

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

SITI HASZIANI BINTI AHMAD

A thesis submitted in
fulfillment of the requirement for the award of the
Master of Science in Technology Management by research

Faculty of Technology Management and Business
Universiti Tun Hussein Onn Malaysia

OCTOBER 2014

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.

CONTENT

	TITLE	i
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	CONTENT	vii
	LIST OF TABLE	x
	LIST OF FIGURE	xi
	LIST OF SYMBOLS AND ABBREVIATIONS	xiii
	LIST OF APPENDICES	xv
CHAPTER 1	INTRODUCTION	
	1.1 Introduction	1
	1.2 Background of Study	2
	1.3 Problem Statement	4
	1.4 Research Question	5
	1.5 Objective	6
	1.6 Scope of Study	6
	1.7 Significance of Study	8
	1.8 Structure of Thesis	8

CHAPTER 2 LITERATURE REVIEW

2.1	Introduction	9
2.2	Scheduling	10
2.3	Critical Path Method	12
2.4	Program Evaluation and Review Technique	13
2.5	Gantt Chart	16
2.6	Genetic Algorithm	18
2.7	Integration Techniques	
2.7.1	Genetic Algorithm integrated with Gantt chart	23
2.7.2	Process Model integrated with Gantt chart	28
2.7.3	Data Flow Diagram integrated with GC and PERT	32
2.8	Summary of the Chapter	37

CHAPTER 3 RESEARCH METHODOLOGY

3.1	Introduction	38
3.2	Details of Program Evaluation and Review Technique	38
3.2.1	Calculation of ES and EF	39
3.2.2	Calculation of Slack Time and Identifying Critical Path	41
3.2.3	Time Estimates in PERT	42
3.2.4	Probability of Completion Time	44
3.2.5	Probability Project Finish before Due Date	45
3.3	Genetic Algorithm	47
3.3.1	Flow Chart of GA Procedures	53
3.4	Gantt Chart	54

3.5	Research Flow Diagram	58
3.6	Summary of the Chapter	59

CHAPTER 4 RESEARCH FINDINGS AND ANALYSIS

4.1	Introduction	60
4.2	Data of Project	60
4.3	Integration between PERT and Gantt Chart	62
4.4	Application of Genetic Algorithm	64
4.5	Summary of the Chapter	79

CHAPTER 5 DISCUSSION AND CONCLUSION

5.1	Introduction	80
5.2	Discussion	80
5.3	Contribution of Study	82
5.4	Impact to Construction Managers, Industry and Researcher	82
5.5	Limitation of Study	83
5.6	Future Research	83
5.7	Conclusion of the Research	84

REFERENCE	85
------------------	-----------

APPENDICES	94
-------------------	-----------

LIST OF TABLES

1.1	Report of Project Failed to Finish According to the Schedule	3
2.1	Comparison with Dispatching Rules	20
2.2	Data of Case Example	21
2.3	Result of Experiments	22
2.4	The Result of Crossover	25
2.5	A Distributed Scheduling Problem	27
3.1	Time Estimates for Project	40
3.2	ES and EF	41
3.3	Slack Time	42
3.4	Expected Time and Variance	43
3.5	Dave Carhart's Consulting Company	55
4.1	Data of the Project	61
4.2	Calculation of ES and EF	62
4.3	Parent 1 and Parent 2	65
4.4	Offsprings 1 and 2 and their Mutations	67
4.5	Parent 3 and Parent 4	68
4.6	Offsprings 3 and 4, and their Mutations	69
4.7	New Duration of the 1 st Generation	70
4.8	New Duration of the 2 nd Generation	71
4.9	Data of the First Generations	75
4.10	Probability of Time	76
4.11	New Duration of Project	77

LIST OF FIGURES

2.1	Gantt chart	18
2.2	Figure of Schedule	28
2.3	Integration Frameworks of Process Management and Project Management	29
2.4	DFD-0	33
2.5	DFD-1 (General Process P1”Blown-Up”)	33
2.6	A Complex DFD Denote DFD-0 and DFD-1	34
2.7	MS Project Gantt Diagram Representations of DFD’s Objects	34
2.8	MS Project Gantt Diagram Representations of DFD’s Objects	35
2.9	Database Schema for the DFD-Gantt Mapping	36
3.1	Example of ES and EF	39
3.2	Beta Probability Distribution with Three Time Estimates	43
3.3	Bell-Shaped Normal Curve	45
3.4	Probability the Project Will Meet the 16-Week Deadline	46
3.5	Value For 99% Probability of Project Completion	47
3.6	Uniform Crossover	49
3.7	One-point Crossover	49
3.8	Two-point Crossover	50
3.9	Random Mutation	51
3.10	Inorder Mutation	51
3.11	Flow chart of Procedures of GA	53
3.12	Gantt chart	55

3.13	Gantt chart of Dave Carthart's Consulting Company	56
3.14	Research Flow Diagram	58
4.1	Gantt chart of PERT Integrates with Gantt chart.	63
4.2	Gantt chart of New Duration of First Generation	72
4.3	Gantt chart of New Duration of Second Generation	73
4.4	Frequency Distribution of EF	76
4.5	Probability Distribution of EF	76
4.6	New Gantt chart	78



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>i</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
<i>N</i>	–	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



LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Normal Table Distribution	94
B	100 Generations of Project Scheduling	95
C	Coding of MATLAB	129



PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

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 <i>et al.</i> ,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

	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 15 th 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; Shtub 1997).

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.

REFERENCE

- Abdullah, M. R, Azis, A. A. A., & Rahman, I. A. (2011). Potential effects on large MARA construction projects due to construction delay. *International Journal of Integrated Engineering*, 1(2), 53-62.
- Abe, K., & Araya, S. (1986). Train traffic simulation using the longest path method, *J. Inform Process. Japan* 27 (1)
- Azaron, A., Perkgoz, C., & Sakawa, M. (2005). A genetic algorithm approach for the time-cost trade-off in PERT networks, *168*, 1317–1339.
- Aziz, R. F. (2013). ORIGINAL ARTICLE RPERT : Repetitive-Projects Evaluation and Review Technique. *Alexandria Engineering Journal*.
- Balin, S. (2011). Non-identical parallel machine scheduling using genetic algorithm. *Expert Systems with Applications*, 38(6), 6814–6821.
- Banerjee, A., & Paul, A. (2008). On Path Correlation and PERT Bias. *European Journal of Operational Research*, 189(3), 1208–1216.
- Bhattachsriya, R. K. (2012). Introduction to Genetic Algorithms. Department of Civil Engineering, Indian Institute of Technology Guwahati.
- Booz, Allen, Hamilton. (2008) "Earned Value Management Tutorial Module 2: Work Breakdown Structure", Office of Project Assessment, doe.gov.
- Bruni, M. E., Beraldi, P., Guerriero, F., & Pinto, E. (2011). A scheduling methodology for dealing with uncertainty in construction projects. *Engineering Computations*, 28(8), 1064–1078.
- Chang, C. K., Christensen, M. J., & Zhang, T. (2001). Genetic Algorithms for Project Management, 107–139.

- Cheng, Y. (1996). Optimal train traffic rescheduling simulation by a knowledge-based system combined with critical path method. *Simulation Practice and Theory*, 4(6), 399–413.
- Cheng, Y., Tomii, N., Ikeda, H., & Hayashi, Y. (1994). A feasible partial train traffic simulation using diagram expressed in network, in: *Proceedings of the International Conference of New Directions in Simulation for Manufacturing and Communications*, Tokyo, Japan, 439-445.
- Chretienne, P., & Sourd, F. (2003). PERT scheduling with convex cost functions. *Theoretical Computer Science* 292 (2003) 145-164, 292, 145–164.
- Cohen, Y., Sadeh, A. (2007). A new approach for constructing and generating AOA networks. *Journal of Computer Science* 1(1).
- Davis, E. W. & Heidorn, G. E. (1971), “An Algorithm for Optimal Project Scheduling under Multiple Resource Constraints,” *Management Science* 17, 12, B803–B817.
- Dong, N., Ge, D., Fischer, M., & Haddad, Z. (2012). Advanced Engineering Informatics A genetic algorithm-based method for look-ahead scheduling in the finishing phase of construction projects. *Advanced Engineering Informatics*.
- Ebrahimzadeh, A., & Ranaee, V. (2009). Recognition of control chart patterns using genetic algorithm and support vector machine. *First International Conference on Networked Digital Technologies*, 489–492.
- Eiben, A. E., (1999). Experimental Results on the Effects of Multi-Parent Recombination: An Overview, 487-499.
- Elmaghraby, S. E., (1997). *Activity Networks: Project Planning and Control by Network Models*, John Wiley and Sons, New York.
- Eppinger, S. D., (2001). Innovation at the Speed of Information. *Harvard Business Review* 79 (1), 149–158.
- Evans, H. F., (1964) *Introduction to PERT*. Allyn and Bacon Inc., Boston.
- Fatemi Ghomi, S. M., & Rabbani, M. (2003). A new structural mechanism for reducibility of stochastic PERT networks. *European Journal of Operational Research*, 145(2), 394–402.

- Fung, I. W. H., Huang, C., & Tam, V. W. Y. (2011). Application of GA Techniques for Solving Precedent Relationship Problem in Project Scheduling Optimization. *Procedia Engineering*, 14, 2527–2534.
- Gelbard, R., Pliskin, N., & Spiegler, I. (2002). Integrating system analysis and project management tools. *International Journal of Project Management*, 20(6), 461–468.
- Georgy, M. E. (2008). Evolutionary resource scheduler for linear projects, *Automation in Construction* 17, 573–583.
- Geraldi, J., & Lechter, T. (2012). Gantt charts revisited: A critical analysis of its roots and implications to the management of projects today. *International Journal of Managing Projects in Business*, 5(4), 578–594.
- Gkoutioudi, K., & Karatza, H. D. (2012). A Simulation Study of Multi-criteria Scheduling in Grid Based on Genetic Algorithms. *IEEE 10th International Symposium on Parallel and Distributed Processing with Applications*, 317–324.
- Goldberg, D. E. (1995). *Algoritmy genetyczne i ich zastosowania*, Warszawa, WNT.
- Gonçalves, J. F., Mendes, J. J. M., & Resende, M. G. C. (2008). A genetic algorithm for the resource constrained multi-project scheduling problem. *European Journal of Operational Research*, 189(3), 1171–1190.
- Guo, P., Wang, X., & Han, Y. (2010). The enhanced genetic algorithms for the optimization design. *3rd International Conference on Biomedical Engineering and Informatics, (Bmei)*, 2990–2994.
- Hahn, E. D. (2008). Mixture densities for project management activity times: A robust approach to PERT. *European Journal of Operational Research*, 188(2), 450–459.
- Hajdu, M. (2013). Automation in Construction Effects of the application of activity calendars on the distribution of project duration in PERT networks . *Automation in Construction*.
- Heizer & Render (2011). *Operation Management's text book Tenth edition*. Pearson.
- Henderckson, C. & Au, T. (2008). *Project management for construction*, department of civil and environmental engineering, Carnegie Mellon University, Pittsburgh, PA 15213, Version 2.2.

- Holland J., *Adaptation in natural and artificial systems*, University of Michigan Press, Ann Arbor, 1975.
- Howard, D. (2009). A Method of Project Evaluation and Review Technique (PERT) Optimization by Means of Genetic Programming. *Symposium on Bio-Inspired Learning and Intelligent Systems for Security*, 132–135.
- Jia, H. Z., Nee, A. Y. C., Fuh, J. Y. H., & Zhang, Y. F. (2003). A modified genetic algorithm for distributed scheduling problems. *Journal of Intelligent Manufacturing*, 14, 351–363.
- Jia, H. Z., Fuh, J. Y. H., Nee, A. Y. C., & Zhang, Y. F. (2007). Integration of genetic algorithm and Gantt chart for job shop scheduling in distributed manufacturing systems. *Computers & Industrial Engineering*, 53(2), 313–320.
- Jianhua, L., Xiangqian, D., & Qing, Y. (2006). Family genetic algorithms based on gene exchange and its application, 17(4), 864–869.
- Jun-Yan, L. (2012). Schedule Uncertainty Control: A Literature Review. *Physics Procedia*, 33, 1842–1848.
- Karova, M., Petkova, J., & Smarkov, V. (2008). A Genetic Algorithm for Project Planning Problem, 647–651.
- Kelly, J. E., (1961). Critical path planning and scheduling mathematical bases, 9: 246-320.
- Kim, J., & Jr, R. D. E. (2005). A Framework For Integration Model of Resource-Constrained Scheduling Using Genetic ALgorithm. *Proceedings of the 2005 Winter Simulation Conference M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines, Eds.*, 2119–2126.
- Knosala, R., & Wal, T. (2001). A production scheduling problem using genetic algorithm. 109, 90–95.
- Kementerian Kesejahteraan Bandar, Perumahan dan Kerajaan Tempatan Komunikasi Korporat,(2013).From http://www.kpkt.gov.my/media_akhbar/jawapan_terbengkalai.pdf
- Laslo, Z. (2010). Project portfolio management: An integrated method for resource planning and scheduling to minimize planning/scheduling dependent expenses. *International Journal of Project Management*, 28(6), 609–618.

- Li, X., Gao, L., Zhang, G., Zhang, C., & Shao, X. (2008). A Genetic Algorithm for Integration of Process, 495–502.
- Liao, T. W., Egbelu, P. J., Sarker, B. R., & Leu, S. S. (2011). Automation in Construction Metaheuristics for project and construction management – A state-of-the-art review. *Automation in Construction*, 20(5), 491–505.
- Liu, N., Abdelrahman, M., & Ramaswamy, S. (2005). A Genetic Algorithm for Single Machine Total Weighted Tardiness Scheduling Problem, 10(3), 218–225.
- Long, L. D., & Ohsato, A. (2009). A genetic algorithm-based method for scheduling repetitive construction projects. *Automation in Construction*, 18(4), 499–511.
- Lu, M., Lam, H. C., & Dai, F. (2008). Resource-constrained critical path analysis based on discrete event simulation and particle swarm optimization. *Automation in Construction*, 17(6), 670–681.
- Luz, S., & Masoodian, M. (2011). Comparing Static Gantt and Mosaic Charts for Visualization of Task Schedules. *15th International Conference on Information Visualisation*, 182–187.
- Maghfiroh, M. F. N., Darmawan, A., & Yu, V. F. (2013). Genetic Algorithm for Job Shop Scheduling Problem : A Case Study, 4(1).
- Mawdesley, M. J., Al-jibouri, S. H., & Yang, H. (2002). Genetic Algorithms for Construction Site Layout in Project Planning, (October), 418–426.
- Mayer, M. K. (1999). A network parallel genetic algorithm for the one machine sequencing problem. *Computers & Mathematics with Applications*, 37(3), 71–78.
- Mehta, S.V., & Uzsoy, R. M. (1998). “Predictable scheduling of a job shop subject to breakdowns”, *IEEE Transactions on Robotics and Automation*, Vol. 14 No. 3, pp. 365-78
- Mehrotra, K., Chai, J. & Pillutla, S., (1996). A Study of Approximating The Moments Of The Job Completion Time In PERT Networks. *Journal of Operations Management* 14, 277-289.
- Michalewicz, Z. (1999). Genetic algorithms+Data Structures=Evolution Programs, 3rd Edition, Springer, NY, USA.

- Mohd Yusof, Z. (2009). *Utusan Malaysia Online*. Retrieved on June 04, 2009, from http://www.bharian.com.my/bharian/articles/10hingga15peratusprojekpembinaan_gagaldisiapkanikutjadual/Article/index_html
- Mohring, R. H., & Stork, F. (2000), “Linear preselective policies for stochastic project scheduling”. *Mathematical Methods of Operations Research*, Vol. 52 No. 3, pp. 501-15.
- Montoya-Torres, J. R., Gutierrez-Franco, E., & Pirachicán-Mayorga, C. (2010). Project scheduling with limited resources using a genetic algorithm. *International Journal of Project Management*, 28(6), 619–628.
- Mouhoub, N. E., Benhocine, A., & Belouadah, H. (2011). A new method for constructing a minimal PERT network. *Applied Mathematical Modelling*, 35(9), 4575–4588.
- Muñoz, E., Capón-García, E., Moreno-Benito, M., Espuña, A., & Puigjaner, L. (2011). Scheduling and control decision-making under an integrated information environment. *Computers & Chemical Engineering*, 35(5), 774–786.
- NASA (2001). NASA NPR 9501.2D. May 23.
- Pontrandolfo, P. (2000). Project duration in stochastic networks by the PERT-path technique. *International Journal of Project Management*, 18(3), 215–222.
- Poon, P. W., & Carter, J. N. (1995). Genetic algorithm crossover operators for ordering applications. *Computers and Operations Research*, 22(1), 135–147
- Premachandra, I. M., (2001). An approximation of the activity duration distribution in PERT, 28 February, 443–452.
- Qing, L., Ytrliu, C., & Qing, W. (2002). Integration of Process and Project Management System’2. Integrating framework of process and project management, *Proceedings of IEEE TENCON* .1582–1586.
- Ramirez Campos, S. M., Fierro, S., Solis, A. P (2003). Modeling an assembly line combining Pert/Cpm to study the flexibility of a mexican automotive plant using simulink. *Proceedings of the 8th Annual International Conference on Industrial Engineering – Theory, Applications and Practice*, Las Vegas, Nevada, USA, November 10–12.

- Ramzan, M., Iqbal, M. A., Jaffar, M. A., Rauf, A., Anwar, S., & Shahid, A. A. (2010). Project Scheduling Conflict Identification and Resolution Using Genetic Algorithms. *International Conference on Information Science and Applications*, 1–6.
- Rodenbeck, P., & Schumacher, T. (2012). New Tools in Project Planning: An Introduction to the Rodenbeck Project Tower. *2012 Proceeding of PICMET'12 : Technology Management for Emerging Technologies*, 2492–2505.
- Saifullslam, M., & Rokonuzzaman, M. (2009). Process Centric Work Breakdown Structure for Easing Software Project Management Challenges : Business Case Analysis Example, (Iccit), 21–23.
- Sambasivan, M., & Soon, Y. W. (2007). Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management*, 25(5), 517–526.
- Senouci, A. B., Eldin, N. N., & Asce, M. (2004). Use of Genetic Algorithms in Resource Scheduling of Construction Projects. *Journal of Construction Engineering and Management*, (December), 869–877.
- Shenhar, A. J. & Dvir, D. (2007). *Reinventing Project Management*, Boston: Harvard Business School Press.
- Shi, Q., & Blomquist, T. (2012). A new approach for project scheduling using fuzzy dependency structure matrix. *International Journal of Project Management*, 30(4), 503–510.
- Shtub, A, Bard, J F & Globerson, S. (1994). *Project Management: Engineering Technology and Implementation* Prentice Hall, Englewoods Cliffs, NJ.
- Shtub, A. (1997). Project segmentation- A tool for project management. *International Journal of Project Management*, 15(1), 15–19.
- Sinar Harian (2012). *Sinar Harian Online*. Retrieved on March 04, 2012, from <http://www.sinarharian.com.my/edisi/utara/bangunan-baru-jpam-kedah-dijangka-siap-mei-1.29334>
- Sriprasert, E., & Dawood, N. (2001). Genetic Algorithms For Multi-Constraint Scheduling: An Application For The Construction Industry Multi-Constraint Scheduling.

- Sugimura, N., Hino, R., & Moriwaki, T., (2001). Integrated Process Planning and Scheduling in Holonic Manufacturing Systems. *IEEE International Symposium on Assembly and Task Planning Soft Research Park*, vol. 4, pp. 250–254. IEEE Press, New York.
- Tamaki, H. Ochi, M. & Araki, M., (1996). Application of genetic-based machine learning to production scheduling. *Proceedings of the Japan/USA Symposium on Flexible Automation*, Vol. 2, ASME, pp. 1221-1224
- Tang, Y., Liu, R., & Sun, Q. (2014). Automation in Construction Schedule control model for linear projects based on linear scheduling method and constraint programming, 37, 22–37.
- The Malaysian Insider (2013). *The Malaysian Insider.Com*. Retrieved on October 01, 2013, from <http://www.themalaysianinsider.com/bahasa/article/prestasi-fizikal-empat-projek-dbkl-kurang-memuaskan>
- Tory, M., Staub-French, S., Huang, D., Chang, Y.-L., Swindells, C., & Pottinger, R. (2013). Comparative visualization of construction schedules. *Automation in Construction*, 29, 68–82.
- Trietsch, D., & Baker, K. R. (2012). PERT 21: Fitting PERT/CPM for use in the 21st century. *International Journal of Project Management*, 30(4), 490–502.
- Truscott, W.G., & Cho, D.I., 1987. Scheduling batch production with character graphics. *Industrial Engineering* 19 (2), 17– 22.
- Utusan Malaysia (2013). *Utusan Malaysia Online*. Retrieved on November 21, 2013, from http://ww1.utusan.com.my/utusan/info.asp?y=2009&dt=0604&pub=Utusan_Malaysia&sec=Rencana&pg=re_07.htm
- Wang, S., Wang, G., Lu, M., & Gao, G. (2008). Enterprise resource planning implementation decision & optimization models. *Journal of Systems Engineering and Electronics*. 19(3), 513–521.
- Wilson, J. (2003), “Gantt charts: a centenary appreciation”, *European Journal of Operational Research*, Vol. 149 No. 2, pp. 430-7.

- Wilson, J.M., (1997). A genetic algorithm for the generalised assignment problem. *Journal of the Operational Research Society* 48 (8), 804–809.
- Wennink, M., & Salvendy, M., (1996). Towards a planning board generator. *Decision Support Systems* 17 (3), 199– 226.
- Zheng, D. X. M., Ng, S. T., Kumaraswamy, M. M., & Asce, M. (2004). Applying a Genetic Algorithm-Based Multiobjective Approach for Time-Cost Optimization, (April), 168–176.



PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH