميته في تحسين طرق تنفيذ المشاريع الهندسية.

List of Acronyms

PMI	Project Management Institute
USA	United State American
UNRWA	United Nations Relief and Work Agency
CPM	Critical Path Method
PERT	Program Evaluation and Review Technique
AS	Activity Scanning
PI	Process Interaction
ACD	Activity Cycle Diagram
WBS	Work Breakdown Structure
ABC	Activity- Based Construction
HSM	Hierarchical Simulation Modeling
PS	Pilot Study
GS	Gaza Strip
SPA	Simulation Package Arena
BOQ	Bill of Quantity
SPSS	Statistical Package for Social Science
Qty.	Quantity

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CHAPTER 1

Introduction

In the present work, engineering-project time schedules are prepared by implementing the production rate measurement using Simulation. This study is being applied to a case in Gaza Strip. The factors influencing production rates are discussed as complementary to the main study.

In this chapter, a brief introduction to the construction industry and the project management techniques being applied in Gaza Strip are presented. Also, the problem definition, importance, and the objectives of thesis are laid out.

1.1 Background

Little data is available that describes the status of the construction industry in Gaza Strip. Lack of knowledge and experience in construction management techniques, such as productivity measurement by scientific methods, during preparation of time schedules produce many problems during the implementation of the project.

The construction sector in Gaza had experienced a considerable growth in the aftermath of 1967 war (El- Sawalhi, 2002). By the year 1991, the construction sector enjoyed a steady increase, due to “Pent-up“ demand from the Intifada. The peace process accelerated this increase, especially after the return of many Palestinians from Diaspora.

1.2 Research Problem

It is observed that the current practices in preparing a time schedule for a construction project in Gaza Strip by the engineers do not take into consideration labor production rates measurement to determine the required time, number of labor, and cost for each activity in the project.

Current practices for preparing time schedules depend mainly on experience with similar projects, approximation of level of efforts, and estimated cost of activities as bided. Resource management in terms of resource allocation, leveling and effectiveness are rarely tackled. Therefore, most time schedules prepared in Gaza strip are not true representation of projects. In other words, determining the required time and resources for any activity is usually not made by using production rates methods or simulation to obtain the optimum time and productivity simultaneously.

Current methods usually result in many problems in the construction industry in Gaza strip, especially, the problems between the owners and contractors during the construction phase. Some of these problems are:

- Conflict between the planned and actual resources.
- Conflict between the planned duration of the activity and the actual duration which causes disruption of the works.
- Revising the time schedule many times during the implementation of the projects to accommodate the changes.
- The delay in the completion of the project.
- Increase in the indirect and direct costs which may cause failure of many projects.
- Payments, especially when the payment is determined in the contract as a monthly payment.

1.3 Importance of the Present Work

The importance of the present research can be realized from the following:

- There is a need to develop and control a time schedule based on well estimated production rates.
- There is a need to use techniques such as simulation, to measure the production rate and prepare realistic time schedules.
- Current methods used local proved, from experience, that they yield either over estimated or underestimated contracts. Therefore, there is a need to investigate current methods and possibly suggest modifications.
- At least in Gaza Strip, it is noticed that there are no reference handbooks and/or manuals of production rates relevant to the construction industry to estimate the required resources and time to control projects.

1.4 Objective

The main goal of this study is to use simulation as a technique for estimating production rates in an attempt to improve the preparation of time schedules of construction projects. The specific objectives are:

- To determine the factors that affect production rates of the construction projects in Gaza Strip.
- To layout the foundation for estimating the production rates using simulation as a tool.
- To prepare an optimal time schedule for an ongoing project as a case study.
- To formulate recommendations to the contractors about how to integrate planning effectively in their projects.

1.5 Research Design

This research is mainly based on site investigations through data gathering, field survey “questionnaire”, and case study.

The methodology adopted in this research consists of two complementary parts:

Field study (Questionnaire), supported with personal interviews with many of Gazian contractors, was conducted to collect information about the factors influencing the production rates in the construction industry.

As a case study, Beach Camp Shore Protection project was taken to study the production rate of labor and hence to obtain the duration of the project using simulation.

The research was conducted in the order given below:

A literature review was carried out before data collection and analysis.

A field survey was conducted in Gaza Strip by means of a questionnaire applied to selected (40) contracting companies. Also data were collected from an ongoing project to measure the production rates by simulation methods in order to prepare a time schedule for the project. The project selected is in Gaza Strip.

The collected data was complied, analyzed and presented.

Conclusions of research and recommendations were then drafted.

Figure 1.1 depicts a flowchart for the described methodology and its components.

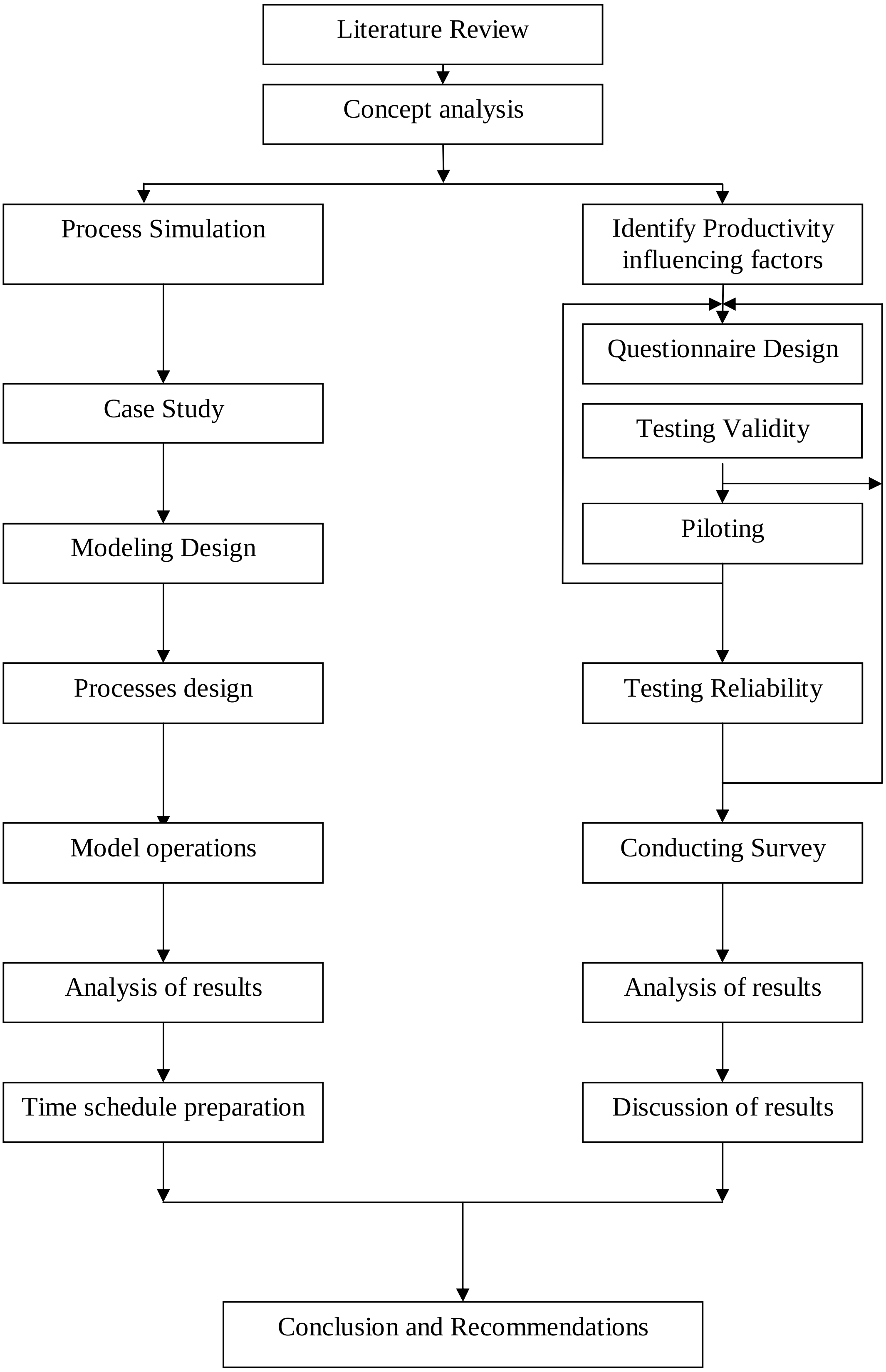


Figure 1.1 Methodology

CHAPTER 2

Literature Review

This chapter reviews projects scheduling concept based on determination of production rates using process simulation.

2.1 Project Management Process

Project management in the construction industry is very important for managing time, cost and quality of projects during achievement of the activities. Kohli (1996) said, "project management is the process of planning, scheduling, organization, leading and controlling the efforts of organizational members, and the use of other organizational resources, in order to achieve stated organizational goals".

Project management is the art of directing and coordinating human and material resources through the life of a project by using modern management techniques to achieve predetermined objectives of scope, cost, time, quality and participant satisfaction (Cleland,1999).

Sansom and Coates (1999) reported, "project management is an integrated activity dependent on the ability to ensure that the efforts of the project staff are co-coordinated and guided towards the achievement of the project's objectives" .

Oberlender (1993) mentioned, " project management may be defined as the art and science of co-ordinating people, equipment, materials, money, and schedules to complete the project within approved cost ".

2.2 Project Scheduling

The Period of time before the work is commenced on a site provides an opportunity for the critical re-examination of the methods that will be used to carry out the work. Scheduling is the process of determining the actual time periods during which the activities are scheduled to take place (Poskitt, 1986).

Oberlender (1993) mentioned that project planning is the core of well project management and also establishes the benchmark for the project control system to track cost, quantity, and timing of the work required to complete the project.

Kohli (1996) stated that project scheduling is a crucial part of the planning process, since it is the basis for allocating resources, estimating costs, and tracking project performance. Stevens (1989) indicated that a very crucial part of a plan is the time_ based schedule which is so important for all concerned.

Hinze (1998) indicated that a schedule is a timetable of activities, such as of " what" will be done or " who " will be working.

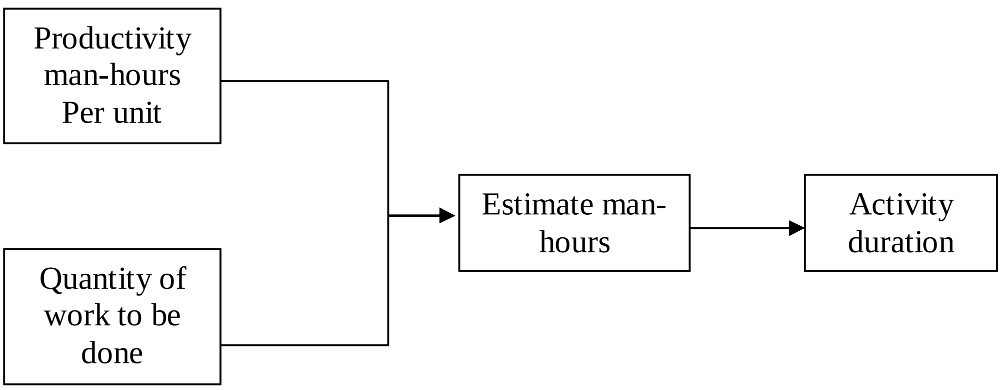
From the above statements, it is concluded that project scheduling is an important part of the "deciding" aspect of the project team's job-thinking about the project's future in relationship to its present in such a way that organizational resources can be allocated in a manner which best suits the project's purpose.

2.2.1 Activity Duration

There are several methods for determining activity duration as the following :

1. Analyzing historical records from previously completed projects.
2. From the experience and judgement of the person who will be performing the work.
3. By manual references.

Ahuja (1994) suggested that the time required to do the work can be determined by dividing the quantity of work by the labour productivity (see Figure 2.1).



`Figure 2-1 Activity duration estimation (Ahuja, 1994)

Hinze (1998) reported that the method used to establish the duration of an activity depends on the size, in terms of time consumption of the activity, and the amount of accuracy that is required. Activity duration frequently are tied directly to the resources applied to them and the productivity of these resources.

Barrie and Paulson (1992) indicated that the activity duration estimate is the product of careful thinking involving the methods by which the activity will be accomplished, the resources that are available, productivity and external constraints.

2.2.2 Construction Scheduling Techniques

There are several techniques used for preparation of project scheduling in the construction industry. Among mostly used methods:

- Bar chart;
- Critical Path Method (CPM); and
- Program Evaluation and Review Technique (PERT).

2.2.2.1 Bar Chart

Bar chart was developed by Henry Gantt (Mawdesley et al, 1997). The bar chart is still the best known technique for representing plans. Gantt chart is one of the oldest planning tools that have proven to be a useful tool. It is clear, simple and easy to use and understand. Bar charts are also fairly broad scheduling and planning tools, so they require less revision and updating than more complicated systems (Abbasi and Al- Maharma, 2000).

However, it is difficult to use it for forecasting the effects that changes in a particular activity will have on the overall schedule. Therefore, it is limited as a control tool (Barrie and Paulson, 1992).

2.2.2.2 Critical Path Method (CPM)

Critical path method "CPM" identifies those chains of activities in the project that control how long the project will take (Hinze, 1998). The critical path method evolved as a joint venture between Remington and Dupont (Bedworth and Bailey, 1987). The Critical path method enables planners and managers to thoroughly analyze the sequential logic and timing of all operations required to complete a project before committing time, labor, equipment, material and money for construction and engineering (Barrie and Paulson, 1992). Some Authors recommend that bar charts be complemented with the use of a critical path method schedule (Ahuja, 1994).

This method calculates the minimum completion time for a project along with the possible start and finish time for the project activities (Hendrickson, 2000).

2.2.2.3 Program Evaluation and Review Technique (PERT)

The concept was based on breaking the project down into individual components

(activities), probabilistically estimating the times required to complete the work, and estimating the project completion time with an associated probability distribution. In essence, the duration of each activity will be estimated using a three – time reflecting the pessimistic, optimistic, and most likely values of the duration

2.3 Labor Resource Management

The manpower (labor) is considered the most important resource for any construction project. So the planner should take into account planning of the activity in accordance with allocation and estimation of necessary manpower (labor) to achieve the activity in the determined time. Most planners usually concentrate their efforts on the timing such as planning and scheduling of the projects without taking into account the required resources that are needed to carry out the work based on productivity (Mawdesley et al, 1997).

Estimating the needs of manpower (labor) for any project is considered difficult. It is noted that the estimating process of the needs for labor in the projects achieved in the past is not accurate. This resulted in shortage of labor during the implementation of the work, decrease of production rates and decrease of quality.

2.3.1 Resources Allocation and Leveling

There are two factors affecting the availability of resources which are superimposed on the critical path method (Ahuja, 1994) which are:

- Limited resources (variable project duration); and

- Unlimited resources (fixed project duration).

The first case is called resource allocation and the other case is called resource leveling. The two cases should be considered during the preparation of time schedule for any project in construction industry in an attempt to improve resources management and estimate production rate of the resource before starting work.

2.3.1.1 Resource Allocation

Resources scheduling can be defined as the allocation of limited resources to different activities. Resources allocation is used when resources are limited (Hinze, 1998). Pilcher (1992) indicatd that the nature of the problem in resources allocation is that of optimizing the project duration, wherever there are certain constraints as to the quantity of the resources that will be available during the project.

2.3.1.2 Resource Leveling

Resource levelling is a process to determine the resource allocation to project activities for improving production rate and efficiency of the work (Steven, 1989).

Kohli (1996) suggestd that the main goal of levelling resources is to reduce

(highs and lows) of resources requirements during the life cycles of project.

The resource levelling process is very important along the period of project because it helps avoid or minimise the need for hiring short- term workers. Also, levelling the resources of the project will increase the production rate and complete the project within the required period (Hinze, 1998).

Mawdesley et al (1997) defined the resource leveling as “ a process of producting a schedule that reduces the variation between maximum and minimum values of resource requirement”. Resource leveling often results in project duration that is longer than the preliminary schedule (PMI, 1996).

2.4 Productivity Definition

Productivity is the ratio between the value of a unit of output and the cost of all input (Lvitt, 1982). Fenske (1985) agreed that productivity is a " tangible reality". Pilcher (1992) defined productivity as the rate of producing.

Productivity can also be defined as the amount of work that labor can accomplish in a defined period of time (Paulson, 1992). Also, Paulson indicated that labor productivity is difficult to estimate. Jay and Barry (1996) said that the productivity is the enhancement of the production process.

The main target of productivity is to estimate the production rate for an activity in a project, which depends on previously implemented projects and experience of the planner to determine the required resources (labor) and duration with low cost and high profit.

2.5 Factors Influencing Productivity in Construction

Paul (1998) classifed the factors affecting job-site productivity into two categories, external and internal factors.

External Factors: There are several external factors affecting job- site productivity as the following:

1. Nature of construction industry;

2. The construction client; and

3. Weather.

The manpower functions efficiently at temperature between 16c and 25c with moderate 40-70 % humidity (Markham,1942). Baldwin and Monthei (1971) ranked weather the highest in the causes of construction delays in the United States.

Internal Factors:There are many internal factors influencing job- site productivity as the following :

1. Management;

2. Technology; and

3. Labor.

The motivation of labor is directly related to the level of productivity (Maloney, 1983). Kehn (1986) reported that there are four variables which can increase the productivity. They are:

- Management : planning, scheduling, adequate co-ordination and suitable control;
- Labor : level of skills, union agreements, level of education and training and restrictive work practice;
- Government : Regulations, social characteristic, environmental rules and political conditions; and
- Climatic conditions. (Kehn, 1986)

Jay and Barry (1996) mention that there are three variables which can increase the productivity. They are:

1. Labor;
2. Capital; and
3. Management.

Yates and Guhathakurta (1993) mention that there are several factors affecting lack of productivity in the construction industry which can be summarized in the following:

1. Lack of materials supply due to the required time;
2. Lack of proper tools and equipment;
3. Repeated work; and
4. Inspection delays.

The planner must take into account the time utilization during analyzing activity duration and calculating the productivity of labor.

2.6 Labor Productivity Measurement in the Construction Industry

Gilleared (1992) indicated that the cost of labor makeup 30-50 percent of the overall projects costs. Labor costs make up a large portion of the total cost of a construction project. Therefore, success of the construction companies in today's competitive market largely depends on accurate estimating of productivity, which is not an easy task. Productivity in construction is greatly affected by work conditions that change from project to project. A good estimate of productivity requires a careful analysis of work conditions and their impact on productivity. It is difficult to quantify the impact of work conditions on productivity. Labor productivity can be impaired by several factors including: Contractor management; material management practice; disruptions to the work; changes and weather conditions. (Thamson, Riley and sanvido, 1999).

2.6.1 Work Measurement

work measurement is defined as the application of techniques designed to establish the time for a qualified worker to carry out activity at a defined rate of working (BS 3138, 1979).

Poskitt (1986) indicated that the main target of work measurement is to determine the required time for a qualified worker to achieve a specific task and eliminate ineffective elements of work.

Work measurement is used to find the realistic required time to complete a specific activity by labor without waiting and idling except that required for normal rest and relaxation. Also is it used to :

1. Determine the number of labor to be allocated for activity according to fixed duration and total quantity of work to be achieved.
2. Determine the activity duration in accordance with the resources allocated and total quantity of activity to be achieved.

There are several techniques available for work measurement in the construction industry which are :

1. Time study;
2. Rated activity sampling;
3. Synthesis;
4. Analytical estimating; and
5. Comparative estimating.

2.7 Simulation Concept

In general, simulation is frequently encountered in our everyday lives. Also, simulation is widely used in engineering decision making, wherefore, simulation enables the representation of the system to be changed in order to better understand the real system; of course, this requires the model to be a realistic representation of the system. Simulation is a Principal modeling tool because it allows a model to be altered to reflect conditions that have not occurred in the past but can be expected to occur in the future. Thus, the response of the real system to future extreme conditions of possible prevention action is evaluated.

In this study, the main idea behind conducting a simulation for the project is to implement the project activities theoretically on the computer before the actual project commencement on site. This will help in determining the time duration of each activity as well as the required resources. By conducting scenarios for labors productivity, the scenarios , that shows the best duration for the owner and least cost for the contractor, may be chosen.

Recently, there has been increased interest in the use of simulation for real-time planning, scheduling and control of construction industry projects.

Simulation is a relatively new technique in construction industry scheduling, made by computers, and can obtain the optimum productivity based on duration and number of labors for each activity (Stevens, 1989).

Also, simulation can be used, to solve several problems in the construction industry, such as scheduling of projects based on productivity forecasting.

Since the construction industry is tied with several factors that affect its nature such as weather and management, simulation offers a tool that eliminates several of these limitations. Therefore, simulation is used to present the real system as nearly in practice.

Simulation can be used as a technique to help construction planner in making informal decisions (Zayed and Halpin, 2000). Ioannou and Martine (1996) reported that simulation is often used to evaluate and compare the merits of different construction methods in accordance with several decision criteria in an attempt to select the optimal alternative.

Simulation can be defined as the process of conducting experiments on a model when we cannot experiment directly on the system (Ayyub and McCuen, 1997).

The main objective in using simulation to model construction processes is to evaluate and compare the performance of alternative in construction methods to select the best alternative (Photios and Julio, 1996). Dabbas and Haplin (1983) developed a simulation model that integrates project and process level. Their model provides the capability to estimate project level activity duration using process level simulation network.

The scope of simulation process ranges from productivity management and duration analysis to resources allocation and site schedule .

2.8 Computer Simulation

Computer simulation is the process of designing a mathematical-logical model of a real world system and experimenting with the model on a computer. Three phases can be identified in using simulation to resolve a real world problem as shown in Figure 2.2.

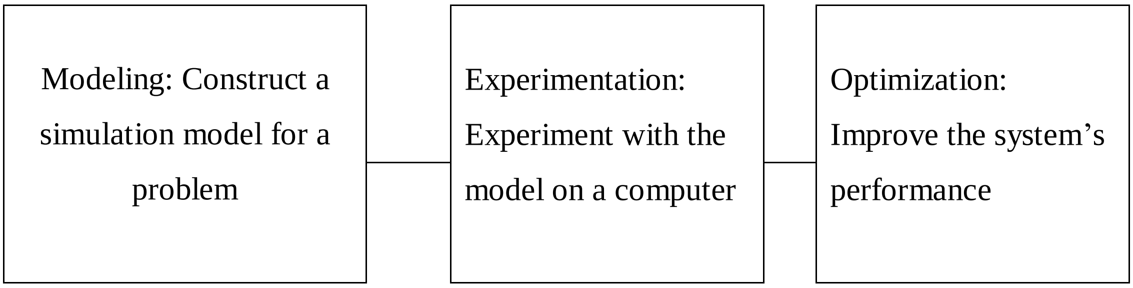


Figure 2-2 Three phases of computer simulation

Modeling is the process to describe a stated problem in terms acceptable to a computing system. The first step in the simulation process is the gathering of the statistical input data; because they are the base that will be used to build the mathematical model which will present the system in the real life (Maio 2000).

Figure 2.3 illustrates the simulation modeling concept where a planner provides input and expects to derive some output. Three phases can be identified in using real system:

1. Building Process Model:

The relative sequence and logic of the processes that makes up a construction operation and data collecting (Observation Analysis) from the site (real system).

2. Generating Statistical Distribution Functions

After the data are collected on a random basis, the data are used to specify a distribution function using computer.

3. Simulation Operation (Programming)

The distribution function is used in the simulation model as source of input data, then the output of simulation process through statistical analysis is calibrated to match the behavior of the real system. Once the system is stabilized, the best conceptual model is then used to run the model.

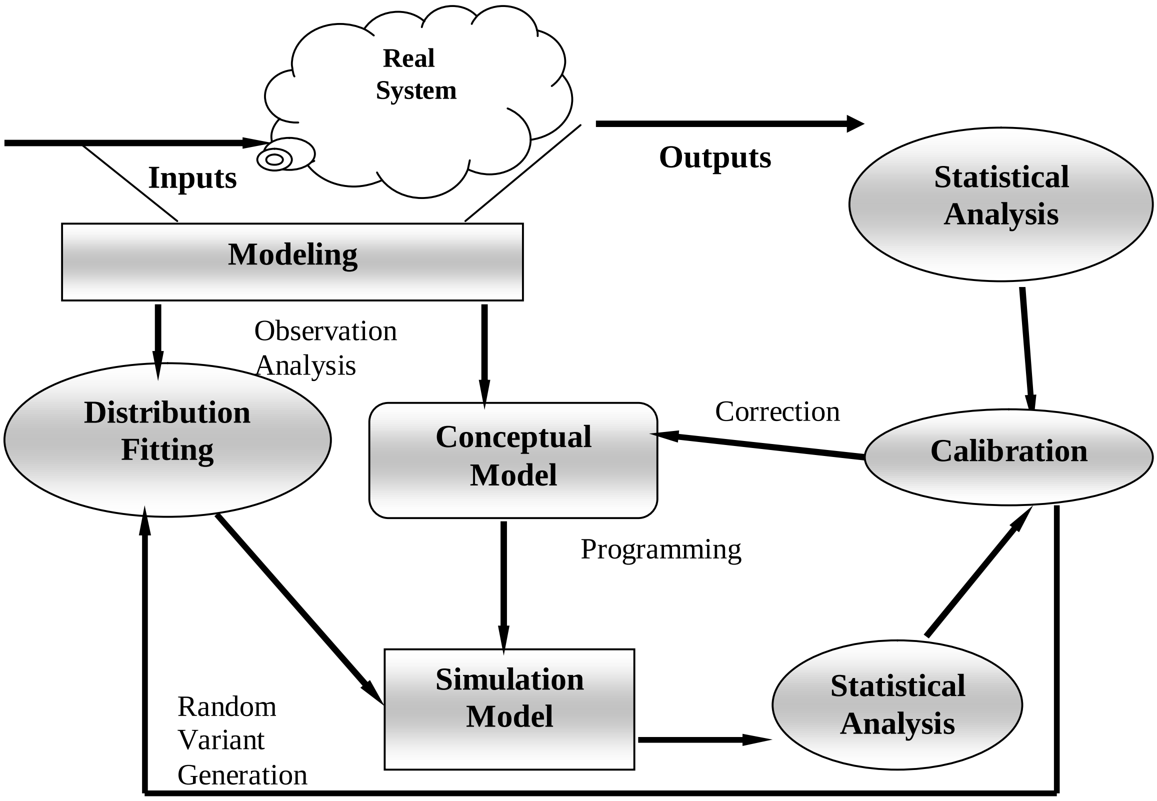


Figure 2.3 Simulation Modeling

2.9 Simulation Techniques

There are several simulation techniques used to present, simulate the real system and estimate the production rates to determine the required resources and optimal duration in the construction industry which are :

2.9.1 Monte Carlo Simulation : A technique using random variables to estimate possible activity duration in a probability distribution. This method is applied for simulation of a PERT network.

2.9.2 Micro Cyclone Simulation

The Micro Cyclone software is actually used to simulate the activities of a project by repeatedly incurring the network logic. Cyclic operations network (Cyclone) was specifically designed for construction (Halpin and Woodhead,1976). The Micro Cyclone tool depend on Fortran language to simulate any system.

2.9.3 Arena Simulation

Arena software (Rockwell Software Manual,2000) is used to simulate and represent the real system which allow the planners to observe the behavior of the system when changes are made in the system. Also Arena enables the planners to bring the power of modeling and simulation to their planning.

In this study, Arena software is used as a technique to prepare a time schedule in the constructions projects based on production rates of labor in an attempt to use this program for the time schedules preparation by the contractors of Gaza in the future. Description of processes, models, and Arena simulation technique will be presented in chapter 4. Arena software was chosen for the application of a case study because of the following:

1. It has good ability for the interface.
2. It has good ability to build scenarios.
3. Data entry are easy.
4. Output reports are more comprehensive.
5. It has good animation for the real system.

2.9.3.1 Basic Process Panel

The basic process panel in arena is used for model building and consists of (8) flowchart modules and (6) data modules.

The flowchart module shapes are placed in the model window and connected to form a flowchart, describing the logic of a process.

The data modules are not placed in the model window. Instead, they are edited via a spreadsheet interface and include entity, queue, resource, schedule, set and variable modules.

2.9.3.1.1 Flow Chart Modules

There are eight flowchart modules which used for model building using Arena package as the following:

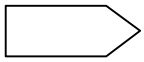
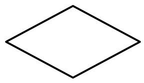
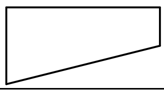
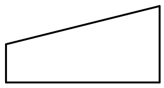
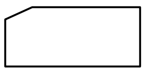
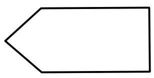
- Create module: This model is intended as the starting point for entities in a simulation model. Entities are created using a schedule or based on a time between arrivals. Entities then leave the module to begin processing through the system.
- Process module: This module is intended as the main processing method in the simulation. Options for seizing and releasing resource constrains are available. The process time is allocated to the entity and may be considered to be value added, non- value added, transfer, wait, or other.
- Decide module: This module allows for decision making processes in the system. It includes options to make decisions based on one or more conditions.
- Assign module: This module is used for assigning new values to variables, entity attributes, entity type, entity pictures, or other system variables. Multiple assignments can be made with a single assign module.
- Batch module: This module is intended as the grouping mechanism of the simulation model. Batches can be permanently or temporarily grouped .Batches may be made with any specified number of entering entities or may be matched together based on an attribute.
- Separate module: This module can be used to either copy an incoming entity into multiple entities or to split a previously batches entity. Rules for allocation cost and time to the duplicate are also specified.
- Record module: This module is used to collect statistics in the simulation model. Various types of observational statistics are available, including time between exits through the module, entity statistics, and interval statistics.
- Dispose module: This module is intended as the ending point for entities in a simulation model. Entity statistics may be recorded before the entity is disposed.

Table 2.1 outlines the description and symbols of these modules.

2.9.3.1.2 Data Modules

- Entity module: This data module defines the various entity types and their initial picture values in a simulation.
- Queue module: This data module may be utilized to change the ranking rule for a specified queue.
- Schedule module: this data module may be used in conjunction with the resource module to define an operating schedule for a resource or with the create module to define an arrival schedule.
- Set module: This data module defines various types of sets, including resource, counter, tally, entity type, and entity picture.
- Variable module: This data module is used to define a variable‘s dimension and initial values. Variables can be referenced in other modules, can be reassigned a New value with the assign module, and can be used in any expression.

Table 2.1 Basic Elements of Arena Simulation

No.	***Name***	***Symbol***	***Description***
1.	Create Module		Starting point for entities in a Simulation model
2.	Process Module		The main processing method in the simulation
3.	Decide Module		Decision-Making processes in the system
4.	Assign Module		Assigning new values to variables
5.	Batch Module		The grouping mechanism within the simulation model.
6.	Separate Module		Split a previously batches entity.
7.	Record Module		Collect statistics in the simulation model.
8.	Dispose Module		Ending point for entities in a simulation model.

2.10 Relevant Studies

Different studies have provided valuable contribution to the growing literature on probabilistic approaches of project scheduling. Recognition of the limitations of deterministic scheduling method (CPM) has led many researchers to investigate the practicality of other methods based on probability distribution for the duration of each project activity. For many practical-size projects, computer simulation is the only reasonable approach to studying the impacts of a variable activity duration on other activities and on overall project duration. Simulation models representing construction processes can be effective management tools supporting project planning and estimating. Many researchers have developed computerized simulation models of these construction operations. Certain input information is necessary to mathematically represent the parameters of the system being modeled.

One of the earliest developments in the model environment for construction simulation was Cyclone (Halpin, 1977). Cyclone can model and simulate repetitive construction processes that are cyclical.

Construction simulation, especially process modeling, has matured over the years with numerous examples as given in Halpin (1990). These include earthmoving, pavement construction, concrete placement in buildings, underground pipe-jacking and others. With an accurate representation, the modeler can estimate the production of the process and probabilities of meeting a given schedule. A number of attempts have been made to simulate project schedules (Carr 1979 ; Woolery and Crandall 1983 ; Ahuja and Naudakumar, 1985). Riggs (1989) summarized past attempts in the area of simulation modeling for planning of construction process.

Construction simulation is a mature and well-established research area. Early efforts can be traced back to Halpin (1977) who popularized it with his development of a system called cyclic operation network (cyclone). (Paulson 1987; Martinez and Ioannou 1994; Chang and Carr 1987) introduced a wider academic audience to computer simulation, its use in the industry was very limited. Hajjar and AbouRizik (1992) reported that despite construction simulation potential, the use of computer simulation for planning construction projects has been limited mainly to academics and a few large contractors who can afford to employ dedicated simulation professionals. Many researchers have attempted to correct and compensate for the limitation of CPM especially for risk – analysis purpose. Most of the work that has been done is of a hybrid nature. Benjamin and Creenwald (1973) explored the effects of weather on construction project using simulation. The work focused on a schedule impacts of daily weather events. Project duration is determined when all activities are completed. Random number are applied in various elements of the model presented in terms of daily weather conditions. Carr (1979) developed a model for uncertainty determination to quantify uncertainty in the project schedule. Carr mentioned that activity duration is dependent on the outcome of random variables such as; crew productivity, subsurface site conditions, effectiveness of supervision, and weather. The simulation produces an estimate of activity times and project duration considering uncertainty variables. Dabbas and Halpin (1982) developed a simulation model that integrates project and process level planning and management. These models provided the capability to estimate project durations using a process level simulation network.

Woolery and Crandall (1983) developed a simulation based CPM that estimates project duration. The simulation model adopted relies on a neural network to estimate the productivity achieved on a given activity. Modeling construction activity time elements is crucial to developing stable simulation procedure because the time elements affect process production rates, the completion of jobs, and resources utilization.

Sawhney and abouRizk (1995) developed a simulation-based environment for planning of construction projects by hierarchical simulation modeling (HSM) method, where, construction projects are characterized by the random nature of the conditions under which they are implemented and by the dynamics use of available resource. Hajjar and AbouRizk (2001) developed a new approach that facilitate the use of simulation in the construction industry, where the previous attempts have been hampered by the gab between the user and simulation software, the power and flexibility of available tools, and the readiness of industry. A new approach is called symphony. This method describes how all of concepts can be combined together using object oriented principles. Also, the methodology was used in the development of a complete simulation tool.

Chua (2002) reported that the discrete- event simulation is an effective approach to analyze construction operations, and thus improve construction industry. A successful simulation model results from the inseparable cooperation between domain experts and simulation engineers.

The study is intended to demonstrate the use of simulation in estimating productivity based on the above mentioned relevant research for determination of probabilistic approaches of project scheduling instead of deterministic approaches. So Arena tool will be used for this purpose.

CHAPTER 3

Part (I) Field Survey

The field survey (Questionnaire) is designed to investigate the project management techniques used by local contractors, measurement methods of production rates and the factors influencing production rates in Gaza companies. This study was applied to the first and second class contractors as classified by the Palestinian Contractor's Union in Gaza.

A field survey has been developed to:

1) Reflect the characteristics of the construction companies in Gaza strip.
2) Collect data about production rates measurement in the local construction industry.
3) Collect data about projects planning, i.e. the tools and techniques used to improve and develop management practices such as the critical path method, bar chart, and the possibility of using simulation presently; and if not, the desire to use simulation in future to improve the planning and scheduling of projects.
4) Collect data about the factors influencing productivity in the construction sector.

The Field Survey adopted in this research passed through several stages as outlined below:

1. Pilot study;
2. Defining the factors affecting productivity of the construction projects;
3. Developing a questionnaire;
4. Instrument (questionnaire) validity;
5. Research sample;
6. Method of collecting data;
7. Instrument (questionnaire) relibility; and
8. Data analysis.

3.1 Pilot Study

The primary data were obtained from interviewing several contractors through the application of a pilot study (PS).

The application of the PS was carried out in the contractor's office with the investigator of this research. Seven experienced and professional contractors participated in this study.

The interview objective were to obtain a consensus on the factors affecting productivity of construction projects during construction phase in Gaza strip.

The outputs of the interviews were formulated and analyzed to obtain a clear picture about the above mentioned objectives. Subsequently, the questionnaire was designed in accordance with the pilot study to serve this investigation.

3.2 Defining the Factors Affecting Productivity of a Construction Project in General in Gaza Strip

A thorough literature review was conducted to identify the factors which affect productivity as recorded by researchers and practitioners in the field of construction management. By combining this literature review with the results of the pilot study (section 3.1), the fundamental factors affecting productivity were identified. These factors are categorized into three groups. Each group is divided into sub-factors as shown in Table 3.1.

Table 3.1 The Factors Affecting Productivity of the Construction Industry.

No.	Group	Factors / Sub-factors
1.	External factors	1. Nature of construction industry 2. Construction client and supervision 3. Procurement policies 4. Weather 5. Local population 6. Level of economic development 7. Political situation 8. Work law

2.	Internal factors	1. Management 1.1 Planning and scheduling 1.2 Adequate co-ordination, co-operation and Communication between the team members 1.3 Suitable control system 2. Technology 2.1 Using the tools to reduce the non-productive time 3. Clear drawings and specifications 4. Technical position of the company 5. Maintenance of equipment 6. Availability of safety measures on site 7. Skilled labor
3.	Motivation of labors	1. Financial motivation 1.1 Paying the salary at the end of each month or week 1.2 Giving advance payments according to worker's need 1.3 Giving cash money at important occasions 1.4 Increasing the salary of hard workers 1.5 Paying over time 1.6 Paying cash money as incentives 2. Moral factors 2.1 Giving workers annual leave 2.2 Securing permanent job for vocational workers 2.3 Treating workers in good way 2.4 Limit the work hours according to work decree 2.5 Employing workers through official contracts 2.6 Availability of safety measures for the workers 2.7 Giving workers breaks from time to time during work

3.3 Development of Questionnaire

A questionnaire was developed as a research tool for this study (see Appendices 1 and 2). The questionnaire consists of three sections:

Section one includes questions about the company profit.

Section two contains fifteen questions about the preparation of a time schedule for a project and the use of simulation packages (Arena) as a new technique for future time schedule preparation.

Section three consists of six questions about the main factors affecting productivity measurement.

The questionnaire is designed to accept variable types of responses: multiple-choice response, single-choice "Rating" response, and single-choice 'Yes-No" response.

The "Rating" responses are asked to asses the main factors and sub-factors affecting productivity in construction industry on a five points scale, where (1) represents very low important, (2) represents low important, (3) represents medium important, (4) represents important and (5) represents very important.

3.4 Instrument Validity

Several contractors and experts in the field of project management diagnosed the validation of the questionnaire. They were requested to identify the internal validity and to what extent the questionnaire was suitable to be used as an instrument to realize the goals and aims of this research. The contractors and experts agreed that the questionnaire is suitable to achieve the study goals with some modifications.

3.5 Sample Size

Only One type of population was considered in this study. The population is the contracting companies (first class and second class) who were registered by the Palestinian Contracting Union in Gaza Strip (list of the year 2002).

To ensure that the sample size will appropriately represent the population, a statistical calculation for the sample size was conducted. The total number of contractors is 45 enterprises distributed between two classes of contractors. The first class represented by 28 companies and the second class represented by 17 companies. By using statistical calculation for the sample size, as recommended by Tannis and Hoog (1997) and taking into consideration that the confidence level is 95

% and the confidence interval is 5, the calculated contractor sample size is 40 companies. To ensure good representation of each stratum, the percent of presentation within the strata was calculated. The number of companies in the first class strata = 28* 40 / 45 = 25 companies. The number of companies in the second class strata = 17* 40 / 45 = 15.

3.6 Sample Method

The samples were selected randomly from each class of the two contractor's categories. The Contractor's Union list is arranged by the company number in accordance with their priority of registration. Two lists of contractors were prepared to represent the first and the second categories. The random selection among the two lists was done by the researcher using non-replacement random selection. Twenty-five and fifteen companies were selected from the first and second lists, respectively, as shown in Table 3.2.

Table 3.2 Sample Size

Class	No. of Contracting Companies	%of the Whole Population	Sample Size Required
First	25	62.5	25
Second	15	37.5	15

3.7 Instrument Reliability

The reliability coefficient of the scale was established by Cronback's alfa, which reflected Alfa coefficient to be 0.8311. It is considered to be highly significant at 0.01 level and this ensures the reliability of the scale.

3.8 Method of Collecting Data

Personal interviews were conducted to collect data. The participants who agreed to cooperate in filling the questionnaire are shown in Table 3.3.

Table 3.3 Number of Questionnaire Respondents

Type of population	Concerned sample size	No. of respondents	Percentage %
Contracting companies	45	40	88.88%

3.9 Method of Data Analysis

The data was analyzed using SPSS package. For analyzing the two last questions in the last part of the questionnaire, an ordinal scale with an importance index (I) was used. The importance index was computed using the following equation.

$$I = \sum_{i=1}^{n} a_i \; x_i / n$$

Where:

I = importance index for all cases.

a_i = constant expressing the weight of the ith response

x_i = frequency of the ith response given as a percentage of the total responses for each case.

i = response category index where i = 1, 2, 3, 4, …n

n = number of rank.

3.10 Presentation of Results

In this section, the outcome of field study will be presented. The population characteristics, the importance of scheduling of construction projects and factors affecting production rate will be presented.

3.10.1 Population Characteristics

The establishment year of the companies are outlined in Table 3.4. Approximately more than half of the contracting companies were established after the evolution of the Palestinian National Authority (PNA). Also shown are the types of construction of the contractors, and the numbers and values of projects executed during the last five years by the contractors.

Table 3.4 The Population Characteristic.

Item		Contractors	
		No.	%
Year of establishment	Before 1994	15	37.5
	1994	6	15
	After 1994	19	47.5
Filed of work	Buildings	37	92.5
	Sewerage	34	85
	Water	30	75
	Roads	32	80
Number of projects executed during the last five years by class (A) and (B)	<30	31	77.5
	>30	9	22.5
Class A	<30	16	64
	> 30	9	34
Class B	< 30	15	100
	> 30	0.00	0.00
Value of projects executed during the last five years (in millions $) by class (A) and (B)	<8	29	72.5
	>8	11	27.5
Class A	< 8	14	56
	> 8	11	44
Class B	< 8	15	100
	> 8	0.00	0.00

Figure 3.1 shows that more than 75% of the contractors have 20 employees or less, whilst 17.5% of the contractors have 20 to 60 employees, and a small percentage 7.5% have more than 60 employees. It seems that most of the contracting companies are small size firms.

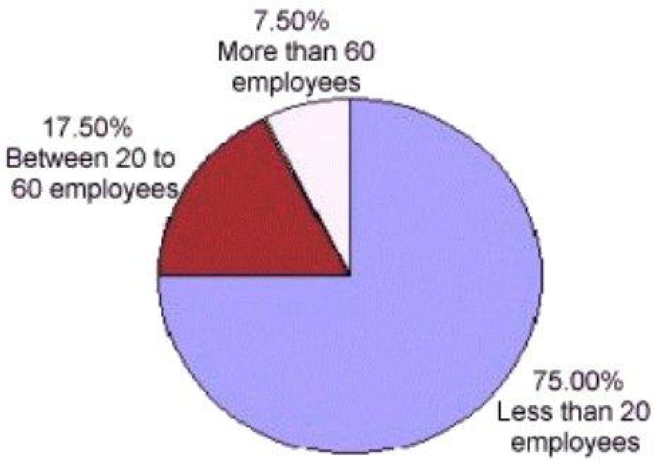


Figure 3.1 Size of Contractors employees

Figure 3.2 shows that 82.5% of the contractors keep records of the previous files of completed projects.

Figure 3.3 shows that 60% have benefited from previously completed projects to implement similar projects, and hence 40% of the contractors have not benefited from previous records.

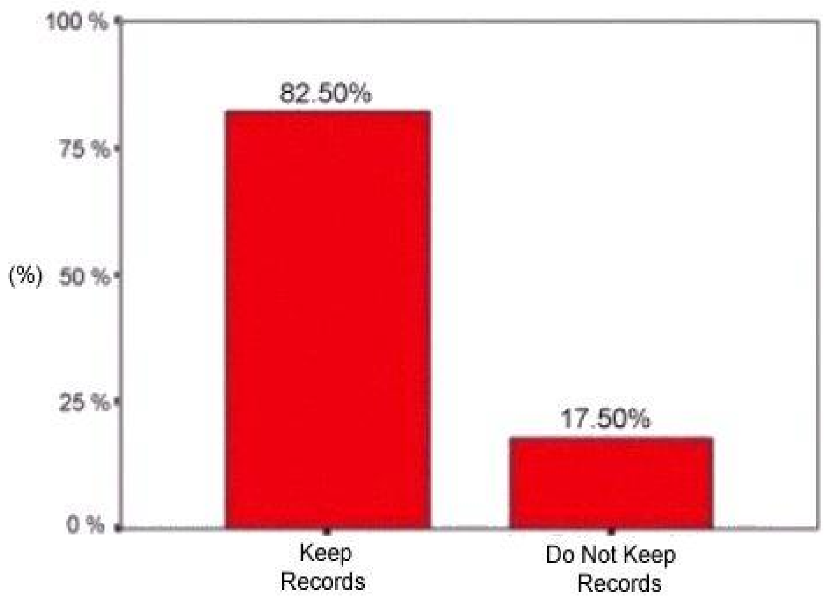


Figure 3.2 keeping the files by the contractors

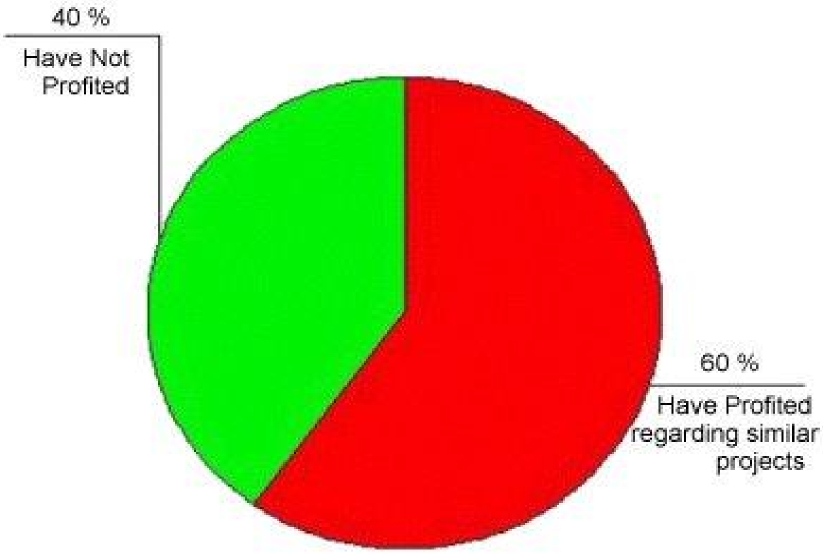


Figure 3.3 Distribution of contractors using previous records

3.10.2 Preparation of Time Schedules in Construction

All the contractors (100%) mentioned that they are using computer in scheduling construction projects. Most contractors 97.5% indicated that they prepare time schedule by themselves while the rest request the services of a consultant.

Table 3.5 shows that more than 50% of the contractors use previously completed projects when preparing time schedules. Also, 80% of the contractors prepare time schedules after awarding the contracts.

Table 3.5 Time Schedule Preparation

Item	Description of method	Contractors	
		No	%
Mechanism of time schedule preparation	Using similar previously executed projects	21	52.5
	Method of time and resources measurement	16	40
	Efficiency technicians	3	7.5
Stage of time schedule preparation	Bid preparation stage	6	15
	After awarding the contract	32	80
	During execution stage	2	5

Figure 3.4 shows that 67.5% of the contractors are not using leveling and allocation of resources during preparation of time schedules, therefore only 32.5% of the contractors use leveling and resource allocation.

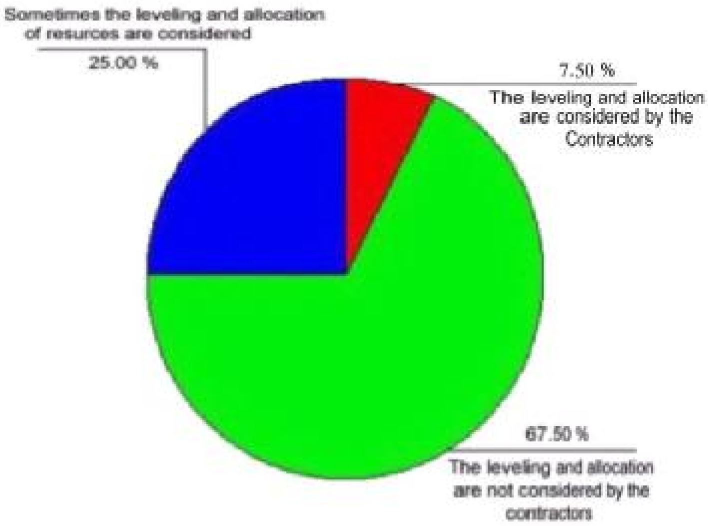


Figure 3.4 Use of leveling and allocation of resources by the contractors

Table 3.6 shows that 80% of the contractors depend on Bill of Quantities (BOQ) and analytical process to estimate the time and resources of a given project.

Table 3.6 Considerations Going to be Taken During Preparation of Time Schedule for Estimating Time and Resources.

Item	Yes		No	
	NO.	%	NO.	%
Visiting site work	23	57.5	17	42.5
Bill of quantity (BOQ) and analytical process of (BOQ)	32	80	8	20
Studying the drawings and specifications	29	72.5	11	27.5
Analytical determined time by the owners	30	75	10	25
Analytical and studying of daily production rate	18	45	22	55
Weather factors	20	50	20	50

Figure 3.5 indicates that 35% of the contractors use time bar chart for preparing time schedules, 25% of the contractors use CPM, and 37.5% of the contractors combine bar chart and CPM, while none use PERT method in the preparation of time schedules.

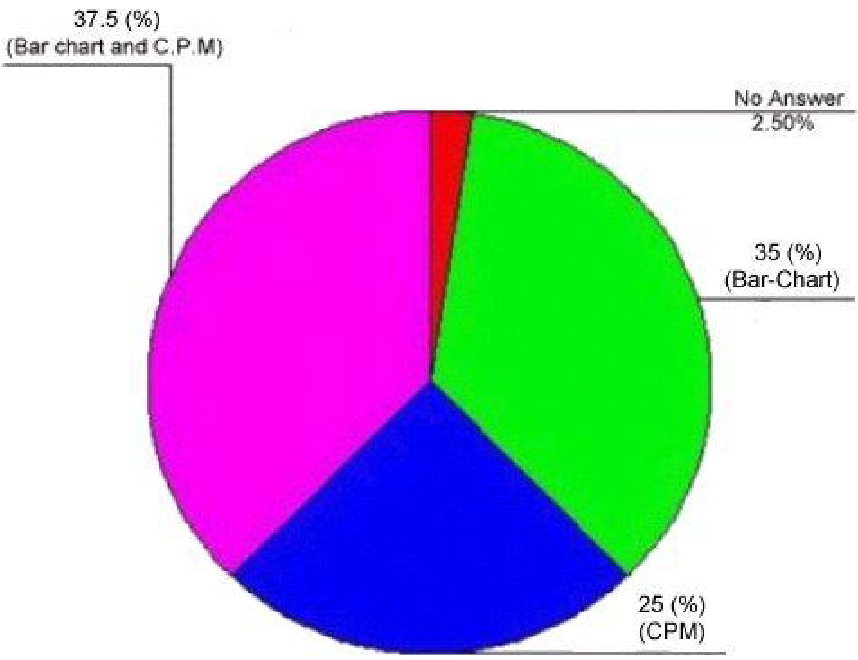


Figure 3.5 Techniques of Time scheduling

Table 3.7 Number of Changes in Time Schedule

Description of the factors	No. of revisions	Contractors	
		No.	%
The number of revised time schedule during the implementation of the project	Number changes	3	7.5
	1 change	8	20
	2-3 changes	21	52.5
	More than 3 changes	8	20

Table 3.7 indicates that the time schedule changes many times during the construction phase of the project.

Table 3.8 shows that the most important factor for revising time schedule, during the construction of a project, is mainly the political conditions which usually lead to shortage of the required construction materials. Also, there is an agreement among the respondents that the difference in the availability between the planned efficiency and the executed one and the delay of supervision in inspection are rated to be the second. The lowest rank factors were: "weakness of cash flow in the company", "difficulty in applying technical specifications", "lack of time schedule planning according to the actual work", "unavailability of technical experience", and “weakness in administration on site". Moreover, "weakness of production rate " is ranked as the fourth which leads to revising time schedules.

Table 3.8 Factors Affecting Revising Time Schedules.

Description of factors	contractors		Rank
	NO.	%	
Political conditions	34	85	1
Variation between the planned and actual work	19	47.5	2
supervision delay in inspecting works	19	47.5	2
Low production rate	17	42.5	4
Shortage of cash flow	9	22.5	6
Difficulty in applying technical specifications	9	22.5	6
Lack of time schedule	9	22.5	6
Weak administration on site	8	20	8
Unavailability of technical experience	7	17.5	9

3.10.3 Simulation in the Local Construction Industry

The results indicate that 100% of the contractors agree that simulation techniques would help them to anticipate the implementation of all components of the project in an integrated and timely manner during both the tendering and the implementation stages. Also, 100% of the contractors indicated that they have no knowledge about Simulation Package Arena (SPA). In addition, 100% of the contractors are interested in a practical course to develop their skills to use Simulation in their future projects.

3.10.4 Using Methods of Production Rate in Construction Industry

3.10.4.1 Determining Required Duration and Resources

As shown in Figure 3.٦, very few contractors (10%) are using previously implemented projects for predicting the duration and resources required for new projects. Also, 10% of the contractors use practical experience for determining the time and resources of a project; while 22.5% of the contractors use the production rate to do the same job. In addition, 30% of the contractors use the combination of production rate and practical experience in planning; while only 15% of the contractors combine the three mentioned methods to determine the duration of an activity and required resources.

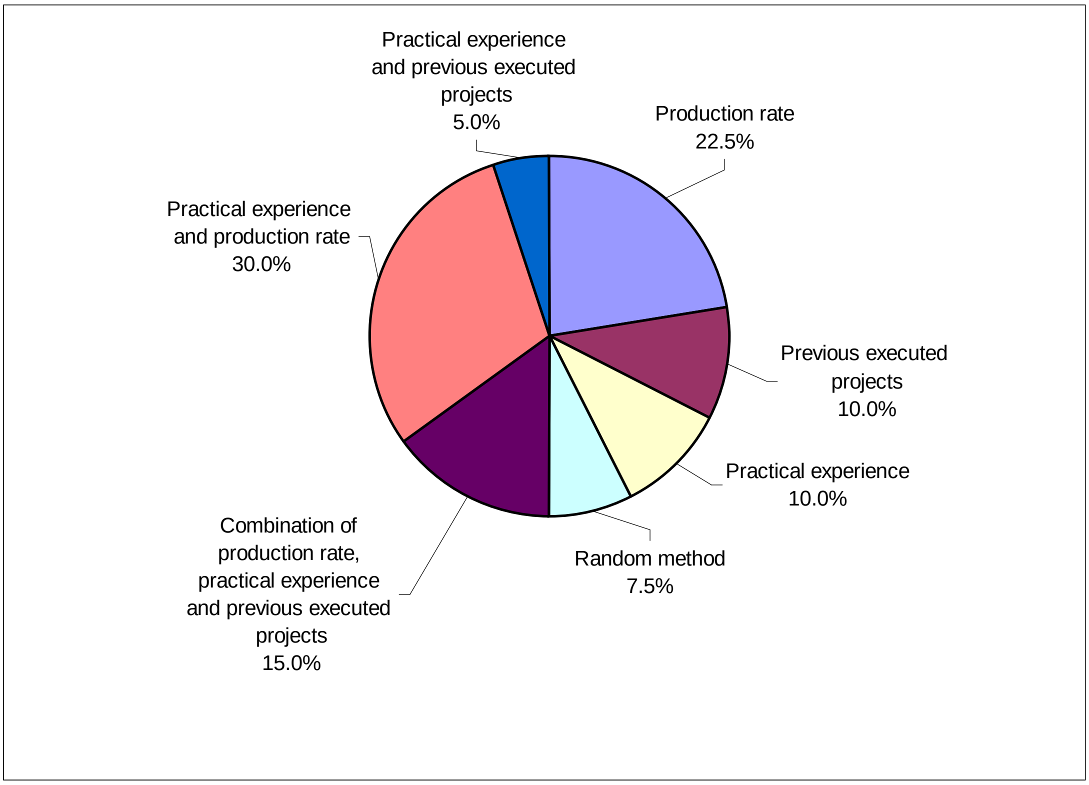


Figure 3.6 Methods of predicting duration and resources required

3.10.4.2 Using Work Measurement for Determining Production Rate

Figure 3.7 indicates that 50% of the contractors do not use work measurement methods while 30% of the contractors use time study method and the remaining percentage of contractors use work sampling and analytical estimating equally.

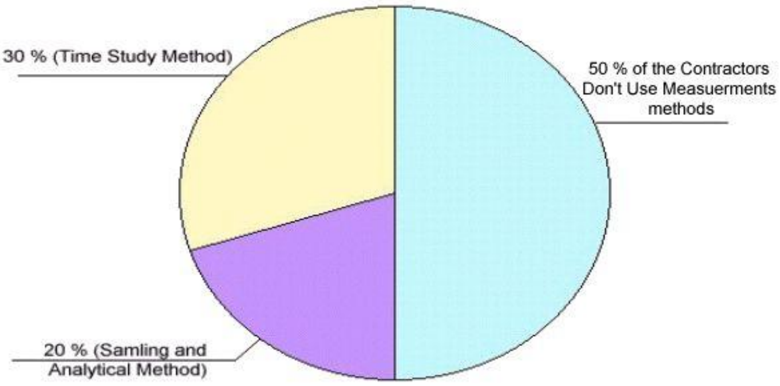


Figure 3.7 Methods of measuring production rates by the contractors

3.10.4.3 Factors Affecting Productivity in the Construction

The following tables show how different types of factors influence production rates with corresponding ranking.

Table 3.9 The Responses of Ranking the Factors Influencing the Production Rate in Gaza Companies.

No	Factors influencing production rate (General Factors)	Ranking of factors	
		Index %	Rank
1	Follow a good management system in the site	93.5	1
2	Financial status of the company	91.5	2
3	Availability needed construction material according to time schedule.	90.5	3
4	Contractors monitoring & follow up of works	90.5	3
5	Availability of skilled labors	87	4
6	Technical status of the company	87	4
7	The owner supervising team	84.5	7
8	Reducing wasted time during work	82	8
9	Periodic weekly meeting of owner and contractor	81.5	9
10	Follow up the timetable for all activities	81.5	10
11	Cooperation between the technical staff and the skilled labors	81	11
12	Adherence to specifications and drawings	78	12
13	Use of modern technical means	78	12
14	Availability of safety measures on site	77.5	14
15	Incentives for workers	69	15
16	Periodic maintenance for equipment	67.5	16
17	Training sessions for the technical staff	65.5	17
18	Work nature	64.5	18
19	People perception of the project importance	62.5	19
20	Weather conditions during the year seasons	42.5	20

Table 3.10 Financial Factors that Increase the Production Rates of Workers

Financial factors used by the company to increase the worker productivity	Ranking of factors	
	Index	Rank
Salary payment at end of month	89	1
Paying of overtime for labors	84.5	2
Salary increase for hard workers	81	3
Loans to needy labor	72.5	4
Paid allowance in occasions for labor	62	6
Payment of incentives	61.5	7

Table 3.11 Moral Factors that Increase the Production Rates of Workers

Moral factors used by the company to increase the productivity of workers	Ranking	
	Index	Rank
Permanent employment of skilled labors	81	1
Complacent & flattery for labors	80	2
Availability of safety measures	78.5	3
Working hours according to labor law	76	4
Allowing for an annual leave	72	5
Allowing for break from time to time	68	6
Official employment	63	7

It can be noticed, from Table 3.11, that securing permanent job for workers and specifying the work according to work decrees have the highest score; while giving the worker rest form time to time and employing the worker through official contracts have the lowest score.

3.11 Discussion of Results

3.11.1 Study Population Characteristic

The results indicate that more than half of the contracting companies were established after the evolution of PNA (1994). This means that most of the companies have a short period of experience, less than eight years, which is likely to influence the degree of using modern techniques/tools in project planning and scheduling. Some of these techniques are: the critical path method and bar chart, PERT and Simulation.

Furthermore, the rapid increase in the number of new established contracting companies, after the arrival of PNA, indicates that the companies were very optimistic in getting a number of projects.

The results show that most of the contractors have less than 20 employees. That is, the majority of the contractors are classified as small size companies, which affected the volume and capacity of the work done by them. Results also indicate that not only the number of projects, executed by each contracting company in a year, is very small (1-5 projects), but also the budget (value) of each project is small ($0.2- 0.55 Million / year).

The results have shown that as the number and values of implemented projects increase above 30 projects, the contractors' experiences increase and hence more dependence on the planning tools by the contractors. This observation is in full agreement with the investigation conducted by El-Sawalhi (2002) which was designed to investigate the size of projects and their values as executed in Gaza Strip by the local companies.

Also, results have shown that most of the companies which implemented more than 30 projects depended on the previously executed projects to improve and develop themselves.

3.11.2 Techniques for Preparation of Time Schedule

3.11.2.1 Preparing of Time Schedule

From the results listed in the previous section, the following can be observed:

- Most of the contracting companies use computer software during preparation of time schedules, while few contractors depend on consulting offices to prepare the required time schedule. This indicates that most of the contracting companies have engineers, with computer skills, for this purpose.

- Both first class and second class contractors prepare time schedule depending on their experience with similar previously executed projects.
- Less than half of the companies use the method of time and resources measurement.
- More than three-fourth of the contractors prepare time schedule after wining the bid.
- About 40% of the contractors use production rates during the preparation of time schedule while, most of them depend on studying the drawings & specifications, BOQ and the distribution of the duration of activities in accordance with the determined period of the project by the owner.
- Less than half of the contractors never used production rates methods to prepare time schedule. This indicates that current practices in preparing a time schedule, for a construction project in Gaza Strip, is not taking into consideration labor production rates measurement to determine the required time for each activity of project.
- The contractors depend mainly on experience with similar projects for preparing time schedule. Therefore, most of the time schedules prepared in Gaza Strip are not true representation of projects, and so; this method usually results in many problems in the construction industry in Gaza, especially, revising time schedule many times during implementation of the projects to accommodate for the changes. This result agrees with some of the problems presented in chapter 1 of this thesis.
- The sample population does not extensively use resources leveling and allocation. Only about 25% of the sample population frequently used this method. This result is similar to the study conduct by El- Sawalhi (2000), and by Abbasi and Al- Mharma (2000) in Jordan. All studies agreed that few contractors use resources allocation and leveling. Furthermore, resources leveling and allocation may consume many efforts and need wide range of data during the planning and scheduling stage, which is not dealt with seriously by Gaza contractors. The above mentioned result supports that there

is a lack of using production rates measurement for preparing time schedule in Gaza companies.

- About 37.5% of the respondents use the combination of bar chart and CPM to prepare time schedule in Gaza companies. This low parentage may be traced back to the unawareness of its importance and to the lack of knowledge about its methodology. This result disagrees with the recommendations of most authors who indicate that bar chart must be complemented with the CPM (Ahuja, 1994). Perhaps the size, the volume and complexity of the project in Gaza Strip directs the planners to use simple tools rather than using others.

3.11.2.2 Revised Time Schedule

The factors that lead to revised time schedule during construction of projects in Gaza are of a political nature. Such conditions are due to the shortage of the required material of construction and to weak production rates. This study indicates that using the production rates measurements and leveling of resources of labor methods lead to revised time schedule several times.

3.11.2.3 Using Simulation in Construction

The results proved that all the study population never knew about Simulation as a technique and never used PERT method for preparation of time schedules. In other parts of the world, recently, many researchers mentioned that simulation has proven to be an excellent strategic tool for the enterprise to perform realistic planning and scheduling. Also, they proved that simulation-based planning and scheduling system would be very successful and is the modern language in this area (Healy, 1997).

Some Authors developed a CPM-based simulation model, which estimates project completion times based on the occurrence of uncertainty (Abourizk, 1997).

Despite of its obvious potential, the use of computer simulation for planning and scheduling construction projects has been limited mainly to academic and a few large contractors who can afford to employ dedicated simulation professionals (Hajjar and abourizk, 2002).

The present study indicates that all contractors in Gaza Strip are interested to learn and study how to use the Simulation Package (Arena) to prepare time schedules for their construction projects. This, in turn, will develop and improve the construction industry sector in Gaza Strip.

In the next chapter, as a case study, the author will focus on the Simulation Package Arena as a new tool for preparing time schedule by forecasting production rates.

3.11.3 Using the Method of Work Measurement in the Construction Industry

The results demonstrated that only 57.5 % of the study sample was using production rates measurement. Such low percentage may be attributed to the unawareness of its importance and due to lack of knowledge about its methodology. Also, this result shows that the contractors in Gaza Strip use their experience to determine the duration of the project.

Furthermore, it was observed that 50 % of the contractors are not using the methods of work measurement, while 30 % of the contractors use the time study method to determine the production rates in the construction industry.

Many investigations have shown that the methods of work measurement is very important for determination production rates of the labor and duration of the project (Poskitt, 1986). Also, Paul (1998) mentioned that the scientific work measurement is the best way to obtain the productivity of the construction industry.

3.11.4 Factors Influencing Production Rates in the Construction Industry

The study population indicated that the highest rated factors, which affect production rates, were: “Good administration in the site“, “Financial position of the company“, “ supplying the required materials for the work“, and “Observing the work by the contractor’s staff“. However, the least rated factor, which affect production rates, was the weather conditions. The rest of the factors (see Table 4.9) moderately affect the production rates.

Consequently, the study indicates that management of the site and cash flow of the companies are very important factors for increasing the productivity rates in Gaza companies.

3.11.4.1 Financial Factors that Increase the Production Rates

The highest rated factors by the study population were “paying the salary of the worker at the end of month”, “Paying over time for the worker “, and “Increasing the salary of hard workers“. These results are supported by Enchasi (1997), where he reported that the above mentioned factors increase the production rates. Also Steven McCabe (1998) reported that motivation and incentives for people are needed to improve productivity rates.

3.11.4.2 Moral Factors that Increase the Production Rates

The highest rated factor by the study population was “Securing permanent job for vocational worker“. This result is supported by Enshasi (1997). Steven McCabe (1998) indicated that permanent employment lead to increase in productivity and this factor impacted and improved production in the Japanese organizations.

The financial and moral factors are very important to increase and impact productivity in the construction industry. These factors are appreciated in developed countries, but in developing countries such as Palestinian, these factors are not considered by the contractors for increasing and improving the construction industry sector. Also, the small size companies in Gaza (as compared to the international companies) and the political conditions, are among the factors that affect the production rates.

3.11.5 Correlation Among Some Variables

This section studies the correlation relationship among some different variables in the field survey in order to know the extent and strength of the relationship connecting them, and the effect of each of them on the others. For example, knowing the extent of the relationship between the contractors classification and productivity rates factors will show the difference, if any, between first and second class contractors and the use of these contractors to the productivity rates factors. Chi Square test was used in all these relationship.

3.11.5.1 Relationship between Classification of the Contractors and the Factors Affecting Production Rates

According to cross tabulation and chi-square tests, it was noticed that the value of chi-square tests = 0.794 at a degree of freedom (df) = 2, and significance level **(ρ) =** 0.672, that is more than 0.05. In this case the Alternative hypothesis **(Ha)** is rejected. The result indicates that there is no relationship between the classification of the contractors and the factors affecting production rates. Also the result indicates that the factors affecting productivity are not considered among the contractors and their classifications in Gaza Strip.

3.11.5.2 Relationship between Time Study and Production Rates

According to cross tabulation and chi-square tests, it was noticed that the value of chi-square tests = 66.96 at a degree of freedom (df) = 42, and significance level (**ρ) =** 0.008, that is less than 0.05. In this case the Null hypothesis (**Ho)** is rejected. The result indicates that there is a relationship between time study and production rates. Wherever, most of the contractors use the time study method to measure the productivity.

3.11.5.3 Relationship between Period of Bids Study and Using CPM

According to cross tabulation and chi-square tests, it was noticed that the value of chi-square tests = 43.84 at a degree of freedom (df) = 35, and significance level (**ρ) =** 0.145, that is more than 0.05. In this case the alternative hypothesis (**Ha)** is rejected. The result indicates that there is no relationship between period of bids study and using CPM. Wherever, most of the contractors use CPM to prepare time schedule after wining the bid.

3.11.5.4 Relationship between Revised Time Schedule and Political Conditions

According to cross tabulation and chi-square tests, it was noticed that the value of chi-square tests = 82.65 at a degree of freedom (df) = 40, and significance level (**ρ) =** 0.027, that is less than 0.05. In this case the Null hypothesis (**Ho)** is rejected. The result indicates that there is a relationship between revised time schedule and political conditions. Wherever, the political conditions affect the delay of the work and planned work on the site. Thus, political conditions lead to prepare time schedule many times during the implementation of the work, because of the difference between actual work and planned work.

3.11.5.5 Relationship between Analytical Daily Productivity and Allocation & Leveling of The Resources

According to cross tabulation and chi-square tests, it was noticed that the value of chi-square tests = 87.10 at a degree of freedom (df) = 56, and significance level (**ρ) =** 0.005, that is less than 0.05. In this case the Null hypothesis (**Ho)** is rejected. The result indicates that there is a relationship between analytical daily productivity and allocation & leveling of resources.

3.11.6 Improvement of Projects Scheduling and Productivity

To improve projects scheduling and productivity, the following points are suggested:

1. Training courses and seminars should be made to the local contractors on how to use scientific methods of productivity estimation and projects scheduling.
2. More attention should be paid to the use of the management tools during the life cycle of the projects.
3. More attention should be paid to the study of the factors affecting the productivity during the period of the scheduling of the projects.
4. Motivation of the technical staff and labor should be applied by the contractors during the life cycle of the projects.

CHAPTER 4

Part (II): Productivity Measurement Using Simulation Process

"Case Study"

The main goal of the case study is to demonstrate how to estimate the production rates of labor and equipment during the implementation of the project activities and to estimate the duration of the project using process simulation technique.

The case study adopted in this research (Beach Camp Shore Protection) passed through several stages as outlined in the following points:

- Project outline,
- Project activities,
- Flow process chart,
- Model development for the implementation of the project,
- Method of collecting data,
- Generating statistical distribution functions
- Simulation process, and
- Results and analysis of the simulation process.

4.1 Project Outline

The project area stretches along the shoreline of Beach Camp, a refugee Camp in the northern part of Gaza City. The project area shoreline has a total length of approximately 1600 m, see Figure 4.1. It is characterized by a sandy coastline with steep cliff- like embankments. The embankments are some 5 to 8 m high. Close to the shoreline, a ridge of beach rock is present. The beach rock comprises consolidated sediments and shells. The project provides for protection of the shore at Gaza Beach Camp by protecting the cliff against erosion. The works include a toe construction along the cliff consisting of a stone fill subsurface apron and a gabion type retaining wall and cliff slope protection works of compacted fill from quarrying inclusive terracing in a steep area which includes gabion retaining walls at elevated levels, see Figure 4.2.

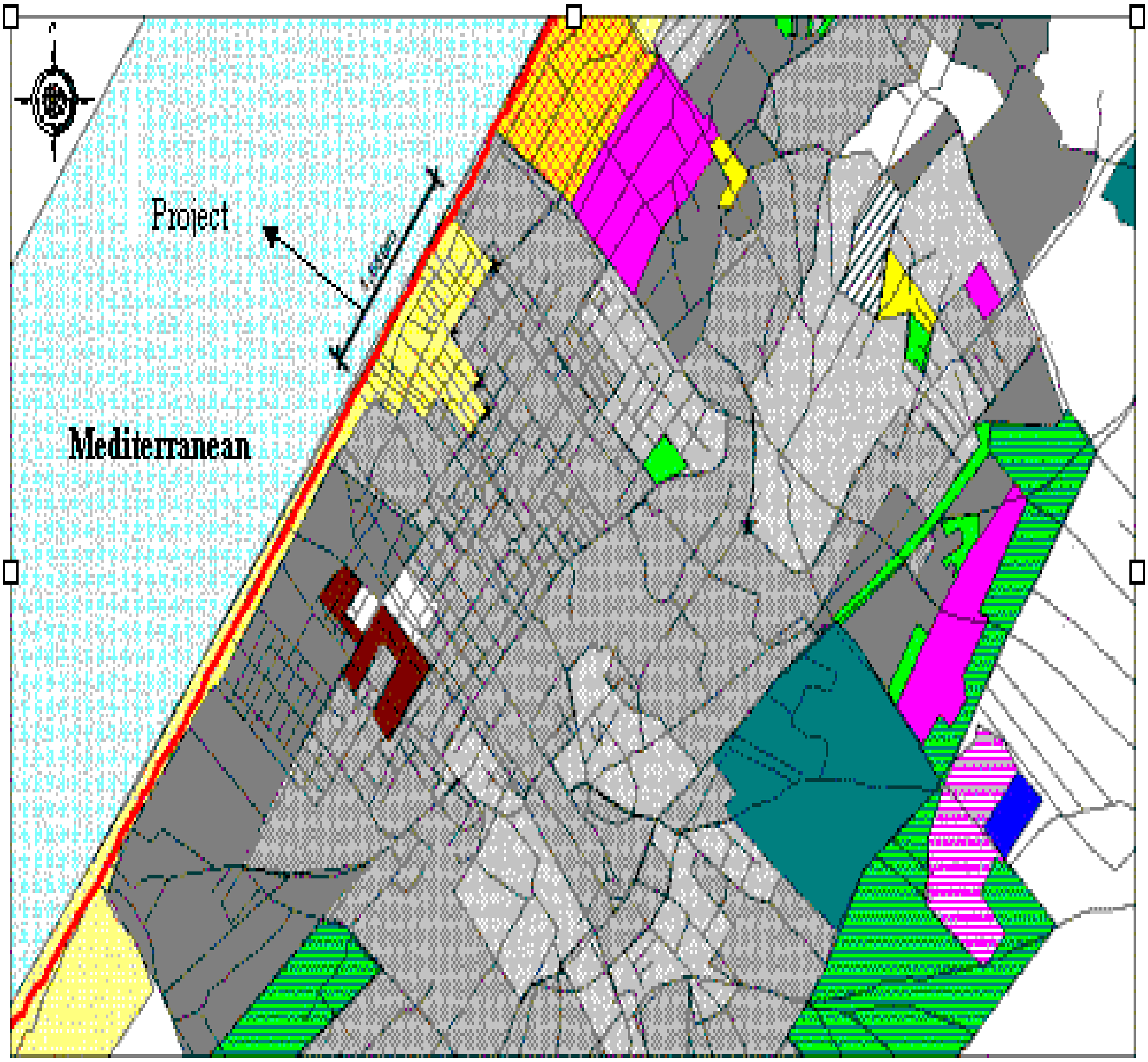


Figure 4.1 Gaza City

4.1.1 Project Activities

In the Beach Camp Shore Protection Project, the model simulates the construction of 1600 meters of gabions which are divided into 32 identical stations as shown in Figure 4.2. Each station is 50 meters long, cross- section of a typical station is depicted in Figure 4.3. The main activities involved can be summarized and sequenced as the following:

1. Excavation of apron and cliff,
2. Laying geotextile,
3. Spreading base-course (filter),
4. Filling and arranging rock inside the apron,
5. Spreading surface – course,
6. Installing box gabions, and
7. Backfilling and compacting sand layers at cliff and beach side slope.

Figure 4.4 outlines the process involved in implementing the above activities.

The required materials for executing the project (32 stations) at a typical station are shown in Table 4.1.

Table 4.1 Required Materials for a Typical Station and the Project

S/N	Description of the Required Material	Unit	Quantity per one station	Quantities per 32 stations
1	Excavated material of the apron and cliff	M3	750.00	24,000.00
2	Geotextile laying inside the apron	M2	516.00	16,512.00
3	Geotextile laying for the gabion	M2	125.00	4,000.00
4	Base-course (filter) spreading for the apron	M3	130.00	4,160.00
5	Rock distribution inside the apron	M3	470.00	15,040.00
6	Base-course (surface- course) spreading	M2	450.00	14,400.00
7	Box gabion installing	no	75.00	2,400.00
8	Rocks filling inside the box gabions	M3	150.00	4,800.00
9	Backfilling the excavated material	M3	1,300.00	41,600.00

A= stockpile of gabion boxes

B= stockpile of base-course (filter)

C= stockpile of rock stone (32cm-70cm)

D= stockpile of Gabion rocks (10cm-28cm)

E= stockpile of base-course (surface)

J= stockpile of Geotextile

K= site office

L= site store (plant)

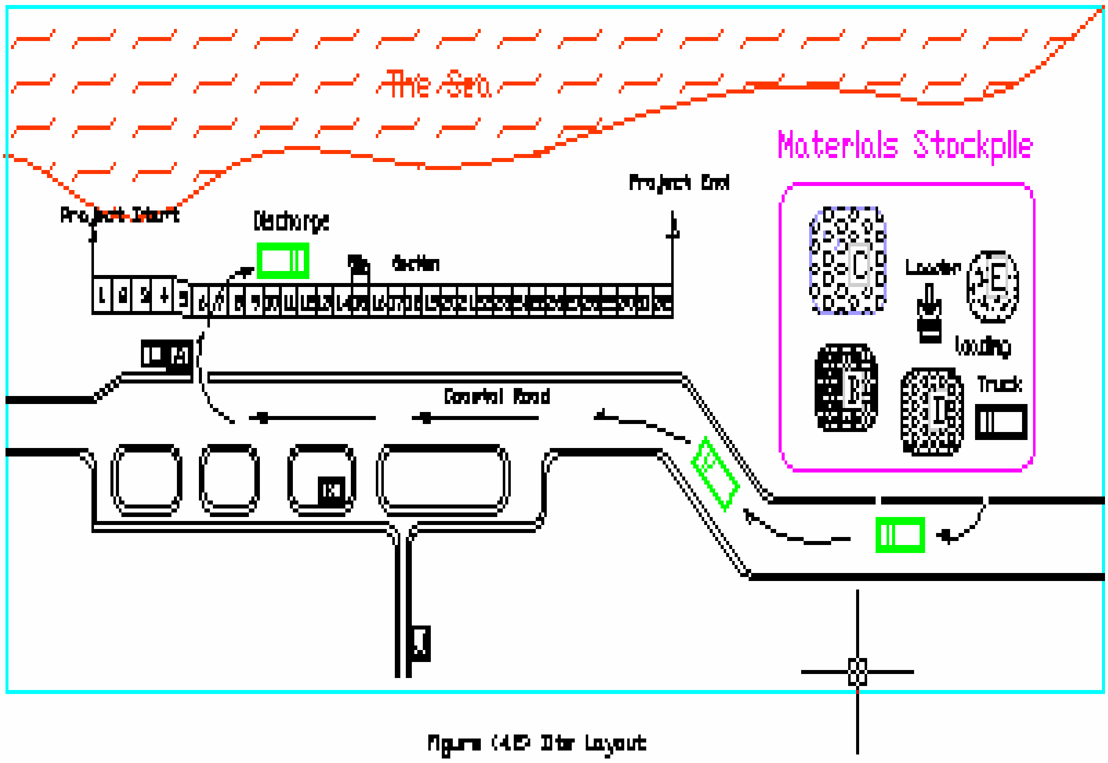


Figure (4.8) Site Layout

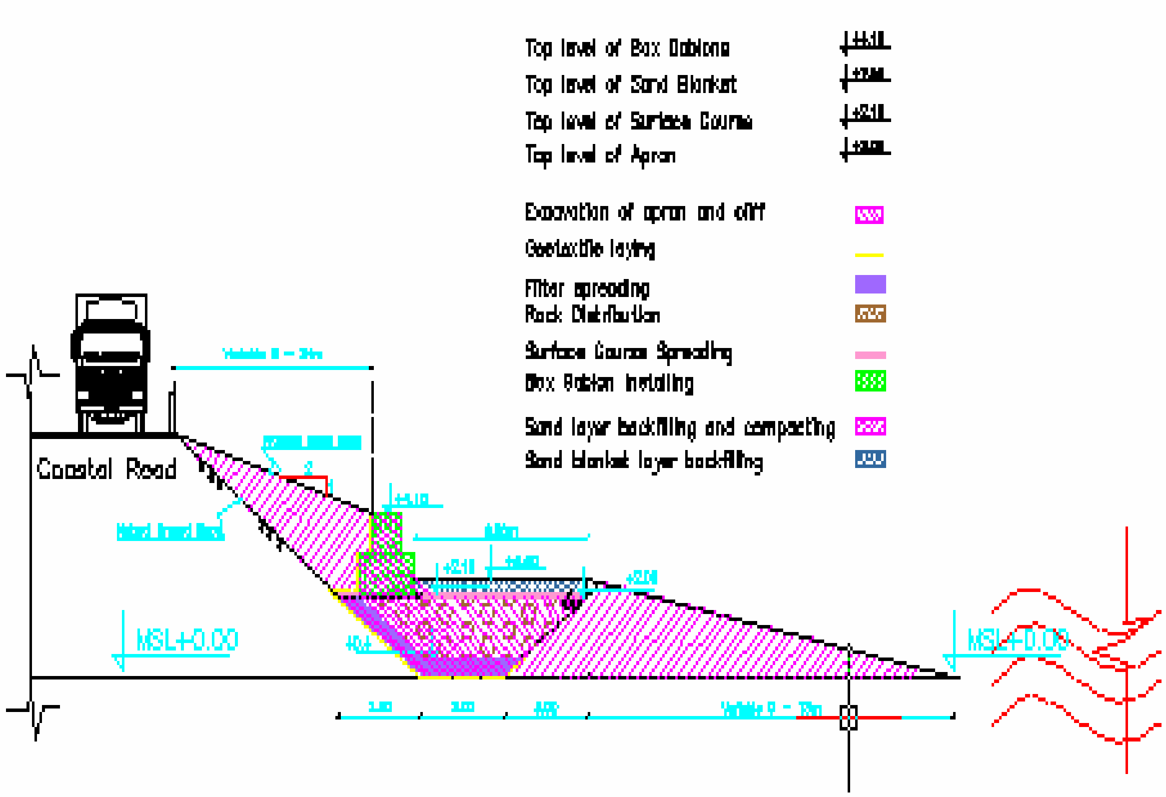


Figure 4.3 Cross Section of a Typical Station

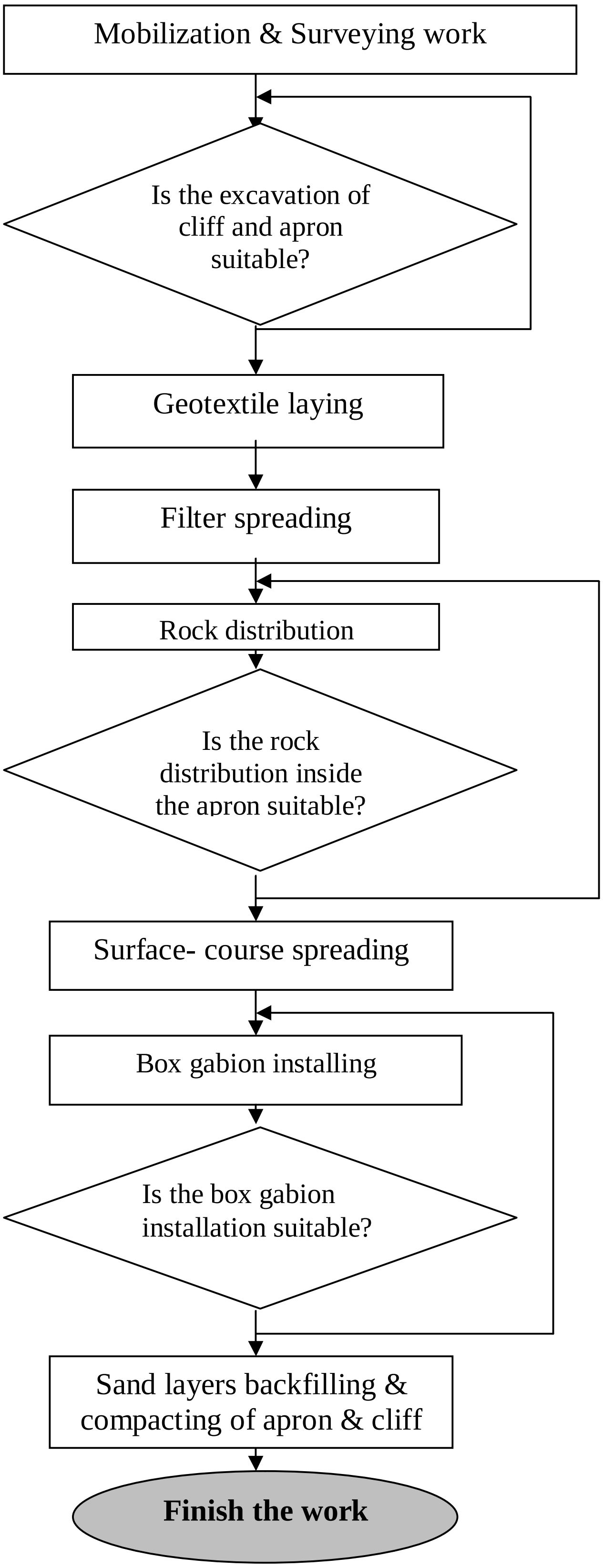
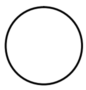
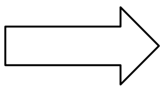
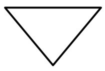
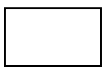
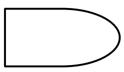
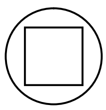


Figure 4.4 Process Sequence of the Main Activities in Beach Camp Shore Protection

4.2 Flow Chart of Processes

The main objective of the flow process chart is to describe the sequence operations of every activity that includes transportation, storage, inspection, delay and other operations**.** Table 4.2 illustrates the process symbols used in construction processes. The process charts are useful in establishing and proving the suitability of the work sequence and in examining the productive work and unproductive work. The standard symbols used in the flow chart processes were converted into a basic panel of simulation tools using Arena package (Paul, 1998**).**

Table 4.2 Standard Symbols Used in Process Charts (Paul, 1998**).**

NO.	**Name**	**Symbol**	**Description**
1.	Operation		Starting the work towards completion of operation.
2.	Transport		Movement of materials, equipment and labor from place to place.
3.	Storage		Protection of the materials.
4.	Inspection		Inspection of quantity and quality.
5.	Delay		Queuing period or any obstruction
6.	Combined		When more events take place together during the performance of the work.

4.3 Model Development

A general model for a typical station is developed to facilitate the research study in accordance with Figure 4.4. The aim of the model is to illustrate the execution method of the project in the site. The stages involved can be summarized as:

- Stage 1 : Excavation of the trench to reach the required level in accordance with the drawings and proposed design. This stage includes loading of the excavated material from the trench to the main stockpile for reuse in the backfilling of the cliff and the sand blanket.
- Stage 2 : Laying geotextile material to keep the stability of the soil and allows the infiltration of water.
- Stage 3 : Spreading base-course (filter) on the geotextile layer to protect it from damage by large rocks, also to prevent erosion soil from beneath it through the upper rock layer.
- Stage 4: Distribution and arrangement of large rocks on layers inside the trench.
- Stage 5 : Spreading of base-course (surface- course) above the last layer of the rock to protect rock layers against any damage and adjust the gabions.
- Stage 6 : Installing gabion boxes to protect the shore.
- Stage 7 : Backfilling and compacting excavated material from apron and cliff to protect the cliff.

The implementation model of a typical station is represented in Figure 4.5. For symbols notations see Table 4.3

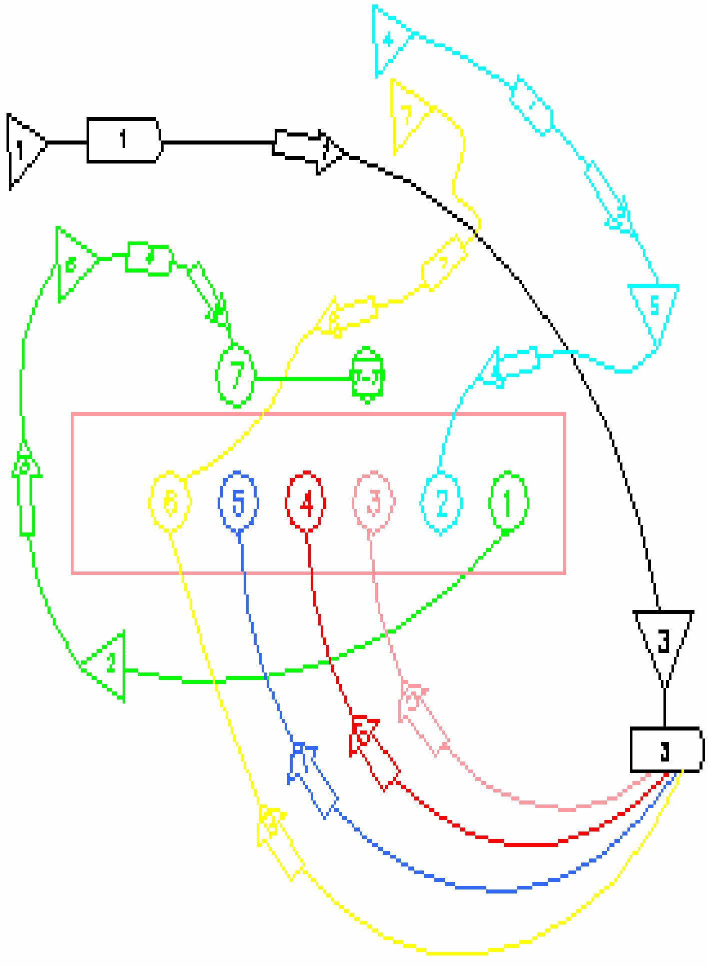


Figure 4.5 Implementation Model of a Typical Station

* For symbols notations, see Table 4.3

Table 4.3 Symbols Notations

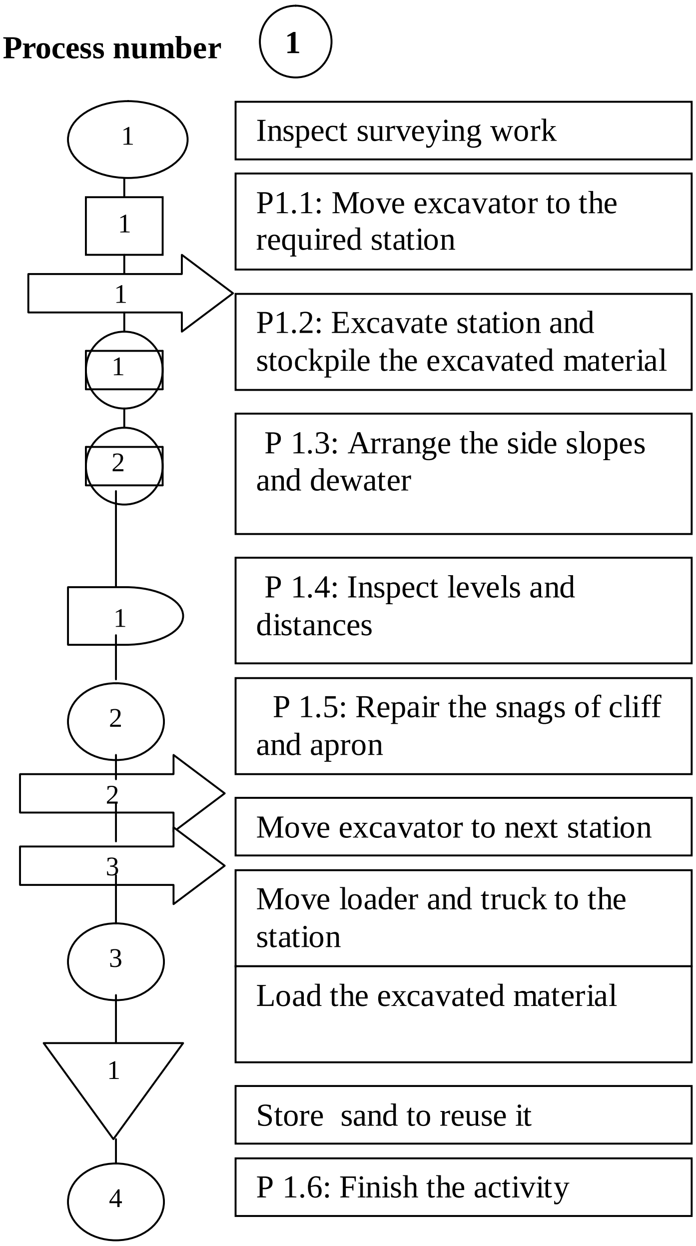
Symbol	**Description**
1	Excavation of cliff and apron
2	Geotextile laying inside the apron
3	Filter spreading inside the apron
4	Rock distribution inside the apron
5	Surface- course spreading
6	Box gabion installing
7	Sand backfilling of Beach sideslope & cliff
1	Storage of material (rocks, base- course, and gabion rock) at the main stockpile.
2	Storage of excavated material at temporary stockpile
3	Storage of material (rocks, base- course, and gabion rock) at temporary stockpile
4	Storage of geotextile at the main stockpile
5	Storage of geotextile inside the site.
6	Storage of excavated material at the main stockpile
7	Storage of box gabion at the site
1	Wait to excavate apron
2	Wait to spread base- course (surface- course)

3	Wait to finish geotextile laying and load rock, base-course & gabion rock respectively to the apron.
4	Wait to finish the gabion rock installation.
1	Transportation of material (rocks, base- course, and gabion rock) from the main stockpile to temporary stockpile.
2	Transportation of geotextile from the main store to temporary store.
3	Transportation of excavated material from apron and cliff to main stockpile.
4	Transportation of geotextile from temporary store to the apron.
5	Transportation of base-course (filter) from temporary stockpile to the apron.
6	Transportation of rock from the temporary stockpile to the apron.
7	Transportation of surface course from temporary stockpile to the apron.
8	Transportation of gabion boxes from store to the apron.
9	Transportation of gabion rock from temporary stockpile to the apron.
10	Transportation of excavated material from the main stockpile to the cliff.
7-7	Combination of backfill and compaction of cliff & beach side slope

Table 4.4 outlines the processes and the associated flow charts for the execution of a typical station.

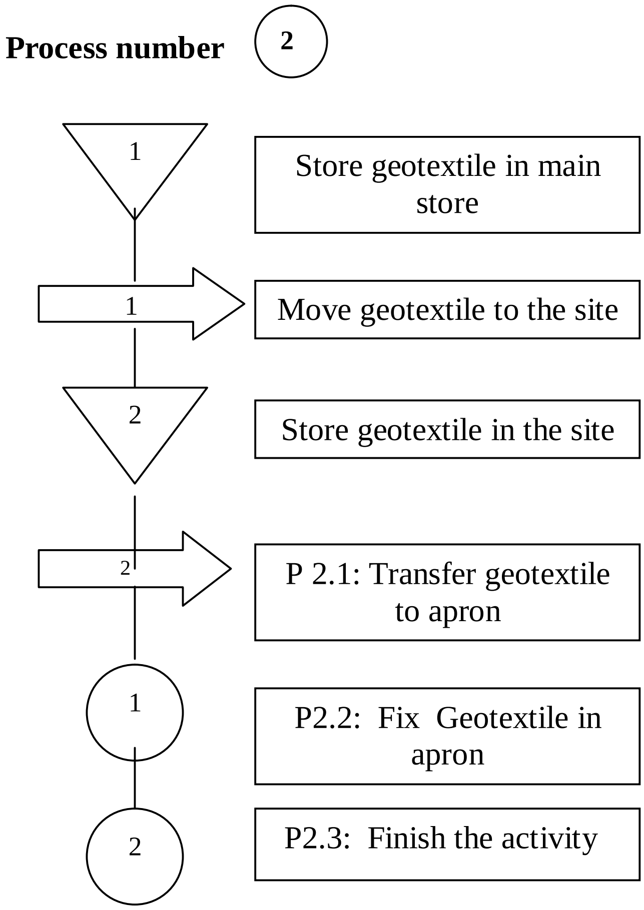
Table 4.4 Sequence of Flow Charts for a Typical Station

Process number	Flow Chart	Flow chart number
1	Excavation of apron and cliff	4.1
2	Geotextile laying in the apron	4.2
3	Base-course (filter) spreading inside the apron	4.3
4	Distribution and arrangement the rocks inside the apron	4.4
5	Base-course (surface-course) spreading	4.5
6	Gabion boxes installation	4.6
7	Backfilling & compacting of sand for beach sideslope	4.7



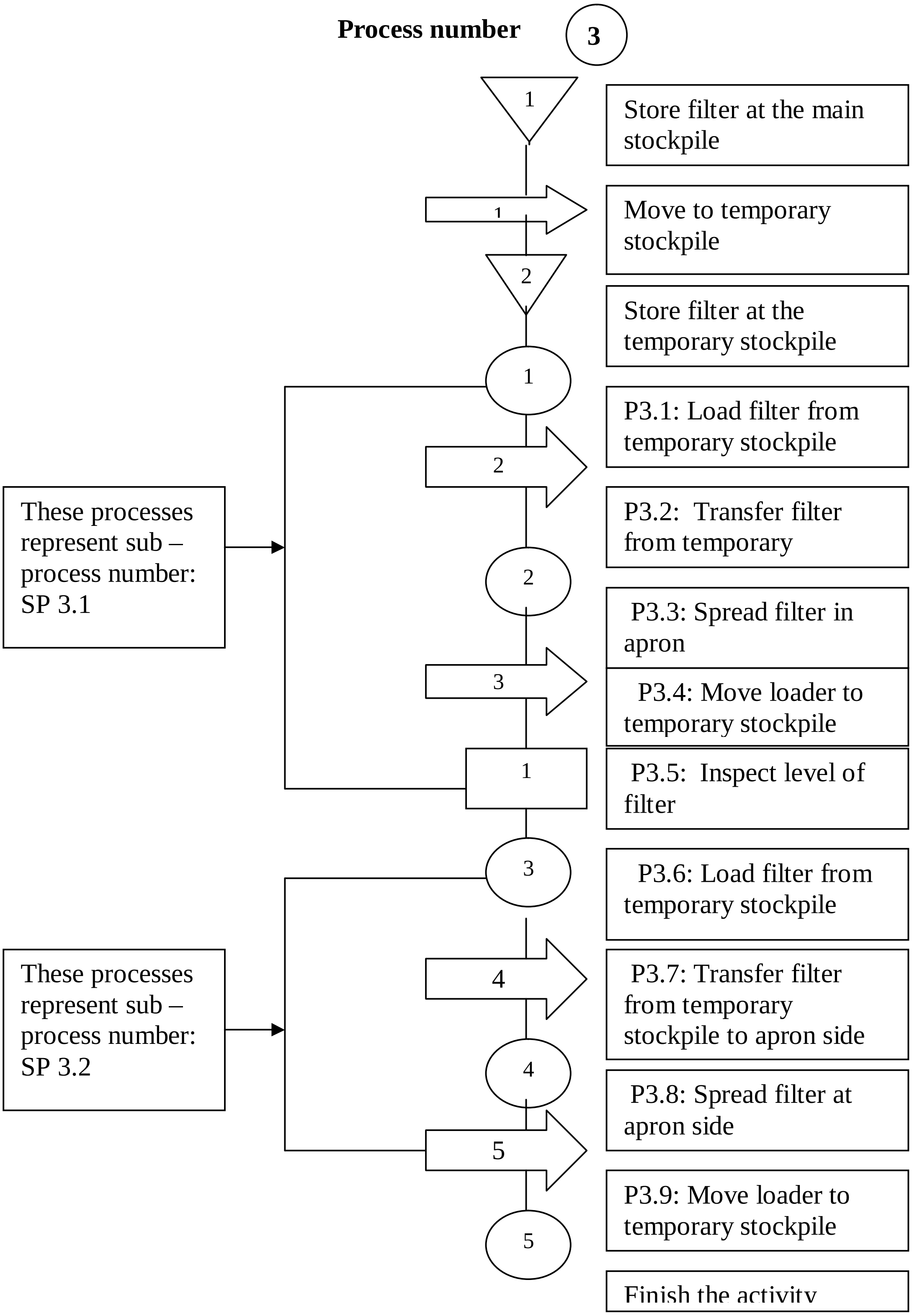
Flow chart 4.1 Process of Excavating Cliff and Apron

- For symbols description, see Table 4.2
- Numbers shown in the symbols above are pertinent to this specific process



Flow chart 4.2 Process of geotextile laying inside the apron

- For symbols description, see Table 4.2
- Numbers shown in the symbols above are pertinent to this specific process

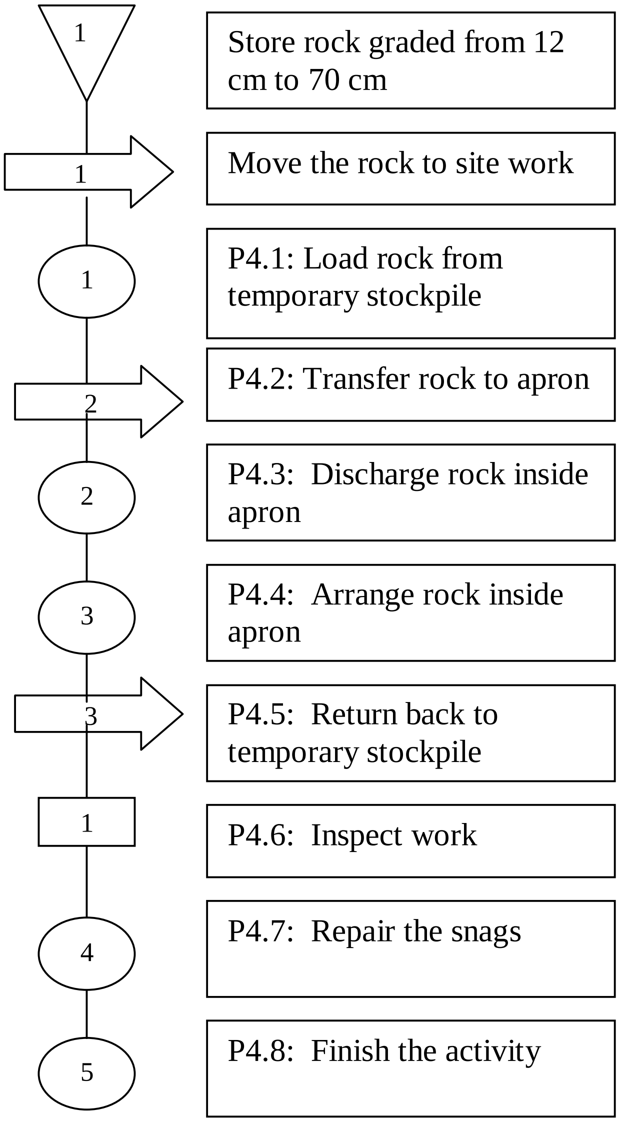


Flow chart 4.3 Process of filter spreading inside the apron

- For symbols description, see Table 4.2

- Numbers shown in the symbols above are pertinent to this specific process

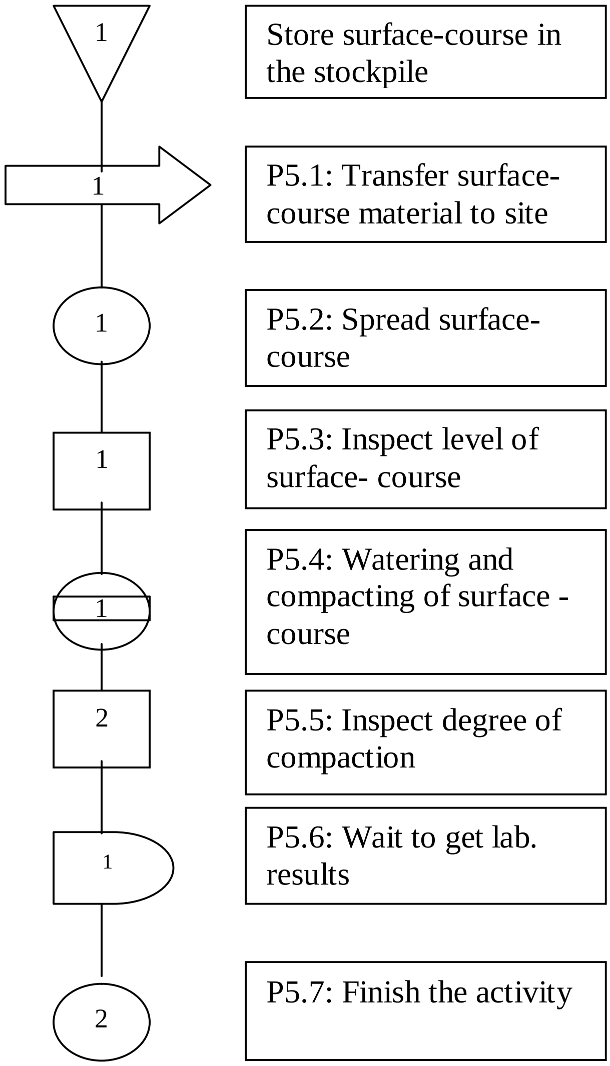
Process Number 4



Flow chart 4.4 Process of rock distribution inside the apron

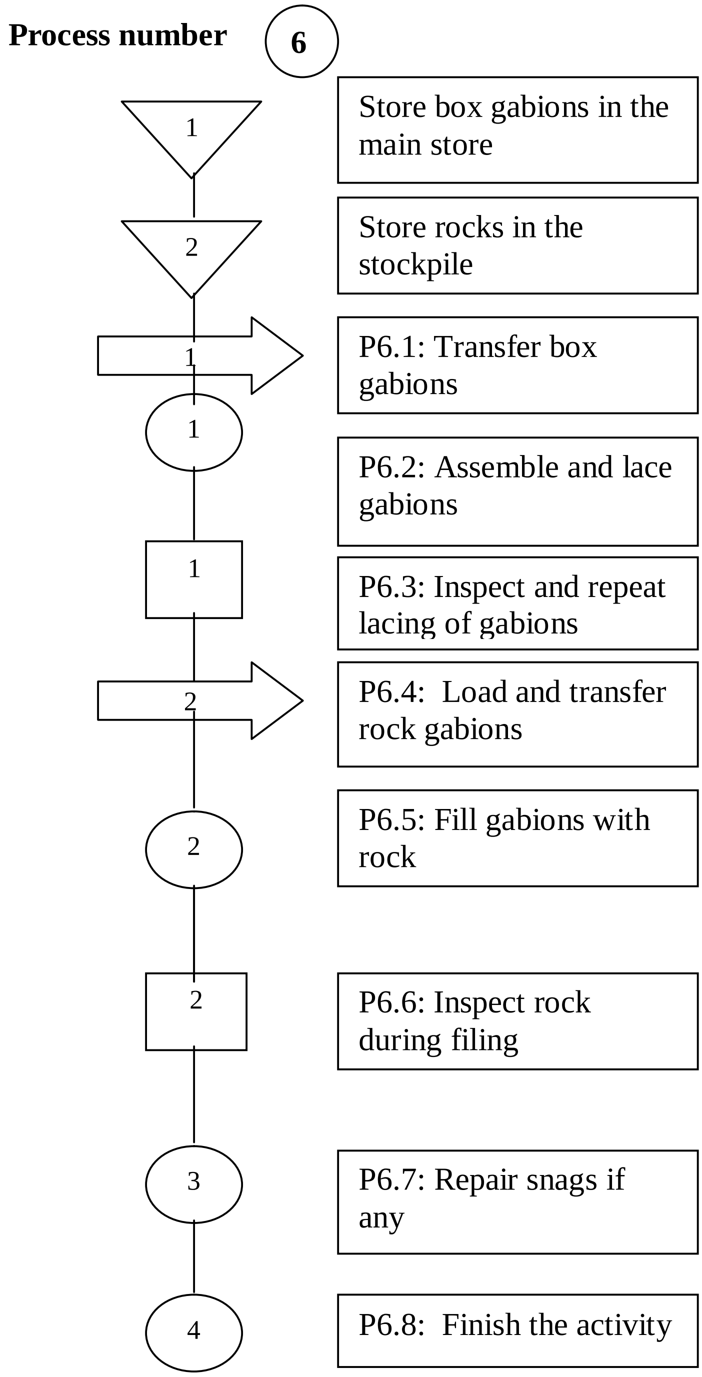
- For symbols description, see Table 4.2
- Numbers shown in the symbols above are pertinent to this specific process

Process number 5



Flow chart 4.5 Process of surface course spreading

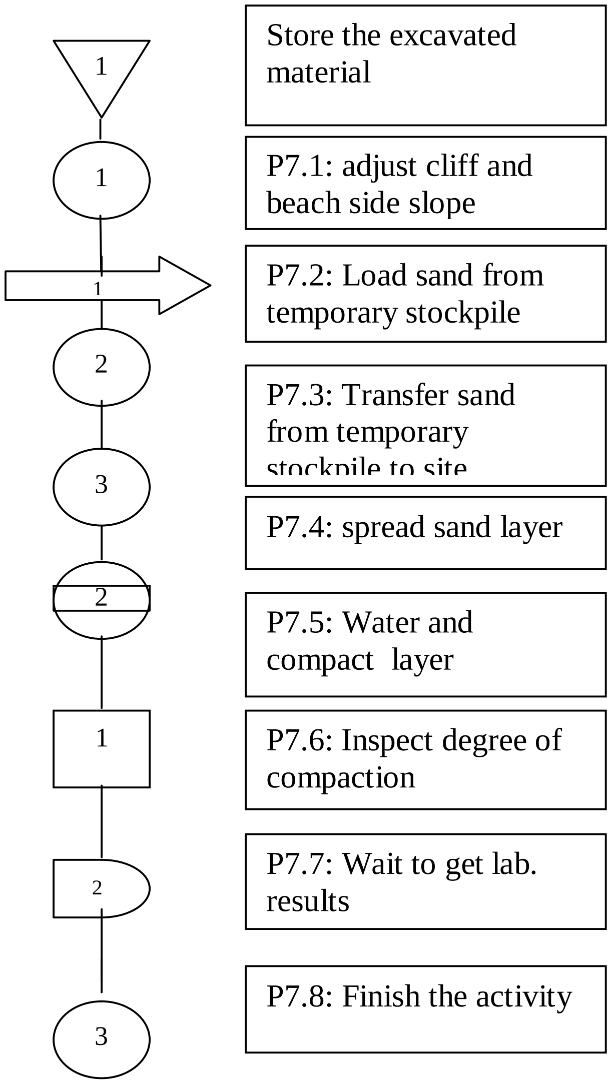
- For symbols description, see Table 4.2
- Numbers shown in the symbols above are pertinent to this specific process



Flow chart 4.6 Process of box gabion installing

- For symbols description, see Table 4.2
- Numbers shown in the symbols above are pertinent to this specific process

Process number 7



Flow chart 4.7 Process of sand backfill of beach side slope and cliff

- For symbols description, see Table 4.2
- Numbers shown in the symbols above are pertinent to this specific process

4.4 Method of Data Collection

Many special forms were designed for controlling and collecting data related to the different activities during the implementation of the project (see Appendix 3). The data was collected by the researcher and assistant technical staff: the project site engineer, surveyor, and foreman. The data were collected at different times (morning, afternoon, evening) and during different seasons (summer and winter). Station number 5, 8, 11, and 14 were chosen as a sample study .

Maio et al (2000) indicated that most researchers used time study method for collecting construction operation cycle data; such researchers are: Clemnes et al. 1978; Aburizk, and Halpin, 1992). Thus the time study method was considered for collecting and surveying data to serve the present investigation.

The survey study was implemented between:

- July 1st, 2002 till the end of October, 2002, and
- Mid of January, 2003 till the end of March, 2003.

4.4.1 Mechanism of Data Collection

According to the implementation of the project activities, the main activities were divided into sub-activities (see flow chart processes, pp. 56-62).

Each process included sub-activities; for example, the process of filling rock inside the trench was divided into several activities as the following:

1. Loading of the rock from stockpile by labor and loader;
2. Traveling of loader from stockpile to trench ;
3. Discharging & arranging rock inside trench;
4. Frequent traveling of loader to the stockpile of rock according to the capacity of loader and volume of each layer;
5. Inspecting rock layer by the Engineer;
6. Repairing work and fixing snags by labor.

The quantity of loaded rocks by the loader and labor for each cycle was fixed under certain conditions for stations 5, 8, 11, and 14 to control the observation process, which was recorded using the special forms. After that, collected data and statistical analysis method were used to calculate the time of sub-activities (see Appendix 4). For example, Table 4.5 shows the time of some sub-activities of rock distribution inside the apron. The calculated data was analyzed by the Simulation Program (Arena) and suitable distribution functions were obtained (see Table 4.6)

Table 4.5 Time Recording During Implementation of Activities for Some Stations

No.	Activity name	Time (min)	Number of Observations					
			St.5	St.8	St.11	St. 14	Total	Mean
1.	Rock loading	1	12	16	15	13	56	14
		2	17	13	15	15	60	15
		3	11	9	6	10	36	9
2.	Loader traveling from stockpile to the apron	1	28	26	24	22	100	25
		2	25	21	22	24	92	23
3.	Rock unloading	1	22	19	21	18	80	20
		2	17	14	16	13	60	15
		3	15	14	12	11	52	13
4.	Loader traveling from apron to stockpile	1	22	21	19	18	80	20
		2	18	15	17	14	64	16
		3	14	11	12	11	48	12

St. = station

4.5 Generating Statistical Distribution Functions

Theoretical distribution functions are usually used to present observed data and to level data irregularities that may be derived from field observation. After the data was collected on a random basis, the data were used to specify a distribution function for each process using Input Analyzer (Arena), where the data are grouped to form a frequency histogram, and fitted to the proper distribution function. The resulting information is transferred to the simulation model. Beta distribution function was noticed to be the most suitable function for the activities of the construction process. Aburizik et al (1991) used Beta distribution to estimate their sample data.

Table 4.6 Statistical Distribution Functions of the Project Activities

No.	**Process number**	**Process Description**	**Distribution Type**
1	P 1.1	Move excavator to the required station	14.5 + 18 *BETA (0.269, 0.389)
2	P 1.2	Excavate station and stockpile excavated material	13.5+ 6 *BETA (0.965, 1.6)
3	P 1.3	Arrange side slope and dewater	120 + 31*BETA(0.241,0.226)
4	P 1.4	Inspect levels and distances	14.5 + 6*BETA(0.488, 0.427)
5	P 1.5	Repair snags of cliff and apron	21.5 + 9 *BETA(0.334, 0.551)
6	P1.6	Finish the activity	-
7	P 2.1	Transfer Geotextile to apron	9.5 + 8 *BETA(1.11, 1.56)
8	P 2.2	Fix Geotextile inside apron	44.5 + 19 *BETA (0.785, 0.73)
9	P2.3	Finish the activity	_
10	P 3.1	Load filter from temporary stockpile	1.5 + 4 *BETA (0.848, 1.82)
11	P 3.2	Transfer filter from temporary stockpile to apron	1.5 + 2 *BETA (1.94, 2.83)
12	P 3.3	Spread filter in apron	0.5 + 5 *BETA (1.77, 1.86)
13	P 3.4	Move loader to temporary stockpile	1.5 + 2*BETA (2.14, 1.89)
14	P 3.5	Inspect level of filter	5.5 + 3 *BETA (0.897, 1.02)
15	P 3.6	Load filter from temporary stockpile	1.5 + 4 * BETA (0.848, 1.82)
16	P 3.7	Transfer filter from temporary stockpile to apron	1.5 + 5 *BETA (0.856, 1.13)
17	P 3.8	Spread filter at apron side	5.5 + 4 *BETA (2.22, 1.56)
18	P 3.9	Move loader to temporary stockpile	1.5 + 2*BETA (2.14, 1.89)
19	P 4.1	Load rock from temporary stockpile	0.5 + 3 *BETA.(1.2, 1.04)
20	P 4.2	Transfer rock to apron	0.5 + 2 *BETA (1.43, 1.49)
21	P 4.3	Discharge rock inside apron	0.5 + 3 *BETA(1.03, 1.25)
22	P 4.4	Arrange rock inside apron	1.5+3* BETA (1.03, 1.19)
23	P 4.5	Return back to temporary stockpile	0.5 + 3 *BETA (1.07, 1.34)
24	P 4.6	Inspect work	14.5+ 11*BETA(0.545, 0.497)

25	P 4.7	Repair snags	29.5 + 11 *BETA (1.24, 1.01)
26	P 4.8	Finish the activity	_
27	P 5.1	Transfer surface course material to site	29.5 + 11 *BETA (0.567, 0.705)
28	P 5.2	Spread surface-course	120 + 27 *BETA (0.519, 0.743)
29	P 5.3	Inspect level of surface- course	9.5 + 5 *BETA (0.708, 0.978)
30	P 5.4	Watering and compacting surface-course	180 + 14 *BETA (0.316, 0.375)
31	P 5.5	Inspect degree of compaction	14.5 + 6 *BETA (0.548, 0.768)
32	P 5.6	Wait to get lab. results	130 + 18 *BETA (0.775, 654)
33	P 5.7	Finish the activity	_
34	P 6.1	Transfer box gabion	14.5 + 8 *BETA (1.28, 1.62)
35	P 6.2	Assemble and lace box gabion	17.5 + 5 *BETA (0.611, 0.5)
36	P 6.3	Inspect and repeat lacing of box gabion	29.5 + 16 *BETA (0.971, 1.27)
37	P 6.4	Load and transfer rock gabion	5.5 + 7 *BETA (1.21, 2.04)
38	P 6.5	Fill box gabion with rock	19.5 + 11 *BETA (0.383, 0.419)
39	P 6.6	Inspect rock during filing	19.5 + 13 *BETA (0.531, 0.804)
40	P 6.7	Repair snags if any	39.5 + 11 *BETA (0.578, 0.633)
41	P 6.8	Finish the activity	_
42	P 7.1	Adjust cliff and Beach side slope	9.5 + 6 *BETA (0.578, 0.809)
43	P 7.2	Load sand from temporary stockpile	14.5 + 10 *BETA (0.346, 1.13)
44	P 7.3	Transfer sand from temporary stockpile to site	14.5 + 6 *BETA (0.43, 1.13)
45	P 7.4	Spread sand layer	11.5 + 5 *BETA (0.661, 1.43)
46	P 7.5	Water and compact layer	14.5 + 16 *BETA (0.61, 0.967)
47	P 7.6	Inspect degree of compaction	9.5 + 6 *BETA (1.82, 2.42)
48	P 7.7	Wait to get lab. results	79.5 + 26 *BETA (0.275, 0.523)
49	P 7.8	Finish the activity	_

P 1.1 = Process number (1) and sub-process number (1)

For more details about the distribution functions see Appendix 4

After the optimized distribution function was fitted by the Input Analyzer of ARENA for each activity, the time function was used in the processes to simulate the optimal probabilistic duration of the activities. Therefore, the productivity rates used were actual data collected during the project implementation.

4.6 Simulation Process

The aim of simulation is to determine the duration of the activities and the project according to the production rates of labor and equipment. Process simulation can also be replicated to find the optimal duration and resources of a project.

After designing the implementation model as shown in Figure 4.2, flow charts for the main activities were designed (see Flow Charts 4.1 to 4.7). The data collected on site (see Appendices 3 and 4) and the associated statistical distribution functions (see Table 4.6 and Appendix 4) were used as input data to the different modules (see Chapter 2, Section 2.9.3.1.1 and Table 2.1).

4.6.1 Simulation Input

The collected data during the implementation of the project was fitted using "input analyzer" of the Simulation program for determining a suitable distribution function. Measurement of time for each sub-activity of the implemented project was considered as input data.

Beta distribution function was chosen as it showed the best fit in most cases (see Table 4.6). These functions were then fed to the Simulation modules (basic processes). For more details about the basic processes panel, and the functions of these processes see Section 2.9.3.1.1 and Table 2.1.

4.6.1.1 Panel of Basic Process

This section shows, as an example, the panels of the basic processes of the Excavation of Cliff and Apron. The panels also show the data input for each module.

4.6.1.1.1 Entity Panel

The flowchart is started using a "Create" module. This is the starting point for the flow of entities through the model. In this example, the station number is considered as the entity through the simulation process. Figure 4.6 shows the basic "Create" panel of the simulation process. Only one entity per station is created throughout the model, see Figure 4.12

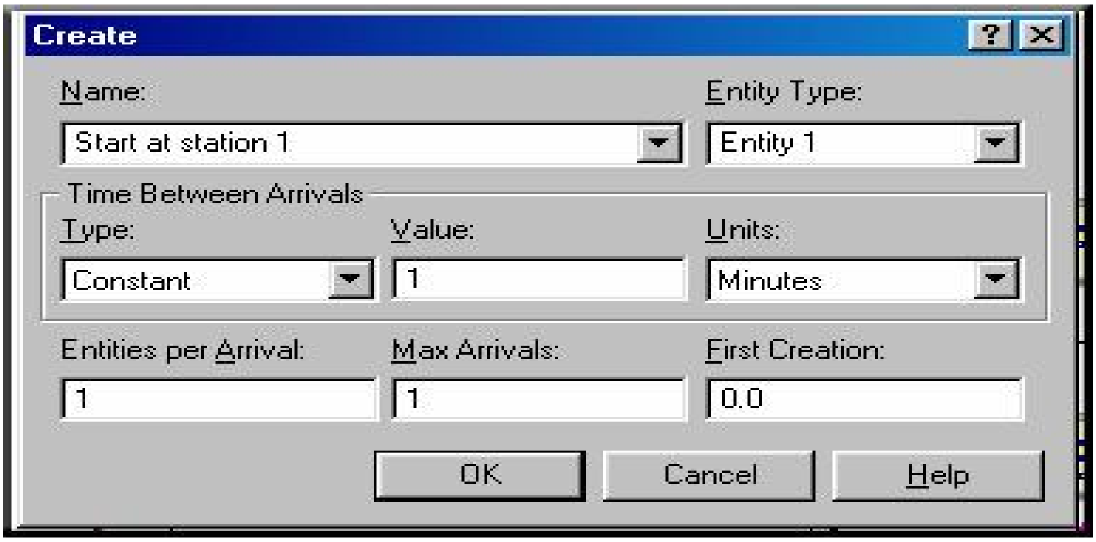


Figure 4.6 Create module

4.6.1.1.2 Assign Panel

As shown in Figure 4.7 “Assign” module is then used. In this example, the total volume of excavation of a station is considered as “Assign” module through the operation of simulation. Figure 4.7 shows the basic “Assign” panel of the simulation process. The total volume assigned will at a later stage checked if it is equal to 750.

4.6.1.1.3 Process Panel

The “Process” module is connected to the “Assign” process. In this example, Move Excavator to the required station; and Excavate station and stockpile of excavated material are considered as “Process” module through the operation of simulation. Figure 4.8 and 4.9 show the basic “Process” panel of these two operations.

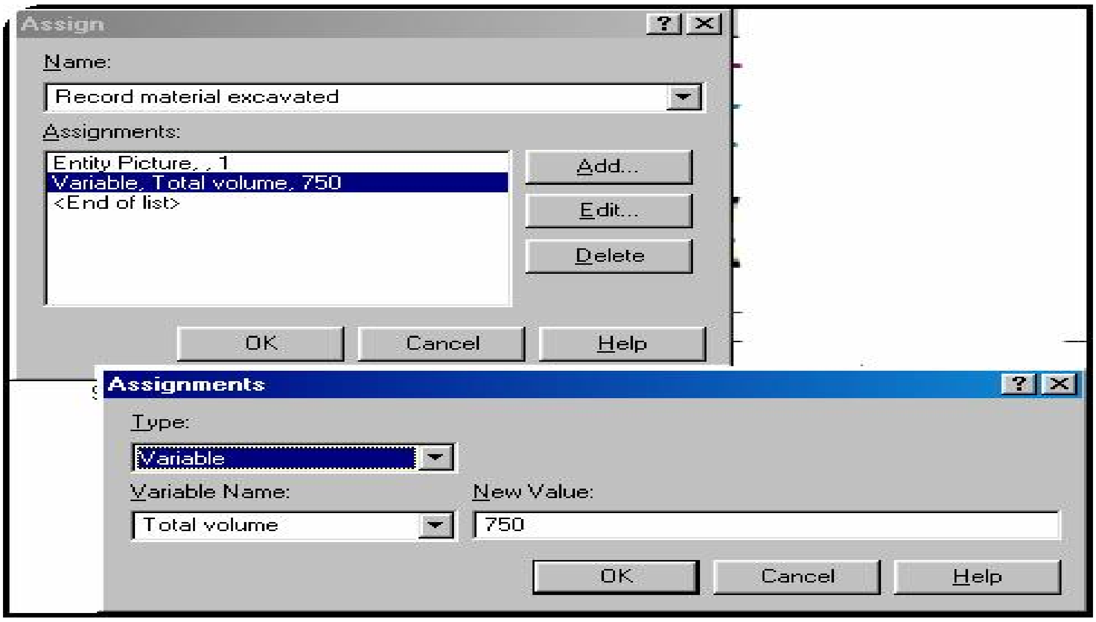


Figure 4.7 Assign module

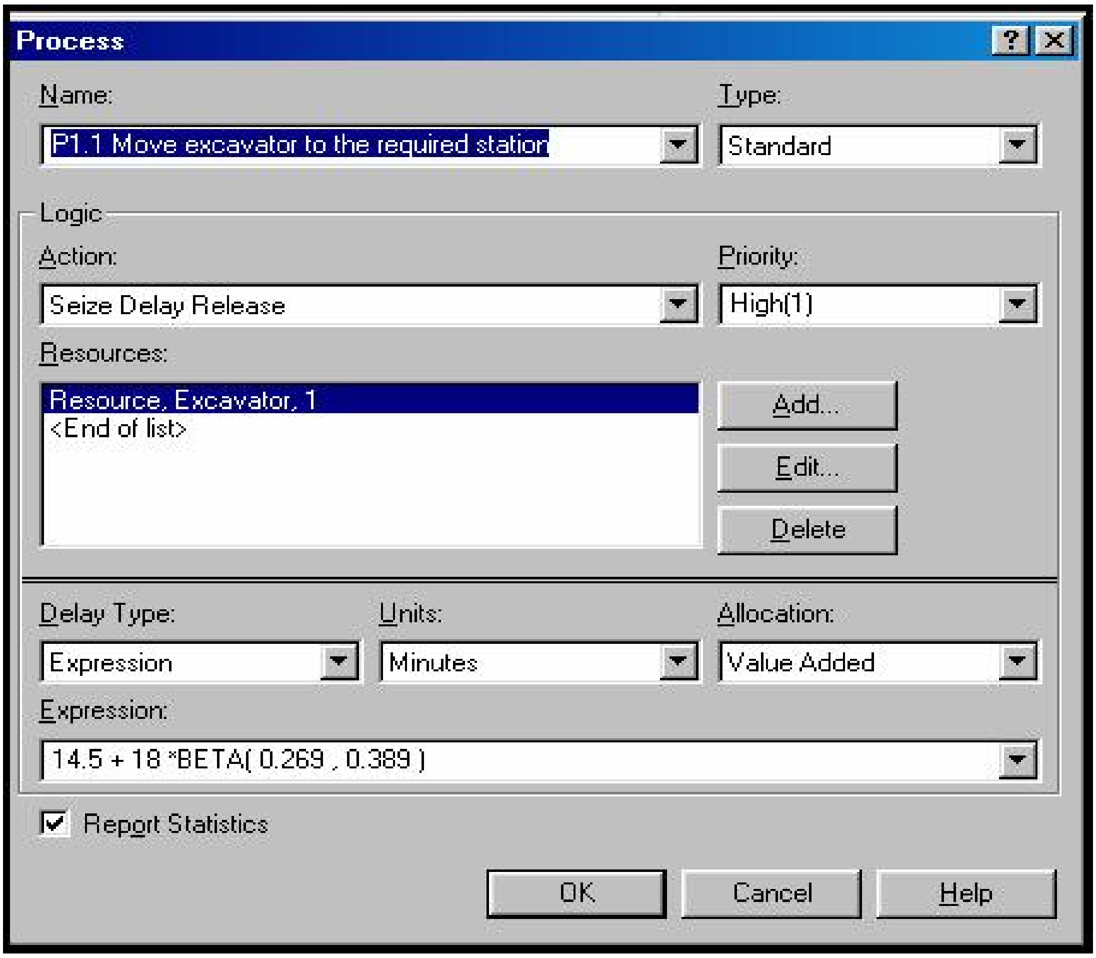


Figure 4.8 Process module (1)

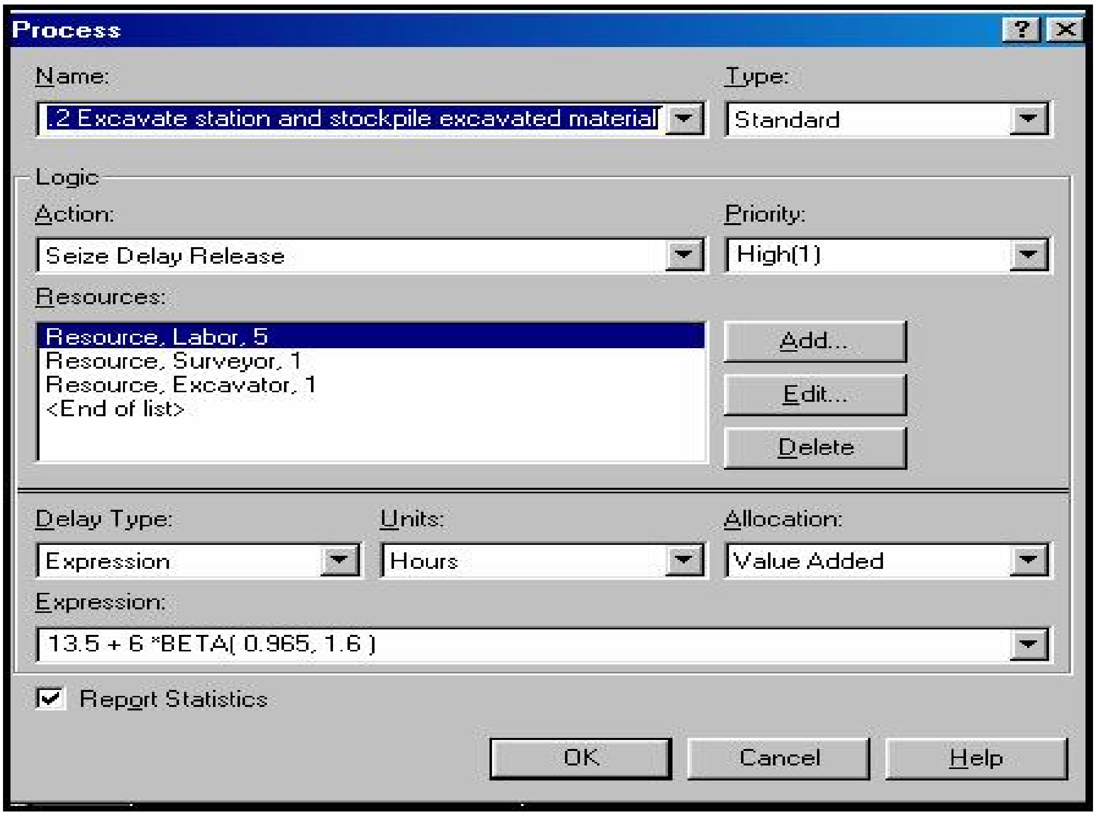


Figure 4.9 Process module (2)

4.6.1.1.4 Decide Panel

The "Decide" module determines whether the excavation of cliff and apron is completed. In this example, checking the level and distances of excavation of cliff and apron are considered as "Decide" module throughout the operation of simulation. Figure 4.10 shows the "Decide" panel for Checking the levels and distances.

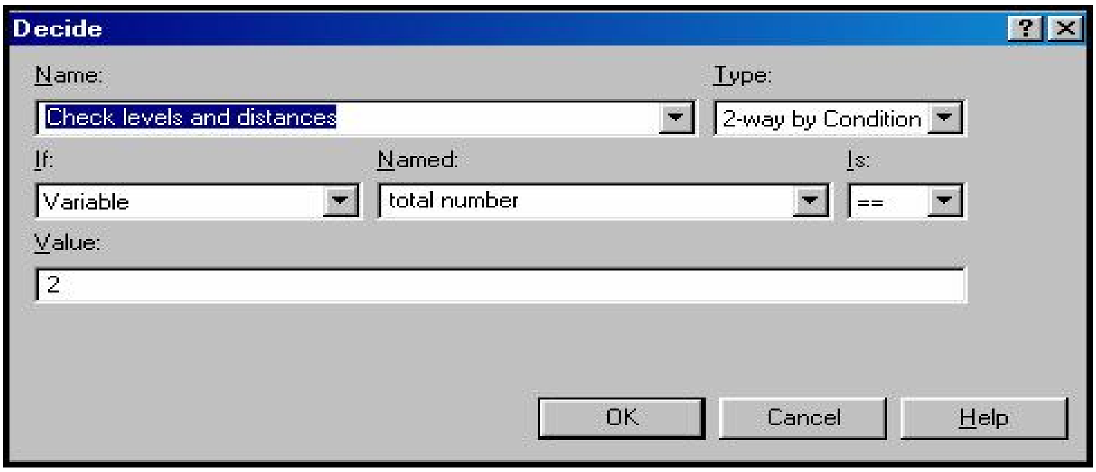


Figure 4.10 Decide module

4.6.1.1.5 Dispose Panel

The "Dispose" module is used to represent the completion of the simulation processes. Figure 4.11 shows the "Dispose" panel.

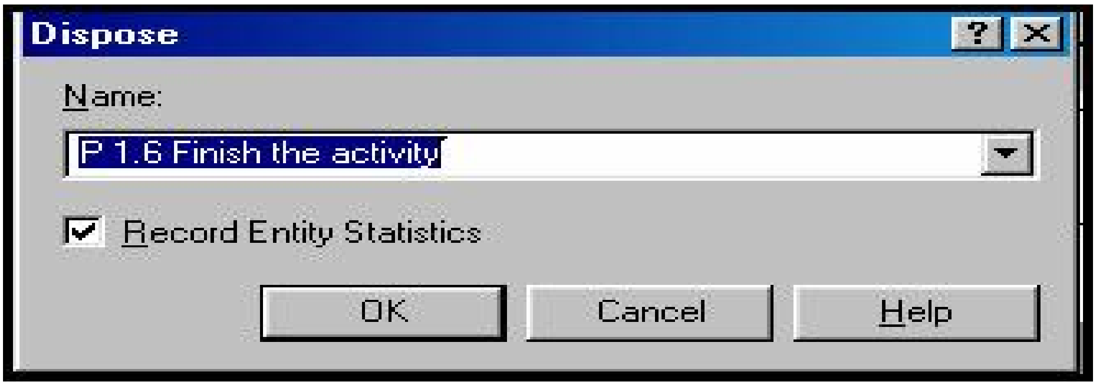


Figure 4.11 Dispose module

4.6.2 Replication of Processes

After completing the entry of the data into the modules of a typical station, one hundred runs of simulation were executed for each process (see Figures 4.12 to 4.19). The completion time was recorded for each process (see Figure 4.20). All probabilities of completion time for each process and duration of each sub- process were obtained through this operation (see Table 4.7). Also, the "Number Busy" and "Utilization" of resources for each activity were obtained (see Table 4.8).

Process: 1

Excavation cliff and apron(Typical station)

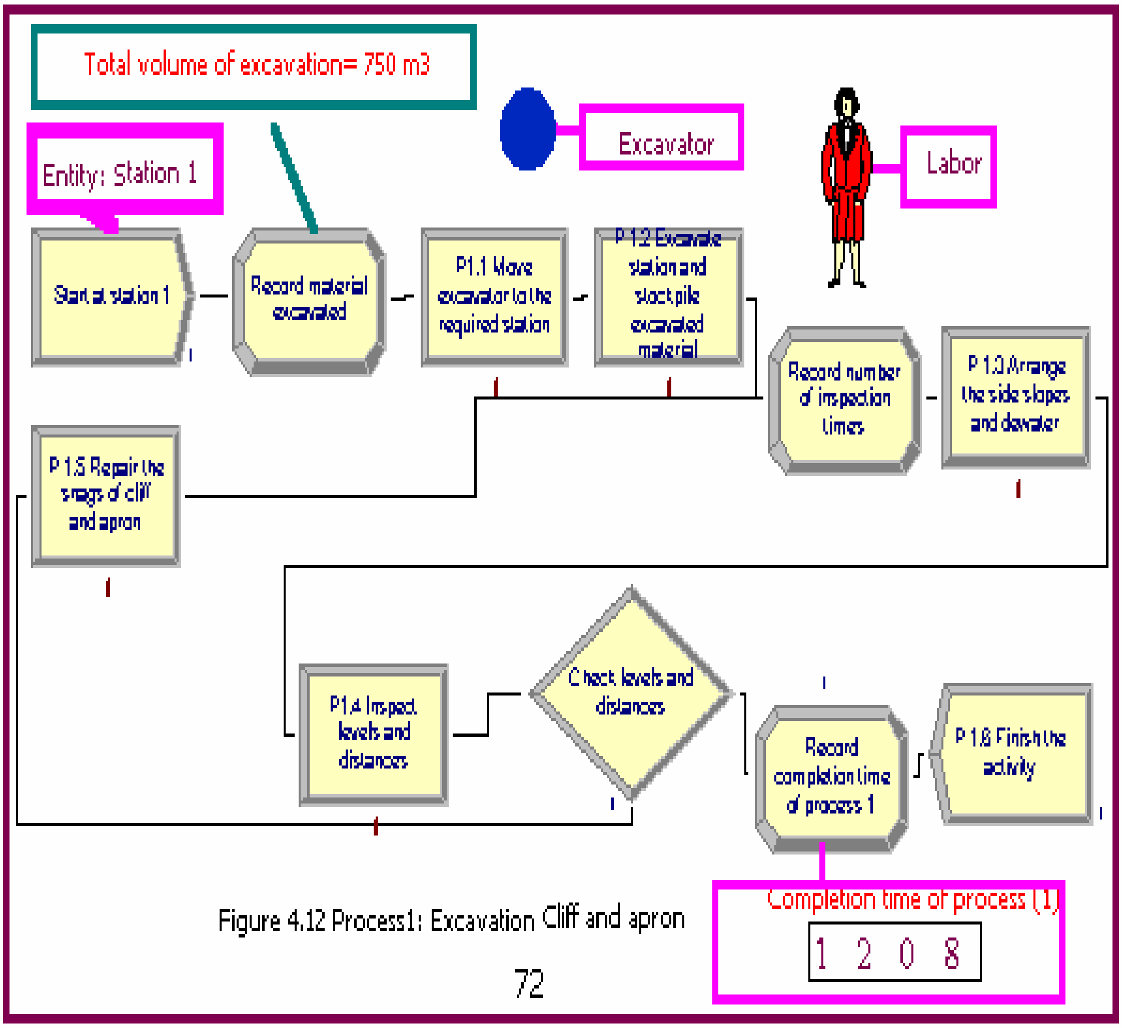


Figure 4.12 Process1: Excavation Cliff and apron

72

Process: 2
Geotextile laying inside the apron

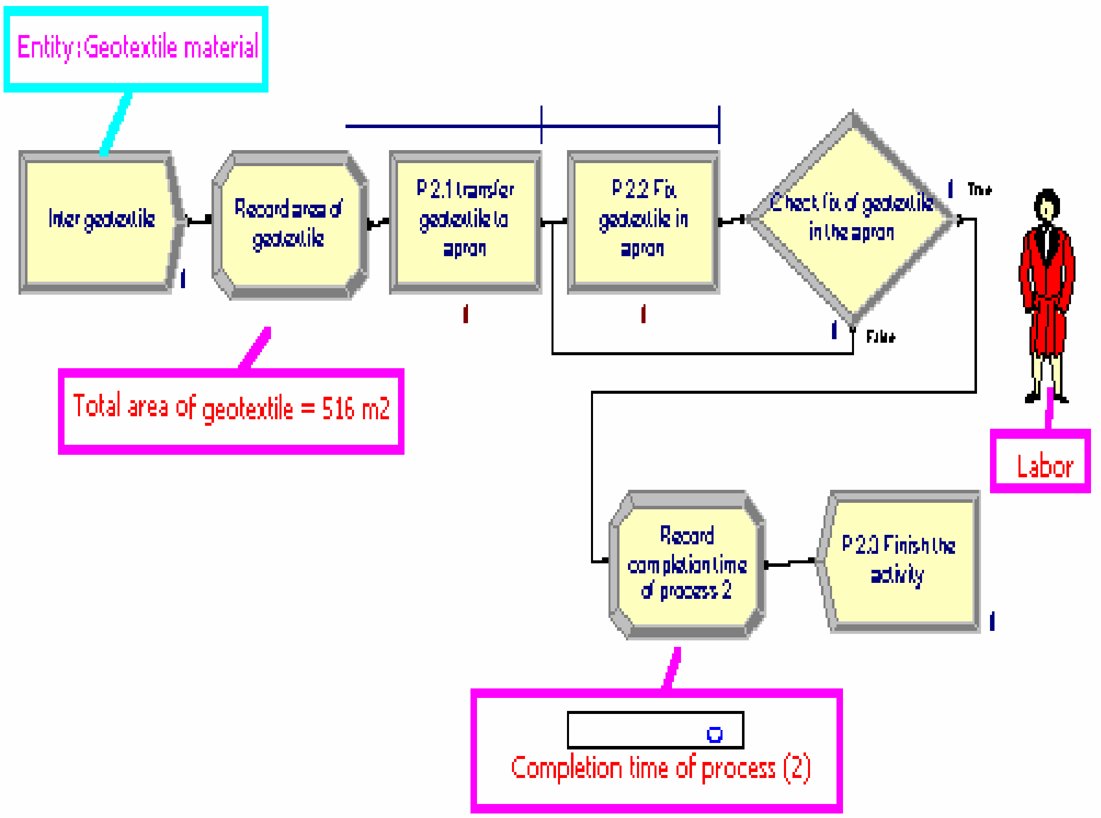


Figure 4.13 Process 2: Geotextile Laying Inside the apron

Process (3) : Filter spreading inside the apron

Sub- Process (3.1): Filter spreading at apron bottom

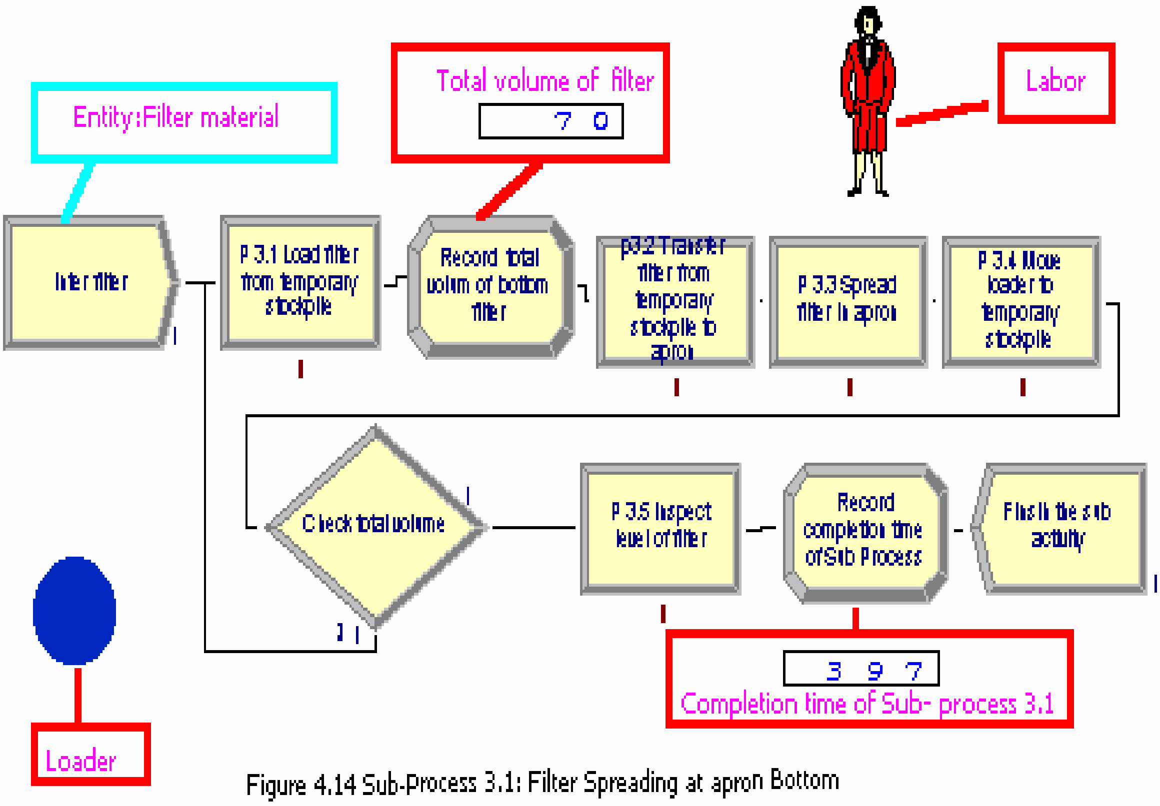


Figure 4.14 Sub-Process 3.1: Filter Spreading at apron Bottom

74

Process (3) : Filter spreading inside the apron

Sub- Process (3.2): Filter spreading at apron side

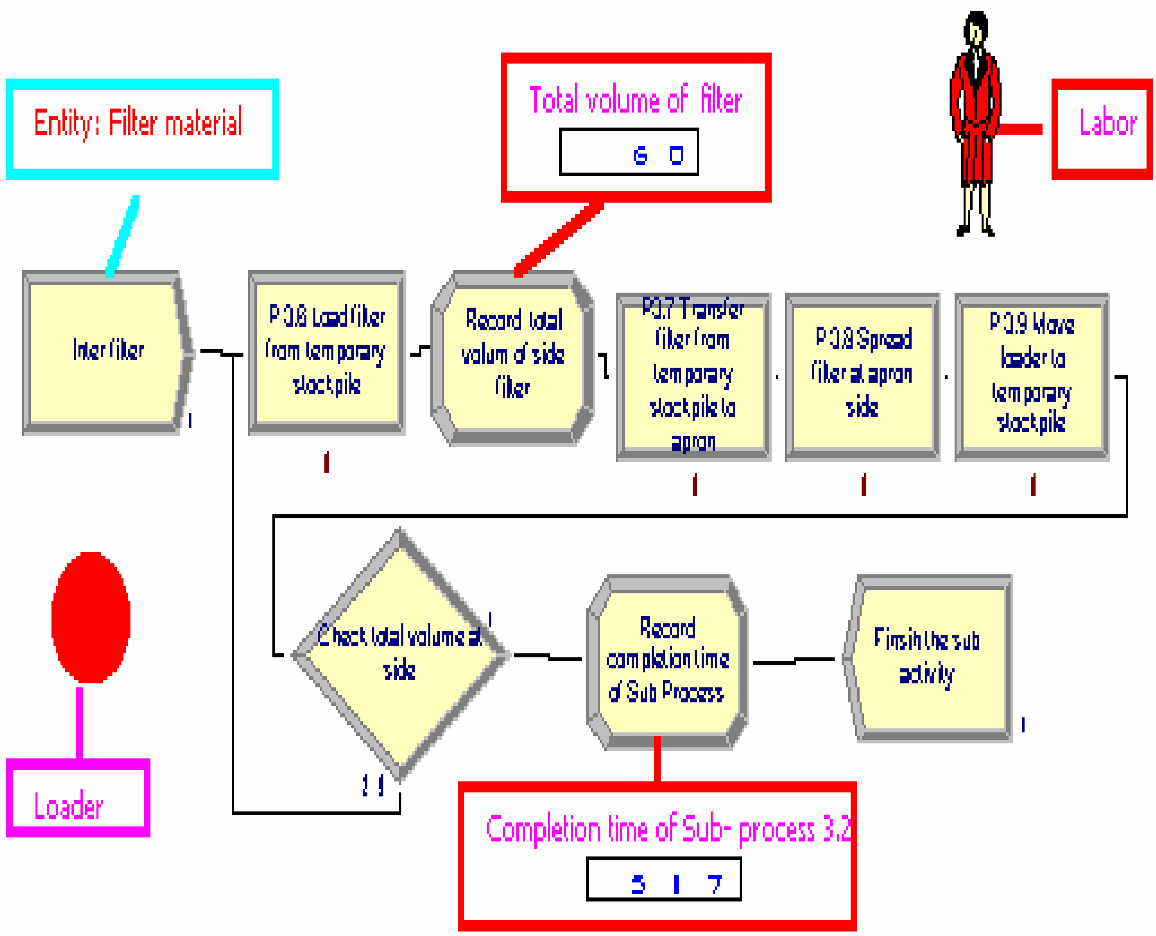


Figure 4.15 Sub-Process 3.2: Filter Spreading at apron Side

75

Process (4)
rock distribution inside the apron

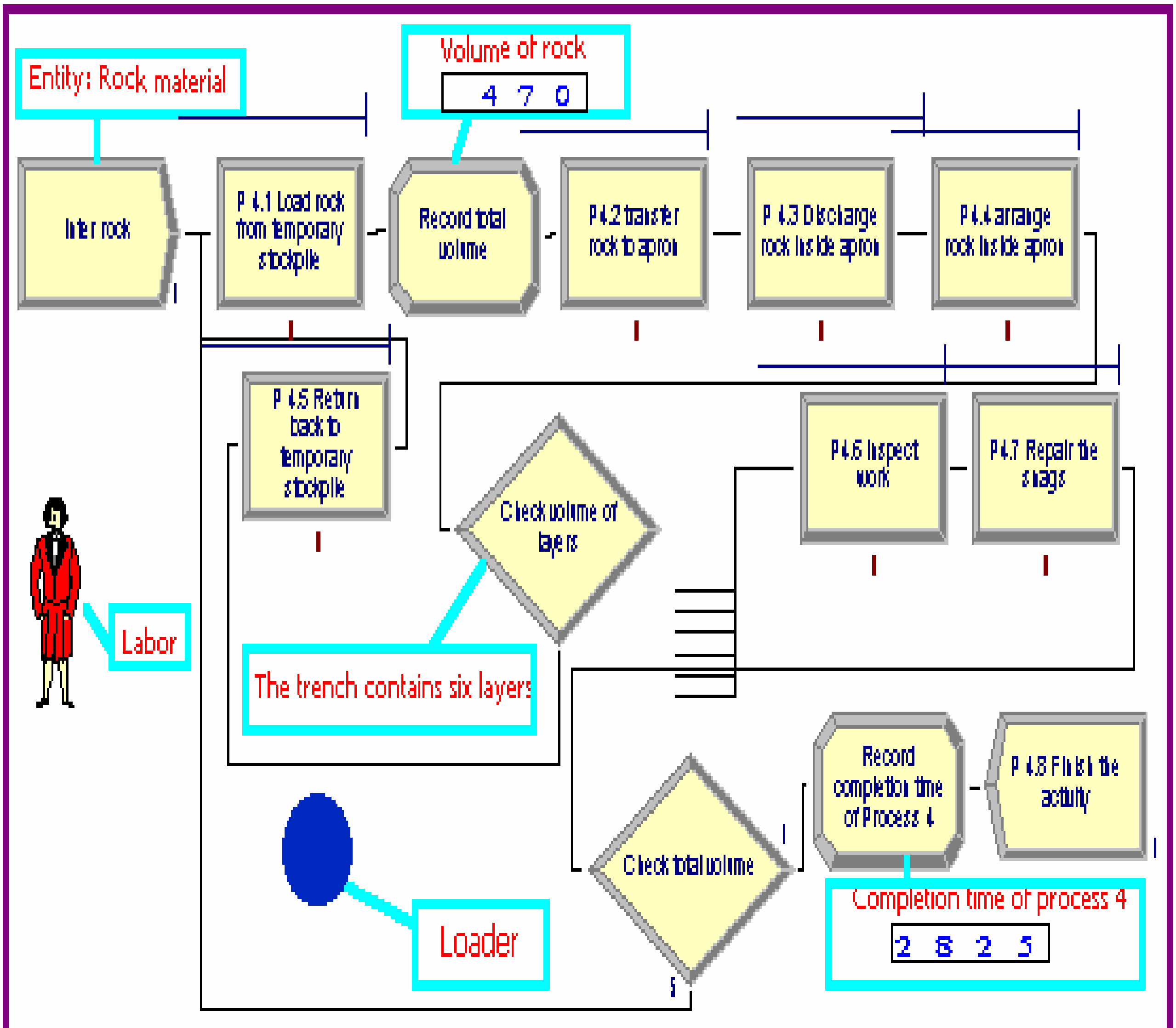


Figure 4.16 Process 4: Rock Distribution Inside the Apron
76

Process: 5
surface course spreading

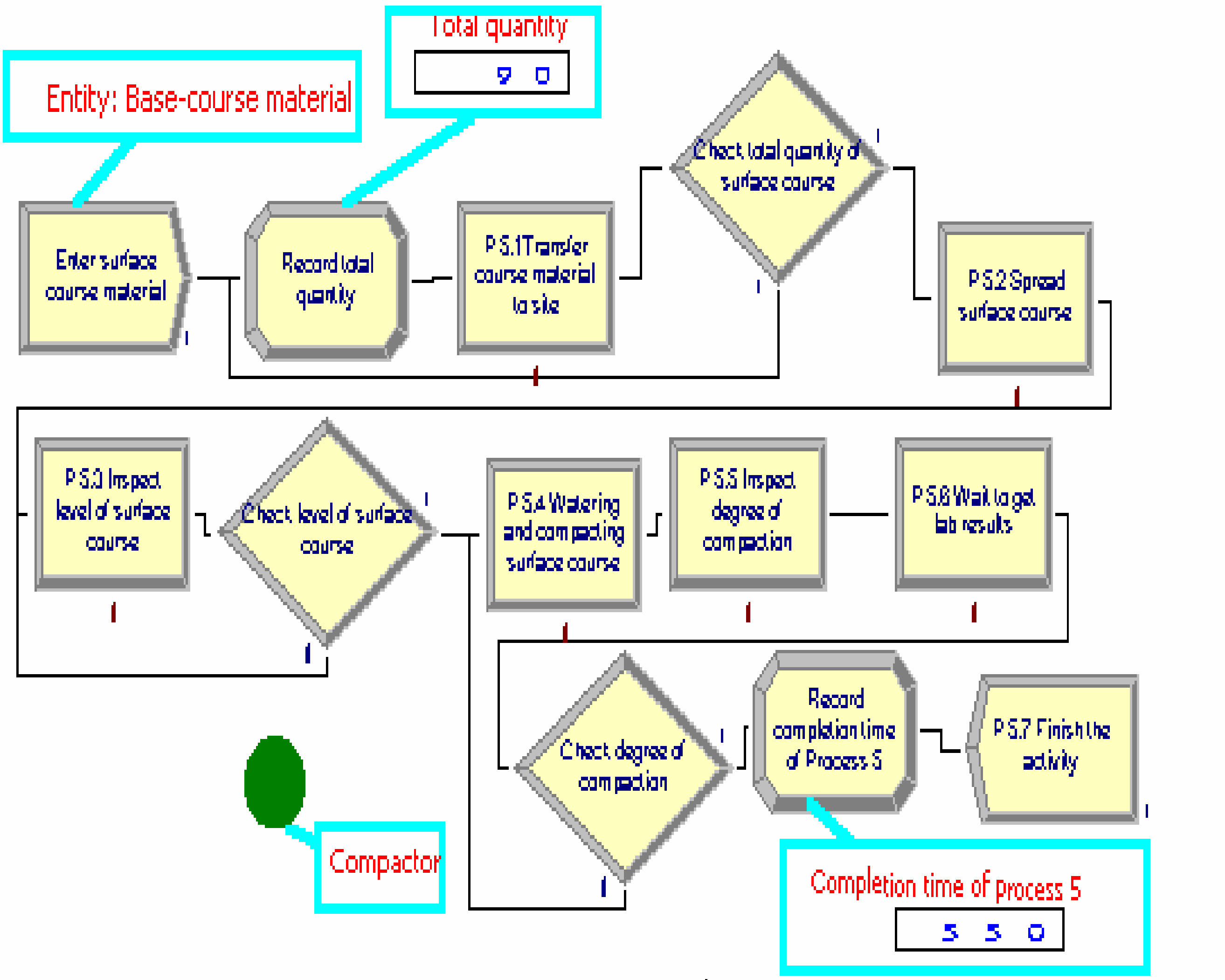


Figure 4.17 Process 5: Surface Course Spreading

77

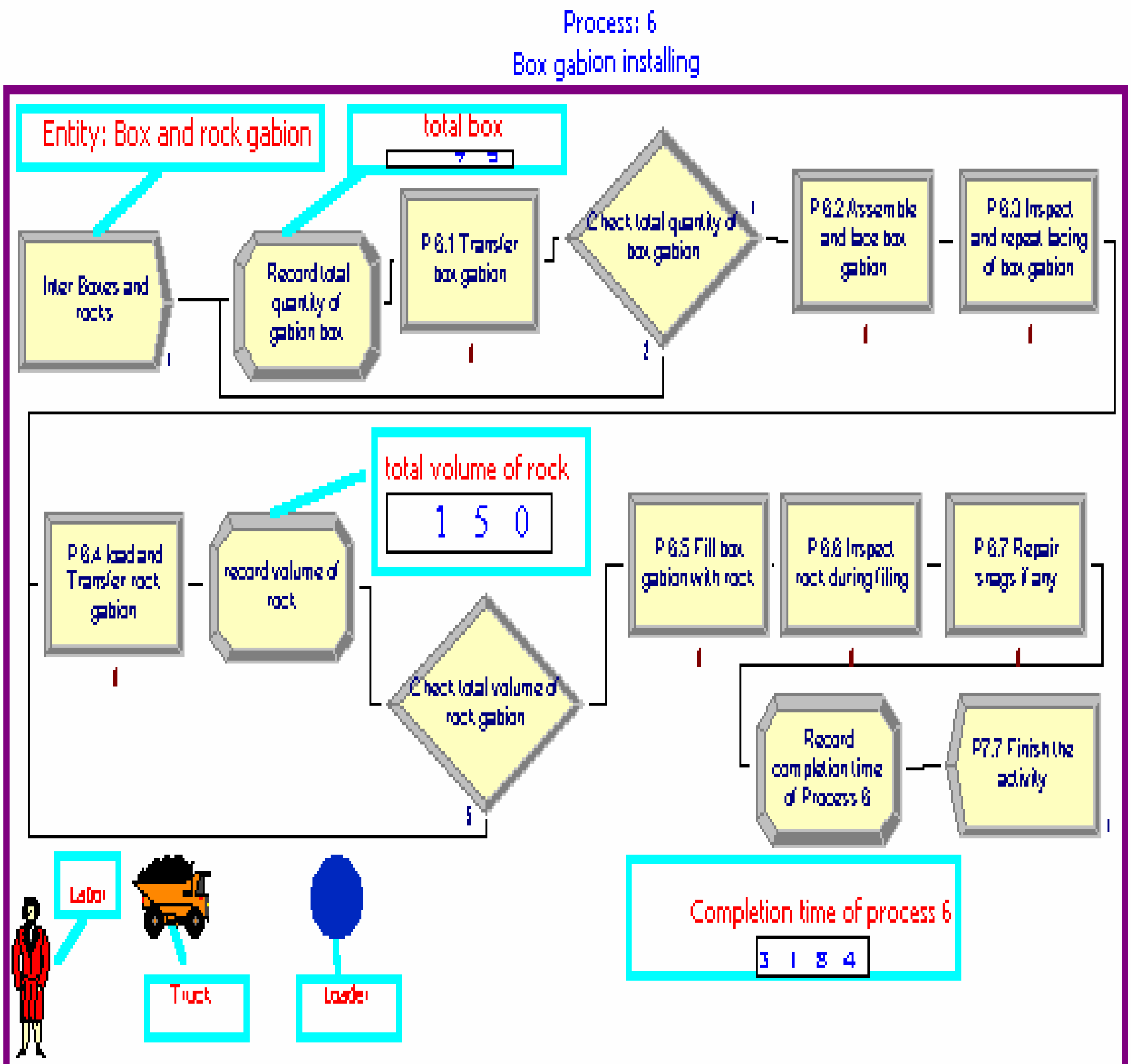


Figure 4.18 Process 6: Box Gabion Installing

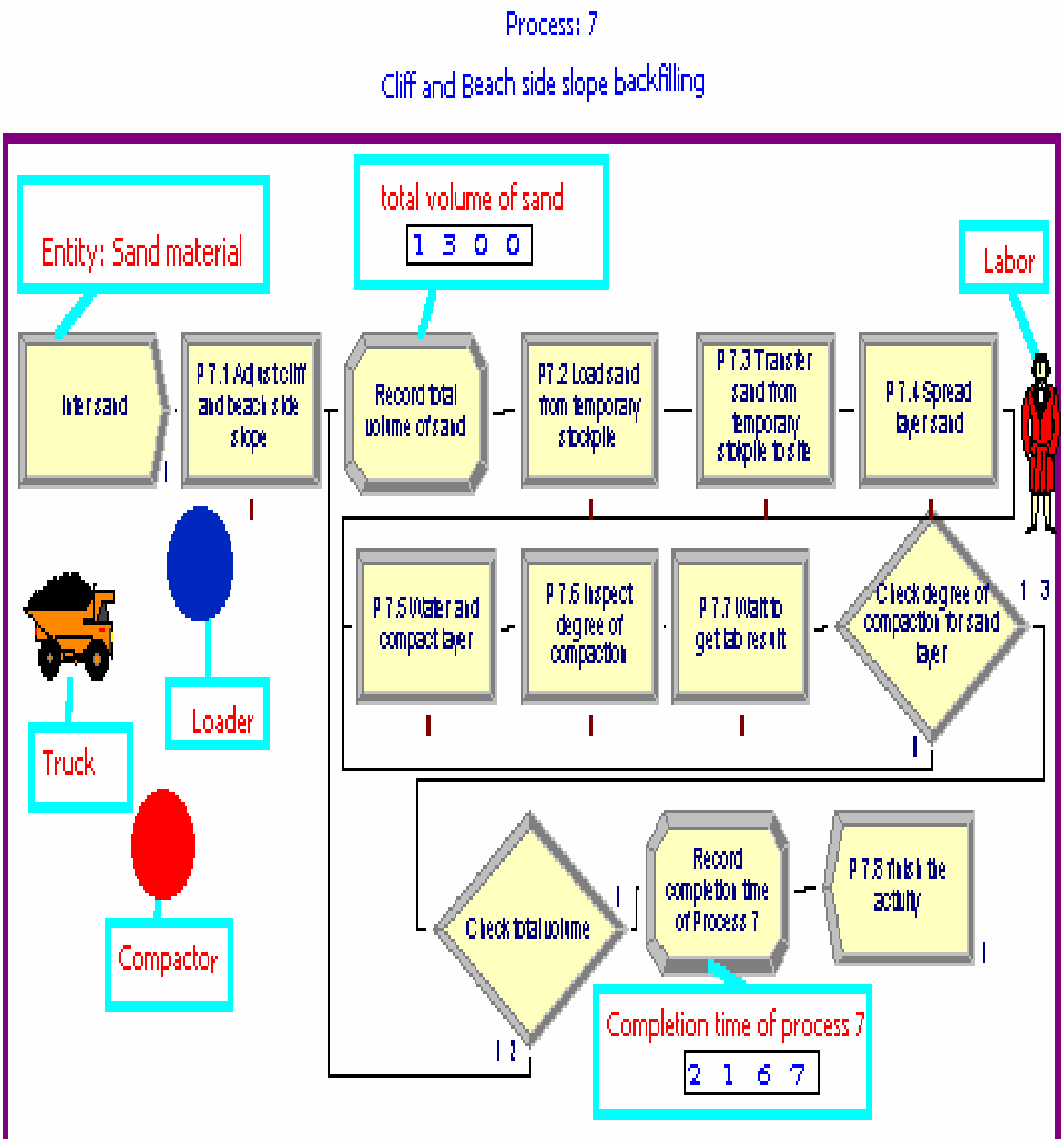
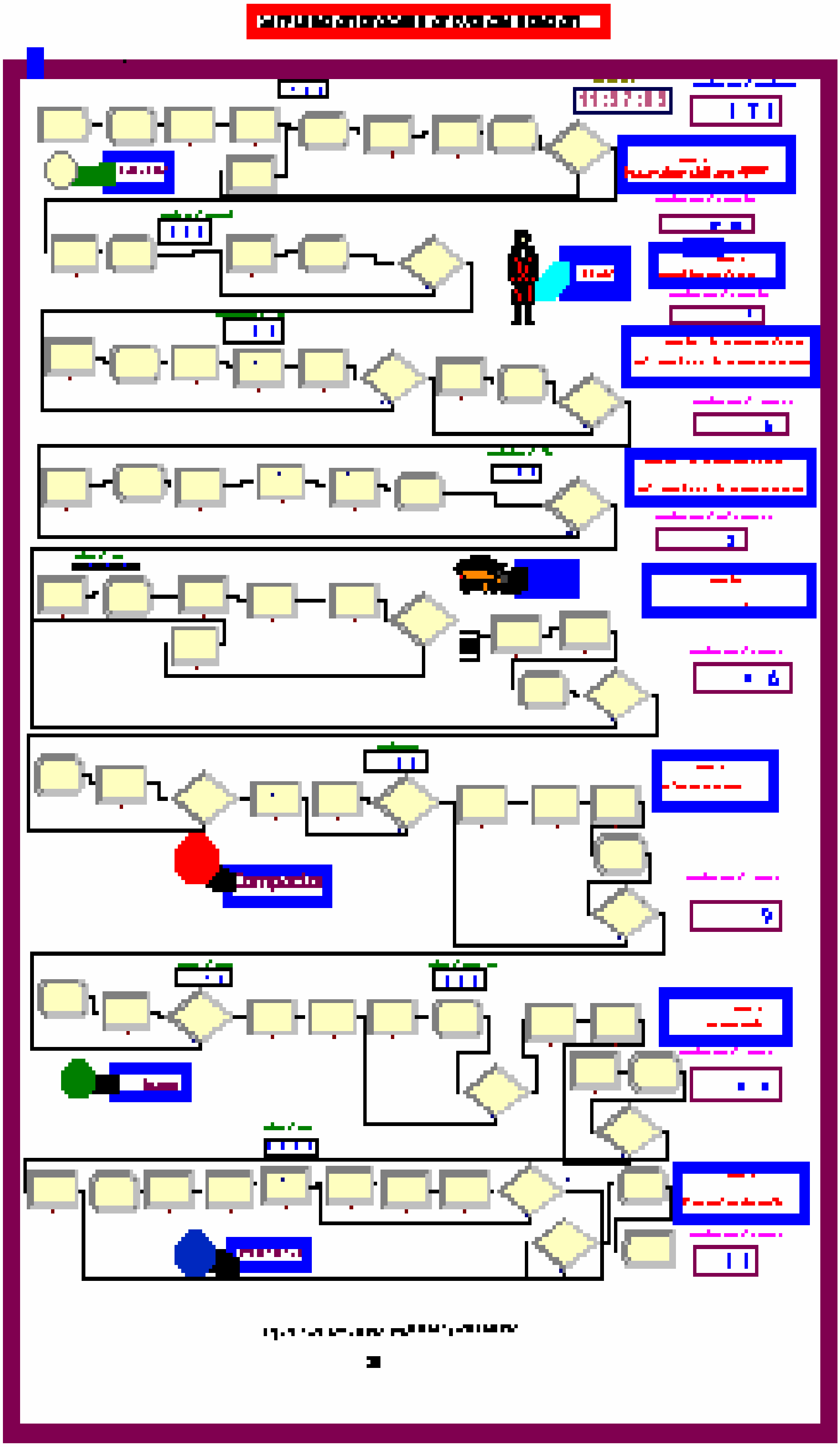


Figure 4.19 Process 7: Cliff and Beach Side Slope Backfilling



4.6.3 Simulation Output

The results of duration of all sub-processes are presented based on 100 replications. Also, the resources, in terms of the “Number Busy”, “Number Scheduled” and resources “Utilization” for all processes are presented.

4.6.3.1 Utilization of Resources for Completing a Typical Station

In most real life projects, resources are limited and hence impose constraints on the scheduling of activities. Thus it can be seen that resource allocation is an essential part of planning. Any one can make a plan, but a plan will be useful only if it can be translated into actual work. A plan can be put into action only if the resources required are available. Resource leveling is an attempt to determine resources to a project in a manner that will improve productivity and efficiency. In this section, the output of the simulated processes which include labor and equipment that are needed to execute the project activities will be discussed.

Table 4.8 illustrates the resources planned for each activity according to simulation input (“Number Scheduled”), and output (“Number Busy”, and “Utilization of Resources”).

“Utilization” is defined here as the relationship between “Number Busy” of an activity and “Number Scheduled” of the same activity.

For example,

Utilization for process (1) = number busy / number schedule = 4.84/5 = 97%

It means that the labor scheduled is busy 97% of the time for carrying out the activity of excavating cliff and apron (P1).

Also, from Table 4.7, it is noted that all workers are busy at all times for completing P2. However, P3, P5, and P7 indicate that Utilization is less than 50%, which means that these activities need only half of the originally planed labor to be completed. As shown in P1, the required time for excavating the apron and cliff by the excavator is equal to 75% of the total time required to finish this activity, and 25% of the time is considered idle time.

Another example: P7 needs the loader only 30% of the time for implementing the backfilling activity, and the remaining percentage 70 % indicates that the loader could work at another activity (see Table 4.7).

Table 4.7 Resources Results

No	Process number	Description of process	Resources type	Number scheduled	Number busy	Utilization
1	P 1	Excavation of cliff and apron (Typical station)	Excavator	1.00	0.74	0.74
			Labor	5.00	4.84	0.97
			Surveyor	1.00	0.026	0.026
			Engineer	1.00	0.026	0.026
2	P 2	Geotextile laying inside the apron	Labor	10	10	1.00
3	P 3	Filter spreading inside the apron	Loader	1	0.98	0.98
			Foreman	1	0.74	0.74
			Labor	2	0.58	0.29
			Surveyor	1	0.02	0.02
4	P 4	Rock distribution inside the apron	Loader	1	0.95	0.95
			Foreman	1	0.85	0.85
			Labor	7	6.63	0.95
			Engineer	1	0.05	0.05
5	P 5	Surface – course spreading	Compactor	1	0.34	0.34
			Labor	3	1.41	0.47
			Loader	1	0.23	0.23
			Truck	1	0.12	0.12
			Surveyor	1	0.02	0.02
6	P 6	Box gabion installing	Labor	12	11.50	0.96
			Loader	1	0.04	0.04
			Foreman	1	0.97	0.97
			Truck	1	0.02	0.02
7	P 7	Cliff and Beach sideslope backfilling	Labor	3	1.4	0.47
			Loader	1	0.3	0.3
			Truck	4	0.21	0.05
			Foreman	1	0.93	0.93
			Compactor	1	0.1	0.1

4.6.3.2 Duration Probabilities for Completing a Typical Station

The simulation output generates three probabilistic values for completing each activity, Minimum value, Maximum value, and Average value, (see Table 4.8). For example, the time required to complete the activity of excavating cliff and apron is

2.7 days. When the weather is bad or the labor productivity encountered is low, the activity of excavation will take up to 3.27 days, however; when the conditions are favorable as few as 2.33 days may be required.

Figure 4.21 illustrates, for example, the sequence of activities for a typical station according to the minimum duration. As shown, the time required to complete the activities of a typical station is 19.58 days.

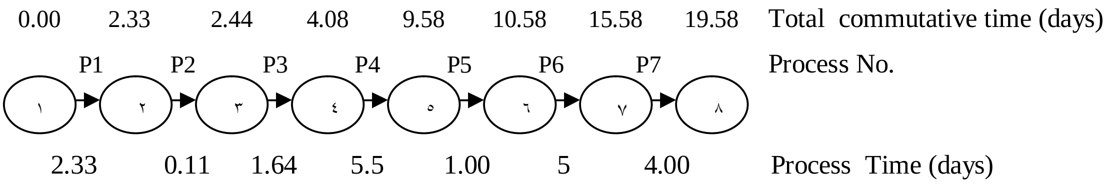


Figure 4.21 Minimum time value of a typical station

Figure 4.22 illustrates the sequence of activities for a typical station according to the maximum duration. As shown, the time required to complete the activities of a typical station is 26.24 day.

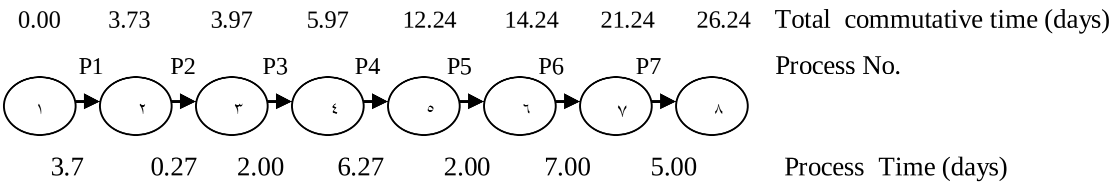


Figure 4.22 Maximum time value of a typical station

Figure 5.23 illustrates the network of activities of the work for a typical station according to the average value. This means that the time required to complete the activities of typical station is 22.31 day.

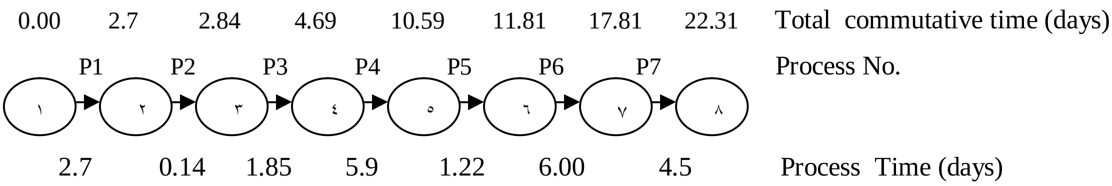


Figure 4.23 Average time value of a typical station

Table 4.8 Simulated Processes and Sub- Processes Duration

No	Process number	Description of sub-process	Average value	Min. value	Max. value	Half Width	Time Unit
1	P 1.1	Move excavator to the required station	20.64	14.4	32.64	0.00	Minute
2	P 1.2	Excavate station and stockpile excavated material	945.6	811.2	1166.4	0.04	Minute
3	P 1.3	Arrange the side slope and dewater	273.6	240	299.0	0.01	Minute
4	P 1.4	Inspect levels and distances	34.1	28.8	40.32	0.00	Minute
5	P 1.5	Repair the snags of cliff and apron	25.92	22.08	30.72	0.00	Minute
	Total	**Duration of P.1**	**1299.86**	**1116.5**	**1569.1**	**-**	Minute
6	P 2.1	Transfer Geotextile to apron	12.82	9.54	17.40	0.43	Minute
7	P 2.2	Fix Geotextile inside apron	55.24	44.66	114.17	1.62	Minute
	Total	**Duration of P.2**	**68.06**	**54.2**	**131.75**	**-**	**Minute**
8	P 3.1	Load filter from temporary stockpile	97.82	84.09	110.78	1.21	Minute
9	P 3.2	Transfer filter from temporary stockpile to apron	81.27	75.52	87.28	0.54	Minute
10	P 3.3	Spread filter in apron	102.58	82.27	119.03	1.27	Minute
11	P 3.4	Move loader to temporary stockpile	89.84	84.55	98.97	0.54	Minute
12	P 3.5	Inspect level of filter	6.95	5.50	8.50	0.18	Minute
	Total	**Duration of SP 3.1**	**378.46**	**331.93**	**424.56**	**-**	**Minute**
13	P 3.6	Load filter from temporary stockpile	84.06	71.83	98.06	1.07	Minute
14	P 3.7	Transfer filter from temporary stockpile to apron	110.45	92.32	130.29	1.61	Minute

15	P 3.8	Spread filter at apron side	234.94	221.21	249.38	0.96	Minute
16	P 3.9	Move loader to temporary stockpile	79.98	70.91	87.35	0.51	Minute
	Total	**Duration of SP3.2**	**509.43**	**456.27**	**565.08**	**-**	**Minute**
17	P 4.1	Load rock from temporary stockpile	667.31	617.76	716.75	3.02	Minute
18	P 4.2	Transfer rock to apron	411.8	383.71	442.97	2.52	Minute
19	P 4.3	Discharge rock inside apron	439.52	403.32	468.16	2.75	Minute
20	P 4.4	Arrange rock inside apron	681.23	649.61	705.64	2.43	Minute
21	P 4.5	Return back to temporary stockpile	327.78	303.04	344.93	1.48	Minute
22	P 4.6	Inspect work	137.45	123.80	151.26	1.15	Minute
23	P 4.7	Repair the snags	166.56	153.23	181.66	1.18	Minute
	Total	**Duration of P.4**	**2831.65**	**2634.5**	**3011.4**	**-**	**Minute**
24	P 5.1	Transfer course material to site	68.92	59.21	80.91	0.95	Minute
25	P 5.2	Spread surface-course	131.08	120.04	146.87	1.62	Minute
26	P 5.3	Inspect level of surface- course	13.06	9.50	33.32	0.83	Minute
27	P 5.4	Watering and compacting surface- course	201.58	180.00	379.46	9.83	Minute
28	P 5.5	Inspect degree of compaction	18.45	14.51	40.20	1.06	Minute
29	P 5.6	Wait to get lab. results	150.65	130.17	295.67	7.49	Minute
	Total	**Duration of P.5**	**583.74**	**513.43**	**976.43**	**-**	**Minute**
30	P 6.1	Transfer box gabion	45.23	45.55	64.90	0.72	Minute
31	P 6.2	Assemble and lace box gabion	1229.59	1050.0	1349.8	20.36	Minute
32	P 6.3	Inspect and repeat lacing of box gabion	36.89	29.58	45.26	0.92	Minute

33	P 6.4	Load and transfer rock gabion	48.73	38.25	57.81	0.81	Minute
34	P 6.5	Fill box gabion with rock	1481.54	1170	1829.9		Minute
35	P 6.6	Inspect rock during filing	24.66	19.51	32.36	50.80	Minute
36	P 6.7	Repair snags if any	44.19	39.51	50.49	0.73	Minute
Total		**Duration of P.6**	**2910.83**	**2352.9**	**3436.5**	**-**	**Minute**
37	P 7.1	Adjust cliff and Beach side slope	11.61	9.50	15.49	0.35	Minute
38	P 7.2	Load sand from temporary stockpile	243.94	215.4	279.94	2.55	Minute
39	P 7.3	Transfer sand from temporary stockpile to site	209.84	197.67	227.67	1.23	Minute
40	P 7.4	Spread layer sand	174.07	157.38	191.12	1.39	Minute
41	P 7.5	Water and compact layer	211.36	199.10	230.29	1.25	Minute
42	P 7.6	Inspect degree of compaction	153.75	140.86	172.51	1.11	Minute
43	P 7.7	Wait to get lab. results	1159.5	1078.9	1271.7	7.90	Minute
Total		**Duration of P.7**	**2164.06**	**1998.8**	**2388.7**	**-**	**Minute**

P .1: It means process number (1). (See Flow Chart 4.1 – 4.7)

PS 3.1: It means sub-model number 3.1

P 1.1: It means sub-process number (1). (See Flow Chart 4.1 – 4.7)

4.6.4 Reliability of the Results

reports contain a column called “Half Width”. This statistic is included to determine reliability of the results from the replication. Three results are possible in the “Half Width” category:

1. Insufficient: The formula used to calculate half width requires the samples to be normally distributed. Arena will return the massage “ Insufficient” for that variable’s half width, indicating there is insufficient data to accurately calculate the half width. Running the simulation for a longer period of time should correct this.

2. Correlated: The formula used to calculate half width requires the samples to be independently distributed. If data is determined to be correlated, the massage "Correlated" is returned for that variable's half width. Running the simulation for a longer period of time should correct this.

3. A value: If a value is returned in the half width category, this value may be interpreted by saying in 95% of repeated trials, the sample mean would be reported as within the interval sample mean (+) or (-) half width. The half width can be reduced by running the simulation for a longer period of time.

4.6.5 Time Schedule Preparation

To design a time schedule for an ongoing project such as "Beach Camp Shore Protection" by the output of the simulation process, the project was divided into 32 stations; each station consists of seven activities (P1 to P7). The time schedule was designed based on the logical relationship of "finish-to-start" for each activity wherever the succeeding activity will start after the completion of the preceding activity (see Figure 4.21). But for the project as a whole, interaction of stations was used during preparation of time schedule for continuing the work without any waste time. For example, after completing the activity of excavating cliff and apron for station 1, immediately the excavation for station 2 would start, and at the same time, distribution of rock for station 1 was started.

Three project duration were used to draw the time schedule:

1. Minimum Value. The completion time of the project was calculated to be 9 months.

2. Maximum Value. The completion time of the project was calculated to be 11 months.

3. Average Value. The completion time of the project was calculated to be 10 months

4.6.6 Production Rates Measurement

4.6.6.1 Production Rates of Excavation

Process 1.2 (see Tables,4.1 ,4.7 and 4.8)

Quantity of excavation = 750 m3 (see Table 4.1)

Number of Excavators   = 1

Utilization of excavator = 0.74 (see Table 4.7)

Min. time of excavation = 811.2 minute (13.52 hour) (see Table 4.8)

average time of excavation = 945.6 minute (15.76 hour) (see Table 4.8)

Max. time of excavation = 1166.4 minute (19.44 hour) (see Table 4.8)

Production rate = Quantity/ (Utilization of Excavator * Time)

Max. production rate = 750 m3 / (0.74 * 13.52) = 75 m3 / hour

Average production rate = 750 m3 / (0.74 * 15.76) = 64.315 m3 / hour

Min. production rate = 750 m3 / (0.74 * 19.44) = 52 m3 / hour

4.6.6.2 Production Rates of Arrange the Side Slope and Dewatering

Process 1.3 (see Tables,4.1 ,4.7 and 4.8)

Area of trench = (3.7*2 + 3) * 50 =520 m2

Number of Labor = 5

Utilization of labor = 4.84 (see Table 4.7)

Min. time of arranging the sides of trench = 240 minute (4 hour) (see Table 4.8)

Average time of arranging the sides of trench = 273.6 minute (4.56 hour) (see Table 4.8)

Max. time of arranging the sides of trench = 299 minute (5 hour) (see Table 4.8)

Production rate = Area/ (Utilization of Labors * Time)

Min. production rate = 520m2 / (4.84 * 5) = 21.48 m2 / labor-hour

Average production rate = 520m2 / (4.84 * 4.56) = 23.56 m3 / labor-hour

Max. production rate = 520m2 / (4.84 * 4) = 26.86 m2 / labor-hour

4.6.6.3 Production Rates of Geotextile Laying Inside the Apron

Process P 2 (see Tables,4.1 ,4.7 and 4.8)

Area of geotextile = 516 m2 (see Table 4.1)

Number of Labor = 10

Utilization of labor = 10 (see Table 4.7)

Min. time of fixing and transferring the geotextile = 54.2 minute (0.90 hour) (see Table 4.8)

average time of fixing and transferring the geotextile = 68.06 minute (1.13 hour) (see Table 4.8)

Max. time of fixing and transferring the geotextile = 131.57 minute (2.2 hour) (see Table 4.8)

Production rate = Area/ (Utilization of Labors * Time)

Max. production rate = 516m2 / (10*0.9) = 57.33 m2 / labor-hour

Average production rate = 516m2 / (10*1.13) = 45.66 m2 / labor-hour

Min. production rate = 516m2 / (10 * 2.2) = 23.45 m2 / labor-hour

4.6.6.4 Production Rates of Loading and Discharging of Filter

Process 3 (see Tables,4.1 ,4.7 and 4.8)

Quantity of filter = 130 m3 (see Table 4.1)

Number of Loader = 1

Utilization of loader = 0.98 (see Table 5.7)

Min. time of spreading the filter = 788.2 minute (13.14 hour) (see Table 4.8)

average time of spreading the filter = 887.89 minute (14.8 hour) (see Table 4.8)

Max. time of spreading the filter = 989.64 minute (16.50 hour) (see Table 4.8)

Production rate = Quantity/ (Utilization of Loader* Time)

Max. production rate = 130 m3 / (0.98 * 13.14) = 10 m3 / hour

Average production rate = 130 m3 / (0.98 * 14.8) = 8.96 m3 / hour

Min. production rate = 130 m3 / (0.98 * 16.50) = 8 m3 / hour

4.6.6.5 Production Rates of Spreading Filter in Apron

Process 3.3 (see Tables,4.1 ,4.7 and 4.8)

Quantity of filter = 130 m3 (see table 4.1)

Number of Labor = 2

Utilization of labor = 0.58 (see table 5.7)

Min. time of labor to spread the filter = 788.2 minute (13.14 hour) (see Table 4.8)

average time of labor to spread the filter = 887.89 minute (14.8 hour) (see Table 4.8)

Max. time of labor to spread the filter = 989.64 minute (16.50 hour) (see Table 4.8)

Production rate = Quantity/ (Utilization of labor* Time)

Max. production rate of labor = 130 m3 / (0.58 * 13.14) = 17m3 / labor-hour

Average production rate of labor = 130 m3 / (0.58 * 4.8) = 15.14m3 / labor-hour

Min. production rate of labor = 130 m3 / (0.58 * 16.50) = 13.6 m3 / labor-hour

4.6.6.6 Production Rates of Arranging Rock Inside Apron

Process 4.4 (see Tables,4.1 ,4.7 and 4.8)

Quantity of rocks = 470 m3 (see Table 4.1)

Number of Labor = 7

Utilization of labor = 6.63 (see Table 5.7)

Min. time of distribution the rocks = 2634.5 minute (43.9 hour) (see Table 4.8)

Average time of distribution the rocks = 2831.65 minute (47.2 hour) (see Table 4.8)

Max. time of distribution the rocks = 3011.4 minute (50.2 hour) (see Table 4.8)

Production rate = Quantity/ (Utilization of Labor* Time)

Max. production rate = 470 m3 / (6.63 * 43.9) = 1.61m3 / labor-hour

Average production rate = 470 m3 / (6.63 * 47.2) = 1.50m3 / labor-hour

Min. production rate = 470 m3 / (6.63 * 50.20) = 1.41 m3 / labor-hour

4.6.6.7 Production Rates of Loading and Discharging of Rock

Process 4 (see Tables,4.1 ,4.7 and 4.8)

Quantity of rocks = 470 m3 (see Table 4.1)

Number of Loader = 1

Utilization of loader = 0.95 (see Table 5.7)

Min. time of transferring the rocks = 2634.5 minute (43.9 hour) (see Table 4.8)

Average time of transferring the rocks = 2831.65 minute (47.2 hour) (see Table 4.8)

Max. time of transferring the rocks = 3011.4 minute (50.2 hour) (see Table 4.8)

Production rate = Quantity/ (Utilization of Loader* Time)

Max. production rate = 470 m3 / (0.95 * 43.9) = 11.27m3 / hour

production rate = 470 m3 / (0.95 * 47.2) = 10.48m3 / hour

Min. production rate = 470 m3 / (0.95 * 50.20) = 9.86 m3 / hour Average

4.6.6.8 Production Rates of Spread Surface-Course

Process 5.2 (see Tables,4.1 ,4.7 and 4.8)

Quantity of base- course = 450 m2 (see Table 4.1)

Number of Labor = 3

Utilization of labor = 1.41 (see Table 5.7)

Min. time of spreading base- course = 513.43 minute (8.56 hour) (see Table 4.8)

Average time of spreading base- course = 583.74 minute (9.73 hour) (see Table 4.8)

Max. time of spreading base- course-course = 976.43minute (16.27 hour) (see Table 4.8)

Production rate = Quantity/ (Utilization of Labor* Time)

Max. production rate = 450 m3 / (1.41 * 8.56) = 37.28 m2 / labor-hour

Average production rate = 450 m3 / (1.41 * 9.73) = 32.8 m2 / labor-hour

Min. production rate = 450 m3 / (1.41 * 16.27) = 19.62 m2 / labor-hour

4.6.6.9 Production Rates of Transferring and Spreading of Surface-Course

Processes 5.1 and 5.2 (see Tables,4.1 ,4.7 and 4.8)

Quantity of base- course = 450 m2 (see Table 4.1)

Number of Loader = 1

Utilization of loader = 0.23 (see Table 5.7)

Min. time of loading and spreading base- course = 227.78 minute (3.79 hour) (see Table 4.8)

Average time of loading and spreading base- course = 200 minute (3.33 hour) (see Table 4.8)

Max. time of loading and spreading base- course = 179.25minute (2.99 hour) (see Table 4.8)

Production rate = Quantity/ (Utilization of Loader* Time)

Max. production rate = 450 m3 / (0.23 * 2.99) = 654.35 m2 / hour

Average production rate = 450 m3 / (0.23 * 3.33) = 587.54 m2 / hour

Min. production rate = 450 m3 / (0.23 * 3.79) = 516.23 m2 / hour

4.6.6.10 Production Rates of Compacting Surface-Course

Process 5.4 (see Tables,4.1 ,4.7 and 4.8)

Quantity of base- course = 450 m2 (see Table 4.1)

Number of Compactor = 1

Utilization of compactor = 0.34 (see Table 5.7)

Min. time of compacting base- course = 180 minute (3 hour) (see Table 4.8)

Average time of compacting base- course = 201 minute (3.35 hour) (see Table 4.8)

Max. time of compacting base- course = 379.46 minute (6.32 hour) (see Table 4.8)

Production rate = Quantity/ (Utilization of Compactor* Time)

Max. production rate = 450 m3 / (0.34 * 3) = 441.2 m2 / hour

Average production rate = 450 m3 / (0.34 * 3) = 395.1 m2 / hour

Min. production rate = 450 m3 / (0.34 * 6.32) = 209.42 m2 / hour

4.6.6.11 Production Rates of Assemble and Lace Box Gabion

Process 6.2 (see Tables,4.1 ,4.7 and 4.8)

Quantity of box gabion = 75 no (see Table 4.1)

Number of Labor = 12

Utilization of labor = 11.5 (see Table 5.7)

Min. time of assembly and lacing box gabion = 1050 minute (17.5 hour) (see Table 4.8)

Average time of assembly and lacing box gabion = 1229.59 minute (20.5 hour) (see Table 4.8)

Max. time of assembly and lacing box gabion = 1349.8 minute (22.5 hour) (see Table 4.8)

Production rate = Quantity/ (Utilization of Labor* Time)

Max. production rate = 75 no / (11.5 * 17.5) = 0.37 no / labor-hour

Average production rate = 75 no / (11.5 * 20.5) = 0.32 no / labor-hour

Min. production rate = 75 no / (11.5 * 22.5) = 0.29 no / labor-hour

5.6.6.12 Production Rates of Filling Box Gabion with Rock

Process 6.5 (see Tables,4.1 ,4.7 and 4.8)

Quantity of rock gabion = 150 m3 (see Table 4.1)

Number of Labor = 12

Utilization of labor = 11.5 (see Table 5.7)

Min. time of filling box gabion = 1170 minute (19.5 hour) (see Table 4.8)

average time of filling box gabion = 1481.54 minute (24.69 hour) (see Table 4.8)

Max. time of filling box gabion = 1829.9 minute (30.5 hour) (see Table 4.8)

Production rate = Quantity/ (Utilization of Labor* Time)

Max. production rate = 150 m3 / (11.5 * 19.5) = 0.69 m3 / labor-hour

Average production rate = 150 m3 / (11.5 * 24.69) = 0.53 m3 / labor-hour

Min. production rate = 150 m3 / (11.5 * 30.5) = 0.43 m3 / labor-hour

4.6.6.13 Production Rates of Spreading Sand Layer

Process 7.4 (see Tables,4.1 ,4.7 and 4.8)

Volume of sand = 100 m3 (see Table 4.1)

Number of Labor = 3

Utilization of labor = 1.4 (see Table 5.7)

Min. time of spreading sand layer = 157.38 minute (2.62 hour) (see Table 4.8)

average time of spreading sand layer = 174.07 minute (2.9hour) (see Table 4.8)

Max. time of spreading sand layer = 191.12 minute (3.19 hour) (see Table 4.8)

Production rate = volume of sand/ (Utilization of Labor* Time)

Max. production rate = 100 m3 / (1.4* 2.62) = 27.26 m3 / labor-hour

Average production rate = 100 m3 / (1.4* 2.9) = 24.63 m3 / labor-hour

Min. production rate = 100 m3 / (1.4 * 3.19) = 22.39 m3 / labor-hour

Table 4.9 Summary of the Simulated and Planned Production Rates of the Resources

Process no.	**Activity**	**Simulated Production Rates**			**Planned Production rate**	**% Difference Between Planned and Average Production rate**	**Resource**
		Min. Production rate	**Average Production rate**	**Max. Production rate**			
P1.2	Excavation and stockpiling of excavated material	52m3/h	64.31m3/h	75m3/h	17.4 m3/h	+ 72.94	Excavator
P1.3	Arranging the side slope and dewater	21.5 m2/h	23.56 m2/h	26.86 m2/h	18.5 m2/h	+ 21.48	Labor
P2	Laying of geotextile inside the apron	23.45 m2/h	45.66 m2/h	57.33 m2/h	5.49 m2/h	+ 87.98	Labor
P3	Spreading filter Inside the apron	8 m3/h 13.6 m3/h	8.97 m3/h 15.14 m3/h	10 m3/h 17 m3/h	2.76 m3/h 0.55 m3/h	+ 69.23 + 96.37	Loader Labor
P4	Distribution of rock inside the apron	1.41 m3/h 9.86 m3/h	1.5 m3/h 10.48 m3/h	1.61 m3/h 11.27 m3/h	5.97 m3/h 15.9 m3/h	- 298 - 51.72	Labor Loader
P5	Surface-course spreading	19.62 m2/h 120.3 m2/h 209 m2/h	32.8 m2/h 200.9 m2/h 394 m2/h	37.3 m2/h 228.6 m2/h 441.2 m2/h	8.65 m2/h 17.3 m2/h 17.3 m2/h	+ 73.63 + 91.39 + 95.61	Labor Loader Compactor
P6.2	Assembly and lacing box gabion	0.29 no/h	0.32 no/h	0.37 no/h	4.3 no/h	- 1243.75	Labor
P6.5	Filling Box gabion with rock	0.43 m3/h	0.53 m3/h	0.69 m3/h	3.61 m3/h	- 581.13	Labor
P7.4	Spreading sand layer	22.39 m3/h	24.63 m3/h	27.26 m3/h	30.6 m3/h	- 24.24	Labor

4.7 Significance of Production Rates

The main objective of simulation is to find the production rates for a case study which will work as a starting point to studying the productivity rate in engineering projects. This will help issuing a manual containing the productivity rates in engineering projects based on scientific and management studies conduct in Gaza Strip. This reference manual will help owners as well as contractors in determining the projects cost and in planning time schedules close to the actual work in site. It is a well known fact that classical methods of management and planning used in Gaza Strip led to some drawbacks in the construction sector in Gaza in the last period.

4.7.1 Comparison between Planned and Simulated Productivity

This study found that the used of simulation is very important in determining the productivity in ongoing project. The results shown three values of productivity that, represented in probabilistic production rates which contradicted the contractor plan which represented deterministic production rates.

This gives flexibility in implementing the engineering projects according to influencing factors in productivity and helps contractors to find out the range of productivity which help them cope with it during the construction phase of the project.

A simple comparison between productivity in principled activities according to simulation results and productivity of the contractor reveals the following:

1.Excavated and storage of excavated material activity:

A big gap was detected between contractor planning and simulated productivity so that the planned productivity was much less than the simulated one and it was found to be out of the allowed range. This proves that no scientific study was done to determine the productivity, hence, the activity cost.

2. Spreading filter inside the apron

The same found so that the planned activity is much less than the simulation results which represents the actual work in site.

3. Distribution of rock inside the apron

The productivity of this activity according to the planned was found to be much more than on site regarding workers and equipment needed to complete this activity. This proves the mis-understanding of the project nature and lack of implementation method studies which represent the actual work on site.

If we have look at the remaining activities in Table 4.9, we will find a huge difference between the simulated productivity and planned one. This show us that the estimation of the productivity rate for activities of the project was not scientifically and technically studied to suit the actuality.

It is obvious, therefore, that the process of productivity estimation for the project activities either overestimated or underestimated. This will negatively affect the implementation of the project and the estimation of the project actual cost which will finally lead to negative effect on the contractor such as:

1. inability to complete in future contract.
2. Revise the time table several times.
3. Disputes between the supervising team and the contractor representative regarding the duration of the project.
4. lack of control on quality.
5. Delays which leads to penalties.
6. Increase the cost of the project and its expenses during the implementation phase.

4.8 Limitations of the Study

The present study is characterized by the following limitations:

1. The study focuses only on the contractors in Gaza Strip.

2. Only contracting companies with 1st and 2nd class classifications are considered in the study.

3. The study considers only one case study.

4. This research concentrates on the construction phase of the life cycle of the project as a case study. In future, other studies should focus on different phases of the project such as estimating cost and time of the project before starting the actual implementation of the project and during the tendering stage.

5. Non-typical construction project was used in the case study which makes the conclusions limited. Studying a number of typical construction projects would results in general constructions and productivity rate that can be used by large number of constructions in planning for large number of projects.

"If any of the above limitations are to be eliminated, more manpower, money, and time are needed."

CHAPTER 5

Conclusion and Recommendations

This chapter outlines a series of conclusions derived from the discussion of the questionnaire and the case study. Based on these findings, recommendations will be also presented.

5.1 Conclusion

The present investigation has proved the following points:

1. Productivity measurement methods are not taken into considerations during the determination of the required duration and resources for planning and implementing the projects by the Gaza Strip contractors.

2. In Gaza companies, it has been proven that methods used for project scheduling are commonly dependent on practical experience and previously implemented projects, rather than depending on scientific methods such as Time Study, Rated Activity Sampling, and Analytical Estimating.

3. Contractors in Gaza lack the basic concept of the simulation technique and any familiarities with any related packages.

4. The study also demonstrated that the use of simulation leads to a range of time values (probabilistic durations) which are more accurate than the deterministic duration that is being used by the majority of the contractors in Gaza Strip.

5. A simulation process is a useful tool for determining the utilization of the required resources to carry out the activities.

6. In Gaza companies, the most important factors affecting productivity such as weather conditions, motivation of workers, and the use of scientific methods are not taken into considerations during the preparation time schedule.

7. The accuracy of data and being representable is necessary for the accurate prediction of duration and productivity.

5.2 Recommendations

For the present study, it is recommended that:

- **At the practice level:**

1. More attention should be paid to the use of the productivity measurement methods in construction sector in Gaza Strip.

2. Local companies should use simulation in preparing time schedules .

3. Local universities should offer and conduct training courses and seminars to local contractors on how to use new scientific tools to help improving project scheduling and productivity measurement.

- **At the research level**

1. There is an urgent need to establish reference manuals of production rates in the construction industry in Gaza

2. There is a need to link the simulation package (Arena) with MS project software to create an automatic interference between the two. This will save time, efforts, and improve performance on site.

3. There is a vital need for more investigations, similar to the present one, but considering different case studies. This will definitely help in achieving a reference manual.

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List of Appendices

Appendix (1)

English Language Questionnaire

Section (I):

Organization profile:

1.Year of establishment ………………..

2.Scope of company

a. Building works ☐ , b. Road works ☐ , c. Sewerage works ☐ ,

d. Water works ☐ , e. Others ☐ .

3. Current field of work, which is well known in the company

a. Building works ☐ , b. Road works ☐ , c. Sewerage works ☐ ,

d. Water works ☐ , e. Others ☐ .

4. Classification degree according to union contractors

a. First class (A) ☐ , b. First class (B) ☐ , c. Second class ☐ ,

d. Third class ☐ .

5. Average of total employees in the company during last five years ……………

6. Average of permanent technicians and workers in the company during the last five years ……………

7. Number of executed project during the last five year

a. Less than 10 ☐ , b. In between 11 – 19 ☐ ,

c. In between 20 – 29 ☐ , d. More than 30 ☐ .

8. Total amount of executed projects during the last five years (US$)

a. Less than 2 ☐ , b. In between 2 – 4 ☐ , c. In between 4 – 7 ☐ ,

d. More than 8 ☐ .

9. Did the company preserve the previous executed files related to the projects ?

a. Yes ☐ , b. Sometimes ☐ , c. No ☐ .

10. In question (9), if the answer is yes, Is there any expected profit regarding similar projects which will be executed in the future ?

a. Yes ☐ , b. Sometimes ☐ , c. No ☐ .

11. Administrator job concerning the person who fill the questionnaire

a. Company director ☐ , b. Projects manager ☐ ,

c. Project manager ☐ , d. Site engineer ☐ , e. Others ☐ .

section (II):

preparation of time schedule for projects:

1. Method of preparing time schedule

a. Manual ☐ , b. Using computer ☐ .

2. Preparing time schedule for any project accomplished by

a. Project manager ☐ , b. Site engineering ☐ , c. Office engineering ☐ ,

d. Advisory office ☐ .

3. Is there any resource presented concerning any project while preparing time schedule and planning

a. Efficiency technicians ☐ , b, Similar projects ☐ ,

c. Method of time and resource measurement ☐ , d. Nothing ☐ .

4. When time schedule usually prepared ?

a. Period of bid study ☐ , b. After gaining the bid and during preparing the work ☐ , c. During commencing of work ☐ .

5. Should any consideration going to be taken for specialization and leveling allocation in regard to (workers and equipment) while preparing time schedule ?

a. Yes ☐ , b. Sometimes ☐ , c. No ☐ .

6. Should any consideration going to be taken during preparing time schedule for estimating time and supplying materials ?

6.1 Visiting the site ☐,

6.2 Bill of quantity and analytic of (BOQ) ☐,

6.3 Studying the drawings and specification ☐,

6.4 Analytic the determined time by the owner ☐,

6.5 Analytic and study of daily production ☐, 6.6 Weather conditions ☐.

7 Which of the following methods is taken during preparing time schedule in the company ?

a. Bar chart ☐, b. C.P.M. ☐, c. PERT ☐, d. Others ☐.

8. Many times time schedule needs to be revised during the project of executing the project

a. No changing ☐, b. Once ☐, c. 2 – 3 times ☐, d. More than 3 times ☐.

9. Reasons which lead to revise time schedule along with it's numerating according to importance of priority

9.1 Political circumstance in Gaza Strip ☐,

9.2 Difference between planned activities and executed activities ☐,

9.3 Weakness of cash flow in the company ☐,

9.4 Weakness of productivity during the work ☐,

9.5 Difficulty in applying technical specification ☐,

9.6 Delay of supervision in inspecting work's efficiency ☐,

9.7 Weakness of administration in site ☐,

9.8 Unavailability of technical experience in the company ☐,

9.9 Lack of time schedule's planning according to the actual work ☐.

10. Is there imagination for the efficiency and linkage of work during preparing time schedule from commencing date to the end of the project ?

a. Yes ☐, b. No ☐.

11. If the previous question is (Yes), to what percentage of accuracy given to such imagination during project executing

a.80 % – 100 % ☐, b. 60 % – 79 % ☐, c. 50 % – 59 % ☐,

d. Less than 50 % ☐.

12. If the question (10) is negative, do you thing the reason is due to technical mechanism such as (Simulation)

a. Yes ☐ , b. No ☐ .

13. What is the extent of your understanding for (Arena) program witch used in (Simulation) work for construction projects.

13.1 don't know the program ☐ ,

13.2 Having a simple idea about the program ☐ ,

13.3 Having a good idea about the program ☐ ,

13.4 Having excellent idea about the program ☐ .

14. If your answer in the previous question (13), "I don't know the program and having a simple idea about it" would you like to take practical courses for the program to develop the work of the company ?

a. Yes ☐ , b. No ☐ .

15. If your answer in the previous question (13), "Having a good and excellent idea" do your company use this program ?

a. Yes ☐ , b. No ☐ .

Section (III):

The factors affecting productivity for preparation of time schedule:

1.Does your company specify a required time for the efficiency and workers according to:

1.1 Production rate ☐ ,

1.2 Comparison of previous executed projects ☐ ,

1.3 Practical experience in planning ☐ ,

1.4 Random methods ☐ .

2.If the answer in previous question with "Production rate" witch of the following methods used for work measurement ?

2.1 Time study ☐ ,

2.2 Work sampling ☐ ,

2.3 Comparative estimating ☐ ,

2.4 Synthesis and analytical estimating ☐ .

3. In case of merging to element from the previous question (1) for determination the time and workers of the activity, select the best

3.1 Production rate and comparison of previous executed projects ☐ ,

3.2 Production rate and practical experience in planning ☐ ,

3.3 Comparison of previous executed projects and practical experience in planning ☐ .

4. Factors affect the increment of production rate in construction projects of Gaza companies

1 = Little importance , 2 = Of some importance , 3 = Quit important

4 = Important , 5 = Very important

No	Description of factors	1	2	3	4	5
1.	Follow a good administration system in the site					
2.	Avail needed construction materials according to T.S.					
3.	Reducing wasted time during the work					
4.	Adhere to specifications and drawings					
5.	Weather conditions during the year seasons					
6.	The owner supervising team					
7.	Contractor monitoring & follow up of works					
8.	Periodic weekly meeting of owner and contractor					
9.	Availability of skilled labors					
10.	Follow up the time table for all activities					
11.	Incentives for workers					
12.	Periodic maintenance for equipment					
13.	Availability of safety measures on site					
14.	Work nature					
15.	Use of modern technical means					
16.	Financial statues of the company					
17.	Technical statues of the company					
18.	People perception of the project importance					
19.	Training sessions for the technical staff					
20.	Cooperation between the technical staff and the skilled labor					

5. Material factors for motivation of the workers and increasing the productivity

1 = Little importance , 2 = Of some importance , 3 = Quit important

4 = Important , 5 = Very important

No	Description material factors	1	2	3	4	5
1.	Salary payment at month end					
2.	Pay of loans according to labor needs					
3.	Paid allowances in occasions for labors					
4.	Salary increment for hard worker					
5.	Paying of over time for the labor					
6.	Payment of incentives					

6. Moral factors for motivation of the workers and increasing the productivity

1 = Little importance , 2 = Of some importance , 3 = Quit important

4 = Important , 5 = Very important

No	Description moral factors	1	2	3	4	5
1.	Allowing for an annual leave for labor					
2.	Permanent employment of skilled labor					
3.	Complacent & flattering for labors					
4.	9 working hours according to labors law					
5.	Official employment & labors					
6.	Availability of safety measures for labors during the work					
7.	Allowing for break for labors from time to time					

Appendix (2)
Arabic Language Questionnaire

الجزء الأول :

السيرة الذاتية للشركة :

١. سنة التأسيس ....

٢. مجالات عمل الشركة :

أعمال مباني ☐ أعمال طرق ☐ أعمال الصرف الصحي ☐

أعمال المياه ☐ أخرى ☐

٣. المجال الأكثر شيوعا في عمل الشركة :

أعمال مباني ☐ أعمال طرق ☐ أعمال الصرف الصحي ☐

أعمال المياه ☐

٤. درجة التصنيف حسب اتحاد المقاولين لمجال العمل الرئيسي :

درجة أولى (أ) ☐ درجة أولى (ب) ☐ درجة ثاني ☐ درجة ثالثة ☐

٥. متوسط إجمالي عدد الموظفين في الشركة خلال الخمس سنوات الماضية ....

٦. متوسط إجمالي عدد العمال و الفنيين الدائمين في الشركة خلال الخمس سنوات الماضية

....

٧. عدد المشاريع المنفذة خلال الخمس سنوات الماضية

أقل من (١٠) ☐ ما بين (١٠-١٩) ☐ ما بين (٢٠-٢٩) ☐

أكثر من (٣٠) ☐

٨. إجمالي قيمة المشروعات المنفذة خلال الخمس سنوات الماضية (بالمليون دولار):

☐

أقل من (٢) ☐ ما بين (٢-٤) ☐ ما بين (٤-٧) ☐ أكثر من (٨) ☐

٩. هل تقوم الشركة بحفظ ملفات المشاريع السابقة التي تم تنفيذها :

نعم ☐ أحيانا ☐ لا ☐

١٠. إذا كانت الإجابة بنعم، فهل يتم الاستفادة منها في مشاريع مستقبلية مشابهة :

نعم ☐ أحيانا ☐ لا ☐

١١. الوظيفة الإدارية لمن يقوم بتعبئة الاستبيان :

مدير الشركة ☐ مدير مشاريع ☐ مدير مشروع ☐ مهندس موقع ☐

أخرى ☐

الجزء الثاني :

<u>تحضير الجداول الزمنية للمشاريع</u> :

١. كيفية تحضير الجدول الزمني :

يدوي ☐ باستخدام الحاسوب ☐ لا يتم تحضير جدول زمني ☐

٢. تحضير الجدول الزمني في الشركة لأي مشروع يتم بواسطة :

مدير المشروع ☐ مهندس الموقع ☐ مهندس مكتب ☐ مكتب استشاري ☐

٣. أثناء تحضير الجدول الزمني و التخطيط لفعاليات العمل هل يتم الاستعانة ب :

☐ فنيين في مجال الفاعلية.

☐ مشاريع مشابهة سبق تنفيذها.

☐ طرق قياس الوقت و الموارد للفاعلية.

☐ لا شيء مما سبق.

٤. متى يتم التحضير للجدول الزمني للمشروع :

☐ فترة دراسة العطاء.

☐ بعد الفوز بالعطاء و أثناء التحضير للعمل.

☐ أثناء البدء بالعمل.

٥. هل يتم الأخذ بعين الاعتبار تخصيص و تسوية الموارد (العمالة، المعدات)أثناء التحضير للجدول الزمني. :

نعم ☐ أحيانا ☐ لا ☐

٦. أثناء تحضير الجدول الزمني و التخطيط للجدول الزمني لتقدير الوقت و الموارد هل يؤخذ بعين الاعتبار :

☐ زيارة الموقع و التعرف على طبيعة العمل فيه.

☐ جدول الكميات و عملية التحليل للجدول.

☐ دراسة الخرائط و المواصفات جيدا.

☐ تحليل الوقت المحدد من قبل المالك.

☐ تحليل و دراسة الإنتاجية اليومية.

☐ العوامل الجوية.

٧. أي من الطرق الآتية تستخدم في تحضير الجدول الزمني في الشركة:

☐ طريقة مخطط القضبان. (Bar Chart)

☐ طريقة المسار الحرج . (C.P.M).

☐ طريقة بيرت (Project Evaluation And Review Technique).

☐ أخرى.

٨. عدد المرات التي يتم فيها تعديل الجدول الزمني خلال فترة تنفيذ المشروع:

لا يتم التعديل ☐ مرة واحدة ☐ (٢ –٣)مرة ☐ أكثر من ٣ مرات ☐

٩. ترجع الأسباب التي تؤدي إلى إعادة تعديل الجدول الزمني مع مراعاة ترقيمها حسب الأهمية :

- الظروف السياسية في قطاع غزة التي تؤدي لنقص المواد اللازمة للعمل. ☐
- وجود فرق بين الفعاليات المخطط لها و الفعاليات التي تنفذ . ☐
- ضعف مالي لدي الشركة (Cash Flow) . ☐
- ضعف الإنتاجية . ☐
- صعوبة تطبيق المواصفات الفنية. ☐
- تأخير من الإشراف في فحص فعاليات العمل لبدء فعاليات أخرى. ☐
- ضعف إداري في الموقع. ☐
- عدم وجود خبرات فنية من طرف الشركة لتحضير الجدول الزمني. ☐
- عدم صحة تخطيط الجدول الزمني حسب واقعية العمل. ☐

١٠. أثناء تحضيرك للجدول الزمني هل يتم رسم صورة كاملة لفعاليات العمل وترابطها مع بعضها البعض من بداية المشروع لنهايته أو بمعنى هل هناك التخيل التام لسير المشروع على الطبيعة بالموارد المطلوبة و الإنتاجية اللازمة لإنهاء المشروع في موعده المحدد:

نعم ☐ لا ☐

١١. إذا كانت الإجابة نعم إلى أي نسبة تصل دقة ذلك التخيل (نسبة مئوية) أثناء تنفيذ المشروع:

من ٨٠ - ١٠٠ ☐ من ٦٠ - ٧٩ ☐ من ٥٠ - ٥٩ ☐ اقل من ٥٠ ☐

١٢. إذا كانت الإجابة بلا ، هل تعتقد وجود تقنية فنية مثل (Simulation) (شرح سؤال "١٠" يساعدك في ذلك):

نعم ☐ لا ☐

١٣. ما مدى مفهومك و معرفتك ببرنامج (Arena) الذي يستخدم في عمل (Simulation) لمشاريع التشييد مثل المساعدة في قياس الإنتاجية و تحديد الوقت و الموارد المطلوبة للفاعلية لتوفير التكلفة :

١. ☐ لا أعرف البرنامج.
٢. ☐ لدي فكرة بسيطة عن البرنامج.
٣. ☐ لدي فكرة جيدة عن البرنامج.

٤. ☐ لدي فكرة ممتازة عن البرنامج.

١٤. إذا كانت الإجابة (١) ، (٢) هل ترغب في أخذ دورات عملية للبرنامج لتطوير أداء الشركة:

نعم ☐ لا ☐

١٥. إذا كانت الإجابة (٣) ، (٤) هل تقوم شركتك باستخدام هذا البرنامج في عمل سيناريوهات لتحديد وقت و موارد (عمالة/معدات) الفاعلية على أساس قياس معدل الإنتاجية اليومية:

نعم ☐ لا ☐

الجزء الثالث :

العوامل المؤثرة في الإنتاجية و قياسها لتحضير الجداول الزمنية في شركات قطاع غزة :

١. هل تقوم شركتك بتحديد زمن الفعالية (النشاط) والعمالة المطلوبة بناء على :

أ. ☐ قياس معدل العمل للفعالية (Production Rate).

ب. ☐ قياس بمشاريع سابقة منفذة .

ج. ☐ خبرة عملية في التخطيط .

د. ☐ طريقة عشوائية لبدء و إنهاء الفاعلية حسب مدة المشروع .

٢. إذا كانت الإجابة ب (أ) أي من الطرق التالية تستخدمها لقياس العمل (Work Measurement)

☐ دراسة الوقت

☐ تقدير تحليلي و اصطناعي

☐ تقدير عن طريق للمقارنة

☐ عينة عمل (عن طريق الملاحظة)

٣قيم العوامل المؤثرة في زيادة الإنتاجية في المشروعات الهندسية في قطاع غزة حسب درجة الأهمية

١ = مهمة بدرجة قليلة ٢ = مهمة بعض الشيء ٣ = مهمة لدرجة ما ٤ = مهمة

٥ = مهمة جدا .

الرقم	العامل المؤثر في الإنتاجية	١	٢	٣	٤	٥
١	اتباع نظام إدارة جيد في الموقع					
٢	توفير المواد اللازمة للعمل حسب الجدول الزمني					
٣	تقليل الوقت الفاقد أثناء العمل					
٤	اتباع المواصفات و الخرائط					
٥	العوامل الجوية في فصول السنة					
٦	جهاز الأشراف من قبل المالك					
٧	مراقبة و متابعة العمل من طرف المقاول					
٨	الاجتماعات الأسبوعية الدورية لطاقم المالك و					

	الإشراف					
٩	توفير الأيدي العاملة المهرة					
١٠	اتباع الجدول الزمني لكل الفعاليات					
١١	عوامل تحفيز العمال					
١٢	عمل صيانة دورية للمعدات					
١٣	توفير عوامل الأمان و السلامة في الموقع					
١٤	طبيعة العمل					
١٥	استخدام الوسائل التقنية الحديثة					
١٦	الوضع المالي للشركة					
١٧	الوضع الفني للشركة					
١٨	مدى فهم السكان المحليين لأهمية المشروع					
١٩	إعطاء دورات تدريبية للطاقم الفني					
٢٠	روح التعاون بين الطاقم الفني و العمال المهنيين					

٣. أي من العوامل الآتية تستعملها الشركة في تحفيز العمال التي تؤثر في زيادة إنتاجية العمل حسب الأهمية:

١ = مهمة بدرجة قليلة ٢ = مهمة بعض الشيء ٣ = مهمة لدرجة ما ٤ = مهمة

٥ = مهمة جدا.

الرقم	تصنيف الحافز	العامل المؤثر في الإنتاجية	١	٢	٣	٤	٥
	مادي						
١		دفع الراتب في نهاية كل شهر					
٢		إعطاء سلف للعمال أثناء حاجة العامل					
٣		صرف نقود في المناسبات المهمة للعمال					
٤		زيادة الراتب للعامل المجتهد					

٥		دفع أجرة الساعات الإضافية للعامل					
٦		صرف حوافز نقدية بين كل فترة و أخرى					
	معنوي						
١		إعطاء العامل إجازة سنوية					
٢		التشغيل الدائم للعمال المهنيين					
٣		عبارات الإطراء و المدح للعمال					
٤		العمل ٩ ساعات يومية حسب قانون العمل					
٥		العمل بعقد رسمي للعمال					
٦		توفير عوامل الأمان و السلامة للعمال					
٧		إعطاء العمال فترات راحة من حين لآخر					

Appendix (3)
Daily Reports of Data Collection

Process number: …………………….. Process name: ………………………………………………………………………………

Activity number: ……………………. Activity name: ……………………………………..……………………………………...

Day: ………………………………… Date:………………………. Weather: ……………………. Station number: …………………….

No.	Material Loading						Equipment Moving			Material discharging						
	Period of Loading		Quantity	Labor	Equipment	Loading Time	Time of Moving		Time	Discharging Time		Time	labor	Returning Time		Time
	Starting	Ending					Starting	Ending		Starting	Ending			Starting	Ending	
1.																
2.																
3.																
4.																
5.																
6.																
7.																
8.																
9.																

Process number: …………………….. Process name: ……………………………………………………………………………………
Activity number: ……………………. Activity name: …………………………………….…..……………………….……………………...
Day: ………………………………… Date:………………………. Weather: ………………………………………. …………………

No.	Station number	Equipment name	Labor	Work starting time	Work ending time	Work time	Time unit	Actually quantity	Unit	Remarks
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										

Process number: …………………….. Process name: ………………………………………………………………………………
Activity number: ……………………. Activity name: ……………………………………..…………………………………...
Day: ………………………………… Date:………………………. Weather: ……………………………………. …………………

No.	Station number	Resources	Inspection starting	Inspection ending	Inspection time	Time unit	Actually quantity	Unit	Remarks
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

Process number: …………………….. Process name: ……………………………………………………………………………………

Activity number: ……………………. Activity name: ……………………………………………..……………………….………………...

Day: ………………………………… Date:……………………….. Weather: ………………………………………. …………………

No.	Station number	Resources	Starting of repairing time	Ending of repairing time	Time of repairing work	Time unit	Actually quantity	Unit	Remarks
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

Appendix (4)

Data Collection and Statistical Distribution Functions

Process number 1: Excavation cliff and apron (Typical station)

P1.1 Move excavator to the required station

No.	Observation number	Time minute	Qty.	Resources	Data summary	Value
1	4	15	-	Excavator, Driver	Number of data points	14
2	2	17	-	Excavator, Driver	Minimum data value	15
3	3	20	-	Excavator, Driver	Maximum data value	32
4	4	30	-	Excavator, Driver	Sample mean	21.9
5	1	32	-	Excavator, Driver	Sample std Dev	6.87

Distribution Summary

Distribution : Beta

Expression : 14.5 + 18 *BETA (0.269, 0.389);Square Error: 0.131548

P1.2 Excavate station and stockpile excavated material

No	Observation number	Time Hr.	Qty.	Resources	Data summary	Value
1	3	14	750	Excavator, 5 labor	Number of data points	10
2	3	15	750	Excavator, 5 labor	Minimum data value	14
3	2	16	750	Excavator, 5 labor	Maximum data value	19
4	1	18	750	Excavator, 5 labor	Sample mean	15.6
5	1	19	750	Excavator, 5 labor	Sample std Dev	1.71

Distribution Summary

Distribution : Beta

Expression : 13.5 + 6 8 BETA (0.965, 1.6);Square Error: 0.032279

P1.3 Arrange the side slopes and dewater

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	3	120	370	5 labor	Number of data points	10
2	2	130	370	5 labor	Minimum data value	120
3	3	145	370	5 labor	Maximum data value	150
4	2	150	370	5 labor	Sample mean	136
					Sample std Dev	12.8

Distribution Summary

Distribution : Beta

Expression : 120 + 31 *BETA (0.241, 0.226); Square Error: 0.134933

P1.4 Inspect levels and distances

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	3	15	370	Surveyor, 2 labor	Number of data points	10
2	2	17	370	Surveyor, 2 labor	Minimum data value	15
3	2	19	370	Surveyor, 2 labor	Maximum data value	20
4	3	20	370	Surveyor, 2 labor	Sample mean	17.7
					Sample std Dev	2.16

Distribution Summary

Distribution : Beta

Expression : 14.5 + 6 * BETA (0.488, 0.427);Square Error: 0.050233

1.5 Repair the snags of cliff and apron

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	4	22	520	5 labor	Number of data points	10
2	1	24	520	5 labor	Minimum data value	22
3	2	25	520	5 labor	Maximum data value	30
4	1	27	520	5 labor	Sample mean	24.9
5	2	30	520	5 labor	Sample std Dev	3.18

Distribution : Beta

Expression : 21.5 + 9 * BETA (0.334, 0.551); Square Error: 0.050816

Process number 2: Geotextile laying inside the apron

P2.1 Transfer Geotextile to apron

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	2	10	516	10 labor	Number of data points	10
2	3	12	516	10 labor	Minimum data value	10
3	3	13	516	10 labor	Maximum data value	17
4	1	15	516	10 labor	Sample mean	12.7
5	1	17	516	10 labor	Sample std Dev	2.11

Distribution Summary

Distribution : Beta

Expression : 9.5 + 8 * BETA (1.11, 1.56); Square Error: 0.100310

P2.2 Fix geotextile in apron

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	2	45	516	10 labor	Number of data points	10
2	1	50	516	10 labor	Minimum data value	45
3	3	56	516	10 labor	Maximum data value	63
4	3	60	516	10 labor	Sample mean	55.1
5	1	63	516	10 labor	Sample std Dev	6.38

Distribution Summary

Distribution : Beta

Expression : 44.5 + 19 *BETA (0.785, 0.73); Square Error: 0.178603

Process number 3: Filter spreading inside the apron

P3.1 Load the filter

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	18	2	2	Loader	Number of data points	35
2	10	3	2	Loader	Minimum data value	2
3	4	4	2	Loader	Maximum data value	5
4	3	5	2	Loader	Sample mean	2.77
					Sample std Dev	0.973

Distribution Summary

Distribution : Beta

Expression : 1.5 + 4 *BETA (0.848, 1.82); Square Error: 0.004846

P3.2 Transfer the filter

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	25	2	2	Loader	Number of data points	35
2	10	3	2	Loader	Minimum data value	2
					Maximum data value	3
					Sample mean	2.29
					Sample std Dev	0.458

Distribution Summary

Distribution : Beta

Expression : 1.5 + 2 * BETA (1.94, 2 83); Square Error: 0.003285

P3.3 Spread filter in apron

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	5	1	2	Loader,2 labor	Number of data points	35
2	7	2	2	Loader,2 labor	Minimum data value	1
3	10	3	2	Loader,2 labor	Maximum data value	5
4	11	4	2	Loader,2 labor	Sample mean	2.94
5	2	5	2	Loader,2 labor	Sample std Dev	1.16

Distribution Summary

Distribution : Beta

Expression : 0.5 + 5 *BETA (1.77, 1.86);Square Error: 0.011714

P3.4 Move loader to temporary stockpile

No.	Observation number	Time minute	Qty.	Resources	Data summary	Value
1	15	3	-	Loader	Number of data points	35
2	20	2	-	Loader	Minimum data value	2
					Maximum data value	3
					Sample mean	2.57
					Sample std Dev	0.50

Distribution Summary

Distribution : Beta

Expression : 1.5 + 2 * BETA (2.14, 1 89);Square Error: 0.000584

P3.5 Inspect level of filter

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	4	6	70	Surveyor, 2 labor	Number of data points	10
2	3	7	70	Surveyor, 2 labor	Minimum data value	6
3	3	8	70	Surveyor, 2 labor	Maximum data value	8
					Sample mean	6.9
					Sample std Dev	0.88

Distribution Summary

Distribution : Beta

Expression : 5.5 + 3 *BETA (0.897, 1.02); Square Error: 0.000941

P3.6 Load filter from temporary stockpile

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	15	2	2	Loader	Number of data points	35
2	13	3	2	Loader	Minimum data value	2
3	4	4	2	Loader	Maximum data value	5
4	3	5	2	Loader	Sample mean	2.86
					Sample std Dev	0.994

Distribution Summary

Distribution : Beta

Expression : 1.5 + 4 * BETA (0.848, 1.82); Square Error: 0.004846

P 3.7 Transfer filter from temporary stockpile to apron

No.	Observation number	Time minute	Qty. M3	Resourc es	Data summary	Value
1	10	2	2	Loader	Number of data points	35
2	8	3	2	Loader	Minimum data value	2
3	6	4	2	Loader	Maximum data value	6
4	6	5	2	Loader	Sample mean	3.66
5	5	6	2	Loader	Sample std Dev	1.43

Distribution Summary

Distribution : Beta

Expression : 1.5 + 5 *BETA (0.856, 1.13); Square Error: 0.000670

P3.8 Spread filter at apron side

No.	Observatio n number	Time (Day)	Qty. M3	Resources	Data summary	Value
1	2	6	60	3 Labor	Number of data points	13
2	8	8	60	3 Labor	Minimum data value	6
3	3	9	60	3 Labor	Maximum data value	9
					Sample mean	7.92
					Sample std Dev	0.954

Distribution Summary

Distribution : Beta

Expression : 5.5 + 4 * BETA (2.22, 1.56); Square Error: 0.138404

P3.9 Move loader to temporary stockpile

No.	Observation number	Time minute	Qty.	Resources	Data summary	Value
1	15	3	-	Loader	Number of data points	35
2	20	2	-	Loader	Minimum data value	2
					Maximum data value	3
					Sample mean	2.57
					Sample std Dev	0.50

Distribution Summary

Distribution : Beta

Expression : 1.5 + 2 * BETA (2.14, 1 89);Square Error: 0.000584

Process number 4: Rock distribution inside the apron

P4.1 Load rock from temporary stockpile

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	35	1	2	Loader	Number of data points	235
2	50	2	2	Loader	Minimum data value	1
3	90	3	2	Loader	Maximum data value	5
4	40	4	2	Loader	Sample mean	2.83
5	20	5	2	Loader	Sample std Dev	1.14

Distribution Summary

Distribution : Beta

Expression : 0.5 +5 *BETA (1.79, 2.05); Square Error: 0.015253

P4.2 Transfer rock to apron

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	110	1	2	Loader	Number of data points	235
2	75	2	2	Loader	Minimum data value	1
3	50	3	2	Loader	Maximum data value	3
					Sample mean	1.74
					Sample std Dev	0.786

Distribution Summary

Distribution : Beta

Expression : 0.5 + 3 *BETA (1.05, 1.48); Square Error: 0..003348

P4.3 Discharge rock inside apron

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	75	3	2	Loader, 7 labor	Number of data points	235
2	60	4	2	Loader, 7 labor	Minimum data value	3
3	55	5	2	Loader, 7 labor	Maximum data value	7
4	25	6	2	Loader, 7 labor	Sample mean	4.67
5	20	7	2	Loader, 7 labor	Sample std Dev	4.91

Distribution Summary

Distribution : Beta

Expression : 2.5 + 75 *BETA (0.96, 15.9) ; Square Error: 0.044362

P4.4 arrange rock inside apron

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	95	2	-	7 Labor	Number of data points	235
2	70	3	-	7 Labor	Minimum data value	2
3	70	4	-	7 Labor	Maximum data value	4
					Sample mean	2.89
					Sample std Dev	0.833

Distribution Summary

Distribution : Beta

Expression : 1.5 + 3*BETA(1.03, 1.19); Square Error: 0.004541

P4.5 Return back to temporary stockpile

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	135	1	-	Loader	Number of data points	235
2	100	2	-	Loader	Minimum data value	1
					Maximum data value	2
					Sample mean	1.43
					Sample std Dev	0.495

Distribution Summary

Distribution : Beta

Expression : 0.5 + 2 *BETA(1.41, 1.64); Square Error: 0.000559

P4.6 Inspect work

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	4	20	48	Engineer	Number of data points	9
2	5	25	48	Engineer	Minimum data value	20
					Maximum data value	25
					Sample mean	22.8
					Sample std Dev	2.64

Distribution Summary

Distribution : Beta

Expression : 19.5 + 6* BETA (0.156, 0.129); Square Error: 0.096354

P4.7 Repair the snags

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	4	25	470	4 Labor	Number of data points	9
2	5	30	470	4 Labor	Minimum data value	25
					Maximum data value	30
					Sample mean	27.8
					Sample std Dev	2.64

Distribution Summary

Distribution : Beta

Expression : 24.5 + 6 * BETA (0.156, 0.129); Square Error: 0.211443

Process number 5: Surface – course spreading

P 5.1 Transfer course material to site

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	2	30	450	truck	Number of data points	10
2	2	32	450	truck	Minimum data value	30
3	2	34	450	truck	Maximum data value	40
4	2	36	450	truck	Sample mean	34.4
5	2	40	450	truck	Sample std Dev	3.63

Distribution Summary

Distribution : Beta

Expression : 29.5 + 11 *BETA(0.567, 0.705); Square Error: 0.090989

P5.2 Spread surface- course

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	3	120	450	Loader, 3 Labor	Number of data points	10
2	3	130	450	Loader, 3 Labor	Minimum data value	120
3	2	135	450	Loader, 3 Labor	Maximum data value	146
4	1	140	450	Loader, 3 Labor	Sample mean	131
5	1	146	450	Loader, 3 Labor	Sample std Dev	8.83

Distribution Summary

Distribution : Beta

Expression : 120 + 27 *BETA(0.519, 0.743) ; Square Error: 0.158964

P5.3 Inspect level of surface- course

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	3	10	450	Surveyor,2 labor	Number of data points	10
2	2	11	450	Surveyor,2 labor	Minimum data value	10
3	3	12	450	Surveyor,2 labor	Maximum data value	14
4	2	14	450	Surveyor,2 labor	Sample mean	11.6
					Sample std Dev	1.51

Distribution Summary

Distribution : Beta

Expression : 9.5 + 5 *BETA (0.708, 0.978); Square Error: 0.044636

P5.4 Watering and compacting surface- course

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	3	180	450	Compactor, 2 Labor	Number of data points	10
2	4	185	450	Compactor, 2 Labor	Minimum data value	180
3	3	193	450	Compactor, 2 Labor	Maximum data value	193
					Sample mean	186
					Sample std Dev	5.36

Distribution Summary

Distribution : Beta

Expression : 180 + 14 *BETA (0.316, 0.375); Square Error: 0.162191

5.5 Inspect degree of compaction

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	3	15	-	-	Number of data points	10
2	2	16	-	-	Minimum data value	15
3	1	17	-	-	Maximum data value	20
4	2	18	-	-	Sample mean	17
5	2	20	-	-	Sample std Dev	1.94

Distribution Summary

Distribution : Beta

Expression : 14.5 + 6 *BETA (0.548, 0.768); Square Error: 0.030132

P5.6 Wait to get lab. results

No.	Observation number	Time minute	Qty. M2	Resources	Data summary	Value
1	2	130	-	-	Number of data points	10
2	1	136	-	-	Minimum data value	130
3	1	140	-	-	Maximum data value	147
4	2	142	-	-	Sample mean	140
5	3	145	-	-	Sample std Dev	6.21
6	1	147	-	-		

Distribution Summary

Distribution : Beta

Expression : 130 + 18 *BETA (0.775, 0.654); Square Error: 0.13274

Process number 6: Box gabion installing

P6.1 Transfer box gabion

No.	Observation number	Time minute	Qty. No.	Resources	Data summary	Value
1	2	15	75	10 Labor	Number of data points	12
2	3	17	75	10 Labor	Minimum data value	15
3	3	18	75	10 Labor	Maximum data value	22
4	1	19	75	10 Labor	Sample mean	18
5	2	20	75	10 Labor	Sample std Dev	2.04
6	1	22	75	10 Labor		

Distribution Summary

Distribution : Beta; Expression : 14.5 + 8 * BETA (1.28, 1.62);

Square Error: 0.058581

P6.2 Assemble and lace box gabion

No.	Observation number	Time (hr)	Qty. No.	Resources	Data summary	Value
1	3	18	75	4 Labor	Number of data points	12
2	2	19	75	4 Labor	Minimum data value	18
3	3	21	75	4 Labor	Maximum data value	22
4	4	22	75	4 Labor	Sample mean	20.3
					Sample std Dev	1.71

Distribution Summary

Distribution : Beta

Expression : 17.5 + 5 *BETA (0.611, 0.5); Square Error: 0.035587

P6.3 Inspect and repeat lacing of box gabion

No.	Observation number	Time minute	Qty. No.	Resources	Data summary	Value
1	2	30	75	Engineer	Number of data points	12
2	4	35	75	Engineer	Minimum data value	30
3	3	37	75	Engineer	Maximum data value	45
4	2	40	75	Engineer	Sample mean	36.3
5	1	45	75	Engineer	Sample std Dev	4.16

Distribution Summary

Distribution : Beta

Expression : 29.5 + 16 * BETA (0.971, 1.27); Square Error: 0.169509

P6.4 Load and transfer rock gabion

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	20	6	2	Loader	Number of data points	75
2	25	8	2	Loader	Minimum data value	6
3	24	9	2	Loader	Maximum data value	12
4	6	12	2	Loader	Sample mean	8.11
					Sample std Dev	1.64

Distribution Summary

Distribution : Beta

Expression : 5.5 + 7 *BETA (1.21, 2.04); Square Error: 0.118868

P6.5 Fill box gabion with rock

No.	Observation number	Time (hr.)	Qty. No.	Resources	Data summary	Value
1	2	20	75	12 Labor	Number of data points	12
2	3	22	75	12 Labor	Minimum data value	20
3	2	23	75	12 Labor	Maximum data value	30
4	1	25	75	12 Labor	Sample mean	24.8
5	4	30	75	12 Labor	Sample std Dev	4.09

Distribution Summary

Distribution : Beta

Expression : 19.5 + 11 *BETA (0.383, 0.419); Square Error: 0.097862

P6.6 Inspect rock during filing

No.	Observation number	Time minute	Qty. No.	Resources	Data summary	Value
1	3	20	75	Engineer	Number of data points	12
2	4	23	75	Engineer	Minimum data value	20
3	2	26	75	Engineer	Maximum data value	32
4	2	30	75	Engineer	Sample mean	24.7
5	1	32	75	Engineer	Sample std Dev	4.16

Distribution Summary

Distribution : Beta

Expression : 19.5 + 13 *BETA (0.531, 0.804); Square Error: 0.130680

P6.7 Repair snags if any

No.	Observation number	Time minute	Qty. No.	Resources	Data summary	Value
1	3	40	75	4 Labor	Number of data points	12
2	2	43	75	4 Labor	Minimum data value	40
3	3	45	75	4 Labor	Maximum data value	50
4	2	48	75	4 Labor	Sample mean	44.8
5	2	50	75	4 Labor	Sample std Dev	3.7

Distribution Summary

Distribution : Beta

Expression : 39.5 + 11 *BETA (0.578, 0.633);Square Error: 0.090555

Process number: 7 Cliff and Beach side slope backfilling

P 7.1: adjust cliff and beach side slope

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	5	10	100	1 Labor	Number of data points	13
2	3	12	100	1 Labor	Minimum data value	10
3	2	13	100	1 Labor	Maximum data value	15
4	1	14	100	1 Labor	Sample mean	12
5	2	15	100	1 Labor	Sample std Dev	1.91

Distribution Summary

Distribution : Beta

Expression : 9.5 + 6 *BETA (0.578, 0.809); Square Error: 0.039334

P 7.2: Load sand from temporary stockpile

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	6	16	100	1 Truck,1Loader	Number of data points	13
2	2	18	100	1 Truck,1Loader	Minimum data value	16
3	3	21	100	1 Truck,1Loader	Maximum data value	25
4	1	24	100	1 Truck,1Loader	Sample mean	18.9
5	1	25	100	1 Truck,1Loader	Sample std Dev	3.27

Distribution Summary

Distribution : Beta

Expression : 15.5 + 10*BETA (0.346, 0.712); Square Error: 0.063882

P 7.3: Transfer sand from temporary stockpile to site

No.	Observation number	Time minute	Qty.	Resources	Data summary	Value
1	7	15	100	Truck	Number of data points	13
2	2	16	100	Truck	Minimum data value	15
3	2	17	100	Truck	Maximum data value	20
4	1	19	100	Truck	Sample mean	16.2
5	1	20	100	Truck	Sample std Dev	1.68

Distribution Summary

Distribution : Beta

Expression : 14.5 + 6 *BETA (0.43, 1.13); Square Error: 0.019118

P 7.4: Spread layer sand

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	6	12	100	Loader, 4 Labor	Number of data points	13
2	3	13	100	Loader, 4 Labor	Minimum data value	12
3	2	15	100	Loader, 4 Labor	Maximum data value	17
4	1	16	100	Loader, 4 Labor	Sample mean	13.4
5	1	17	100	Loader, 4 Labor	Sample std Dev	1.76

Distribution Summary

Distribution : Beta;   Expression:11.5 + 6 *BETA (0.474, 1.04);

Square Error: .027

P 7.5: Water and compact layer

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	6	15	100	Compactor, 2 Labor	Number of data points	13
2	3	16	100	Compactor, 2 Labor	Minimum data value	15
3	2	17	100	Compactor, 2 Labor	Maximum data value	19
4	1	18	100	Compactor, 2 Labor	Sample mean	16.1
5	1	19	100	Compactor, 2 Labor	Sample std Dev	1.32

Distribution Summary

Distribution : Beta; Expression: 14.5 + 5 * BETA (0.661, 1.43);

SquareError:0.002

P 7.6: Inspect degree of compaction

No.	Observation number	Time minute	Qty. M3	Resources	Data summary	Value
1	2	10	100	Technician man	Number of data points	13
2	4	11	100	Technician man	Minimum data value	10
3	5	12	100	Technician man	Maximum data value	14
4	1	13	100	Technician man	Sample mean	11.6
5	1	14	100	Technician man	Sample std Dev	1.12

Distribution Summary

Distribution : Beta;

Expression: 9.5 + 5 *BETA (1.82, 2.42);

Square Error: 0.0215

P 7.7: Wait to get lab. results

No.	Observation number	Time minute	Qty.	Resources	Data summary	Value
1	6	80	-	-	Number of data points	13
2	3	90	-	-	Minimum data value	80
3	1	95	-	-	Maximum data value	105
4	2	100	-	-	Sample mean	88.5
5	1	105	-	-	Sample std Dev	9.22

Distribution Summary

Distribution: Beta ;

Expression:79.5 + 26 *BETA (0.275, 0.523); Square Error:0.106745