INTEGRATION OF PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT), GANTT CHART AND GENETIC ALGORTIHM

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ABSTRACT

Project scheduling is important to the completion of a project. Since having delay, out of inventory and budget overrun make the failure of the project, project managers shall be able to handle a project with a certain scheduling decision making tool accordingly. A good technique for scheduling the project is required such that a proper manageable schedule can be suggested. In this thesis, the discussion on the integration approach, which combines Program Evaluation and Review Technique (PERT), Gantt Chart (GC) and Genetic Algorithm (GA), is carried out. However, there are another techniques that have been considered before choosing that techniques which are Critical Path Method (CPM) and Work Breakdown Structure (WBS). The aims are (1) to review the existing scheduling techniques, (2) to propose an integrated approach for solving the scheduling problem in the construction industry, and (3) to compare the applicable of the approach proposed with the existing techniques. For doing so, three steps are taken into account. First, doing the integration of PERT and GC, where Earliest Start time (ES) and Earliest Finish time (EF) are calculated. Second, is applying GA to the existing integration approach. In GA procedure, the chromosome is generated randomly to obtain the gene of parents. Further from this, the gene of offspring is refined through the operators of crossover and mutation. Third, the diagram of GC is depicted. For illustration, a set of the real data obtained from a construction company is studied. The project is to build the bounding walls at four different roads in Pasir Gudang, Johor Bharu. By using the approach proposed, a comprehensive schedule is produced, where the finishing time of the project is six day earlier or 6.06% than the original finishing time, which is 99 days. In conclusion, the efficiency of the approach proposed is highly recommended for project managers in developing an effective schedule.

ABSTRAK

Jadual adalah penting untuk menyiapkan projek. Untuk mengelakkan masalah kelewatan, kekurangan stok, dan kekurangan bajet yang boleh menyebabkan kegagalan kepada projek, pengurus projek seharusnya menguruskan projek itu dengan menggunakan teknik penjadualan sebaik mungkin. Satu teknik penjadualan projek yang teratur di cadangkan. Dalam kajian ini, teknik Program Evaluation and Review Technique (PERT), Gantt Chart (GC) dan Genetic Algorithm (GA) digabungkan. Namun, terdapat juga teknik lain yang di ambil kira sebelum memilih teknik ini iaitu Critical Path Method (CPM) dan Work Breakdown Structure (WBS). Objektif adalah (1) meninjau teknik-teknik penjadualan yang sedia ada, (2) untuk mencadangkan satu teknik penggabungan untuk menyelesaikan masalah jadual dalam industri pembangunan, dan (3) untuk membandingkan teknik yang di cadangkan dengan teknik terdahulu. Terdapat tiga langkah untuk melaksanakannya. Pertama, menggabungkan antara PERT dengan GC dengan pengiraan untuk Earliest Start time (ES) and Earliest Finish time (EF) dilakukan. Kedua, mengaplikasikan teknik GA ke dalam teknik pergabungan yang dilakukan tadi. Langkah-langkah untuk GA adalah kromosom dihasilkan secara rawak untuk mendapatkan genetik induk. Genetik untuk generasi anak diperbaharui melalui proses penyilangan dan mutasi. Ketiga melakarkan GC yang baru. Data diambil dari syarikat pembinaan. Projek yang dijalankan adalah membina dinding yang terletak di empat tempat yang berbeza di Pasir Gudang, Johor Bharu. Dengan menggunakan teknik yang dicadangkan, jadual yang lebih baik dihasilkan, di mana tarikh untuk menyiapkan projek adalah enam hari lebih awal atau 6.06% dari tarikh asal projek itu iaitu 99 hari. Kesimpulannya, teknik yang dicadangkan ini adalah sangat disarankan untuk pengurus projek dalam menghasilkan jadual yang berkesan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AOA	–	Activity on Arrow
AON	–	Activity on Node
ARIS	–	Architecture of Integrated Information System
CPM	–	Critical Path Method
DFD	–	Data Flow Diagram
EF	–	Earliest Finish Time
ERP	–	Enterprise Resource Planning
ES	–	Earliest Start Time
FCFS	–	First Come First Serve
FS	–	Finish-Start
FF	–	Finish-Finish
GA	–	Genetic Algorithm
GC	–	Gantt chart
i	–	Index
IDEF3	–	Integrated DEFinition for Process Description Capture Method
LF	–	Late Finish Time
LPT	–	Longest Processing Time
LS	–	Late Start Time
M	–	Mutation
MATLAB	–	Matrix Laboratory
N	–	Number of generation
Of	–	Offspring
OSTN	–	Object State Transition Network

P	–	Parent
PERT	–	Program Evaluation and Review Technique
SF	–	Start-Finish
SS	–	Start-Start
SPT	–	Shortest Processing Time
WBS	–	Work Breakdown Structure

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In project management, four stages, which are scheduling, planning, monitoring and controlling resources, are considered. These stages the project to be finished according to the schedule estimated and the budget made. Technique of project management, especially scheduling, is used commonly in the industries that are ranged from business, engineering and construction. A good practice in project management assigns the resources to tasks or activities as the performance of a project is evaluated. On this basis, the typical objectives of project management include minimizing the respective costs of completing the project, maximizing the quality of the product and minimizing the duration of the project. While, the resources include people, skills, time, equipment and facilities.

Project management is the design of an assembly of tasks by a group of individual experts from diverse parts of a society. They work together for a limited duration to contribute towards a specific job (Laslo, 2010).

A project without proper scheduling may lead to a mess, deviation from the expected time and waste of raw materials. To ensure the project completes within a desirable time period, the earliest start and finish times for each activity are determined. In addition to this, the likelihood of project is calculated. Consequently, the minimum cost that is expended for the project can be obtained.

The activities of the production are notified in the scheduling diagram, where their priority to be finished in a certain time period according to the finishing order, is described. Moreover, the critical path of the project and the time for delaying the project can be determined. It is important to notice that the expected time and the slack time of the project completion are then identified.

In this study, Program Evaluation and Review Technique (PERT) and Gantt chart (GC) are integrated with Genetic Algorithm (GA) in solving the scheduling problems. In literature, these techniques are used independently or integrated with one of the others, but three of them do not integrate with each other to obtain the scheduling solutions. The idea, which integrates PERT, GC and GA, gives the motivation for us to explore the applicability of the approach proposed for a better scheduling solution.

1.2 Background of Study

An integration technique that is studied by Jia *et al.* (2007) is the method for job shop scheduling in distributed manufacturing systems. The efficiency of this integration technique in solving small-sized scheduling problem for a distributed manufacturing system was proven, where the makespan for manufacturing of all the jobs is 11 unit times with CPU time of PIII- 1.5G/512-RAM is 10 seconds. In the previous study (Jia, *et al.,* 2007) the computational time is 15 second only by using GA.

Another integration technique is the integrated GA, Enterprise Resource Planning (ERP) and PERT by Wang *et al.* (2008). In their study, the uncertain optimization problems on implementation of schedule, time-cost trade-off and quality are discussed. As mentioned in (Wang *et al*., 2008), the ERP project with stochastic programming model solution is successfully explained. The schedule of optimization model is equivalent to the characters of project management and the result is well-defined.

From the studies of Jia *et al*. (2007) and Wang *et al*. (2008), the advantages of the integrated approaches are beneficial and useful. They inspire us to integrate PERT and GC with GA in order to provide an efficient scheduling solution. Since GA is a natural evolution algorithm, it is desired that the scheduling solution can be improved particularly.

Table 1.1: Report of Project failed to finish according to the schedule

Sources	Statement
(Sambasivan & Soon, 2007)	There are 17.3% of 417 government contract projects were considered sick, or more than 3 months of delay or abandoned.
(Abdullah *et al.*,2011)	More than 90% of large MARA construction projects are experienced delay
The Malaysian Insider (2013)	The physical of four from five projects done did not satisfy the plan. The projects were supposedly to finish between 224 days until 672 days. However, it failed to finish on time even though an extension time was given from 174 days until 617 days. According to the report, there are several weaknesses about the management of the projects. These weaknesses were not investigated before the construction, and the finished projects cannot be used by public or tourist. Other weaknesses are that the projects were not built according to the terms, conditions and specifications of contracts.
Berita Harian (2013)	In every year, there will be 10 until 15 percent of construction projects that do not finish according to the schedule. It is also

Table 1.1: continued

	not doing the construction according to the specification. Many factors occur such as weather, structure of the soil at the site, construction techniques and changes of specification.
Kementerian Kesejahteraan Bandar, Perumahan dan Kerajaan Tempatan Komunikasi Korporat. (2013)	According to the Minister of Urban Wellbeing, Housing and Local Government, there are about 44 of the project are delayed and 186 are considered sick until 15th September 2013.

1.3 Problem Statement

For companies and factories, completing the project in the expected time is a crucial task. The completion of a project gives an economical perspective to satisfy the request of the customers. In construction industry, many projects are not finished accordingly to the schedule. Thus, an extra amount of the budget and time will be requested to finish the project. Due to these reasons, project managers need to have a better technique to develop a good schedule to ensure project can be run smoothly

Furthermore, the project scheduling involves sequencing and allocating time to all project activities. The manager has to decide how long each activity will be taken and to compute how many resources, including workers and materials, will be needed at each stage of the project (Heizer & Render, 2011). Scheduling is normally the bottom atomic partition of the project, which cannot be sectioned. The items of the project are frequently estimated in terms of resource requirements, budget and duration, where they are connected dependently (Ramzan *et al*., 2010).

The existing tools of project management such as Program Evaluation and Review Technique (PERT), Gantt chart (GC), Critical Path Method (CPM), and Work Breakdown Structure (WBS) are the tools used to monitor the project. With these tools, the project can be run smoothly according to the planning and they help managers to cut down costs when projects are completed on time. PERT and GC cannot cope the back-and-forth altercation of information that usually happens in product development projects (Eppinger, 2001; Shi & Blomquist, 2012). Therefore, many studies about the integration of the project management techniques have been done by researchers. For examples, Azaron *et al.* (2005) applied GA to develop a model for solving the time-cost trade-off problem in PERT network, where Erlang distributions of activity durations are generalized. From their experiment, the proposed GA method shows its efficiency. The study of GA with GC by Jia *et al.* (2007) shows that by applying GA to the project duration, the project cost can be reduced.

Unfortunately, the previous studies only integrate two of these techniques without comparing to any other methods. In this study, it is proposed that an integration of three methods, which are PERT, GC and Gantt chart, would be further considered. Additional, a comparison between PERT-GC and PERT- GC-GA are carried out to know which of the technique is able to produce a new scheduling with minimum time and cost. It is noticed that the period of the project would be shortened. This is to ensure that the total cost that is expanded on the project is minimized.

1.4 Research Questions

The research questions of this study are given below:

(a) What are the existing techniques in scheduling?

(b) What is the proposed technique for a better scheduling?

(c) Which is the best approach between proposed and existing technique?

1.5 Objectives

The objectives of this study are given below:

(a) To review the existing techniques in solving the scheduling problems

(b) To integrate Program Evaluation and Review Technique (PERT), Gantt chart (GC) and Genetic Algorithm (GA) for a better solution.

(c) To compare the efficiency of the proposed approach and the existing techniques.

1.6 Scope of the Study

This study focuses on developing a new project management technique which integrates Program Evaluation and Review Technique (PERT), Gantt chart (GC) and Genetic Algorithm (GA) for a better scheduling solution. This developed scheduling technique will directly help project managers to reduce time, to save cost and to avoid any delay of the project. Most of the companies that use project management tools will have benefit from the developed technique, where they can manage the time and the budget efficiently.

In scheduling, many uncertainty variables such as weather, productivity level, quality of goods, space blocking and more can occur when a project is running. These uncertainties will cause the delay of the project. Because of that, PERT has been developed to deal with the uncertainty in the project completion time (Azaron *et al.*, 2005). PERT is used to schedule, control and monitor the large and complex projects. It is used to build up relationships among the tasks and to decide which tasks precede and which tasks should follow the other tasks. PERT also will assign the time and the estimated cost for each task. For the calculation of the project completion time, only the forward pass is considered, where the Earliest Start time (ES) and Earliest Finish time (EF) are determined. The backward pass, which includes Late Start time (LS) and Late Finish time (LF), project crashing and project slack are not applied here.

Gantt chart is a useful way of showing tasks displayed against the time and each of the tasks is represented by a bar. It is also useful to be able to show additional information about the various activities or phases of the project. Then, it is used to see how tasks related to each other and the progress of the project. For this study, GC is used to show the changes that are happened in the new scheduling compared to the original scheduling. In addition, GC is a useful way of showing tasks displayed against the time, where each of the tasks is represented by a bar. The additional information about the various activities or phases of the project and the progress of the project are shown.

Genetic algorithm (GA) is the technique of the optimization. GA works very well with the scheduling problem. It represents a solution of the problem as a chromosome, and has three types of operators, which are selection, crossover and mutation, to evolve in order to find the best solution. Application of GA in this study is to reduce the time of completing a project as well as reducing the cost of the project. Many researchers have used GA not only in construction industry but also in factory. The evolution process is taken into account in finding the best solution. In our study on scheduling, GA is used to minimize the time and the cost of the project scheduling.

In this study, data of the project is collected from a construction company. The project is to build the bounding walls at four different places which are *Jalan Nibong* 4, *Jalan Nibong* 3, *Jalan Tengar* and *Jalan Nibong* 5. There are several assumptions that arise in this study before doing the analysis of the data. The project should not have any shortage in term of raw materials, employees, equipment and skills. In addition, the critical path is not considered in this study.

1.7 Significance of Study

A comprehensive study of the existing techniques in the project management to aid scheduling of a project is provided. At the end of the study, the suggested technique will help project managers to develop an effective schedule to make sure the project completion time is finished on time or earlier than the expected time with enough of raw materials and employees in order to minimize the time and reduce the cost.

The study is to understand on how to integrate PERT, GC and GA to ensure a better scheduling diagram is developed. Besides, a basic knowledge of statistics and the MATLAB coding are requested to generate parents and offspring, and to calculate the new duration of the project. The solutions obtained from the existing technique and the proposed approach are compared and explained.

1.8 Structure of the Thesis.

This thesis consists of five chapters. Some overviews of the thesis are outlined here. In Chapter 2, an introduction of scheduling is given, and it is followed by review on PERT, GA, GC and Critical Path Method (CPM). Then, an explanation on the integration techniques, which includes PERT, GC and GA but not integrating three of them used in previous studies are made.

In Chapter 3, the details of the methodology to fulfill the objectives of this study are discussed. The design of study and techniques used in this study are covered.

In Chapter 4, a discussion of analysis of the study is given and the findings are further explained in this chapter.

In Chapter 5, the limitation of the study is mentioned and the conclusion is made. The future research according to the study is also pointed out.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the previous studies on scheduling are reviewed. Firstly, the definition of the terms in scheduling is given. Then, the corresponding techniques used in scheduling are commented. Particularly, Program Evaluation and Review Technique (PERT), Gantt chart (GC) and Genetic Algorithm (GA) are pointed out. Next, the uses of these methods are further discussed and their applications in scheduling are also highlighted. Accordingly, the details of the integration techniques, which are integration of GA and GC, integration of process model with GC, and integration of data flow diagram (DFD) with GC and PERT, are enlightened. Finally, the summary of this chapter is made.

2.2 Scheduling

In project management, scheduling of the activities in a project is decided, where the start and finish times of the detailed activities are determined (Gonçalves *et al.*, 2008). An efficient scheduling phase is crucial in order to ensure that the project is completed on time and within the budget provided (Bruni *et al.*, 2011). The detailed baseline of the project schedule supports project managers in monitoring the work progress, facilitating resource allocation and providing a basis for managing external activities, such as dealing with contractors (Metha & Uzsoy, 1998; Mohring & Stork, 2000; Bruni *et al.*, 2011).

As said by Korovessi & Linninger, (2006) and Muñoz *et al.* (2011) the purpose of scheduling is to include the association of employees and technological assets in a firm within a range of days to weeks to fulfill consumer demands defined by a production plan subsequent from the company planning role.

Scheduling is one of the important elements in project management. Without a proper scheduling, time overrunning and wasting of raw material as well as over budgeting might occur. According to Davis (1971), a schedule is a specific activity with time-phased works on resources to tasks that satisfies the requirements and constraints.

In scheduling, it is commonly involving in determining on the amount of goods, the distribution of resources to the desirable activities, the sequence in which the different groups are to be achieved and at what time these activities are to be started (Muñoz *et al.*, 2011). A scheduling that can optimize the objectives of a project is the desired schedule. From scheduling, the process plan is obtained, where the tasks are scheduled according to the procedures on the machine as well as to satisfy the precedence relation (Sugimura *et al.*, 2001). In fact, scheduling is one of the greatest essential roles in the construction project management (Georgy, 2008; Tang *et al.*, 2014).

Construction managers have to make a schedule for guiding and monitoring resources of employees, machines and materials in an organized time-efficient situation in order to finish a project within the limited and available time (Lu *et al.*, 2008).

Work breakdown structure (WBS) is a division of components that is used in the project management to describe the group of a project on separate work task in the way to unite and to know the total work scope of the project (NASA, 2001, Booz *et al.*, 2008). Scheduling is a complication of a list of activities that has the proposed start and finish dates in a project. Normally, it starts with the development of a WBS which the project is divided into a set of activities (Ramzan *et al*., 2010).

Laslo (2010) said that in the real practice, managers create and schedule regularly the program based on the estimated values of task periods. However, many real-world planning and scheduling glitches are always changing, and consequently the resources become unattainable or the activities take a longer time than the expected time. There are several problems in scheduling such as time-cost trade off, resource allocation, resource-constrained, resource leveling and integrated models. The basic of the scheduling methods is useful when the project time limit is not fixed and the resources are not controlled by either availability or time constraint (Liao *et al.*, 2011).

In scheduling, several types of techniques which are Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), Gantt chart (GC), and Work Breakdown Structure (WBS), are popular to be used. In particular, PERT and GC are common techniques. WBS is a product-oriented family tree composed of hardwares, services, softwares and data which result from project engineering efforts (Shtub, Bard & Globerson, 1994; Shtub1997).

CPM shows the relationship between activities and the critical activities, where activity float time can be observed, then scheduling can be controlled. CPM has delivered a very useful and important information about the activities of the schedule, so it can be studied intensively, especially for the resourced-constrained issued based on the CPM (Jun Yan, 2012).

Scheduling contains the key element and complex process of organizing activities in construction projects. A schedule for a big project that builds a large building has thousands activities with several constraints between activities. Nevertheless, the schedule still needs to be updated and transformed often according to the reality of the project in field which is uncertainty and unpredictable (Tory *et al.*, 2013).

2.3 Critical Path Method

In 1950s, Critical Path Method has been broadly used as the industry rule for construction project scheduling (Lu *et al.*, 2008). According to Heizer & Render (2011), Critical Path Method is used for the prediction that task times are known with inevitability and only one time factor for each task is needed.

According to Kim & Jr. (2005), CPM has been broadly used in the construction company. It is used to produce a useful data for the project manager in order to plan and control the project more aggressively and competently. Nevertheless, it is proven that CPM is helpful only when the project dead-line is not fixed and the resources are not controlled by either availability or time.

Thus, CPM can be highly employed by combination of knowledge-based system, as suggested by Cheng (1996), where an approximately optimum rescheduling of trains was made under time and resource constraints. During the rescheduling process, the universal information regards to final completion times of trains used was considered as a reaction function to mechanism the delay and resolution the resource conflict in relation to the current processing trains.

There are four methods used to solve the problem of the resource conflict in scheduling which are Prior Arrival Method (Cheng *et al.*, 1994), Local Optimum Method (Cheng *et al.*, 1994, Cheng, 1996), the longest path method (Abe & Araya, 1986; Cheng, 1996) and the combined method (Cheng, 1996). Prior Arrival Method is a method that gives more priority to the arrival train compared to the departure trains for solving the resource conflict between two trains. However, Abe and Araya (1986) suggested the use of the longest path method, where all of the time and resource constraints are changed into consecutive relations in a network. But then, Cheng (1994) proposed another method named Local Optimum Method, which is a disjunctive graph model for getting more accurate simulation under resource constraints. This method is used to reduce the total delay of both arrival and departure trains by choosing one of the disjunctive arcs from a disjunctive arc pair.

As the result, of the combined method in that Prior Arrival Method's total sum of total start delay and total final delay is the longest than those from Local Optimum Method and the combined method. Yet, comparison between the combined method and Local Optimum Method, for an initial 30 minutes delay, which can be considered as small delay, the total start and final delays is almost the same. The computing time for both of the techniques is also the same because the slack time can be calculated if the scale of delay is large. However, for an initial delay that is more than 30 minutes, it can be assumed as a large delay, so the total final delay is reduced rapidly as the initial delay increases. Still, the total start delay is increasing slightly between 30 minutes to 57 minutes of an initial delay, and then the total start delay is reduced gradually.

Nevertheless, the sum of the total start and final delays for the combined method is always less than those obtained from Local Optimal Method. It can be concluded that the combined method is more efficient than Local Optimum Method. In contrast, the computing time of the combined method is larger than Local Optimum Method.

2.4 Program Evaluation and Review Technique

Program Evaluation and Review Technique (PERT) was established by Booz, Allen and Hamilton in 1958 for the U.S. Navy (Heizer & Render, 2011). According to Evans (1964) & Howard (2009), PERT is aimed to examine and to denote the tasks that are involved in a given activity. Nevertheless, in this study, PERT is used to show the flow of the project and to know the earlier start time (ES), the earlier finish time (EF) and the time duration of each activity.

As an early application of PERT, U.S. government applied it in planning and scheduling the research project for building up the Polaris Ballistic Missile (Elmaghraby, 1977; Mehrotra *et al.*, 1996). Then, PERT has become the main tool especially for the project funded by U.S. government, as well as in business world. The analysis of PERT is known as stochastic activity network, which has received considerable attention in the literature (Elmaghraby, 1977; Mehrotra *et al.*, 1996).

A PERT network involves a set of nodes and arrows. Nodes represent the beginning and completion of one or more activities, while arrow shows the connectivity between two nodes. There are two kinds for the PERT network, which are activity on arrow (AOA) and activity on nodes (AON). Many project managers use PERT to schedule, manage and control the large and complex project. By drawing a network graph of AOA or AON, a project manager knows the critical activities in the project, and the activities that might delay the entire project could be identified. Network diagram shows to project manager which activities are non-critical that can be run late without having any delay (Mehrotra *et al.*, 1996).

Hadju (2013) said that originally Program Evaluation and Review Technique (PERT) is an activity-on-arrow technique, which is considered with one start and one finish event that will represent the beginning and the end of an activity in a project. In order to accomplish the project, there are certain activities that must be carried out according to a given pre-defined sequence.

PERT is broadly used as a technique for managing large projects. Many researchers have used PERT in their research, see for examples Pontrandolfo (2000), Hahn (2008) and Mouhoub *et al.,* (2011). Furthermore, PERT is also used as an approach to calculate duration of time, estimated time, mean and variance of the activity duration based on pessimistic, optimistic, and most likely time estimate (Premachandra, 2001).

PERT is used in the job that has activities with stochastic times (Ramirez Campos *et al.*, 2003). Fatemi Ghomi and Rabbani (2003) concluded that PERT is an acyclic, linked and directed network graph, which is a linkage that has one beginning and one terminal node. In project planning and controlling, the PERT network is useful because of the length of all tasks are the positive random variables with the known probability distribution.

Cohen and Sadeh (2007) explained that the creation of the PERT network is much more appropriate for certain analytical method and optimization formulation. Shenhar and Dvir (2007) enlightened that PERT is a tool to evaluate and symbolize the tasks included in finishing a given project.

As stated by Hanh (2008), PERT is a technique that the activities times are taken to be stochastic manner. Hence, to facilitate a project's management, it is needed to produce the task time distributions for the tasks in the project. Hendrickson and Au (2008) mentioned that PERT is used with the famous Gantt chart which is used to signify in time, and the various tasks.

Project management experts use PERT broadly in estimating the project completion time. It is important to know the approximation of project finishing time due to the cost of planning and the resource provision decision are joined crucially on the approximation. Since 1950s, when PERT was formulated, researchers have tried to create a difficult theoretical base and now, it is accepted that the estimations given by PERT are useful (Banerjee & Paul, 2008).

PERT is used to simplify the planning and scheduling of the project. It concerns with the time needed to complete each task, the minimum time to complete the whole project and to schedule a project while not knowing precisely the particulars and periods of all the activities. Project planning and controlling are use PERT as the method that is based on a network representation of the tasks for the structure of the project (Howard, 2009).

As stated by Montoya-Torres *et al.* (2010), PERT and CPM are allowed to be shown by network illustrations where the arcs denote the tasks, nodes denote the actions, and the network structure denote the relationship between the jobs. Trietsch and Baker (2012) said that PERT is focused on generating and monitoring the project schedule in a stochastic manner.

In this study, PERT is used to find ES and EF. It is because the data of the projects is in sequence. ES and EF are easy to use to determine the duration of the project. Many researchers have used PERT in their previous study because scheduling can be represented easily by using PERT.

2.5 Gantt Chart

Gantt chart (GC) has been used as a graphical tool to represent the activities schedule (Luz & Masoodian, 2011). GC is the operational procedure of such graphical schedule because GC is able to chart all of main occasions for all works on the master schedule (Wilson, 2003). Nowadays, GC is known as the most used method to plan and control the project. According to survey with the 750 project managers, GC was the fourth most used techniques out of 70 techniques that are connected with project management (Besner & Hobbs, 2008).

Kelly (1961) concluded that GC is easy to understand and generally consumed for on-site announcement in the employee level. Truscott and Cho (1987; Wilson, 2003) used GC to schedule batch production through multiple work centers. The GC has been used broadly for scheduling and it builds up a planning board generator as a management decision support system (Wennik & Salvesbergh, 1996; Wilson, 2003).

GC practices a time-phased needy demand method to construction planning. Gantt's planning is operated in a "top-down" method by connecting end-item necessities to their essential components with time-phased production. In this way, it allows all mechanisms to be available when they are desired for the following production activities. These due dates are further used to design day-to-day production by deciding the amounts to be completed and then pursuing production against the day-to-day goals (Wilson, 2003).

Wilson (2003) also stated that the determination of GC was not the local optimization but as a portion of a larger scheme to accomplish the planning and mechanism in the factory. It is used to coordinate activities of the project or production and then the orders would flow efficiently through the factory while custody machines and staff are busy. Managers can see the progress of activities as it progresses between work centers and the time planned for each activity.

GC provides means that is fast and simple to understand for recitation project activities. GC shows a readily programme and it is straightforwardly presented in a variety of layouts that is valuable for managers. It is favorable for displaying schedule that is either created manually or through some exploratory of optimizing algorithms (Wilson, 2003). Moreover, Geraldi & Lechter (2012) said that GC is remained as an important method to both in planning and controlling project schedule. The popular project management software such as Microsoft Office Project and Primavera has used GC as the dominant platform to plan and control projects integrating all other functions of the software.

By using the developed GC, project managers can easily ensure that all activities are planned, order of performance is documented, time estimation of activity is recorded and importantly overall of project time is developed. GC is likely a permit for project managers for observing the progress of the task in the respective project. It is also to avoid any delay and in case of any problem, it can easily be spotted quickly (Heizer & Render, 2011).

GC shows the relationship of each activity in the project, if any overlap activity happens, it can be seen in the chart. The estimated and realistic times for a project to be finished are also shown in the chart. Thus, the precedence relationships among tasks are identified and the critical bottleneck in the project is known so that the usage of material, workers and money can be managed easily (Heizer & Render, 2011).

As far for now, GC is usually used in a number of ranges that appears to how natural and effective of the knowledge of demonstrating time-based data streams as quadrilateral bars can be extended along a timeline (Luz & Masoodian, 2011). GC is seen as an easy, natural, applied and useful method to link project tasks and times. Additional, the GC is an instrumental tool to improve the cognitive capability to manage with organizational difficulty which is the coordination of a large number, miscellaneous and interdependent task (Geraldi *et al.*, 2011)

Rodenbeck and Schumacher (2012) said that GC and PERT are well known and they are usually used among project managers as a graphic planning tool. Both of these two charts retain some natural limitations which cannot be negated by the combination. GC is a schedule of activities that are denoted as bars on a timeline and constraints are denoted as lines between the bars (Tory *et al.*, 2013).

According to other previous researches, GC is the common technique used in project management to develop the schedule of the project. It is suitable because GC is readable graph. For this study, by using GC, the new schedule is developed. Figure 2.1 shows the example of the Gantt chart.

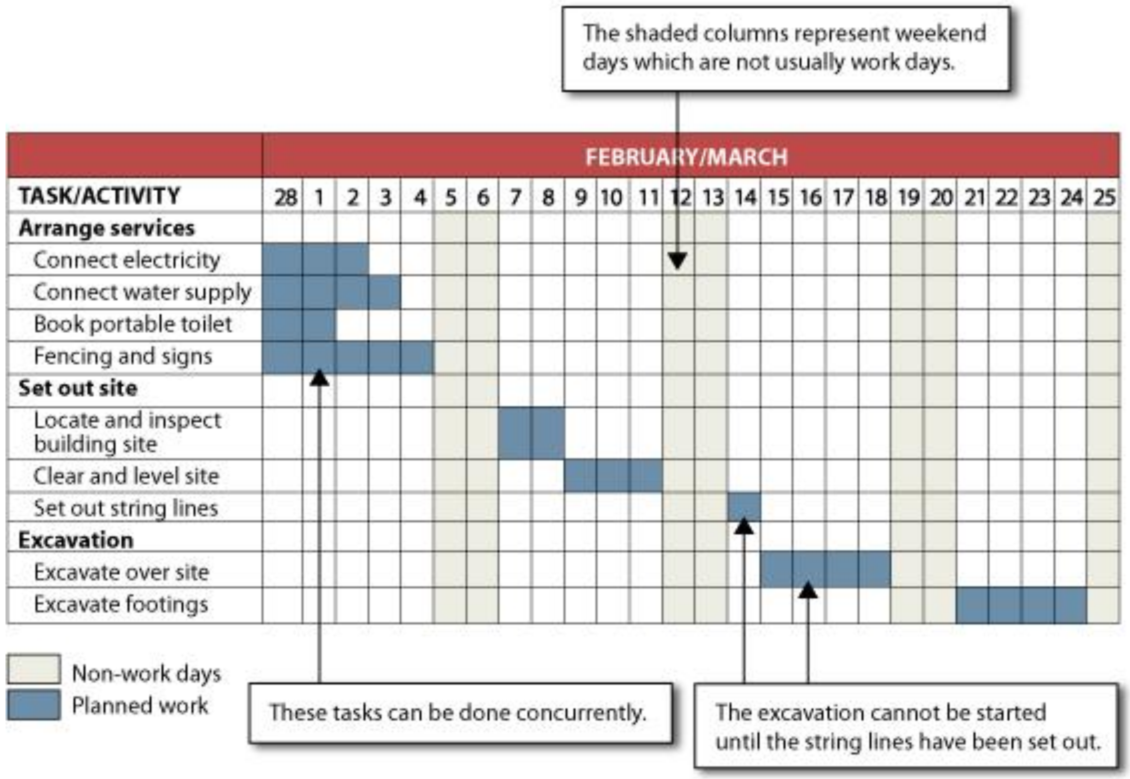

Figure 2.1: Gantt chart (nationalvetcontent.edu.au)

2.6 Genetic Algorithm

Genetic algorithms (GAs) are strong general-purpose search approach based on the tool of natural selection and natural genetic (Holland, 1975; Karova *et al.*, 2008). The developing of genetic algorithm is to simulate the genetic evolution process which is survival of the fittest. The growth procedure forecasts the survival and characteristic of the offspring on the root of understanding the characteristics of their parents. By nature and based on the fitness of a chromosome, GA is run by three main operators, which are selection, crossover and mutation (Mayer, 1999).

According to Montoya-Torres *et al.* (2010), a GA is a problem resolving method that has used the concept of development and inheritance to generate a good result to complex problems that naturally have massive search space and are problematic to solve. Methods such as analytical and heuristic methods are ranged from mathematical programming to the game theories which are applied to ensure project schedules as good as possible (Goldberg, 1995; Tamaki *et al.*, 1996; Knosala & Wal, 2001).

GA is one of the optimization procedures, which is designed to imitate some of the methods observed in the proper development (Guo *et al.*, 2010). Many of GA models rearrange crossover and mutation operators to manage the precedent relationships of contiguous activities (Fung *et al.*, 2011).

GAs are modeling methods based on genetic behavior. GA depends on the rapidity of the computers to chain fundamentals from two parents or to mutate a single parent to a difficult problem to generate an offspring, if the offspring is better than parents, then it will survive, however the worst offspring will die (Wilson, 1997; Mawdesley *et al.*, 2002). Michalewicz (1999) and Ebrahimzadeh and Ranaee (2009) said that GA is a stochastic optimization algorithm which adopts the Darwin's theory of subsistence of the fittest.

GA applies the imitation of the natural development, by acting on a population in favor of making new individuals that are better than their predecessors, as weighed uses some criteria, such as an objective function (Carl *et al.*, 2001). GAs are work on the coded task parameters, which are transformed from values of function domain to the coded strings in order to find a maximum value of some functions (Knosala and Wal, 2001).

As stated by Zheng *et al.* (2004), GAs simulate the normal genetic procedures of living organisms and highlight the strength of the algorithms as the skill to engagement of the random choice as an instrument to control a greatly explorative search through an originally unidentified space. The searching method has an original track for manipulating offspring and consequently a better child generation is assured.

Karova, Petkova and Smarkov (2008) stated that GA is a stochastic approach that can be used to resolve a class of optimization difficulties. GA's specialty is to explain planning and scheduling problems in an experimental way under reflection of the problem's environment.

GA is used to solve job shop scheduling (Maghfiroh *et al.*, 2013), multi-constraint scheduling for construction industry (Dawood & Sriprasert, 2001), and for solving precedent relationship problem in project scheduling optimization (Fung *et al.*, 2011). For more examples, see (Dong *et al.*, 2012), (Senouci *et al.*, 2004), (Long & Ohsato, 2009), (Liu *et al.*, 2005), (Knosala & Wal, 2001), and (Li *et al.*, 2008). It is proven that GA is usually used by previous researchers in their study in scheduling. GA is used to solve the problem in schedule while reduce time and cost of the project

For the job shop scheduling problem (Maghfiroh *et al.*, 2013), the optimal objective values are shown in Table 2.1.

Table 2.1: Comparison with Dispatching Rules

	Mean Flow Time	**Makespan**
Genetic Algorithm	6155	17600
Actual Condition- Longest Processing Time (LPT)	12840	20220
Shortest Processing Time (SPT)	7560	18020
First Come First Serve (FCFS)	8760	18080

The result of Table 2.1 shows the time arrangement of job based on company data by using GA, longest processing time (LPT) rule, shortest processing time (SPT) and first come first serve (FCFS). The mean flow time and the makespan obtained by using GA are the minimum solution, which are compared to the solution obtained by LPT. Notice that GA outperforms other procedures in terms of solution quality. In job shop scheduling problem, 13% of improvement of the makespan and 52% of mean flow time are given by GA. It is known that GA is the best solution method based on the LPT rule (Maghfiroh *et al*, 2013).

In construction industry, GA is applied to reduce the total time for finishing a project and to minimize the total cost that is expended. Sripraset and Dawood (2001) studied the application of GA in construction industry. In their paper, the GA application was employed with the real project data that has nine tasks. The data of the project is shown in Table 2.2.

Table 2.2: Data of Project

				Resource 1	Resource 2	Resource 3	Space 1	Space 2	Space 3	Drawings		Materials		Aggregation	
ID	Act.	Dur.	Pred.	Assignment (unit/day)	Assignment (unit/day)	Assignment (unit/day)	Occupation (m^2/day)	Occupation (m^2/day)	Occupation (m^2/day)	ERT (Date)	Ready Status	ERT (Date)	Ready Status	Constraint Date	Ready Status
1	A	5 6		5 3	4 4	5 5	50	0	0	15/9/02	True	18/9/02	True	NA	True
2	B	9	A	4	5	2	0	80	20	20/9/02	True	25/9/02	True	NA	True
3	C	12 13	B,D	4 3	6 6	6 5	50	0	0	1/10/02	False	1/10/02	True	1/10/02	False
4	D	15	A	5	2	4	0	50	0	5/10/02	True	1/10/02	True	NA	True
5	E	12 13 14	D,F	1 1 1	5 5 5	6 4 3	0	70	0	15/10/02	False	10/10/02	False	15/10/02	False
6	F	16 17 18 19	A	6 5 4 3	4 3 2 1	4 3 2 1	0	0	60	20/9/02	True	25/9/02	False	25/9/02	False
7	G	13 14	F	3 3	3 2	6 5	0	0	80	15/10/02	False	5/10/02	True	15/10/02	False
8	H	7 8	C,E	6 6	4 3	3 2	0	50	0	18/10/02	False	15/10/02	False	18/10/02	False
9	I	9	G,H	5	5	5	50	30	30	1/11/02	False	1/11/02	False	1/11/02	False

Notes: 1. Standard costs for resource 1, 2, and 3 are 10, 15, and 12 $/unit/day respectively
2. Maximum units for resource 1, 2, and 3 are 8, 10, and 10 units/day respectively
3. Sizes of space 1, 2, and 3 are 50, 100, and 80 m^2 respectively
4. Due to increase demand for storage area, size of space 2 will be reduced to 70 m^2 after 20/10/02
5. Project start date = Mon 16/9/02
6. ERT = Estimated ready time obtained from supply chain

The origin project period before attending the constraints was 57 days. After that, the constraints were solved by using the standard resource leveling feature in Microsoft Office Project and the developed GA-based approach. In order to fulfill the constraints, the length of the project was prolonged to 91 days when the scheduling problem was resolved by using MS Office software, while the period was 85 days when GA was applied to resolve the problem.

Without having any constraint, the GA further reduced the project time to 70 days. The reduction of 23% of fluctuation and consumption period of Resource 1, the cost has been reduced with amount of $1760, and the reduction of 28% of consumption period of Space 2. Table 2.3 shows the result of the experiment and the processing time.

Table 2.3: Results of Experiments

	Initial Schedule + All Constraints		Constraint-free Schedule by MS Project		Constraint-free Schedule by GA (1)		Constraint-free Schedule by GA (2)		Constraint-free Schedule by GA (3)	
Criteria & Weights	Fix option		Fix option		Fix option Duration = 100%		Duration = 100%		Duration, Cost, Mx+My for R1, My for S2 = 25% each	
Activity	Priority	Option	Priority	Option	Priority	Option	Priority	Option	Priority	Option
A	Medium	1	Medium	1	Medium	1	Highest	1	Lowest	1
B	Medium	1	Medium	1	Very High	1	Low	1	High	1
C	Medium	1	Medium	1	Medium	1	Highest	1	Low	2
D	Medium	1	Medium	1	Medium	1	Do not Level	1	Medium	1
E	Medium	1	Medium	1	Very Low	1	Higher	2	Higher	2
F	Medium	1	Medium	1	Higher	1	Medium	4	High	4
G	Medium	1	Medium	1	Very High	1	Higher	1	Lower	2
H	Medium	1	Medium	1	Lowest	1	Low	1	Low	1
I	Medium	1	Medium	1	Very High	1	Medium	1	Medium	1
Duration	57 days		91 days		85 days		70 days		71 days	
Cost	$ 15,685		$ 15,685		$ 15,685		$ 13,925		$ 13,610	
For R1 Mx + My	Over-allocated		21,143		19,241		14,853		14,757	
For S2 My	Over-loaded		131,570		136,460		98,630		95,200	
CPU Time	NA		Less than 2 seconds		300.33 seconds (1,000 search spaces)		300.33 seconds (1,000 search spaces)		2770.17 seconds (10,000 search spaces)	

Several terms are used in GA such as genetic, chromosome, crossover, selection, mutation, population and fitness function (Bhattachariya, 2012). Three common operators of GA are selection, crossover and mutation (Bhattachariya, 2012). In selection, the pairs of parents are produced. Reproduction defines the way of generating parents. Crossover describes how chromosomes are swapped between parents to produce the corresponding offspring. Mutation alters the chromosome that is likely to increase the quality of the population.

In a population, once the genes of a pair of parents are generated, a pair of offspring can be created by using the crossover. A group of offspring should be energetic than their parents and inherited the best characteristic from their ancestors. (Gkoutioudi & Karatza, 2012).

Poon and Carter (1995) said that the crossover operator recombines the gene from two noble parents into the superior offspring solutions. Crossover creates a new population from the previous population that is available in the mating pool after applying selection. It exchanges the information of the gene between the populations in the mating pool (Bhattachariya, 2012). On the other hand, mutation is the random operator, where one or more alleles will be changed randomly and the variety in the population is maintained.

A fitness function counts for the optimality of a population. A particular population is ranked by the value of the fitness function and then it is used to go against all the other values of the fitness function in population. A fitness value is assigned to each population accordingly if it closes to the optimal value of the fitness in the population. (Bhattachariya, 2012).

GA is applicable to our research because by applying GA, the objective will be accomplished. GA also will reduce time for the project and it will be easy to choose which duration and time of the project reduces.

2.7 Integration Techniques

The integration technique combines two or more methods for solving the scheduling problems. By integrating the methods used in scheduling with GA, different results of the schedule such as the length of the period are reduced and smaller cost is provided.

2.7.1 Genetic Algorithm integrated with Gantt chart

Jia *et al.* (2007) showed the usage of GA that the crossover operator is applied once, and the mutation operator is applied twice to improve the selections of factory and job sequence. A better scheduling that reduces the period of the project can be developed when GA is integrated with GC. In this integrated approach, objectives such as minimization of the total length of the schedule, reducing cost and more in the reasonable computational time can be considered. Jia *et al.* (2003) suggested this integrated technique, which modifies GA to solve problems in a distributed manufacturing environment. In their technique, the small-sized or medium-sized of the scheduling problem was resolved in more efficient and effective way.

In description of the distributed manufacturing system, different machines with the available times for each factory to process the jobs are considered (Jia *et al.*, 2007). There are four main sections and five sub-sections. At first, the selected factories and the job operations are chosen. It is complicated to encode the chromosome for the scheduling problem when jobs are being dispatched to many factories. It happens because the chromosome has to comprise more information such as selected factory for every job and their operation sequence.

In the proposed integration GA technique, three digits are used as a gene to represent a factory and the operation of a job. For a selected factory, the job that is being processed is donated by the first digit and the next two digits denote the operation of a job random combination of operation genes are used for all of the jobs. It is called chromosome in GA terminology. A preliminary chromosome population will be initially produced at random. Then, crossover and mutation are used for recombination of genes for the offspring.

For crossover operation, the procedure is given below:

(a) Choose the chromosome randomly for the gene of the parents.

(b) Exchange the genes of the parents to produce two offspring chromosomes.

(c) Authorize the offspring chromosomes by adding or deleting the genes of the parents. All of the operations which take over the genetic traits from their parents shall be covered.

The missing genes (job operations) are added and the redundant genes are deleted at the end of generating of each offspring chromosome as shown in Table 2.4.

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