PROJECT PLANNING MODEL BUILDING FOR PACKAGED SYSTEMS DEVELOPMENT

Pilot Study:
Biometric Time and Attendance Systems Development Project Management
at P.T. Marga Computindo Sarana Semarang

Thesis

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2005

Certificate

I, Ign. Eka Budi Sudarto, certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree. I certify this thesis is the product of my own independent research. I'm fully responsible regarding this thesis.

I also certify that to the best of my knowledge any help received in preparing this thesis, and all sources used has been acknowledged.

Ign. Eka B. Sudarto

THESIS APPROVAL

We, undersigned, stated that the following thesis:

PROJECT PLANNING MODEL BUILDING
FOR
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I dedicate this thesis to:

my parents, who always inspire me
the meaning of continuous learning

my wife, Maya, and my daughter Vanessa and Erica
for their endless love, supports and patience

when did the last time you
do a new thing for the
first time ... ?

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Abstract

Information Technology (IT) has an important impact on organizational structure, behavioral patterns, and other aspect of management. Ability to manage technology, including Information Technology, has become strength factor of a company. IT is expected to play a key role in current Time-based competition.Unfortunately, IT Projects, especially Software Development are suffering from many difficulties. Failed IT Projects reaching a number of 90%, while 80% suffered from delays and over-budget and even 40% among them completely terminated. Software Development with is virtual and very difficult to measure.

Operation Management and Operations Research offer a number of models in managing a project. Combined with Forecasting Techniques provided by Econometrics, supported by series of Statistical tests, followed by Object Oriented Technology (OOT) implementation, problems in Software Development is expected to be solved.

The research is conducted using Quasi-Experimental Method, Single Subject Research Design with A-B-A-B pattern. Subject of the research is Job assignment, submitted to a programmer. The research uses a Pilot Study: *"Biometrics Time and Attendance Systems Development"*. Two novice programmers involved with 56 jobs each. Job Type AD1 are submitted to Programmer 1 and RP1 Job Type are submitted to Programmer 2. The "A" sessions are non-treatment experiment, no detailed descriptions, leaving the job to the programmer's instinct in mixed sequence. The "B" are treatment experiment, detailed description provided and properly sequenced. The "B" sessions for both programmers shows 72% to 84% learning rate, whereas no Learning Curve found in "A" sessions. Regression Analysis is used to construct forecasts for both Job Type using Log-linear model.

Both Job-Type are mixed in the Pilot Study. Work Breakdown Structure and Network Diagram of the Pilot Study are constructed in order to obtain sub-module precedence. The construction time is estimated using forecast data obtained previously. Three approaches are designed to construct the project: (1) Modular (module based development), (2) Job Type (Job Type based development), (3) Optimized Job Type. Modularity is provided by the OOT. Learning effect cannot be observed in the modular approach, whereas the Optimized Job-Type approach can reflect learning curve. Idle time can be minimized and shorter construction time is expected. The probability of the project completed under certain time is computed. Efficiency and Interruption are considered to be the source of uncertainties. Combinations of several level of Efficiency and Interruption are calculated. Increasing efficiency and minimizing interruption are proven to increase the probability of works completed under certain time. A set of simple mathematical models is then developed based on the result of the experiment.

A properly sequenced job assignment is proven to increase Learning Rate. The Learning Rate can be used to estimate the construction time of a Software Development Project which implements OOT, by using PERT/CPM model.

Abstraksi

Teknologi Informasi (TI) mempunyai pengaruh yang sangat penting dalam struktur suatu organisasi, perilaku dan aspek-aspek lain dari manajemen. Kemampuan untuk menguasai teknologi, termasuk TI menjadi faktor kekuatan suatu perusahaan. TI diharapkan dapat memainkan peranan kunci dalam Kompetisi Berbasis Waktu terjadi dalam lingkungan bisnis saat ini. Namun Proyek TI, terutama Pembuatan Piranti Lunak, mengalami banyak hambatan. Kegagalan Proyek TI yang ada mencapai 90%, dimana 80% diantaranya mengalami keterlambatan dan melampaui anggaran, 40% bahan dihentikan sama sekali. Sifat alamiah dari Pembuatan Piranti Lunak adalah tidak kasat mata dan sulit diukur

Manajemen Operasi dan Riset Operasi menawarkan sejumlah model dalam mengelola suatu proyek. Dengan menggabungkan model tesebut dengan model Ekonometrika dan sejumlah test Statitik yang ada, diikuti dengan implementasi Teknologi Berorientasi Obyek (TBO), problem dalam proses pembangunan Piranti Lunak diharapkan dapat diatasi.

Penelitian ini dilakukan dengan metode Quasi-Expertimental, dengan desain penelitian Single Subject Research, menggunakan pola A-B-A-B. Subyek penelitian adalah perintah kerja yang diberikan kepada programmer. Penelitian ini menggunakan pilot studi *"Pembuatan Sistem Presensi dengan Biometrik"*. Dua orang programmer muda terlibat dalam penelitian ini dengan mengerjakan masing-masing 56 perintah kerja. Jenis pekerjaan AD1 ditujuan kepada Programmer 1 dan jenis RP1 diberikan kepada Programmer 2. Sesi "A" adalah experiment tanpa treatment, dimana tidak ada penjelasan detail tentang pekerjaan, tergantung pada insting programmer dalam urutan yang tak beraturan. Sesi "B" adalah sesi dengan treatment, dimana pada penjelasa detail dan urutan pekerjaan diatur secara berurutan. Pada sesi "B" ditemukan Learning Rate 72%-84%, sedangkan pada sesi "A" tidak ada Kurva Belajar. Analisa Regresi dengan model Log-linear digunakan untuk membuat peramalan.

Kedua jenis pekerjaan tersebut dicampur pada Pilot Study. Work Breakdown Structure dan Network Diagram dibangun untuk mencari ketergantuan antar sub-module. Waktu pengerjaan diperikaran menggunakan data peramalan diatas. Tiga pendekatan dirancang untuk membangun proyek: (1) Pendekatan Modular, (pembuatan berdasar modul), (2) Pendekatan Jenis Pekerjaan, (3) Pendekatan Jenis Pekerjaan yang dioptimasi. Modularitas diatur oleh TBO. Efek Belajar tidak ditemukan dalam Pendekatan Modular, sedangkan pada Pendekatan Jenis Pekerjaan yang dioptimasi dapat ditemukan efek belajar. Waktu tunggu dapat diminimalkan dan waktu pembangunan proyek dapat dipersingkat. Probabilitas selesainya pekerjaan dalam waktu tertentu juga dihitung. Efisiensi dan Interupsi dianggap sebagai sumber ketidakpastian. Perhitungan menggunakan kombinasi dari berberapa tingkat efisiensi dan interupsi dilakukan. Terbukti bahwa peningkatan efisiensi dan pengurangan interupsi dapat meningkatkan probabilitas selesainya pekerjaan dalam waktu tertentu. Serankaian model matematis sedehana dibangun berdasarkan hasil penelitian ini. Serangkaian perintah kerja yang berurutan terbutki dapat meningkatkan Learning Rate, Learning Rate dapat digunakan untuk memperkirakan waktu pembangunan suatu proyek Piranti Lunak yang mengimplementasikan OOT, dengan menggunakan mode PERT/CPM

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CHAPTER I
INTRODUCTION TO STUDY

1.1 Backgrounds to the research

A company that can bring out new products three times faster than its competitor enjoys a huge advantage. (Stevenson, 2003). In today's global markets, you don't have to go abroad for competition. Sooner or later, the world comes to you (Bartlett and Ghoshal, 2000). Product and/or service quality has become the weapon in the battle for the world's market (Graither and Frazier, 2001). Universally, quality and time are two important factors in building strategies. Quality-based strategy focuses in all phases of an organization, while Time-based strategy focuses on reduction of time needed to accomplish tasks. The rationale is that by reducing time, costs are generally less, productivity is higher, product innovations appear on the market sooner and customer service is improved (Stevenson, 2003). Fast new product development can lead to competitive advantage (Blackburn, *et al.,* 1996; Datar, *et al.,* 1997)

Information is one of the competitive advantage for a company (Porter, 1979). Technology is one of the supports activities, needed for a company to reach a sustainable competitive advantage (Porter, 1985). Further more, ability to manage technology, including Information Technology, has become strength factor in SWOT Analysis (Thompson and Strickland, 2003)

Information Technology has an important impact on organizational structure, behavioral patterns, and other aspect of management. (Bittel and Ramsey, 1989). Information Technology, as a part of Information Systems, has contributed to organizational efficiency and effectiveness (Laudon and Laudon, 2000).

Information Technology (IT) helps people to solve lots of problems accurately in a quicker manner, for example: in telecommunications, data processing in private or public firms, banks etc. Personal Computer (PC) has become an essential peripheral nowadays. Emails, Chatting, Online Access, Video Conference is now commonly heard. Information Technology, has changed our daily habits (Vernon-Wortzel and Wortzel, 1997).

Information Technology implementation begins at 1954 when General Electric (GE) start their own Payroll Application using UNIVAC Computer (Suwardy, *et al.*, 2003). The other companies followed GE to implement business applications in any scale. Nowadays, Accounting Information Systems (AIS) cannot be separated from computers (Cushing and Romney, 1994; Gelinas, Oram and Wiggins, 1990; Hall, 2004; Muscove, Simkin and Bagranoff, 1990; Romney and Steinbart, 2000; Suwardhy *et al.*, 2003; Wilkinson, 1991). Without IT Systems, the company may lose the ability to compete in the fast-moving global economy (Murch, 2001)

Although Information Technology is currently inevitable, there is an astonishing fact. 90% of IT Projects, especially Software Development, actually failed, 80% suffer form delays and over budget and 40% of those are terminated (Clarke and Doherty, 2004; Dube, 1998; Krishnan, 1998; Suwardhy, et al, 2003; Tong, 1994). Lots of users still do not satisfied with the product of IT Projects (Herzwurm, 2003).

Software Development, is commonly known to be late. Many claims that software is an "art", not science. But knowing how to manage the software development process as a controllable process will be a key for global competitiveness (Blackburn, *et al.,* 1996).

According to Davis and Wilder (1998), said that, in a survey of 150 project managers, poor Project Management is one of the problem which cause failure in Software Development.

According to Project Management Institute (PMI), Project Management Knowledge (critical path, work breakdown structures, etc) is an intersection of knowledge of general management area with the domain knowledge of the project itself. In case of Software Development Project, the domain knowledge is some specific aspects of Engineering (Futrell, Shafer and Shafer, 2002)

One of the biggest challenge in managing an IT Project, especially Software Development, is lack of exact and standard Project Metrics in order to plan and measure stages in the project itself (Lowson, 2002; Pressman, 2001;Rothenberger, 2002). Time estimation is one of the stages in Project Management (Schonberger and Knod, 1994). Poor estimating techniques is often made by the project managers. Estimation is made by guessing best-calculated estimate (jokingly "guesstimate") and then doubling that number. This is not a scientific approach (Whitten, Bentley and Dittman, 2000)

Software Development evolutions, specifically in Programming Language is extremely fast. Emerging of Object Oriented Programming (OOP), which differs from procedural language (Stroo, 1999), makes the problem even more complex.

The question is: *why do people put so many efforts in software development ?* It's because software plays a crucial role in every Information Systems. Simply stated, software delivers the most important thing in our life: *information* (Pressman, 2001), whereas information is one of the resources owned by the company to gain a competitive advantage (Ferdinand, 1999; Porter 1979).

Software Development Companies occasionally raised from small scope family business (Carmel and Sawyer, 1998). In fact, there are many Software Development Companies still managed in family business environment. Traditionally, managers using their intuition and experience only in order to understand variables and their interconnections (Tan and Platts, 2003). Intuition and experience based decision making is suitable in family business environment (Allio, 2004). But in today's Time Based Competition, the company should take an action to make their products appear faster in the market (Blackburn, *et al.*, 1996). Raising pressure in Time to Market (TTM) and International Quality Standards such as ISO 9001:2000 (Carmel and Sawyer, 1998; McGrath, 2004), drives companies to focus on customer satisfaction (Jovanovic and Shoemaker, 1997; Babu and Suresh, 1997, Walker and Gee, 1997). Attention in Customer Focus, Process Approach and System Approach to Management, which are parts of Eight Quality Management (ISO, 2004), is very important in a struggle to seek a breakthrough in operations innovations. Turbulent Environment, Time Based Competition, Customer and Quality Focus and Time to Market ever increasing pressures drive Software Development Companies to refine their strategic operations.

Project Managers in Systems Development Projects usually build a Work Breakdown Structure (WBS) in order to complete the project. Software is a separated from hardware, but has the same level in Work Breakdown Structure (Futrell, Shafer and Shafer, 2002). Hardware Engineering refers to standard procedures. But Software Engineering or specifically Software Development relies on creativity and instinct of the programmers (Tong, 1994). Software Development has become the most frustrating component in Systems Development (Reid, 1998). Beside all of those difficulties mentioned above, Software Development environment, especially in Packaged Software Development, is very young, dynamic and liquid (Dube, 1998). This industry grows rapidly and globally. This environment makes this industry attractive despite of their difficulties and challenges.

IT products is one of the High Technology Product. High Technology development companies, according to Ayal and Izraeli (1997) and Kotler (2003) usually faces handicaps:

- Short Product Life Cycle. Especially for Software Products, Product Life Cycle is approximately only three years
- Similarities in customer's expectations
- Rapid Communications Grapevine
- High R&D expenditures
- Turbulent environment
- Multiple flow of information
- Low international barrier to entry

Economics, especially Operations Management and Operations Research, provides a wide variety of models which can be used to support a project. Model can assists managers to make a decision in a situation where lots of variables interfere and relate each others (Babu and Suresh, 1997; Walker and Gee, 2000). Proficiency in understanding and using models is needed in making a decision (Garvin and Roberto, 2001)

PERT/CPM is the commonly used model in Operations Management and Operations Research (Heizer and Render, 2004; Hillier and Lieberman, 2001; Krajewski and Ritzman, 1990; Muscove, Simkin and Bagranoff, 1990; Nahmias, 2001; Russel and Taylor, 2003; Stevenson, 2003). PERT/CPM has also been implemented in IT Projects, but PERT/CPM alone is not sufficient to make IT

Projects finished on time and satisfies customer's need. Customer's satisfaction dimension is an integral part for companies, which provides services in a dominant proportion (Behara and Gundersen, 2001).

Difficulties in activity estimation process always occur. As we have mentioned earlier, software engineering depends on instinct and creativity of the programmer (Tong, 1994). PERT/CPM needs *an accurate time estimation each activity* in the project. PERT/CPM also needs also needs *an accurate information of the order of each activities*. (Hillier and Lieberman, 2001). Difficulties in building time estimation of each activities caused PERT/CPM in Software Development unable bring a good solutions in IT Projects. Intuition and past experience are not enough in building an accurate time estimation. Innovations in Operations are required to bring a better solution (Hammer, 2004).

Fortunately, Operations Management and Operations Research provide techniques and models to build a better time estimation of an activity such as:

- Work Measurement Techniques (Bodnar and Hopwood, 2001; Graither and Frazier, 2001)
- Learning or Experience Curve (Heizer and Render, 2004; Hillier and Lieberman, 2001; Krajewski and Ritzman, 1990; Lapre, Mukherjee and Van Wassenhowe, 2000; Nahmias, 2001; Russell and Taylor, 2003; Stevenson, 2003)
- Standardization, Mass Customization, Modularity and Reliability Concepts, Simulateous Development and Concurent Engineering (Chase, Jacobs and Aquilano, 2004; Heizer and Render, 2004; Stevenson, 2003)

These models can be combined together to make a more accurate time estimation of an activity so that PERT/CPM model can give a better result.

There are some additional factors to consider in Software Development are:

- Programming language aspects (in this research, Visual Basic), for example: Projects, Forms, Classes, Designers, Codes (Bradley and Millspaugh, 2005; Landgrave, *et. al.*, 1999; Stroo, 1999)
- Object Oriented Programming (OOP), Component-ware and Component Reusability (Bodnar and Hopwood, 2001; Hoffman, Muench and Stynes, 1999; Ihlsoon and Young-Gul, 2003; Laudon and Laudon, 2000; Rothenberger, 2003)
- Linkage with Accounting Information Systems (AS), where the goal of application implementations is to optimize a company's business process (Verdaasdonk, 2004).

Human Resource, together with Technology, are important support activities to reach a competitive advantage (Porter, 1985, Laudon and Laudon. 2000). Human Resource Information Systems helps the company to manage their valuable resource of the company (Dessler, 2000)

Human Resource Information Systems (HRIS), as an integral part of Accounting Information Systems (AIS) (Bodnar and Hopwood, 2001; Hall, 2004), is one of the systems which uses computers intensively today (Dessler, 2000; Mayfield, Mayfield and Lunce, 2003; McLeod, 2001). One of the commonly used application in HRIS is Payroll Systems. Payroll Systems use data generated by time cards provided by Time Keeping Systems (Davis, Alderman and Robinson, 1990; Hall, 2004; Mulyadi, 1997; Stice, Stice and Skousen, 2004). Fast and accurate payroll data is required in Cost of Goods Sold calculation (Hansen and Mowen, 2003; Horngren, Datar and Foster, 2003; Horngren and Sundem, 1987).

In order to accelerate the payroll calculation process and minimize data entry errors, the Time Keeping Systems should use an accurate of Human Identification Techniques available (Clarke, 1994). The accurate Human Identification Technique makes Automated Time and Attendance Systems possible. Automated Time and Attendance consists of hardware and software (Reid, 1998). Hardware component consists of Electronic Time Recording Terminals with an ability to read Bar Codes or Magnetic Stripes in employee's badge (Reid, 1998; Romney and Steinbart, 2000). But Bar Codes and Magnetic Stripes implementation still cannot stop *Buddy Punching* practice (Roberts, 2003). This practice become a thread in attendance data validity (Muscove, Simkin and Bagranoff, 1990). Biometric Technologies developed to solve this problem (Harris and Yen, 2002; Klein, 2003; Larcinese, 2000; Liu, 2000; Pierce, 2003; Reid, 1998). Biometric Technologies burned inside Time Recording Terminals. Nowadays Biometrics has become an integrated component in Payroll Systems (Chandra and Calderon, 2003). Biometric Time and Attendance Terminals are expected to reduce paper works done by data entry staff. They can spend their time in a more comprehensive personnel administration works (Lee-Mortimer, 2001).

In marketing view, Biometric Time and Attendance Machine has a good prospect in the future. According to Roberts (2003), based on International Biometric Group (IBG) survey, market for Biometrics is predicted to catch a number of $500 millions in 2005. But actually in 2003, Biometrics Market has grown to reach $719 millions and expected to reach $1,2 billion in 2004. Fingerprint market share, as the most popular Biometrics, predicted to reach $800 million in 2008 (Reid, 2004). Biometric Time and Attendance Systems implementation process is not always smooth. As a whole systems, Biometric Time and Attendance Terminals hardware should be perfectly integrated with an appropriate software.

Lots of efforts has been conducted in order to improve IT project management (Tesch, Kloppenborg and Stemer, 2003), but still there is no satisfactorily reports (Suwardy, *et al,* 2003)

As a division which operates in Software Development, Systems Integration Division of P.T. Marga Computindo Semarang also experience the same problems as described in several journal articles by the experts. Systems building can extremely exceeds the projected time to a number of 3 to 4 times. The division tried hard to seek solutions for this problems by using a random and trial-and-error methods, which significantly cut half of the delay time. Management and the Company Leaders has seen an improvement and consider this result is positive, but still seeking a better alternative to cut the delay even further. Management's decision is to improve this effort continuously towards International Quality ISO 9001:2000 achievement.

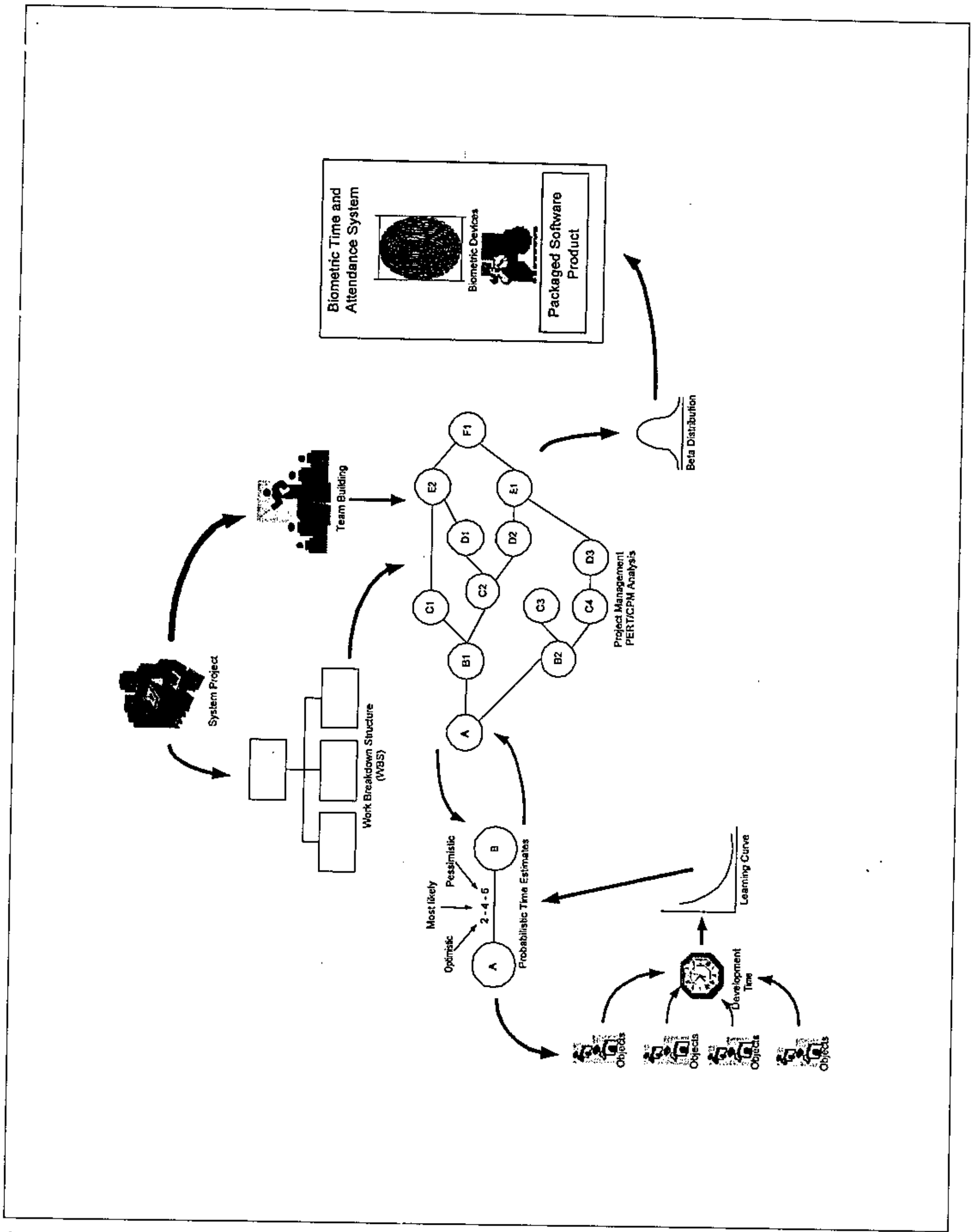
Based on the previous findings and the empirical fact of problems faced by P.T. Marga Computindo Sarana - Semarang, specifically Software Development in System Integration Division, further research is needed.

According to the problems described above, this research is a Strategic Operations Research, which relates to innovations in Software Development. A breakthrough in Operations innovation does not only provides continuous improvement, but can beat the competitors and shake the industry (Hammer, 2004)

Application of some technical terms are unavoidable in this research. But this research primarily focused in Project Management aspects, not programming and technical aspects of Software Development. Figure 1-1 describes the natural flow of the problems in this research.

Figure 1-1

Graphical representation of research problems



Source: Developed for this thesis

1.2 Research Problem

Information Technology has an important impact in many aspect of management. Thousands of applications running everyday, especially accounting applications (including Time and Attendance Applications) in order to support business process of an organization. Software plays an important role in every Information Technology applications, because software delivers information. But, efforts to build a new software product to support hardware to become a solid systems is now easy. The nature of IT, (virtual, short product life cycle and turbulent environment) increases the difficulties in Software Development

As described earlier in this chapter, 90% of IT Projects, especially Software Development Projects, failed to meet its objectives, 80% suffered from delays and over budget, 40% of them were terminated. Several alternatives in project management has already been developed by the experts, but a lot of users still disappointed by IT products, especially Software Development Products.

Poor estimating techniques which analyst and project managers do. Estimation is made by guessing best-calculated estimate (jokingly "guesstimate") and then doubling that number. Obviously, this is not a scientific approach

Because software become a main component in IT Projects, further research in building a model to predict the length of the software development process is needed, so that delays can be minimized. However, the model should be simple and easy to implement.

Simple stated, research problem is:

- *How to estimate the Construction Time of a Packaged Software Development Project accurately ?*

1.3 Research Questions

According to the research problem, research questions are:

1. *What are Critical Time determinants in Packaged Software Development?*

2. *Is Standardized Object Specifications in a module can improve programmer's Learning Curve ?*

3. *Is programmer's learning curve in building a module can improve overall Construction Time Estimation of Packaged Software Development Projects.?*

4. *How to accommodate uncertainty in Critical Time of Packaged Software Development Projects?*

5. *How Standardized Object Specifications, Learning Curve and Uncertainty can be incorporated in Packaged Software Development so that construction time can be accurately estimated?*

1.4 Objectives

Research objectives is not always looking for a "Generalizability of Population" (Dube, 1998). Research can be done in order to predict or to control specific individual behavior (Furlong, Lovelace and Lovelace, 2000). Repeatedly accurate measurement and the usage of sufficiently standardized treatment creates a possibility for another researcher to follow the steps in this research. In other words, makes replication possible. By conducting an ability of replication, specified research meets Generalizability aspect (Gay and Diehl, 1996)

Based on the statements mentioned above, the objective of this research is to gain a deep understanding of the real problems of IT Project Management, specifically Packaged Software Development, and to build a model based on several previously available models in Economics, especially in Operations Management and Operations Research. The model is designed to be simple and easy to implemented

1.4.1 Broad Research Objective

Broad research objective is:

To build a simple and easy to implement model in IT Project Management, specifically Packaged Software Development Projects based on Object Oriented Programming (OOP) technology in order to:

- *assist development time estimation*
- *minimize delays*
- *lead the company to gain a Competitive Advantage*

1.4.2 Specific Objectives

Specific objectives of this research are:

1. To identify and analyze Critical Time determinants in Packaged Software Development Project Management

2. To analyze the effect of Object Planning and Standardized Object Specifications to the programmer's working time and learning curve.

3. To analyze the effect of programmer's learning curve to the overall Construction Time of the Packaged Software Development Project

4. To analyze the effect of uncertainty in Critical Time of Packaged Software Development Project

5. To build a simple model, called *Object Planning, Standardized Specification and Construction Estimate (OPSS-CE),* involving Standardized Object Specifications, Learning Curve and Uncertainty, which can be expected to assists in estimating Packaged Software Development based on Object Oriented Programming (OOP) technology Construction Time more accurately.

6. To implement the model in a Pilot Study of Biometric Time and Attendance Project Management

1.5 Research Purpose

The purpose of this research are:

1. *For the company, where the pilot study of this research being held:*
   to provide a better Project Management approach in Packaged Software Development, especially in Biometrics Systems Development.

2. *For academic purposes, especially for Magister Manajemen Programme of Diponegoro University:*
   to make a contribution in research enrichment and to give a broader horizons in integration of Economics, as a dynamic science, with the another sciences such as Computer Sciences, Software Engineering, and Biometrics. Such integration is expected to rise innovations in Systems Development, New Product Developments, IT Project Management, etc.

3. *For the Management Science universally:*
   to become a foundation and starting point of future research in IT Projects Management, Systems Development, New Product Development and Software Engineering

1.6 Basic and important research assumptions:

There are some basic and important assumptions in this research:

1. This research is a Strategic Operations Research, focusing on Work Measurement to establish a Standardized Time

2. The focus of IT Project being analyzed is Software Development

3. Software Development being analyzed is Packaged Software Development, classified as Application Software. Tailor-made Software Development (also known by some experts as IS Software Development) is behind the scope of this research. Further explanations regarding this issue can be found in part 2-9 of this research.

4. Client Operating Systems Environment (COE) used in this research is Microsoft® Windows™ family. The reason of using this Operating Systems is the fact of Microsoft held 93,8% of Client Operating Systems market (Rohde, 2003). From managerial perspective, using another Operating Systems, (open-source software such as Linux) raises many issues regarding after-sales supports. The initial cost is low (free, in fact), but no authorized person will provide a support concerning a question of software problems (Thompson and Cats-Baril, 2003).

5. Language being used by the programmers in this research is Microsoft® Visual Basic™ 6. The programming language should match the Client Operating Systems.

6. The programmers being analyzed feel generally fit with their working environment and they generally accept the condition of the condition implied by their working environment.

7. The programmers has been trained before to master the specific aspects of the programming language being used. Training based on "Desktop Applications for Microsoft Visual Basic 6.0 MCSD Training Kit" (Stroo, Ed., 1999) book. They are required to complete a computer-assisted test using the companion CDROM and yield at least 60 points. The period of time required by the programmer to master the materials is not counted

8. The main Database engine is JET Database Engine with the format of Microsoft® Access™ MDB, although usages Microsoft® MSDE™ in some parts already implemented. This is expected to become a migration path to Microsoft® SQL Server™ .

9. Approximate age of the programmer's is 25-35 years old. No formal education background is assumed to give a significant infulence in this research, since treatment in this reseach is done after a properly training session is given to the programmers.

10. Considerations of factors such as perception of the salary, enumerations, environment and another programmer's subjective matters are behind the scope of this research. This assumption based on the first assumption mentioned above

11. The company has a strong commitment to finance this project. Also assumed that there is no significant problem in the budget to complete the project

12. Researcher has an unlimited access to the company's resources and data required in this research

CHAPTER II
LITERATURE REVIEW

2.1 Introduction

We live in turbulent times. The world has changed extremely fast. All aspects of our life, such as social, political and economic environment has changed so fast. Some of them changed evolutionary but the rest of them revolutionary changed. A Company should be able to deliver their product faster than the others in order to win the competition and to reach competitive advantage (Stevenson, 2003)

Information Technology has an important impact on organizational structure, behavioral patterns, and other aspect of management. It has been observed by intelligent practitioners for many years. However, among academic researcher, there has seemed to be in recent years a "discovery" that the impact of technology is important and real (Bittel and Ramsey, 1989). Information Technology, as a part of Information Systems, has contributed to organizational efficiency and effectiveness (Laudon and Laudon, 2000). It helps people to solve variety of problems quickly and accurately. Ability to manage Information Technology may lead an organization or a company to a sustainable competitive advantage (Porter, 1985, Thompson and Strickland, 2003)

Economics, as a dynamic science, deeply influenced by the advancement of Information Technology. Management Information Systems has grown so fast. The fact of IT influence in the business process of a company triggers an interaction between economics with another science, such as Computer Sciences, Software Engineering, Biometrics etc.

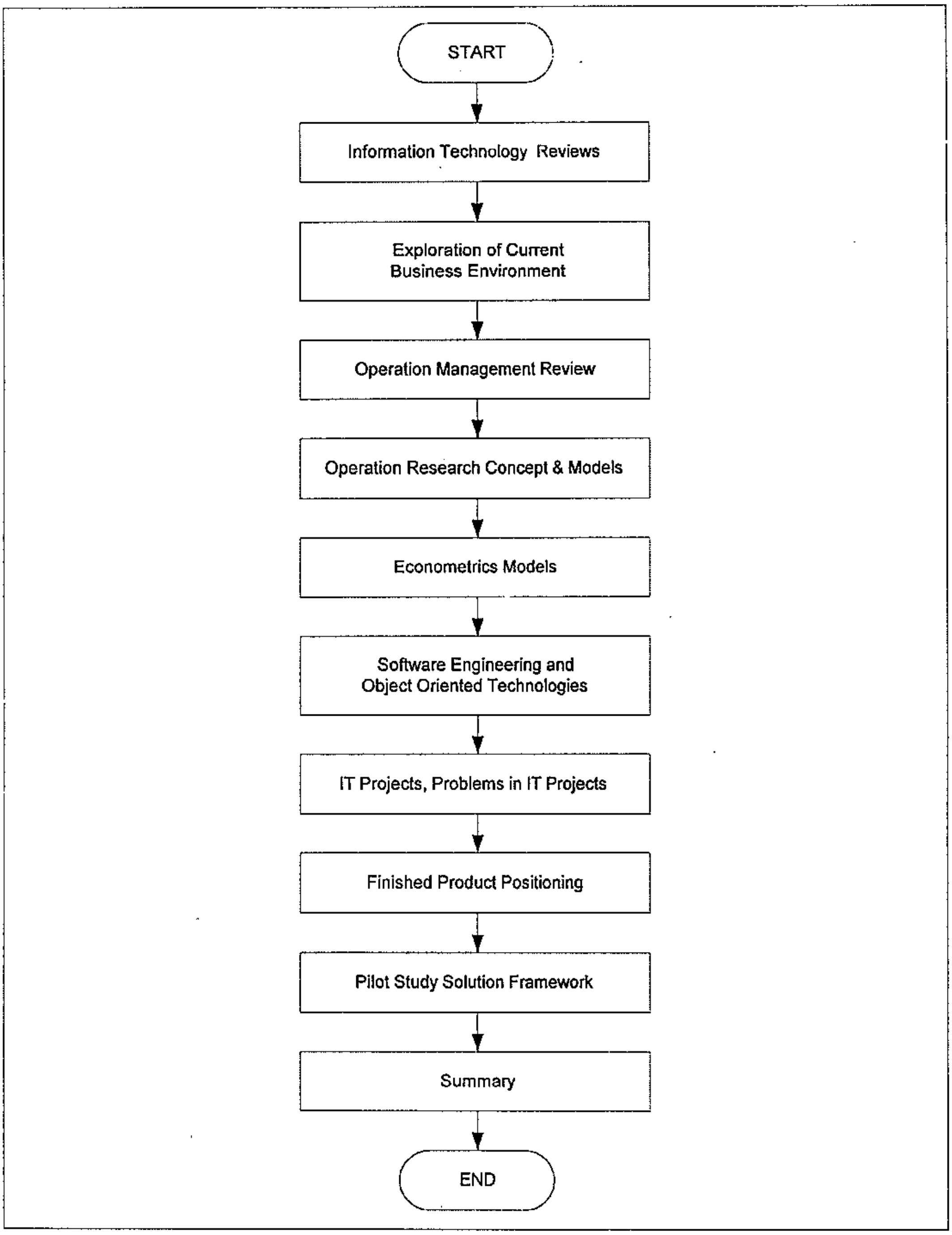
Information Technology (IT) is very young and liquid (Dube, 1998). This IT characteristics may lead to difficulties in Information Technology infrastructure development, which in turn may lead to difficulties in reaching a sustainable competitive advantage. Lots of difficulties found in IT Projects, from delays to cancellation of the project.

Regarding to these empirical facts, researcher tries to find academic facts from many scientific readings, including text books, journals, articles and web sites of various technology consortium, international standardization bodies, well-known universities and also hardware and software developer.

2.2 Outline of Literature Review

Literature review in this research is arranged in a systematic manner, expected to be easily understood. Figure 2-1 shows the outline of the Literature Review Graphically in order to grasp the essence of this Literature Review.

Figure 2-1
Literature Review Outline



Source: Developed for this thesis

Some pointers regarding the contents of each subjects can be found in the following paragraphs.

1. Information Technology Reviews

   Information Technology, Evolution of Information Technology, Definition of Information Systems (IS), Information Technology (IT) and the role of Information Systems in an organization. Also presented here the characteristics of High Technology Industry.

2. Exploration of current business environment:

   Time-based Competition, Time-based Strategy, Technology and Sustainable Competitive Advantages and Strategic Operations Framework

3. Management Science/Operation Research/Operations Management:

   Backgrounds to Operations Management and Management Science/Operations Research (MS/OR) and Project Management

4. Some models available in Operations Management and Operations Research:

   - Management Science and Operations Research scientific steps
   - PERT/CPM Model, Critical Time, Time Estimations, Work Breakdown Structure (WBS)
   - Work Measurement techniques
   - Learning Curve
   - Standardization, Modularity and Reliability Concepts

- Probabilistic Time Estimates using Beta Distribution.

5. Regression Analysis:

   Regression Analysis; Linear and Log-linear Model; Statistical Tests; Best-Fit model selection criteria

6. Software Engineering:

   IS and Packaged Software Development, Team Approach in Software Development, Classification of Software, Object Oriented Technology and Modularity, Software Development Metrics, Project Management in Software Development, IT Project Failures

7. Materials which describe the basic knowledge of the Pilot Study. Also description of where the Pilot Study final product is expected to fit in daily Business Process of a company:

   - Human Resource Information Systems (HRIS) as a part of Information Systems (IS), specifically Management Information Systems (MIS)

   - Time and Attendance Systems as a part of Human Resource Information Systems (HRIS)

   - Human Identification Technologies exploration, especially Biometrics

   - How Human Identification Technologies can support and enhance Automated Time and Attendance Systems.

8. Solution Framework:

   Pilot Study Description and the Solution Framework

9. Summary of the Literature Review:

Summarizes subjects in the Literature Review

A pilot study is needed in order to conform the experimental research methodology used in this research (Zikmund, 2003). Pilot Study is also useful to identify the essential process in Software Development (Jovanovic and Shoemaker, 1997). Management Science and Operations Research process steps requires testing process for reasonableness of the solution followed by the implementation for the solution itself (Levine, *et al.*, 1989) The Pilot Study in this research is Biometric Time and Attendance Systems Development, focusing in its Packaged Software Development part.

2.3 Information Technology Reviews

2.3.1 Information Technology Evolution

The powerful worldwide changes have altered the business environment into a very competitive environment. The major change in business environment is the very nature of organization and management. Newer managers relies on informal commitment and networks to establish goals, a flexible arrangement of teams and individuals working in a task forces, a customer orientation and appeals to professionalism and knowledge to ensure proper operation of the firm . Information Technology makes this management style possible. (Laudon and Laudon, 2000).

Information Technology helps people in many organizations, namely in banking, manufacturing industries, tourism, government offices, non-profit organizations such as hospitals, retail business - small scale to multinational scale, etc.

Discussing Information Technology, computer is an essential part. Information Technology has made people do more work in shorter time ("Getting more done in less time", according to Intel Corp). Personal Computers (PC) can be operated easily in many organizations nowadays. Email, Chatting. Online access, Video Conferencing has become common terms. Information Technology has changed our habit (Vernon-Wortzel and Wortzel, 1997). Millions of peoples across the world can communicate each other at home or in the office (Evans and Wurster, 1997). Further more, Information Technology has change the management process by providing wide number of powerful tools to do daily business tasks (Laudon and Laudon, 2000)

Information Technology evolution has been commencing for more than 50 years. The first implementation of commercial application of Information Technology in management field is done at General Electric (GE) in 1954. They start their payroll application running in a UNIVAC Computer (Suwardhy, *et al.*, 2004). IBM established a historical event by releasing IBM 360 in 1964. This also considered as an important milestone in Information Technology history (Feld and Stoddard, 2004). Many companies then followed to implement IT. According to Laudon and Laudon (2000), there are 4 (four) generations of computer hardware since 1954.

1. **First Generation: Vacuum Tube Technology (1946-1956)**

   This generation uses Vacuum Tune Technology. Memory and processing power of the first generation of the computers are very limited. Computers are commonly used in scientific research, military institutions and in certain multinational companies

2. **Second Generation: Transistors (1957-1963)**

   Transistors replace vacuum tubes, because they are smaller and more reliable compared to vacuum tubes. Besides, transistors uses least electricity power and reduce heat emissions. This generation comes with a more better processing power, so that computers can be used to automate repetitive business tasks (generally payroll and billing)

3. **Third Generation: Integrated Circuits (1964-1979):**

   Computers of this generation made of hundred or thousand of transistors in a tiny silicone chip. This IC can boost computer performance to reach 5 MIPS (millions instructions per second). Third generation of computers can be implemented without an exhaustive training program, which open the possibility to run business applications. This generation shows a a significant increase in computer implementations in business area.

4. **Fourth Generation: Very Large Scale Integration Circuits (VLSIC), from 1980:**

   A fourth generation computer uses more than 10 millions of circuits in a single chip, integrating memory, logic and control. This chip called a *microprocessor*. Fourth generation computers reach 1 BIPS (billions instructions per second). They also reach every aspect of human being.

By 2007, Intel Corp predicted the new technology would allow it to build chips with one billion transistors and operate at a speed of 20 Gigahertz. Gordon Moore, the Intel co-founder, establish Moore's Law with state that semi-conductor chips double the number of circuits roughly every 18 months (Murch, 2001; Thompson and Cats-Baril, 2003). Supported by the evolution of computer hardware IT creates so many opportunities as well as threat. Revolutionary products such as HDTV is invented, services can be easily reached and become more and more flexible (for example: courier services) , even to the invention of robotics and automation systems (Stevenson, 2003). New products and services continuously being invented, many companies founded, although some of them managed to survive while the rest not (Thompson and Cats-Baril, 2003).

Based on explanation above, Information Technology conclusively may lead a company or an organization to a competitive advantage. To make a deeper understanding of how Information Technology may lead a company to a competitive advantage, it is advisable to properly understand what Information Technology is.

2.3.2 Information, Information Systems, Information Technology

2.3.2.1 Definitions

There are two popular terms in the context of Information Technology: Information Technology and Information Systems. Occasionally, both are considered to be the same, but actually there are some fundamental difference between them. According to Whitten, Bentley and Dittman, 2001; Wilkinson, 1991; definition for each terms are:

1. **Information Systems (IS)** is an arrangement of people, data, processes, and interfaces that interacts to support and improve day-to-day operations in a business as well as support the problem-solving and decision-making needs of management and users

2. **Information Technology (IT)** is a contemporary term that describes a combination of computer technology (hardware and software) with telecommunications technology (data, image and voice networks).

An Information Systems exists *with or without* a computer. But when Information Technology is used in Information Systems, it significantly expands the power and potential of most information Systems.

Based on both definitions above, Information technology (IT) is a part of an Information Systems (IS). The easiest way to understand an Information Systems is the usage of Information Technology (IT) for specific purposes in an organization (Thompson and Cats-Baril, 2003)

2.3.2.2 Purpose of information processing

A company receives a lot of information in their daily operations from both internal and external environment. Information is data which has been processed (McLeod, 2000; Laudon and Laudon, 2000; Wilkinson, 1991). Information managed by Information Systems (IS) (Biswajit and Shweta, 2004), using the transformation process done by the software (Pressman, 2001).

Information Systems plays an important role in an organization. Digital technology has transform an organization's behavior. There are interdependencies observed, between business strategies, business rules, business procedures in one side and information systems, software, hardware and communications on the other side. (Laudon and Laudon, 2000)

Information System serves two important functions in an organization (Gelinas, Oram and Wiggins, 1996), yaitu

1. **Horizontal Information Flows:**

   Daily operations transaction processing, recording and reporting.

2. **Vertical Information Flows:**

   supporting managerial activities such as decision making

In order to maximize the utility of information to support a business operations, information has to be properly managed. Computer can easily obtained today. This means that there is an ever increasing information flows in social environment especially in business environment (Kendall and Kendall, 1992).

2.3.3 Relationship Between Information Systems and Organizations

No one can deny that information systems have contributed to organizational efficiency and effectiveness. Information Systems and organizations have a mutual relationship each other (Laudon and Laudon, 2000).

To understand relationship between Organizations and Information Systems, one should understand properly the definition of an organization:

1. **Technical definition:**

   Organization is a stable, formal social structure that takes resources from environment and process them to produce outputs

2. **Behavioral definition:**

   Organization is a collection of rights, privileges, obligations and responsibilities that are delicately balanced over time through conflict and conflict resolution

A firm is an organization that combines and organizes resources for the purpose of producing goods and/or services for sale (Salvatore, 1989).

Still according to Laudon and Laudon, 2000, Information Systems can markedly alter life in an organization. Information Systems changes the balance of rights, privileges, obligations and responsibility and feelings that has been established over a long period. The blueprint or plan that expresses the desired future structure for the information systems in an organization is called Information Systems Architecture (Hoffer, Prescott and McFadden, 2005)

2.3.3.1 How Organizations affect Information Systems

Organizations have a direct impact in information technology in a two way process.

1. Organization decides what and how the technology will be used and what role it will play in an organization

2. Organization decide who will design, build and operate the technology within the organization. Organization can obtain technologies from internal specialists and external specialists, such as hardware vendors, software development firms and also consultants.

2.3.3.2 How Information Systems affects Organization

The explanation of how Information Systems affect organization can be explored from several thcories:

1. **Microeconomic theory:**

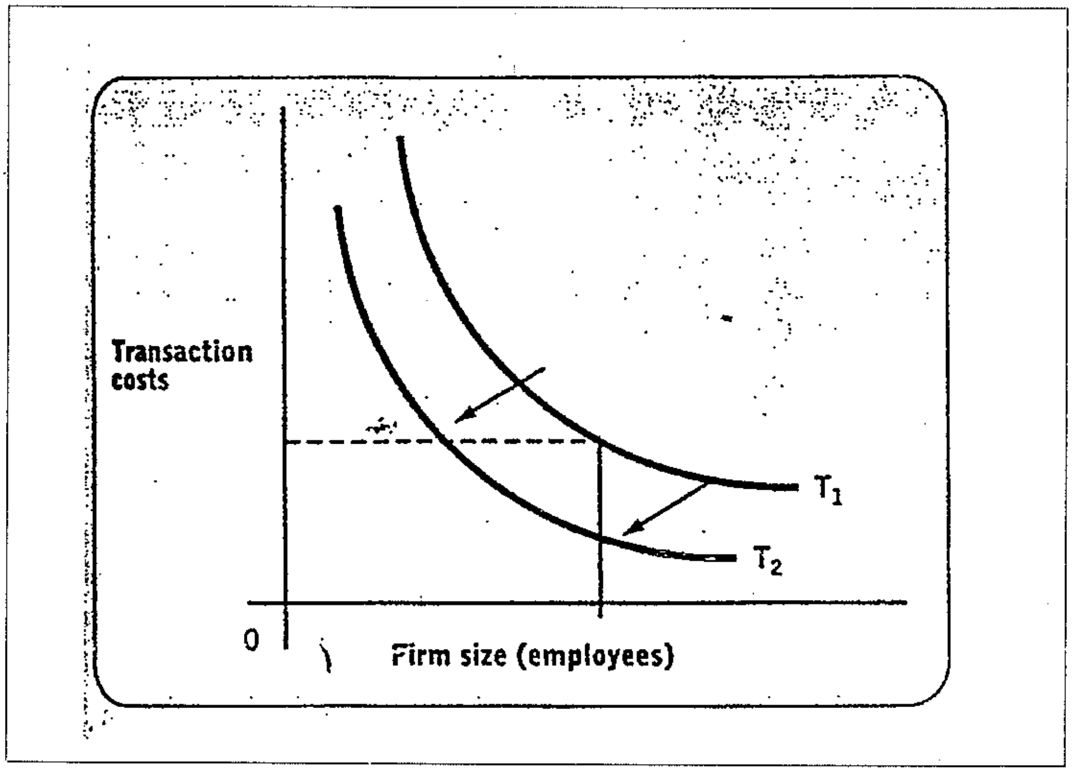
   According to microeconomic theory, Information Technology should result in a decline in the number of middle managers and clerical workers as Information Technology substitutes for their labor

2. **Transaction Cost theory:**

   Transaction cost theory stated that firms and individuals seek to economize on transaction costs. The firm generally grew to reduce transaction costs. Information Technology potentially reduces costs for a given size, shifting the transaction cost curve inward, opening up the possibility of revenue growth without increasing size or even revenue growth accompanied by shrinking size.

Figure 2-2

Transaction cost theory



Source: Laudon and Laudon, 2000, *Management Information Systems*

3. **Agency cost theory:**

Agency cost theory believes the positive impact of Information Technology. As firms grow in size and complexity, they experience rising agency costs. Information technology shifts the agency cost curve down and to the right, allowing firms to increase size while lowering agency costs.

2.3.3.3 Path of Information Technology implementation in organization

Ilharco (1999), explains the path of Information Technology in an organization. There are five phase of Information Technology implementation in an organization as follows:

1. Ad Hoc (1960s to 1970s)
   IT enters organization. Used in ad-hoc ways

2. Vertical (mid 1960s to 1970s):
   IT accelerate and automate existent functions and tasks

3. Strategic (late 1970s to date):
   IT is a facilitator of the implementation of strategy

4. Horizontal (late 1980s to date):
   IT is enables redesign of the horizontal process

5. Exploitative (mid 1990s to date):
   No clear direction

The entire organization (specifically entire enterprise) has becoming increasingly dependent on technology to sustain and grow profits, and develop and implement new service or products. Chief Executive Officers are now aware of the need to sustain their IT department in order to maintain the health of their business. Without staffing for IT Systems, the corporation may experience major loss of market share and loss of the ability to compete in the fast moving global economy (Murch, 2001)

Using all of those explanations as a reference, we can conclude that Information Technology has a positive impact in organizations

That's why firms are interested in deploying Information Technology to increase its efficiency and effectiveness. Some firms decided to build Information Systems internally. In contrary, some other businesses have a policy of not building any systems they can purchase (Whitten, Bentley and Dittman, 2000). This policy makes Information Technology vendors thrive.

It is a benefit to explore the environment characteristics of the firms who provide High Technology products as Information Technology vendors are among them. The High Technology firms have a unique environment which can never be found in another industries.

A better understanding about environment characteristics of a can give a better ability to understand its business strategy.

2.3.4 Characteristics of High Technology Firms

Firms which operate in High Technology operates in a unique environment according to characteristic of their product and their market. Ayal and Izraeli (1997), Dube (1998) and Kotler (2003), describe this unique environment has a characteristic of the high technology firms as follows:

1. Short Product Life Cycle; usually 3 to 10 years. Software product has an even shorter life cycle: approximately shorter than 3 years

2. Similarity in customer's expectations.

3. High Research and Development expenditures

4. Turbulent environment

5. Rapid Communication Grapevines

6. Relatively low International Barrier to Entry

In fast-cycle high technology industries, the speed and rate at which companies can introduce products into market are critical for sustaining competitive advantage and market share (Datar, *et al.,* 1997). There is a severe contradiction between Short Product Life Cycle and High Research and Development Expenditures required to build a High Technology Product until finally reaching the commercialization phase. Some research found that the time required for the process is approximately 10 years.

Based on those severe contradiction, an effort to shorten development time is very crucial (Ogbuehi and Bellas, 1997). This effort might meet its objective when supported by innovations in operations. The main approach is to operate in a lower cost and provide a better quality and services compared with its competitors. Innovations in operations may lead a company to operate in a different path ahead from their competitors. (Hammer, 2004)

All of those characteristics described above can be found in Information Technology firms. IT Project problems have their roots in those characteristics.

2.4 Exploration of Current Business Environment

2.4.1 Time-based Competition and Time-base Strategy

A company that can bring out new products three times faster than its competitor enjoys a huge advantage. (Stevenson, 2003). Time to market is widely viewed as a key source of competitive advantage, especially in "fast-cycle" industries (Datar, *et al.,* 1997). In most industries, the most critical dimension in competition is the speed of the company to respond to customer demands. Therefore, a fast new product development can lead a company to a sustainable competitive advantage.(Blackburn, *et al.,* 1996, Chase, Jacobs and Aquilano, 2004). In today's global markets, you don't have to go abroad for competition. Sooner or later, the world comes to you (Bartlett and Ghoshal, 2000). But in today's global business environment there are opportunities for an organization to offer new products and services to faraway locations (Laudon and Laudon, 2000).

Traditionally, business strategies of an organization have tended to emphasize cost minimization of product differentiation. While not abandoning those two approaches, many organizations have embrace strategy based on Quality and/or Time (Stevenson, 2003). Product and/or service quality has become the weapon in the battle for the world's market (Graither and Frazier, 2001). Universally, quality and time are two important factors in building strategies. Quality-based strategy focuses in maintaining the quality of an organization's product and/or services. Time-based strategy focuses on reducing of time needed to accomplish tasks. The rationale is that by reducing time, costs are generally less, productivity is higher, product innovations appear on the market sooner and customer service is improved (Stevenson, 2003).

2.4.2 Technology and Sustainable Competitive Advantage

Every company in the world are exposed to external environments. External environment consists of Competition, Government Regulations, Technology, Market Trends and Economic. Technology is one of the five external environment which may affect a company's strategy. (Dessler, 2000; Stevenson, 2003).

Porter, 1984, introduced forces governing competition in an industry. There are five factors governing competition in an industry:

1. Threat of new entrants
2. Bargaining power of suppliers
3. Bargaining power of customers
4. Threat of substitute product and/or services
5. Rivalry among within industry competitors

In order to build an accurate strategy, an Environmental Scanning is essential. Environmental Scanning is a process to observe company's business environment and make a future trend prediction (Wilson, 1984). As an element of a company's business environment, technology is included as an essential factor to be considered in environment scanning process.

Technology, despite "high technology" or "low technology", is important. Information is pervasive in a value chain of a company, because every company uses technology for example for scheduling and controlling purposes. Technology also involved in office administrator, because it optimizes the clerical activities and all of the office functions. Technology also become a key factor to build a barrier to entry, where barrier to entry is one of the external environment, as stated by Porter, 1979.

Technology can decrease scale of economies in nearly every activities. Technology can become the basis of Learning Curve. Why ? Because learning curves comes from improvements such as layout, designs, speed of the machines, which notably a product of technology (Porter, 1979 and 1985)

Technology is one of the forces that can influence industrial structure by spreading information rapidly to each element of the organization (Thompson and Strickland, 2003; Porter 2001). The speed of information transmission influence company's competitive advantage (Porter, 1985). Further more, Information Technology become a strength element of the SWOT analysis (Thompson and Strickland, 2003). Information Technology will help to build a comparative advantage, which in turn builds a Competitive Advantage (Porter, 1985; Biswajit and Shweta, 2004). Porter urged companies to build a sustainable competitive advantage.

Competitive Advantage is a company's ability to perform in one or more ways that competitors cannot and will not match. Any Competitive Advantage should be seen by customer as a *Customer's Advantage.* So, to achieve a competitive advantage, a company must focus on building customer advantage (Kotler, 2003).

Competitive Advantage will shape the strategy of the company (Porter, 1987)

2.4.3 Strategic Operations Framework

At the very basic level, all business must be concerned with capturing and retaining monetary value. The reason is quite simple: if an organization is unable to capture or retain sufficient monetary value, it will cease to exists. Incidentally, this holds true for public sector or not-for-profit organization (Thompson and Cats-Baril, 2003).

This fact leads to an effort to provide products and/or services to the customer, a company usually exposed to some alternatives of operations activity. An effort to make that decision actually becomes the beginning of a strategy. Strategy is a matter of choices (Lowson, 2002). The essence of a strategy is choosing a different activity from the competitors (Porter, 1996).

Operations Strategy is concerned with setting a broad policies and plans for using resources of a firm to best support its long term competitive strategy (Chase, Jacobs and Aquilano, 2004). Porter (1985), said that in competitive terms, value is an amount which customer is willing to pay to a firm for something the firm had given him.

Classical literatures on competitiveness claims that firms position themselves strategically in the marketplace along one of two dimensions: lower cost or cost differentiation. However, cost and product are not the only two dimensions which firms distinguishes themselves. Nahmias (2001) said that there are some factors which relate directly to operations functions as follows:

- Quality
- Delivery speed
- Delivery reliability
- Flexibility

Chase, Jacobs and Aquilano (2004), described this competitive dimensions even further as follows:

- Cost, means "Make it cheap"
- Quality and Reliability, means "Make it good"
- Delivery Speed, means "Make it fast"
- Delivery Reliability, means "Deliver it when promised"
- Coping with changes and demand, means "Change its volume"
- Flexibility and new product introduction speed, means "Change it"
- Other product-specific area, means "Support it"

Quality, according to Hansen and Mowen (2003), has an operational definition as "something with meets or exceeds customer's requirements".

Software Developers agree that Quality is an important goal Software Development companies. According to Pressman (2001), Software Quality means conformance to explicitly stated functional and performance requirements, explicitly documented development standards and implicit characteristics that are expected of all professionally developed software. According to Galin (2004), official IEEE definition of Software Quality is:

1. The degrees to which a system, component or process meets specified requirements

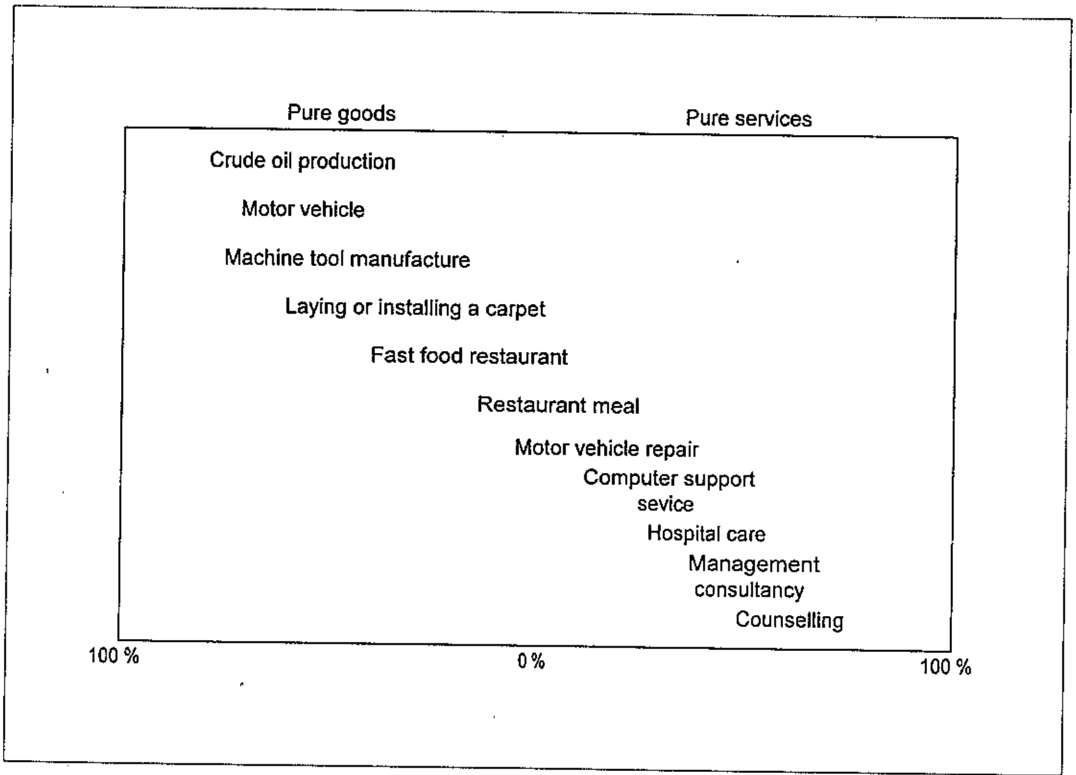
2. The degree to which a system, component or process meets customer of user needs or expectations.

In today's competitive environment, product/service quality has become an important weapon in the battle for the world markets of mass-produced products

(Graither and Frazier, 2001). Specifically, flexibility, responsiveness and time has become the weapon to reach competitive advantage (Lowson, 2002). This will lead to a time-based competition (Blackburn, *et. al,* 1996)

As described in the previous sub-chapter, there is a combination of products and services aspect in Operations Management.

Figure 2-3
The goods-service continuum



Source: Lowson (2002), *"Strategic Operations Management, The New CompetitiveAdvantage"* and Stevenson (2003), *"Operations Management"*

This combination is very important. Modern operations increases to offer bundles of products, services, supports and knowledge continuously, using customer as the main focus (Vandermerwe and Rada, 1998). Innovations in operations are required. The more and more combination of products and services offered. So, pressure to make innovations, in order to offer cheaper product supported by prime quality of services, are increased (Hammer, 2004).

Computer support services (including software) are considered to have a more service content than product in "The Goods and Services Continuum" shown in figure 2-3 (Lowson, 2002; Stevenson, 2003)

Considering strategic dimensions of Operations Strategy and pressure to reach sustainable competitive advantage, Operations Strategy becomes the foundation of making decisions has several important characteristics as follows:

1. *a middle and long time horizon:*

   related to customer's demand and the method to satisfy it in 1 to 5 years period (shorter time horizon are considered as operational manager decision making)

2. *Operations Level Analysis*

   needs to analyze operational process across the whole firm

3. *Conceptualization in operations level:*

   to decide what product and/or services should be offered to satisfy customer's need, including the quality of product and/or services in the future, not in daily process

4. *Strategic, not tactical*

   decisions that relates to the whole transformation systems of the firm, not just decisions for daily operations

If those decisions can satisfy customer's need and reach all of the potential customers, it can be said that the company reach an operations effectivity which will increase company's performance to reach sustainable competitive advantage (Porter, 1986). Hammel and Prahalad said "The essence of strategy lies in creating tomorrow's competitive advantage faster than the competitors mimic the ones you possess today" (Thompson and Strickland, 2003, p. 148)

Struggling to reach a sustainable competitive advantage, a company makes a lot of activities. Those activities become more and more complicated. The company consists of some specialized departments and become more and more autonomous to decide the activities which usually perfect only for catching its own department objectives. Obviously, complexity in allocating company's resources will increase. There is a trend for Operations Research to develop tools to solve these problems (Hillier and Lieberman, 2001).

Systems Development companies, including Packaged Software Development company, actually dealing with some aspects of Project Management. It is possible for them to use Operations Research models and combine them to build a new model. This model enables them to operate to produce combination of product and/or services required by their customer in a using the principles in Strategic Operations Management. Therefore strategic objectives in Strategic Operations Management may lead the company to achieve a competitive advantage (Stevenson, 2003)

A breakthrough in operations innovation not only gives a continuous development, but can defeat the competitors and rock the industry (Hammer, 2004)

2.5 Operations Management Reviews

2.5.1 A Brief History of Operations Management

Operations Management (OM) is defined as the design, operation and improvement of the systems that create and deliver the firm's primary products and services (Chase, Jacobs and Aquilano, 2004). The operations functions consists of all activities directly related to producing goods and/or providing services (Krajewski and Ritzman, 1990; Schonberger and Knod, 1994; Stevenson, 2003)

Systems for production have existed since ancient times. The Great Wall of China, the Egyptian Pyramids, ships of Roman and Spanish empires provide examples of human ability to organize production. Production for sale and modern factory systems had their roots in the Industrial Revolution, began in 1770 in England and spread to the rest of Europe to United States during the nineteenth century. A number of innovations changed the face of production, basically substituting machine power for human power.

Scientific Management, spearheaded by Frederick Winslow Taylor, believed that management should be responsible for training, carefully selecting and training workers, finding the best way to perform activities and separate management activities from work activities. A number of pioneers, including Frank Gilberth, Henry Gantt, Henry Ford, Lillian Gilberth, Elton Mayo, Frederick Herzberg, Douglas MacGregor, W Shewhart, Edward Deming etc give a valuable contributions to Operations Management. Japanese Manufactures developed or refine management practices to increase productivity of their operations and quality of products (Heizer and Render, 2004; Stevenson, 2003).

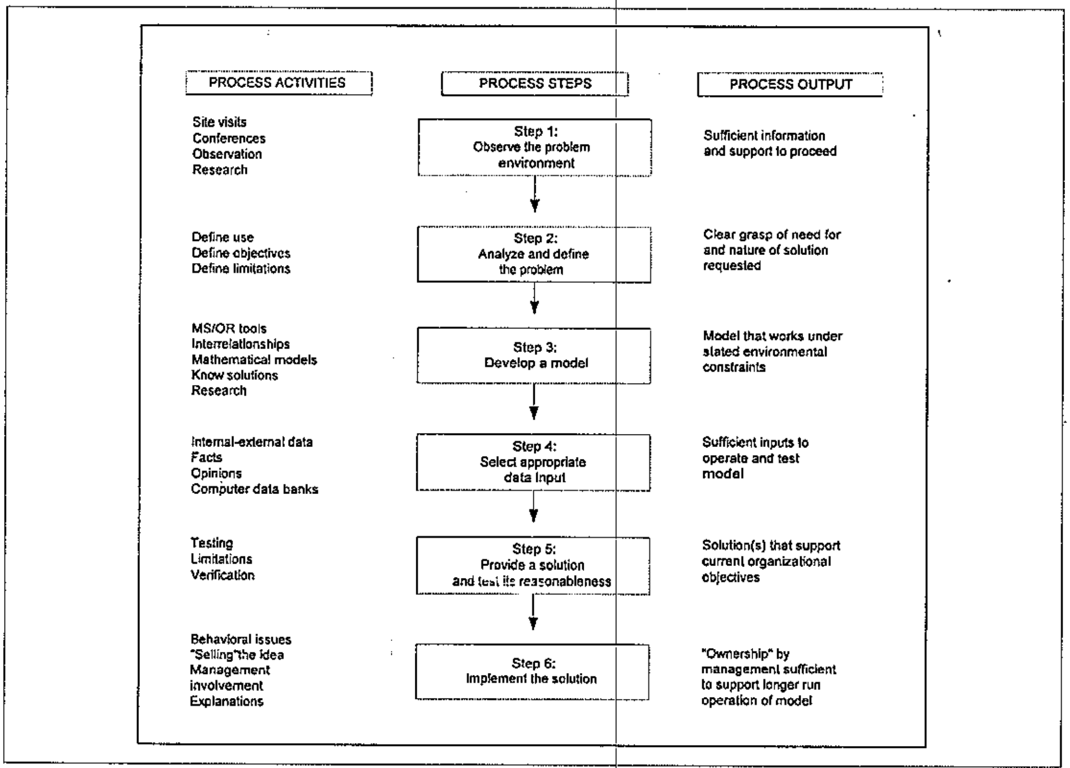
Operations Management frequently confused with Management Science and Operations Research (MS/OR) and industrial Engineering (IE). Operations Management is a field of management. Management Science/Operations Research is the application of quantitative methods to decision making in all fields. Industrial Engineering is an engineering discipline. Thus, while operations managers use the decision making tools of MS/OR (such as critical path scheduling) and concerned with many of the same issues as Industrial Engineering, distinct Operations management role distinguish it from another discipline. (Chase, Jacobs and Aquilano, 2004). The term Management Science sometimes is used as a synonym of Operations Research (Hillier and Lieberman, 2001)

Scientist and engineers involved in military activities. MS/OR concepts begins from military standpoint before the World War I. In the years of 1914-1915 F.W. Lancaster attempted to treat military operations quantitatively in England. Several scientist continue this effort. In World War II, in 1939, nucleus of a British operational research organization already in exist and its contributions were quickly followed by various important ways such as early-warning radar systems, anti aircraft gunnery, etc. American military leaders consider that operations research activities are so valuable. Such function is not discontinued at the end of the World War II. (Bittel and Ramsey, 1989; Levin, *et al,* 1989)

By early 1950s some individuals and business consultants introduced Operations Research to a variety of organizations in business, industries and also government. George Dantzig develops *simplex method* to solve linear programming in 1947. Computer revolution, especially emerging of Personal Computers (PC) in1980, boosts OR software packages. Nowadays, personal computers used by millions of people to solve Operations Research problems. Operations Research models routinely helps Operations Managers to make decisions (Hillier and Lieberman, 2001). Figure 2-4 shows steps in Management Science/Operation Research process

Figure 2-4

Management Science/Operation Research Process



Source: Levin, *et al.*, 1989, *"Quantitative Approaches to Management"*

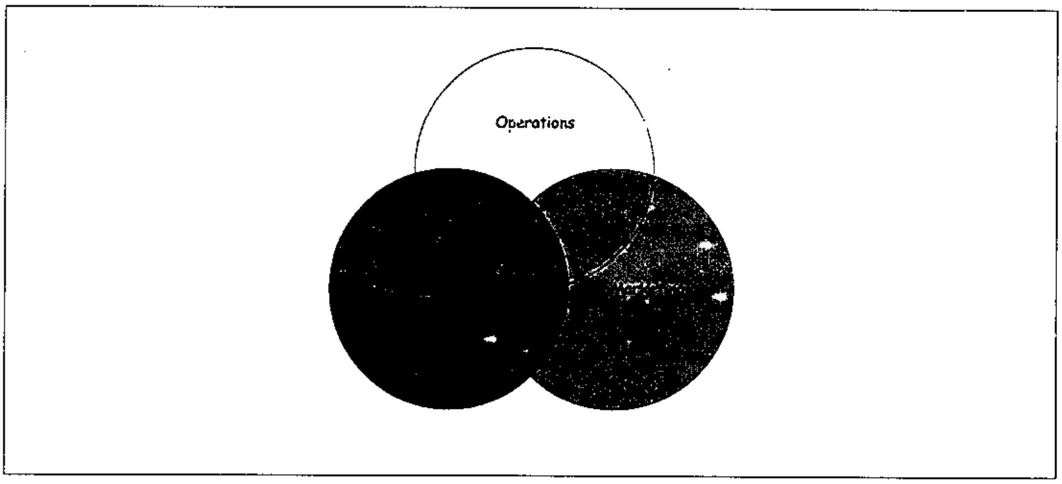
It is true that historically Operations Management dealing with household value- adding activities where certain resource transformation take place. Modern Operations Management shows interdependencies with other area of sciences such as marketing, accounting, human resources and information systems (Schonberger and Knod, 1994). The evolution of Operations Management alters its scope and role within organizations.

2.5.2 The Scope of Operations Management

Operations Manager is responsible for creation of goods and services. Business organizations are devoted to producing goods and /or providing services. Typically they consists of three basic functions: finance, marketing and operations. Operations consists all activities directly related to producing goods or providing services (Stevenson, 2003). Production transforms input or resource to become output such as product of services (Salvatore, 1989).

There are interdependencies between those three basic functions of an organization. The interdependency is depicted by overlapping circles in figure 2-5

Figure 2-5:
Interdependencies of major functions in an organization



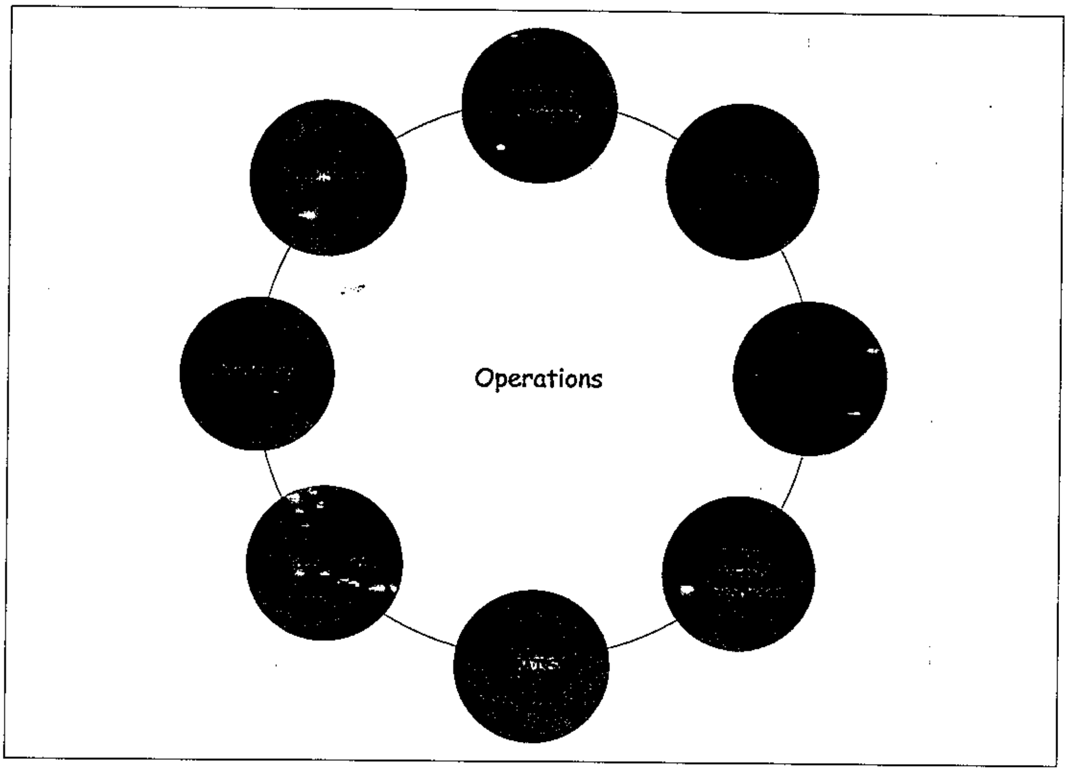
Source: Stevenson, 2003, *"Operations Management"*

There are some other support functions in an organization. Those support functions are: Accounting and Purchasing. Depends on the mature of the organization, they may include Distribution, Industrial Engineering, Maintenance, Personnel or Human Resource Management, Management Information Systems (MIS) and Public Relations. Lowson (2002), underlines the role of technology in Operations Management.

Those functions interfaces with Operations. Refer to figure 2-6 for the graphical representation of Operations and its supporting functions.

Figure 2-6

Operations interface with a number of supporting functions



Source: Stevenson, 2003, *"Operations Management"*

In accordance to role of Operations within an organizations described above, decisions made by Operations Manager can be classified into Strategic Level Decisions. Strategic Level Decisions typically have a broad scope. Time frame for a strategic level decisions are long, usually several years of more. Operations Strategic Level Decisions examples are: product innovations, production capacity, quality level, scheduling, customer relationship management etc. Strategic Level Decision making process relates to Operations Strategy. (Chase, Jacobs and Aquilano, 2004; Schonberger and Knod, 1994)

2.5.3 Project Management

Many events and people have contributed to the modern project management, beginning from the Industrial Revolution in UK. Frederick Taylor (1856-1915) - known as the "Father of Management", Henry Gantt (1816-1919) - introduces the well-known Gantt Chart, W. Edward Deming (1900-1993) - the "Father of Quality", have founded several significant milestones toward modern project management (Murch, 2001).

In order to understand the essence of Project Management, it is necessary to understand specific meaning of each word.

Project is a sequence of unique, complex and interconnected activities, having one goal or purpose and must be completed by a specified time, within budget and according to specification (Whitten, Bentley and Dittman, 2000). Several example of project in business organization are shopping mall development development project, designing information systems, designing databases, designing web sites and software development project (Stevenson, 2003).

Management is getting things done through other people. This definition stresses teamwork, delegation and results. Management is partly an art and partly a science. This definition recognizes the presence of intuitive, subjective skills in some management process and the growing importance of verified knowledge as a guide to managerial decision and action. (Bittel and Ramsey, 1989). The primary managerial functions are designated as planning, organizing, actuating and controlling. Traditional management group relied - and still does - on formal plans, rigid division of labor and formal rules. Newer managers relies on informal commitment and networks to establish goals (rather than formal planning), a flexible arrangement of teams and individuals working in a task forces, a customer orientation to achieve coordination among employees and appeals to professionalism and knowledge to ensure proper operation of the firm (Laudon and Laudon, 2000).

Project Management is a collection of techniques, procedures and methods to systematically plan, organize, monitor and control cost, time and the specification of the project itself. Components in project management include organizing a project team, managing conflicts, building organizational structure and implementing quantitative methods (Bittel and Ramsey, 1989). According to Project Management Institute (PMI), Project Management is a set of principles, methods and techniques for the effective planning, scheduling, controlling and tracking of deliverable-oriented work (results) that help to establish a sound historical basis for future planning of projects (Futrell, Shafer and Shafer, 2002; Murch, 2001). There are two important concept in Project Management.

1. *Management:*

   Project Management skills are a subset of general management

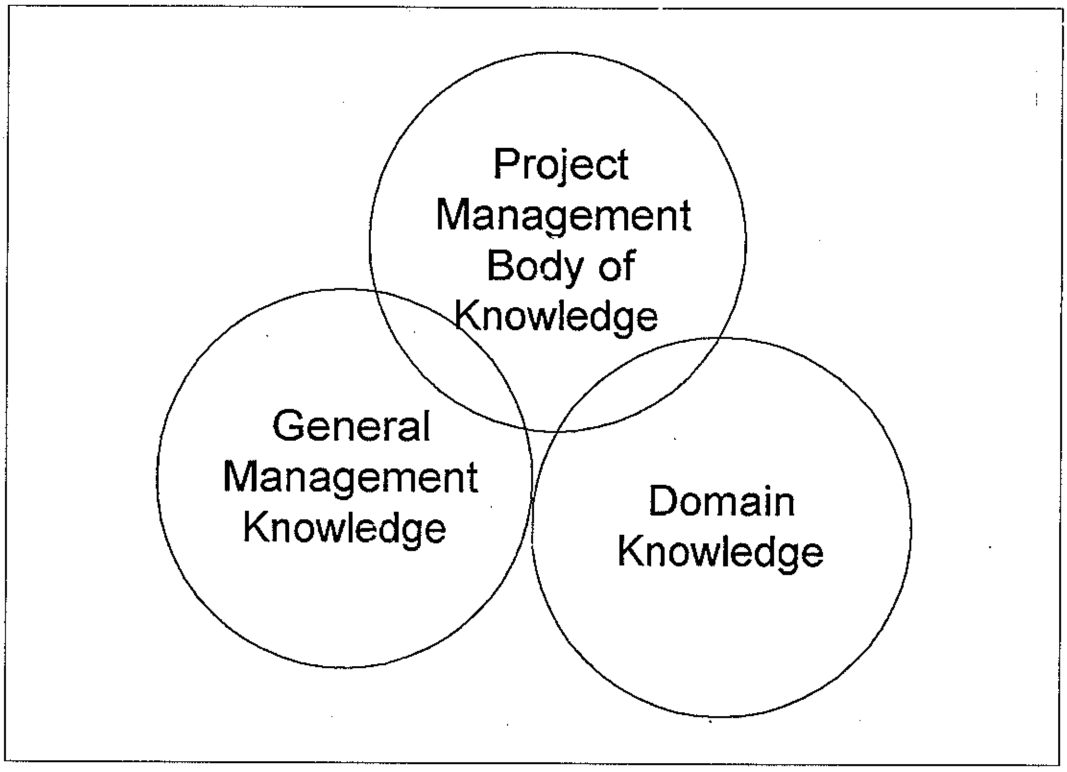
2. *Skill:*

   Application of management skill in order to achieve the objective of the project.

Project Management Institute (PMI) described that Project Management Body of Knowledge (PMBOK) (for example: Critical Path, Work Breakdown Structure, etc) as an intersection of general management area with the domain of knowledge of the project. (Futrell, Shafer and Shafer, 2002). In case of Packaged

Software Development Projects, the domain of knowledge is some aspect of Software Engineering.Illustration can be found in figure 2-7.

Figure 2-7:
Project Management Body of Knowledge (PMBOK)



Source: Project Management Institute (PMI), cited by Futrell, Shafer and Shafer, 2002, *"Quality Software Project Management"*

In General Management Area, there are several Operations Research quantitative models which can be used as tools in managing projects, such as PERT/CPM, Work Breakdown Structure, Learning Curve, .

Systems Development Project Management is a well-known activity in Information Systems Development. Systems Development Project Management is an activity of defining, planning, monitoring and controlling project to build systems in allocated time and budget (Whitten, Bentley and Dittman, 2000).

Institute of Electrical and Electronics Engineer (IEEE), cited by Futrell, Shafer and Shafer (2002), defines Systems as a collection of components, organized to run a specific function. Project Managers in Systems Development Projects usually build a Work Breakdown Structure (WBS) consists of hardware and software component in the same level.

Software component in Work Breakdown Structure can be divided into several activities. Activities can be divided into several tasks. Tasks and activities are often used interchangeably. Unfortunately, there is no consensus within the software project management community for relations between activities and tasks. According to Futrell, Shafer and Shafer (2002), the 2000 edition of PMBOK makes a clear distinction in the context for Software Project Management as follows:

1. *Task* is a generic term for work not included in the Work Breakdown Structure, but potentially could be a further decomposition of work by individuals responsible for work. Also, it is the lowest level of effort on a project

2. *Activity* is an element of work performed during the course of a project. An activity normally has an expected duration, expected cost and expected resource requirements. An activity can be sub-divided into tasks.

Exploration of how to improve Software Development Projects using Operations Management and Operations Research is the main subject of this research. Hardware development is beyond the scope of this research. Some basic understanding of Software Development is provided in the next sub-chapter

2.6 Operation Research Models

2.6.1 Work Breakdown Structure

Work Breakdown Structure is the first step in project management which divide a large and complex project into a small and manageable parts. (Stevenson, 2003). Also, Work Breakdown Structure is the backbone of any project. It describes necessary steps needed to carry out the project and their relationship each other (Futrell, Shafer and Shafer, 2002). Work Breakdown Structure is a representation of the building block structure of the project. It shows major project modules, secondary modules and so on (Schonberger and Knod, 1994). Activities within a projects, as a result of Work Breakdown Structure, become an activity of a node (Activity on Node) in CPM/PERT model as described in chapter 2.6.2.

Work Breakdown Structure is a structured list of all the work packages and activities that have to be carried out to complete the project (Bonnal, Gourc and Lacoste, 2002). Work Packages defines the work product in such a way that each package is clearly distinguished from all other work packages in the project (Futrell, Shafer and Shafer, 2002)

The Work Breakdown Structure defines the hierarchy of project activities, sub-activities and work packages. Completion of one or more work packages results in completion of sub-activities, completion of sub-activities results in completion of activity and finally, completion of all activities is required to complete the project (Chase, Jacobs and Aquilano, 2004)

Further, Shafer and Shafer (2002), said specifically, in Software Development environment, Work Breakdown Structure defined as a set of work tasks required to build the software; defined as part of the process model . Work tasks may include:

- Description of work product expected
- Staffing Requirements
- Scheduled start and end dates

In planing any project, there is a simple rule to determine the work package: If an item is too complicated to manage, it becomes a list of smaller items

In this research, work tasks is consider as an independent sub-module which can be arranged and build an interaction to form a module. The technical steps to build a sub-module, such as program statements inside the sub module, are beyond the scope of this research.

Software Development Projects usually consists of several modules which is interconnected. For this reason, Work Breakdown Structure must be carefully planned to ensure modularity in the project.

Modularity is a strategy to organize complex product or process. Modular Systems is an independent systems but still function properly in a complete integration (Baldwin and Clark, 1997)

According Feitzinger and Lee (1997) a modular product has three main advantages:

1. The company can maximize the number of standard components in the product itself at the beginning stage of the production

2. The company can produce components separately. The company can manufacture more than on component in the same time to shorten production time

3. Potential problems can be identified and isolated as soon as possible

These advantages lead to a better quality of the product.

Work Breakdown Structure and Modularity principles can be implemented in Software Development. Next step to implement Work Breakdown Structure and Modularity principles are:

1. Process postponement, especially for lower priority sub modules

2. Re-sequencing process (sub modules re-sequencing)

3. Process standardization

PERT and CPM models provide an easy way to establish the sequence of each activities in a Work Breakdown Structure.

2.6.2 PERT and CPM Analysis

2.6.2.1 History of PERT and CPM Analysis

PERT (Program Evaluation and Review Techniques) and **CPM** (Critical Path Method) are the most commonly used models in the process of planning and coordinating large scale projects (Stevenson , 2003). By using PERT and CPM method, project manager can get

1. Graphical display of project activities
2. Estimation of how long the project will commence
3. Indication of the most critical activities in project completion time
4. Indication of how long an activity in a project can be delayed without delaying the whole project.

PERT and CPM initially developed individually in 1950s. PERT was developed through the joint effort of Lockheed Aircraft, U.S. Navy Special Project Office and Booz, Allen and Hamilton Consulting Firm in an effort to speed up the Polaris missile project. That time the US Government was concerned that Soviet Union might be getting nuclear superiority over the United States. This is a huge project involving more than 3.000 contractors and thousands of activities. PERT is successful in shaving off approximately two years of the length of the project.

CPM was developed by J. E. Kelly of the Remington Rand Corporation and M. R. Walker of DuPont to plan and coordinate maintenance projects in chemical plants.

Although PERT and CPM were developed independently, they have a great deal in common. Moreover, many of initial differences between them have disappeared as users borrowed certain features from each other. PERT initially stressed probabilistic time estimates, whereas CPM based on deterministic time estimates. At present, both of them can be used with deterministic or probabilistic time estimates (Eppen, Gould and Schmidt, 1988; Hillier and Lieberman, 2001; Levin, *et al.,* 1989, Stevenson, 2003).

According to Stevenson, 2003, in order to avoid confusion, for practical purposes, both PERT and CPM techniques are considered to be the same, since differences among them are relatively small.

2.6.2.2 Network Diagram

PERT and CPM uses **Network Diagram** which is also known as **Precedence Diagram** to show activities in a project and their sequential relationships. There are two slightly different conventions in constructing a Network Diagram, called **Activity on Arrow (AOA)** and **Activity on Node (AON)**. Activities consumes resources. The node in Activity on Arrow represents an activity.

There are some important terms in PERT and CPM.

1. *Activity:*

   A project consist of many activities. Those activities consumes resources and/or time

2. *Nodes:*

   Node represent an event of starting and ending point of an activity.

3. *Events:*

   Events are points in time and did not consume any resource and/or time

4. *Path:*

   Path is a sequence of activities from Starting Node to Ending Node. Path is very important because path represents the sequential activities between them.

5. *Critical Path:*

   Critical Path is the longest Path which determine the length of the whole project.

6. *Critical Activities:*

   Critical activities are activities which happened in the Critical Path. Any delay in an activity of the critical activities will case a delay in the whole project.

7. *Slack:*

   Slack is how long an activity can be delayed without causing a delay in the whole project

2.6.2.3 Deterministic Time Estimates

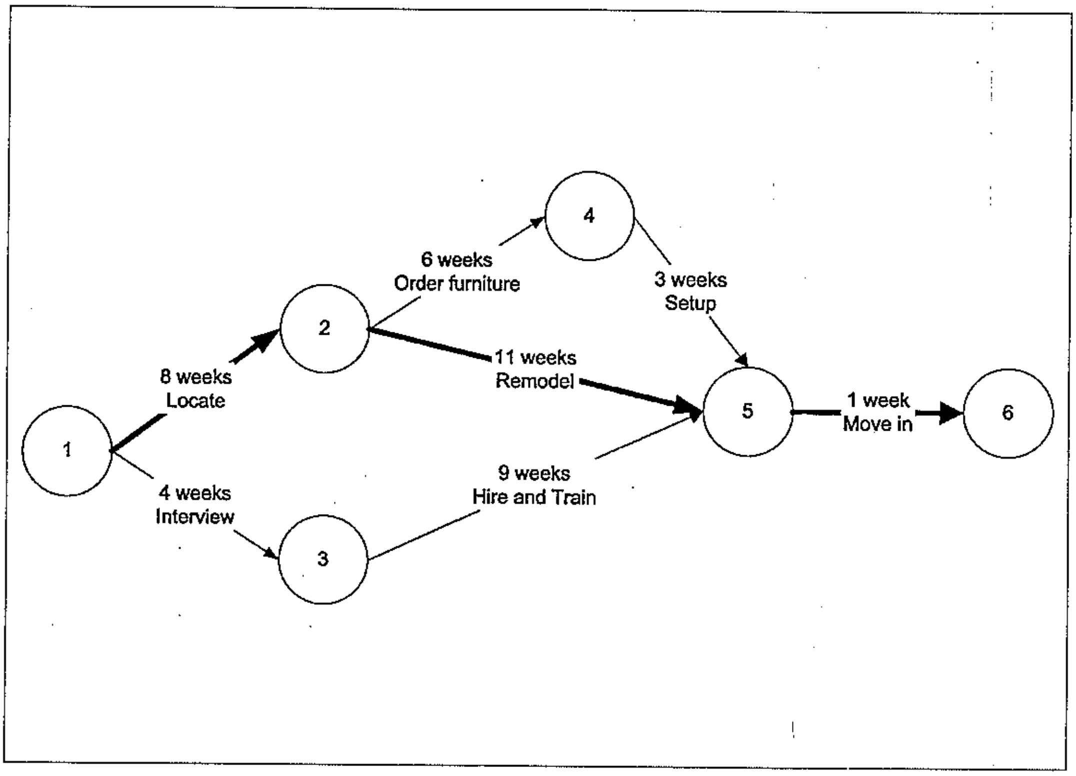
The most important essence in PERT and CPM method is time estimation for each activity. The following illustrations provide two examples of time estimates.

Figure 2-8 illustrate a sequence of activity, including the length of time each activity will commence. The time estimate of every path can be computed. Path

1-2-5-6 is the longest path which takes 20 weeks to complete. This path is called *Critical Path.*

Figure 2-8

Critical path, using Activity On Arrow (AOA) Convention

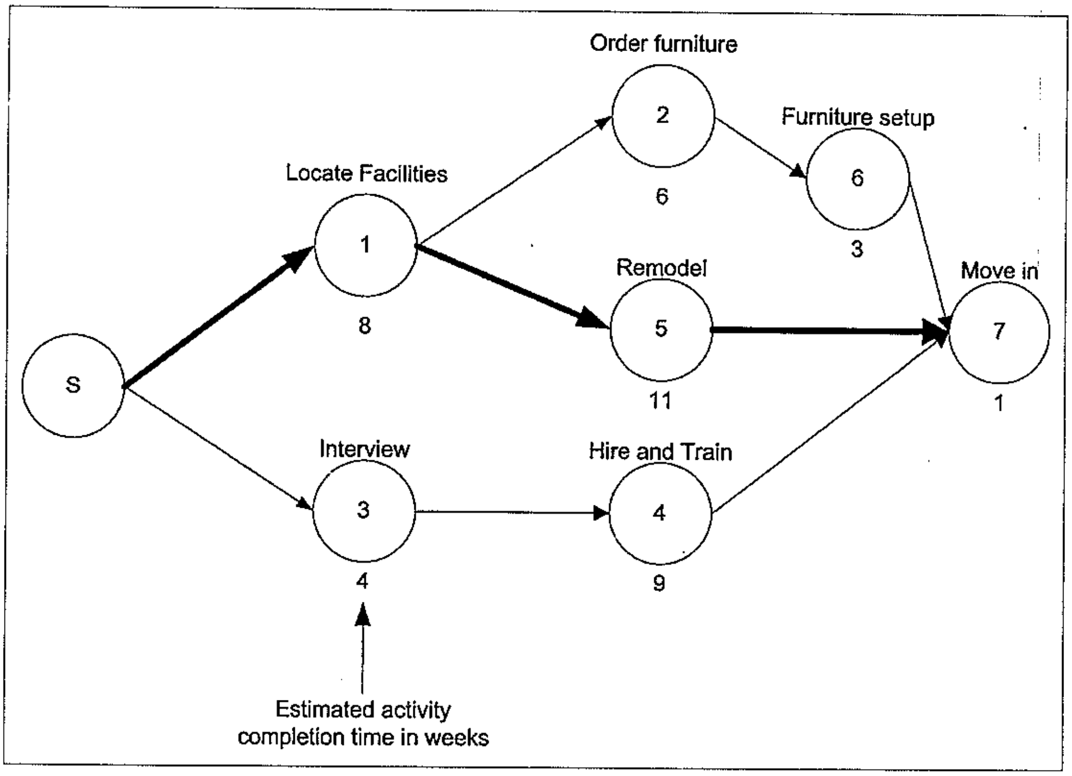


Source: Stevenson, 2003, *"Operations Management"*

The Critical path can also be computed using Activity on Node (AON) convention of the Network Diagram.

Figure 2-9 shows that the critical path is S-1-5-7, with time required to complete is 20 weeks.

Figure 2-9
Critical path, using Activity On Node (AON) convention



Source: Stevenson, 2003, *"Operations Management"*

2.6.2.4 Slack Time

Slack time is the amount of time for an activity can be delayed without causing delays in the whole project

Slack time can be computed after Critical Path determined. Slack Time is computed by calculating the difference between each path with critical path.

2.6.2.5 Earliest Start and Latest Finish

Real-life project is bigger than those in the examples. The project manager requires more information about the earliest time an activity can begin vice versa (Eppen, Gould and Schmidt, 1988; Hillier and Lieberman, 2001; Levin, *et al.,* 1989; Render and Heizer, 2004; Stevenson, 2003). Required information is described below.

1. Earliest Start (ES):

   ES is: the earliest time of an activity can start

2. Earliest Finish (EF)

   EF is the latest time of an activity can finish

3. Latest Start (LS):

   LS is the latest time of an activity to start without delay the project

4. Latest Finish (LF)

   LF is the latest time of an activity can finish without delay the project

All of those information can be computed using a simple formula, using the information of estimate time to finish the activity (t). The formula to compute the variable ES, EF, LS and LF is.

$$EF = ES + t \tag{2.1}$$

EF of an activity becomes ES time for the next activity

$$LS = LF - t \tag{2.2}$$

LF calculated using Backward Pass of the last activity. LS time will become the LF time for the previous activity.

2.6.2.6 Probabilistic Time Estimates

The preceding discussion assumed that the activity times were known and not subject to variation. While this assumption is appropriate in some situations, there are many others which is not. (Stevenson, 2003). In everyday's life uncertainty always happen. Uncertainty is a situation where there are more than one probable result of a decision-making process (Salvatore, 1989)

In this situation *probabilistic approach* is needed. (Hiller and Liberman, 2001; Stevenson, 2003; Render and Heizer; 2004). This approach needs 3 (three) time estimates for each activity:

1. Optimistic Time:

   Optimistic Time (t_0) is the length of time required to complete an activity under an optimum condition

2. Pessimistic Time:

   Pessimistic Time (t_p) is the length of time required to complete an activity under the worst condition

3. Most Likely Time:

   is the most probable length of time required to complete an activity.

Managers can make all of those estimation. A *Beta Distribution* is generally used to describe the inherent variability in time estimates (Hillier and Lieberman, 2001). Although there is no real theoretical justification for using the Beta

Distribution, it has certain features that make it attractive in practice: The Distribution can be symmetrical of skewed to either right or left according to the nature of particular activity. The mean and variance of the distribution can readily obtained from the three estimates described above. The distribution is Unimodal with high concentration of probability surrounding the most likely time estimate. Of special interest in network analysis are the expected time for each activity (t_e) and the variance of each activity time σ_i^2(Stevenson, 2003)

The next step required is:

1. to calculate estimate time (t_e) using the formula:

$$t_e = \frac{t_o + 4t_m + t_p}{6} \tag{2.3}$$

2. to calculate the expected duration of a path,

$$P_e = \sum t_e \tag{2.4}$$

The expected duration of a path is also the Path Mean, so the formula can be rewritten as follows:

$$\overline{P} = \sum t_e \tag{2.5}$$

3. to calculate the Standard Deviation of each activities

$$\sigma^2 = \left[\frac{(t_p - t_0}{6}\right]^2 \tag{2.6}$$

aor

$$\sigma^2 = \frac{(t_p - t_0)^2}{36} \tag{2.7}$$

4. to calculate the standard deviation of the expected time untuk for each path

$$\sigma_{path} = \sqrt{\sum \sigma^2_{activity}} \tag{2.8}$$

5. to calculate the probability that the given path can be completed within a specified length of time (specified timc symbolized by t)

$$z = \frac{t - \overline{P}}{\sigma_{path}} \tag{2.9}$$

2.6.2.7 Phased PERT/CPM

Once PERT/CPM model built, member can use it for many purpose such as capacity planning, task sequencing, projecting completion, identifying most critical path, scheduling etc. This multiple use of PERT/CPM tends to group into four phases of project management (Schonberger and Knod, 1994). Those phases are: (1) Project planning and sequencing, (2) Time and Path Analysis, (3) Project Scheduling, (4) Reporting and Updating

Accurate time estimates can assists a good project time estimates. An accurate time estimates in each activity (symbolized by mode in PERT/CPM) is required in order to make a good project time estimates. Scientific Work Measurement practice show be conducted in order to estimate the time required to complete an activity.

2.6.3 Work Measurement

Work measurement is concerned with determining the length of the time for a worker to complete the job. Job times are vital inputs for manpower planning, estimating labor costs, scheduling, budgeting and designing incentive systems. A Time standard is the amount of time it should take a qualified worker to complete a specified task, working at a sustainable rate, using given methods, tools and raw material inputs (Krajewski and Ritzman, 1990; Stevenson, 2003)

Each unit of work (such as job, task and projects) has some attributes, including the time taken to perform it (Schonberger and Knod, 1994). The fundamental purpose of work measurement is to set a time standard for a specific work (Chase, Jacobs and Aquilano, 2004).

There are two common techniques for measuring work and setting standards: time study and work sampling. The choice of techniques depends of detail desired and the nature of work itself. Highly detailed, repetitive work usually calls for time study analysis. Infrequent work or entails a long cycle time requires work sampling (Bittel and Ramsey, 1989; Chase, Jacobs and Aquilano, 2004; Graither and Frazier, 2001; Heizer and Render, 2004; Nahmias, 2001; Krajewski and Ritzman, 1990; Russel and Taylor, 2003; Schonberger and Knod, 1994; Stevenson, 2003).

Time Study is generally made with stopwatch, either on the spot or by analyzing a videotape for the job. The job or task to be studied is separated into measurable parts of elements and each element is timed individually.Work sampling involves observing a portion of work activity. Then, based on this sample, statements can be made about this activity.

2.6.4 Setting-up Standard Time

The next step is setting a standard time. Select Time ($\bar{t}$), frequency of work element per cycle (F) and Rating Factor (RF) untuk menentukan Waktu Normal (Normal Time). Researcher usually give a Rating Factor for each worker's performance. The rating factor is a subjective judgement of a researcher (Krajewski and Ritzman, 1990).

$$NT = \bar{t}(F)\cdot(RF) \tag{2.10}$$

where:
NT=Normal Time
$\bar{t}$=Select Time
F=frequency of work element per cycle
RF=Rating Factor

The Normal Time dos not take several factors such as fatigue, interruptions or any other reduction factors into account. Allowance Time is added to accommodate such those factors. Normal Time plus Allowance Time is called Standard Time

$$ST = NT(1+A) \tag{2.11}$$

where
ST=Standard Time
NT=Normal Time
A=Allowance Time

A is Allowance Time, where A is proportional to Normal Time. Standard Time can also be obtained using Allowance Time, where Allowance Time is the proportion of the Standard Time

$$ST = \frac{NT}{(1+A)} \tag{2.12}$$

where
ST=Standard Time
NT=Normal Time
A=Allowance Time

Allowance Time usually 10% s/d 20% of the normal time (Krajewski and Ritzman, 1990). Software Development usually consume 15% Allowance Time (Laudon and Laudon, 2000). Whitten, Bentley and Dittman, 2000, give a more detailed explanation. They said that there are two important people factor to be considered:

1. Efficiency: No worker performs at 100 percent efficiency.Most people do coffee breaks, lunch breaks, reading their emails, check their calendars, participate in non-project work and even engage in idle conversation. Experts differ on just how productive the average worker is. One commonly figure is 75 percent.

2. Interruptions: People experience phone calls, visitors and other unplanned interruptions. Interruption can consume 10% to 50%of programmer's time. Those interruptions will increase project time.

Whitten, Bentley and Dittman (2000), suggest that expected duration has to consider interruptions and delays. They suggest that that 75 percent efficiency and 15 percent interruption is a realistic figure. The calculation formula will be described in equation 2.13 and 2.14

$$Coeff = \frac{1}{Eff} \div (1 - i) \qquad (2.13)$$

where:
Coeff=Uncertainty coefficient
Eff=efficiency
i=interruption

$$Coeff = \frac{1}{0.75} \div (1.00 - 0.15) \tag{2.14}$$
$$Coeff = 1.57$$

where:
Efficiency = 75%
Interruption=15%

This means that the estimation time will increase to 157% of their original estimation value.

Software Development consists of many modules. Each module is divided into several sub-modules. Software is some times considered as an art (Blackburn, *et. al.,* 1996) and depends on the creativity of the programmers (Tong, 1994). That's why, there is no clear standard for defining a module. Sub-Modules are the smallest job entities or work orders for programmers in this research. Work orders is designed to resemble a repetitive task in a small work cycle (Russel and Taylor, 2003).

Standard time or predefined time for each work order (referred to as a sub-module) is suitable for this type of work (Bopnar and Hopwood, 2001; Graither and Frazier, 1999). That is the reason of conducting a research in order to define a standardized time for a sub module.

An effort to slice a project into small portions called sub-modules has can be seen as building modular structure as described in modularity and standardization concept in Operations Management.

2.6.5 Standardization and Modularity

Industry and businesses use standards to solve problems that occur again and again and to facilitate internal and external communications with everyone involved in an activity or operation. Standards cover almost every field and discipline. They are invaluable to the industry in design, production, quality control construction etc (Bittel and Ramsey, 1989)

Stevenson (2003), covers many issues in standardization. Standardization refers to the extent to which there is absence of variety in product, service or process. Standardized products are made in large quantities of identical items. Standardized process deliver standardized service or produce standardized goods. Standardization carries a number of benefits as well as disadvantages. Standardized products means interchangeable parts which greatly lower the cost o f production an improving reliability. The disadvantages is lack variety which might limit product or service appeal to the customers.

Company like standardization, but customer likes variety. The producers resolve this issue by mass customization. Mass customization is producing basically standard goods, but incorporating some degree of customization. There are types of mass-customization:

1. *Delayed customization:*

   Delayed customization is postponement tactic, producing but not completing until customer's specifications of preferences are known.

2. *Modular design:*

   Modular design is a form of standardization in which component parts are grouped into modules that are easily replaced or interchanged.

Modular design is actually an extension of standard parts. The quality of standard parts can be set relatively easier that non-standard part. This means that standardized products improves quality. Modular design which consists of many standardized part have a better quality. The quality of standard parts can be set relatively easier that non-standard part. This means that standardized products improves quality (Stevenson, 2003).

Better quality means a better reliability. Reliability means ability of a product or service to perform its intended function under a prescribed set of condition. Reliability is very important in services industry (Behara and Gundersen, 2001; Berawi, 2004).

Using a solid modular structure enables the company to offer products that supports mass customization (Gilmore and Pine, 1997).

Ability to build a complex, but modular product (including software) by building independent blocks or independent modules makes the productivity dramatically increased. So, there is a tendency to enlarge product modularity into planning phase. This is not an easy task (Baldwin and Clark, 1997)

Some inventions in Software Engineering aim to reach modularity. Object Oriented Programming (OOP) technology born with modularity concepts in mind. Despite is complexities, it offers some useful approach in building a modular software (Pressman, 2001). Deeper explanations regarding Object Oriented Technology and Linkage between Modularity and Object Oriented Programming will be observed in sub-section 2.8.6

2.6.6 Learning Curve

2.6.6.1 Learning Curve Concept

Learning curve phenomenon was observed in airframe manufacturing as far back as 1925. As people learn, time required for them to do a given task decreases (Schonberger and Knod, 1994). Commander of the Wright-Patterson Air Force Base in Dayton, Ohio, observed that workers exhibited definite learning patterns in manufacturing operations (Graither and Frazier, 2001). Aircraft industry develop learning curve theory prior to World War II based on this phenomenon (Krajewski and Ritzman, 1990). As experience gain with the production of particular product, either by a single worker or by an industry as a whole, the production process becomes more efficient. Learning curve also means of describing dynamic economies of scale (Nahmias, 2001).

According to Graither and Frazier (2001), the concept of learning curve rests well with operations managers, because they know through experience that in the beginning of the production runs, workers are unfamiliar with their tasks and the amount of time required to produce the first few units is high. But as the workers learn their tasks, their output per day increases up to a point and then levels off to a rather constant output rate. Additionally learning curve based on these underpinnings:

1. Where there is life, there can be learning

2. The more complex the life, the greater the rate of learning

It is helpful to be able to analyze the worker's learning situation and to be able to estimate :

1. the average number of labor hours required per unit for N units in production run

2. Total number of labor-hours required to produce N units in a production run

3. The exact number of labor hours required to produce the n^{th} unit of a production run

More recently, learning curves has been developed as a tool for supporting organizations' operations strategies. The learning curve is a long term strategic, rather than a short term tactical concept. By combining the effect of various factors, such as specialization, standardization, product re-design, improved process and methods, management can exploit experience cost opportunities to drive down the cost of production (Chambers and Johnston, 2000). Experience Curve has been used to describe the cost reduction phenomenon (Nahmias, 2001).

According to Graither and Frazier (2001); Krajewski and Ritzman (1990); Nahmias (2001); Schonberger and Knod (1994); Russel and Taylor, (2003); the decreasing production time can accurately be represented by an exponential relationship as follows

$$k_n = k_1 n^b \qquad (2.15)$$

where:
k_1=direct labor hours for the first unit
n=cumulative number of units produced

$$b = \frac{\log r}{\log 2} \qquad (2.16)$$

where:
r=learning rate

2.6.6.2 Learning Rate

Learning Rate can be estimated using a logarithmic model of the available historical data. There are two steps to follow in order to calculate the learning rate (Krajewski and Ritzman, 1990; Russel and Taylor, 2003)::

1. Estimate the value of b using logarithmic model as per equation *(2.15)* as follows:

$$k_n = k_1 n^b$$

Given the value of k_n, k_1 and n, the value of b can be computed using equation:

$$n^b = \frac{k_n}{k_1} \quad (2.17)$$

$$b \log n = \log\left(\frac{k_n}{k_1}\right) \quad (2.18)$$

$$b = \frac{\log\left(\frac{k_n}{k_1}\right)}{\log n} \quad (2.19)$$

2. By definition of b, Learning Rate (r) and be done by:

$$\frac{\log r}{\log 2} = b \quad (2.20)$$

$$\log r = b \log 2 \quad (2.21)$$

$$r = 10^{(b \log 2)} \quad (2.20)$$

2.6.6.3 Learning Curve and Competitive Advantage

Learning Curve Concept helps the managers of estimating the cost of a production process. Generally, a production process would become more and more efficient as the worker's experiences increasing (Hillier and Lieberman, 2001)

In a competition, new comers continuously attempting to enter the market, attracting the existing customers using many strategies (Porter, 1980). A company might try to reduce the price, but such company has to increase the sales volume in order to defend their profitability. Such company attempts to reduce the learning curve into the lowest point by raising the sales volume (Krajewski and Ritzman, 1990).

The Manufacturing Process Life Cycle should be understood in order to achieve the goal.Manufacturing Life Cycle includes Start-up, Rapid Growth, Maturation and Stabilization atau Decline (Nahmias, 2001). A company has a very limited sales volume in Start-up phase whereas the design of the product has not yet been stable. The company is also vulnerable to its suppliers. Automatization can be deployed in The Rapid Growth and Maturation Phase. The cost of production starts to decline as the effect of Learning Curve. Standardization can suitable be applied in the Stabilization Phase. However, the Learning Rate will never ever reach zero (Stevenson, 2003)

2.6.6.4 Learning Curve in Job-shop

Learning Curve is very important in a particular company which has a Job-shop production or custom service oriented (Graither and Frazier, 1999).

The reasons are:

1. The product has a custom design. The worker has to start their work almost at the same time as the batch of the production commences. Batch size is usually small

2. Small production batch size may cause labor cost to increase significantly in producing the first unit of product

3. The goods or services tend to be complex which will trigger a substantial raise in labor cost

Software Development Company faces all of the problem described above. Batch production size is relatively small, the labor cost is expensive and the product is usually very complex. The Short Product Life Cycle as described previously forces the Software Development Company to increase the learning rate in order to shorten the construction time of a module. Miscalculation might make the product obsolete before even arriving in the market.

2.7 Econometric Models

Once the Work Breakdown Structure is established and precedence of each work element is discovered, the time required to accomplish the work should be estimated. Poor estimation techniques may ruin the whole project.

Several estimation techniques are available. There are two common techniques for measuring work and setting standards: time study and work sampling. The choice of techniques depends of detail desired and the nature of work itself. Highly detailed, repetitive work usually calls for time study analysis. Infrequent work or entails a long cycle time requires work sampling (Bittel and Ramsey, 1989; Chase, Jacobs and Aquilano, 2004; Graither and Frazier, 2001; Heizer and Render, 2004; Nahmias, 2001; Krajewski and Ritzman, 1990; Russel and Taylor, 2003; Schonberger and Knod, 1994; Stevenson, 2003). Time Study is generally made with stopwatch, either on the spot or by analyzing a videotape for the job.

The result of time study can be used to perform a forecasting process. Econometrics offered several forecasting techniques. Statistics offered some test in order to verify the validity of several calculations. Among several models available Regression Analysis is selected is this research

2.7.1 Regression

The term *Regression* was introduced by Francis Galton. The Galton's *law of universal regression* was confirmed by his friend Karl Pearson. Modern interpretation of Regression analysis says that the Regression Analysis is concerned with the study of dependence of one variable, the dependent variable, on one or more other variables, with a view to estimating and/or predicting the population mean or average value of the former in terms of known or fixed (in repeating sampling) values of the latter. Types of data may include time series, cross section and pooled data (Gujarati, 2003). The simplest possible regression analysis involves a dependent variable (the regressand) and a single explanatory variable or independent called the regressor (Bowen and Starr, 1982; Greene, 2003; Gujarati, 2003; Salvatore, 1989; Thomas, 1996; Webster, 1996). The general expression of simple linear regression is:

$$y = a + bx \tag{2-21}$$

where
a is the vertical intercept of the estimated linear relationship
b is the slope of line

In a linear regression model, the relationship between x and y variable can be represented by a straight line. It hold that as x changes, y changes by a constant amount. Curvilinear regression model uses a curve to express the relationship between x and y. It maintains that as x changes, y changes by a different amount each time (Gaynor and Kirkpatrick, 1994; Webster, 1996).

Thomas (1996) suggested several important criteria in selecting models:

1. A model should be data coherent, means that model should be able to explain adequately existing data. It is not enough that an equation should have a high R^2 or high $\overline{R^2}$.Another test results such as auto-correlation should be taken into account.

2. Regressor should be exogenous.

3. A satisfactory model should have constant parameters and be able to forecast well outside the sample period used to estimate it.

4. Functional form should be data admissible

5. Models should be consistent with the economic theory

6. Models should be parsimonious, which means a simple explanation of the data should always be preferred to a more complicated explanation

2.7.2 Log-linear model

Learning Curve has a curvilinear equation as follows

$$k_n = k_1 n^b \qquad (2.22)$$

where:
k_1=direct labor hours for the first unit
n=cumulative number of units produced

$$b = \frac{\log r}{\log 2} \qquad (2.23)$$

where:
r=learning rate

According to Thomas (1997) models should be consistent with the economic theory and should be parsimonious. But those models cannot be processed using simple Linear Regression. According to Gujarati (2003) the Log-linear model can be used. Natural Logarithm is used to transform the non-linear variables into linear parameters as follows:

$$\ln(k_n) = \ln(k_1) + b\ln(n) \qquad (2.24)$$

where:
k_1*=direct labor hours for the first unit*
n=cumulative number of units produced

2.7.3 Best-fit model Criteria

Several Statistical Tests are available in selecting the best fit model. Basically the research has to choose whether Linear or Log-linear is the Best Fit model in each experiment sessions. Criteria used in selecting the Bet-Fit model in this chapter are:

1. Pearson Correlation Values

2. Significance of Parameters estimates

3. R^2 and Adjusted R^2 ($\overline{R^2}$). It should be carefully understood that the $\overline{R^2}$ can be negative (Greene, 2003; Gujarati, 2003), even though the R^2 cannot be zero. Gujarati (2003) said that a negative value of $\overline{R^2}$ should be considered to zero when it happens. $\overline{R^2}$ can be computed using the following equation

$$\overline{R^2} = 1-(1-R^2)\frac{n-1}{n-k} \qquad (2.25)$$

where
k = the number of parameters in the model including the intercept term

4. Durbin Watson Test Result:
Durbin-Watson statistic test according to Webster (1998); Gujarati (2003); Salvatore (1989); Thomas (1997) can be expressed as follows:

$$d = \frac{\sum(e_t - e_{(t-1)})^2}{\sum e_t^2} \qquad (2\text{-}26)$$

where:
e_t *is the error in time period t*
$e_{(t-1)}$ *is the error in the previous time period*

2.7.4 ANOVA and Experimental Design

Statistical studies can be classified as being either experimental or observational. In an experimental study, variable(s) of interest are identified. Then one or more factors in the study are controlled so that the data can be obtained about how the factors influence the variables. Cause effect relationships can be difficult to establish in observational studies; such relationship are easier to establish in experimental studies. The process of replication is another important principle o an experimental design (Anderson, Sweeney and Williams, 2002). Several ways of ANOVA experiment can be designed . The most common is *completely randomized design* or *One-way ANOVA* (Webster, 1998). Management problems often involves more than two populations and decision makers want to know whether the means of these populations are, or are not, equal. A test called Analysis of Variance (ANOVA) is performed by analyzing the variance in the sample means in order to decide whether to accept or reject the hypothesis of equal population means (Bowen and Starr, 1982). The variation between samples can be caused by the same random factors as the variation within a sample plus any additional influence that the different treatments may have. According to Andersen, Sweeney and Williams (2002), the hypotheses used when analyzing the data from a completely randomized design are:

$$H_0 : \mu_1 = \mu_2 = \ldots = \mu_k$$
$$H_a : \textit{Not all population means are equal}$$

There can be a treatment effect between samples because each sample gets a different treatment (Webster, 1998). Several following equations are adopted from Webster (1998) and Andersen, Sweeney and Williams (2002).

$$SST = SSTR + SSE \qquad (2\text{-}27)$$

where:
SST=Total sum of squares
SSTR=Treatment sum of squares
SSE=Error sum of squares

Total sum of squares can be computed as follows:

$$SST = \sum_{i=1}^{r}\sum_{j=1}^{c}(x_{ij} - \bar{\bar{x}})^2 \tag{2-28}$$

where:
SST=Total sum of squares
$\bar{\bar{x}}$*=Grand mean*
i=row of the cell
j=column of the cell

Grand mean can be computed as follows:

$$\bar{\bar{x}} = \frac{\sum x_{ij}}{n} \tag{2-29}$$

where:
n = total number of samples

Treatment sum of square can be computed as follows:

$$SSTR = \sum r_j(\bar{x}_j - \bar{\bar{x}})^2 \tag{2-30}$$

where
SSTR=Treatment sum of squares
r=the number of observations

Error of sum squares can be computed as follows:

$$SSE = \sum\sum(x_{ij} - \bar{x}_j)^2 \tag{2-31}$$

where:
SSE=Error sum of squares

Alternatively Treatment sum of square can be computed as follows:

$$SSTR = SST - SSE \tag{2-32}$$

where:
SST=Total sum of squares
SSTR=Treatment sum of squares
SSE=Error sum of squares

Degree of Freedom for SST is $n-1$, Degree of Freedom for SSTR is $c-1$ and Degree of Freedom for SSE is $n-c$.

Total Mean Square can be computed as follows:

$$MST = \frac{SST}{n-1} \tag{2-33}$$

where:
MST = Total Mean Squares
SST=Total sum of squares

The Treatment Mean Square can be computed as follows

$$MSTR = \frac{SSTR}{c-1} \tag{2-34}$$

where:
MSTR = Treatment Mean Squares
SSTR=Treatment sum of squares

Mean Square Error is:

$$MSE = \frac{SSE}{n-c} \tag{2-35}$$

where:
MSE= Error Mean Square
SSE=Error sum of squares

F-Ration for a test of means can be computed using the following equation:

$$F = \frac{MSTR}{MSE} \tag{2-36}$$

where:
F=F Ratio
MSTR = Treatment Mean Squares
MSE= Error Mean Square

ANOVA can only tell whether all means are equal or not. When the hypothesis is rejected, ANOVA does not reveal which mean(s) is (are) different from the rest. Another statistical test has to be conducted to make the determination. Tukey's method can be used. Tukey's method, developed by J.W. Tukey in 1953, requires the Tukey criterion as follows:

$$T = q_{\alpha,c,n-c}\sqrt{\frac{MSE}{r}} \tag{2-37}$$

where:
T=Tukey's criterion
q=studentized range distribution with c and $n-c$ degrees of freedom and α selected value

2.8 Software Engineering

2.8.1 Software Engineering in General

The role of Information Systems in an organization has been observed in sub-section 2.3.3. Definition of Information Systems and Information technology has also been presented in sub-section 2.3.2. It has also been realized the strategic role of Information Technology in today's turbulent business environment.

Software is one of the components in Information Technology. Software can essentially be viewed as being instructions that tell the hardware what to do (Thompson and Cats-Baril, 2003). IEEE (Institute of Electric and Electronic Engineer) defines software as computer programs, procedures and possibly associated documentation and data pertaining to the operation of a computer system. This definition is similar to ISO definition of Software as contained in ISO, 1997, Sec. 3.11 and ISO/IEC 9000-3 Sec.3.14 (Galin, 2004).

Software should be developed in order to achieve the goal of the overall Information Systems. Software is a product of Software Engineering. Software Engineering is an effort to produce a software economically and run properly in the real machines using engineering principles (Futrell, Shafer and Shafer, 2002).

Software has a very important role in today's business process, because it delivers the most important product today: *information*. It manages business information to enhance competitiveness; it provides a gateway to worldwide information networks and provides the means of acquiring information in all of its forms (Pressman, 2001).

Information is data that have been shaped into a form that is meaningful and useful to human beings. Data is stream of raw facts representing events occurring in organizations or the physical environment, before the have been organized and arranged into a form that people can understand or use (McLeod, 2000; Laudon and Laudon, 2000; Wilkinson, 1991)

Main focus of Software Development currently is in Business Application Software (Blackburn *et al,* 1996). Software Development Projects, according to Dube (1998), and Carmel and Sawyer (1998), can be divided into two main categories:

1. *IS (Tailor Made) Software Development:*
   Software Development Model which does not face the time to market constraints

2. *Packaged Software Development:*
   This Packaged Software development deals with the Time to Market (TTM) pressure

2.8.2 IS Software Development

IS software development, also known as *tailor made software development or custom software development.* Custom Software Development begins with a field survey, followed with a contact or an agreement to build a software to solve a specific problem in a company. The software is built exactly upon the request and the specification of the customer. Some times, the specified software become a part of a management consultation contract. So the contract of the software development often become part of another bigger contract. Software, as the output of the contract, can only be implemented in customer's company. It is very difficult or sometimes illegal to implement it in another company.

The software development team usually follows the instructions from a consulting company, which manage the overall management problem of a company. In this case the team is not suffering from Time to Market pressures. So, this IS Software Development is not he scope of current research.

2.8.3 Packaged Software Development

Packaged software development is intended to build a general software package that can be accepted and suitable for some companies. It is expected that the software can be sold off-the-selves. Packaged software development compete directly with some other companies in order to win the customer's attention. Time does really matter in this case. So, the Packaged Software Development company suffers from *time to market pressure.*

Packaged Software Development in in a very young, dynamic and liquid environment *(Dube, 1998).*This industry grows globally. This make the industry attractive. Time to market constraint does not prohibit some people to get into. Even though risky, the importance of Information Technology makes this industry profitable.

The company which build Packaged Software called Independent Software Vendors (ISVs). They build information systems and applications for resale to another business. They may specialize in specific business applications (called *horizontal applications*, such as accounting or human resources), application for specific industries (called *vertical applications*, such as health care or higher educations) or integrated enterprise wide applications (called *enterprise resource planning*). Software packages are typically written to the most common business requirement of their intended market. This approach often offer a limited customizability.

The challenge is how to make the Packaged Software Development faster, more effective and more efficient, but offers a wide customizability (Whitten, Bentley and Dittman, 2000).

2.8.4 Team Approach in System Development

Modern Software development cannot be done alone by a single programmer. The rigid System Development Life Cycle is not suitable to catch required respond time of the company.

Time pressures, support requirement and necessity to create new features force Software Development Company to build teams. Team building is expected to create synergy between team members so that they can create a reliable software package while providing a better support for the customers (Whitten, Bentley and Dittman, 2000).

Team building has a drawback. It can cause another problem. Size to the team, team work and communication between team members have to be carefully designed. Every company has a limited resource. It cannot hire as many as workers they want (Salvatore, 1989).

According to Dube (1998), a Core Team has to meet some specifications as follows;

1. Team should be relatively small

2. Team member should be cross function, from marketing, Finance etc.

3. Team should be led by a project manager who is fully responsible for the goal of the team and able to solve the problems

Cusumano (1997), also advise similar recommendation regarding the core team.

Considering the team work and the opportunity to slice the project into a smaller and manageable modules, job shop process is suitable for this kind of project. Job shop project is an intermittent production process, based on start-and-stop method (Gaither and Frazier, 1999)

2.8.5 Classification of software

There are millions of software exists now. In order to give a comprehensive understanding regarding the scope of this research and also the Pilot Study, it is necessary to understand the classification of software.

The simplest classification scheme of software is to consider all software as being either a Systems Software and Applications Software (Thompson and Cats-Baril, 2003).

1. *Systems Software:*

   System software is a set of programs that manage the operation of computer hardware and necessary for user applications to work. Examples of this category are:

- Operating Systems, such as Windows XP and Linux for PCs, VSE/ESA for IBM mainframes, UNICOS and COS for Cray super-computers, UNIX for midrange systems of HP, IBM and Sun-Solaris.

- Utility programs, such as Norton Utilities

- Language Translators, which is used to translate programming languages into the machine language understood by the computer hardware

2. *Applications Software:*

   Application Software is software that is used to complete a specific tasks or participate in different forms of entertainment. Sub-categories of Application Software are:

   - Applications, such as payroll systems, inventory systems

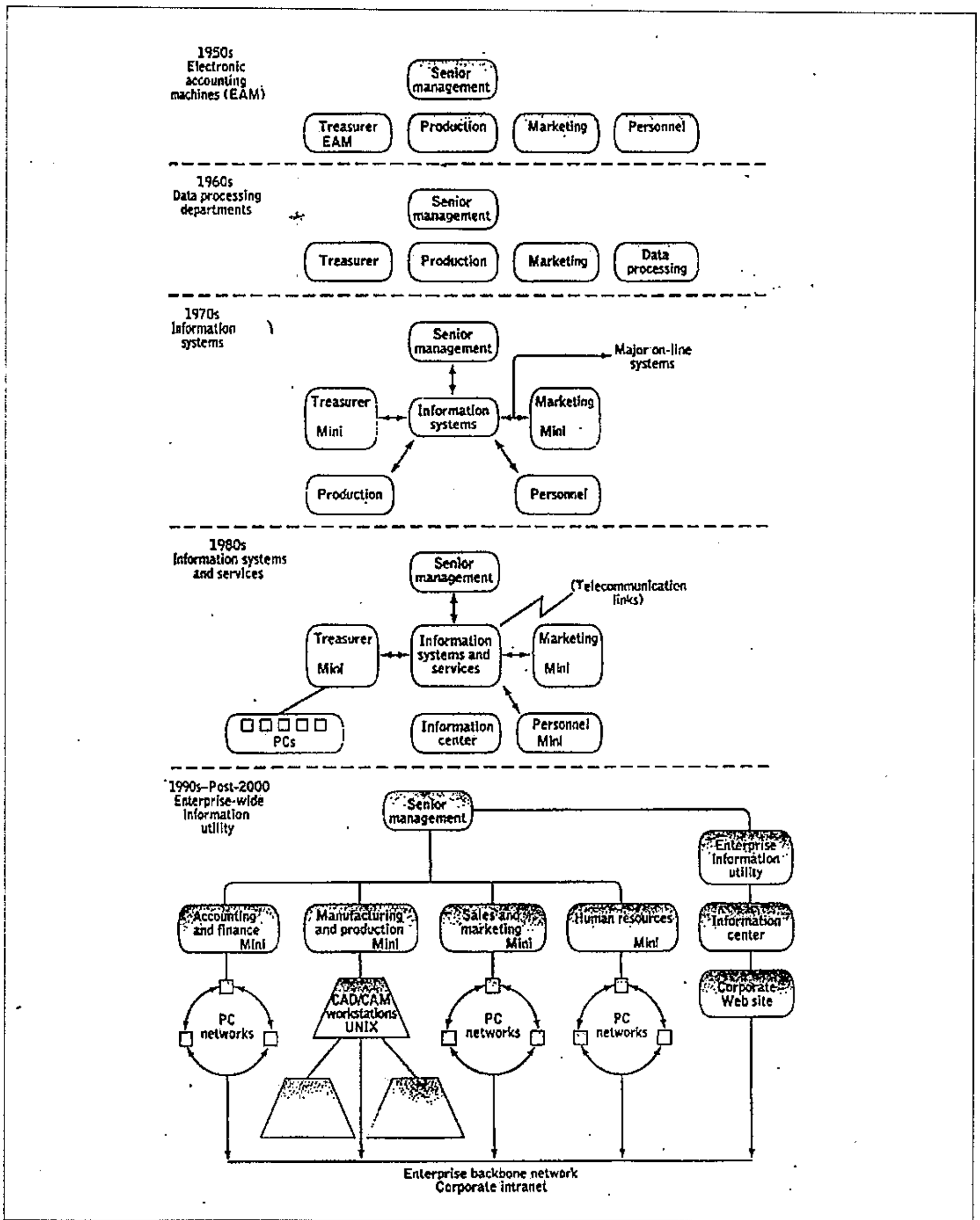
   - Programming Language, such as Visual Basic, C++, Java, HTML, XML, JavaScript, VBScript

   - Application Generators and Productivity Tools, such as Spreadsheet software, Word processors, presentation software, multimedia authoring tools etc.

Application software is software which made to solve a specific problem in a company (Laudon and Laudon, 2000). Many application software has been installed since 1954 for many purposes such as Inventory Control, Payroll, Time and Attendance, Point of Sale (POS), General Ledger, Fixed Assets Control. Evolution in Application Software also happens during that period. Figure 2-10 shows the Evolution of Information Systems.

Figure 2-10

Information Systems Evolution



Source: Laudon and Laudon (2000), *Management Information Systems*

The Packaged Software Development scope of this research is on Application development. It is Biometric Time and Attendance Application used in Biometric Time and Attendance Systems. In conjunction the Information Systems Evolution described by Laudon and Laudon (2000), presented in the Figure 2-10, The Packaged Software Output is designed to be fit in Human Resources. Sub-section 2.9 describes the Finished Product Positioning in a more detailed manner.

The programming language used to build the application is Microsoft® Visual Basic™ version 6.0. The programming language should match the Client Operating Systems Environment (COE). COE used in this research is Microsoft® Windows™ family. The reason of using this Opcrating Systems is the fact of Microsoft held 93,8% of Client Operating Systems market (Rohde, 2003). From managerial perspective, using another Operating Systems, (open-source software such as Linux) raises many issues regarding after-sales supports. The initial cost is low (free, in fact), but no authorized person will provide a support concerning a question of software problems (Thompson and Cats-Baril, 2003).

The Microsoft® Visual Basic™ version 6.0 supports many but not all elements of an Object Oriented Language. It prepared to be a stepping stone from procedural to Object Oriented Programming (Bradley and Millspaugh, 2005). But some other author still consider Visual Basic 6.0 is an Object Oriented Language (Bopnar and Hopwood, 2001)

Some issues regarding programming language specific features such as Object Oriented Programming will be extensively discussed at sub-section 2.8.6.

2.8.6 Object Oriented Technology and Modularity

Object Oriented Technology includes Object Oriented Programming and Object Oriented Database. These concepts are related. Object Oriented Database cannot be implemented outside Object Oriented Programming environment (Bopnar and Hopwood, 2001).

Object Oriented is seen to be a major conceptual nature of programming. Like most concepts, it is difficult to define precisely. Think of an object as a thing, or noun (Bradley and Millspaugh, 2005). According to Romney and Steinbart (2000), an object is an element of data and a set of instructions that specify the actions that to be performed on the data. Hoffer, Prescott and McFadden (2005), defines object as an instance of class that encapsulates data and behavior. Behavior in Object Oriented circle is commonly referred to as method, operation or service (Whitten, Bentley and Dittman, 2000)

Objects are used in Object Oriented Languages. An Object Oriented Language (OOL) is a programming language which the user select objects instead of writing a procedural code (Romney and Steinbart, 2000).

Cho and Kim (2001), describe Object Oriented Programming is a technology used to solve problems in programming by using object's features such as *inheritance, encapsulation, polymorphism, and message passing.* Encapsulation means information hiding (Bopnar and Hopwood, 2001). Inheritance means ability to create a new class from existing classes. The term polymorphism means ability to take on many shapes or forms (Bradley and Millspaugh, 2005).

OOP concepts are associated with SIMULA Language, developed in the late 1960s and the language SmallTalk, developed in the mid-1970s. Objective C, ADA, Visual Basic, Java and C++ are considered to be OOP Languages (Bopnar and Hopwood, 2001; Post, 2002). In OOP model, programs are no longer procedural. The programmer does not take control and determine the sequence of execution. Instead, the user can press keys and click various buttons and boxes in a window which trigger an event to occur (Bradley and Millspaugh, 2005).

Object Oriented Programming method involves linking objects and writing only a small amount of code (Romney and Steinbart, 2000). The goal of OOP is to make software easier to create, simpler to use, and more reliable through object reusability. Thus programs can be built from prefabricated, pretested building blocks (Bopnar and Hopwood, 2001). A set of interacting objects that provide a set of well defined services for accomplishing task is called an *Object Framework*. Group of objects can be packed together into one unit called a *Component*. The use of component. Using Object Framework and Components, software developer can easily package, distribute programming codes to others to achieve object reusability. By using Object Framework and Components developer can concentrate on developing the logic that is new or unique to the application thus reducing the overall time required to build the entire systems (Whitten, Bentley and Dittman, 2001).

Operations Management literatures has a solid definition regarding modularity (see sub-section 2.6.5). Modular design is actually an extension of standard parts. The use of standard parts means that workers of developers have fewer part to deal with (Stevenson, 2003). The use of Object Framework and Components can resemble modular design concept in Operations Management. Object Oriented Technology increases the ease of building modular components (Ihlson and Youg-Gul, 2002).

Modular design which consists of many standardized part have a better quality. The quality of standard parts can be set relatively easier that non-standard part. This means that standardized products improves quality (Stevenson, 2003). Better quality means a better reliability, which is very important in services industry (Behara and Gundersen, 2001; Berawi, 2004).

The advantages of building a modular design which consists of many standardized components in Operations Management can be replicated in Software Development. The quality of an object inside a component is easier to determine. This means that using Components as a Standardized Building Blocks can improve overall quantity of the Software.

A huge project should be divided into small and manageable parts, which can be done by Work Breakdown Structure (Stevenson, 2003). Analogously, a huge Software Development Project should be broken down into small and manageable modules or sub-modules. Ability to build objects, grouping objects into components and building an object framework makes Object Oriented Programming (OOP) an affordable choice in Software Development. The Pilot Study, Biometric Time and Attendance Systems, is designed to fully exploit the advantage of Object Oriented Programming features supported by Microsoft® Visual Basic™ 6.0. Sub-modules are built by objects arranged to interact in harmony in order to accomplish a specific task. Sub-modules performs modules, which in turn build primary modules. Primary modules construct the overall systems.

Construction sequence of a module or sub-module can be visually represented by network diagram. This means, several Operation Management concept can be adopted in Software Development.

2.8.7 Software Development Metrics

Software Engineering has a very close relationship with some programming technologies. Currently, Object Oriented Programming (OOP) grows vastly (Ilhsoon and Young-Gul, 2002; Laudon and Laudon, 2000; Pressman, 2001). Commonly used software development is Function Points (Pressman, 2001), but Function Points was developed based on procedural programming. Function Points has to be modified to adopt Object Oriented Programming.

Several models has been suggested in order to accommodate the Object Oriented Technology, especially Object Oriented Programming, such as COCOMO and COCOMO II developed by Barry Boehm (Boehm, 1996; Boehm, *et. al.*, 2004). Unfortunately, those model is not easy to implement.

The biggest challenge in estimating the construction time of a software development project is to understand the behavior of existing variables and to understand the relationship between them. A simple model has to be constructed once the relationship was discovered. A model is a simplified abstraction of a real-world system (Holter, 1998; Post, 2002). The model has to be simple and flexible but easy to implement.

A number of Operations Research models were investigated. Project Management models, such as Learning Curve and PERT/CPM model were selected. Regression Analysis, one of the most famous Econometric models, was selected to support Operations Research models. Several Statistical test were deployed to investigate the goodness of fit. Synergy of both Operations Research and Econometric, supported by several Statistical Test is expected to produce a simple but applicable model.

2.8.8 Project Management in Software Development

The subject of this research is Project Management, which is held in Software Development Company. It seems to be strange that the project management principles deployed in a Software Development Company. The nature of Software Development with is virtual and very difficult to measure (Tong, 1994). The progress of the project cannot be seen. Project Management techniques usually deployed in a construction project which the product is completely physical product and progress can easily be measured. An extensive coverage of Project Management can be found in sub-section 2.5.3

Tan and Platts (2003), discovered relationships between physical projects and IT projects. Deck and Strom (2002), showed a clear relationships between Project Management and IT Infrastructure.

For any Systems Development which Packaged Software Development reside, an effective project management is necessary to ensure that the project meets the deadline, is develop within acceptable budget, fulfills customer expectation and specification. A prerequisite for a good project management is a well-defined system development process (Whitten, Bentley and Dittman, 2000).

But not all IT Projects, especially Software Development Projects are successful. Failures and limited success outnumber the successful information systems. Project mis-management can undermine the best application of systems development

2.8.9 IT Projects failures

Information Technology Projects, especially Software Development are suffering from many difficulties. Failed IT Projects reaching a number of 90%, while 80% suffered from delays and over-budget and even 40% among them completely terminated (Tong, 1994; Krishnan, 1998; Suwardhy, et al, 2003; Clarke and Doherty, 2004; Dube, 1998). Many users still do not satisfied with the result of IT Projects (Herzwurm, 2003).Delays in Software Development Projects is enough to justify that the project is failed. On time delivery aspect had been covered in sub chapter 2.8.8

What causes a Packaged Software Development Project to succeed or fail? Tong (1994), and Landgrave, Maples and Wilson (1999), advise several but similar criteria from a general project management perspective and from Microsoft Solution Framework. A Packaged Software Development Project is considered success if:

- The resulting information system is acceptable to customer.
- The system was delivered on time
- The system was delivered within budget
- The system development process had a minimal impact on ongoing business operations.

Failure of IT Projects cause a lot of problems. Orders cannot be processed properly, customer's complaints can not reach helpdesk etc. According to Gartner Research, at least $500 billions of IT budget is wasted around the world (Feld and Stoddard, 2004).

Software Development faces a lot of problems in project management (Software Development Project Management). Software is a virtual thing that depends on the imagination and intuition of the programmers. Tong, 1994, highlights some difficult characteristics of Software Development as follows:

1. By nature, Software Development very difficult to measure
2. Only a few development standards to become a reference
3. Very short history of Software Development, especially in measurement standards
4. Software Development generally has a worse reputation compared with another functions

Some project mis-management problems observed by Whitten, Bentley and Dittman, 2000 are:

1. Failure to establish upper-management commitment to the project - sometimes commitment changes during a project
2. Lack of Systems Development Methodology
3. Poor estimating techniques - many analyst and project managers estimate by making best-calculated estimate (jokingly "guesstimate") and then doubling that number. This is not a scientific approach
4. Mythical man-month - there is no linear relationship between time and number of the personnel
5. Failure to manage the plan

It is desired by Software Development Project Managers to produce a high quality software in a low cost. The fact that software is virtual makes their dreams cannot come true. Software quality has to be improved by fixing bugs at the end at the end of the production process. This is an expensive task and in some cases impossible. Plans at the very beginning stage of software development process is needed to avoid this problem (Misra and Bhavsar, 2005)

Galin (2004) outlines several fundamental factors which makes software development difficult:

1. Complexity:
   Software products:
   Usually very complex product, allowing for a very large number of operational options

2. Visibility of the product:
   Invisible product, impossible to detect defects or omissions by sight

3. Nature of development and production process:
   Opportunities to detect defects arise only in one phase, namely product development

Some models available from Operations Management and Operations Research, supported by Econometric and Statistical Tests is expected to assists Packaged Software Development to produce a high quality of software at a lower cost.

2.9 Finished product positioning

2.9.1 Finished product in Information Systems Framework

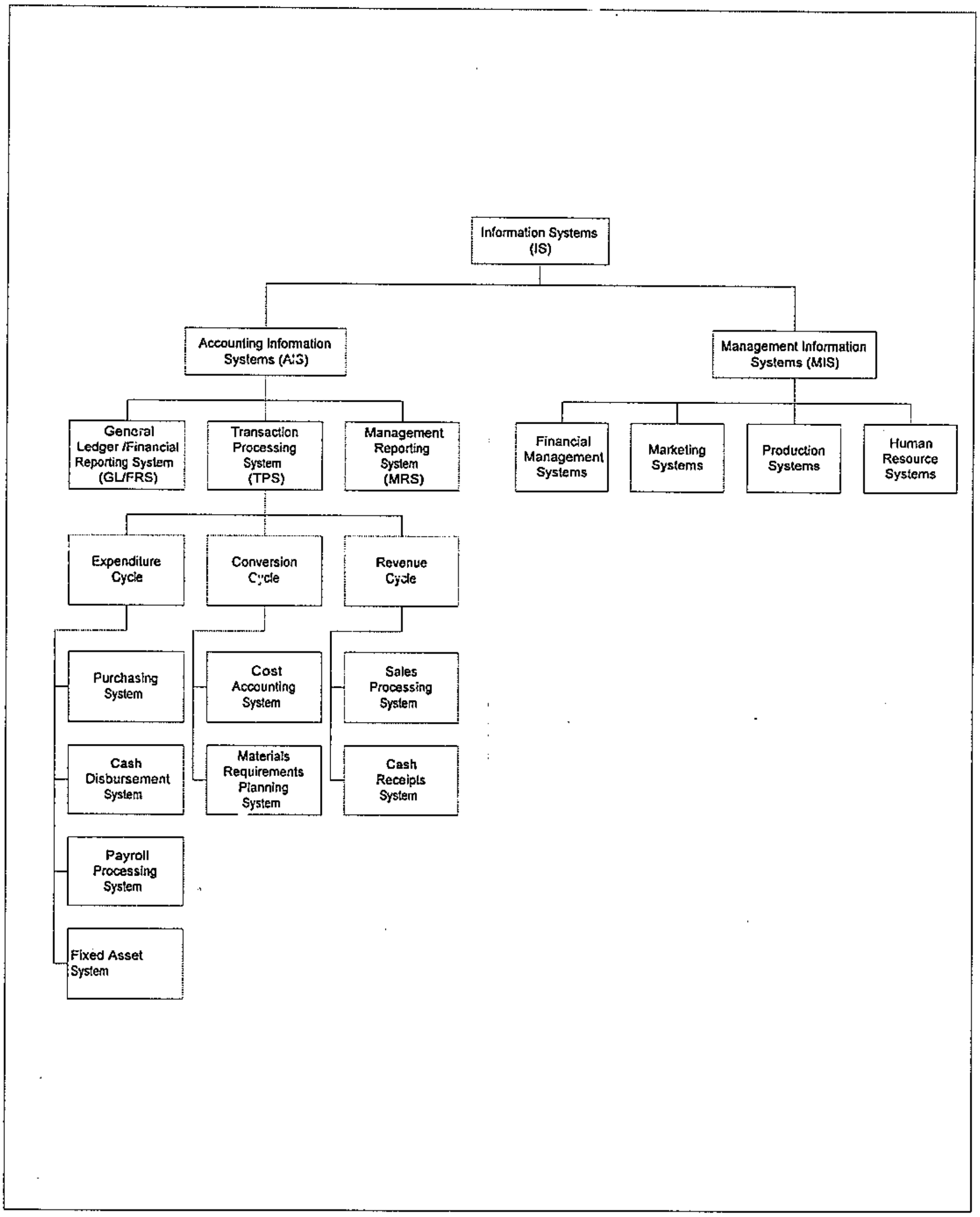
Software is one of the components in Information Technology. This research observed software development process, intended to produce software which become the application element of Biometric Time and Attendance Systems. Application software is software which made to solve a specific problem in a company. (Laudon and Laudon, 2000). This sub-section describes where the output of Pilot Study is expected to fit in daily Business Process of a company.

Hall, 2004, describes a framework in Information Systems, which consists of Accounting Information Systems (AIS) and Management Information Systems (MIS). Figure 2-11 shows the framework.

Referring to Information Systems Framework made by Hall, 2004, there is a sub-system in Management Information Systems called Human Resource Information Systems. Human Resource Information Systems (HRIS) is a system which extensively using Information Technology, specifically computers (McLeod, 2001; Dessler, 2000; Mayfield, Mayfield and Lunce, 2003). Finished product of this pilot study is expected to make a contributions in Human Resource Information Systems (HRIS).

Deeper evaluation of Human Resource Information Systems, in order to build an understanding of the linkage between the output of the Pilot Project conducted in this research and the Information Systems Framework, presented in the next sub-chapter.

Figure 2-11
Information Systems Framework



Source: Hall, 2004, *"Accounting Information Systems"*

2.9.2 Time and Attendance Systems in HRIS

Human Resource Information Systems (HRIS) is a sub-system of Accounting Information Systems (AIS) which directly connected to this research. The scope of the Pilot Project of this research, Time and Attendance is one of the sub-systems in Human Resource Information Systems (Bodnar and Hopwood, 2001).

Human Resource Information Systems (HRIS) is a system which responsible of collecting and managing Human Resource related data, transforming data to become information and present them to the users (McLeod, 2000)

The evolution of Human Resource Information Systems begins in order to support some United States Government regulation such as Equal Employment Opportunity (EEO), Occupational Safety and Health Administration (OSHA) and Affirmative Action Program (AAP) between 1960 and 1970s. Companies are responsible to present data and statistics regarding personnel practices in the organization. Government is going to measure about how far the Human Resource practice comply with the regulations (McLeod, 2000, and Gelinas, 1990).

Those Government regulations urged the companies to allocate their resources to build an information systems focusing on Human Resources. This information systems initially built by Information Systems experts in cooperation with Human Resources Department.

When microcomputer era begins, Human Resource Department installs microcomputers in their department, build Local Area Networks (LANs) and connecting their information systems to company's information systems backbone. Some companies also invest mini computers of even mainframe to support their Human Resource Information Systems.

According to Dessler, 2000, there are 3 (three) main reasons building Human Resource Information Systems as follows:

1. Competitiveness:

   HRIS can significantly increase Human Resource Operation efficiency, which in turn increasing company's competitiveness.

2. Human Resource Information Systems can produce numbers of Human Resource related reports quickly.

3. HRIS can help to manage routine transactional works and enable the Human Resource decision makers to concentrate in Strategic Human Resource Management tasks.

Evolution of Information Technology influence Human Resource Information Systems model. McLeod (2001) builds a Human Resource Information Systems as shown in figure 2-12

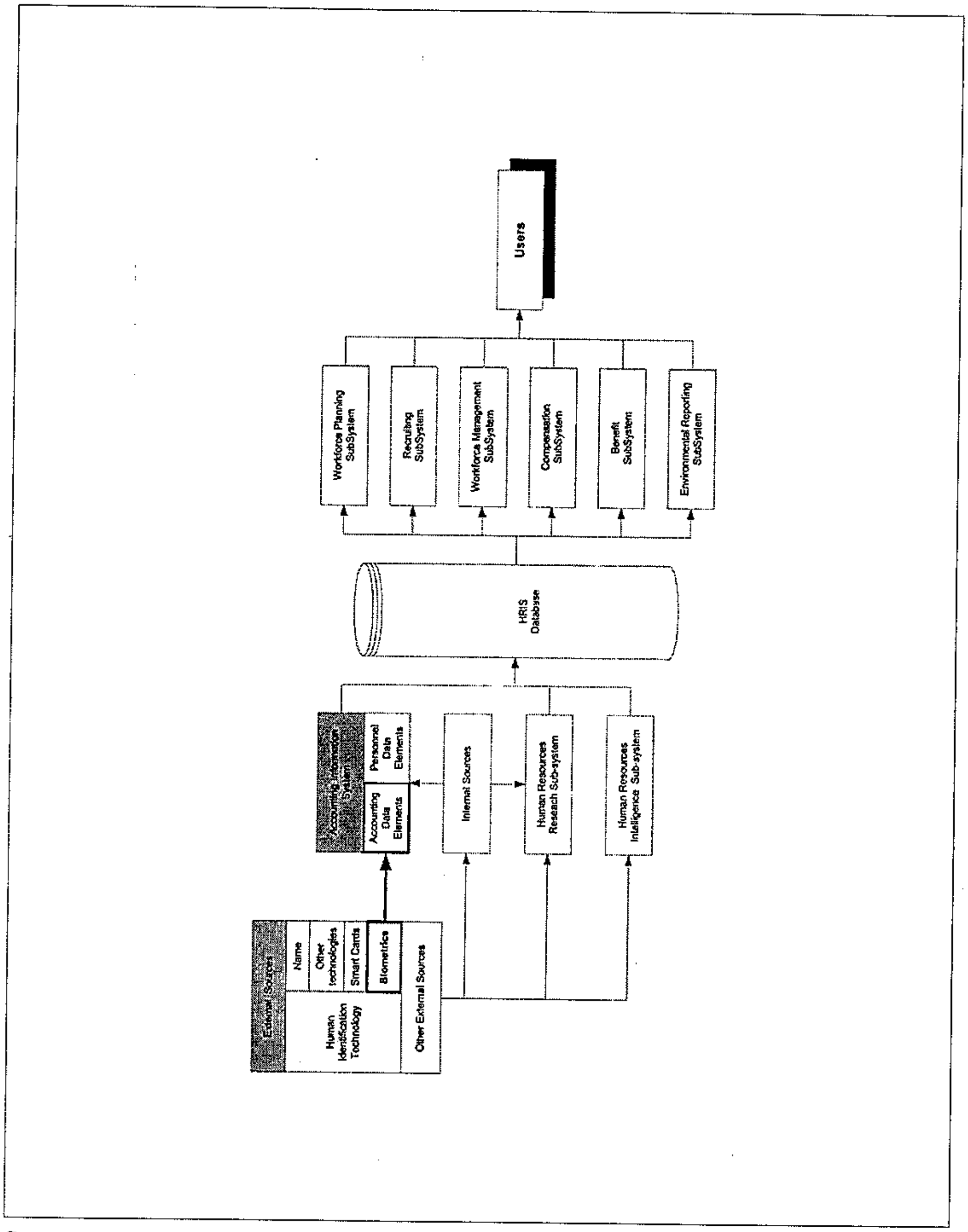
McLeod (2001) describes several components of Human Resource Information Systems as follows

1. **Accounting Information Systems:**

   actually intersection between personnel data and accounting data (Bodnar and Hopwood, 2001; Gelinas, Oram, Wiggins, 1990; Hall, 2004; Muscove, Simkin and Bagranoff, 1990; Romney and Steinbart, 2000; Wilkinson, 1991)

Figure 2-12:

Human Resource Information Systems Model



Source: McLeod, 2001, *"Management Information Systems"*

2. **Human Resource Research Sub-System**

3. **Human Resource Intelligence System**

4. **HRIS Database:**

   Usually contains personnel data and its relationship with organizational data.

   HRIS Database can be found physically in Human Resource Department, Information Systems Department or in third party Service Provider (Ball, 2000)

5. **Workforce Planning Sub-system**

6. **Recruiting Sub-system**

7. **Workforce Management Sub-system**

   Usually consists of Performance Appraisal, Training, Position Control, Relocation, Skills and Competency, Succession and Disciplinary. Performance Appraisal and Disciplinary can use Time and Attendance Sub-System, which come form Time and Attendance recording Terminal

8. **Compensation Sub-system**

   Compensation Sub-System has more attention than another sub-system. Many organization implement some application this sub-system, such as Merit increases, Payroll, Executive Compensation, Bonus and incentives also Time and Attendance

9. **Benefit Sub-system**

10 Environmental Reporting Sub-system

Payroll System is the most popular sub-system in Human Resource Information Systems. Payroll Systems use data generated by Time Cards in Time Keeping (Time and Attendance) Systems (Davis, Alderman and Robinson, 1990; Mulyadi, 1997; Stice, Stice and Skousen, 2004). Availability of quick and accurate data of Time Keeping Systems and Payroll Systems is mandatory in Cost of Goods Sold Calculation process (Hansen and Mowen, 2003; Horngren, Datar and Foster, 2003; Horngren and Sundem, 1987). Time and Attendance also affect employees in terms of their income (Hall, 2004).

In order to accelerate the payroll calculation process and minimize data entry errors, the Time Keeping Systems should use an accurate of Human Identification Techniques available (Clarke, 1994). The accurate Human Identification Technique makes Automated Time and Attendance Systems possible. Several techniques has been developed, but it still make the systems vulnerable to *Buddy Punching* practice (Roberts, 2003). This practice become a thread in attendance data validity (Muscove, Simkin and Bagranoff, 1990). Biometric Technologies developed to solve this problem (Harris and Yen, 2002; Klein, 2003; Larcinese, 2000; Liu, 2000; Perez, 2003; Pierce, 2003; Reid, 1998).

A brief discussion regarding Human Identification Technology, which has been built for centuries, presented in sub-chapter 2.9.3 It is expected to build some basic understanding of several methods which is relevant to this research.

2.9.3 Human Identification Technology

Human Identification History has the same age as the Human History. According to Clarke (1994) the term "identification" means :

> *the act or the process of "establishing the identity of, [or] recognizing" or "the treating of a thing as identical with another" or "the act [or process] of recognizing or establishing as being a perticular person", but also "the act [or process] of making, representing to be, or regarding or treating as the same or identical" (Clarke, 1994)*

In the context of Information Systems, especially Human Resource Information Systems, Human Identification Technology is implemented in order to link streams of data and human beings.

In the beginning, Human Identification is intended to serve social purpose only. A human being tries to memorize specific identification of another, whom they interact together. When the interaction has an economic value, problems in accurately identify human being occurred. Everybody involved in economic activity needs to accurately identify whom they interact.

2.9.4 Basic of Formal Identifications

There are several ways in Human Identification Technology in order to recognize another person and associate date with them. Those methods include:

- Appearance
- Social Behavior
- Names
- Codes
- Knowledge
- Tokens

- Bio-dynamics
- Natural Physiography
- Imposed Physical Characteristic

Some of those methods will be investigated in details.

2.9.4.1 Name

Naturally, name has a string correlation with culture and legal environment. Clarke (1994) conducted several research in several countries which culture significantly influenced by English atmosphere. Names usually consists of Christian name, First name, Given or Fore-name and Surname (one word or two words or hyphenated)

Name systems found in several European countries influenced by French Culture is deeply influenced by Code Napoleon (Clarke, 1994)

Name brings several difficulties in human identification because a lot of duplication found. Lack of naming standard also creates another problem.

In some countries which do not use Roman alphabet. The use of Roman diacritics (ü ç ö ø etc) brings some difficulties in using Name as identification standard. The use of sequencing consonants ("...wrysczwicz") brings difficulties to use name as an identification key.

2.9.4.2 Code

In order to solve the problem, some organization uses Codes as the basis of their identification systems. A Code can consists of a string of numbers and/or alphabets.

The main reason of using Code is *uniqueness* dari Code. Some organization uses Codes in numerous transactions

In certain circumstances, Codes can be inserted characters (i.e. Check characters) to ensure the validity of the Code itself.

Code is sometimes difficult to memorize especially a long stream of code. Several technology emerge to solve the problem such as Bar Code, Magnetic Stripe Card, memory chips etc.

2.9.4.3 Knowledge-based Identification System

A human being can be recognized via specific information regarding the private person information of the person itself, such as Father's name, Mother's name, address, birthday etc. This technique is called Knowledge-based Identification System.

Knowledge-based Identification System cannot solve the entire problem, because the are somebody who does has the information itself, such as refugees. In certain stages, the information can be easily revealed by another.

Common application of Knowledge-based Identification System include adalah Password and Personal Identification Number (PIN)

2.9.4.4 Token

Token is "something specific" that belongs to somebody, such as birth certificate, marriage certificate, driving licenses, passport, credit cards etc. Token is still widely used nowadays. But those are important documents which is usually stored in a safe place reduces its flexibility.

2.9.4.5 Biometrics

Biometrics is a human identification technique which use physical and difficult to alienate characteristics (Clarke, 1994). Biometric is a measurement Physiological and/or behavioral trait that can be captured and subsequently compared with another instance at the time of verification (Ashbourn, 2003; Biometrics Consortium, 2003; Duta and Jain, 2003). This technique is called *positive identification* (Clarke, 1994).

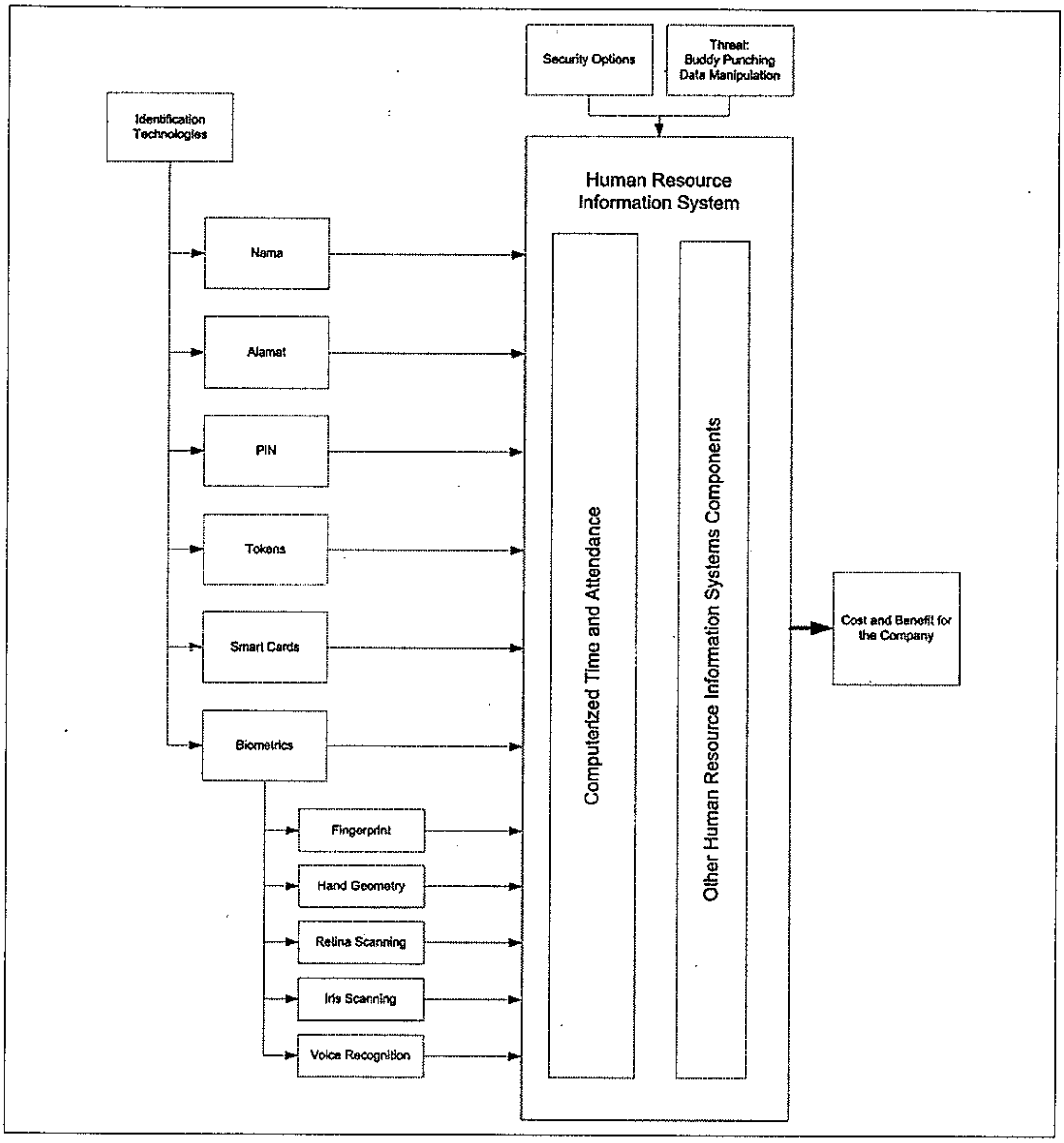
There are several Techniques available in Biometrics such as:

- *Appearance,* for example body height, weight, skin color, eye and hair color, race, gender etc (Clark, 1994).
- *Social behavior,* for example: body movement, general voice characteristics, style of speech (Biometrics Consortium, 2003;Kulkarni and Jain, 2003)
- *Bio-dynamics*, which includes statistically analyzed voice patterns, keystroke dynamics (especially for Login-Id and Password related purposes) (Kulkarni and Jain, 2003)
- *Natural Physiography,* which includes skull dimensions, fingerprints, hand geometry, DNA-patterns, iris and retinal scan (Hong, *et al.*, 2003; Ross, Jain and Pakanti, 2003)

Several techniques of Human Identification Technology has been implemented in Human Resource Information Systems. Figure 2-13 shows the relationship between Human Identification Technology and Human Resource Information Systems. Specific coverage regarding Biometrics applications in Human Resource Information Systems can be found in the next sub-section.

Figure 2-13

Human Identification Technology and
Human Resource Information Systems Relationship



Source: Developed for this thesis, partially adopted from McLeod, 2000, *"Management Information Systems"*

2.9.5 Biometrics in Human Resource Information Systems

The Biometrics Consortium (2003), defines Biometrics as a process which recognize somebody through specific human characteristics. Biometric Technology has already given a substantial amount of innovation in Information Technology since the last decade. Biometrics attempts to describe the process of recognizing human characteristics automatically using certain devices. Logically, Biometrics is suitable for security matters such as Access Control and Automation Process such as Time and Attendance.

Liu (2000), describe that there are 3 (three) authentication types commonly used in security matters:

1. *something you know* - such as password, PIN

2. *something you have* - such as cards, keys, smart cards, token ID

3. *something you are* - which is Biometrics

Biometrics is unarguably become the most secure authentication type. Biometrics uses something that can not be lost, something that can not be lend, something that cannot be left behind and something that cannot be stolen. It is nearly impossible to manipulate Biometrics data. Replacement part surgery is the only extraordinary exception. It is considered to be excluded in this topic.

Time based competition pushes every process in the company done quicker and quicker. Payroll Systems, as a part of in Human Resource Information Systems, usually consumes a large amount of processing time. Payroll Systems use data generated by time cards provided by Time Keeping Systems (Davis, Alderman and Robinson, 1990; Hall, 2004; Mulyadi, 1997; Stice, Stice and Skousen, 2004). Fast and accurate payroll data is required in Cost of Goods Sold calculation (Hansen and Mowen, 2003; Horngren, Datar and Foster, 2003; Horngren and Sundem, 1987).

In order to accelerate the payroll calculation process and minimize data entry errors, the Time Keeping Systems should use an accurate of Human Identification Techniques available (Clarke, 1994). The accurate Human Identification Technique makes Automated Time and Attendance Systems possible. Automated Time and Attendance consists of hardware and software (Reid, 1998). Hardware component consists of Electronic Time Recording Terminals with an ability to read Bar Codes or Magnetic Stripes in employee's badge (Reid, 1998; Romney and Steinbart, 2000). But Bar Codes and Magnetic Stripes implementation still cannot stop *Buddy Punching* practice (Roberts, 2003). This practice become a thread in attendance data validity (Muscove, Simkin and Bagranoff, 1990). Biometric Technologies developed to solve this problem (Harris and Yen, 2002; Klein, 2003; Larcinese, 2000; Liu, 2000; Perez, 2003; Pierce, 2003; Reid, 1998). Biometric Technologies burned inside Time Recording Terminals. Nowadays Biometrics has become an integrated component in Payroll Systems (Chandra and Calderon, 2003)

Biometric Time and Attendance Terminals are expected to reduce paper works done by data entry staff. They can spend their time in a more comprehensive personnel administration works (Lee-Mortimer, 2001).

The output of the Pilot Study is expected to provide a fast and accurate Time and Attendance data. A fast and accurate Time and Attendance may increase company efficiency which may lead to a sustainable competitive advantage.

Biometrics devices has a good prospect in the future. Terrorism, as the most frightening issue nowadays, accelerate the growth of Biometric devices. Microsoft, a well known software giant has integrate Biometrics support in Windows XP Operating Systems (Verton, 2001)

In marketing view, Biometric Time and Attendance Machine has a good prospect in the future. According to Roberts, 2003, based on International Biometric Group (IBG) survey, market for Biometrics is predicted to catch a number of $500 millions in 2005. But actually in 2003, Biometrics Market has grown to reach $719 millions and expected to reach $1,2 billion in 2004. Fingerprint market share, as the most popular Biometrics, predicted to reach $800 million in 2008 (Reid, 2004). The government of United Kingdom is considering to implement National Biometric ID Cards. The United Kingdom Passport Agency begins trial on Biometric IDs (Rohde, 2004).

The widespread adoption of Biometrics in many aspect of everyday life makes Biometric Systems Development interesting. Based on these facts, the Biometric Time and Attendance Systems Development Project Management was selected to become Pilot Study of this research. A new and fast growing technology, Biometrics, blended together with Software Engineering and General Management Sciences such as Project management, Operation Research and Econometric Models supported by Statistical tools makes the Pilot Study even more challenging.

The output of the Pilot Study is expected to accelerate Time and Attendance Data capturing and rapidly transform it into a meaningful report. The report can be used in particular department such as Payroll and Production to estimate the Cost of Goods Sold. The speed of information may lead the company to gain a competitive advantage in a time-based competition currently.

2.10 Solution Framework for the Pilot Study

2.10.1 Pilot Study Description

The Pilot Study in this research is *"Biometric Time and Attendance Systems Development Project Management"*. From Project Management Body of Knowledge point of view, Project Management involves General Management Area and several domain of knowledge, such as Software Engineering (engineering aspect of software development) and Biometrics.

Although there are many domain of knowledge involved in this research, the primary focus of this research is in General Management Area. As the title suggests, Project Management aspects become the subject of the research. Operations Research models, PERT/CPM, selected to become the basic model of Software Development Project Management. PERT/CPM supported by a number of tools such as Work Breakdown Structures, Network Diagram, Gantt Chats etc.

Difficulties in estimating construction time of each activity in PERT/CPM model is the main problem. There are only limited number of existing standard in estimating construction time of a sub-module in a software development project. Poor estimation techniques, jokingly called "Guesstimate" was suspected to become the root of the problem in Software Development Project. Econometrics has a wealth of forecasting model. Regression is one of the most famous model in Econometrics.

Learning Curve Concept has been discovered 70 years ago. This research investigate the effect of Learning Curve for a programmer. Series of experiments in two kind of Job-Types are conducted. A Log-linear model is used in regression analysis. Linear model is also used in Regression Analysis to select the Best fit model for each Job-Type. Statistical tests are used to determine the "goodness of fit". As soon as the Best-fit model discovered, a forecasting process is done.

Learning Curve is calculated. The best learning rate is elected in order to establish the best method for submitting job assignments to the programmer.

Forecast data and learning rate calculation result become the construction time estimate for each activity in PERT/CPM model.

Work Breakdown Structure is done to determine sub-modules involved in the project. Network Diagrams are constructed in order to determine the precedence of each activity. Object Oriented Technology which consists of Object Oriented Programming is implemented in the project in order to improve the modularity aspect of the project. Object Oriented Programming may emphasize Object Standardization. Object Oriented Programming makes Object Framework and Component Interoperability possible. A modular design, which relies heavily on Standardization and Component Interoperability, will make the process of breaking down the project much much easier, while increasing the reliability of the finished product.

The length of overall construction time of the project is estimated using three different approach:

1. Modular Approach, which means job assignments are submitted to programmer in a module-by-module basis. Current module has to be completed before another module can proceed

2. Job-Type approach, which means submitting job assignments based on Job-Types. Similar Job-Types will be submitted in sequence, but the sequence cannot violate activity precedence.

3. Optimized Job-Type approach, which use Job-Type approach but programmer workload re-balanced by modifying the sequence of job assignments. The goal is to minimize idle time of a programmer found in previous Job-Type Approach.

The result of those approaches are analyzed in order to determine the effect of job-assignment sequence in the overall construction time.

Nobody can avoid Uncertainties. Software Development Project also vulnerable to Uncertainties. This research assumes Efficiency and Interruptions as the source of Uncertainties. Different level of Efficiency and Interruptions, which become the Uncertainty Coefficients, are investigated. The probability of works completed under specified time, involving by certain Uncertainty Coefficient, are calculated.

Based on the findings of the research, a simple model, which consists of several mathematical models can be constructed. The model is expected to make a contribution in future Software Development Project Management.

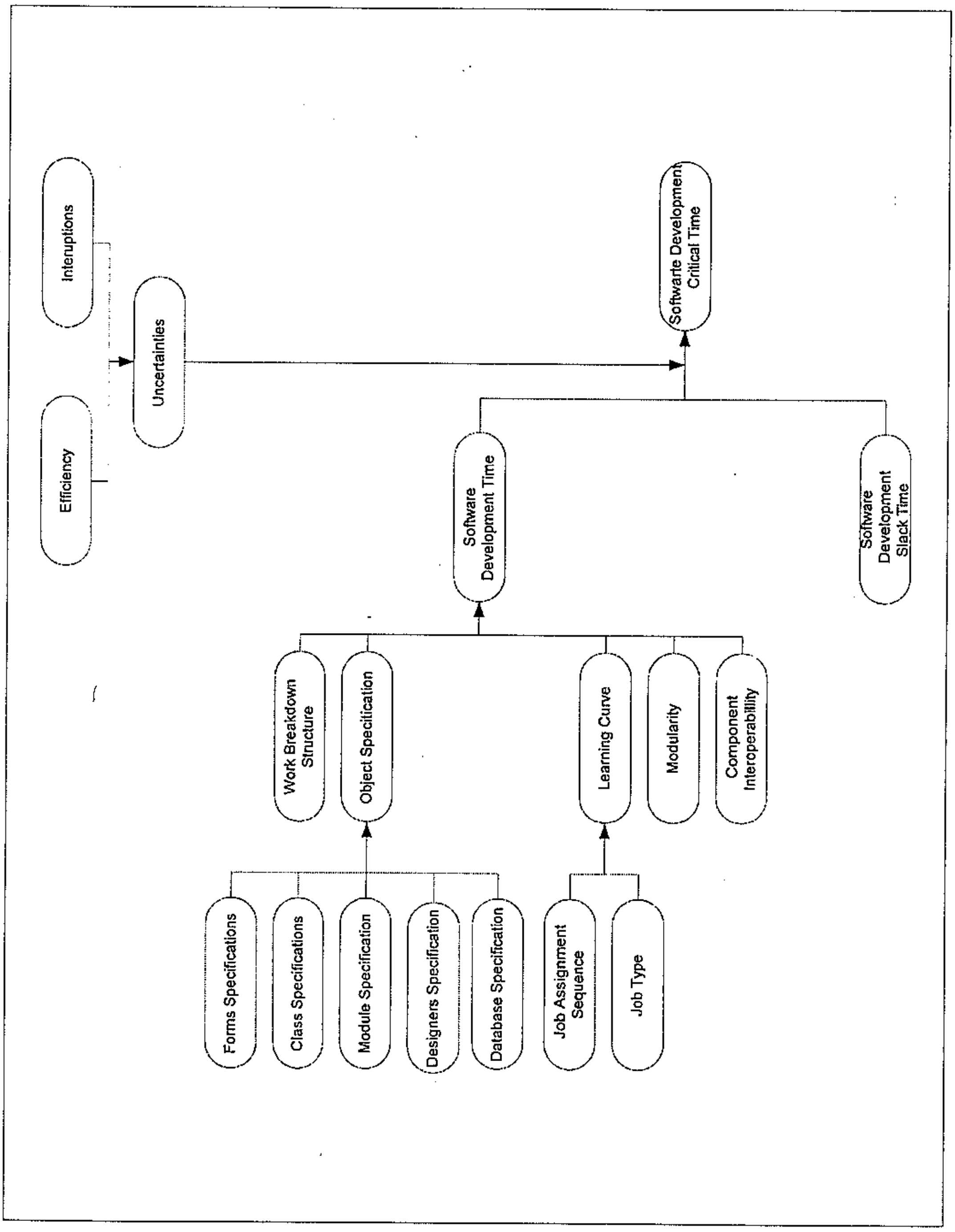
2.10.2 Solution Framework for the Pilot Study

Information Technology Projects, especially Software Development Project has already been known for suffering from delays. It has been observed previously that poor project management as become the root of the problem (Whitten Bentley and Dittman, 2000). Economics, especially Operation Research and Operation Management offered a wealth of models which suitable in managing projects. Combined with Econometric models and Statistical Tests, a new model is constructed in order to solve the problem.

Figure 2-14 identifies some determinants of Software Development Construction Time. Each job-assignment in this research contains objects. Object Specifications become a determinant in Software Development Construction Time. The effect of establishing Standardized Object Specifications is heavily observed. Learning Curve of a programmer is suspected to influence the development time. Job-assignment sequence and Standardized Job-Type also deeply observed. The effect of Uncertainties is also analyzed. Efficiency and Interruptions caused Uncertainties.

Figure 2-15 shows the framework of finding the solution to the problem.

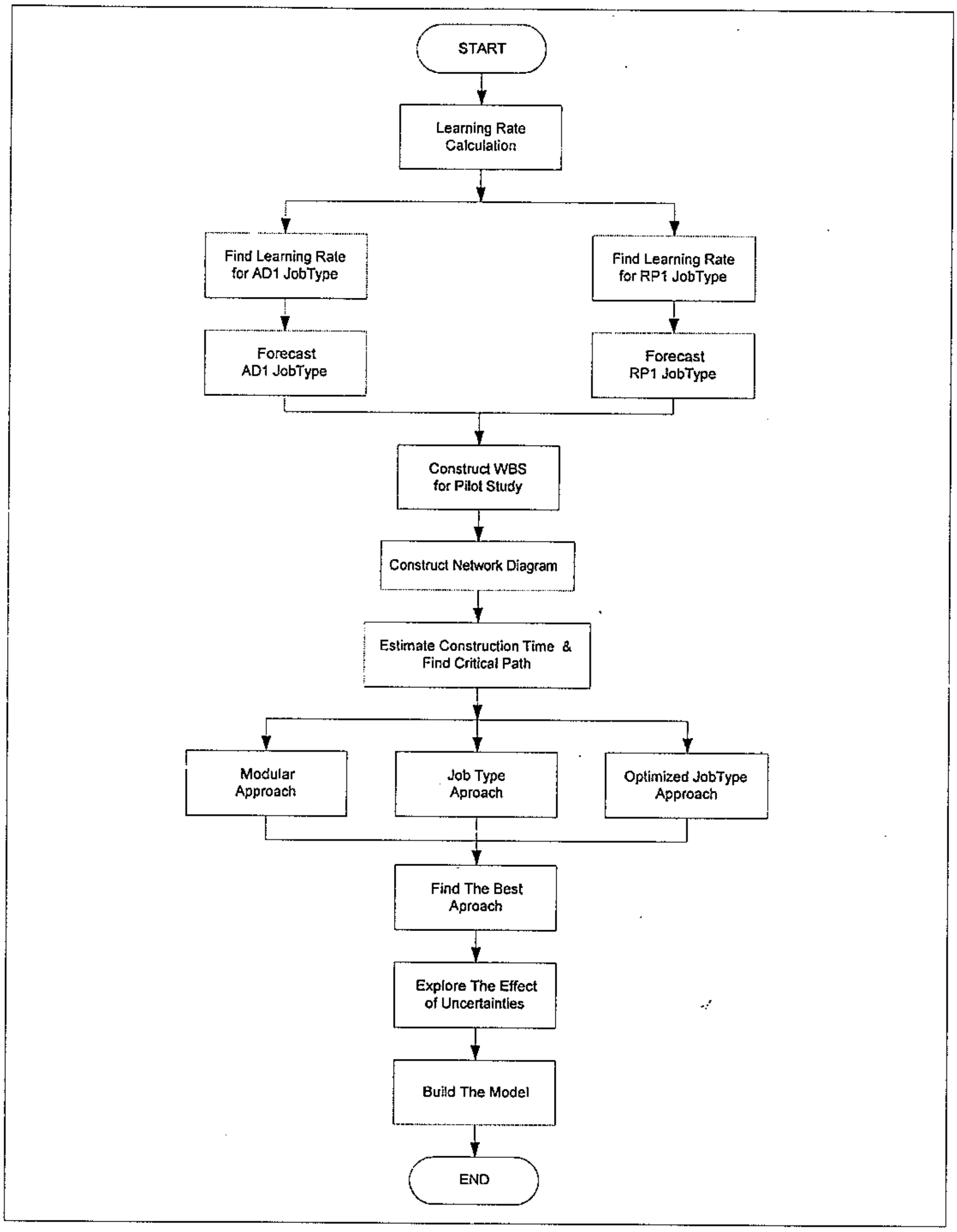
Figure 2-14:
Factors affecting Software Development Construction Time



Source: Developed for this thesis

Figure 2-15

Solution Framework



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2.11 Previous Findings

Several researches has been conducted prior to this research. The findings had become the entry point of this research. Table 2-1 list those findings.

Table 2-1

Previous Findings

No.	Author	Findings and Contributions
1	Carmel and Sawyer	The nature of Software: Virtual and difficult to measure
2	Clarke and Doherty (2004)	Software Development environment
3	Cusumano (1997)	Delays in Software Development Projects, Team Development Approaches
4	Dube (1998)	
5	Galin (2004)	
6	Herzwurn (2003)	
7	Krishnan (1998)	
8	Reid (1998)	
9	Suwardhy, et.al. (2003)	
10	Tong (1994)	
11	Whitten, Betley and Dittman (2000)	Software Development Projects and Project mis-management
12	Laudon and Laudon	Poor estimation time causing delays
13	Futrell, Shafer and Shafer (2002)	Project Management, Work Breakdown Structure
14	Landgrave, Maples and Wilson (1999)	in Software Project Management
15	Cho and Kim (2001)	Object Oriented technology (OOT), Object Oriented Programming (OOP) and its contribution
16	Bradley and Millspaugh (2005)	to Software Development and Modularity
17	Bopnar and Hopwood (2001)	
18	Post (2002)	
19	Ihlson and Youg-Gul (2002)	
20	Chase, Jacobs and Aquilano (2004)	Operation Researh Models, Project Management Models, Work Breakdown Structures
21	Gaither and Frazier (2001)	Network Diagram, PERT/CPM Model, Uncertainties, Model Building
22	Hillier and Lieberman (2001)	
23	Krajewski and Ritzman (1990)	
24	Levin, et.al. (1989)	
25	Render and Heizer (2003)	
26	Render and Stair (2000)	
27	Stevenson (2003)	
28	Lowson (2002)	Strategic role of Operations Management
29	Hammer (2004)	Innovation in the Production area
30	Gujarati (2003)	Econometric Models
31	Greene (2003)	Statical Tests and Model Fit
32	Thomas (1997)	
33	Bowen and Starr (1982)	
34	Webster	
35	Clarke (2001)	Human Identification Technologies
36	Ashbourn (2003)	Biometrics
37	Duta and Jain (2003)	
38	Hong, et.al. (2003)	
39	Kulkarni and Jain (2003)	
40	Liu and Silverman (2004)	
41	Perez (2003)	
42	Prabakar and Jain (2003)	
43	Reid (2004)	
44	Ross and Jain (2004)	
45	Verton (2001)	

Source: Developed for this thesis

2.12 Summary of Literature Review

Information Technology (IT) as an integral part of Information Systems (IS) has involved nearly every aspect of modern life. Information Technology has changed our habit (Vernon-Wortzel and Wortzel, 1997). Information Technology has change the management process by providing wide number of powerful tools to do daily business tasks (Laudon and Laudon, 2000). Information Technology has an important impact on organizational structure, behavioral patterns, and other aspect of management (Bittel and Ramsey, 1989)

Information is one of the competitive advantage for a company (Porter, 1979). Technology is one of the supports activities, needed for a company to reach a sustainable competitive advantage (Porter, 1985). Technology is one of the forces that can influence industrial structure by spreading information rapidly to each element of the organization (Thompson and Strickland, 2003; Porter 2001). The speed of information transmission influence company's competitive advantage (Porter, 1985). Ability to manage technology, including Information Technology, has become strength factor in SWOT Analysis (Thompson and Strickland, 2003). Information Technology will help to build a comparative advantage, which in turn builds a Competitive Advantage (Porter, 1985; Biswajit and Shweta, 2004).

In today's global markets, you don't have to go abroad for competition. Sooner or later, the world comes to you (Bartlett and Ghoshal, 2000). Time to market is widely viewed as a key source of competitive advantage, especially in "fast-cycle" industries (Datar, *et al.,* 1997). A company that can bring out new products three times faster than its competitor enjoys a huge advantage. (Stevenson, 2003). In most industries, the most critical dimension in competition is the speed of the company to respond to customer demands. Therefore, a fast new product development can lead a company to a sustainable competitive advantage.(Blackburn, *et al.,* 1996, Chase, Jacobs and Aquilano, 2004)

An effort to provide products and/or services to the customer, a company usually exposed to some alternatives of operations activity. An effort to make that decision actually becomes the beginning of a strategy. Strategy is a matter of choices (Lowson, 2002). The essence of a strategy is choosing a different activity from the competitors (Porter, 1996). Operations Strategy is concerned with setting a broad policies and plans for using resources of a firm to best support its long term competitive strategy (Chase, Jacobs and Aquilano, 2004). A breakthrough in operations innovation not only gives a continuous development, but can defeat the competitors and rock the industry (Hammer, 2004).

Ironically, there are lots of problems occurred in Information Technology implementations. Information Technology Projects, especially Software Development are suffering from many difficulties. Failed IT Projects reaching a number of 90%, while 80% suffered from delays and over-budget and even 40% among them completely terminated (Tong, 1994; Krishnan, 1998; Suwardhy, et al, 2003; Clarke and Doherty, 2004; Dube, 1998). Many users still do not satisfied with the result of IT Projects (Herzwurm, 2003). Software has a very important role in today's business process, because it delivers the most important product today: *information*. It manages business information to enhance competitiveness; it provides a gateway to worldwide information networks and provides the means of acquiring information in all of its forms (Pressman, 2001).

Software is some times considered as an art (Blackburn, *et. al.,* 1996) . The nature of Software Development with is virtual and very difficult to measure.

Environment surrounding software development is very young and liquid. Only a few of development standards can become a reference (Tong, 1994).

Software Development companies are suffering from huge pressure from their customers regarding the IT implementations. Some project mis-management problems observed by Whitten, Bentley and Dittman, 2000. Poor estimating techniques is one of them. Many analyst and project managers estimate by making best-calculated estimate (jokingly "guesstimate") and then doubling that number.

Operations Management (OM) is defined as the design, operation and improvement of the systems that create and deliver the firm's primary products and services (Chase, Jacobs and Aquilano, 2004). The operations functions consists of all activities directly related to producing goods and/or providing services (Krajewski and Ritzman, 1990; Schonberger and Knod, 1994; Stevenson, 2003).

Operation Management and Operations Research offer a number of models in managing a project. It seems to be strange that the project management principles deployed in a Software Development Company. Tan and Platts, 2003, discovered relationships between physical projects and IT projects. Modern Operations Management shows interdependencies with other area of sciences such as marketing, accounting, human resources and information systems (Schonberger and Knod, 1994). According to Project Management Institute (PMI), Project Management is a set of principles, methods and techniques for the effective planning, scheduling, controlling and tracking of deliverable-oriented work (results) that help to establish a sound historical basis for future planning of projects (Futrell, Shafer and Shafer, 2002; Murch, 2001).

Work Breakdown Structure is the first step in project management which divide a large and complex project into a small and manageable parts. (Stevenson, 2003). Also, Work Breakdown Structure is the backbone of any project. It describes necessary steps needed to carry out the project and their relationship each other (Futrell, Shafer and Shafer, 2002). Work Breakdown Structure is a representation of the building block structure of the project. It shows major project modules, secondary modules and so on (Schonberger and Knod, 1994). Time standard is the amount of time it should take a qualified worker to complete a specified task, working at a sustainable rate, using given methods, tools and raw material inputs (Krajewski and Ritzman, 1990; Stevenson, 2003)

PERT (Program Evaluation and Review Techniques) and **CPM** (Critical Path Method) are the most commonly used models in the process of planning and coordinating large scale projects (Stevenson , 2003). By using PERT and CPM method, project manager can get: (1) Graphical display of project activities, (2) Estimation of how long the project will commence, (3) Indication of the most critical activities in project completion time, (4) Indication of how long an activity in a project can be delayed without delaying the whole project.

Each unit of work (such as job, task and projects) has some attributes, including the time taken to perform it (Schonberger and Knod, 1994). The fundamental purpose of work measurement is to set a time standard for a specific work (Chase, Jacobs and Aquilano, 2004). Time standard is the amount of time it should take a qualified worker to complete a specified task, working at a sustainable rate, using given methods, tools and raw material inputs (Krajewski and Ritzman, 1990; Stevenson, 2003).

Regression Analysis is used in constructing time standard in this research. Consistency with economic theory is important in selecting best model (Thomas, 1997). Learning Curve model is not a linear model. Gaynor and Kirkpatrick (1994) outlines some Curvilinear models. Gujarati (2003), offers some approaches in transforming Non-Linear model into Linear model so that Linear Regression can be used to solve the problem. Log-linear model is used in order to estimate Learning Rate of a programmer.

The output of pilot study is expected to fit in daily business process. The Biometric Time and Attendance Systems is an application software which can produce an accurate Time and Attendance data. Application software is software which made to solve a specific problem in a company. (Laudon and Laudon, 2000). The application is useful in Human Resource Information Systems which become a member in an Information Systems of a company(Hall, 2004). Compensation and Workforce Management is suitable for this application (Laudon and Laudon, 2000). A reliable authentication is required in time keeping process. There are several types of authentication. Biometrics uses something that can not be lost, something that can not be lend, something that cannot be left behind and something that cannot be stolen. It is nearly impossible to manipulate Biometrics data (Liu, 2000). Thus, a valid data can be captured rapidly.

Implementation of a good Project Management Techniques is expected to assists the Software Development Company to bring the product on time and on budget which is expected to bring a satisfaction to the customer. The user of Information Technology may use the product in order to reach a sustainable competitive advantage.

CHAPTER III
METHODOLOGY

3.1 Introduction

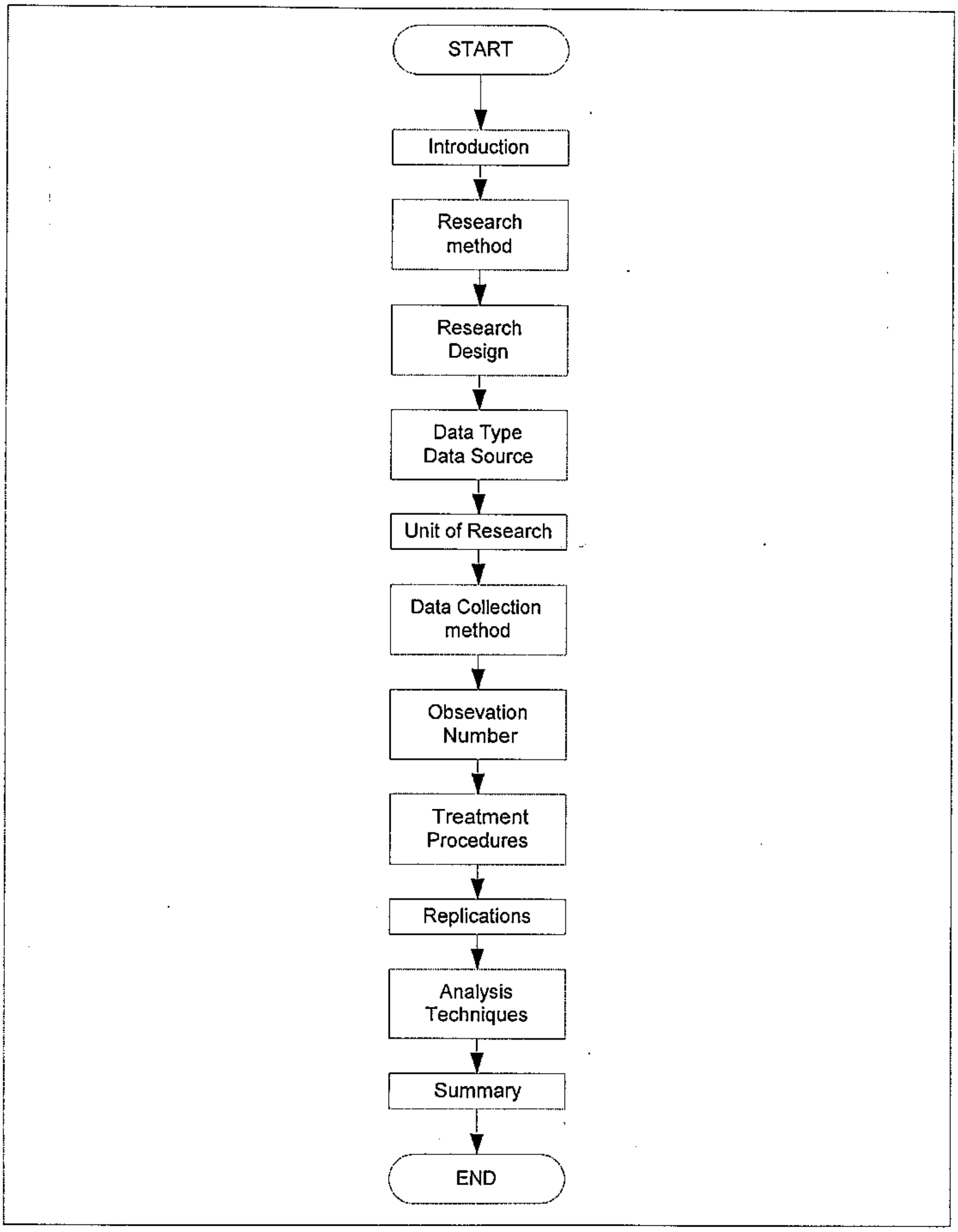
A scientific research has to follow certain rules to become a valid research. This chapter describe details of research methodology of this research. Research methods and designs are carefully described here, accompanied by the reason and supporting facts.

The unique nature of Information Technology Projects, especially Software Projects, become the most important considerations in choosing the research method and research design. Handicaps and difficulties in satisfying sampling techniques are describe followed the the remedy. Research site is briefly described in this chapter. Data Collection Techniques and Analysis Techniques are described in details. This research uses primary data collected from series of experiments conducted in the research site. Unit of analysis is also described.

The pattern of experiment is also presented in this chapter. The condition of treatment and non-treatment is fully described. Basic formula to determine the number of observations can be found here. Explanation of analysis techniques used in this research is deeply investigated. This chapter is concluded by a summary of research methodology

The framework of current chapter is described in figure 3-1.

Figure 3-1
Research methodology chapter framework



Source: Developed for this thesis

3.2 Research method

Research Method used in this thesis is Exploratory Research Technique, using Experimental Method as a basic research method (Zikmund, 2004).

Exploratory Research gives a deep understanding regarding one or several concepts and crystalizing the problem. According to Zikmund, 2004, there are three inter-related objectives in exploratory research:

1. diagnosing certain circumstances
2. screening several alternatives
3. looking for new ideas

There are some categories in exploratory research. Pilot Study is elected in this research. This pilot study is intended to collect primary data. Pilot Study is a research project which involves sampling procedures, but rigorous sampling standard has been relaxed. However, this will not prohibit theory building because a theory can be built upon many research techniques including case study research (Eisenhardt, 1989). Pilot Study is also useful to identify the essential process in Software Development (Jovanovic and Shoemaker, 1997).

Experimental Method is the only research method which test several interrelated hypothesis which has a cause-effect relationship. Experimental method is the most valid approach to bring solutions in business-management related problems (Gay and Diehl, 1996).

A researcher manipulates at least one independent variable in an experimental while controlling another relevant variables and observes the impact on one or more dependent variable (Furlong, Lovelace and Lovelace, 2000).

The research process can be represented in a flowchart in figure 3-2.

3.3 Research Design

This research is a Strategic Operation Research. This research is closely related in innovation in production area of a software development company. The company is in a process of shifting its product platform which may involve rebuilding the existing modules. Innovation in production area will affect every aspect in the company (Hammer, 2004).

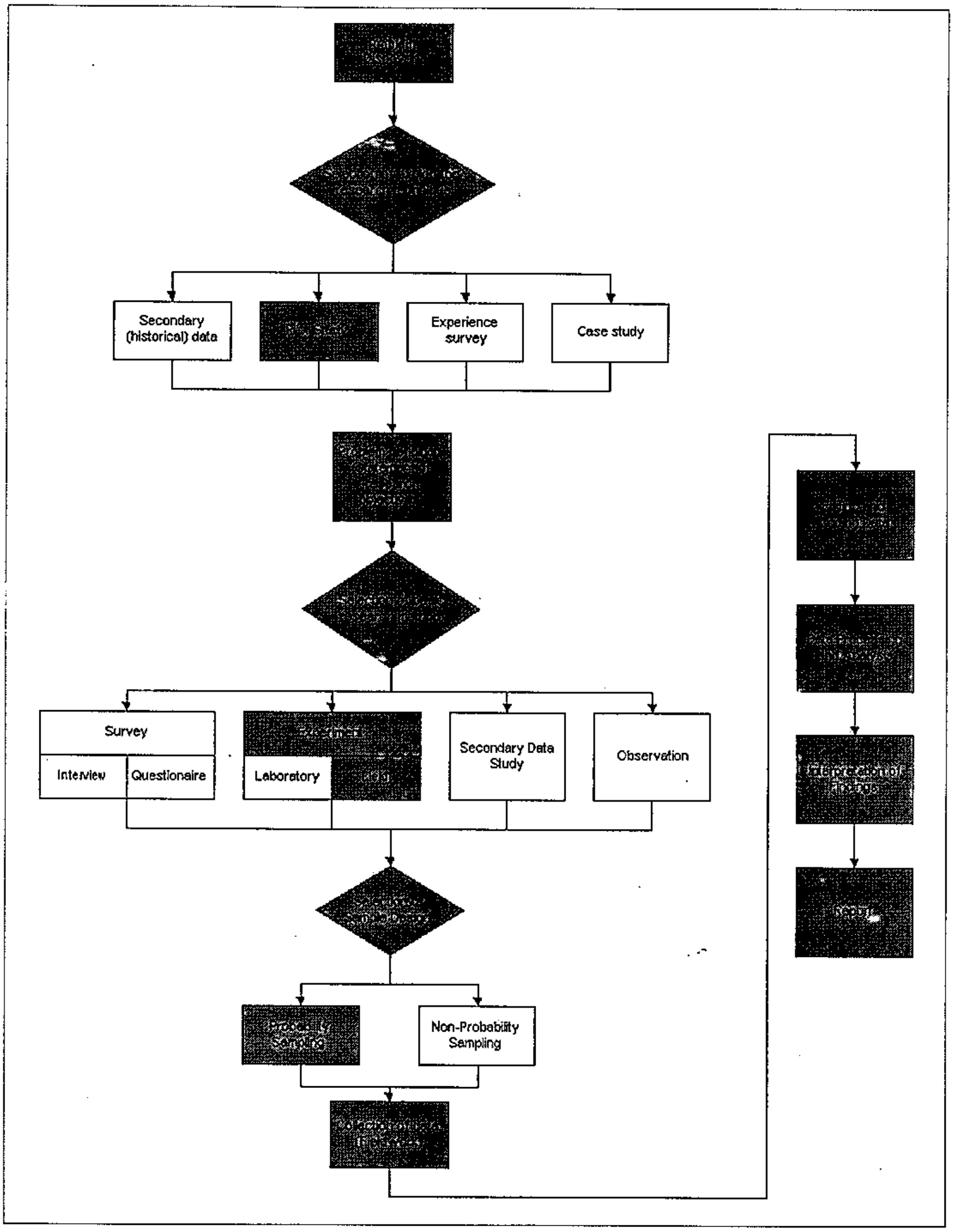
Information Technology Projects, especially Software Development Projects, were known to be very difficult to measure. The measurement standards themselves are very few (Tong, 1994). Software Development grows rapidly in a vary young, dynamic and liquid environment (Dube, 1998)

Base on those facts, a Quasi-Experimental Design is built in this research.

It has been realized that only a few measurement standards exist in Software Development. This fact may cause a problem in selecting a homogenous population from which samples can be drawn. But difficulties in satisfying sampling procedures will not prohibit this research to commence

Figure 3-2

Research Process Flowchart



Source: Zikmund, (2004), *Business Research Methods*

Chapter 1 has described the broad objective of this research. A simple model is expected at the end of this research. Observing relationships between job assignment patterns and the construction time of each sub module carefully is done in order to build a model in this volatile environment. **Single Subject Research** is suitable for this research. Furlong, Lovelace and Lovelace, 2000, said that the subject is not always a person. The subject in this research is job submitted to a programmer. Each job represent a sub-module to be constructed by a programmer. Each construction time is recorded and analyzed in order to build the model.

Jobs submitted to the programmers in several conditions. There are two conditions in this experiment:

1. Non-treatment condition

2. Treatment condition

Detailed job description always provided to the programmer in treatment condition.Description of every control in the project is provided. A color coded scheme is also included in every job. It is expected that a programmer has a clear description of each assignment. According to Tong, 1994, Software Development relies on creativity and instinct of the programmers. Creativity and instinct is very difficult to measure. Those factors are expected to be minimized in Treatment condition by providing a detailed job description.

Non-treatment condition is the opposite of treatment condition. A very limited job description is provided. Programmers are free to interpret the job. Managing construction time differences between those two conditions is the key of this research. The research follows A-B-A-B pattern. The "A" pattern means non-treatment condition, whereas the "B" pattern reflects the treatment condition. The number of experiment conducted in each session is determined by a pilot observation in the beginning of the study.

3.4 Data Type and Data Source

Primary data is used throughout the research. Primary data were obtained during several series of direct observations in the company. Type of data is Time-Series data.

The research site is System Integration Division of P.T. Marga Computindo Sarana Semarang. This company has produced a number of software packages in years. The company is in the middle of shifting its development platform when the research is conducted. Sifting development platform requires a huge effort for a software development company. It affects every technical and non-technical aspects throughout the company. The process has been gradually implemented since 2001. The process should not affect the company in supporting its customer.

P.T. Marga Computindo Sarana is running on the computer business for more than 25 years. P.T. Marga Computindo Sarana is a member of Multicom Group. The group exists in several major cities in Indonesia such as Jakarta, Bandung, Semarang, Surabaya and some other cities in eastern Indonesia.

The researcher has an unlimited access to the company data from any management stages, especially at the top management data. This advantage is definitely supports the overall research process.

3.5 Unit of Research

The unit of research is job assignments which contain sub-module development description submitted to the programmers of P.T. Marga Computindo Sarana. The programmers receive job assignments in a form of a Development Request designed by a System Analyst. The Development Request contains Form sketches, Module, Class requirements, Data Report Designer and Data Environment sketches.

Programmer's qualification is a programmer who manage to pass several tests based on CD Test of Microsoft Certified Solution Developer - Developing Desktop Applications, with the minimum result of 60. Programming language is Basic languange implemented in Microsoft® Visual Basic™ version 6.0.

3.6 Data Collection Method

Data was collected using observation method, where the researcher become a participant observer instead of anonymous observer. The programmers clearly understand that they were observed. They can easily and clearly identify the observer's existence in their daily tasks.

There are several jargons, acronyms and local meanings of words in Software Development (Dube, 1998). The observer has to understand properly those jargons, acronyms and local word meanings. To be a participant observer is considered to be the best approach in this circumstances.

Becoming a participant observer carries another advantages. The researcher can obtain first hand information. As a participant observer, researcher can easily conduct a direct observation. An in-depth interview can be easily conducted by the researcher to enrich and support the findings (Zikmund, 2004).

Understanding the circumstances surrounding the software development environment, the researcher develop strategies to collect data as follow:

1. *Qualitative dengan in-depth interview:*

   The interview is expected to collect qualitative information to enrich and support the findings. Qualitative is expected to explain several phenomena during the research

2. *Experiment:*

   Experiment is expected to provide Quantitative data. Several number of experiments involving two programmers are conducted in A-B-A-B pattern to collect the construction time data. The quantitative data is expected to become the basis for forecasting and building the best overall construction time.

Quantitative and qualitative data collected in this in-depth study will be processed using some project management techniques to build the final set of model.

> *A qualitative approach brings a wealth of information not easily obtained with other types of inquiry and is well suited to capture the complexity of organization behavior. The complex, intangible, emotional dimensions of organizations probably cannot be processed through the fine filter of linear statistics. In line with Czarniawska-Joerges (1992), it is better to think this study as part of cumulative science where various elements contribute to growing understanding of complex organization (Dube, 1998)*

3.7 Observation Number

Observation number in a Work Standard Measurement research is very crucial. According to Krajewski and Ritzman, 1990; and Russel and Taylor, 2003; the number of observation can be computed using the formula:

$$n = \left[\left(\frac{1,96}{p} \right) \left(\frac{s}{t} \right) \right]^2 \qquad (3.7)$$

where:
n=required sample size
p=degree of precision of the estimate
t=select time for work a work element
s=sample standard deviation of representative observed time for a work element

Confidence level is assumed to be 95%. The value of 1,96 describes ±1,96 standard deviation of the mean, leaving 5% value at both tail of normal distribution curve.

$\left(\frac{s}{t} \right)$ is the coefficient of variance of the sample

Degree of precision, *p*, describe the proportion of true but unknown time consumption of a work element. Confidence level if this research is 95% and Degree of Precision of the Estimate is 0,1

3.8 Treatment procedure

Treatment in a job assignment is achieved by:

1. Each form and design contain objects which follow certain standards. Each object is clearly defined. Color codes are also applied to emphasize the standard.

2. Each objects included in a job assignment has to follow certain specification of properties, including object dimensions, object type naming conventions, data field properties etc. Events and methods were also standardized. Programmer's free interpretation is minimized.

3. Job assignment sequence is systematically planned.

Non-treatment condition is the opposite of treatment procedures as follows:

1. Only minimal description of object is provided in a form or design. No color code applied.

2. Objects are loosely defined. Programmer is free to determine the specification of each object.

3. Jobs are randomly assigned. There is no specific rule is submitting job assignments.

3.9 Replications

Replication is a way to validate a single subject research (Reeves, 1992; Zikmund, 2004). Therefore, two programmers were invited in this research to strengthen the findings. The A-B-A-B pattern is implemented for both programmers.

3.10 Analysis Techniques

The research is divided into two major part. The first part involves data collection, regression calculations, calculating learning curve and forecasting procedures. This first part of the research is intended to seek relationship between Object Specifications and Construction time of a sub-module. Relationship between Object Specification and existence of learning effect of a programmer is deeply analyzed. This part of research relay heavily on Econometric Analysis. Regression analysis, both Linear and Curvilinear model, typically the Log-linear model, is the primary model used here. The forecast result will be used in the second part of the research.

The second part deploys several Operation Research model in order to predict overall construction time of a project. Work Breakdown Structure, Activity on Arrow (AOA) PERT and CPM models were the backbone of the second part research. Network diagrams and Gantt Charts are also drawn to support the readability of the calculations. Two approach are used: Modular approach and Job-Type approach. Modified Job-Type approach is also conducted in order to optimize the construction time estimates. One of those approaches is elected to be the most efficient approach, based on the the length of the overall construction time, the length of idle time of each programmer and length of critical path.

Probabilistic Estimates to anticipate uncertainties were also conducted. Efficiency and Interruptions are considered as the source of uncertainties. Several combinations of efficiency and interruptions are used in order to analyze their effects on the probability of works completed under specified construction time. A model, consists of a set of mathematical models, is expected to built as the result of the research.

3.11 Summary

This research is a Strategic Operations Research in a Software Development business. The research employs Exploratory Research Technique, using Experimental Method as a basic research method. The nature of Information Technology (IT) Projects, especially Software Development Projects were evaluated. The Quasi-Experimental Design was chosen in this research. Lack of development standards and yong, dynamic and liquid environments lead to difficulties in finding homogenous population. Single Subject Research is considered to be the most suitable answer to those difficulties. Unit of research is job assignments which contain sub-module development description submitted to the programmers. The research is held in System Integration Division of P.T. Marga Computindo Sarana, Semarang, a member of Multicom Group.

The observer become a participant observer. Specific jargons, acronyms, local meaning of words requires in Software Development a deep understanding of the research field. Series of experiments are conducting following the pattern of A-B-A-B. Ability to conduct an in-depth interview is an advantage of becoming a participant observer. In-depth interview is also conducted to capture qualitative data in order to explain several phenomena found in this research. The research is replicated to another programmer to strengthen the findings.

The research is divided into two major parts. The first part involves series experiments in order to seek the relationship between Object Specifications and Construction Time. Learning effect is also investigated by calculation each experiment session of each programmer. Econometric Analysis, especially Regression Analysis, has become the basic model in this part. Forecasting process is also conducted at the end of the analysis.

The second part uses the forecasting data of the first part of the experiment to predict the overall construction time. Operation Research models are the backbone of this part of the research. Three approaches to accomplish the project are conducted including Modular Approach, Job-Type Approach and Optimized Job-Type Approach. The best approach is elected to be the most efficient approach, based on the the length of the overall construction time, the length of idle time of each programmer and length of critical path.

Probabilistic estimates are calculated to anticipate Uncertainties. Efficiency and interruptions are considered to be the source of uncertainties. Several combinations of those two factors are investigated to calculate the probability of works completed under certain construction time. A model consists of sets of simple mathematical models is raised at the end of the second part of the research.

The following chapter describe every detail of data collecting and analysis process of current research.

CHAPTER IV: ANALYSIS

4.1 Introduction to Study

Series of experiments involving time measurement was done in order to accomplish the objective of this research. Analysis framework can be examined in Figure 4-1. A skilled programmer and two novice programmers were selected for this research.

A pilot study was conducted prior to the full study. A skilled programmer was requested to build 10 sub modules of any kind in a random order. The time required to build the sub module were recorded. Based on this pilot study, the number of sample for the full study was determined.

Four series of A-B-A-B session was then conducted for each novice programmer. Section A indicates a free programming session with minimal treatment. Sub modules were not properly sequenced. Programmers are free to extend their imagination since description to the job was set to minimal.

The B Section consists of sub-modules which followed strict treatments. Sub modules were properly sequenced. Detail description of the job were provided

Those two novice programmers were required to accomplish 14 sub modules in each session of the observations. The time required to complete each sub-module were collected. A total of 56 observation data were produced at the end of the observation series of each novice programmer.

Data obtained from this observation were written down and processed using simple Excel Spreadsheet. Data were converted to minutes. This kind of data is called original data (for simplicity reason only). The original data become the input of SPSS version 12 Statistical Package for Regression Analysis.

Time required to complete the job were suspected to follow a curvilinear pattern instead of linear pattern. Logarithm transformation was done to the original data. as described in Nahmias, 2001. According to Gujarati, 2003, and Thomas, 1997, this model is called Log-linear model. The objective of this transformation is to perform curvilinear regression in SPSS Regression Analysis.

Both Linear and Logarithm transformed data were fed into SPSS in order to perform Regression Analysis. Regression calculation in SPSS were done both using Linear and Log-linear model. The regression output of both Linear and Log-linear model were compared in order to seek a better fit model.

Indicators which were used to determine the "better fit model" are Pearson Correlation, Durbin Watson test result and R Squared value. Once better model was selected, further analysis was performed on it and the less-fit model was rejected. Learning rate for each session of the experiment were computed.

Scatter plots were also drawn. Scatter plots were intended to give a better visual understanding and visual comparison. Several plots were drawn as follows:

1. Linear plot of the linear data, intended to reflect the Linear model
2. Logarithmic Plot of the linear data, intended to reflect the Log-linear model.

3. Linear plot of Log-linear model data was added as a supplemental plot supporting the Log-linear model.

Next step was comparing the four sets of analysis following the A-B-A-B sequence. A conclusion was drawn based on the comparison of those four sets of analysis.

Based on the slope and coefficient obtained from database processing, a forecast can be done, to predict changes in the future

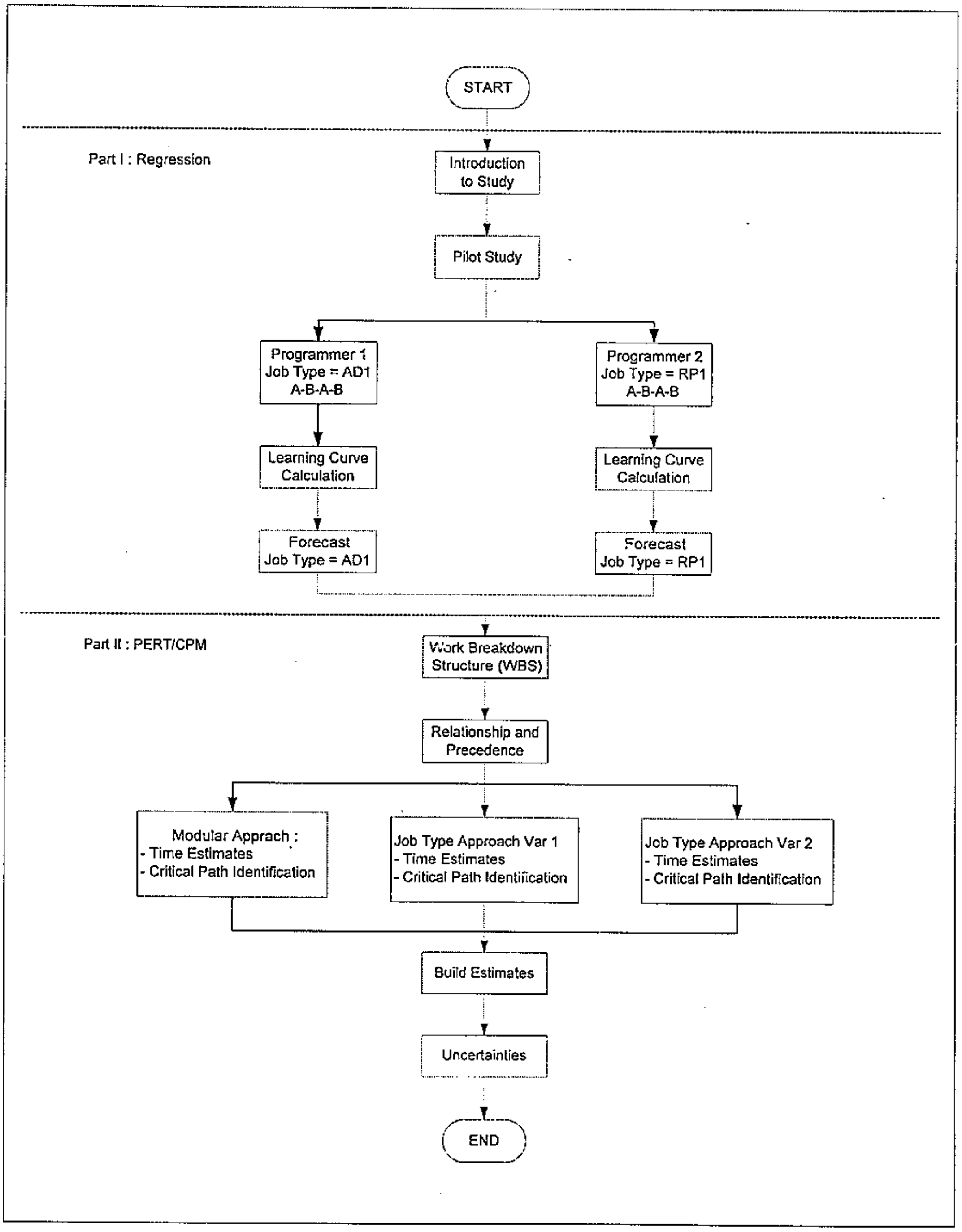
The result of forecasting process is used to determine each work element in a project. A critical path of a project can be determined based on PERT/CPM model. The length of the critical path can be better estimated using forecast data obtained from the previous analysis.

Learning curve can be used as a basis for forecasting process in order to build a better model in estimating the length of a project's critical path in PERT/CPM method.

Finally, relationship between modules in Biometric Time and Attendance System Development is presented. This chart shows a loose relationship only. A Network Diagram of Sub-module relationship is drawn to show precedence and relationship between Sub Modules. Estimation of time will be computed based on the forecast being made on the previous subsection.

Probabilistic Time Estimates is used to reflect the uncertainties. A *Beta Distribution* is used to describe the inherent variability in time estimates (Hillier and Lieberman, 2001).

Figure 4-1
Analysis Framework



Source: Developed for this thesis

4.1 Critical Values

Some critical values needed to be computed in order to become benchmark values for certain analysis. Number of samples of each session in this research are 14. Number of independent variable is 1. Degree of freedom (df) is 12.

4.1.1 Confidence Level

According to Zikmund, 2003, Confidence Level means a percentage or decimal that tells how confident a researcher can be about being correct. It states the long-run percentage of the time that the results will be correct. Zikmund, 2003, said that traditionally researcher have utilized the 95 percent confidence level. Following Zikmund's statements, Confidence Level used in this research is 95% and $\alpha = 0.05$, while $t_{0.05,12} = 2.179$

4.1.2 Durbin-Watson Critical Values

According to Gujarati, 2003, Durbin Watson d statistic critical value d_L and d_U at 0.05 level of significance, $n = 1, k' = 1$ are:

1. $d_L = 1.045$
2. $d_U = 1.350$

Another critical values can be computed as follows:

1. $4 - d_U = 2.650$

2 $4 - d_L = 2.955$

4.2 The Preliminary Study

Many companies that develop work standards experience productivity gain. Managers use standards to define work order. There are various work measurement methods available. Method chosen depends on the purpose for which the data will be used

The method used most often for setting standards for a task is time study. A job divided into a series of smaller work elements. The number of sample needed for a time study is obtained using formula:

$$n = \left[\left(\frac{1.96}{p} \right) \bullet \left(\frac{s}{\bar{t}} \right) \right]^2 \qquad (4.1)$$

where:
n = required sample size
p = precision of the estimator
t = select time for work element
s = sample standard deviation of representative observed time for a work element

In order to determine the sample size a Preliminary study is conducted. Observation time is 10 times and precision of estimate is 0.05. A programmer is required to do 10 work orders. The result is presented in Table 4-1. Column 1 shows observation number. Column 2 and 3 show time required to accomplish the job in Hour and Minute, which is translated into minutes in column 4.

Table 4-1:
The result of the Preliminary Study

No.	Hour	Minute	Total (Minute)
1	5	50	350
2	4	45	285
3	6	35	395
4	5	55	355
5	6	0	360
6	5	30	330
7	5	45	345
8	5	25	325
9	5	15	315
10	6	20	380

Source: Processed primary data

Total of column minutes required to accomplish all of the job is 3,440 minutes. Mean is 344 minutes, Standard Deviation is 31.95483

Using equation number 4.2.1, sample size can be computed as follows:

$$n = \left[\left(\frac{1.96}{0.05}\right) \bullet \left(\frac{31.95483}{344}\right)\right]^2$$
$$n = 13.25953$$

Sample size of this experiment is set to 14 experiments. Since experiment design pattern used in this research is A-B-A-B, there will be 56 experiments divided in 4 (four) sections, each consists of 14 assignments.

4.3 The Full Study of Programmer 1

As described earlier, 56 experiments were conducted. There are 56 sub modules submitted to Programmer 1. Type of module was AD-1 (screen input routines). The result of this experiment is presented in Table 4-2.

Table 4-2:
Experiment for Programmer 1 - Module Type AD-1

	Session A1: (without treatment)			Session B1: (with treatment)			Session A2: (without treatment))			Session B2: (with treatment)		
No.	Hour	Min	Min Total	Hour	Min	Min Total	Hour	Min	Min Total	Hour	Min	Min Total
1	6	0	360	16	0	960	9	0	540	5	55	355
2	6	15	375	7	0	420	8	10	490	4	40	280
3	7	0	420	6	30	390	7	0	420	3	55	235
4	8	15	495	5	50	350	11	0	660	2	30	150
5	10	30	630	6	10	370	6	30	390	2	30	150
6	8	0	480	5	45	345	5	30	330	2	30	150
7	7	0	420	5	55	355	8	0	480	3	10	190
8	7	0	420	4	55	295	6	0	360	3	15	195
9	6	30	390	4	30	270	6	30	390	3	10	190
10	6	0	360	4	55	295	6	15	375	2	20	140
11	7	0	420	5	10	310	7	0	420	2	0	120
12	8	0	480	4	30	270	6	30	390	1	50	110
13	6	30	390	4	25	265	5	50	350	1	30	90
14	7	0	420	3	10	190	7	0	420	1	30	90
Total			6060			5085			6015			2445

Source: Processed Primary data

Each section of the experiment was used to determine the rate of learning. Further, data were used to forecast the time required to accomplish the same type of job in the future.

Formula for calculating learning curve is:

$$k_n = k_1 n^b \tag{4.2}$$

where:
k_1*=direct labor hours for the first unit*
n*=cumulative number of units produced*

If dependent variable k_n was substituted with with y, independent variable n with x and constant k_1 with a we have the following equation:

$$y = ax^b \tag{4.3}$$

The equation is not linear and also known as exponential regression model (Gujarati, 2003). When relationship between time and y is not direct (i.e., not linear) a curvilinear model is needed (Gaynor and Kirkpatrick, 1994). Gujarati (2003), Nahmias (2001) and Thomas (1997), said that logarithmic transformation can be applied. If logarithm transformation applied both sides, the result is:

$$\ln(y) = \ln(a) + b\ln(x) \tag{4.4}$$

where ln*=natural* log *(*log *to the base of e, and where* $e = 2.718$*)*

Gujarati (2003), and Thomas (1997), called this Log-Linear Model.

Substituting $\ln(a)$ with α and replacing b with β, the equation is:

$$\ln(y) = \alpha + \beta\ln(x) \tag{4.5}$$

Linear regression was used to fit the value of *a* and *b* to actual data after the logarithm transformation has been made (Thomas, 1997).

Logarithm transformation of each session of experiment result presented in the beginning of each A1, B1, A2 and B2 experiment session

4.3.1 Programmer 1 - Section A1 - Construction Time

Logarithm transformation of Session A1 of Programmer 1 presented in Attachment C-1. These values were fed to a statistical package to estimate the value of intercept and slope of the regression line. Two linear regression calculations were performed to select the best model fit as follows:

1. Linear Model:

   x was declared as independent variable and y was declared as dependent variable.

2. Log-Linear Model:

   $\ln(x)$ was declared as independent variable, whereas $\ln(y)$ declared as dependent variable

Detailed result of those two regression calculations can be observed in Attachment A-1 and Attachment A-2

4.3.1.1 Linear and Log-linear Model Comparison

Regression output, presented at Attachment A-3 and A-4 contain useful values in order to select the best model fit between the usage of Linear and Log-linear model. Comparison of several indicators were presented in table 4-4.

Table 4-3
Regression Output Comparison
for Session A1 of Programmer 1

Indicators	Linear model	Log-linear model
Pearson Correlation	(-0.085)	0.122
Correlation Significance	0.386	0.339
Adjusted R-Squared	(0.075)	(0.067)
Durbin-Watson	1.080	1.001

Source: Processed primary data

The Pearson correlation coefficient is a measure of linear association between two variables. Some evidence can be evaluated as follows:

1. Correlation value of Log-linear model is 0.122, whereas the Correlation value of Linear model is -0.085. Those value was relatively low

2. Correlation Significance value of Linear model is 0.386. Correlation Significance value of Log-linear model is 0.339. Both values exceed significance level of 0.05.

Those two values indicated that there was no significant correlation between those variables. Further, there was no correlation between variables in session A1 of programmer 1. It was true, because no explanations provided to the programmer 1 regarding the job. Only limited description was given to the programmer and the programmer was free to make any interpretations. Both model does not give a good result, but Log-linear is slightly better than Linear model. Further observation of the Log-linear model is presented in this sub-section.

Attachment A-2 contains of the model summary of Log-linear model. Predictors are $\ln(x)$ and $\ln(y)$.

1. R, the multiple correlation coefficient, is the correlation between the observed and predicted values of the dependent variable. R value was only approximately 0.1221. This value was very low and indicated a weak relationship between the observed and predicted values of the dependent variable

2. R squared is the proportion of variation in the dependent variable explained by the regression model. The value was only 0.01. Small values indicate that the model does not fit the data well

3. Adjusted R Square is -0.067. According to Gujarati (2003), this value is considered to be zero.

Those values indicated that there are no strong relationship and the model does not fit the data well.

Durbin-Watson value was 1.001. This value was less than d_L critical value stated at 4.1.2. Combined with small values of Correlation, as presented at Attachment A-2, this model may not be correct. Gaynor and Kirkpatrick (1994), suggested that small values of correlation and small Durbin-Watson test values might indicate that the model is not correct.

Attachment A-2 contains coefficient value for Log-linear Model. The Coefficient values are:

1. Constant value is 6.016687

2. Coefficient of $\ln(x)$ value is 0.023696

Equation model is $\ln(y) = 6{,}016687 + 0{,}023696\ln(x)$.

Some evidence regarding the coefficient value for $\ln(x)$ were found :

1. t test value was small

2. significant value exceeded critical value of 0.05.

3. coefficient value of variable $\ln(x)$ is positive

Those two evidence suggested that there were only small significance and relative importance of variable $\ln(x)$ in the model.

4.3.1.2 Anti-Logarithm transformation

Log-Linear Model can be converted back to exponential model as follows:

1. Converting α value to a, using $\exp(\alpha)$ function

$$\alpha = 6.016687$$
$$a = \exp(6.016687)$$
$$a = 410.217292$$

2. The equation can be rewritten to:

$$y = 410.217292 \bullet x^{0.023696} \qquad (4.6)$$

4.3.1.3 Learning Rate Calculation

Based on 2.6.6.2 Learning Rate can be calculate as follows:

$$r = 10^{(b \log 2)}$$

$$r = 10^{\left(0.023696 \times \log(2)\right)}$$
$$r = 10^{0.007133}$$
$$r = 1.007159$$

Learning rate of Programmer 1 in Session A1 is 1.007159. Learning rate is positive and greater than 1. This means that time required to complete the job is increasing.

4.3.1.4 Scatter Plot

Scatter plots are also drawn in Attachment A-2. The curvilinear fit showed an unexpected learning curve. This meant that job assignment sequence and job type failed to bring any learning effect for the Programmer 1 in session A1

4.3.1.5 Conclusion for Programmer 1 - Session A1

Based on several findings presented before, conclusion for Session A1 were:

1. Model is not fit
2. There is no significant relative importance of variable $\ln(x)$.
3. Value of b coefficient is positive
4. Learning rate is greater than 1 and positive.

This conclusion matched with the experiment rules set in session A1. In session A1, no or very limited instruction is given to the programmer. Development of sub-modules relied on the imagination of the programmer. Value of *b* coefficient value which was positive. This made the slope of the curve higher according to the time. The learning rate is positive and is greater than 1. So, it can be concluded that there was no learning effect in Section A1 of the experiment.

4.3.2 Programmer 1 - Session B1

Experiment Session B1 for Programmer 1 was conducted after 14 observations for section A1 were all done. Full descriptions were given in the job specification form. Each property of the objects presented on the screen were carefully defined. 14 observations were conducted in this session for the same category of job. Information were color coded to maximize readability of the job sheet, since many information were found on the same sheet. Time consumed by Programmer 1 in Session B1 were collected and presented in Attachment C-2

4.3.2.1 Programmer 1 - Session B1 - Construction time

The time required by Programmer 1 to complete each job in Session B1 were presented in Attachment C-2. The logarithm transformation of each were also presented. Programmer 1 needed as much as 16 hours or 960 minutes to complete the first job. Programmer 1 needed more time to interpret the job description, especially control properties. Also, programmer 1 needed more time to ask some new settings in the job description and screen layout. Second job was accomplished in 7 hours or 420 minutes. Programmer 1 needed less than a half time compared to the first job. Construction time decreased to 4 to 6 hours minutes before it finally reached 3 hours and 10 minutes or 190 minutes It can be predicted that programmer 1 has become accustomed with the jobs.

Logarithmic transformations of the construction time (in minutes) were needed in further calculations in linear regression. However, in order to test the best model fit, calculations were performed both in linear and log-linear models. Two linear regression calculations were performed using the same procedure as the previous session. The complete result of the regression calculation can be found in Attachment A-3 for linear model trial and Attachment A-4 for Log-linear model.

4.3.2.2 Linear and Log-linear Model Comparison

Regression output, presented at Attachment A-3 and A-4 contain useful values in order to select the best model fit between the usage of Linear and Log-linear model. Comparison of several indicators were presented in table 4-4.

Table 4-4
Linear and Log-linear comparison table

Indicator	Linear model	Log-linear model
Pearson Correlation	-0.694	-0.909
Significance	0.003	0.000
Durbin-Watson	1.226	1.590
Adjusted R Squared	0.439	0.813

Source: Processed primary data

Durbin Watson value of Linear Values was only 1.226, which was less that d_U value (1.350). Greene (2003), said that a low Durbin-Watson value may be caused by improper model fit.

Pearson Correlation value of Linear model was -0,694. On the contrary, Pearson Correlation value of Log-linear model as -0.909. Gaynor and Kirkpatrick, 1994, said that low correlation and Durbin-Watson values indicates improper model fit.

Adjusted R Squared value of Log-linear model was 0.813. This value was higher that Adjusted R Squared of Linear Model which was only 0.439. According to Bowen and Starr (1985) and Webster (1998), higher value of Adjusted R Squared indicated a better model.

Analyzing some indicators mentioned above, it can be concluded that the usage of Log-linear model leaded to a better model fit. Regression analysis using Linear model in Session B1 would not be discussed again. Discussion is limited to Regression Analysis using Log-linear model.

The Pearson correlation coefficient is a measure of linear association between two variables. Some evidence can be evaluated as follows:

1. Correlation value was -0.909. The absolute value of this correlation was close to 1.

2. Significance was 0.000. This value was far below significance level of 0.05.

Negative correlation value indicated that there was a negative correlation between $\ln(x)$ and $\ln(y)$. Those two values indicated that there was a strong and significant correlation between those variables; and the correlation itself was negative. This meant that time requirement to complete the job continuously declined.

4.3.2.3 Model Summary

Attachment A-4 contains the model summary for the session. Predictors are Constant and $\ln(x)$ and the dependent variable was $\ln(y)$.

1. R, the multiple correlation coefficient, is the correlation between the observed and predicted values of the dependent variable. R value was

0.909374. This value was very close to 1, so it a strong relationship between the observed and predicted values of the dependent variable

2. R squared is the proportion of variation in the dependent variable explained by the regression model. The value was only 0.826961. This indicates that 82,6961% change in $\ln(y)$ can be explained by the change of $\ln(x)$. Large value of R squared indicates that the model does fit the data well

3. Adjusted R Square of Linear Model is 0.439, while Adjusted R Square of Log-linear model is 0.813

Values which were presented above showed a strong relationship between the predictor and dependent variable and the model was fit

Durbin-Watson value was 1.589516. This value exceeded d_U critical value stated at 4.1.2. According to Webster, 1998, no auto-correlation detected when the value of Durbin Watson test lied between 2 and d_U critical value. Using previous definition, it can be concluded that there was no auto-correlation in session B1 of Programmer 1.

Log-linear model coefficient can also be found in Attachment A-4. Coefficient values are:

1. Constant value is 6.586770

2. Coefficient of $\ln(x)$ value is -0.425554

Equation model is $\ln(y) = 6.586770 - 0.425554\ln(x)$.

Some evidence regarding the coefficient value for $\ln(x)$ were found :

1. t test value are large. t test value for the constant is 60,175613. The absolute value of t test for $\ln(x)$ is 7.572982. Both of them are larger than $t_{0.05;12} = 2.179$. This means that those coefficients are statistically significant at the 5% level.

2. Significance value of the constant is 0.000000. Significance value of $\ln(x)$ coefficient is 0.000007. Both values are less than 0.05 significance level. This means that those coefficients are significant at 5% level.

3. coefficient value of variable $\ln(x)$ is negative

Those two evidence suggested that the constant and coefficient of $\ln(x)$ are significant. The negative value of $\ln(x)$ coefficient suggested that the slope is negative. So, the time needed for Programmer 1 to accomplish the job decreased as more and more fully described jobs were given.

4.3.2.4 Anti-Logarithm transformation

Log-Linear transformation can be converted back to exponential regression model as follows:

1. Converting α value to a, using $\exp(\alpha)$ function

$$\alpha = 6.586770$$
$$a = \exp(6.586770)$$
$$a = 725.433930$$

2. The equation can be rewritten to:

$$y = 725.433930 \bullet x^{-0.425554} \qquad (4.7)$$

4.3.2.5 Learning Rate Calculation

Based on 2.6.6.2 Learning Rate can be calculate as follows:

$$r = 10^{(b \log 2)}$$

$$r = 10^{-\left(0.425554 \times \log(2)\right)}$$
$$r = 10^{-0.007133}$$
$$r = -0.744553$$

4.3.2.6 Scatter Plot

Scatter Plots can be observed in Attachment A-4. The curvilinear fit showed an expected learning curve. This meant that job assignment sequence and job type were successfully bring any learning effect for the Programmer 1 in session B1

4.3.2.7 Conclusion for Programmer 1 - Session B1

Based on several findings presented before, conclusion for Session B1 were:

1. Model is fit
2. There is significant relative importance of constant and variable $\ln(x)$.
3. Learning rate is -0.744553

This conclusion matched with the experiment rules set in session B1. In session B1, fully described instructions were given to the programmer. Development of sub-modules was not rely solely on the imagination of the programmer. Value of b coefficient value which was negative. This made the slope of the curve lower according to the time.

Learning rate is negative. The absolute value of learning rate is lower than 1. This means that the time required to complete current the job is 74.4553% of the time required to complete previous job.

It can be concluded that learning effect can be observed in Section B1 of the experiment.

4.3.3 Programmer 1 - Section A2 - Construction Time

Experiment Session A2 for Programmer 1 was conducted after 14 observations for section B1 were all done. Very limited instructions were given in the job specification form. 14 observations were conducted in this session for the same category of job. Original construction time data and their Logarithm transformation of Session A2 of Programmer 1 presented in Attachment C-3. These values fed to a statistical package to estimate the value of intercept and slope of the regression line. Two linear regression calculations were performed to select the best fit model using the same procedure as the previous sub-session. Detailed result of regression calculation can be found in Attachment A-5 and A-6

4 3.3.1 Linear and Log-linear Model Comparison

Regression output, presented at Attachment A-5 and A-6 contain useful values in order to select the best model fit between the usage of Original and Log-linear model values. Comparison of several indicators are presented in table 4-5.

Table 4-5
Comparison of regression output
between Linear Model and Log-linear model.

Indicators	Linear model	Log-linear model
Pearson	-0.53	-0.582
Significance	0.026	0.014
Durbin-Watson	2.598	2.747
Adjusted R Squared	0.220	0.284

Source: Processed primary data

Durbin Watson value of Linear model is 2.598. This value falls between 2 and $4-d_U$. This means that there is no auto-correlation. Durbin-Watson value of Logarithm is 2.747, which means no decision can be made.

Pearson Correlation value of Linear model is -0,530. On the contrary, Pearson Correlation value of Log-linear model is -0.582. Both values do not give any indication of strong correlation. But, absolute value of Pearson Correlation Value of Log-linear model is slightly larger than the absolute value of Pearson Correlation Value of Linear model

Adjusted R Squared value of Log-linear model is 0.284. This value was higher that Adjusted R Squared of Linear model which is only 0.220. Both values does not indicate a good Adjusted R squared value. But Adjusted R Squared value of Lg-linear Model is better.

Analyzing some indicators mentioned above, it can be concluded that both Linear model or Log-linear model do not produce a good model fit. Using better Adjusted R Squared value of Log-linear model, it can be concluded that Log-linear model values produce a better fit model. So, the following discussion is current subsection is limited to Regression Output using Log-linear model

Correlation between $\ln(x)$ and $\ln(y)$ presented in Attachment A-6. The Pearson correlation coefficient is a measure of linear association between two variables. Some evidence can be evaluated as follows:

1. Correlation value was -0.582. The absolute value of this correlation is far from 1.

2. Significance was 0.014. This value is below significance level of 0.05.

Negative correlation value indicated that there was a negative correlation between $\ln(x)$ and $\ln(y)$. Although significance of Pearson Correlation is significant, but that there there is no strong indication between those variables; and the correlation itself was negative. This means that time requirement to complete the job is expected to be declined.

Attachment B-6 contains the model summary for the Log-linear Model. Predictors are Constant and $\ln(x)$ and the dependent variable was $\ln(y)$.

1. R, the multiple correlation coefficient, is the correlation between the observed and predicted values of the dependent variable. R value was 0.339100. This value is far from 1, so it a does not show any strong relationship between the observed and predicted values of the dependent variable

2. R squared is the proportion of variation in the dependent variable explained by the regression model. The value is only 0.582323. This indicates that 58,2323% change in $\ln(y)$ can be explained by the change of $\ln(x)$. Large value of R squared indicates that the model does fit the data well

Adjusted R Square of Linear model is 0.220 and Adjusted R Square Value of Log-linear model is 0.284. Those values presented above failed to show a strong relationship between the predictor and dependent variable. This means that the model is not fit.

Coefficient values for Programmer 1 - Session A2 - Log-linear Model are presented in Attachment B-6. Coefficient values are:

1. Constant value was 6.298506

2. Coefficient of $\ln(x)$ value was -0.140439

Equation model is $\ln(y) = 6.298506 - 0.140439\ln(x)$.

Some evidence regarding the coefficient value for $\ln(x)$ are :

1. t test values are large. t test value for the constant is 57.131926. The absolute value of t test for $\ln(x)$ is 2.481342. Both of them are greater than $t_{0.05;12} = 2.179$. This means that those coefficients are statistically significant at the 5% level.

2. Significance value of the constant was 0.000000. Significance value of $\ln(x)$ coefficient was 0.028887. Both values were less than 0.05 significance level. This means that those coefficients were significant at 5% level.

3. coefficient value of variable $\ln(x)$ is negative

Those two evidence suggested that the constant and coefficient of $\ln(x)$ are statistically significant. The negative value of $\ln(x)$ coefficient means that the slope is negative,. So, the time needed for Programmer 1 to accomplish the job decreased as more and more fully jobs are given.

4.3.3.2 Anti-Logarithm transformation

Log-linear transformation can be converted back to exponential regression model as follows:

1. Converting α value to a, using $\exp(\alpha)$ function

$$\alpha = 6.298506$$
$$a = \exp(6.298506)$$
$$a = 543.758927$$

2. The equation can be rewritten to:

$$y = 543.758927 \bullet x^{-0.140439} \qquad (4.8)$$

4.3.3.3 Learning Rate Calculation

Based on 2.6.6.2 Learning Rate can be calculate as follows:

$$r = 10^{(b \log 2)}$$

$$r = 10^{-\left(0.140439 \times \log(2)\right)}$$
$$r = 10^{-0.042276}$$
$$r = -0.907243$$

4.3.3.4 Scatter Plot

Scatter Plots can be found in Attachment A-6. The curvilinear fit showed a pattern of learning curve. This is suspected that learning curve still exists from Session B1, but not as large as learning rate of session B1.

4.3.3.5 Conclusion for Programmer 1 - Session A2

Based on several findings presented before, conclusion for Session A2 are:

1. Model of this session is not fit

2. There is significant relative importance of constant and variable $\ln(x)$.

3. Lcarning rate is -0.907423

4. Curvilinear plot is still showing and effect of learning curve.

Jobs are randomized in this session. This may lead to the fact that the model is not fit in this session. Although jobs are randomized, it is suspected that learning effect of previous session (session B1) is still exist, but not as not as large as the learning effect in session B1.

Those findings above may lead to a conclusion that careless preparation of job descriptions may damage the existing learning rate of the programmer.

4.3.4 Programmer 1 - Session B2

Experiment Session B2 for Programmer 1 was conducted after 14 observations for section A2 were all done. Full descriptions were given again in each job specification form. Each property of the objects presented on the screen were carefully defined. 14 observations were conducted in this session for the same category of job. Information were color coded to maximize readability of the job sheet, since many information were found on the same sheet. Time consumed by Programmer 1 in Session B2 were collected and presented in Attachment C-4

Programmer 1 needed as much as 5 hours 55 minutes or 355 minutes to complete the first job. Programmer 1 needed more time to get accustomed with the job description. Also, programmer 1 needed more time to recall some new settings in the job description and screen layout. The initial construction time is not as much as in session B1. Second job was accomplished in 4 hours 40 minutes or 280 minutes. Programmer 1 needed less than a half time compared to the first job. Construction time then decreased to reached 1 hours and 30 minutes or 90 minutes It can be predicted that programmer 1 has become accustomed with the jobs. The construction time im this session decreased faster into a lower level than the consumption in session B1. Two linear regression calculations were performed using the same procedures as the previous sub-section. The complete result of the regression calculation can be found in Attachment A-7 for linear model trial and Attachment A-8 for logarithmic calculations.

4.3.4.1 Linear and Log-Linear Model Comparison

Regression output, presented at Attachment A-7 and A-8 contain useful values in order to select the best model fit between the usage of Linear and Log-Linear Models. Comparison of several indicators were presented in table 4-6.

Table 4-6:
Comparison of regression output between
Linear and Log-Linear Model

Indicator	Linear Model	Log-linear model
Pearson Correlation Significance	(0.836) 0.000	(0.877) 0.000
Durbin-Watson	0.680	0.689
Adjusted R Square	0.673	0.750

Source: Processed primary data

Durbin Watson value of Linear Model is 0.680, which is less that d_L value (1.045) - see subsection 4.1.2. Durbin-Watson test value of Log-linear model values is 0.689. This value is also less that d_L value (1.045) - see subsection 4.1.2. Further analysis of this situation can be found in subsection 4.3.4.2.

Pearson Correlation value of Linear model is -0,836. On the contrary, Pearson Correlation value of Log-linear model as -0.877.

Adjusted R Squared value of Log-linear model is 0.769. This value was higher that R Squared of Linear which is 0.698. According to Bowen and Starr (1985) and Webster (1998), 76.9% variation of $\ln(y)$ can be explain by $\ln(x)$. This value is higher than R Squared of Linear model. Adjusted R Square for Log-linear Model is 0.750. Adjusted R Square for Linear Model is 0.673.

Analyzing some indicators mentioned above, it can be concluded that the usage of Log-linear leaded to a better model fit. Regression analysis using Linear

Model in Session B2 would not be discussed again. Discussion is limited to Regression Analysis using Log-linear model values.

The Pearson correlation coefficient is a measure of linear association between two variables. Some evidence can be evaluated as follows:

1. Correlation value was -0.877. The absolute value of this correlation was close to 1.

2. Significance was 0.000. This value was far below significance level of 0.05.

Negative correlation value indicated that there was a negative correlation between $\ln(x)$ and $\ln(y)$. Those two values indicated that there was a strong and significant correlation between those variables; and the correlation itself was negative. This meant that time requirement to complete the job continuously declined.

Attachment A-8 contains model summary values for Log-linear model. Predictors are Constant and $\ln(x)$ and the dependent variable was $\ln(y)$.

1. R, the multiple correlation coefficient, is the correlation between the observed and predicted values of the dependent variable. R value is 0.876924. This value is very close to 1, so there is a strong relationship between the observed and predicted values of the dependent variable

2. R squared is the proportion of variation in the dependent variable explained by the regression model. The value was only 0.768996. This indicates that

76.8996% change in $\ln(y)$ can be explained by the change of $\ln(x)$. Large value of R squared indicates that the model does fit the data well

Values, which presented above, shows a strong relationship between the predictor and dependent variable and the model is fit

4.3.4.2 Durbin-Watson Test

Table - contained the result of Durbin-Watson test for current session

Durbin-Watson value is 0.689300. This value is lower than d_L critical value stated at 4.1.2. This situation indicates that there is a positive auto-correlation (Gujarati, 2003; Webster, 1998). Further analysis should be conducted.

Gujarati, 2003, has an explanation regarding this situation. This problem relates to time series data which follow a natural ordering over time so that successive observations are likely to exhibit inter-correlations, especially, if time interval between observations are short such as a day, a week, a month rather than a year. The term auto-correlation may be defined as "correlation between member of series of observations ordered in time as in time series data. There are several reasons of this phenomena. One of them is **inertia**. A salient feature in economic time series is inertia or sluggishness. In upward (or downward) swing of a growth, value of a series at one point in time is greater than its previous value. Thus there is a "momentum" built into them until something happens. Therefore, in regressions involving time series data, successive observations are likely to be interdependent.

This explanation answers the question why Durbin-Watson test result of Session B2 of Programmer 1 shows positive auto-correlation. The effect of learning may build a strong "momentum" that drives construction time of Programmer 1 down greater and greater in successive observations. This momentum can be explained by the formula of learning curve itself :

$$k_n = k_1 n^b$$

The power of n indicates a non-linear impact. So the phenomena supports the basic understanding of learning curve.

4.3.4.3 Coefficient

Coefficient values are:

1. Constant value is 5.906228

2. Coefficient of $\ln(x)$ value is -0.456211

The Log-linear Equation model is $\ln(y) = 5.906228 - 0.456211\ln(x)$.

Some evidence regarding the coefficient value for $\ln(x)$ were found :

1. t test value are large. t test value for the constant is 45.007667. The absolute value of t test for $\ln(x)$ is 6.320379. Both of them are larger than $t_{0.05;12} = 2.179$. This means that those coefficients are statistically significant at the 5% level.

2. Significance value of the constant is 0.000000. Significance value of $\ln(x)$ coefficient is 0.000038. Both values are less than 0.05 significance level. This means that those coefficients are significant at 5% level.

3. coefficient value of variable $\ln(x)$ is negative

Those two evidence suggested that the constant and coefficient of $\ln(x)$ are significant. The negative value of $\ln(x)$ coefficient suggested that the slope is negative. So, the time needed for Programmer 1 to accomplish the job decreased as more and more fully described jobs were given.

4.3.4.4 Anti-Logarithm transformation

Log-linear model can be converted back to exponential regression model as follows:

1. Converting α value to a, using $\exp(\alpha)$ function

$$\alpha = 5.906228$$
$$a = \exp(5.906228)$$
$$a = 367.318015$$

2. The equation can be rewritten to:

$$y = 367.318015 \bullet x^{-0.456211} \qquad (4\text{-}9)$$

4.3.4.5 Learning Rate Calculation

Based on 2.6.6.2 Learning Rate can be calculate as follows:

$$r = 10^{(b \log 2)}$$

$$r = 10^{-\left(0.456211 \times \log(2)\right)}$$
$$r = 10^{-0.137333}$$
$$r = -0.728898$$

4.3.4.6 Scatter Plot

Attachment C-8 contains scatter plot for Log-linear model. The curvilinear fit showed an expected learning curve. This meant that job assignment sequence and job type were successfully bring any learning effect for the Programmer 1 in session B2

4.3.4.7 Conclusion for Programmer 1 - Session B2

Based on several findings presented before, conclusion for Session B2 are:

1. Model is fit

2. There is significant relative importance of constant and variable $\ln(x)$.

3. Learning rate is negative and the absolute value of learning rate is below 1

4. A low Durbin-Watson test is further investigated. This observation involves time series data, conducted in small time intervals. Inertia effect, the "momentum" of growth and the power of n of learning curve formula also support the explanation above

The term "inertia" was actually borrowed from physics. According to Microsoft ® Encarta ® Reference Library 2005, Inertia is the property of matter that causes it to resist any change of its motion in either direction or speed. This property is accurately described by the first law of motion of the English scientist Sir Isaac Newton: An object at rest tends to remain at rest, and an object in motion tends to continue in motion in a straight line unless acted upon by an outside force. For example, passengers in an accelerating automobile feel the force of the seat against their backs overcoming their inertia so as to increase their velocity. As the car decelerates, the passengers tend to continue in motion and lurch forward. If the car turns a corner, then a package on the car seat will slide across the seat as the inertia of the package causes it to continue moving in a straight line

This conclusion matched with the experiment rules set in session B2. In session B2, fully described instructions were given to the programmer. Development of sub-modules was not rely solely on the imagination of the programmer. Value of *b* coefficient value which was negative. This made the slope of the curve lower according to the time.

Learning rate is -0.728898. This means that time required to complete current job is only 72.8898% of time required to complete previous job.

It can be concluded that learning effect can be observed in Section B2 of the experiment.

4.3.5 Forecasting

A curvilinear model has already been built in previous sub section. After building a curvilinear model, we may use it to forecast estimates for future periods (Gaynor and Kirkpatrick, 1994). So, the construction time forecast can be conducted based on learning curve formula of Programmer 1 (Equation# 4.9).

The formula is

$$y = 367318015 \bullet x^{-0.456211}$$

where:
y = construction time in minutes
x = experiment number or job number

Table 4-7 contains this forecast. This forecast is useful to predict the consumption required for a programmer to complete specified job under certain assumptions. The assumptions are

1. Preceding job should have similar level of difficulties and similar characteristics.

2. Detailed job description is provided

3. Job sequence is properly designed

Table 4-7

Construction time forecast for Programmer 1

Job#	Time	Job#	Time	Job#	Time
1	367.318015	21	39.928144	41	24.518121
2	221.626682	22	38.596944	42	24.091228
3	164.918533	23	37.366415	43	23.681555
4	133.721691	24	36.225043	44	23.288029
5	113.648665	25	35.163042	45	22.909669
6	99.506002	26	34.172038	46	22.545571
7	88.930737	27	33.244816	47	22.194906
8	80.682932	28	32.375130	48	21.856908
9	74.045164	29	31.557540	49	21.530869
10	68.571579	30	30.787285	50	21.216134
11	63.969522	31	30.060179	51	20.912098
12	60.038398	32	29.372526	52	20.618197
13	56.635803	33	28.721052	53	20.333908
14	53.657657	34	28.102839	54	20.058745
15	51.026006	35	27.515284	55	19.792252
16	48.681224	36	26.956055	56	19.534007
17	46.576878	37	26.423054	57	19.283614
18	44.676230	38	25.914391	58	19.040702
19	42.949804	39	25.428357	59	18.804925
20	41.373662	40	24.963403	60	18.575957

Source: Processed primary data

4.3.6 Analysis of Variance and Tukey Test

This study is an experimental study. This sub-section examines whether the A1, B1, A2 and B2 sessions of Programmer 1 are really different. Attachment D-1 provides a One-way ANOVA Calculation. The number of sessions is 4 (A1, B1, A2, B2), the number of observations in each session is 14 and total number of the observation is 56. The hypotheses are:

$$H_0 : \mu_{A1} = \mu_{B1} = \mu_{A2} = \mu_{B2}$$
$$H_a : \textit{Not all population means are equal}$$

Several important result can be observed: (1) SST = 1,286,574.553571; (2) SSE = 668,712.500000; (3) SSTR= 617,862.053571; (4) MSTR = 205,954.017857; (5) MSE=12,158.409091 and (6) F Ratio is 16.939224.

Nominator Degree of Freedom is 3, and Denominator Degree of Freedom is 53. Value of α is 0.05. Using F distribution table, the value of $F_{0.05;3:53}$ is 2.788000. The F Ratio exceeds the critical F value, so H_0 is rejected. This means not all the means are equal.

Using Tukey's approach further investigation in order to find which means are significantly different. The value $q_{0.05;3;53}$ is 3.77250. The value of T criterion can be computed using Equation 2.37, which yields 113.252296. Attachment D-1 shows the pair-wise differences. It can be observed which pair of means has a significant difference

4.3.7 Programmer 1 - Experiment conclusion

Programmer 1 has completed 4 experiment sessions. Each session has shown a different pattern.

Jobs in Session A1 were prepared with no detailed description. Programmer 1 is free to make interpretation regarding those jobs. Learning rate of Programmer 1 in Session A1 is 1.007159. Learning rate is positive and greater than 1. This means that time required to complete the job is increasing. Learning rate at Session A2 is -0.907423. These fact suggest that there is no evidence of learning curve was found at the end of the session. The model is not fit. Detailed description can be found in sub-section 4.3.1 and 4.3.3.

Session B1 consists of 14 systematically prepared jobs Detailed description regarding each control in each job were provided. The first job requires larger amount of time. But as the session commence, time required to complete the jobs were steadily decreased (from approximately 960 minutes to 190 minutes). A fit model can be constructed at the end of the session. Learning rate is 74.4553%.

Detailed job descriptions were removed at session A2. Learning curve is still present (90.7423%), but the learning rate is smaller than learning rate found in session B1. The logical explanation is: the programmer still remember session B1's treatment. In other word, treatment effect is still present but dramatically decreased. This may lead to a conclusion that careless preparation may ruin the learning curve.

Detailed job description were provided in Session B2. Learning curve is 72.8898%. Inertia effect is also found.

There are several findings regarding those experiments:

1. Series of jobs, equipped with detailed job description, which were logically arrange, may construct a good learning curve.

2. A good learning curve may trigger Inertia effect.

3. Poor job description and poor job sequence plan may damage existing learning curve, which may in turn, stop the inertia effect.

The similar experiment was also conducted with Programmer 2 in order to strengthen the findings.

4.4 The Full Study of Programmer 2

Experiments involving Programmer 2 was conducted simultaneously.

The result of the observation was shown in table 4-8. There are 54 jobs of 54 sub modules were submitted to Programmer 2. The experiment divided into four sessions using A-B-A-B pattern. Pattern A were conducted with minimal directions, while jobs in pattern B were equipped with full directions. Those session are renamed into A1-B1-A2-B2 for identification purpose only.

Each job in this experiment has the same module type which has the same difficulty level. Module type for the jobs being submitted to Programmer2 is RP1

The One-way ANOVA explains that not all population means are not equal. Further investigation is conducted regarding the result of One-way ANOVA. The significant differences along pairs of means can be observes using Tukey's approach.

Each section of the experiment was used to determine the rate of learning. Further, data were used to forecast the time required to accomplish the same type of job in the future.

Table 4-8

Experiment for Programmer 2 - Module Type RP-1

No.	A			B			A			B		
	Hour	Min	Min Total	Hour	Min	Min Total	Hour	Min	Min Total	Hour	Min	Min Total
1	18	0	1080	23	0	1380	16	0	960	17	45	1065
2	12	15	735	22	0	1320	19	30	1170	14	45	885
3	10	15	615	19	0	1140	22	0	1320	13	30	810
4	11	0	660	16	45	1005	20	0	1200	12	30	750
5	14	30	870	15	30	930	23	30	1410	13	0	780
6	10	0	600	16	0	960	18	30	1110	11	30	690
7	7	0	420	14	30	870	24	0	1440	12	30	750
8	19	45	1185	15	15	915	16	0	960	12	0	720
9	22	0	1320	13	30	810	20	30	1230	11	30	690
10	13	30	810	12	15	735	16	0	960	11	20	680
11	15	45	945	14	0	840	14	0	840	10	0	600
12	21	30	1290	13	30	810	18	0	1080	9	30	570
13	17	0	1020	12	45	765	19	30	1170	8	30	510
14	11	0	660	13	30	810	17	0	1020	9	0	540
Total			12210			13290			15870			10040

Source: Primary data

4.4.1 Programmer 2 - Section A1 - Construction Time

Appendix C-5 shows the result of construction time of Programmer 2 (in minutes) and their Log-linear model values. x is the experiment sequence in each sessions and y indicates original value of the construction time to complete the job in minutes. These values are referred as Linear model in this sub-chapter. $\ln(x)$ and $\ln(y)$ are the logarithmic transformation value of x and y. This model is referred as log-linear model. These pair of values were fed to a statistical package to estimate the value of intercept and slope of the regression line. Two linear regression calculations were performed using the same procedures as the previous sub-section.

4.4.1.1 Linear and Log-linear Model Comparison

Regression output, presented at Attachment B-1 and B-2 contain useful values in order to select the best model fit between the usage of Linear and Log-linear Model. Comparison of several indicators were presented in table 4-9

Table 4-9
Regression Output Comparison
for Session A1 of Programmer 2

Indicators	Linear model	Log-linear model
Pearson Correlation	0.277	0.142
Correlation Significance	0.169	0.314
Adjusted R-Squared	0.000	(0.062)
Durbin-Watson	1.632	1.592

Source: Processed primary data

Correlation value of Linear Model is 0.277. The significance value is 0.169. These values are higher than Correlation and significance value of Log-linear Model which are 0.142 for Correlation and 0.314 for significance value. The sign of both set of data are positive. This means that there is a positive correlation between the independent and dependent variable, although the correlation itself is low and insignificant.

Durbin Watson test result of Linear model is 1.632. DW Test value for Log-linear Model is 1.592. These Durbin Watson Test result are higher than d_U value. But still, Correlation value of Linear model is low and the significance value exceeds the value of α. This indicates that the model is not fit.

Adjusted R Square of Log-linear model is negative. According to Gujarati (2003), and Greene (2003), negative value of Adjusted R Square is possible and considered to be zero when it happens. Greene (2003), said that negative value of Adjusted R Square will happen if correlation between independent and dependent variable is zero or near to zero.

The coefficient of x is 18.395604. Significant level exceeds α value. The t value is 1.000042. This value is below $t_{0.05;12}$. The model is $y = 734.175824 + 16.395604x$.

Scatter Plots for both models can be observed in Attachment B-1 and Attachment B-2.

4.4.1.2 Conclusion for Programmer 2 - Session A1

Based on several findings presented before, conclusion for Session A1 were:

1. The model is not fit

2. x variable is not statistically significant.

3. Value of b coefficient is positive

This conclusion matched with the experiment rules set in session A1. In session A1, no or very limited instruction is given to the programmer. Development of sub-modules relied on the imagination of the programmer. Value of b coefficient value which was positive. This made the slope of the curve higher according to the time. The learning rate is positive and is greater than 1. So, it can be concluded that there was no learning effect found in Section A1 of the experiment.

4.4.2 Programmer 2 - Session B1

Experiment Session B1 for Programmer 2 was conducted after 14 observations for section A1 were all done. Full descriptions were given in the job specification form. Each property of the objects presented on the screen were carefully defined. 14 observations were conducted in this session for the same category of job.Information were color coded to maximize readability of the job sheet, since many information were found on the same sheet. Time consumption data and their logarithmic transformed values can be observed in Attachment C-6.

Programmer 2 needed as much as 23 hours or 1380 minutes to complete the first job. Programmer 2 needed more time to interpret the job description, especially control properties. Also, programmer 2 needed more time to ask some new settings in the job description and screen layout. Construction time decreased and finally it reached approximately 12 hours. It can be predicted that programmer 2 has become accustomed with the jobs.

4.4.2.1 Linear and Log-linear Model Comparison

Regression output, presented at Attachment B-3 and B-4 contain useful values in order to select the best model fit between the usage of Linear and Log-Linear transformation values. Comparison of several indicators were presented in table 4-10.

Table 4-10
Regression Output Comparison
for Session B1 of Programmer 2

Indicator	Linear Model	Log-linear model
Pearson Correlation	(0.874)	(0.960)
Significance	0.000	0.000
Adjusted R Square	0.744	0.916
Durbin-Watson Test	0.639	2.173

Source: Processed primary data

Pearson Correlation value of Linear Model was -0,874. On the contrary, Pearson Correlation value of Log-linear Model as -0.960. The absolute value of Pearson Correlation of the Log-linear Model indicates that there is a better correlation in Log-linear model compared to Linear model. The negative sign is consistent with the theory of learning curve. Consistency with economic theory is important in selecting best model (Thomas, 1997)

Adjusted R Squared value of Log-Linear model is 0.916. This value was higher that Adjusted R Squared of Linear model which was only 0.744. According to Bowen and Starr (1985) and Webster (1998), higher value of Adjusted R Squared indicates a better model.

Durbin Watson value of Linear Model was only 0,639, which was less that d_U value (1.350) - see subsection 4.1.2. Greene (2003) said that a low Durbin-Watson value may be caused by improper model fit. Durbin Watson Test Value of

Log-Linear model lies between 2 and $4-d_U$, which means there is no auto-correlation detected

Analyzing some indicators mentioned above, it can be concluded that the usage of Log-linear model to a better model fit. Regression analysis using Linear Model in Session B1 will not be discussed again. Discussion is limited to Regression Analysis using Log-linear model.

The Pearson correlation coefficient is a measure of linear association between two variables. Some evidence can be evaluated as follows:

1. Correlation value is -0.960335. The absolute value of this correlation is very close to 1. The negative sign conforms underlying theory of learning curve.

2. Significance was 0.000000. This value is far below significance level of 0.05.

Negative correlation value indicated that there is a negative correlation between $\ln(x)$ and $\ln(y)$. Negative correlation is consistent with Learning Curve Theory. Those two values indicated that there is a strong and significant correlation between those variables; and the correlation itself is negative. This means that time requirement to complete the job continuously decline.

Several evidence can be found in the model summary found at attachment B-4. Predictors are Constant and $\ln(x)$ and the dependent variable is $\ln(y)$.

1. R, the multiple correlation coefficient, is the correlation between the observed and predicted values of the dependent variable. R value was

0.960335. This value was very close to 1, so it a strong relationship between the observed and predicted values of the dependent variable

2. R squared is the proportion of variation in the dependent variable explained by the regression model. The value was only 0.922243. This indicates that 92.2243% variation $\ln(y)$ can be explained by the variation of $\ln(x)$. Large value of R squared indicates that the model does fit the data well

3. Adjusted R Square ($\overline{R}^2$) is 0.915763. This value supports the findings that the model is fit

Values which were presented above showed a strong relationship between the predictor and dependent variable and the model was fit

Durbin-Watson value of the session is 2.173286. This value falls between 2 and 4-d_U critical value stated at 4.1.2. According to Webster, 1998, no auto-correlation detected when the value of Durbin Watson test falls between 2 and 4-d_U critical value. Using previous definition, it can be concluded that there is no auto-correlation in session B1 of Programmer 2.

Attachment B-4 shows the Coefficient values:

1. Constant value is 7.271738

2. Coefficient of $\ln(x)$ value is -0.241504

Equation model is $\ln(y) = 7271738 - 0241504 \ln(x)$.

Some evidence regarding the coefficient value for $\ln(x)$ are found :

1. t test values are large. t test value for the constant is 184.415385. The absolute value of t test for $\ln(x)$ is 11.930067. Both of them are larger than $t_{0.05;12} = 2.179$. This means that those coefficients are statistically significant at the 5% level.

2. Significance value of the constant is 0.000000. Significance value of $\ln(x)$ coefficient is 0.000000. Both values are less than 0.05 significance level. This means that both the constant and the coefficient are statistically significant at 5% level.

3. coefficient value of variable $\ln(x)$ is negative

Those two evidence suggested that the constant and coefficient of $\ln(x)$ are significant. The negative value of $\ln(x)$ coefficient suggested that the slope is negative. So, the time needed for Programmer 2 to accomplish the job decreased as more and more fully described jobs were given.

4.4.2.2 Anti-Logarithm transformation

Log-linear model can be converted back to exponential regression model as follows:

1. Converting α value to a, using $\exp(\alpha)$ function

$$\alpha = 7.271738$$
$$a = \exp(7.271738)$$
$$a = 1{,}439.049349$$

2. The equation can be rewritten to:

$$y = 1{,}439.049349 \bullet x^{-0.241504} \qquad (4.10)$$

4.4.2.3 Learning Rate Calculation

Based on 2.6.6.2 Learning Rate can be calculate as follows:

$$r = 10^{(b \log 2)}$$

$$r = 10^{-\left(0.241504 \times \log(2)\right)}$$
$$r = 10^{-0.072700}$$
$$r = 0.845863$$

Learning rate value is 0.845863. This value means that the time required by programmer 2 to accomplish the current job is only 84,5863% of time required of the previous job. This performance can be achieved by :

1. giving a detailed job description in each sub module
2. arranging Sub modules in a proper sequence

4.4.2.4 Scatter Plot

Scatter pot is also drawn at Attachment B-4. There are two useful plots :

1. Linear Plot of Log-linear Model. Linear scatter plot for $\ln(x)$ in x axis and $\ln(y)$ in y axis
2. Logarithmic Plot of the Linear model.
   The figure showed an expected learning curve in curvilinear fit. This meant that job assignment sequence and job type were successfully bring any learning effect for the Programmer 2 in session B1

4.4.2.5 Conclusion for Programmer 2 - Session B1

Based on several findings presented before, conclusion for Session B1 were:

1. The model is fit

2. The constant and $\ln(x)$ variable are statistically significant.

3. Learning rate is 0.845863

This conclusion matched with the experiment rules set in session B1. In session B1, fully described instructions were given to the programmer. Development of sub-modules was not rely solely on the imagination of the programmer. Value of b coefficient value which was negative. This made the slope of the curve lower according to the time.

The value of learning rate is lower than 1. This means that the time required to complete current the job is 84.5863% of the time required to complete previous job.

It can be concluded that learning effect can be observed in Section B1 of the experiment.

4.4.3 Programmer 2 - Session A2

Experiment Session A2 for Programmer 2 was conducted after 14 observations for section B1 were all done. Very limited instructions were given in the job specification form. 14 observations were conducted in this session for the RP1 category of job. Linear model construction time data and their Logarithm transformation are presented in Attachment C-7. Two linear regression calculations were performed using the same procedures as the previous sub-section.

4.4.3.1 Linear and Log-linear Model Comparison

Regression output, presented at Attachment B-5 and B-6 contain useful values in order to select the best model fit between Linear and Log-linear Model. Comparison of several indicators are presented in table 4-11.

Table 4-11
Regression Output Comparison
for Session A2 of Programmer 2

Indicators	Linear model	Log-linear Model
Pearson Correlation	-0.323	-0.155
Significance	0.13	0.298
Adjusted R Square	0.03	-0.057
Durbin Watson Test	2.174	1.948

Source: Processed primary data

Pearson Correlation value of Linear Model is -0.323. The significance value is 0.130. These values are higher than Correlation and significance value of Log-linear Model which are 0.155 for Correlation and 0.298 for significance value. However, both Significance values exceed Significance Level used in this research. The sign of the Pearson Correlation value of both set of data are negative. This means that there is a negative correlation between the independent and dependent variable, although the correlation itself is low and insignificant.

Adjusted R Square Value of Linear Model is 0.03. This means only 3% variation of dependent variable can be explained by the variation of independent variables. Adjusted R Square Value of Log-linear model is -0.057. According to Gujarati, 2003, negative value of Adjusted R Square is possible and considered to be zero when it happens.

Durbin Watson test result of Linear model is 2.174. This value is lower than $4-d_U$ value. Durbin Watson Test value for Log-linear Model is 1.948, which is higher than d_U critical values. So, both Durbin Watson Test result show no auto-correlation.

Both model do not fit the model, but Linear model is slightly better than Log-linear model. Coefficient of Linear model will be calculated in order to build the scatter plot for this session.

Coefficient values of Linear Model is presented in Attachment B-5. The constant is 1,236.923077 and the coefficient of x is 13.780220. Significant value is 0.260138, exceeds the significance level exceeds α value. The t value is 1.81898. This value is below $t_{0.05;12}$. So, the equation is $y = 1{,}236.923077 - 13.780220x$.

Scatter Plot of both models can be observed in Attachment B-5 and B-6

4.4.3.2 Conclusion

Based on several findings presented before, conclusion for Session A2 are:

1. The model is not fit

2. x variable is not statistically significant.

3. Value of b coefficient is negative

This conclusion matched with the experiment rules set in session A2. In session A2, no or very limited instruction is given to the programmer. Development of sub-modules relied on the imagination of the programmer. Value of b coefficient value which is negative. This made the slope of the curve lower according to the time, but in a linear manner only. So, it can be concluded that there was no learning effect in Section A2 of the experiment.

4.4.4 Programmer 2 - Session B2

Experiment Session B2 for Programmer 2 was conducted after 14 observations for section A2 were all done. Full descriptions were given again in each job specification form. Each property of the objects presented on the screen were carefully defined. A number of 14 observations were conducted in this session for the same category of job. Information were color coded to maximize readability of the job sheet, since many information were found on the same sheet. Time consumed by Programmer 2 in Session B2 were collected and presented in Attachment C-8

Programmer 2 needed as much as 17 hours 45 minutes (see table 4-8) or 1,065 minutes to complete the first job. Based on the interview conducted during the experiment, Programmer 2 said that more time needed to get accustomed with the job description. Also, programmer 2 needed more time to recall some new settings in the job description and screen layout. The initial construction time is not as much as in session B2.

Second job was accomplished in 14 hours 45 minutes (see table 4-8) or 885 minutes. Programmer 2 needed less than a half time compared to the first job. Construction time then decreased to reached 13 hours and 30 minutes or 810 minutes (see table 4-8). It can be predicted that programmer 2 has become accustomed with the jobs. The construction time im this session decreased faster into a lower level than the consumption in session B1

Two linear regression calculations were performed using the same procedures as the previous sub-section. The complete result of the regression calculation can be found in Attachment B-7 for linear model and Attachment B-8 for Log-Linear calculations.

4.4.4.1 Linear and Log-Linear Model Comparison

Regression outputs, which can be examined at Attachment B-7 and B-8, contain useful values in order to select the best model fit between Linear and Log-Linear model. Comparison of several indicators is presented in table 4-12.

Table 4-12
Regression Output Comparison
for Session B2 of Programmer 2

Indicators	Linear model	Log-linear model
Pearson Correlation	(0.926)	(0.935)
Significance	0.000	0.000
Adjusted R Square	0.846	0.864
Durbin Watson Test	1.211	0.870

Source: Processed primary data

Pearson Correlation value of Linear Model was -0,926. On the contrary, Pearson Correlation value of Log-linear Model as -0.935. The absolute value of Pearson Correlation of the Log-linear Model indicates that there is a better correlation in Log-linear model compared to Linear model. The negative sign is consistent with the theory of learning curve. Consistency with economic theory is important in selecting best model (Thomas, 1997). Both models have 0.000 significance value. Those values are lower than significance level of this research.

Adjusted R Squared value of Log-Linear model is 0.864. This value was higher that Adjusted R Squared of Linear model which was only 0.846. According to Bowen and Starr (1985) and Webster (1998), higher value of Adjusted R Squared indicates a better model.

Durbin Watson value of Linear model is 1.211, which falls in no conclusion area. Durbin-Watson test value of Log-linear model is 0.870. This value is also less that d_L value (1.045) - see subsection 4.1.2. Further analysis of this situation can be found in subsection 4.4.4.2. Analyzing some indicators mentioned above, it can be concluded that the usage of Log-linear model to a better model fit. Regression analysis using Linear Model in Session B1 will not be discussed again. Discussion is limited to Regression Analysis using Log-linear model.

The Pearson correlation coefficient is a measure of linear association between two variables. Some evidence can be evaluated as follows:

1. Correlation value is -0.935008. The absolute value of this correlation is very close to 1. The negative sign is consistent with the theory of learning curve.

2. Significance was 0.000000. This value is far below significance level of 0.05.

Model summary can be found in Attachment B-8. Predictors are Constant and $\ln(x)$ and the dependent variable is $\ln(y)$.

1. R, the multiple correlation coefficient, is the correlation between the observed and predicted values of the dependent variable. R value was

0.935008. This value was very close to 1, so it a strong relationship between the observed and predicted values of the dependent variable

2. R squared is the proportion of variation in the dependent variable explained by the regression model. The value was only 0.874240. This indicates that 87.4240% change in $\ln(y)$ can be explained by the change of $\ln(x)$. Large value of R squared indicates that the model does fit the data well

3. Adjusted R Square ($\bar{R}^2$) is 0.863760. This value supports the findings that the model is fit

Values which were presented above showed a strong relationship between the predictor and dependent variable and the model was fit

4.4.4.2 Durbin-Watson Test

Durbin-Watson value is 0.870176. This value is lower than d_L critical value stated at 4.1.2. This situation indicates that there is a positive auto-correlation (Gujarati, 2003; Webster, 1998). Further investigation should be conducted.

Gujarati, 2003, has an explanation regarding this situation. This problem relates to time series data which follow a natural ordering over time so that successive observations are likely to exhibit inter-correlations, especially, if time interval between observations are short such as a day, a week, a month rather than a year. The term auto-correlation may be defined as "correlation between member of series of observations ordered in time as in time series data. There are several reasons of this phenomena. One of them is **inertia**.

The term "inertia" was actually borrowed from physics. According to Microsoft ® Encarta ® Reference Library 2005, Inertia is the property of matter that causes it to resist any change of its motion in either direction or speed. This property is accurately described by the first law of motion of the English scientist Sir Isaac Newton: An object at rest tends to remain at rest, and an object in motion tends to continue in motion in a straight line unless acted upon by an outside force. For example, passengers in an accelerating automobile feel the force of the seat against their backs overcoming their inertia so as to increase their velocity. As the car decelerates, the passengers tend to continue in motion and lurch forward. If the car turns a corner, then a package on the car seat will slide across the seat as the inertia of the package causes it to continue moving in a straight line

A salient feature in economic time series is inertia or sluggishness. In upward (or downward) swing of a growth, value of a series at one point in time is greater than its previous value. Thus there is a "momentum" built into them until something happens. Therefore, in regressions involving time series data, successive observations are likely to be interdependent.

This explanation answers the question why Durbin-Watson test result of Session B2 of Programmer 2 shows positive auto-correlation. The effect of learning may build a strong "momentum" that drives construction time of Programmer 2 down greater and greater in successive observations. This momentum can be explained by the formula of learning curve itself :

$$k_n = k_1 n^b$$

The power of n indicates a non-linear impact. So the phenomena supports the basic understanding of learning curve.

Thomas, 1997, also suggest that 'false' auto-correlated might occur in time series data. Estimating a linear equation when true relationship is nonlinear can also result in sequences of positive and negative residuals. There are two suggestion in dealing with low Durbin Watson test value:

1. considering alternative functional form for the regression equation
2. add variables

Unfortunately, those two suggestions above will violate learning curve theory consistency.

4.4.4.3 Coefficient

Coefficient values are:

1. Constant value is 6.986836
2. Coefficient of $\ln(x)$ value is -0.238958

Equation model is $\ln(y) = 6.986836 - 0.238958\ln(x)$.

Some evidence regarding the coefficient value for $\ln(x)$ are found :

1. t test values are large. t test value for the constant is 137.099383. The absolute value of t test for $\ln(x)$ is 9.133446. Both of them are larger than $t_{0.05;12} = 2.179$. This means that those coefficients are statistically significant at the 5% level.

2. Significance value of the constant is 0.000000. Significance value of $\ln(x)$ coefficient is 0.000001. Both values are less than 0.05 significance level. This means that those coefficients are significant at 5% level.

3. coefficient value of variable $\ln(x)$ is negative

Those two evidence suggested that the constant and coefficient of $\ln(x)$ are significant. The negative value of $\ln(x)$ coefficient suggested that the slope is negative. So, the time needed for Programmer 2 to accomplish the job decreased as more and more fully described jobs were given.

4.4.4.4 Anti-Logarithm transformation

Log-linear model can be converted back to exponential regression model as follows:

1. Converting α value to a, using $\exp(\alpha)$ function

$$\alpha = 6.986836$$
$$a = \exp(6.986836)$$
$$a = 1{,}082.291682$$

2. The equation can be rewritten to:

$$y = 1{,}082.291682 \bullet x^{-0.238958} \qquad (4.11)$$

4.4.4.5 Learning Rate Calculation

Based on 2.6.6.2 Learning Rate can be calculate as follows:

$$r = 10^{(b \log 2)}$$

$$r = 10^{-(0.238958 \times \log(2))}$$
$$r = 10^{-0.071928}$$
$$r = 0.847357$$

Learning rate value is 0.847357. This value means that the time required by programmer 2 to accomplish the current job is only 84,7357% of time required of the previous job. This performance can be achieved by :

1. giving a detailed job description in each sub module
2. arranging Sub modules in a proper sequence

4.4.4.6 Scatter Plot

Scatter Plot can be found in Attachment B-7 and B-8. The curvilinear fit shown in Attachment B-8 showed an expected learning curve. This meant that job assignment sequence and job type were successfully bring any learning effect for the Programmer 2 in session B2

4.4.4.7 Conclusion for Programmer 2 - Session B2

Based on several findings presented before, conclusion for Session B2 were:

1. Model is fit
2. There is significant relative importance of constant and variable $\ln(x)$.
3. Learning rate is 0.847357

This conclusion matched with the experiment rules set in session B2. In session B2, fully described instructions were given to the programmer.

Development of sub-modules was not rely solely on the imagination of the programmer. Value of *b* coefficient value which was negative. This made the slope of the curve lower according to the time.

The value of learning rate is lower than 1. This means that the time required to complete current the job is 84.7357% of the time required to complete previous job.

It can be concluded that there is a clear indication of learning effect in Section B2 of the experiment.

4.4.5 Forecasting

Construction time forecast can be conducted based on learning curve formula of Programmer 2 (Equation# 4.11).

The formula is

$$y = 1{,}082291682 \bullet x^{-0.238958}$$

where:
y = construction time in minutes
x = experiment number or job number

Table 4-7 contains this forecast. This forecast is useful to predict the consumption required for a programmer to complete specified job under certain assumptions. The assumptions are

1. Preceding job should have similar level of difficulties and similar characteristics.
2. Detailed job description is provided
3. Job sequence is properly designed

Figure 4-13

Construction time forecast for Programmer 2

Job#	Time	Job#	Time	Job#	Time
1	1,082.29168	21	522.86484	41	445.61183
2	917.08754	22	517.08469	42	443.05324
3	832.40059	23	511.62123	43	440.56903
4	777.10064	24	506.44443	44	438.15539
5	736.74949	25	501.52822	45	435.80877
6	705.34055	26	496.84980	46	433.52589
7	679.83166	27	492.38918	47	431.30368
8	658.48175	28	488.12869	48	429.13929
9	640.20703	29	484.05267	49	427.03006
10	624.28992	30	480.14718	50	424.97350
11	610.23232	31	476.39974	51	422.96727
12	597.67533	32	472.79916	52	421.00921
13	586.35232	33	469.33535	53	419.09725
14	576.06018	34	465.99921	54	417.22947
15	566.64088	35	462.78248	55	415.40406
16	557.96919	36	459.67765	56	413.61931
17	549.94430	37	456.67788	57	411.87362
18	542.48397	38	453.77691	58	410.16547
19	535.52027	39	450.96902	59	408.49342
20	528.99650	40	448.24894	60	406.85612

Source: Processed primary data

4.4.6 Analysis of Variance and Tukey Test

This study is an experimental study. This sub-section examines whether the A1, B1, A2 and B2 sessions of Programmer 2 are really different. Attachment D-2 provides a One-way ANOVA Calculation. The number of sessions is 4 (A1, B1, A2, B2), the number of observations in each session is 14 and total number of the observation is 56. The hypotheses are:

$$H_0 : \mu_{A1} = \mu_{B1} = \mu_{A2} = \mu_{B2}$$
$$H_a : \textit{Not all population means are equal}$$

Several important result can be observed: (1) SST = 3,470,433.928571; (2) SSE = 2,211,885.714286; (3) SSTR= 1,258,548.214286; (4) MSTR= 419,516.071429; (5) MSE= 41,733.692722 and (6) F Ratio is 10.052215.

Nominator Degree of Freedom is 3, and Denominator Degree of Freedom is 53. Value of α is 0.05. Using F distribution table, the value of $F_{0.05;3;53}$ is 2.788000. The F Ratio exceeds the critical F value, so H_0 is rejected. This means not all the means are equal.

Using Tukey's approach further investigation in order to find which means are significantly different. The value $q_{0.05;3;53}$ is 3.77250. The value of T criterion can be computed using Equation 2.37, which yields 205.835718. Attachment D-2 shows the pair-wise differences. It can be observed which pair of means has a significant difference

4.4.7 Programmer 2 - Experiment conclusion

Programmer 2 has completed 4 experiment sessions. Each session has shown a different pattern.

Jobs in Session A1 were prepared with no detailed description. Programmer 2 is free to make interpretation regarding those jobs. There is no evidence of learning curve was found at the end of the session. The model is not fit.

Session B1 consists of 14 systematically prepared jobs. Detailed description regarding each control in each job were provided. The first job requires larger amount of time. But as the session commence, time required to complete the jobs were steadily decreased. A fit model can be constructed at the end of the session. Learning rate is 84,5863%.

Detailed job descriptions were removed at session A2. Learning curve disappeared. This means that unstructured job may ruin the existing learning curve of a programmer.

Detailed job description were provided in Session B2. Learning rate of 84.7357% can be achieved. Learning curve is present. Inertia effect is also found. According to the Encarta Dictionary, Inertia is the property of matter that causes it to resist any change of its motion in either direction or speed.

Standard Error of Estimates in A1 and A2 sections are higher than Standard Error of Estimates found in B1 and B2 sections. Higher value of Standard Error of Estimates indicates larger dispersion between the observations and the regression line. Jobs with detailed description have smaller dispersion. Since the slope of regression lines in B Sections are negative, it can be concluded that time requirements in the observation also decrease consistently, following the regression lines.

Based on the the facts found in B Sessions:

1. Large value of Adjusted R Square and Statistical Significancy of the constant and coefficient of the equation

2. Inertia effect in time series data, explained by Gujarati, 2003.

3. Estimating different function form of regression equation might cause 'false' auto-correlation, explained by Thomas, 1997.

4. Consistency with Learning Curve Theory as the basis of selecting best fit model (explained by Gujarati, 2003 and Thomas, 1997).

the model is still considered to be fit

There are several findings regarding those experiments:

1. Series of jobs, equipped with detailed job description, which were logically arrange, may construct a good learning curve.

2. A good learning curve may trigger Inertia effect.

3. Poor job description and poor job sequence plan may damage existing learning curve, which may in turn, stop the inertia effect.

4.5 The Work Breakdown Structure

Work Breakdown Structure is the first step in project management which divide a large and complex project into a small and manageable parts. (Stevenson, 2003). Work Breakdown Structure is a representation of the building block structure of the project. It shows major project modules, secondary modules and so on (Schonberger and Knod, 1994). Activities within a projects, as a result of Work Breakdown Structure, become an activity of a node (Activity on Node) in CPM/PERT model.

Systems Development Project Management is an activity of defining, planning, monitoring and controlling project to build systems in allocated time and budget (Whitten, Bentley and Dittman, 2000). Software is one of the components in Systems Development. Software can essentially be viewed as being instructions that tell the hardware what to do (Thompson and Cats-Baril, 2003).

As described in section 2.5.3, the main subject of this research is how to improve Software Development Projects using Operations Management and Operations Research. Hardware development is beyond the scope of this research. The Work Breakdown Structure of the Biometric Time and Attendance Systems Development is being constructed.

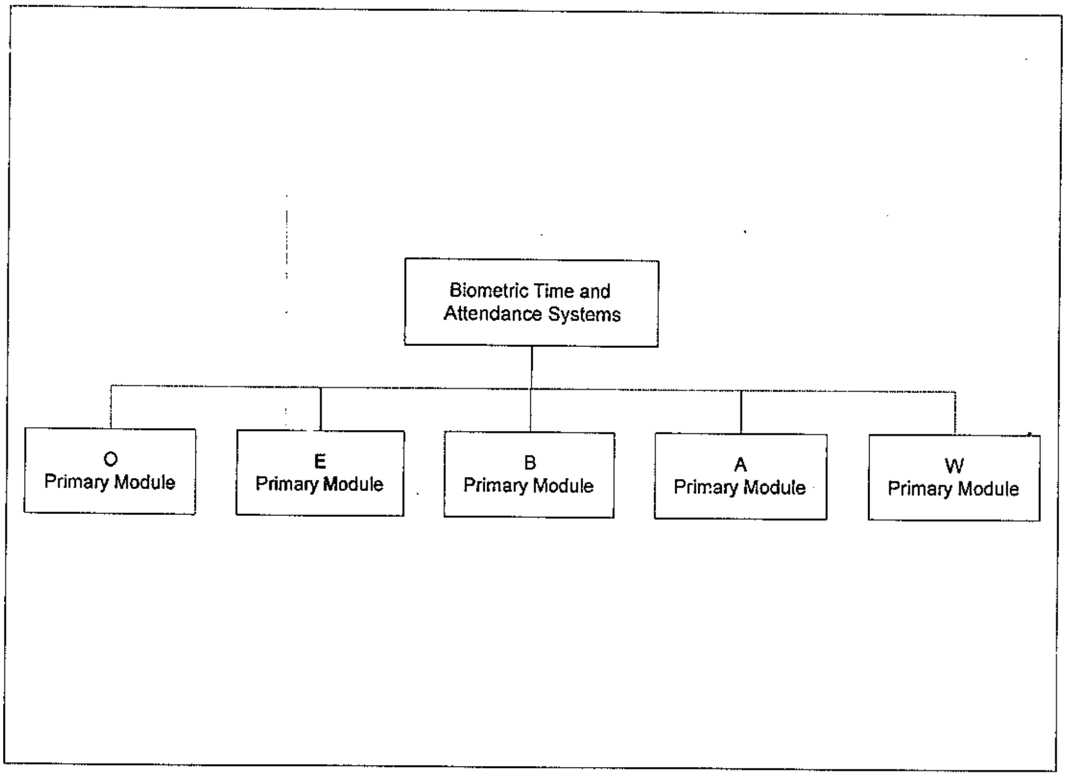
The Biometric Time and Attendance Systems Development consists of five inter-related primary modules, divided by two Integration Points. Each primary module is divided into several modules. Each module consists of several sub-modules. Each sub-module is an activity of the project. As described earlier, each activity become and activity of a node.

4.5.1 Primary Module Work Breakdown Structure

The Biometric Time and Attendance Systems consists of several primary modules which interact one and another. The Biometric Time and Attendance Systems becomes a part of continuous development held by Systems Integration Development of P.T. Marga Computindo Sarana in order to build a full scale integrated systems. The number of primary modules is expected to grow as the development process commences.

This research is conducted in the first stage of the development. There are 5 (five) different modules designed for the first stage of development.

Figure 4-2
Work Breakdown Structure - Primary Modules



Source: Primary data

Figure 4-2 shows the Work Breakdown Structure of these primary modules. It should be noted that this figure does not intended to show primary module sequence nor primary module precedence.

Primary Modules are identified by alphanumeric codes as follow:

1. O: Organization Primary Module
2. E: Personnel Primary Module
3. A: Attendance Admin Primary Module
4. W: Working Schedules Primary Module
5. B: Biometric Data Reader Primary Modules

Primary Modules described above were divided into several modules. The Work Breakdown Structure of these primary modules are described in the next section

4.5.2 Module Work Breakdown Structures

Each primary module is divided into several modules. The number of module varies among those primary modules. Module coding follows a general nomenclature : fist digit reflects module code, followed by a dash, terminated with one character (alphanumeric) module code. The following sections describe each Work Breakdown Structure.

4.5.2.1 Organization Primary Module WBS

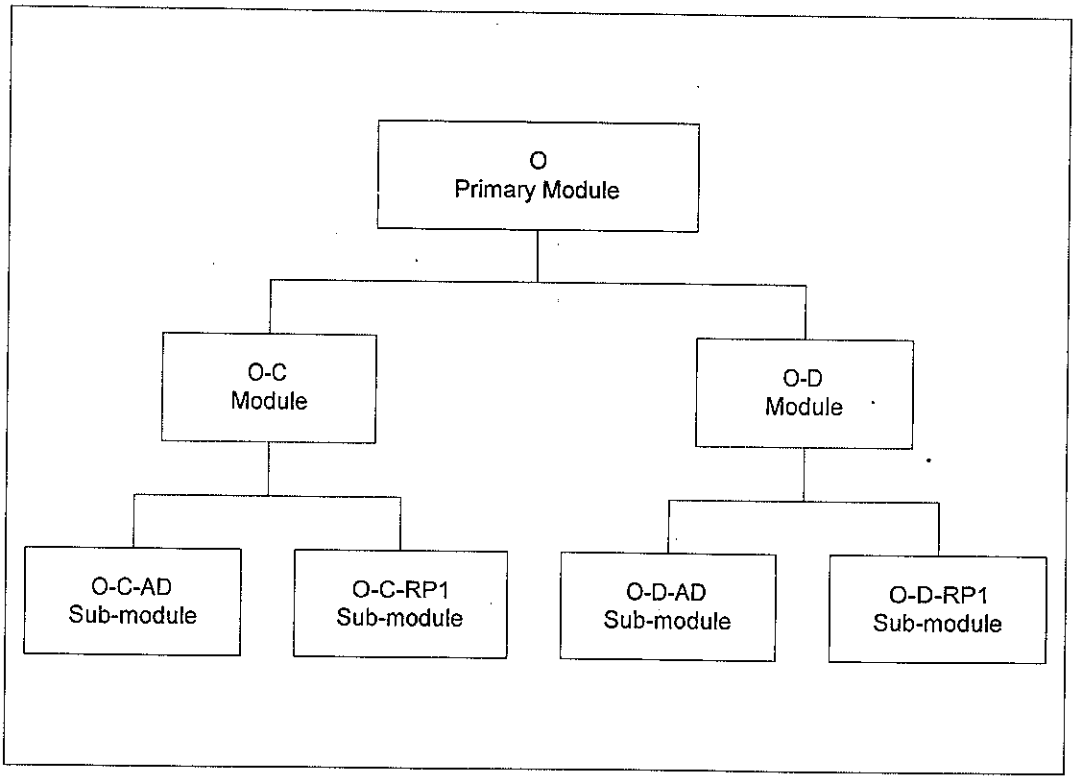
Organization Primary Module consists of two modules as follows:

1. O-D Module

2. O-C Module

O-D Module is divided into an input sub-module (O-D-AD) and a reporting module (O-D-RP1). O-C Module is also divided into an input sub-module (O-C-AD) and a reporting module (O-C-RP1).

Figure 4-3
O Module Work Breakdown Structure



Source: Primary Data

4.5.2.2 Personnel Primary Module WBS

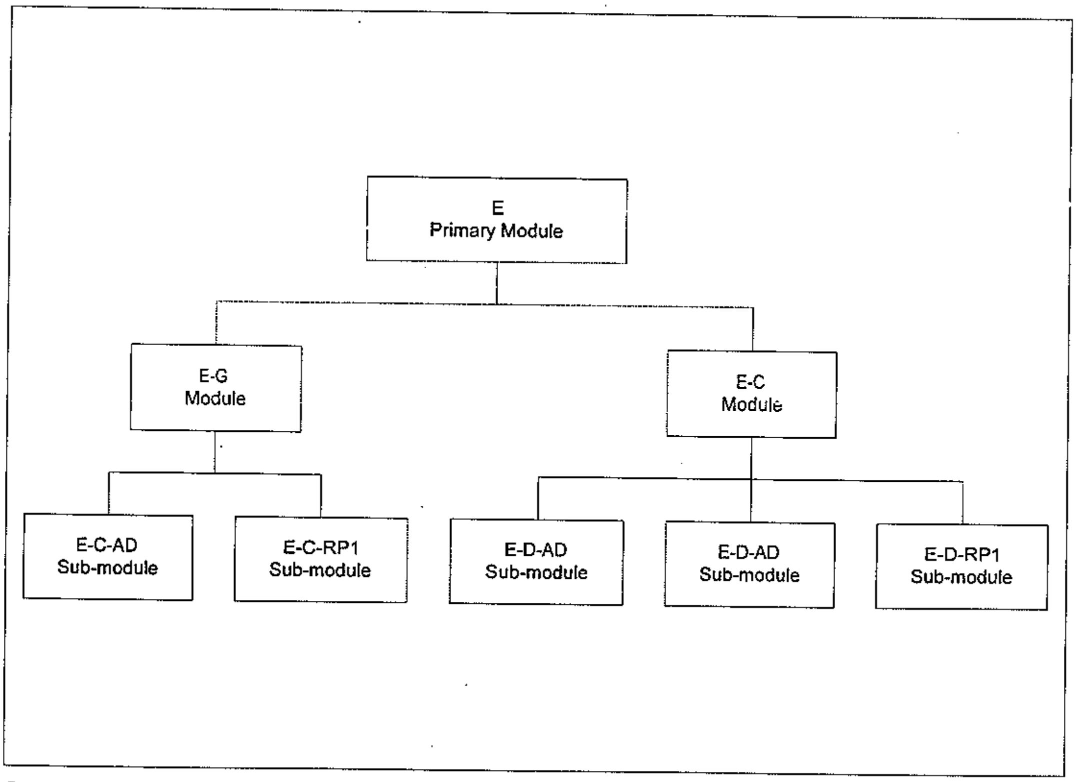
Personnel Primary Module consists of two modules as follows:

1. E-G Module

2. E-C Module

E-G Module is divided into an input sub-modules (E-G-AD) and a reporting sub-module (E-G-RP1). E-C Module is divided into two input sub-module (E-C-AD1 and E-C-AD2) and a reporting sub-module (E-C-RP1)

Figure 4-4
E Module Work Breakdown Structure



Source: Primary Data

4.5.2.3 Attendance Admin Primary Module WBS

Attendance Admin Primary Module consists only three modules as follows:

1. A-G Module
2. A-E Module
3. A-X Module

A-G Module is divided into an input module (A-G-AD) and a reporting module (A-G-RP1).

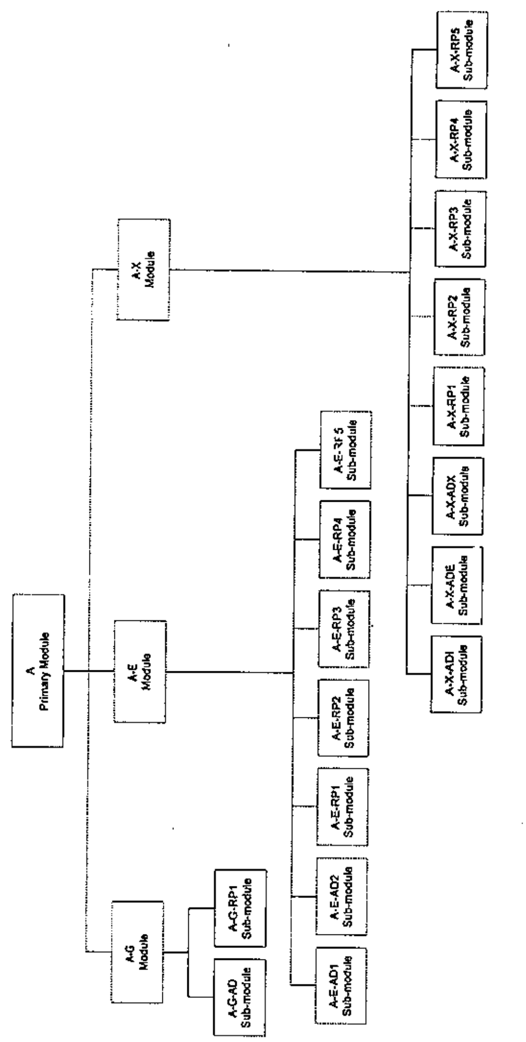
A-E module is a large module. It consists of two input sub-module and 5 (five) reporting sub-modules. Inputting sub-modules are A-E-AD1 and A-E-AD2. Reporting sub-modules A-E-RP1, A-E-RP2, A-E-RP3, A-E-RP4, and A-E-RP5)

A-X module is also a large module. It consists of three input module and 5 (five) reporting modules. Inputting modules are A-X-ADI, A-X-ADE and A-X-ADX. Reporting modules are A-X-RP1, A-X-RP2, A-X-RP3, A-X-RP4, and A-X-RP5

Figure 4-5 shows the Work Breakdown Structure of Module A.

Figure 4-5

Attendance Admin Module Work Breakdown Structure



Source: Primary Data

4.5.2.4 Working Schedule Primary Module WBS

Working Schedule Primary Module consists of two modules as follows:

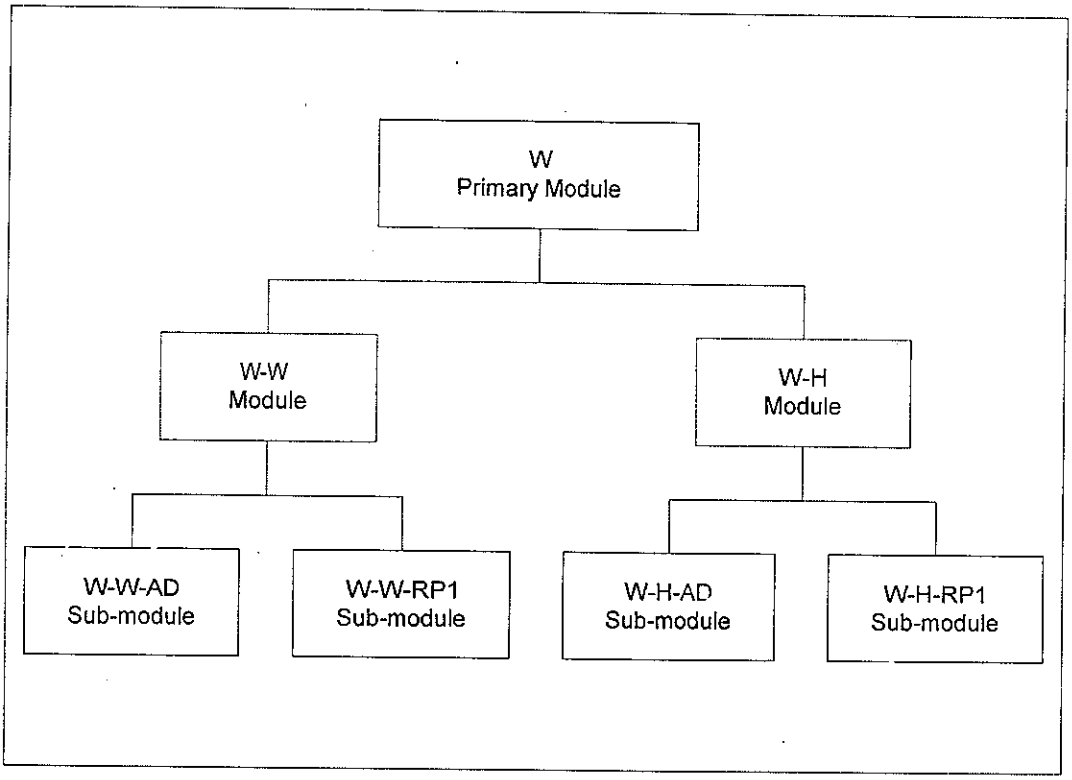
1. W-W Module

2. W-H Module

W-W Module is divided into an input sub-module (W-W-AD) and a reporting module (W-W-RP1). W-H Module is also divided into an input sub-module (W-H-AD) and a reporting module (W-H-RP1).

Figure 4-6

W Primary Module Work Breakdown Structure



Source: Primary Data

4.5.2.5 Biometric Data Reader Module Work Breakdown Structure

Biometric Data Reader Primary Module consists of two modules:

1. B-I Module
2. B-A Module

The B-I module is responsible for Biometric Attendance Machine data interpretation. This module is the heart of the overall systems. It download data for the machine and interpret them into a readable format. Downloaded data is a stream of numeric data which is very difficult to read. This module extract, slice, and analyze data in order to create meaningful records in a table.

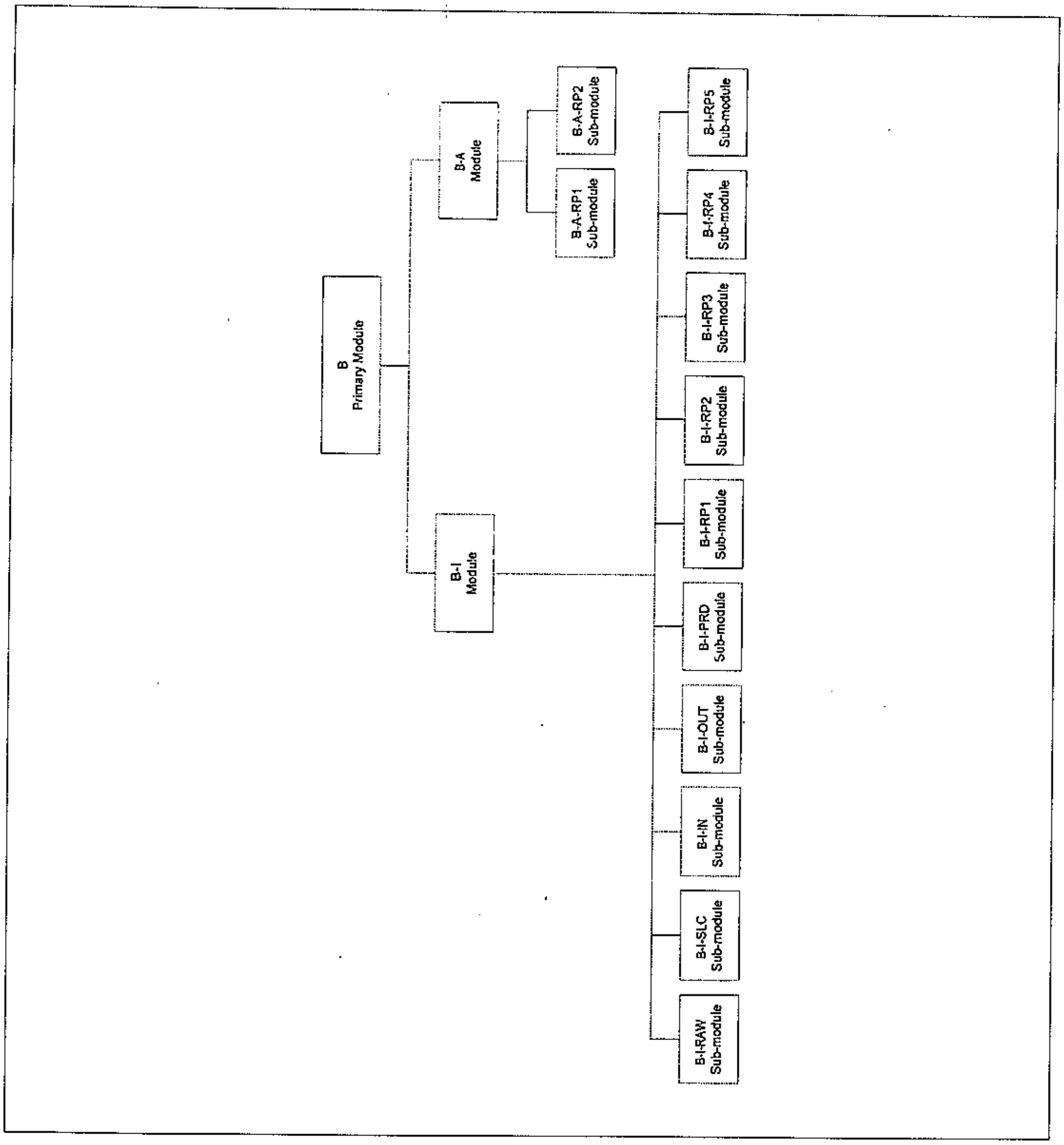
The B-I module consists of 5(five) interpreter sub-module and 5 (five) reporting sub-modules. The interpreter sub-modules are:

1. B-I-RAW
2. B-I-SLC
3. B-I-IN
4. B-I-OUT
5. B-I-PRD

The reporting sub-modules are B-I-RP1, B-I-RP2, B-I-RP3, B-I-RP4 and B-I-RP5. Those reporting modules are very important as they the interpretation of Biometric Attendance Machine data. The is a direct relation between Biometric Attendance Machine data and the B-I reporting sub-modules

The B-A module consists of two reporting sub-module: B-A-RP1 and B-A-RP2. The B-A module contains no interpretation sub-module.

Figure 4-7
B Primary Module Work Breakdown Structure



Source: Primary data

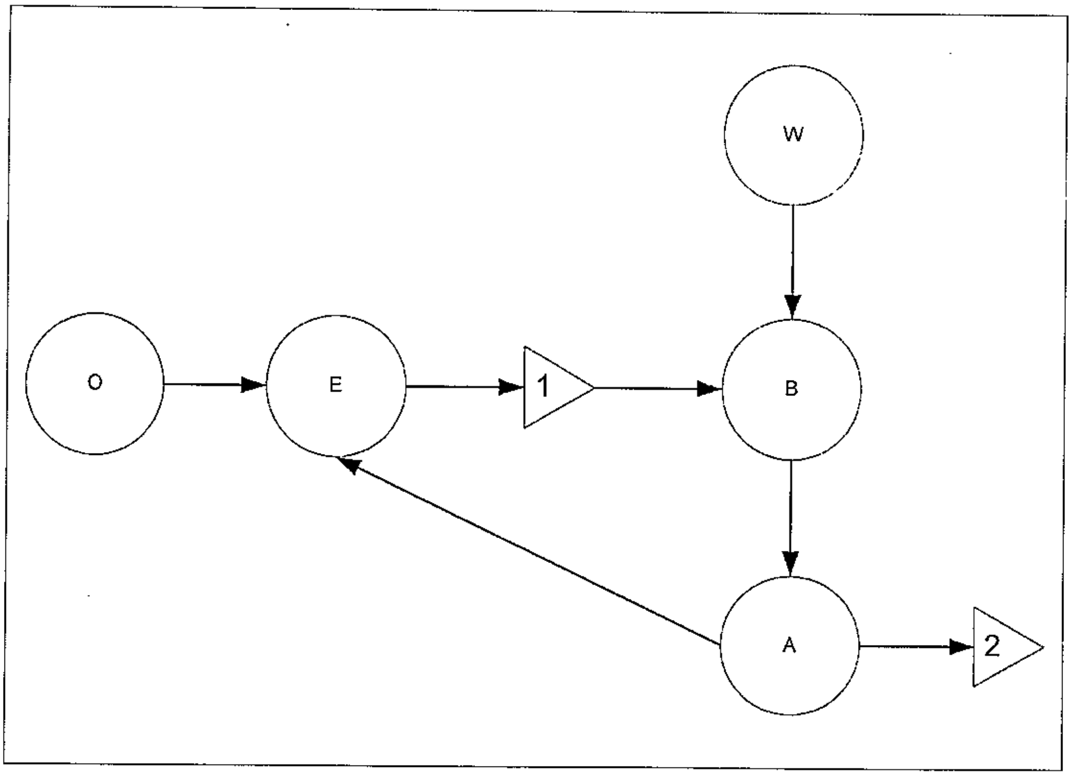
The following section describes the relationship between modules based on the Work Breakdown Structures defined.

4.6 Relationships

4.6.1 Primary Module Relationship

It has been defined that there are 5 (five) primary modules currently in the development. The systems is built based on the interaction of these modules. Figure 4-8 explains the primary module interaction. This is the foundation of Biometric Time and Attendance Systems. *This figure shows primary module relationship only. It should be understood that the figure does not explain any precedence between primary modules. Precedence will be explained in sub-section 4.6.3.*

Figure 4-8
Primary Module Relationship



Source: Processed primary data

4.6.2 Integration Points

There are 2 (two) Integration Points. An integration Point is an event where several sub-modules consolidated (Cusumano, 1997). Integration Points serves as a mile stone of the entire development process. Integration Point is represented by a triangle with a number inside.

Each module, located between those integration Points, is separated from another modules. Module separation supports the modularity principles, also known as *Modularization.* Modularity in this development process is enabled by Object Oriented Technology. Cusumano, 1997, mentioned that modularization can be done based on subsystems and also objects.

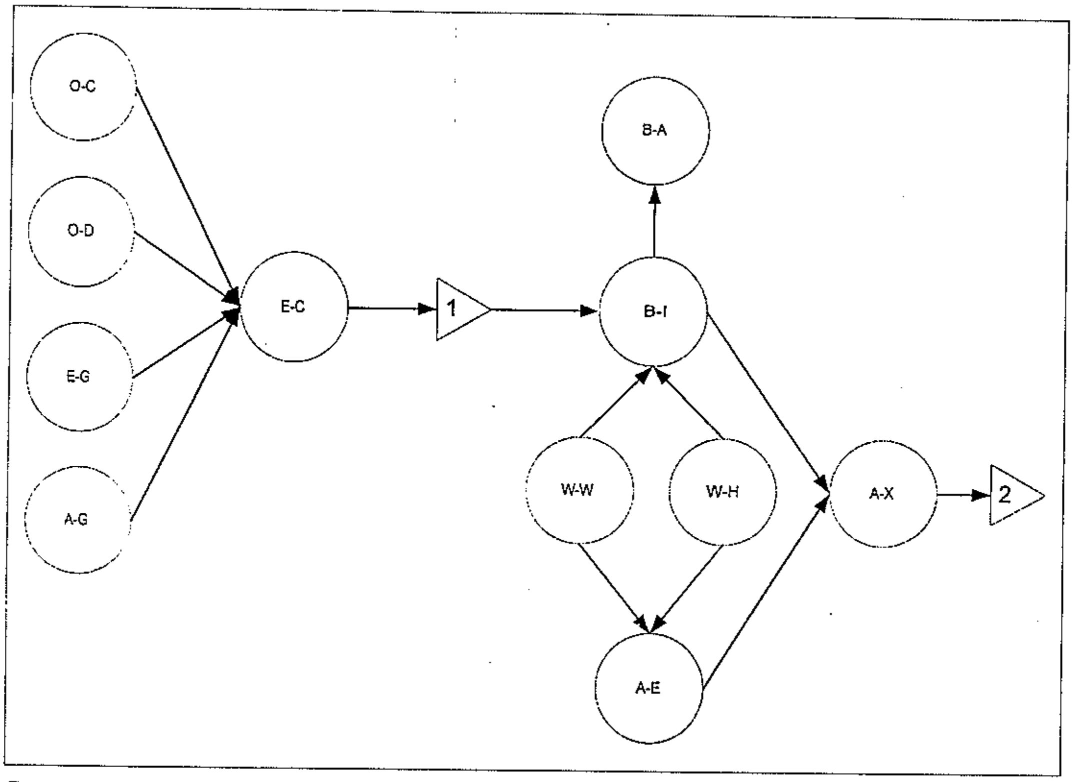
4.6.3 Module Relationship

Relationship between primary modules has been explained in the previous sub-section. A drill down analysis is performed to examine module relationship, based on the primary module relationship defined previously.

Module relationship is shown in Figure 4-9. *This figure shows sequence and precedence among modules.*

The A primary module is divided into three sub modules (A-G, A-E and A-X). These modules spread across the integration points. This means, the A-G module will be examined in Integration Point 1, whereas A-E and A-X modules will be examined in Integration Point 2.

Figure 4-9
Module Relationship



Source: Processed primary data

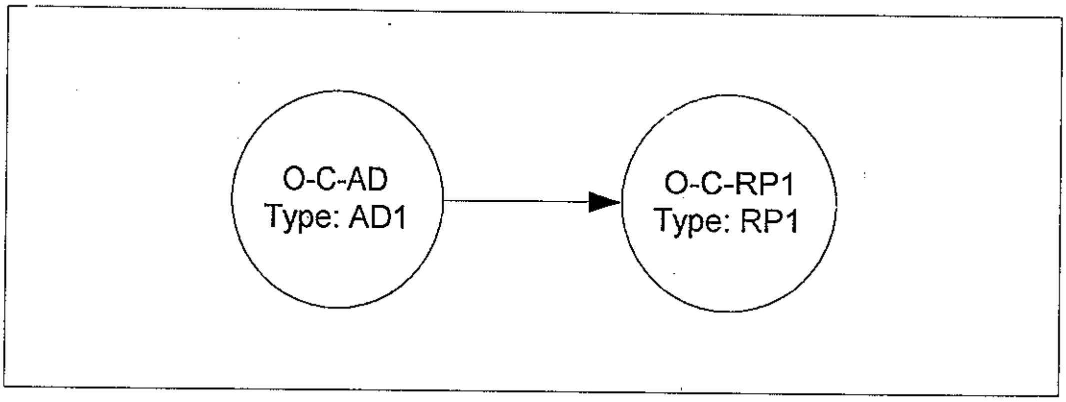
4.6.4 Sub Module Relationship

Module relationship has already been described in the previous section. This section is intended to explore the relationships among sub modules inside a module. Cross-modular relationship is also possible here.

4.6.4.1 O-C Sub-module Relationship

There are two sub-modules in O-C module. There is only a simple relationship exists between them. There is no cross-modular relationship found.

Figure 4-10
O-C Sub-module Relationship



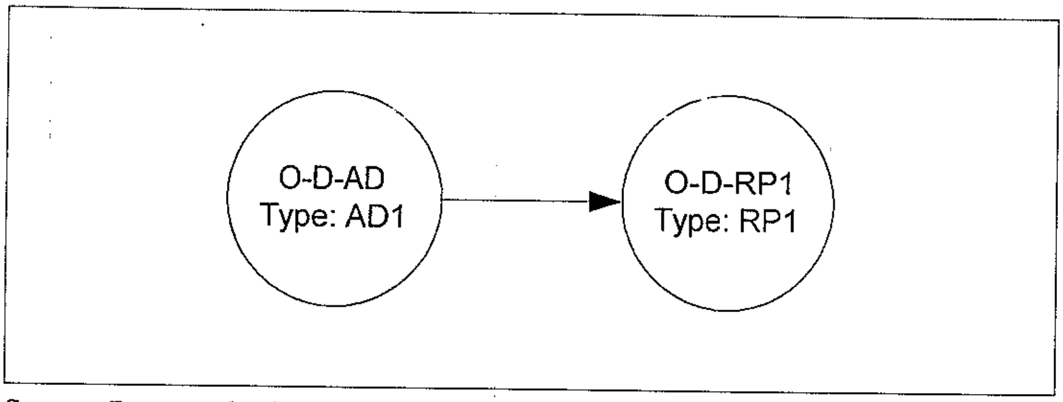
Source: Processed primary data

4.6.4.2 O-D Sub-module Relationship

There are two sub-modules in O-D module. There is only a simple relationship exists between them. There is no cross-modular relationship found.

Figure 4-12 shows the relationship between O-D-AD and O-D-RP1 sub-modules in O-D module.

Figure 4-12
O-D Sub-module Relationship

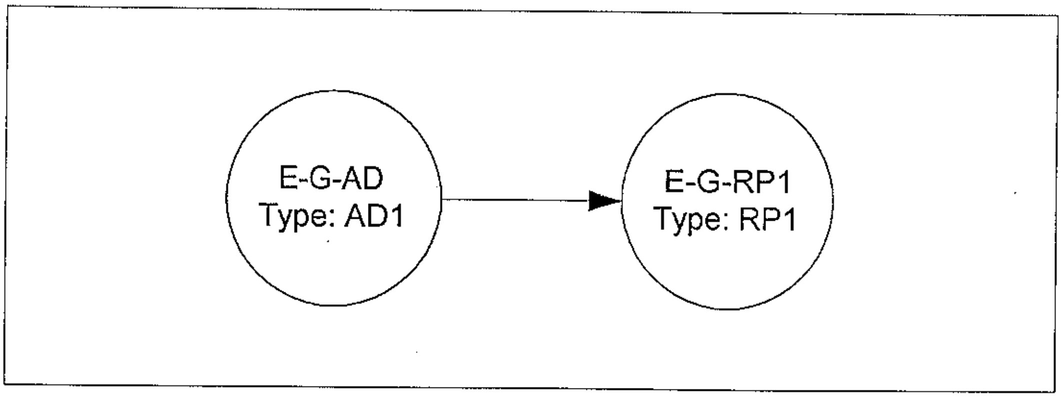


Source: Processed primary data

4.6.4.3 E-G Sub-module Relationship

There are two sub-modules in E-G module. There is only a simple relationship exists between them. There is no cross-modular relationship found.

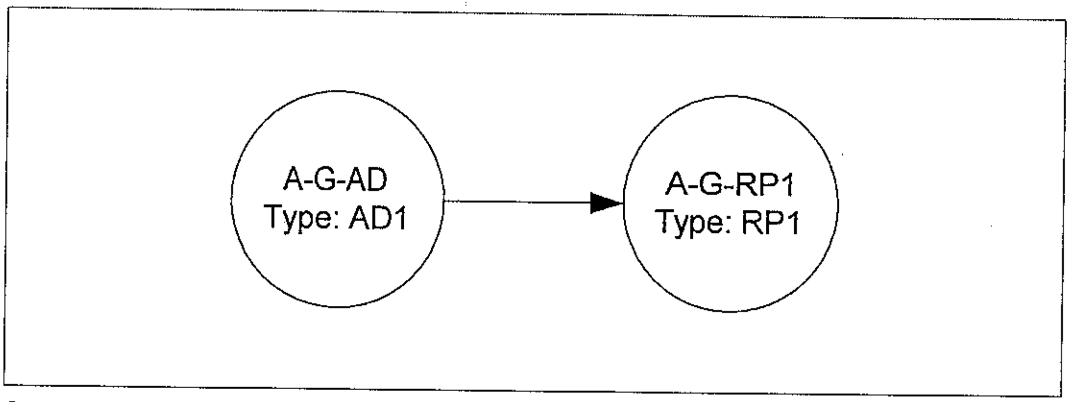
Figure 4-11
E-G Sub-module Relationship



4.6.4.4 A-G Sub-module Relationship

There are two sub-modules in A-G module. There is only a simple relationship exists between them. There is no cross-modular relationship found.

Figure 4-13
A-G Sub-module Relationship



Source: Processed primary data

4.6.4.5 E-C Sub-module Relationship

There are 3 (three) sub-modules inside E-C Module. It is identified that there are some cross-modular relationship as follows:

1. Between E-C module and O-C module

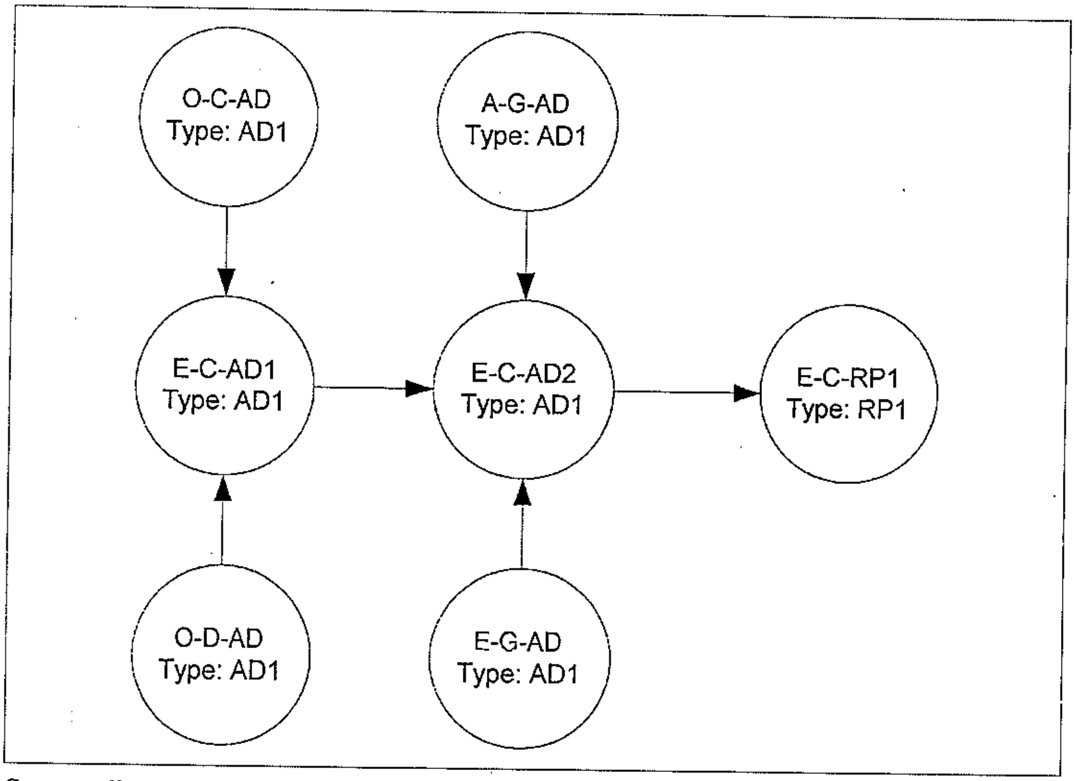
2. Between E-C module and O-D module

3. Between E-C module and E-G module

4. Between E-C module and A-G module

The relationship can be examined in Figure 4-14. Additionally, it shows the job type of each sub module

Figure 4-14
E-C Sub-module Relationship



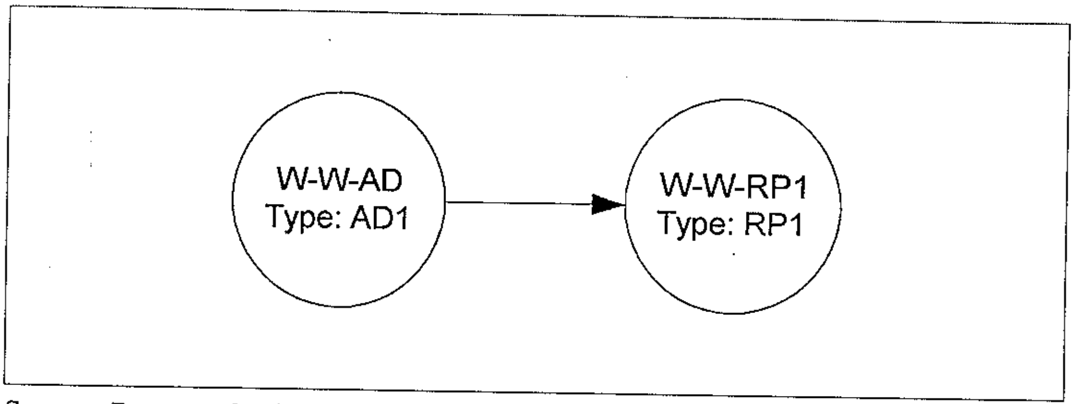
Source: Processed primary data

4.6.4.6 W-W Sub-module Relationship

There are two sub-modules in W-W module. There is only a simple relationship exists between them. There is no cross-modular relationship found.

Figure 4-15 shows the relationship between W-W-AD and W-W-RP1 sub-modules in W-W module.

Figure 4-15
W-W Sub-module Relationship

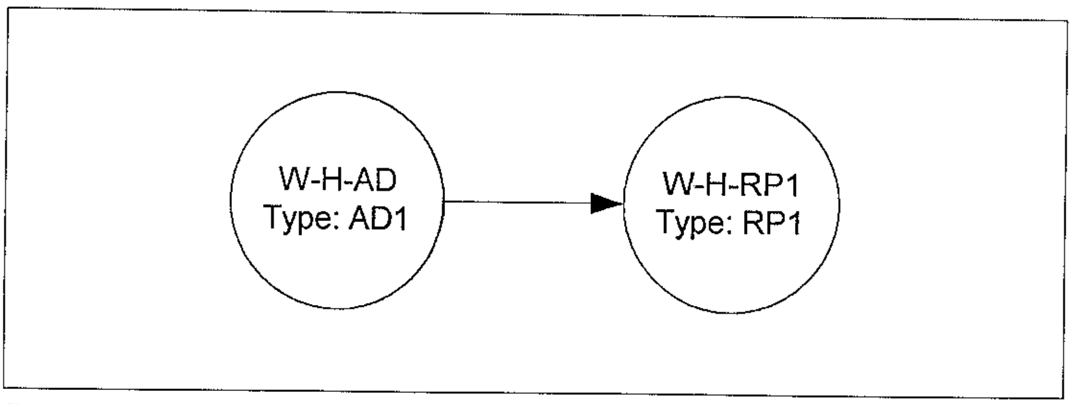


Source: Processed primary data

4.6.4.7 W-H Sub-module Relationship

There are two sub-modules in W-H module. There is only a simple relationship exists between them. There is no cross-modular relationship found.

Figure 4-16
W-H Sub-module Relationship



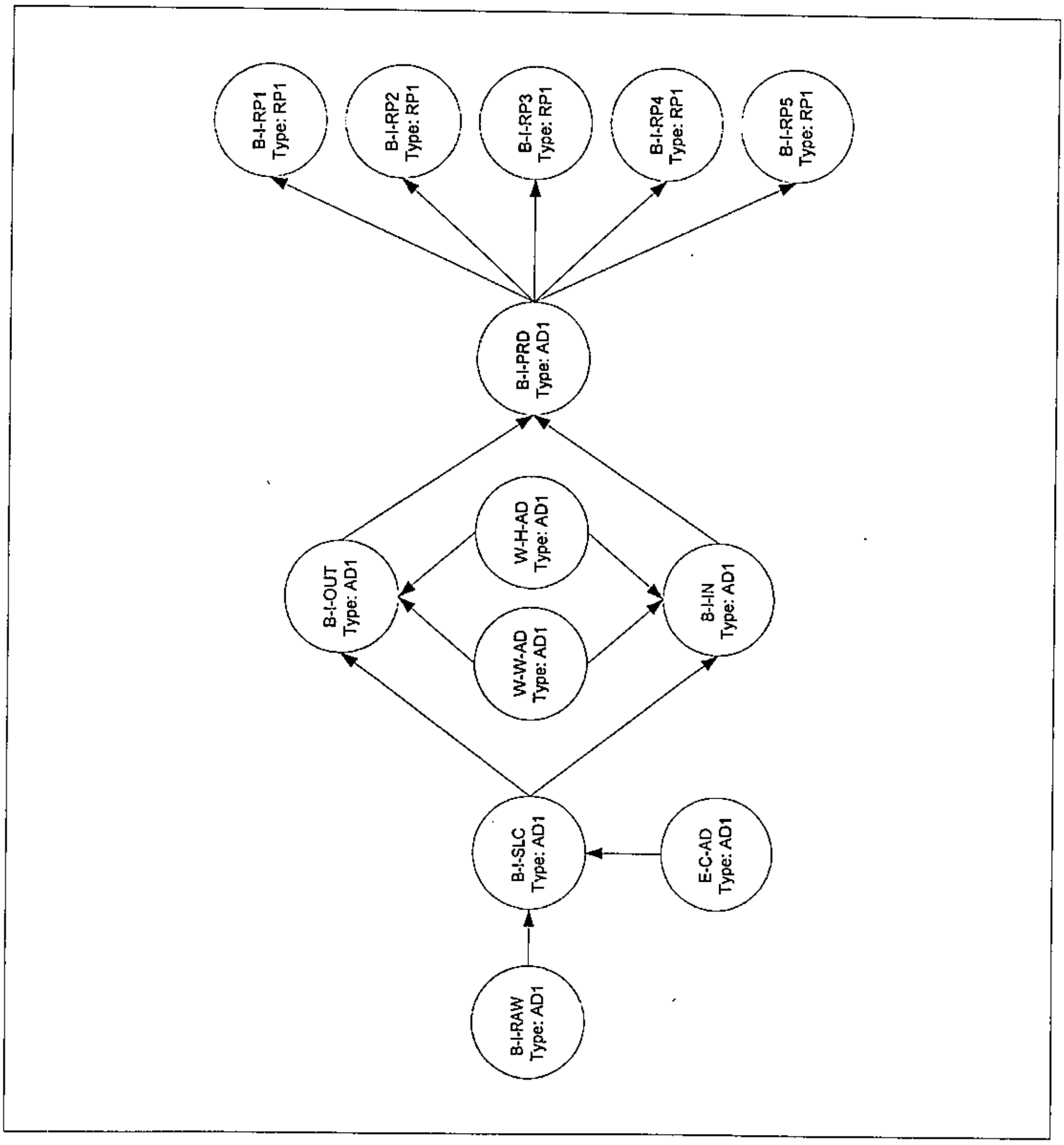
Source: Processed primary data

4.6.4.8 B-I Sub-Module Relationship

There are 10 (ten) sub-modules currently found in B-I Module. As mentioned earlier, this is the heart of the systems. So, it is definitely has several cross-modular relationships. Those relationship can be examined in Figure 4-17.

Figure 4-17

B-I Sub-module Relationship

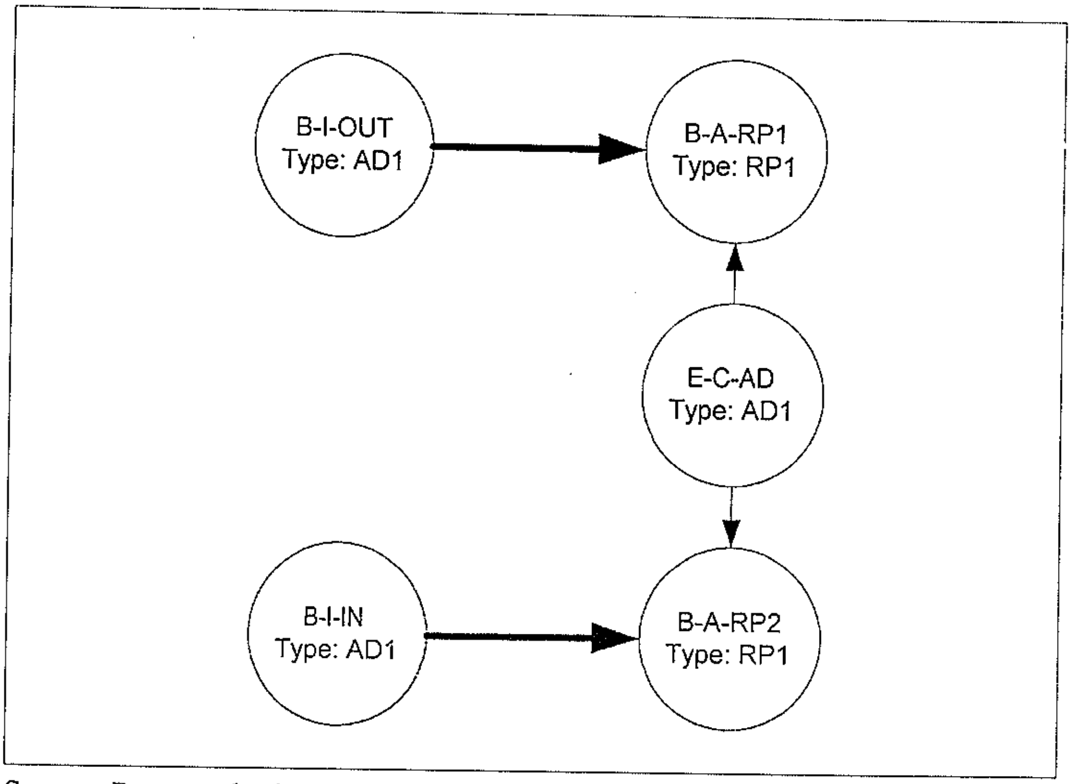


Source: Processed primary data

4.6.4.9 B-A Sub-module Relationship

There are two reporting sub-modules in B-A module. Unlike another sub-modules, there is no inputting sub-module found here. Although there is no inputting sub-module, cross-modular relationship exists between this module and E-C module.

Figure 4-18
B-A Sub-module Relationship

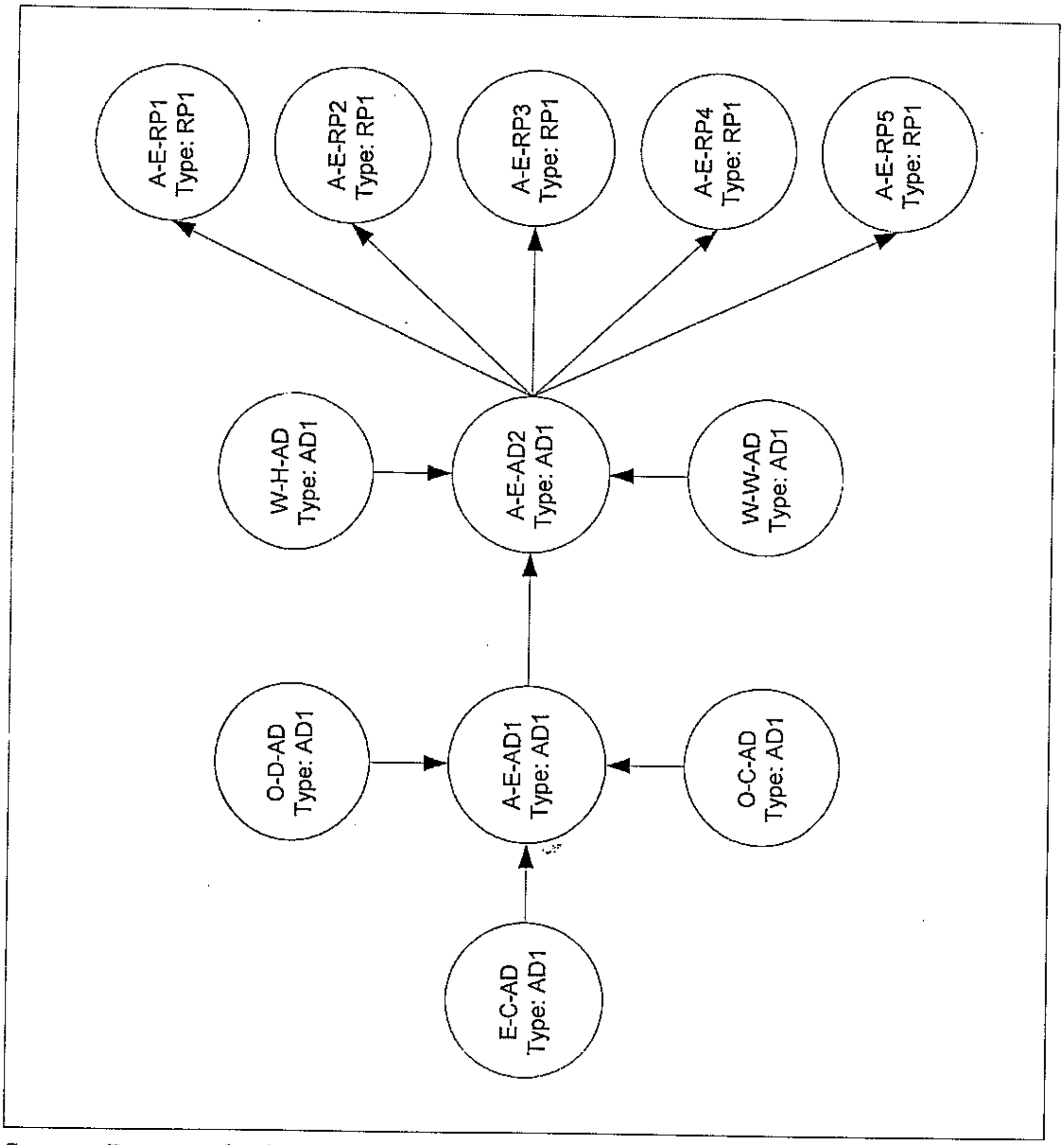


Source: Processed primary module

4.6.4.10 A-E Sub-Module Relationship

The A-E module is a large module. It consists of 2 (two) inputting sub-modules and 5 (five) reporting sub-modules. Figure 4-19 shows the complex relationship of this module graphically.

Figure 4-19
A-E Sub-module Relationship

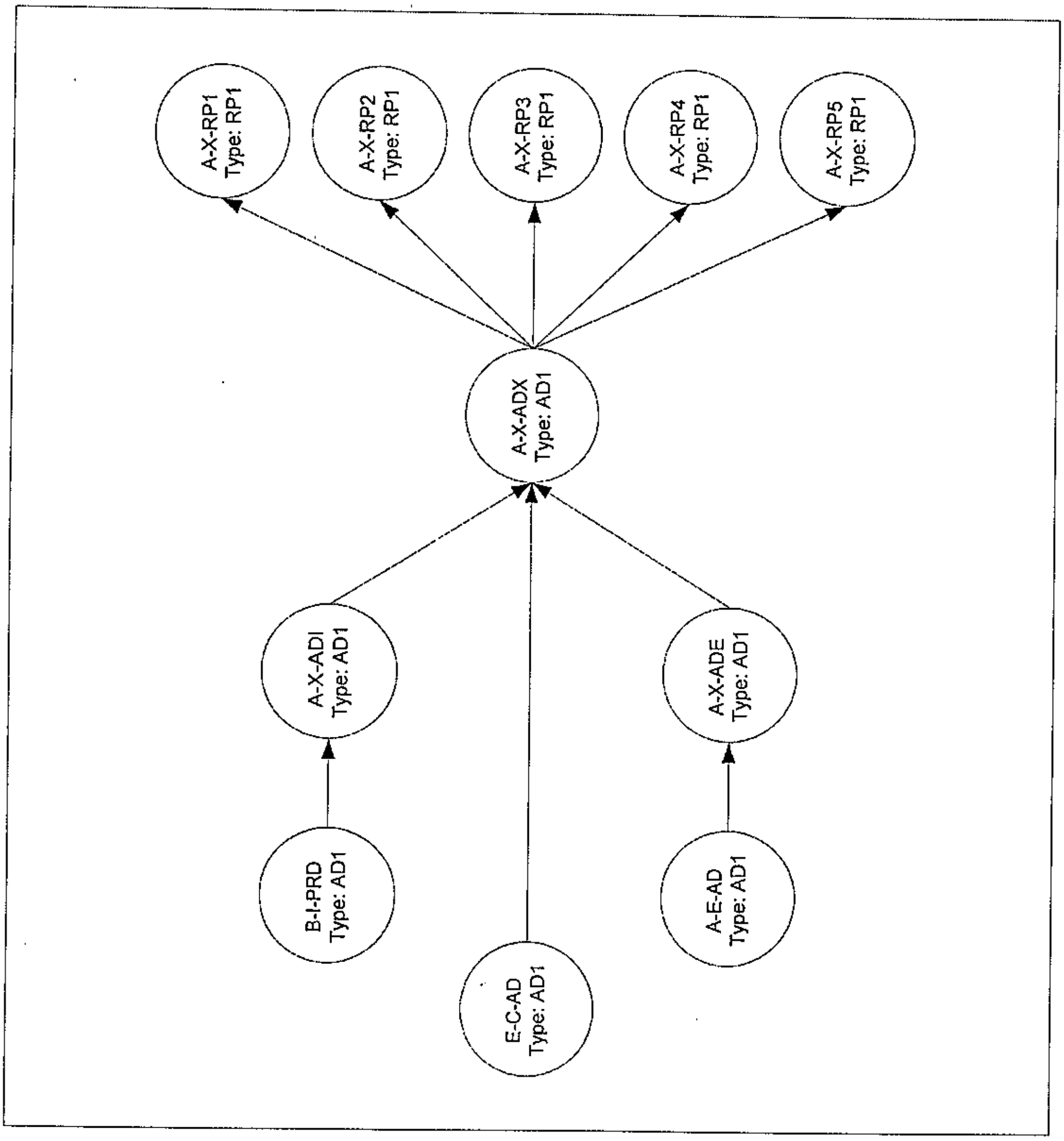


Source: Processed primary data

4.6.4.11 A-X Sub-Module Relationship

Figure 4-20 shows the relationship graphically. It also shows the job type of each sub module.

Figure 4-20
A-X Sub Module Relationship



Source: Processed primary data

There are 8 (eight) sub-modules inside A-X Module. It is identified that there are some cross-modular relationship as follows:

1. Between A-X module and A-E module

2. Between A-X module and B-I module

3. Between A-X module and E-C module

All relationship between modules has been discussed here. Theses sub-module relationships examinations serves as a foundation of building sub-module sequencing in order to identify the critical path.

4.7 Sub module Sequencing

Sub-module relationship examination has already been done. The most important result of previous process is sub-module dependency identification. Using the graphical figures found in previous section, sub-module precedence can be determined.

The next step is to build the sequence of these sub-module developments. This process is very critical because this process will determine the overall development time. Obviously, the sequence of the sub-module development based on the sub-module precedence and sub-module dependencies mentioned above.

This research attempts to find the most efficient development time through two different approaches:

1. Modular approach
2. Job type approach

The modular approach tries to develop the system module by module. A programmer is assigned to develop a series of sub-modules of a specific module regardless the type of the sub-module. Specifically, this approach ignores the job type. As module development completes, the programmer is assigned to develop another module.

The second approach, the job-type approach, tries to build a development sequence based on the type of the sub-module. It is obvious that sub-module precedence is taken into account properly. A series of sub-modules which have the same job type is assigned to the programmer. Job type is the main concern in building this development sequence.

The sequence is constrained by the Integration Point. So, there are two development sequences (please refer to figure 4-8 on page 224 and figure 4-9 on page 226). In order to simplify the identification the following terms are used:

1. Phase 1:

   Begins at the start node, ends at the Integration Point 1

2. Phase 2:

   Begins at the end of Integration Point 1, ends at the Integration Point 2

There are two programmers projected to build the systems for each development phase.

Figure 4-21 on page 239 shows the network diagram of the development using Modular Approach of phase 1 of the Biometric Time an Attendance Systems, whereas the figure 4-22 on page 240 shows the network diagram of the development using Job Type Approach of phase 1.

Figure 4-23, 4-24, and 4-25 shows the network diagram of the development using Modular Approach of phase 2 of the Biometric Time an Attendance Systems, whereas the figure 4-26, 4-27 and - shows the network diagram of the development using Job Type Approach of phase 2.

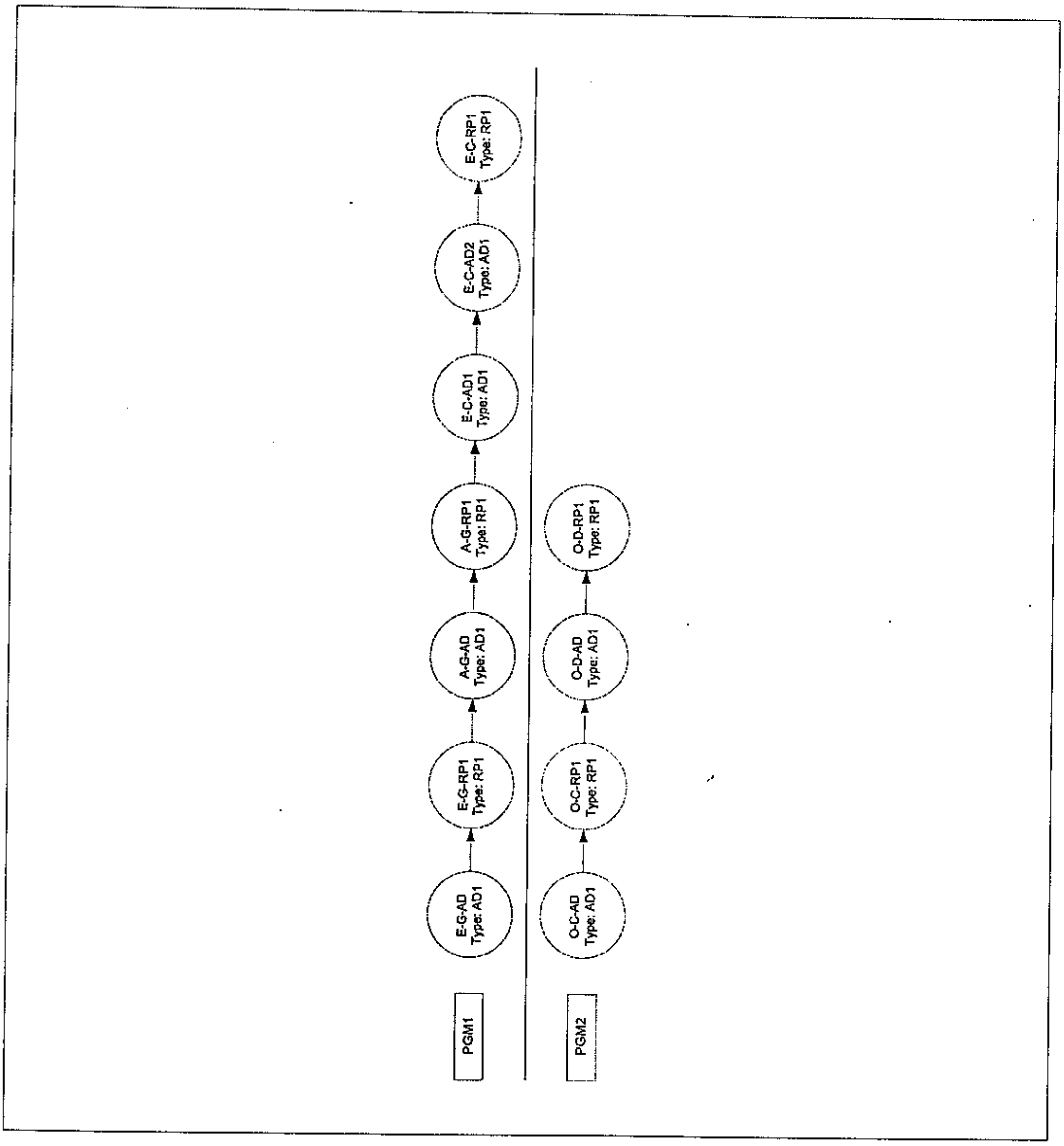
Development time of each sub module is then estimated. The modular approach uses the initial development time of a module of the previous experiments.

Development time of each module in Job Type approach is estimated using the initial development time and learning rate obtained in the previous experiments.

4.7.1 Modular Approach Network Diagram Phase 1

The first phase of the development using Modular Approach involves all modules of O and E primary module and A-G module. Phase 1 commences until the Integration Point 1

Figure 4-21
Modular Approach Network Diagram (Phase 1)

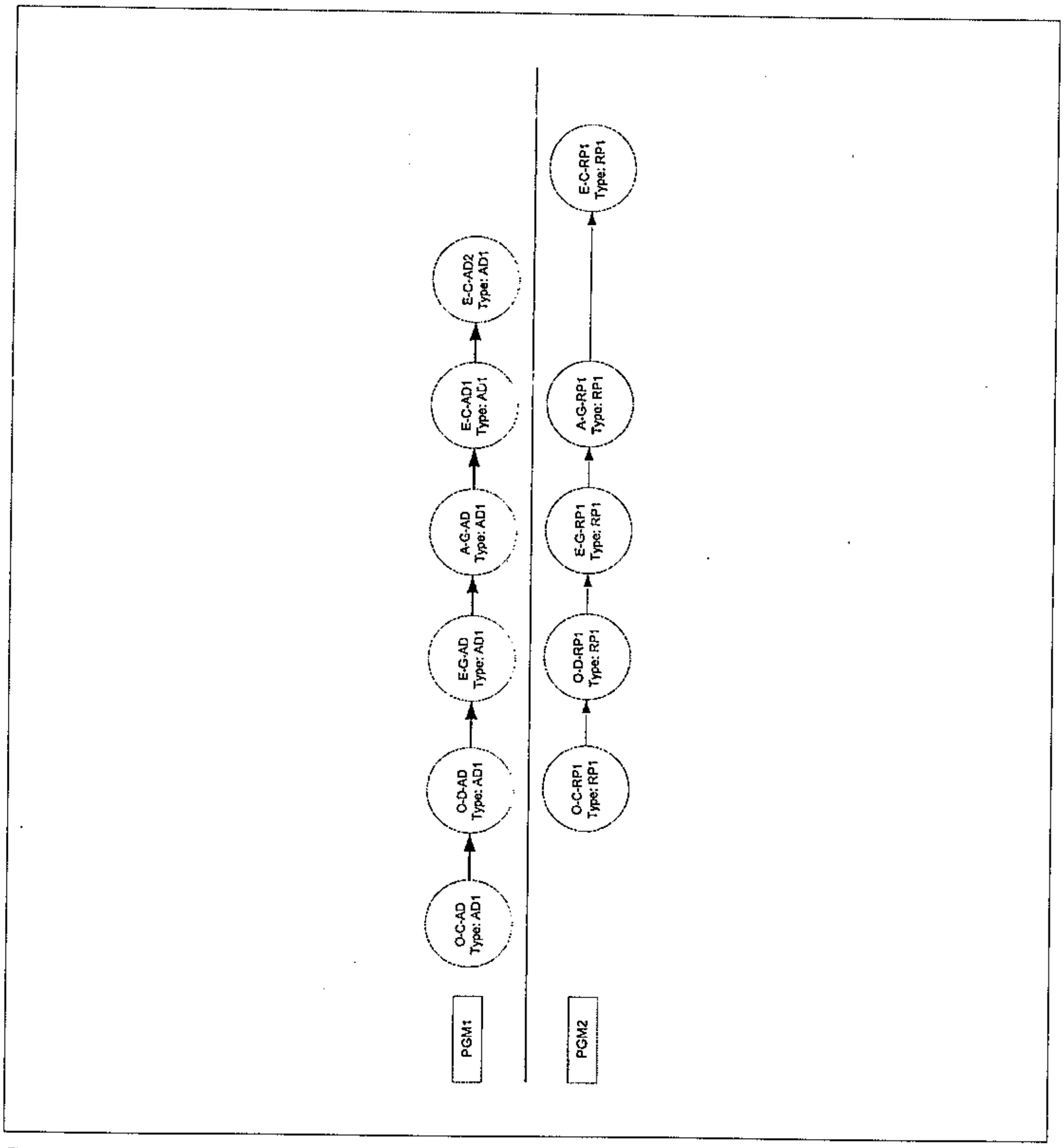


Source: Processed primary data

4.7.2 Job Type Approach Phase 1

Job Type Approach Phase 1 involves the sub-modules of O-C, O-D, E-G, E-C, and A-G module. Those sub-modules are arranged based on their job type.Programmer 1 is assigned to build RP1 sub module type, whereas Programmer 2 is assigned to build AD1 sub module type

Figure 4-22
Job-Type Approach Network Diagram (Phase 1)



Source: Processed primary data

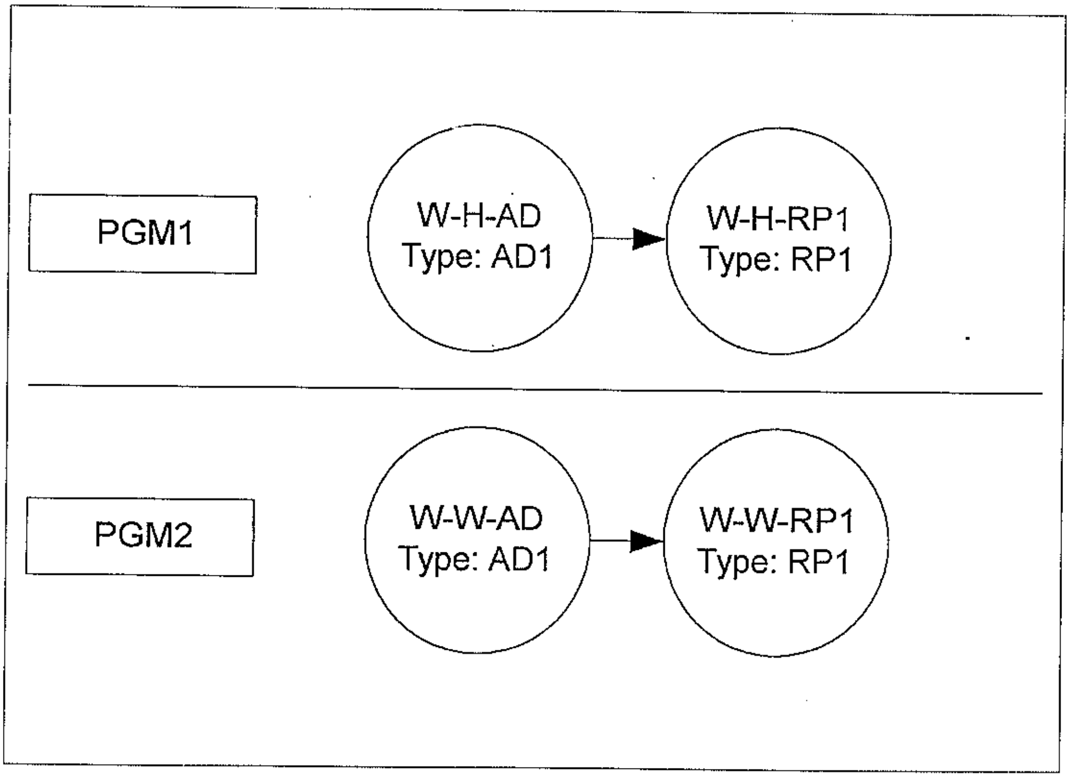
4.7.3 Modular Approach Phase 2

Development at Phase 2 is more complicated than development at Phase 1. Phase 2 is divided into three steps, named Phase 2A (see figure 4-23), 2B (see figure 4-24) , and 2C (see figure 4-25)

4.7.3.1 Modular Approach Phase 2A

Phase 2A is the shortest phase in the development. It involves only W primary modules. Programmer 1 is assigned to build W-H module and programmer 2 is responsible to build W-W module

Figure 4-23
Modular Approach Phase 2A

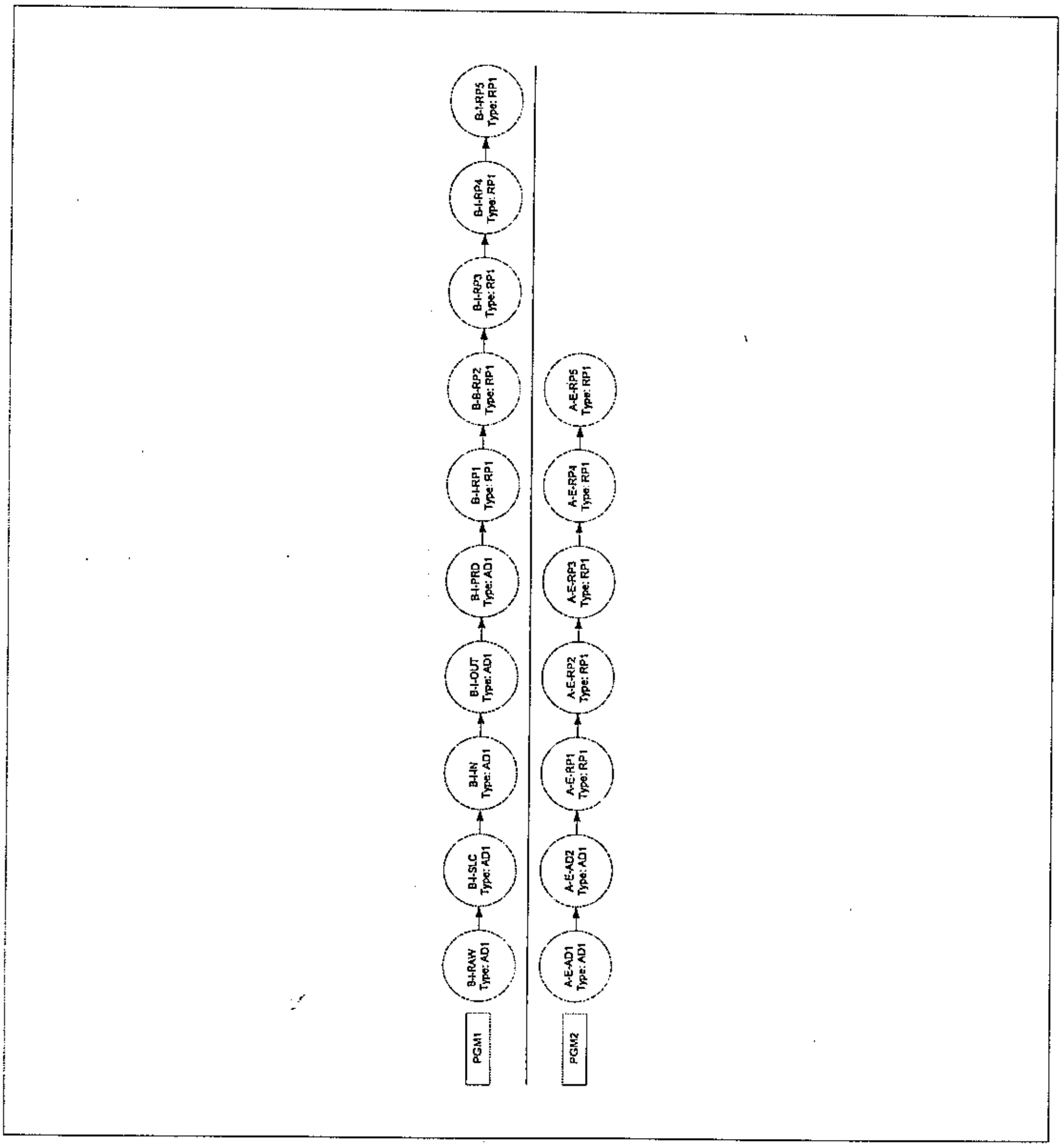


Source: Processed primary data

4.7.3.2 Modular Approach Phase 2B

This modular approach of phase 2B involves B-I and A-E module. Programmer 1 is assigned to develop B-I module, which consists of 10 sub-modules. Programmer 2 is assigned to develop 7 sub-modules of A-E module

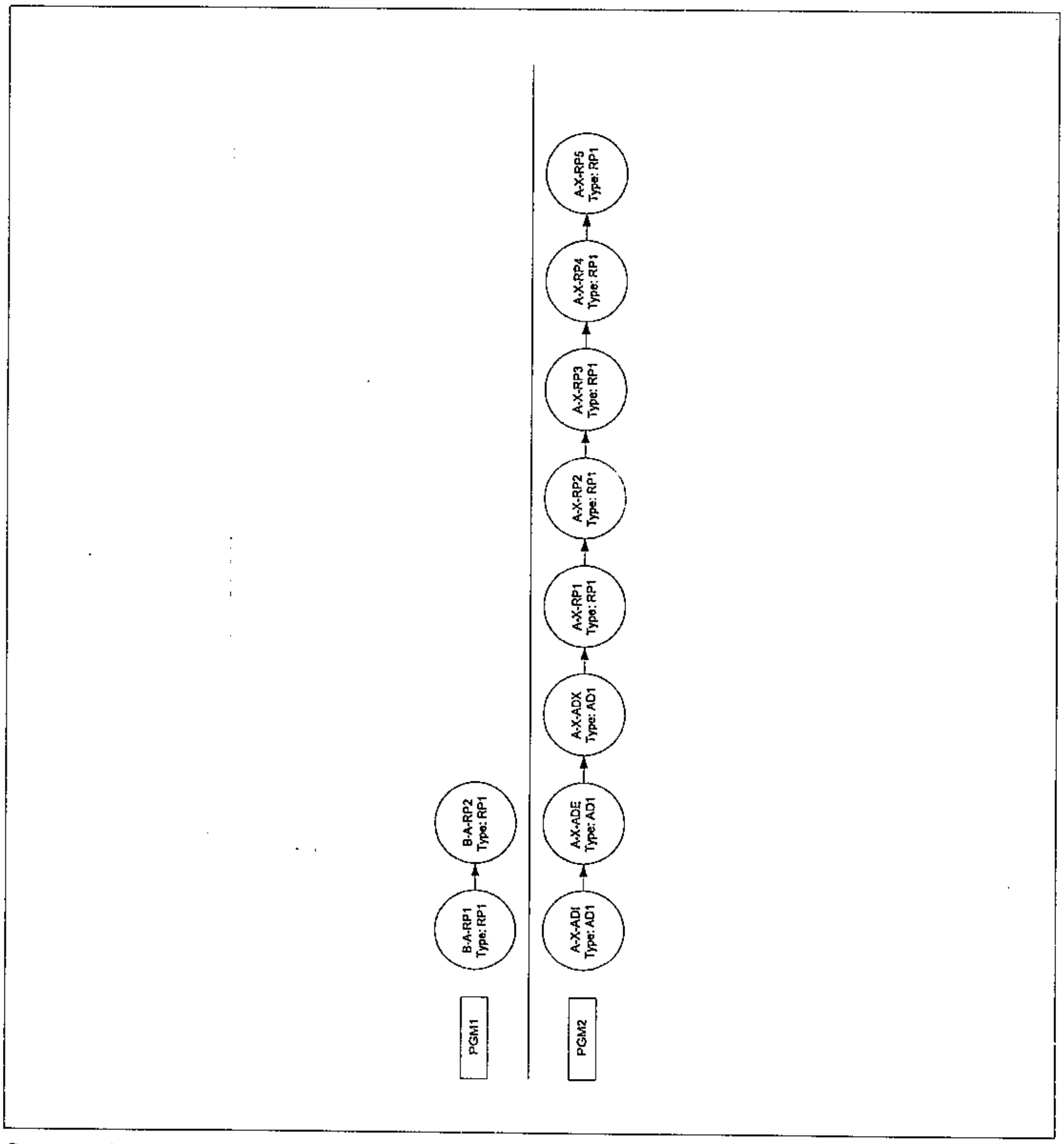
Figure 4-24
Modular Approach Phase 2B



4.7.3.3 Modular Approach Phase 2C

Phase 2C of development using Modular Approach involves B-A and A-X modules. Since A-X contains more sub-modules than B-A, there is a substantial amount of idle time of programmer 1

Figure 4-25
Modular Approach Phase 2C



Source: Processed primary data

4.7.4 Job Type Approach -Phase 2

This section examines another approach in setting-up the sequence. Job type is the foundation of this approach. There are two job types: AD1 and RP1. The sub-module development sequence is built based on these two job types.

Since the sequencing criteria is job type, it is possible that a programmer develop some sub-modules that belong to another module. It is true that there are an increased complexity in arranging the sub modules, but learning effect of each programmer is expected to cut the development time.

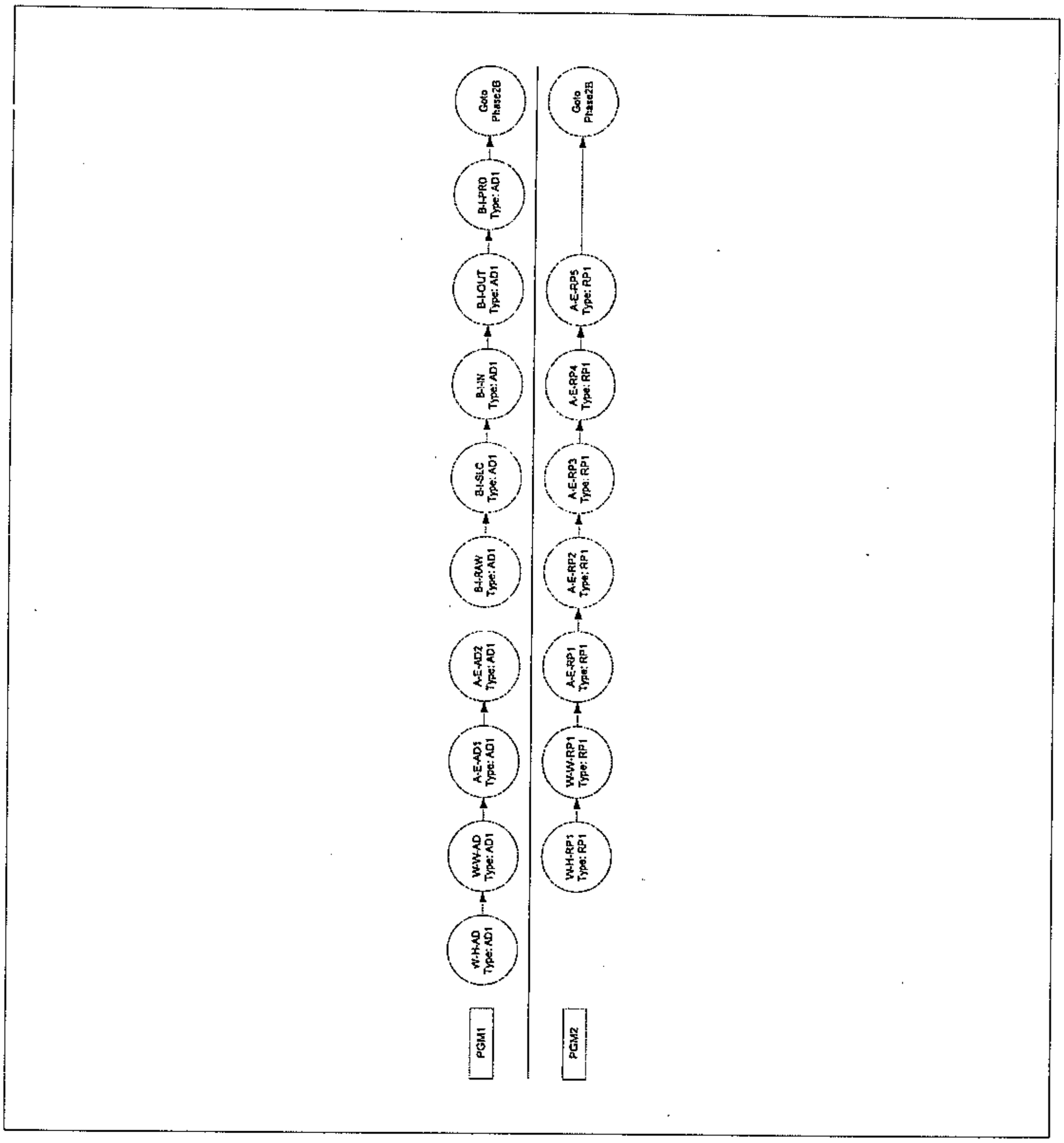
Previous modular approach requires 3 (three) steps. Job-type approach currently discussed only needs 2 (two) development step. Figure 4- on page 245 shows the first step, called Phase 2A.

Second step involves many sub-modules. This step is called Phase 2B is presented in figure 4-27 on page 246

4.7.4.1 Job Type Approach Phase 2A

Job Type Approach Phase 2A involves all modules of W primary modules, B-I modules and A-E modules. Sub-modules development is spread to two programmers based on the job type. Programmer 1 is assigned to develop AD1 job type while programmer 2 is assign to develop RP1 job type. Figure 4-26 shows the network diagram of this phase.

Figure 4-26
Job Type Approach Phase 2A

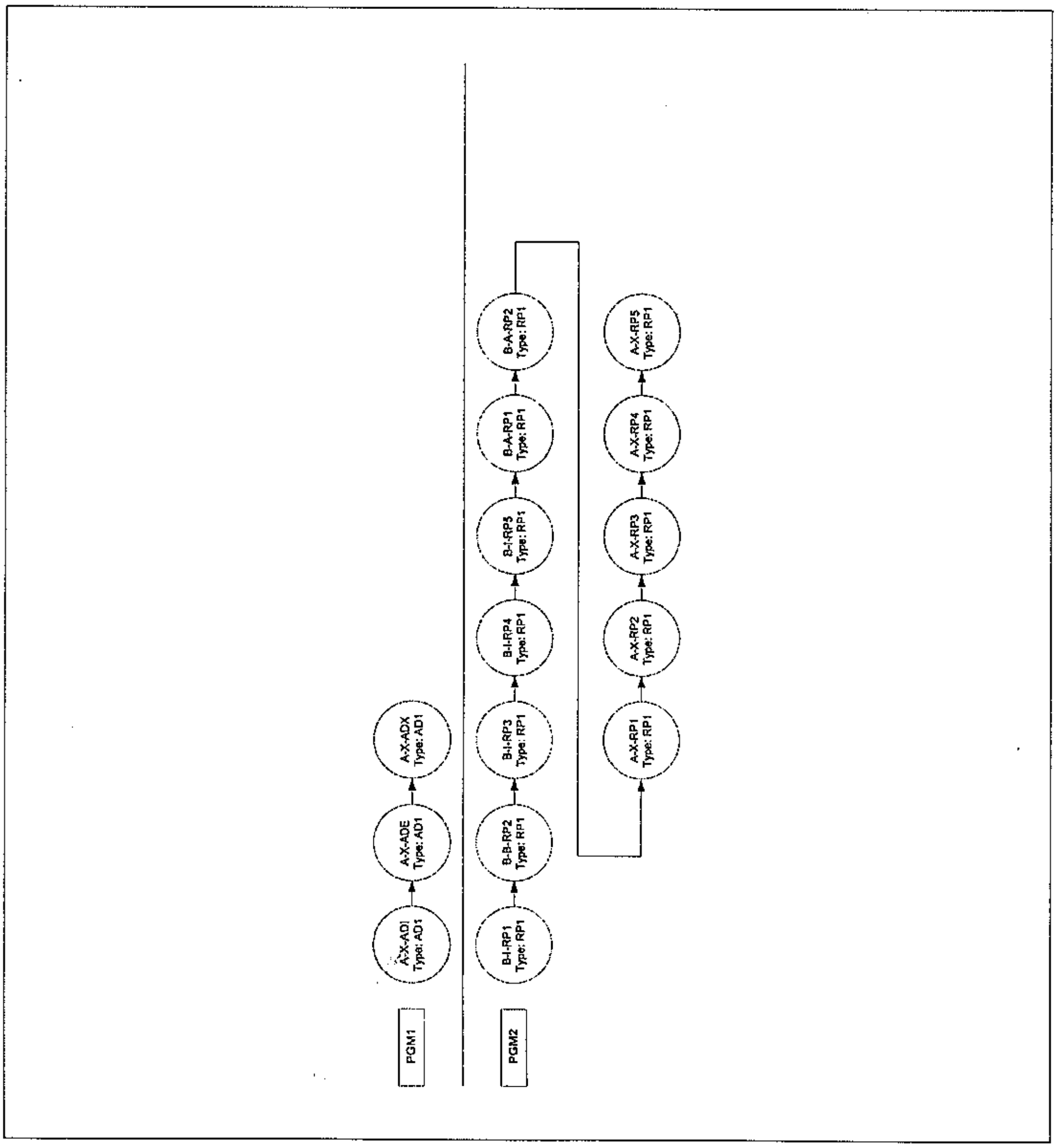


Source: Processed primary data

4.7.4.2 Job Type Phase 2B

Phase 2B involves A-X modules and some of B-I modules. It has been mentioned previously that programmer 1 is assigned to develop AD1 job type, whereas RP1 is assigned to programmer 2.

Figure 4-27
Job Type Phase 2B Variant 1



Source: Processed primary data

4.8 Development Time Estimation

Sub-modules involved in this Systems Development have already been defined. Two development approaches have been introduced in previous sub-section. Development time estimation is now ready to be calculated. The estimation process is based on the forecast of each job type. The forecast has already been shown in the earlier section. Please refer to Table 4-7 on page 180 for AD1 Job Type forecast and Table -. on page for RP1 Job Type.

Estimation of Development time is done for each approach. Sub-section 4.8.1 contains Modular Approach time estimates. Job Type Approach time estimates is shown in sub-section 4.8.2.

Idle time and development time for each programmer will be calculated and then compared. A conclusion will be drawn based on this comparison.

4.8.1 Modular Approach Time Estimation

Development time estimate of modular approach is calculated. Phase 1 calculation is done in sub-section 4.8.1.1. Phase 2 calculation is done in sub-section 4.8.1.2.

4.8.1.1 Modular Approach Phase 1 Time Estimation

Time estimation of Phase 1 of Modular Approach is presented in Table 4-14. Programmer 1 is assigned to develop E-G, A-G and E-C module, while programmer 2 is assigned to build O-C and O-D modules.

Table 4-14

Modular Approach Phase 1 Time Estimates

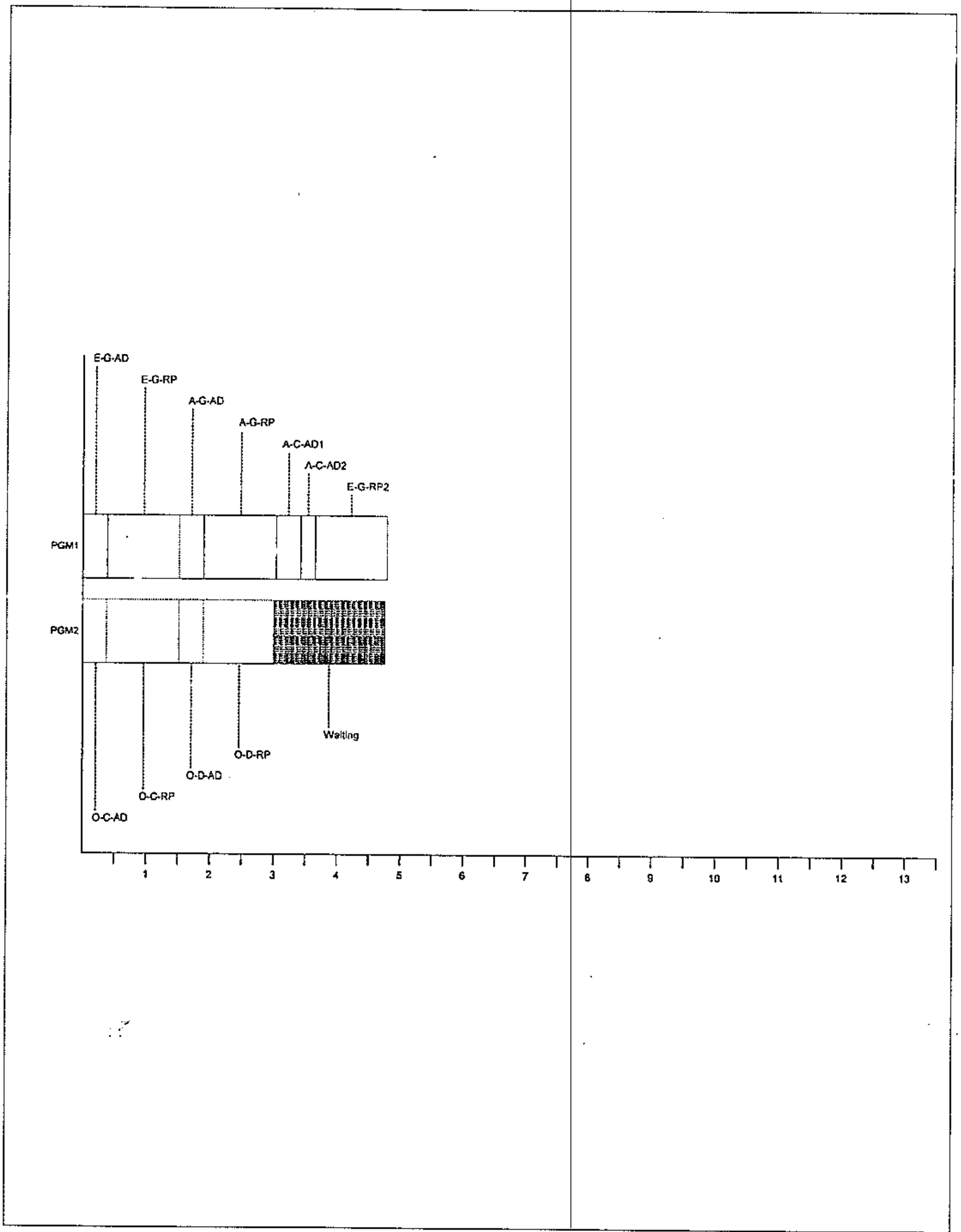
Modular Approach Phase 1

No.	Phase	Seq#	Programer 1				Phase	Seq#	Programmer 2			
			Sub-module	Job Type	Time	Cummulative			Sub-module	Job Type	Time	Cummulative
1	1	1	E-G-AD	AD1	367,318015	367,318015	1	1	O-C-AD	AD1	367,318015	367,318015
2	1	2	E-G-RP	RP1	1.082,291682	1.449,609697	1	2	O-C-RP	RP1	1.082,291682	1.449,609697
3	1	3	A-G-AD	AD1	367,318015	1.816,927713	1	3	O-D-AD	AD1	367,318015	1.816,927713
4	1	4	A-G-RP	RP1	1.082,291682	2.899,219395	1	4	O-D-RP	RP1	1.082,291682	2.899,219395
5	1	5	E-C-AD1	AD1	367,318015	3.266,537410						
6	1	6	E-C-AD2	AD1	221,626682	3.488,164092						
7	1	7	E-C-RP	RP1	1.082,291682	4.570,455774			Waiting		1.671,236379	4.570,455774
									Total idle		1.671,236379	

Source: Processed primary data

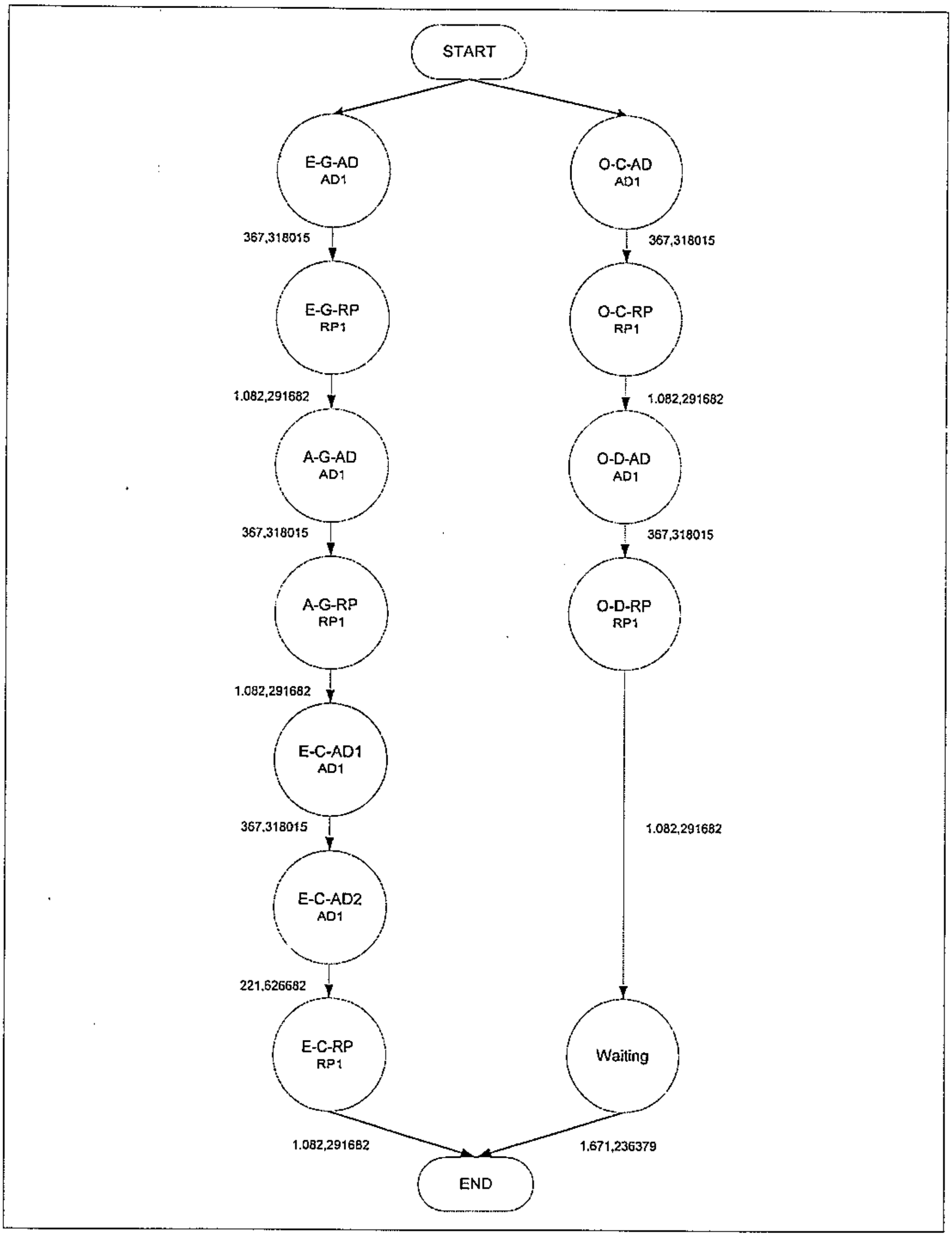
Figure 4-28

Modular Approach Phase 1 Gantt Chart



Source: Processed primary data

Figure 4-29
Modular Approach Phase 1 Network Diagram



Source: Processed primary data

The amount of time required by programmers to complete their assignments are taken from table Table 4-7 (for AD1 Job Type) and Table - (for RP1 Job Type).

Modular Approach Phase 1 takes 4,570.455774 minutes to complete. Programmer 2 requires only 2,899.219395, programmer 1 has to wait Programmer 1 to complete the work. So, idle time is 1.671,236379. A Gantt Chart is provided to visualize this situation (see Figure 4-28). Network Diagram for Programmer 1 Modular Approach Phase 1 can be found in figure 4-29.

4.8.1.2 Modular Approach Phase 2 Time Estimation

Phase 2 of Modular Approach development is started just after Integration Point 1. Programmer 1 is assigned to build W-H (Phase 2A), B-I (Phase 2B) and B-A (Phase 2C) modules. Programmer 2 is assigned to build W-W (Phase 2A), A-E (Phase 2B) and A-X (Phase 2C) modules. Figure 4-15. shows time estimates of current development phase.

Phase 2C of programmer 2 A-X (module)is delayed until programmer 1 finish building Phase 2B (B-I module). It is recognized that there is 412.288889 minutes of idle time.

Programmer 1 is projected to finish the work earlier than programmer 2, since there is only a few sub-modules in Phase 2C. A huge amount of idle time (3,714.320978 minutes) occurs. There are several sub-modules with similar job type projected to run consecutively. Learning curve is expected to occur in this situation.

Gantt Chart for this phase can be examined at figure 4-30. Network Diagram is also provided. Since the are so many nodes, Network Diagram is split into figure 4-31, 4-32 and 4-33.

Table 4-15

Modular Approach Phase 2 Time Estimates

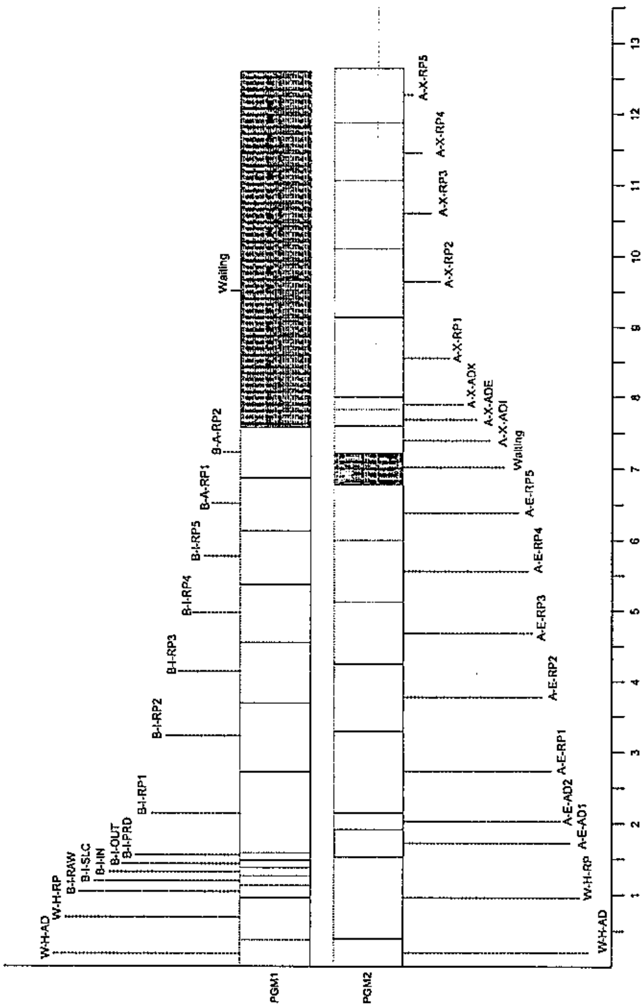
Modular Approach Phase 2

No.	Phase	Seq#	Programer 1 Sub-module	Job Type	Time	Cummulative	Phase	Seq#	Programmer 2 Sub-module	Job Type	Time	Cummulative
1	2A	1	W-H-AD	AD1	367,318015	367,318015	2A	1	W-W-AD	AD1	367,318015	367,318015
2	2A	2	W-H-RP	RP1	1.082,291682	1.449,609697	2A	2	W-W-RP	RP1	1.082,291682	1.449,609697
3	2B	1	B-I-RAW	AD1	367,318015	1.816,927713	2B	1	A-E-AD1	AD1	367,318015	1.816,927713
4	2B	2	B-I-SLC	AD1	221,626682	2.038,554395	2B	2	A-E-AD2	AD1	221,626682	2.038,554395
5	2B	3	B-I-IN	AD1	164,918533	2.203,472928	2B	3	A-E-RP1	RP1	1.082,291682	3.120,846077
6	2B	4	B-I-OUT	AD1	133,721691	2.337,194619	2B	4	A-E-RP2	RP1	917,087544	4.037,933621
7	2B	5	B-I-PRD	AD1	113,648665	2.450,843284	2B	5	A-E-RP3	RP1	832,400591	4.870,334212
8	2B	6	B-I-RP1	RP1	1.082,291682	3.533,134966	2B	6	A-E-RP4	RP1	777,100645	5.647,434857
9	2B	7	B-I-RP2	RP1	917,087544	4.450,222510	2B	7	A-E-RP5	RP1	736,749494	6.384,184351
10	2B	8	B-I-RP3	RP1	832,400591	5.282,623101						
11	2B	9	B-I-RP4	RP1	777,100645	6.059,723745						
12	2B	10	B-I-RP5	RP1	736,749494	6.796,473240			Waiting		412,288889	6.796,473240
13	2C	1	B-A-RP1	RP1	705,340553	7.501,813793	2C	1	A-X-ADI	AD1	367,318015	7.163,791255
14	2C	2	B-A-RP2	RP1	679,831656	8.181,645449	2C	2	A-X-ADE	AD1	221,626682	7.385,417937
15							2C	3	A-X-ADX	AD1	164,918533	7.550,336470
16							2C	4	A-X-RP1	RP1	1.082,291682	8.632,628152
17							2C	5	A-X-RP2	RP1	917,087544	9.549,715697
18							2C	6	A-X-RP3	RP1	832,400591	10.382,116288
19							2C	7	A-X-RP4	RP1	777,100645	11.159,216932
20			Waiting		3.714,320978	11.895,966427	2C	8	A-X-RP5	RP1	736,749494	11.895,966427
			Total idle		4.126,609867							

Source: Processed primary data

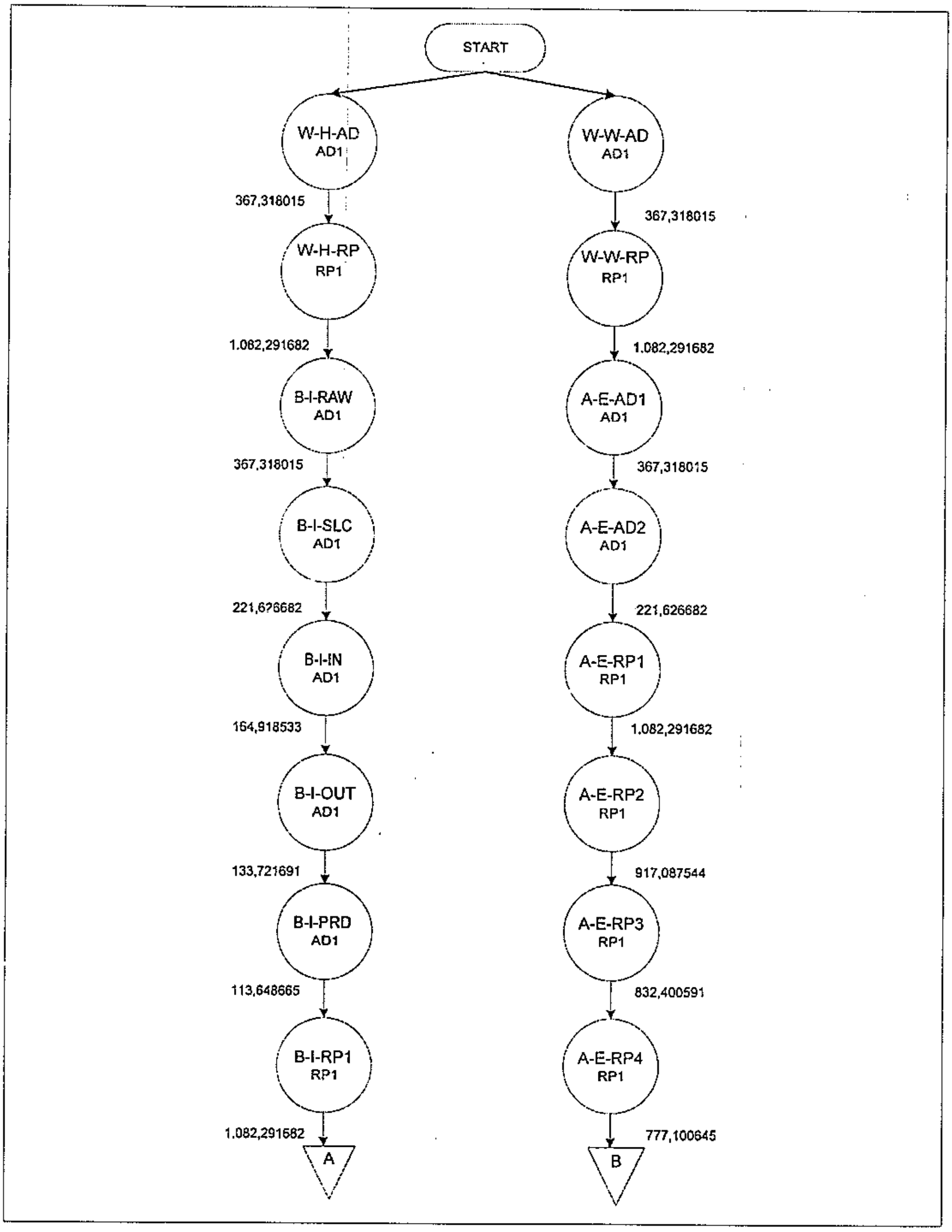
Figure 4-30

Modular Approach Phase 2 Gantt Chart



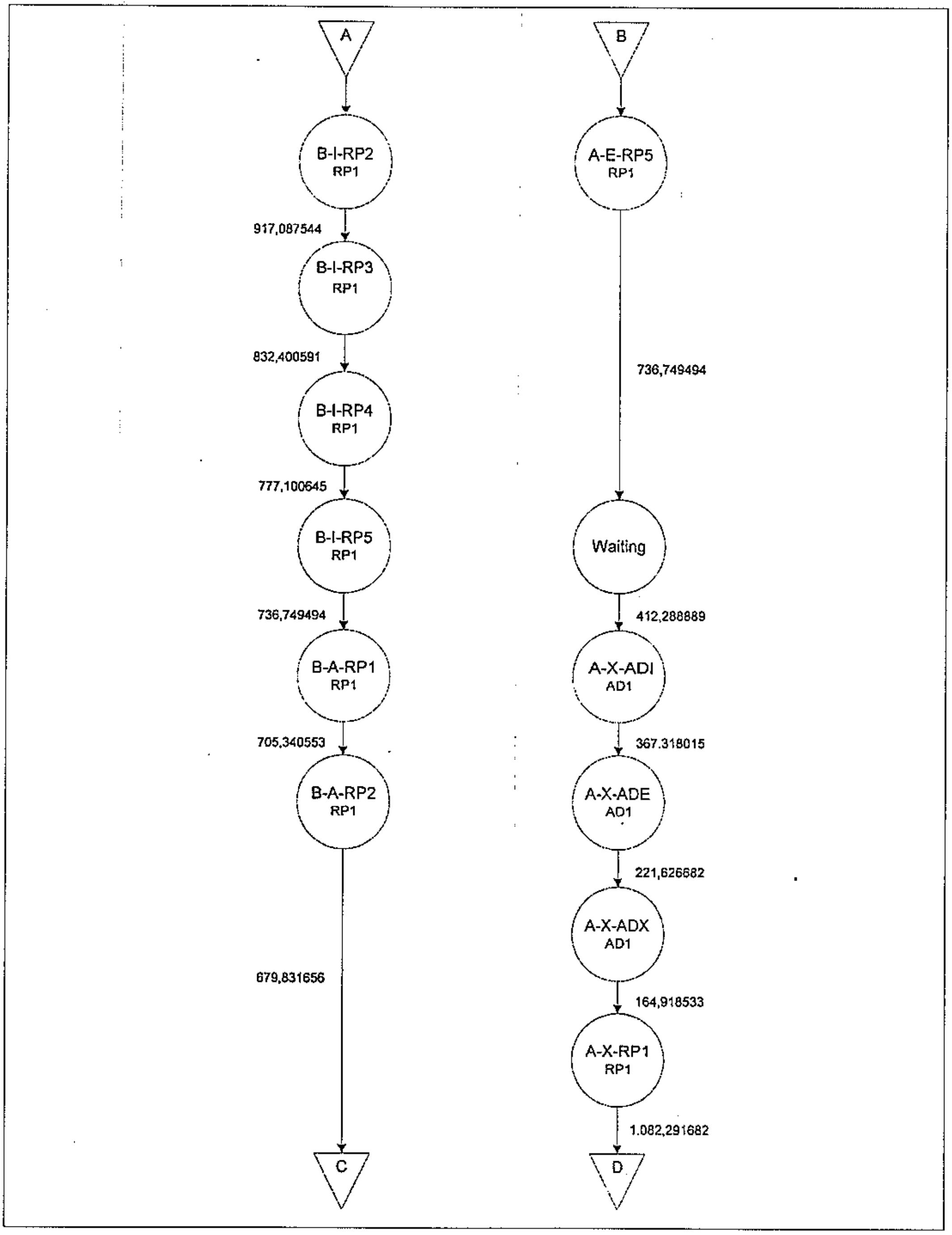
Source: Processed primary data

Figure 4-31
Modular Approach Phase 2 Network Diagram (Page 1)



Source: Processed primary data

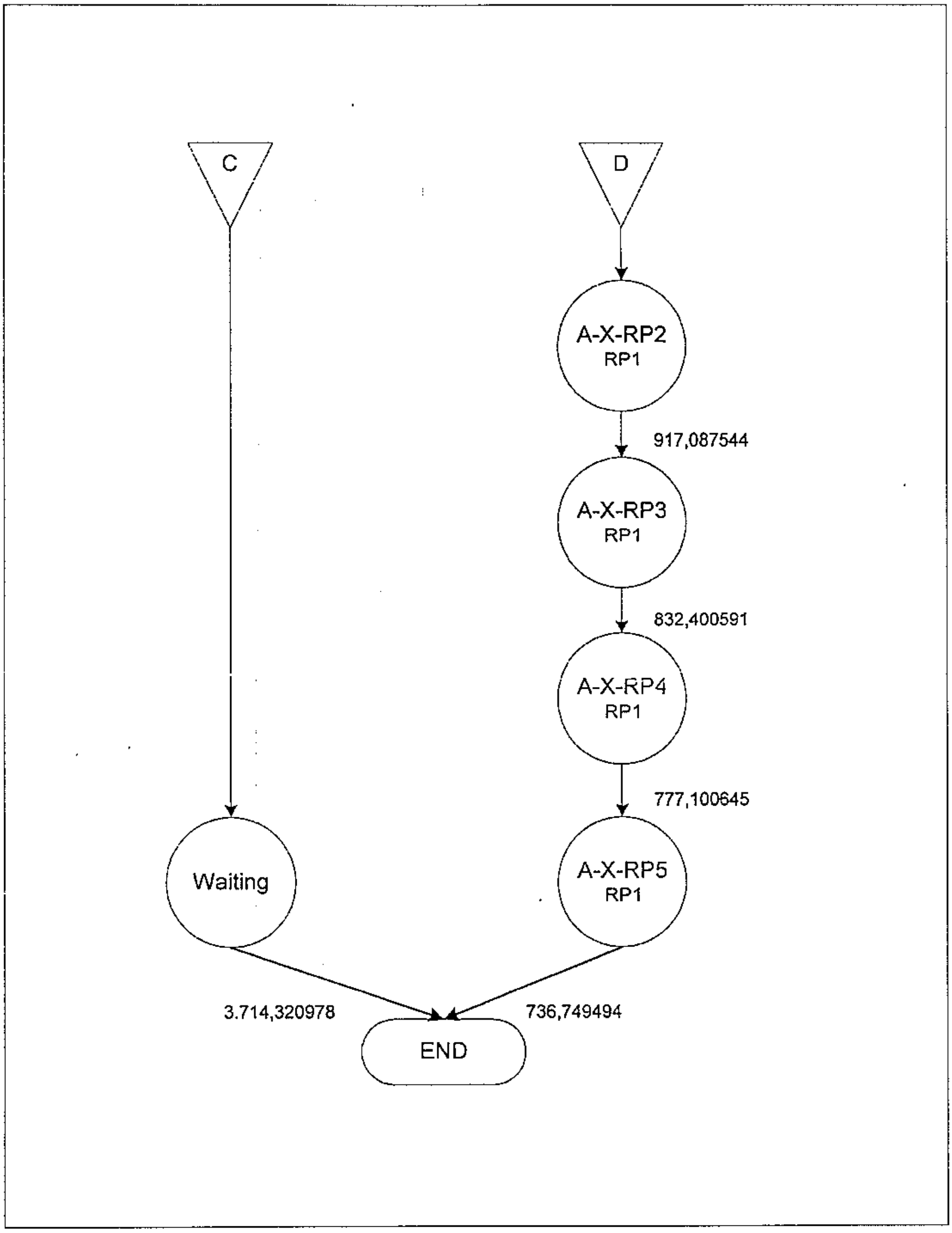
Figure 4-32
Modular Approach Phase 2 Network Diagram (Page 2)



Source: Processed primary data

Figure 4-33

Modular Approach Phase 2 Network Diagram (Page 3)



Source: Processed primary data

4.8.2 Job Type Approach Time Estimates

Development time estimate of Job-Type approach is calculated. Phase 1 calculation is done in sub-section 4.8.2.1. Phase 2 calculation is done in sub-section 4.8.2.2.

4.8.2.1 Job Type Approach Phase 1 Time Estimation Variant 1

The basis Job Type approach development is Job-Type. Programmer 1 is assigned to build AD1 Job Type. Table 4-16 shows time estimate of Job Type Approach Phase 1 variant 1 done by programmer 1

Programmer 1 is assigned to develop 6 sub-modules of AD1 Job Type. It is expected that learning effect can be detected. Development time is expected to decline as the programmer become accustomed to the standard. Development time estimation is done based on table 4-7. First sub-module is expected to take approximately 367.318015 minutes, while the last sub-module is expected to take only 99.506002 minutes. Cumulative development time is 1.100,739588.

Programmer 2 is assigned to build RP1. Table 4-16 shows time estimate of Job Type Approach Phase 2 variant 1 done by programmer 2. Programmer 2 is assigned to build RP1 Job Type. There are 5 sub-modules assigned to Programmer 2. According to the sub-module precedence, programmer 2 has to wait until Programmer 1 finish O-C-AD sub-module. Learning rate is also expected to occur. Development time estimation is done based on table -. The first sub-module (O-C-RP) is projected to take 1,082.291682 minutes, while the last sub-module is expected to take 736.749494 minutes. Cumulative development time is 4,712.947972.

Programmer 2 needs more time that Programmer 1 to complete all jobs, although Programmer 2 has fewer assignment than Programmer 1 has.

Table 4-16

Job Type Approach Phase 1 Variant 1 Time Estimates

Job Type Approach Phase 1 Variant 1

			Programer 1						Programmer 2			
No.	Phase	Seq#	Sub-module	Job Type	Time	Cummulative	Phase	Seq#	Sub-module	Job Type	Time	Cummulative
1	1	1	O-C-AD	AD1	367,318015	367,318015	1		Waiting		367,318015	367,318015
2	1	2	O-D-AD	AD1	221,626682	588,944697	1	1	O-C-RP	RP1	1.082,291682	1.449,609697
3	1	3	E-G-AD	AD1	164,918533	753,863231	1	2	O-D-RP	RP1	917,087544	2.366,697242
4	1	4	A-G-AD	AD1	133,721691	887,584921	1	3	E-G-RP	RP1	832,400591	3.199,097833
5	1	5	E-C-AD1	AD1	113,648665	1.001,233586	1	4	A-G-RP	RP1	777,100645	3.976,198477
6	1	6	E-C-AD2	AD1	99,506002	1.100,739588	1	5	E-C-RP	RP1	736,749494	4.712,947972
7			Waiting		3.612,208383	4.712,947972						
			Total idle time		3.979,526399							

Source: Processed primary data

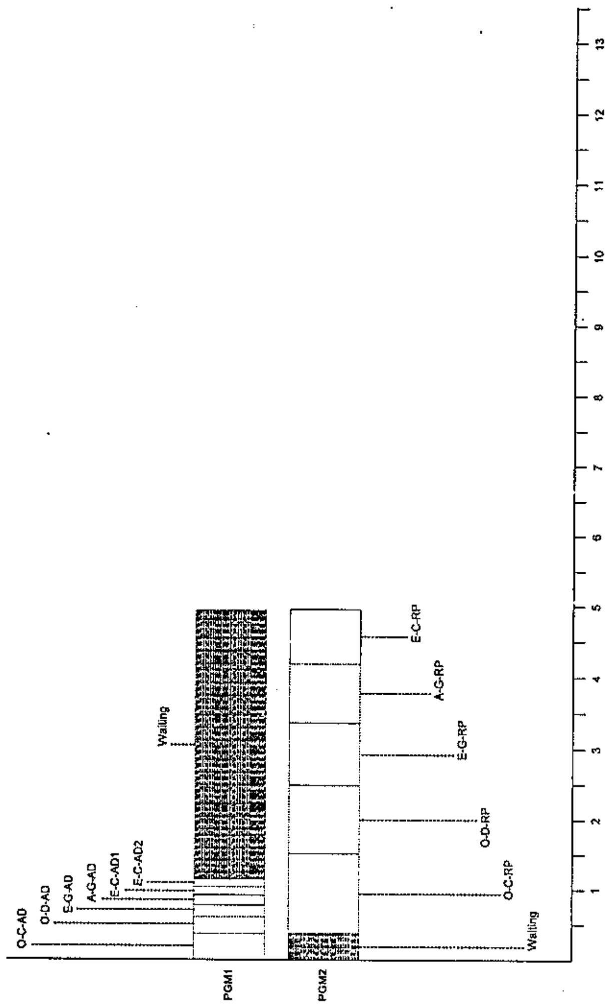
Programmer 1 has 3,612.208383 minutes of idle time. The reason is RP1 sub-modules takes more time to complete than AD1 job type.

A Gantt Chart is provided to visualize the calculation (see Figure 4-34). Network Diagram for Job-Type Approach Phase 1 can be observed at Figure 4-35.

Job type approach is designed to be free of modular boundaries. So, sub-modules can be re-arranged to to minimize idle time. This optimization, called Variant 2, can be examined in sub-section 4.8.3.1.

Figure 4-34

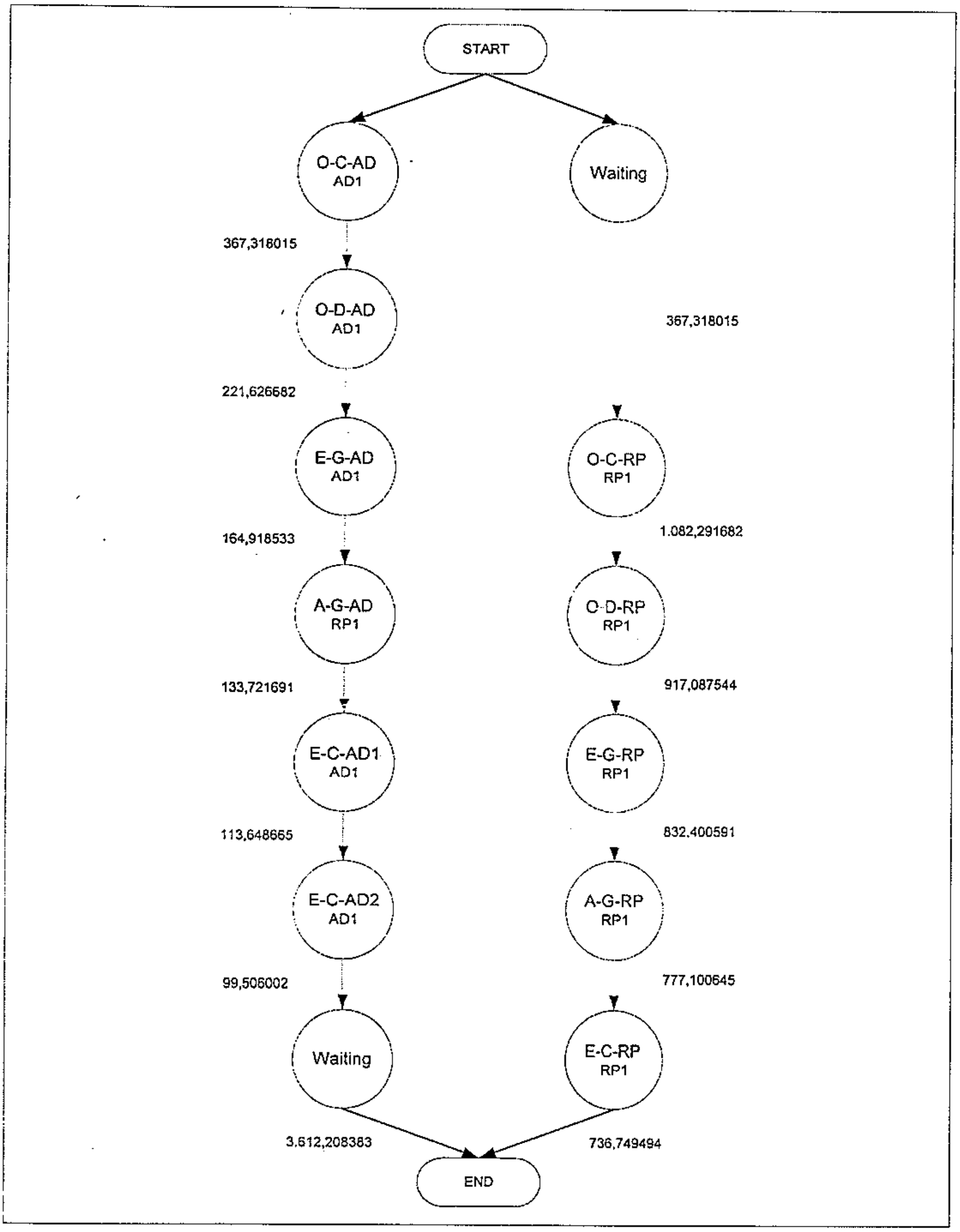
Job-Type Approach Phase 1 Variant 1 Gantt Chart



Source: Processed primary data

Figure 4-35

Job-Type Approach Phase 1 Variant 1 Network Diagram



Source: Processed primary data

4.8.2.2 Job Type Approach Phase 2 Time Estimates - Variant 1

Job Type Approach Phase 2 starts from Integration Point 1 to Integration Point 2. There are 12 (twelve) AD1-Type sub-modules and 20 (twenty) RP1-Type sub-modules. Those modules are divided in 2 steps, called Phase 2A and Phase 2B (see figure 4-26 and figure 4-27). Again, Programmer 1 is assigned to develop AD1-type sub-modules and Programmer 2 is assigned to develop the RP1-type sub-modules. Table 4-17 shows estimated development time.

Development time for AD1-Type sub-modules is expected to decline from 367.318015 minutes to 60.038398. Table 4-7 is used to construct this estimation. Total development time needed by programmer 1 is 13,143.977652 minutes.

RP1-Type sub-modules are developed by Programmer 2. Table - is used to construct this estimation. Development time of each sub-module is expected to decline from 1,082.29168 minutes to 535.520275 minutes. Learning rate effect is expected to occur in this development phase. According to the sub-module relationship and precedence, Programmer 2 has to wait 367.318015 minutes until Programmer 1 finishes W-H-AD sub-module. At the end of the development Phase Programmer 1 has to wait 11,606.999732 minutes.

Obviously, this is not a good condition. Optimization is conducted to minimize idle time. Sub-section 4.8.3.2 shows the result of the optimization process, called Phase 2 variant 2.

Table 4-17

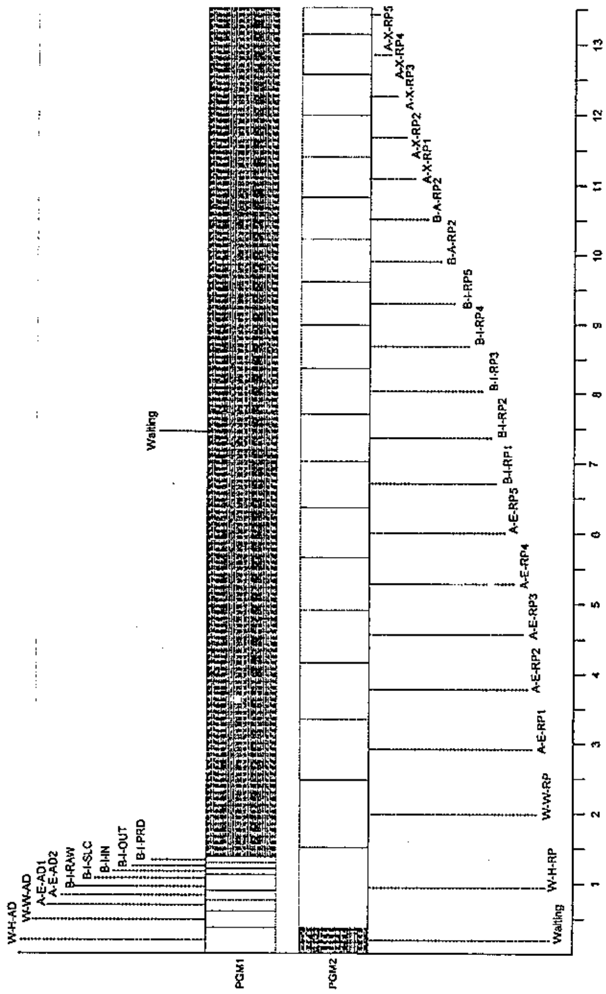
Job Type Approach Phase 2 Variant 1 Time Estimates

Job Type Approach Phase 2 Variant 1

No.	Phase	Seq#	Programer 1				Phase	Seq#	Programmer 2			
			Sub-module	Job Type	Time	Cummulative			Sub-module	Job Type	Time	Cummulative
1	2A	1	W-H-AD	AD1	367,318015	367,318015			Waiting		367,318015	367,318015
2	2A	2	W-W-AD	AD1	221,626682	588,944697	2A	1	W-H-RP	RP1	1.082,291682	1.449,609697
3	2A	3	A-E-AD1	AD1	164,918533	753,863231	2A	2	W-W-RP	RP1	917,087544	2.366,697242
4	2A	4	A-E-AD2	AD1	133,721691	887,584921	2A	3	A-E-RP1	RP1	832,400591	3.199,097833
5	2A	5	B-I-RAW	AD1	113,648665	1.001,233586	2A	4	A-E-RP2	RP1	777,100645	3.976,198477
6	2A	6	B-I-SLC	AD1	99,506002	1.100,739588	2A	5	A-E-RP3	RP1	736,749494	4.712,947972
7	2A	7	B-I-IN	AD1	88,930737	1.189,670326	2A	6	A-E-RP4	RP1	705,340553	5.418,288525
8	2A	8	B-I-OUT	AD1	80,682932	1.270,353258	2A	7	A-E-RP5	RP1	679,831656	6.098,120181
9	2A	9	B-I-PRD	AD1	74,045164	1.344,398422	2B	1	B-I-RP1	RP1	658,481751	6.756,601932
10	2B	1	A-X-ADI	AD1	68,571579	1.412,970001	2B	2	B-I-RP2	RP1	640,207031	7.396,808962
11	2B	2	A-X-ADE	AD1	63,969522	1.476,939523	2B	3	B-I-RP3	RP1	624,289917	8.021,098879
12	2B	3	A-X-ADX	AD1	60,038398	1.536,977921	2B	4	B-I-RP4	RP1	610,232322	8.631,331202
13							2B	5	B-I-RP5	RP1	597,675328	9.229,006530
14							2B	6	B-A-RP1	RP1	586,352316	9.815,358846
15							2B	7	B-A-RP2	RP1	576,060182	10.391,419028
16							2B	8	A-X-RP1	RP1	566,640883	10.958,059911
17							2B	9	A-X-RP2	RP1	557,969189	11.516,029100
18							2B	10	A-X-RP3	RP1	549,944303	12.065,973403
19							2B	11	A-X-RP4	RP1	542,483975	12.608,457378
20			Waiting		11.606,999732	13.143,977652	2B	12	A-X-RP5	RP1	535,520275	13.143,977652
			Total idle Time		11.974,317747							

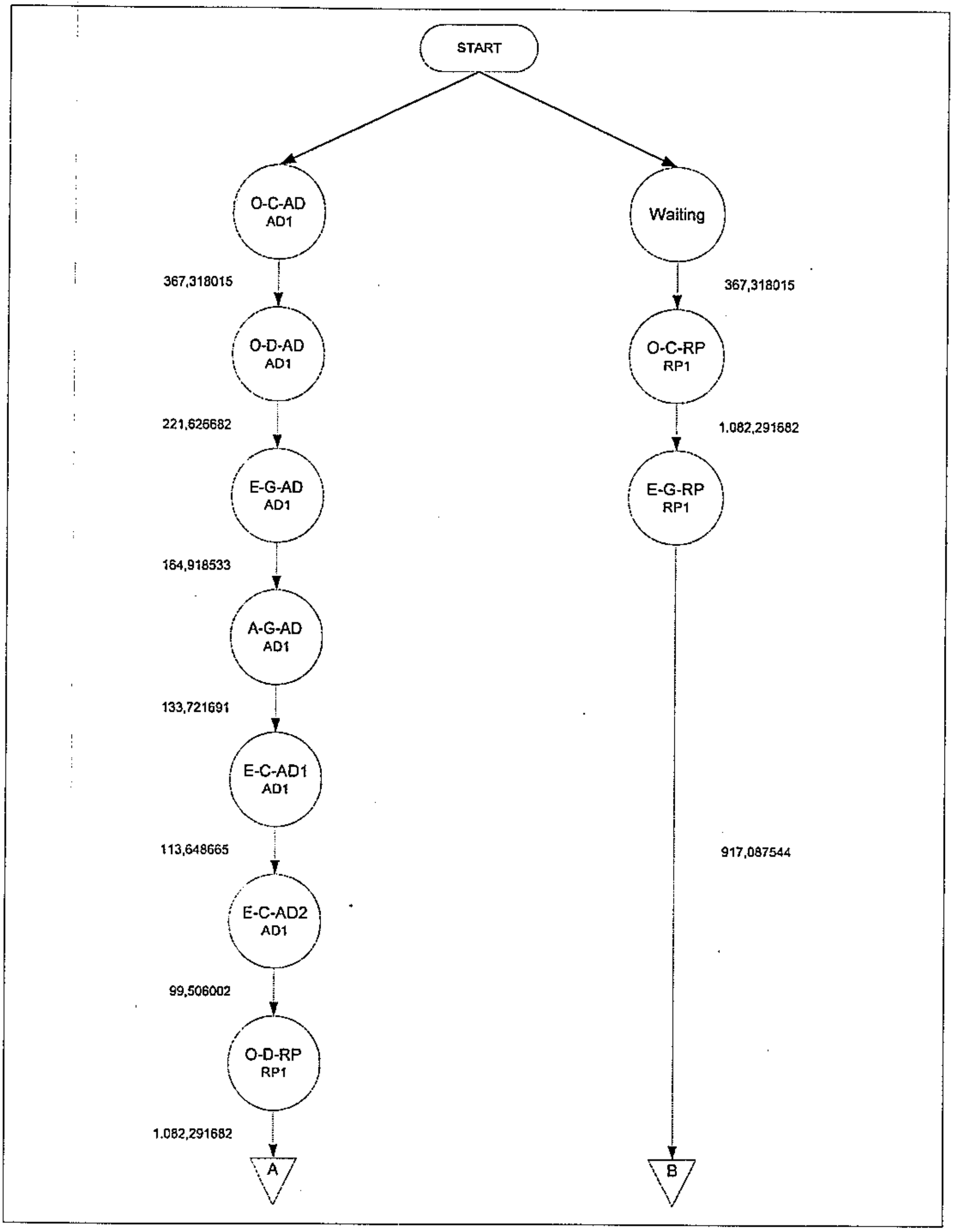
Source: Processed primary data

Figure 4-36
Job-Type Approach Phase 2 Variant 1 Gantt Chart



Source: Processed primary data

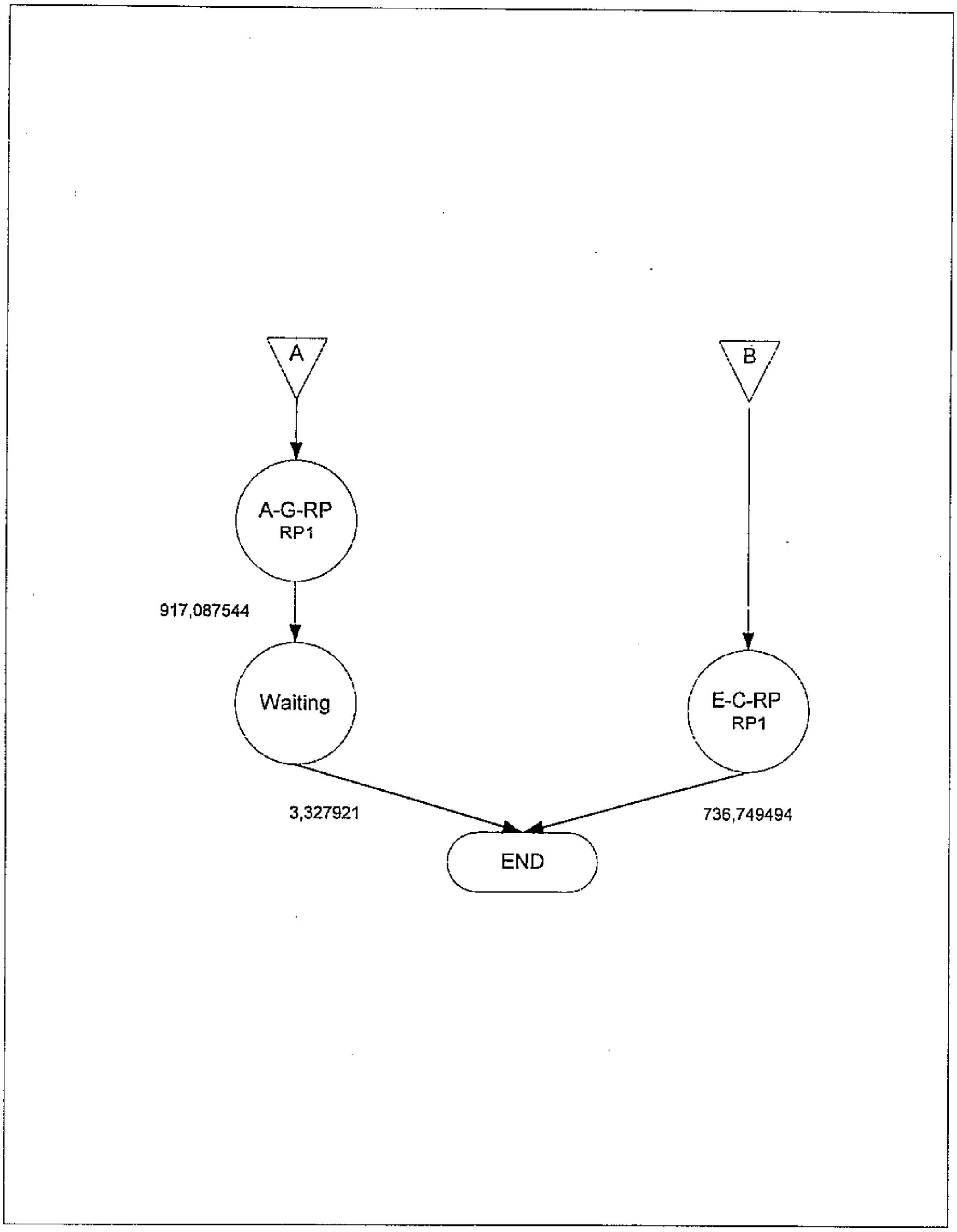
Figure 4-37
Job-Type Approach Phase 2 Variant 1 Network Diagram (Page 1)



Source: Processed primary data

Figure 4-38

Job-Type Approach Phase 2 Variant 1 Network Diagram (Page 2)



Source: Processed primary data

4.8.3 Job Type Approach Optimization

Lengthy idle time is not a good condition. Idle time means inefficiency. Project manager always seeks a better work method. This condition also applies to the current development process. Suffering a substantial amount of idle time, an optimization process is conducted. The following two sub-sections describe the optimization process. Basically, optimization process is done by re-arranging sub-module sequence to balance the workload of a programmer without sacrificing sub-module precedence.

4.8.3.1 Job Type Approach Phase 1 Time Estimation Variant 2

Programmer 1 has a substantial amount of idle time at the end of the process. As soon as the programmer finishes AD1-Type sub-modules, RP1-Type sub-modules are assigned. O-D-RP and A-G-RP sub modules are switched from Programmer 2 to Programmer 1. Table 4-18 shows the result of this optimization process.

Total idle time is decreased from 3,979.526399 to 370.645937 minutes. It is inevitable that Programmer 2 has to wait Programmer 1 finishes the O-C-AD. Switching O-D-RP and A-G-RP sub-module to Programmer 1 does not violate the sub-module relationship and precedence. Beside, those two sub-modules have the same job type, so learning effect is expected to occur again.

Table 4-18

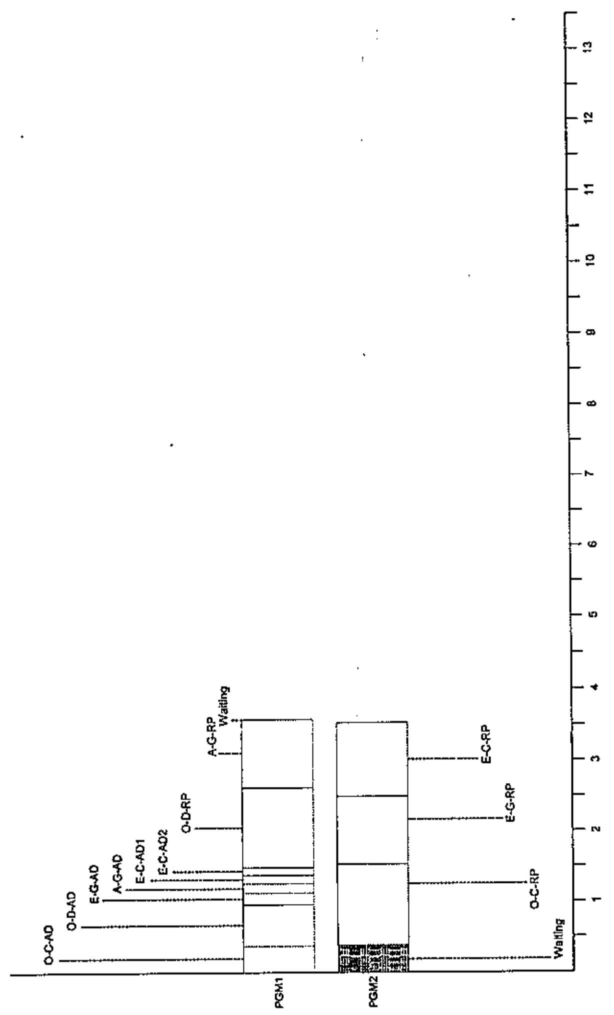
Job Type Approach Phase 1 Variant 2 Time Estimates

Job Type Approach Phase 2 Variant 1

No.	Phase	Seq#	Programer 1				Phase	Seq#	Programmer 2			
			Sub-module	Job Type	Time	Cummulative			Sub-module	Job Type	Time	Cummulative
1	2A	1	W-H-AD	AD1	367,318015	367,318015			Waiting		367,318015	367,318015
2	2A	2	W-W-AD	AD1	221,626682	588,944697	2A	1	W-H-RP	RP1	1.082,291682	1.449,609697
3	2A	3	A-E-AD1	AD1	164,918533	753,863231	2A	2	W-W-RP	RP1	917,087544	2.366,697242
4	2A	4	A-E-AD2	AD1	133,721691	887,584921	2A	3	A-E-RP1	RP1	832,400591	3.199,097833
5	2A	5	B-I-RAW	AD1	113,648665	1.001,233586	2A	4	A-E-RP2	RP1	777,100645	3.976,198477
6	2A	6	B-I-SLC	AD1	99,506002	1.100,739588	2A	5	A-E-RP3	RP1	736,749494	4.712,947972
7	2A	7	B-I-IN	AD1	88,930737	1.189,670326	2A	6	A-E-RP4	RP1	705,340553	5.418,288525
8	2A	8	B-I-OUT	AD1	80,682932	1.270,353258	2A	7	A-E-RP5	RP1	679,831656	6.098,120181
9	2A	9	B-I-PRD	AD1	74,045164	1.344,398422	2B	1	B-I-RP1	RP1	658,481751	6.756,601932
10	2B	1	A-X-ADI	AD1	68,571579	1.412,970001	2B	2	B-I-RP2	RP1	640,207031	7.396,808962
11	2B	2	A-X-ADE	AD1	63,969522	1.476,939523	2B	3	B-I-RP3	RP1	624,289917	8.021,098879
12	2B	3	A-X-ADX	AD1	60,038398	1.536,977921	2B	4	B-I-RP4	RP1	610,232322	8.631,331202
13							2B	5	B-I-RP5	RP1	597,675328	9.229,006530
14							2B	6	B-A-RP1	RP1	586,352316	9.815,358846
15							2B	7	B-A-RP2	RP1	576,060182	10.391,419028
16							2B	8	A-X-RP1	RP1	566,640883	10.958,059911
17							2B	9	A-X-RP2	RP1	557,969189	11.516,029100
18							2B	10	A-X-RP3	RP1	549,944303	12.065,973403
19							2B	11	A-X-RP4	RP1	542,483975	12.608,457378
20			Waiting		11.606,999732	13.143,977652	2B	12	A-X-RP5	RP1	535,520275	13.143,977652
			Total idle Time		11.974,317747							

Source : Processed primary data

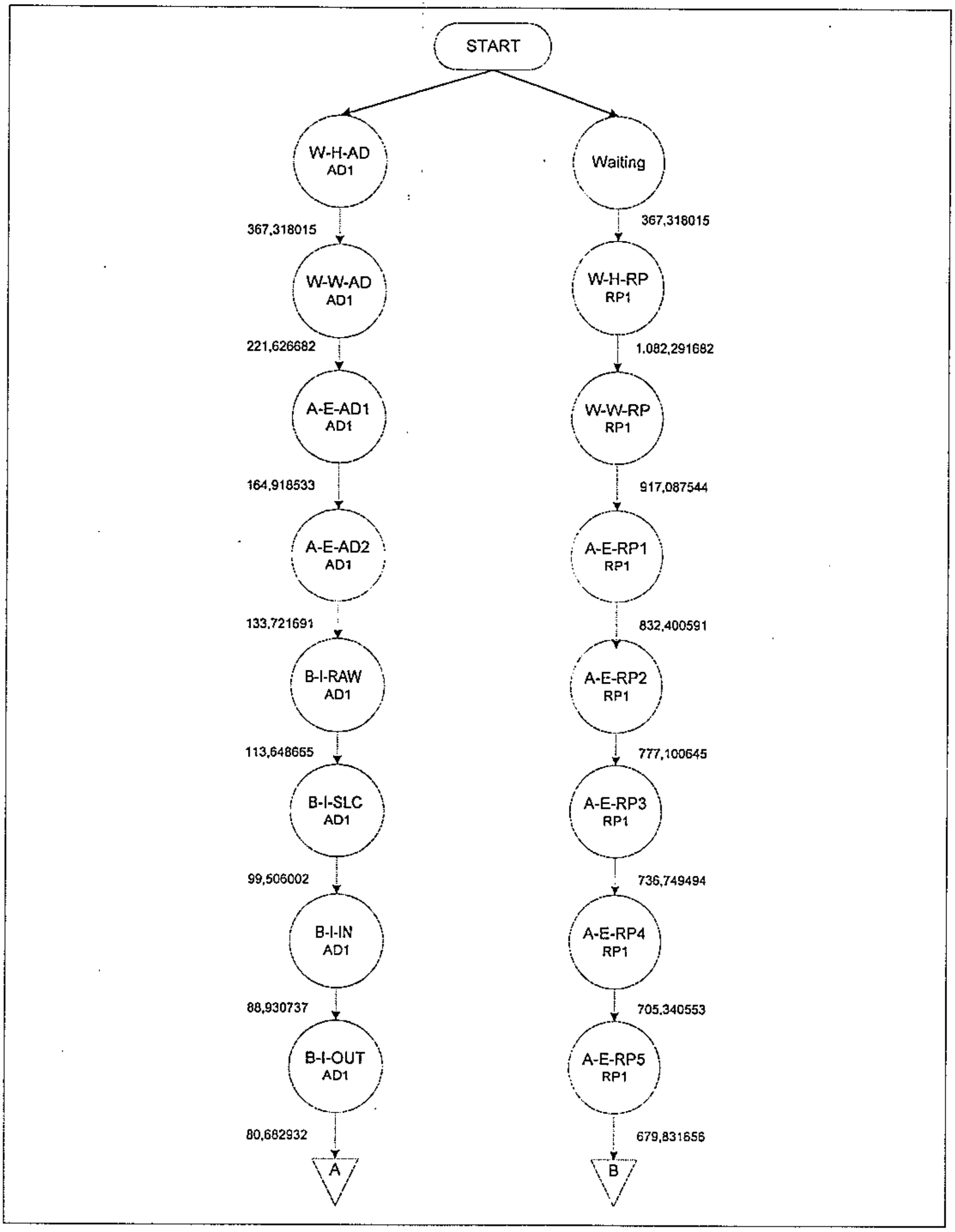
Figure 4-39
Job-Type Approach Phase 1 Variant 2 Gantt Chart



Source: Processed primary data

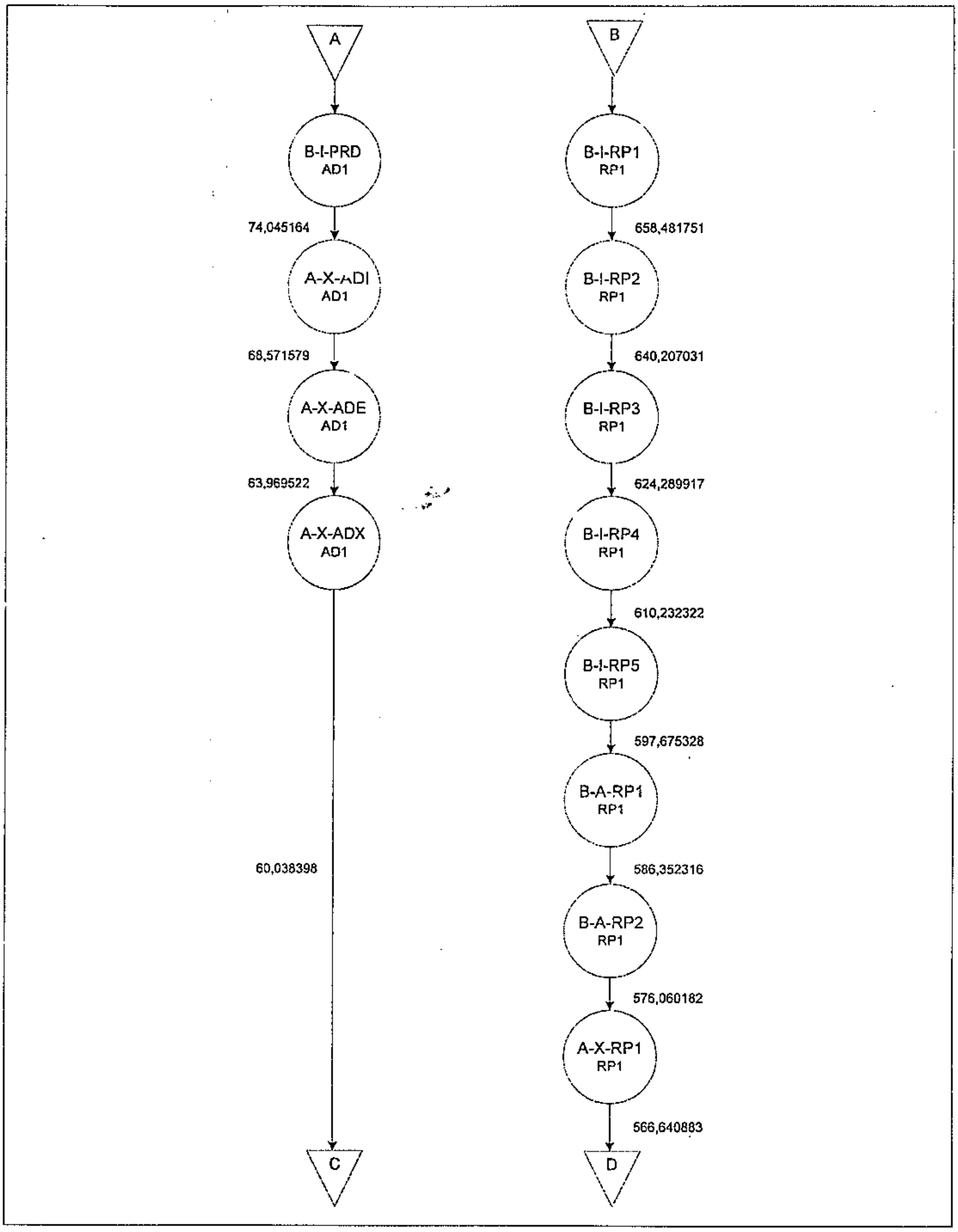
Figure 4-40

Job-Type Approach Phase 1 Variant 2 Network Diagram (Page 1)



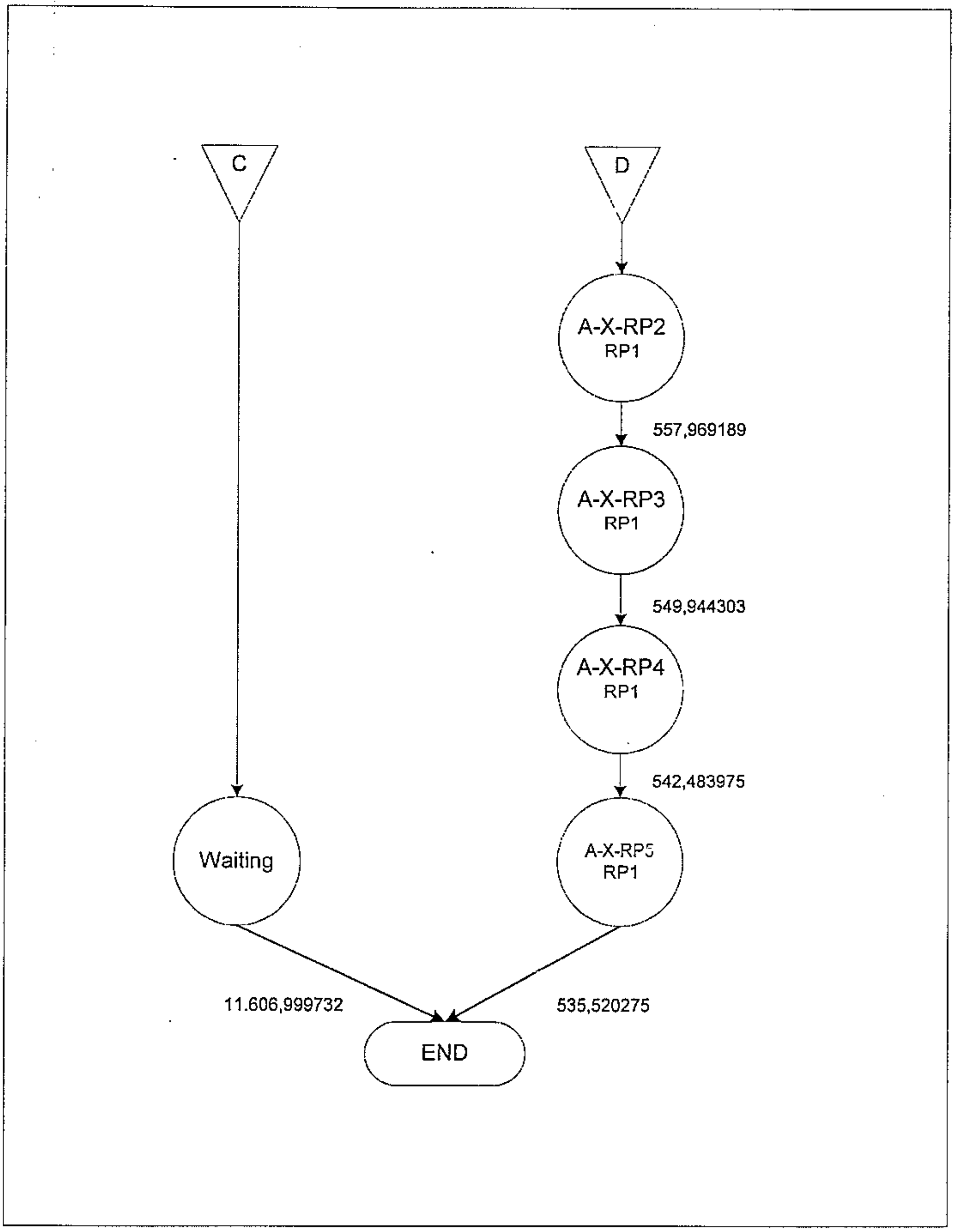
Source: Processed primary data

Figure 4-41
Job-Type Approach Phase 1 Variant 2 Network Diagram (Page 2)



Source: Processed primary data

Figure 4-42
Job-Type Approach Phase 1 Variant 2 Network Diagram (Page 3)



Source: Processed primary data

4.8.3.2 Job Type Approach Phase 2 Time Estimation Variant 2

Optimization process is also done in Phase 2 of Job Type Approach. The optimization process is done by switching A-E-RP1, A-E-RP2, A-E-RP3, A-E-RP4, A-E-RP5, A-X-RP1 and A-X-RP1 sub-modules from Programmer 2 to Programmer 1. These sub-modules has the same job type: RP1. Table 4-19 show the result of this optimization process.

This process is projected to cut the idle time from11,974.317747 minute to 491.967972 minutes. This optimization process does not sacrifice the sub-module precedence. Re-arranging sub-modules is possible, because Job Type approach does not restrict the development sequence based on the modules.

Table 4-19

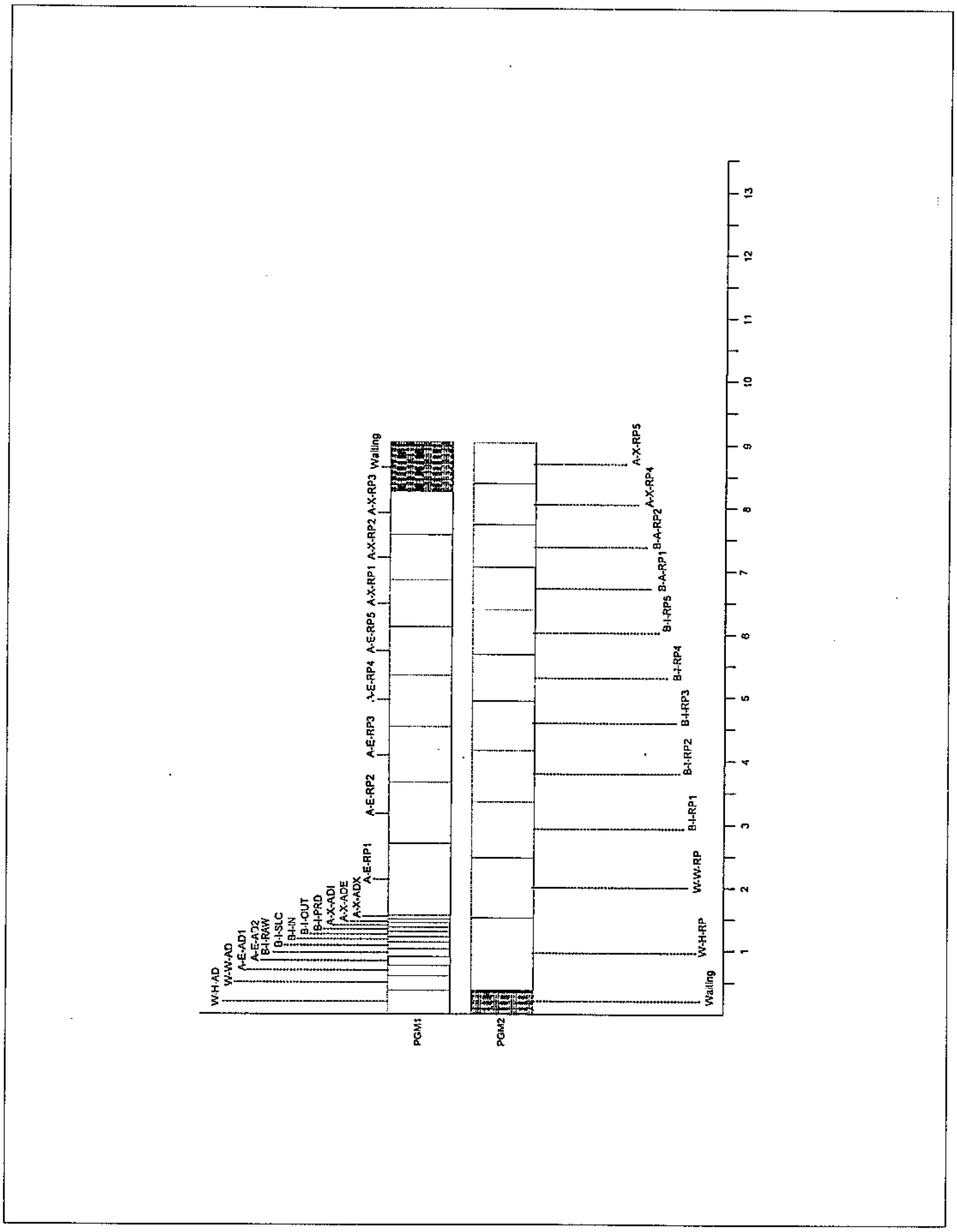
Job Type Approach Phase 2 Variant 2 Time Estimates

Job Type Approach Phase 2 Variant 2

			Programer 1						Programmer 2			
No.	Phase	Seq#	Sub-module	Job Type	Time	Cummulative	Phase	Seq#	Sub-module	Job Type	Time	Cummulative
1	2A	1	W-H-AD	AD1	367,318015	367,318015			Waiting		367,318015	367,318015
2	2A	2	W-W-AD	AD1	221,626682	588,944697	2A	1	W-H-RP	RP1	1.082,291682	1.449,609697
3	2A	3	A-E-AD1	AD1	164,918533	753,863231	2A	2	W-W-RP	RP1	917,087544	2.366,697242
4	2A	4	A-E-AD2	AD1	133,721691	887,584921	2B	1	B-I-RP1	RP1	832,400591	3.199,097833
5	2A	5	B-I-RAW	AD1	113,648665	1.001,233586	2B	2	B-I-RP2	RP1	777,100645	3.976,198477
6	2A	6	B-I-SLC	AD1	99,506002	1.100,739588	2B	3	B-I-RP3	RP1	736,749494	4.712,947972
7	2A	7	B-I-IN	AD1	88,930737	1.189,670326	2B	4	B-I-RP4	RP1	705,340553	5.418,288525
8	2A	8	B-I-OUT	AD1	80,682932	1.270,353258	2B	5	B-I-RP5	RP1	679,831656	6.098,120181
9	2A	9	B-I-PRD	AD1	74,045164	1.344,398422	2B	6	B-A-RP1	RP1	658,481751	6.756,601932
10	2B	1	A-X-ADI	AD1	68,571579	1.412,970001	2B	7	B-A-RP2	RP1	640,207031	7.396,808962
11	2B	2	A-X-ADE	AD1	63,969522	1.476,939523	2B	10	A-X-RP4	RP1	624,289917	8.021,098879
12	2B	3	A-X-ADX	AD1	60,038398	1.536,977921	2B	11	A-X-RP5	RP1	610,232322	8.631,331202
13	2A	4	A-E-RP1	RP1	1.082,291682	3.448,988924						
14	2A	5	A-E-RP2	RP1	917,087544	4.366,076468						
15	2A	6	A-E-RP3	RP1	832,400591	5.198,477059						
16	2A	7	A-E-RP4	RP1	777,100645	5.975,577704						
17	2A	8	A-E-RP5	RP1	736,749494	6.712,327198						
18	2B	9	A-X-RP1	RP1	705,340553	7.417,667751						
19	2B	10	A-X-RP2	RP1	679,831656	8.097,499407						
20	2B	11	A-X-RP3	RP1	658,481751	8.755,981158			Waiting		124,649956	8.755,981158
									Total Idle time		491,967972	

Source: Processed primary data

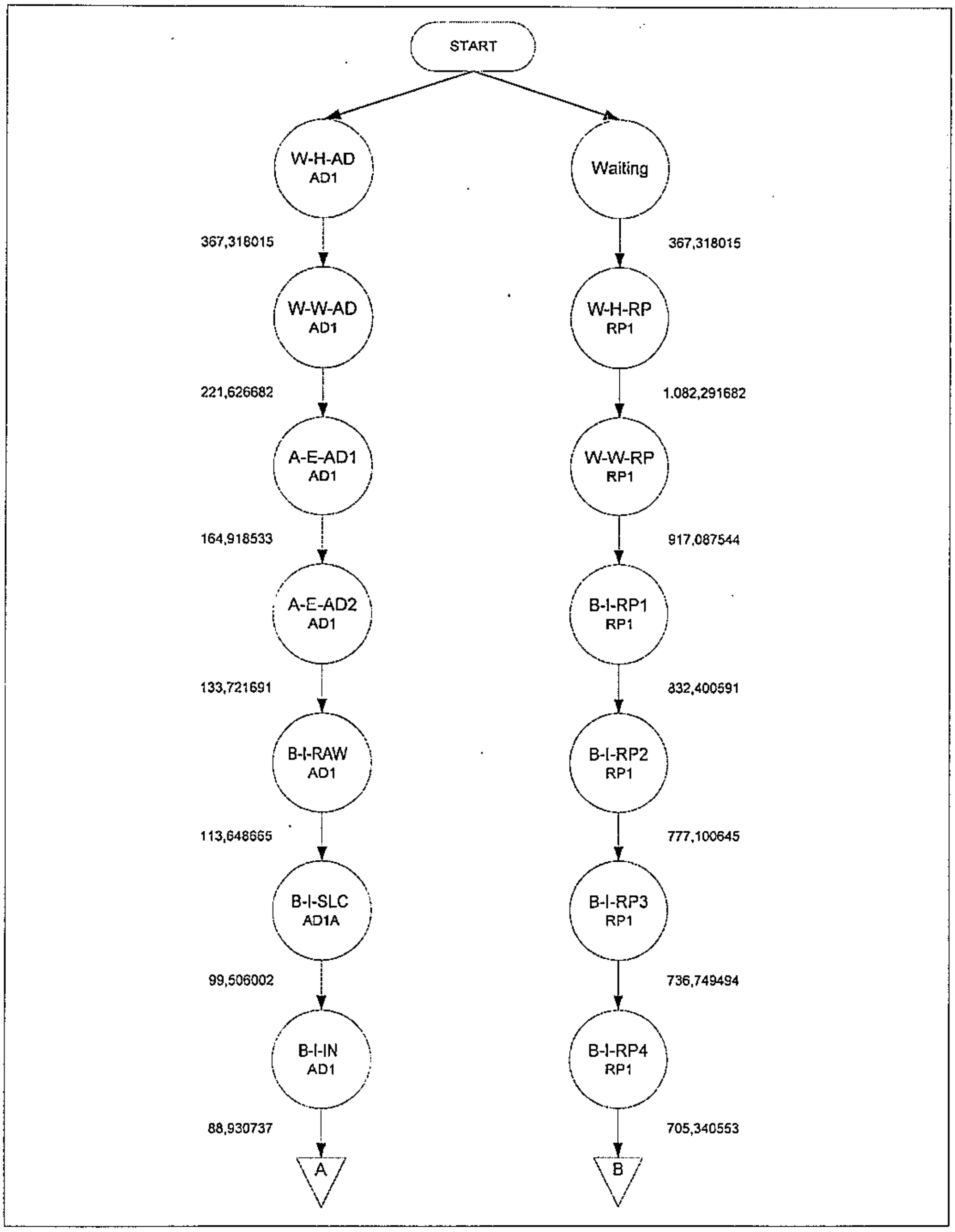
Figure 4-43
Job-Type Approach Phase 2 Variant 2 Gantt Chart



Source: Processed primary data

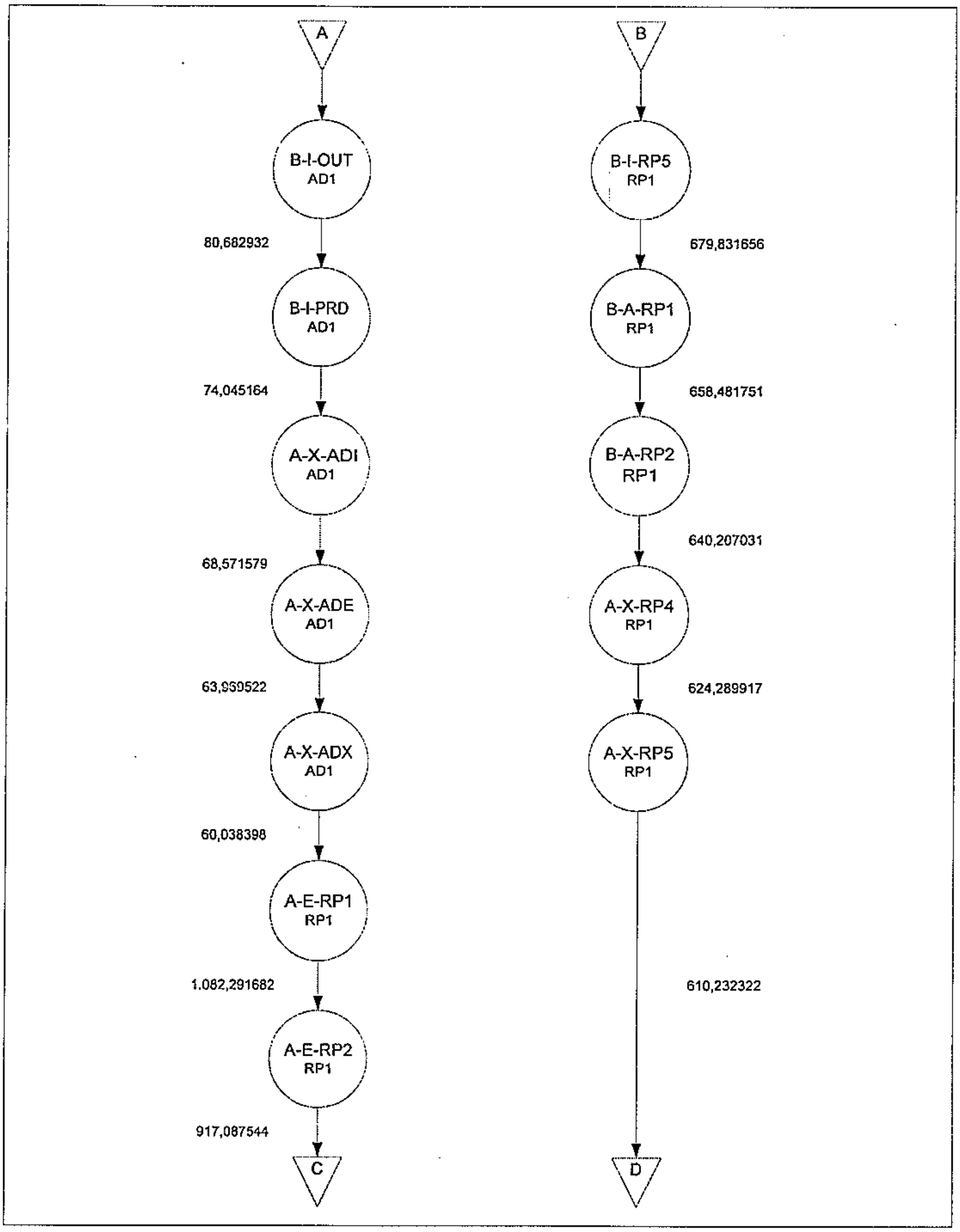
Figure 4-44

Job-Type Approach Phase 2 Variant 2 Network Diagram (Page 1)



Source: Processed primary data

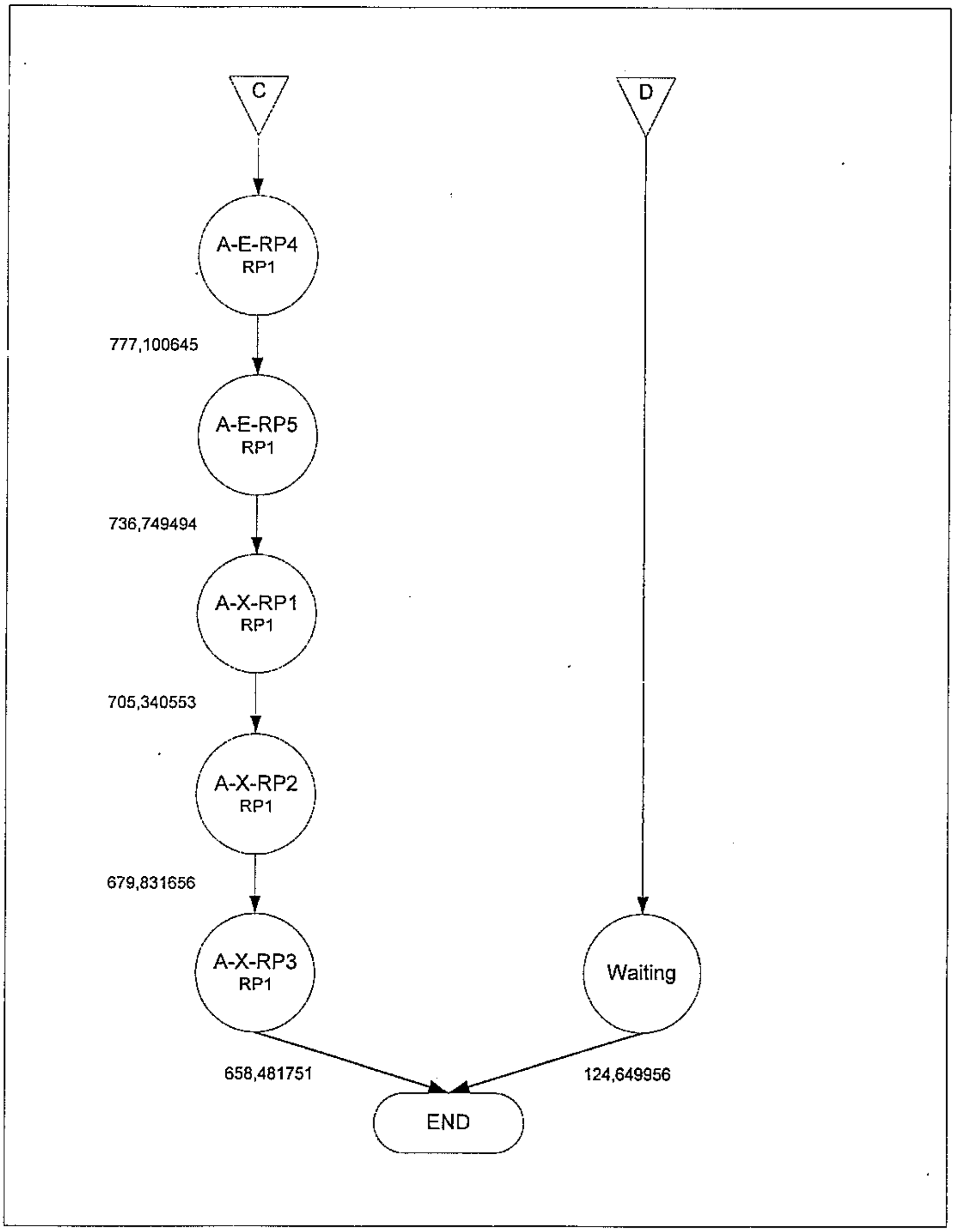
Figure 4-45
Job-Type Approach Phase 2 Variant 2 Network Diagram (Page 2)



Source: Processed primary data

Figure 4-46

Job-Type Approach Phase 2 Variant 2 Network Diagram (Page 3)



Source: Processed primary data

4.8.4 Critical Path and Slack Time Calculations

The Biometric Time and Attendance Systems Development contains many sub-modules. The precedence of those sub-modules has been observed previously. As the complexity of the project grows, the project manager requires more information about the earliest time an activity can begin vice versa (Eppen, Gould and Schmidt, 1988; Hillier and Lieberman, 2001; Levin, *et al.,* 1989; Render and Heizer, 2004; Stevenson, 2003). Required information is described below.

1. Earliest Start (ES): the earliest time of an activity can start

2. Earliest Finish (EF): the latest time of an activity can finish

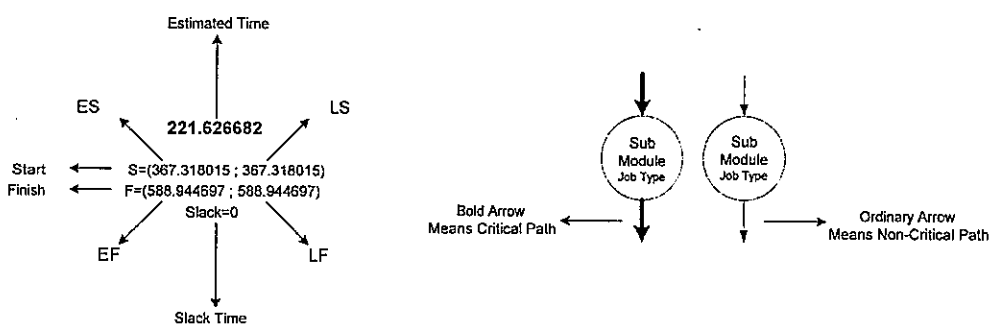
3. Latest Start (LS): the latest time of an activity to start without delay the project

4. Latest Finish (LF): the latest time of an activity can finish without delay the project

5. Slack time: the amount of time for an activity can be delayed without causing delays in the whole project.

ES, EF, LS, LF and Slack Time Calculation and Critical Path Identification will be presented in the following tables and figures. Figure 4-47 is provided to help interpretation of the numbers

Figure 4-47
ES, EF, LF, LS and Slack Time Legend



Source: Developed for this thesis. Partially adopted from Hillier and Lieberman (2001), *"Introduction to Operations Research"*

ES, EF, LS, LF and Slack Time Calculation of Modular Approach Phase 1 is provided in Table 4-20, while Phase 2 is provided in Table 4-21. Graphical representation and Critical Path Identification for Phase 1 is provided in Figure 4-48 while Phase 2 can be found in Figure 4-49, 4-50 and 4-51. The length of Critical Path is 16.099,104185 minutes.

ES, EF, LS, LF and Slack Time Calculation of Job-Type Approach Phase 1 Variant 1 is provided in Table 4-22, while Phase 2 Variant 1 is provided in Table 4-23. Graphical representation and Critical Path Identification for Phase 1 Variant 1 is provided in Figure 4-52 while Phase 2 Variant 1 can be found in Figure 4-53, 4-54 and 4-55. The length of Critical Path is 16.247,424388 minutes.

ES, EF, LS, LF and Slack Time Calculation of Job-Type Approach Phase 1 Variant 2 is provided in Table 4-24, while Phase 2 Variant 2 is provided in Table 4-25. Graphical representation and Critical Path Identification for Phase 1 Variant 2 is provided in Figure 4-56 and 4-57, while Phase 2 Variant 1 can be found in Figure 4-59, 4-60 and 4-61. The length of Critical Path is 11.859,427894 minutes.

The result of the estimation process is summarized in Table 4-26

Table 4-20

Slack Time Calculation for
Modular Approach Phase 1

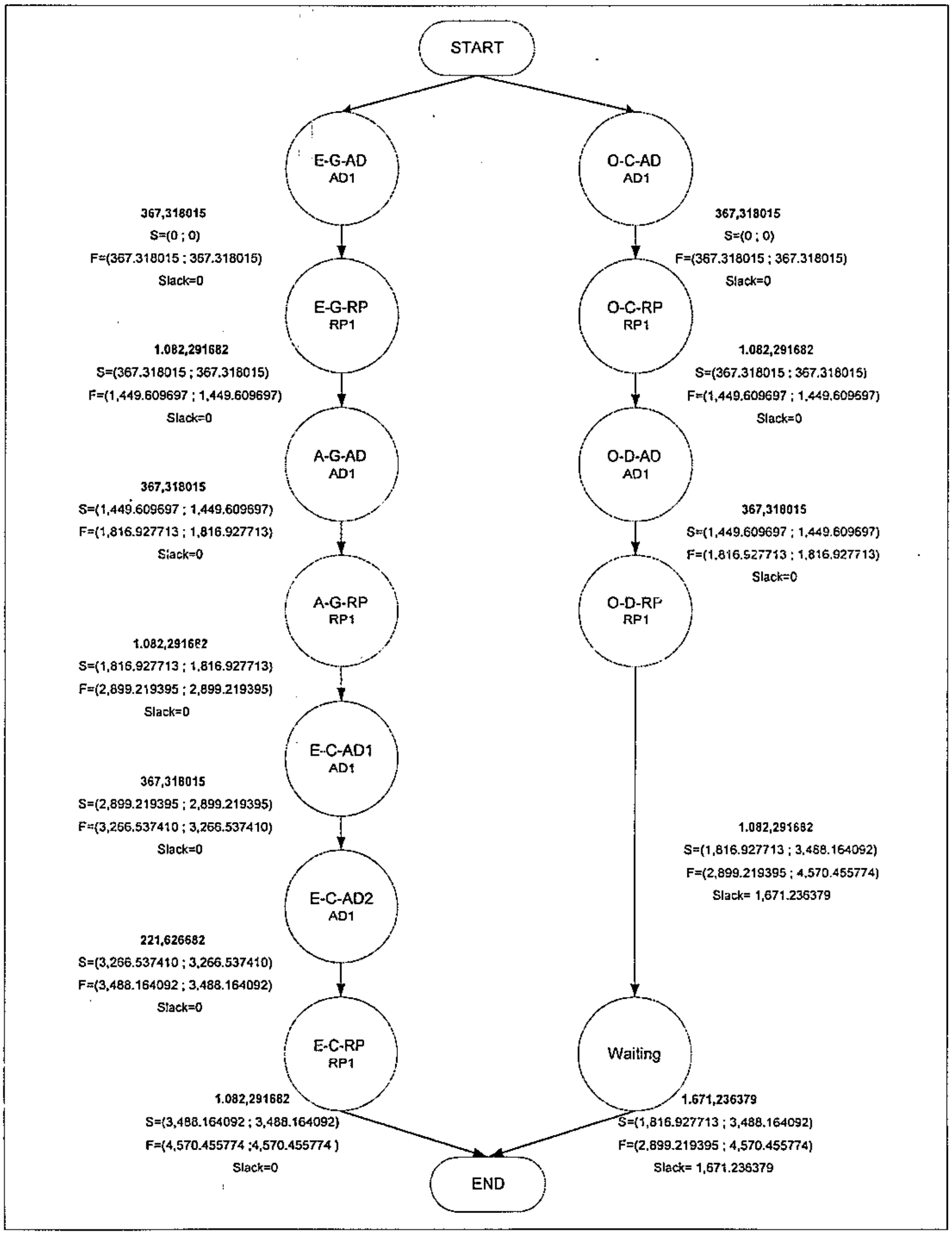
SlackTime Calculation
Modular Approach Phase 1

No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	1	1	1	E-G-AD	AD1	367,318015	367,318015	-	367,318015	367,318015	-	-	Yes
2	1	1	2	E-G-RP	RP1	1.082,291682	1.449,609697	367,318015	1.449,609697	1.449,609697	367,318015	-	Yes
3	1	1	3	A-G-AD	AD1	367,318015	1.816,927713	1.449,609697	1.816,927713	1.816,927713	1.449,609697	-	Yes
4	1	1	4	A-G-RP	RP1	1.082,291682	2.899,219395	1.816,927713	2.899,219395	2.899,219395	1.816,927713	-	Yes
5	1	1	5	E-C-AD1	AD1	367,318015	3.266,537410	2.899,219395	3.266,537410	3.266,537410	2.899,219395	-	Yes
6	1	1	6	E-C-AD2	AD1	221,626682	3.488,164092	3.266,537410	3.488,164092	3.488,164092	3.266,537410	-	Yes
7	1	1	7	E-C-RP	RP1	1.082,291682	4.570,455774	3.488,164092	4.570,455774	4.570,455774	3.488,164092	-	Yes

No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	2	1	1	O-C-AD	AD1	367,318015	367,318015	-	367,318015	367,318015	-	-	No
2	2	1	2	O-C-RP	RP1	1.082,291682	1.449,609697	367,318015	1.449,609697	1.449,609697	367,318015	-	No
3	2	1	3	O-D-AD	AD1	367,318015	1.816,927713	1.449,609697	1.816,927713	1.816,927713	1.449,609697	-	No
4	2	1	4	O-D-RP	RP1	1.082,291682	2.899,219395	1.816,927713	2.899,219395	4.570,455774	3.488,164092	1.671,236379	No
5	2	1	5	Waiting		1.671,236379	4.570,455774						

Source: Processed primary data

Figure 4-48
ES, EF, LF, LS and Slack Time for
Modular Approach Phase 1



Source: Processed primary data

Table 4-21

Slack Time Calculation for
Modular Approach Phase 2

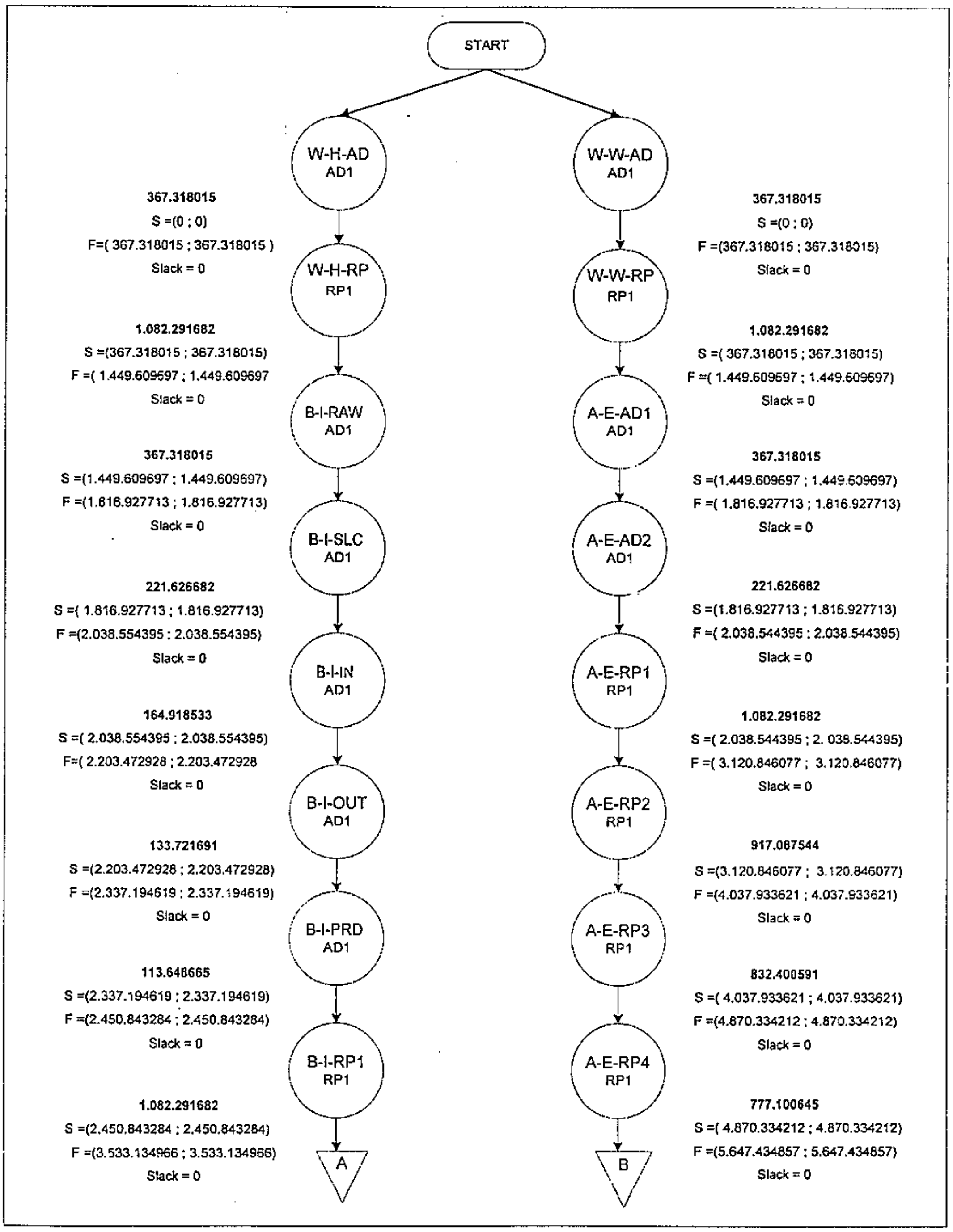
SlackTime Calculation
Modular Type Phase 2

No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	1	2A	1	W-H-AD	AD1	367,318015	367,318015	-	367,318015	367,318015	-	-	Yes
2	1	2A	2	W-H-RP	RP1	1.082,291682	1.449,609697	367,318015	1.449,609697	1.449,609697	367,318015	-	Yes
3	1	2B	1	B-I-RAW	AD1	367,318015	1.816,927713	1.449,609697	1.816,927713	1.816,927713	1.449,609697	-	Yes
4	1	2B	2	B-I-SLC	AD1	221,626682	2.038,554395	1.816,927713	2.038,554395	2.038,554395	1.816,927713	-	Yes
5	1	2B	3	B-I-IN	AD1	164,918533	2.203,472928	2.038,554395	2.203,472928	2.203,472928	2.038,554395	-	Yes
6	1	2B	4	B-I-OUT	AD1	133,721691	2.337,194619	2.203,472928	2.337,194619	2.337,194619	2.203,472928	-	Yes
7	1	2B	5	B-I-PRD	AD1	113,548665	2.450,843284	2.337,194619	2.450,843284	2.450,843284	2.337,194619	-	Yes
8	1	2B	6	B-I-RP1	RP1	1.082,291682	3.533,134966	2.450,843284	3.533,134966	3.533,134966	2.450,843284	-	Yes
9	1	2B	7	B-I-RP2	RP1	917,087544	4.450,222510	3.533,134966	4.450,222510	4.450,222510	3.533,134966	-	Yes
10	1	2B	8	B-I-RP3	RP1	832,400591	5.282,623101	4.450,222510	5.282,623101	5.282,623101	4.450,222510	-	Yes
11	1	2B	9	B-I-RP4	RP1	777,100645	6.059,723745	5.282,623101	6.059,723745	6.059,723745	5.282,623101	-	Yes
12	1	2B	10	B-I-RP5	RP1	736,749494	6.796,473240	6.059,723745	6.796,473240	6.796,473240	6.059,723745	-	Yes
13	1	2C	1	B-A-RP1	RP1	705,340553	7.501,813793	6.796,473240	7.501,813793	7.501,813793	6.796,473240	-	No
14	1	2C	2	B-A-RP2	RP1	679,831656	8.181,645449	7.501,813793	8.181,645449	11.895,966427	11.216,134771	3.714,320978	No
15	1			Waiting		3.714,320978	11.895,966427						

No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	2	2A	1	W-W-AD	AD1	367	367	-	367,318015	367,318015	-	-	No
2	2	2A	2	W-W-RP	RP1	1.082	1.450	367,318015	1.449,609697	1.449,609697	367,318015	-	No
3	2	2B	1	A-E-AD1	AD1	367	1.817	1.449,609697	1.816,927713	1.818,927713	1.449,609697	-	No
4	2	2B	2	A-E-AD2	AD1	222	2.039	1.816,927713	2.038,554395	2.038,554395	1.816,927713	-	No
5	2	2B	3	A-E-RP1	RP1	1.082	3.121	2.038,554395	3.120,846077	3.120,846077	2.038,554395	-	No
6	2	2B	4	A-E-RP2	RP1	917	4.038	3.120,846077	4.037,933621	4.037,933621	3.120,846077	-	No
7	2	2B	5	A-E-RP3	RP1	832	4.870	4.037,933621	4.870,334212	4.870,334212	4.037,933621	-	No
8	2	2B	6	A-E-RP4	RP1	777	5.647	4.870,334212	5.647,434857	5.647,434857	4.870,334212	-	No
9	2	2B	7	A-E-RP5	RP1	737	6.384	5.647,434857	6.384,184351	6.796,473240	6.059,723745	412,288889	No
10	2			Waiting		412	6.796						
11	2	2C	1	A-X-ADI	AD1	367	7.164	6.796,473240	7.163,791255	7.163,791255	6.796,473240	-	Yes
12	2	2C	2	A-X-ADE	AD1	222	7.385	7.163,791255	7.385,417937	7.385,417937	7.163,791255	-	Yes
13	2	2C	3	A-X-ADX	AD1	165	7.550	7.385,417937	7.550,336470	7.550,336470	7.385,417937	-	Yes
14	2	2C	4	A-X-RP1	RP1	1.082	8.633	7.550,336470	8.632,628152	8.632,628152	7.550,336470	-	Yes
15	2	2C	5	A-X-RP2	RP1	917	9.550	8.632,628152	9.549,715697	9.549,715697	8.632,628152	-	Yes
16	2	2C	6	A-X-RP3	RP1	832	10.382	9.549,715697	10.382,116288	10.382,116288	9.549,715697	-	Yes
17	2	2C	7	A-X-RP4	RP1	777	11.159	10.382,116288	11.159,216932	11.159,216932	10.382,116288	-	Yes
18	2	2C	8	A-X-RP5	RP1	737	11.896	11.159,216932	11.895,966427	11.895,966427	11.159,216932	-	Yes

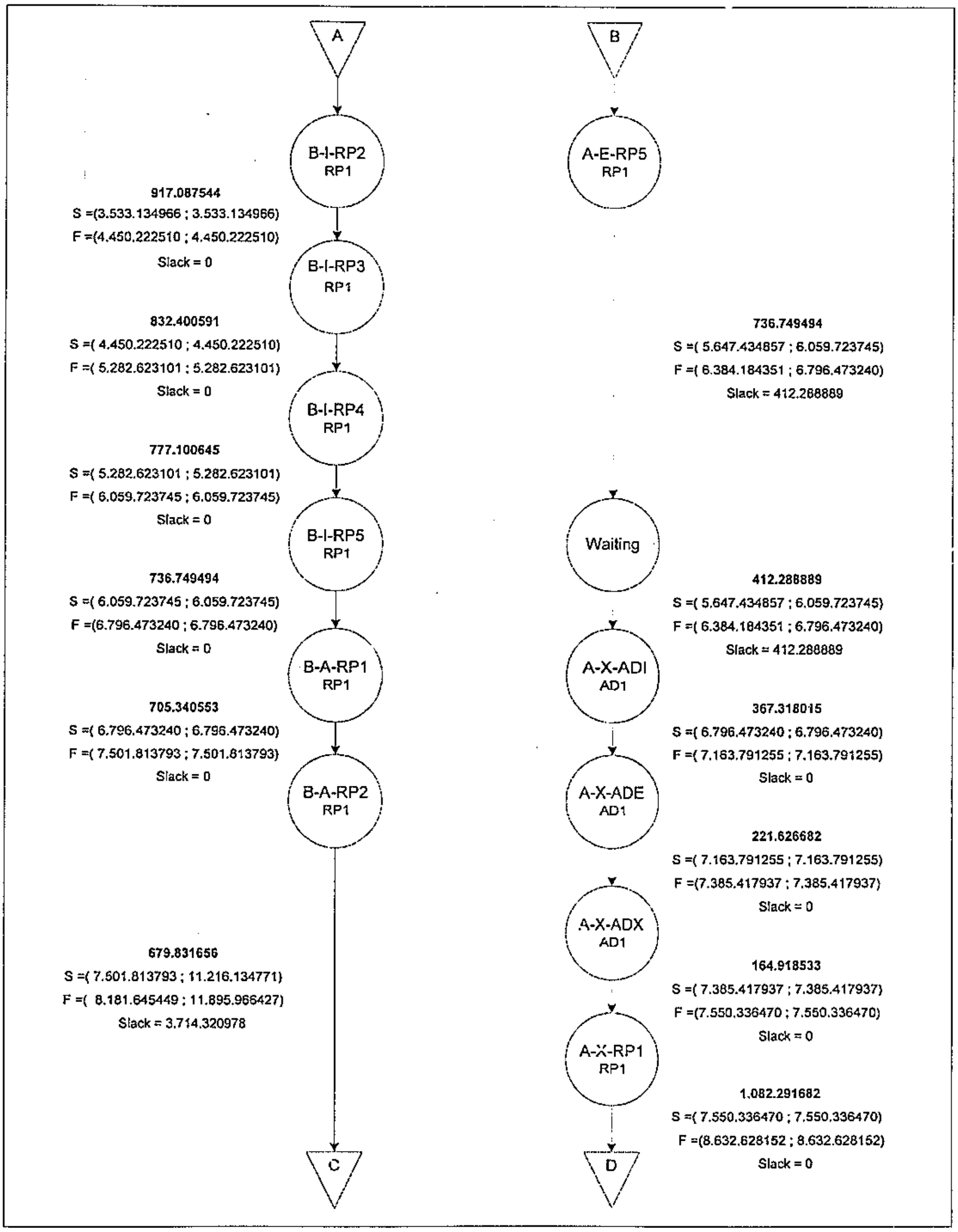
Source: Processed primary data

Figure 4-49
ES, EF, LF, LS and Slack Time
Modular Approach Phase 2 (Page 1)



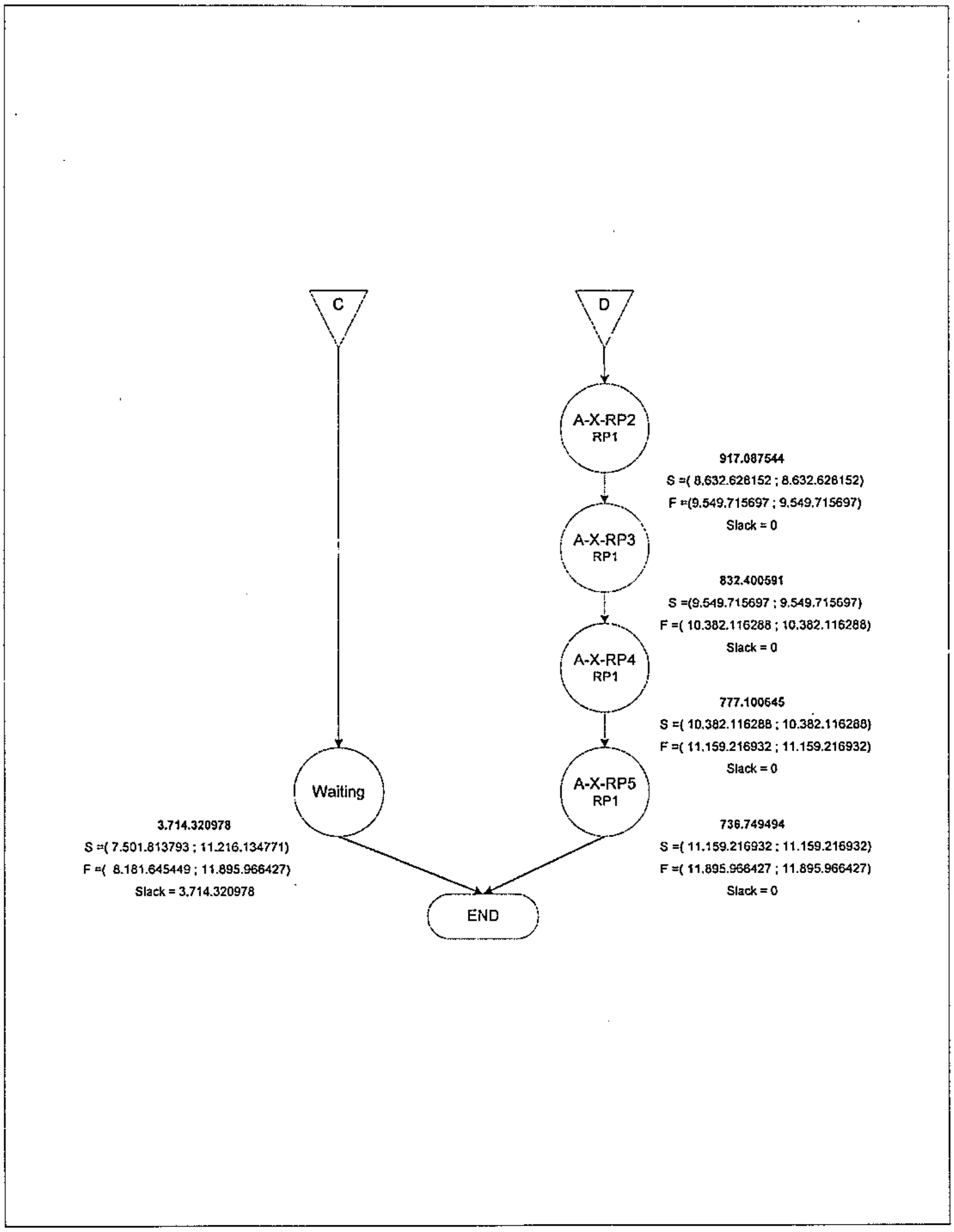
Source: Processed primary data

Figure 4-50
ES, EF, LF, LS and Slack Time
Modular Approach Phase 2 (Page 2)



Source: Processed primary data

Figure 4-51
ES, EF, LF, LS and Slack Time
Modular Approach Phase 2 (Page 3)



Source: Processed primary data

Table 4-22

Slack Time Calculation for
Job Type Approach Phase 1 Variant 1

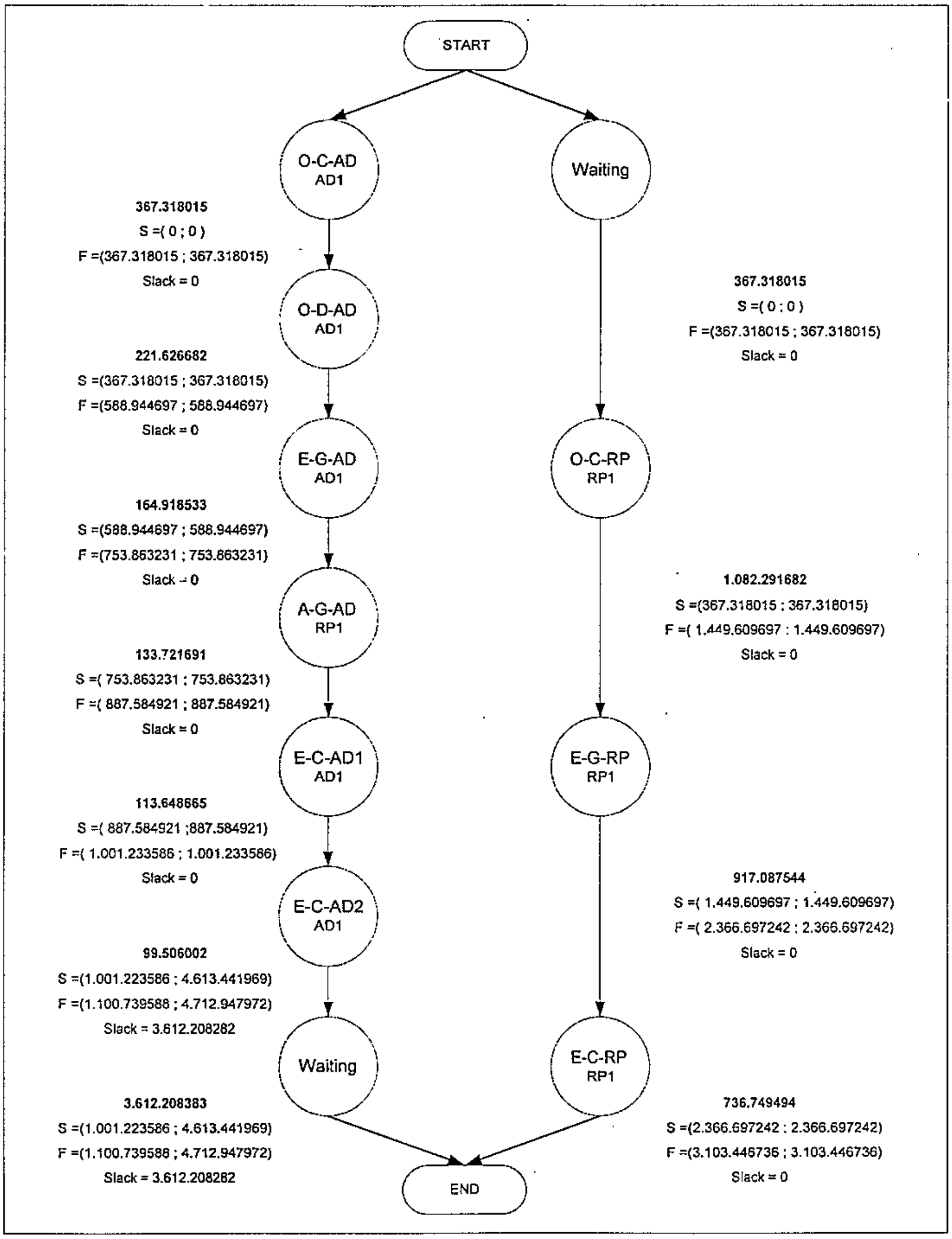
SlackTime Calculation
Job Type Approach Phase 1 Variant 1

No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	1	1	1	O-C-AD	AD1	367,318015	367,318015	-	367,318015	367,318015	-	-	No
2	1	1	2	O-D-AD	AD1	221,626682	588,944697	367,318015	588,944697	588,944697	367,318015	-	No
3	1	1	3	E-G-AD	AD1	164,918533	753,863231	588,944697	753,863231	753,863231	588,944697	-	No
4	1	1	4	A-G-AD	AD1	133,721691	887,584921	753,863231	887,584921	887,584921	753,863231	-	No
5	1	1	5	E-C-AD1	AD1	113,648665	1.001,233586	887,584921	1.001,233586	1.001,233586	887,584921	-	No
6	1	1	6	E-C-AD2	AD1	99,506002	1.100,739588	1.001,233586	1.100,739588	4.712,947972	4.613,441969	3.612,208383	No
7	1	1		Waiting		3.612,208383	4.712,947972						

No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	2	1	-	Waiting	-	367	367	-	367,318015	367,318015	-	-	Yes
2	2	1	1	O-C-RP	RP1	1.082	1.450	367,318015	1.449,609697	1.449,609697	367,318015	-	Yes
3	2	1	2	E-G-RP	RP1	917	2.367	1.449,609697	2.366,697242	2.366,697242	1.449,609697	-	Yes
4	2	1	3	E-C-RP	RP1	737	3.103	2.366,697242	3.103,446736	3.103,446736	2.366,697242	-	Yes

Source: Processed primary data

Figure 4-52
ES, EF, LF, LS and Slack Time for Job-Type Approach
Phase 1 Variant 1



Source: Processed primary data

Table 4-23
Slack Time Calculation for
Job Type Approach Phase 2 Variant 1

SlackTime Calculation
Job Type Approach Phase 2 Variant 1

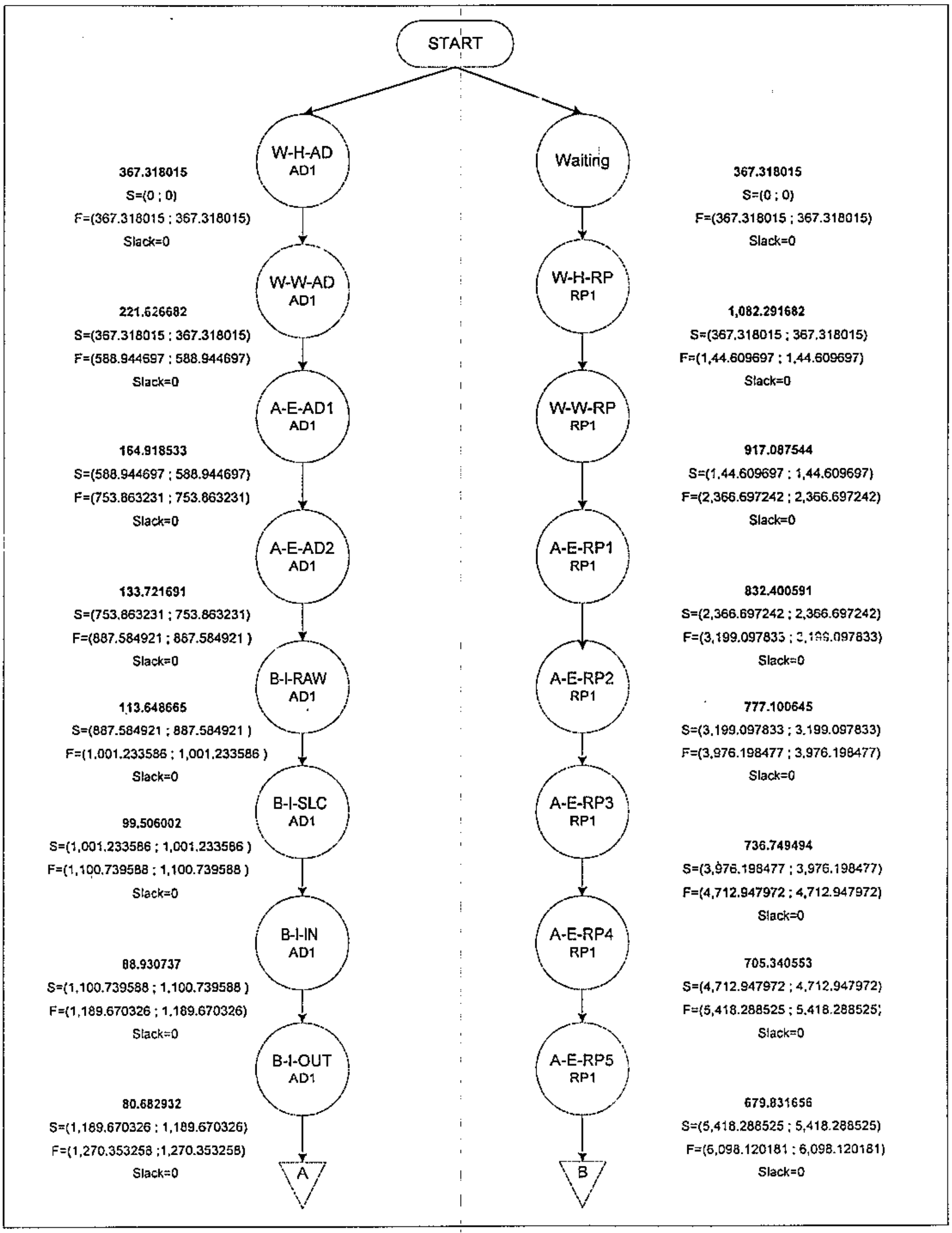
No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
						V		1	3	4	2		
1	1	2A	1	W-H-AD	AD1	367,318015	367,318015	-	367,318015	367,318015	-	-	No
2	1	2A	2	W-W-AD	AD1	221,626682	588,944697	367,318015	588,944697	588,944697	367,318015	-	No
3	1	2A	3	A-E-AD1	AD1	164,918533	753,863231	588,944697	753,863231	753,863231	588,944697	-	No
4	1	2A	4	A-E-AD2	AD1	133,721691	887,584921	753,863231	887,584921	887,584921	753,863231	-	No
5	1	2A	5	B-I-RAW	AD1	113,648665	1.001,233586	887,584921	1.001,233586	1.001,233586	887,584921	-	No
6	1	2A	6	B-I-SLC	AD1	99,506002	1.100,739588	1.001,233586	1.100,739588	1.100,739588	1.001,233586	-	No
7	1	2A	7	B-I-IN	AD1	88,930737	1.189,670326	1.100,739588	1.189,670326	1.189,670326	1.100,739588	-	No
8	1	2A	8	B-I-OUT	AD1	80,682932	1.270,353258	1.189,670326	1.270,353258	1.270,353258	1.189,670326	-	No
9	1	2A	9	B-I-PRD	AD1	74,045164	1.344,398422	1.270,353258	1.344,398422	1.344,398422	1.270,353258	-	No
10	1	2B	1	A-X-ADI	AD1	68,571579	1.412,970001	1.344,398422	1.412,970001	1.412,970001	1.344,398422	-	No
11	1	2B	2	A-X-ADE	AD1	63,969522	1.476,939523	1.412,970001	1.476,939523	1.476,939523	1.412,970001	-	No
12	1	2B	3	A-X-ADX	AD1	60,038398	1.536,977921	1.476,939523	1.536,977921	13.143,977652	13.083,939255	11.606,999732	No
13	1			Waiting		11.606,999732	13.143,977652						

No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	2	-	-	Waiting	-	367,318015	367,318015	-	367,318015	367,318015	-	-	Yes
2	2	2A	1	W-H-RP	RP1	1.082,291682	1.449,609697	367,318015	1.449,609697	1.449,609697	367,318015	-	Yes
3	2	2A	2	W-W-RP	RP1	917,087544	2.366,697242	1.449,609697	2.366,697242	2.366,697242	1.449,609697	-	Yes
4	2	2A	3	A-E-RP1	RP1	832,400591	3.199,097833	2.366,697242	3.199,097833	3.199,097833	2.366,697242	-	Yes
5	2	2A	4	A-E-RP2	RP1	777,100645	3.976,198477	3.199,097833	3.976,198477	3.976,198477	3.199,097833	-	Yes
6	2	2A	5	A-E-RP3	RP1	736,749494	4.712,947972	3.976,198477	4.712,947972	4.712,947972	3.976,198477	-	Yes
7	2	2A	6	A-E-RP4	RP1	705,340553	5.418,288525	4.712,947972	5.418,288525	5.418,288525	4.712,947972	-	Yes
8	2	2A	7	A-E-RP5	RP1	679,831656	6.098,120181	5.418,288525	6.098,120181	6.098,120181	5.418,288525	-	Yes
9	2	2B	1	B-I-RP1	RP1	658,481751	6.756,601932	6.098,120181	6.756,601932	6.756,601932	6.098,120181	-	Yes
10	2	2B	2	B-I-RP2	RP1	640,207031	7.396,808962	6.756,601932	7.396,808962	7.396,808962	6.756,601932	-	Yes
11	2	2B	3	B-I-RP3	RP1	624,289917	8.021,098879	7.396,808962	8.021,098879	8.021,098879	7.396,808962	-	Yes
12	2	2B	4	B-I-RP4	RP1	610,232322	8.631,331202	8.021,098879	8.631,331202	8.631,331202	8.021,098879	-	Yes
13	2	2B	5	B-I-RP5	RP1	597,675328	9.229,006530	8.631,331202	9.229,006530	9.229,006530	8.631,331202	-	Yes
14	2	2B	6	B-A-RP1	RP1	586,352316	9.815,358846	9.229,006530	9.815,358846	9.815,358846	9.229,006530	-	Yes
15	2	2B	7	B-A-RP2	RP1	576,060182	10.391,419028	9.815,358846	10.391,419028	10.391,419028	9.815,358846	-	Yes
16	2	2B	8	A-X-RP1	RP1	566,640883	10.958,059911	10.391,419028	10.958,059911	10.958,059911	10.391,419028	-	Yes
17	2	2B	9	A-X-RP2	RP1	557,969189	11.516,029100	10.958,059911	11.516,029100	11.516,029100	10.958,059911	-	Yes
18	2	2B	10	A-X-RP3	RP1	549,944303	12.065,973403	11.516,029100	12.065,973403	12.065,973403	11.516,029100	-	Yes
19	2	2B	11	A-X-RP4	RP1	542,483975	12.608,457378	12.065,973403	12.608,457378	12.608,457378	12.065,973403	-	Yes
20	2	2B	12	A-X-RP5	RP1	535,520275	13.143,977652	12.608,457378	13.143,977652	13.143,977652	12.608,457378	-	Yes

Source: Processed primary data

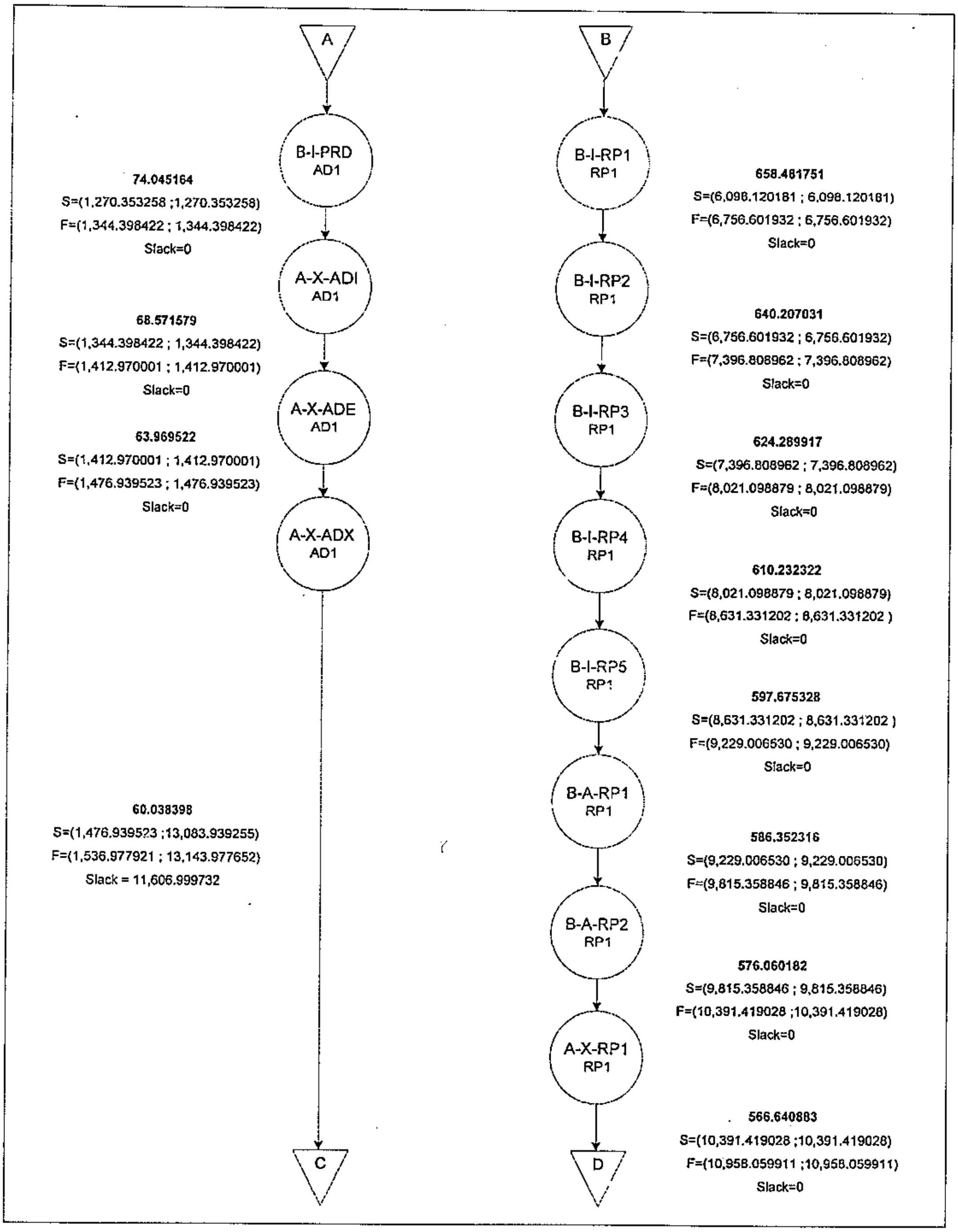
Figure 4-53

ES, EF, LF, LS and Slack Time for Job-Type Approach
Phase 2 Variant 1 (Page 1)



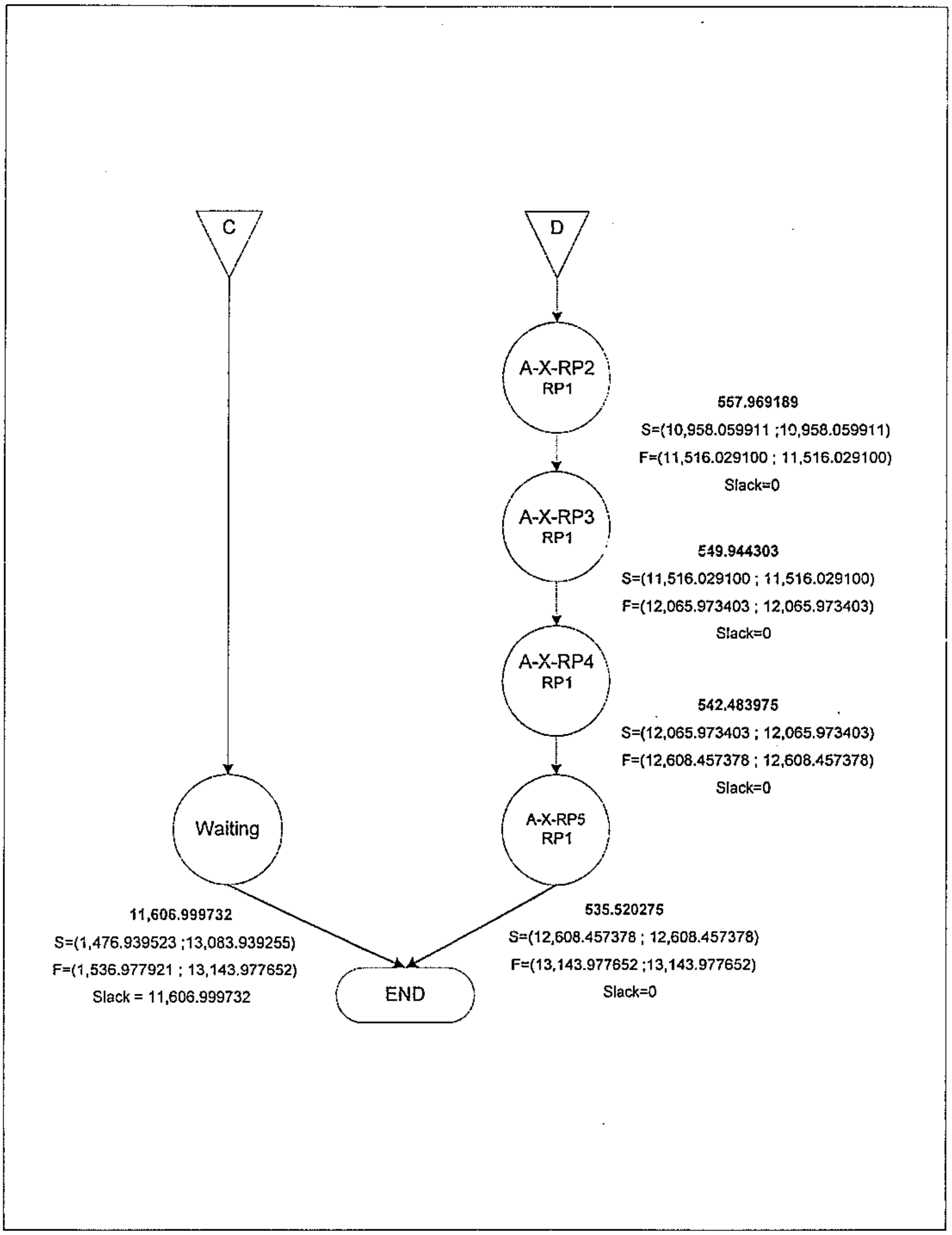
Source: Processed primary data

Figure 4-54
ES, EF, LF, LS and Slack Time for Job-Type Approach
Phase 2 Variant 1 (Page 2)



Source: Processed primary data

Figure 4-55
ES, EF, LF, LS and Slack Time for Job-Type Approach
Phase 2 Variant 1 (Page 3)



Source: Processed primary data

Table 4-24

Slack Time Calculation for
Job Type Approach Phase 1 Variant 2

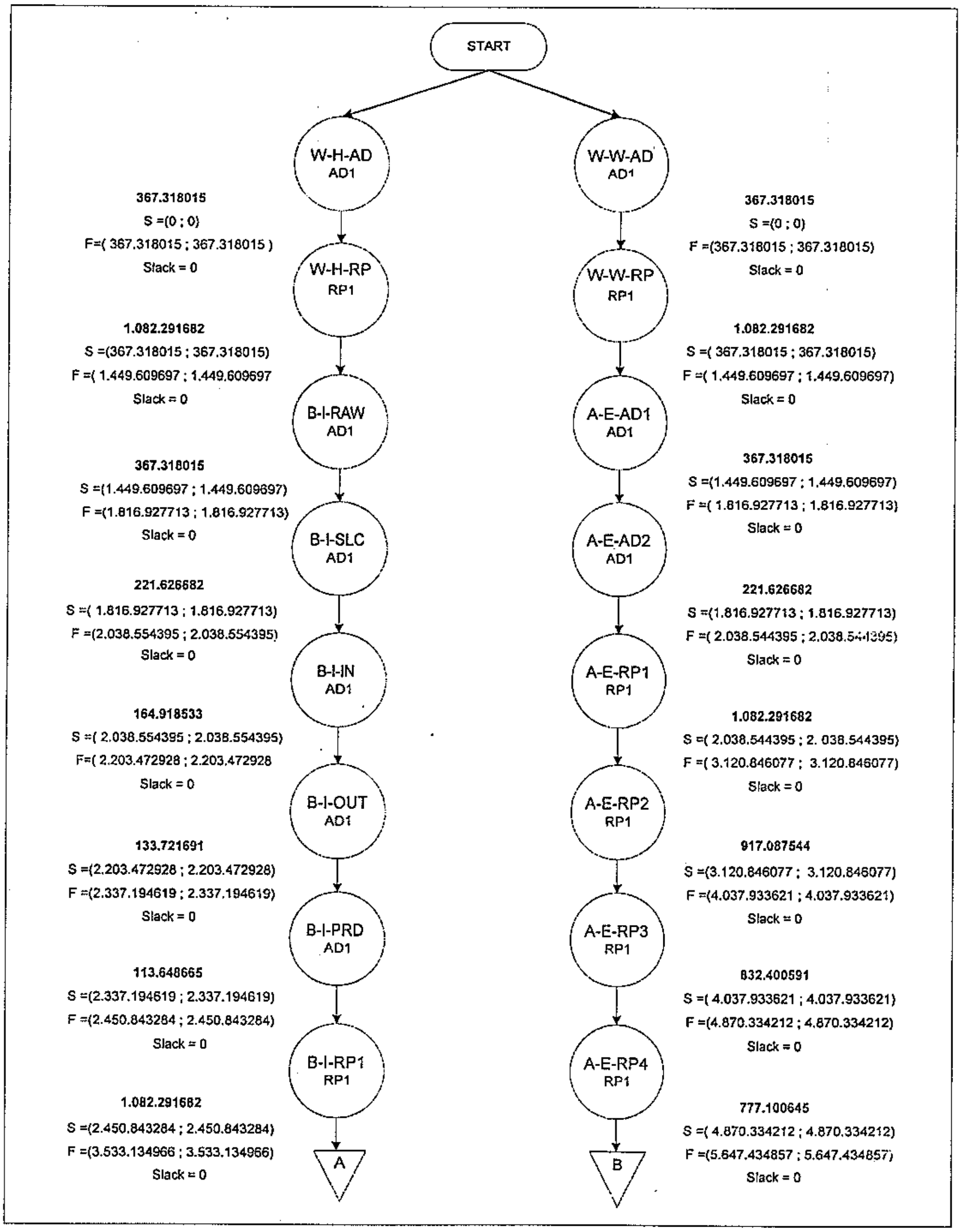
SlackTime Calculation
Job Type Approach Phase 1 Variant 2

No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	1	1	1	O-C-AD	AD1	367,318015	367,318015	-	367,318015	367,318015	-	-	No
2	1	1	2	O-D-AD	AD1	221,626682	588,944697	367,318015	588,944697	588,944697	367,318015	-	No
3	1	1	3	E-G-AD	AD1	164,918533	753,863231	588,944697	753,863231	753,863231	588,944697	-	No
4	1	1	4	A-G-AD	AD1	133,721691	887,584921	753,863231	887,584921	887,584921	753,863231	-	No
5	1	1	5	E-C-AD1	AD1	113,648665	1.001,233586	887,584921	1.001,233586	1.001,233586	887,584921	-	No
6	1	1	6	E-C-AD2	AD1	99,506002	1.100,739588	1.001,233586	1.100,739588	1.100,739588	1.001,233586	-	No
7	1	1	7	O-D-RP	RP1	1.082,291682	2.183,031270	1.100,739588	2.183,031270	2.183,031270	1.100,739588	-	No
8	1	1	8	A-G-RP	RP1	917,087544	3.100,118815	2.183,031270	3.100,118815	3.103,446736	2.186,359192	3,327921	No
9	1	1	9	Waiting		3,327921	3.103,446736						

No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	2	1	-	Waiting	-	367,318015	367,318015	-	367,318015	367,318015	-	-	Yes
2	2	1	1	O-C-RP	RP1	1.082,291682	1.449,609697	367,318015	1.449,609697	1.449,609697	367,318015	-	Yes
3	2	1	2	E-G-RP	RP1	917,087544	2.366,697242	1.449,609697	2.366,697242	2.366,697242	1.449,609697	-	Yes
4	2	1	3	E-C-RP	RP1	736,749494	3.103,446736	2.366,697242	3.103,446736	3.103,446736	2.366,697242	-	Yes

Source: Processed primary data

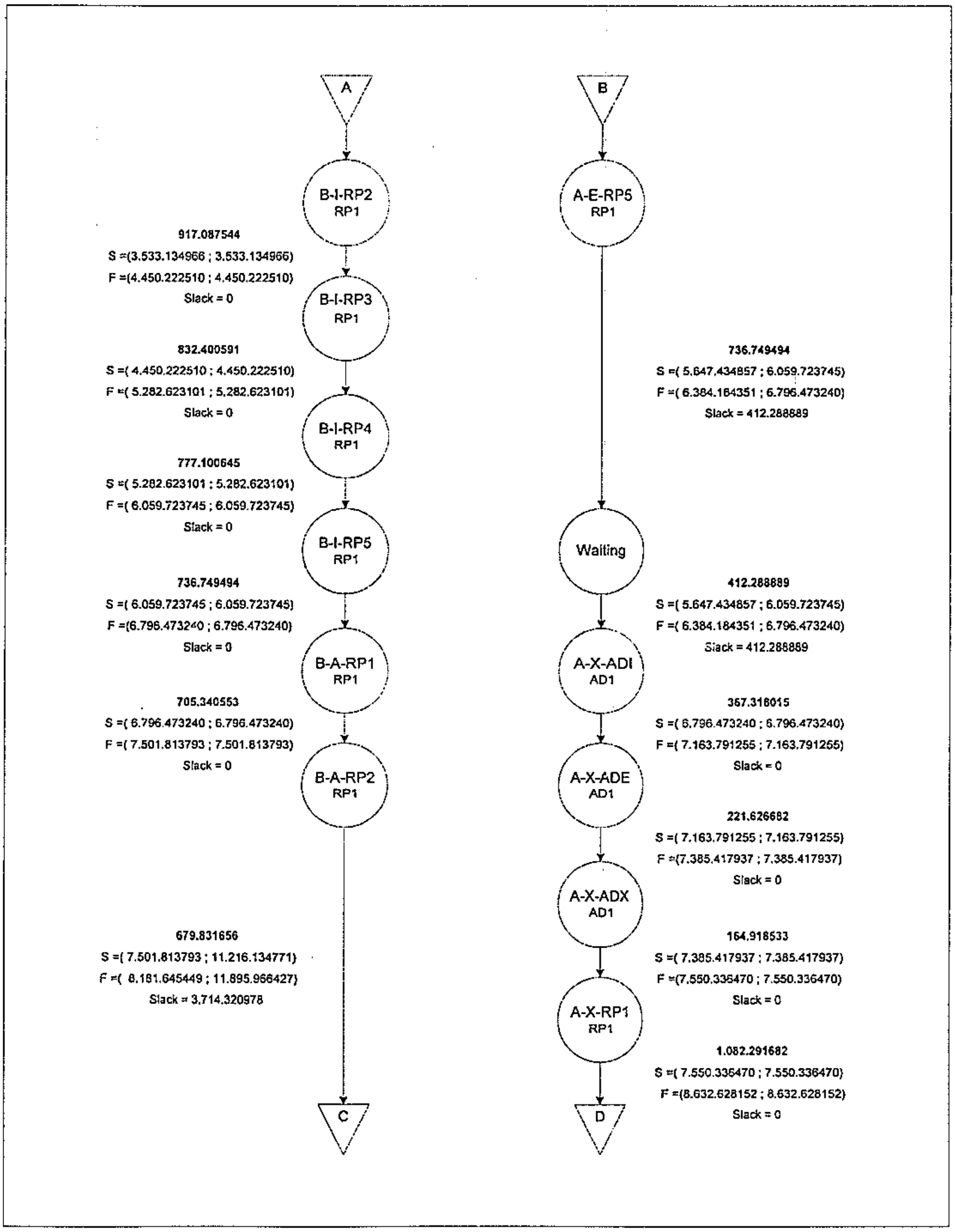
Figure 4-56
ES, EF, LF, LS and Slack Time for Job-Type Approach
Phase 1 Variant 2 (Page 1)



Source: Processed primary data

Figure 4-57

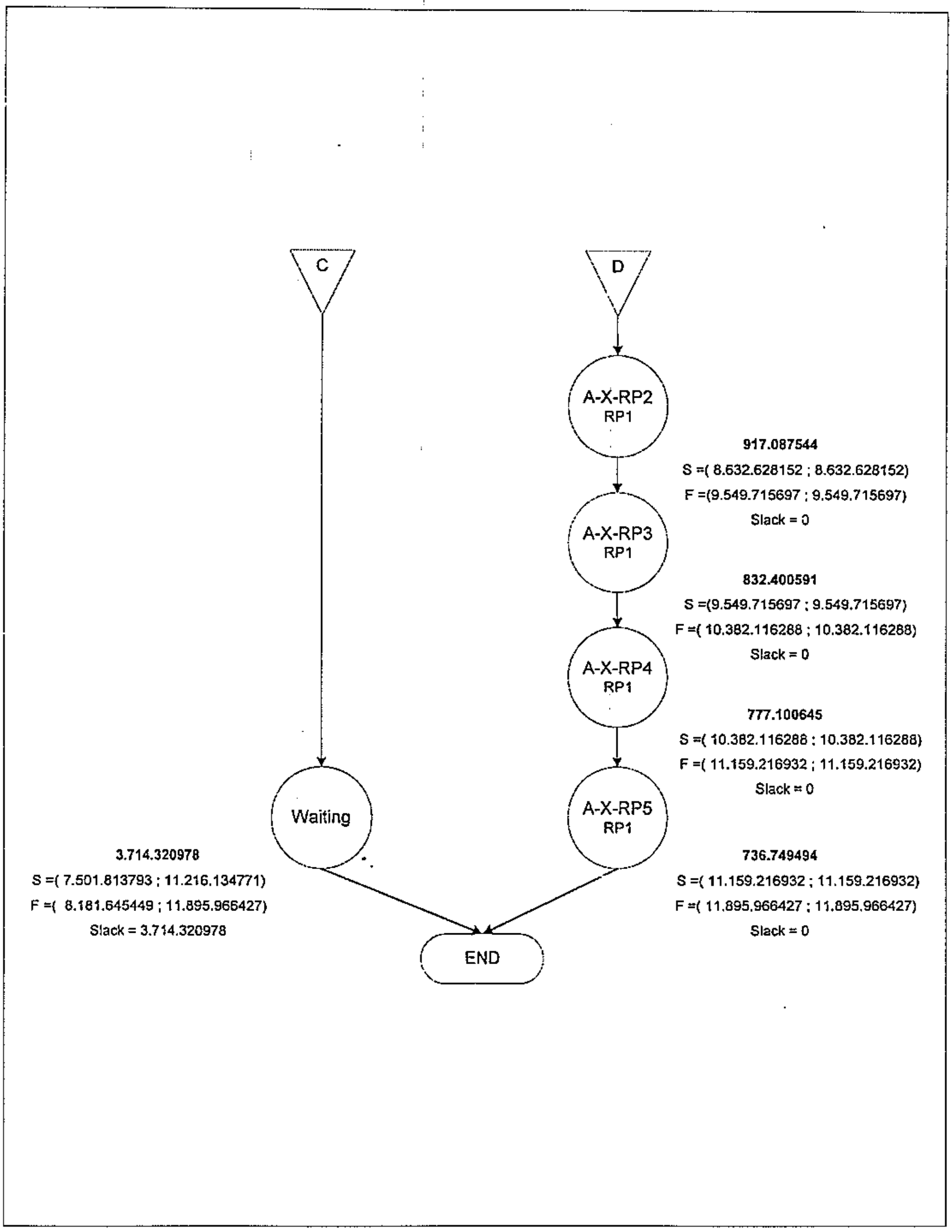
ES, EF, LF, LS and Slack Time for Job-Type Approach
Phase 1 Variant 2 (Page 2)



Source: Processed primary data

Figure 4-58

ES, EF, LF, LS and Slack Time for Job-Type Approach
Phase 1 Variant 2 (Page 3)



Source: Processed primary data

Table 4-25

Slack Time Calculation for
Job Type Approach Phase 2 Variant 2

SlackTime Calculation
Job Type Approach Phase 2 Variant 2

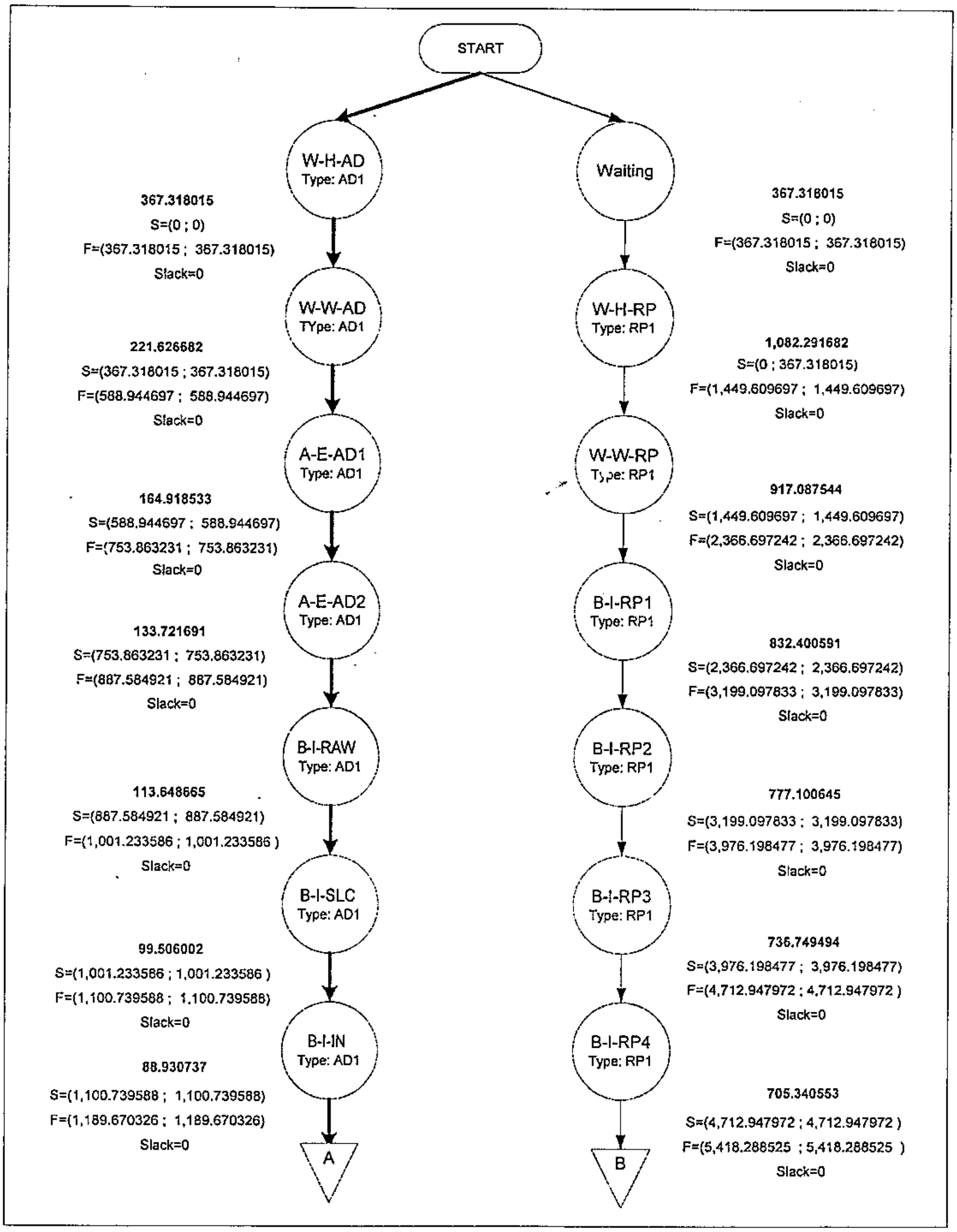
No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	1	2A	1	W-H-AD	AD1	367,318015	367,318015	-	367,318015	367,318015	-	-	Yes
2	1	2A	2	W-W-AD	AD1	221,626682	588,944697	367,318015	588,944697	588,944697	367,318015	-	Yes
3	1	2A	3	A-E-AD1	AD1	164,918533	753,863231	588,944697	753,863231	753,863231	588,944697	-	Yes
4	1	2A	4	A-E-AD2	AD1	133,721691	887,584921	753,863231	887,584921	887,584921	753,863231	-	Yes
5	1	2A	5	B-I-RAW	AD1	113,648665	1.001,233586	887,584921	1.001,233586	1.001,233586	887,584921	-	Yes
6	1	2A	6	B-I-SLC	AD1	99,506002	1.100,739588	1.001,233586	1.100,739588	1.100,739588	1.001,233586	-	Yes
7	1	2A	7	B-I-IN	AD1	88,930737	1.189,670326	1.100,739588	1.189,670326	1.189,670326	1.100,739588	-	Yes
8	1	2A	8	B-I-OUT	AD1	80,682932	1.270,353258	1.189,670326	1.270,353258	1.270,353258	1.189,670326	-	Yes
9	1	2A	9	B-I-PRD	AD1	74,045164	1.344,398422	1.270,353258	1.344,398422	1.344,398422	1.270,353258	-	Yes
10	1	2B	1	A-X-ADI	AD1	68,571579	1.412,970001	1.344,398422	1.412,970001	1.412,970001	1.344,398422	-	Yes
11	1	2B	2	A-X-ADE	AD1	63,969522	1.476,939523	1.412,970001	1.476,939523	1.476,939523	1.412,970001	-	Yes
12	1	2B	3	A-X-ADX	AD1	60,038398	1.536,977921	1.476,939523	1.536,977921	1.536,977921	1.476,939523	-	Yes
13	1	2A	4	A-E-RP1	RP1	1.082,291682	3.448,988924	1.536,977921	3.448,988924	3.448,988924	2.366,697242	-	Yes
14	1	2A	5	A-E-RP2	RP1	917,087544	4.366,076468	3.448,988924	4.366,076468	4.366,076468	3.448,988924	-	Yes
15	1	2A	6	A-E-RP3	RP1	832,400591	5.198,477059	4.366,076468	5.198,477059	5.198,477059	4.366,076468	-	Yes
16	1	2A	7	A-E-RP4	RP1	777,100645	5.975,577704	5.198,477059	5.975,577704	5.975,577704	5.198,477059	-	Yes
17	1	2A	8	A-E-RP5	RP1	736,749494	6.712,327198	5.975,577704	6.712,327198	6.712,327198	5.975,577704	-	Yes
18	1	2B	9	A-X-RP1	RP1	705,340553	7.417,667751	6.712,327198	7.417,667751	7.417,667751	6.712,327198	-	Yes
19	1	2B	10	A-X-RP2	RP1	679,831656	8.097,499407	7.417,667751	8.097,499407	8.097,499407	7.417,667751	-	Yes
20	1	2B	11	A-X-RP3	RP1	658,481751	8.755,981158	8.097,499407	8.755,981158	8.755,981158	8.097,499407	-	Yes

No.	Pgm	Phase	Seq	Sub Module	Job Type	Time	Cummulative	ES	EF	LF	LS	Slack	Critical Path
1	2	-	-	Waiting	-	367,318015	-	-	367,318015	367,318015	-	-	No
2	2	2A	1	W-H-RP	RP1	1.082,291682	1.449,609697	-	1.449,609697	1.449,609697	367,318015	-	No
3	2	2A	2	W-W-RP	RP1	917,087544	2.366,697242	1.449,609697	2.366,697242	2.366,697242	1.449,609697	-	No
4	2	2B	1	B-I-RP1	RP1	832,400591	3.199,097833	2.366,697242	3.199,097833	3.199,097833	2.366,697242	-	No
5	2	2B	2	B-I-RP2	RP1	777,100645	3.976,198477	3.199,097833	3.976,198477	3.976,198477	3.199,097833	-	No
6	2	2B	3	B-I-RP3	RP1	736,749494	4.712,947972	3.976,198477	4.712,947972	4.712,947972	3.976,198477	-	No
7	2	2B	4	B-I-RP4	RP1	705,340553	5.418,288525	4.712,947972	5.418,288525	5.418,288525	4.712,947972	-	No
8	2	2B	5	B-I-RP5	RP1	679,831656	6.098,120181	5.418,288525	6.098,120181	6.098,120181	5.418,288525	-	No
9	2	2B	6	B-A-RP1	RP1	658,481751	6.756,601932	6.098,120181	6.756,601932	6.756,601932	6.098,120181	-	No
10	2	2B	7	B-A-RP2	RP1	640,207031	7.396,808962	6.756,601932	7.396,808962	7.396,808962	6.756,601932	-	No
11	2	2B	10	A-X-RP4	RP1	624,289917	8.021,098879	7.396,808962	8.021,098879	8.021,098879	7.396,808962	-	No
12	2	2B	11	A-X-RP5	RP1	610,232322	8.631,331202	8.021,098879	8.631,331202	8.755,981158	8.145,748835	124,649956	No
13	2	-	-	Waiting	-	124,649956	8.755,981158						

Source: Processed primary data

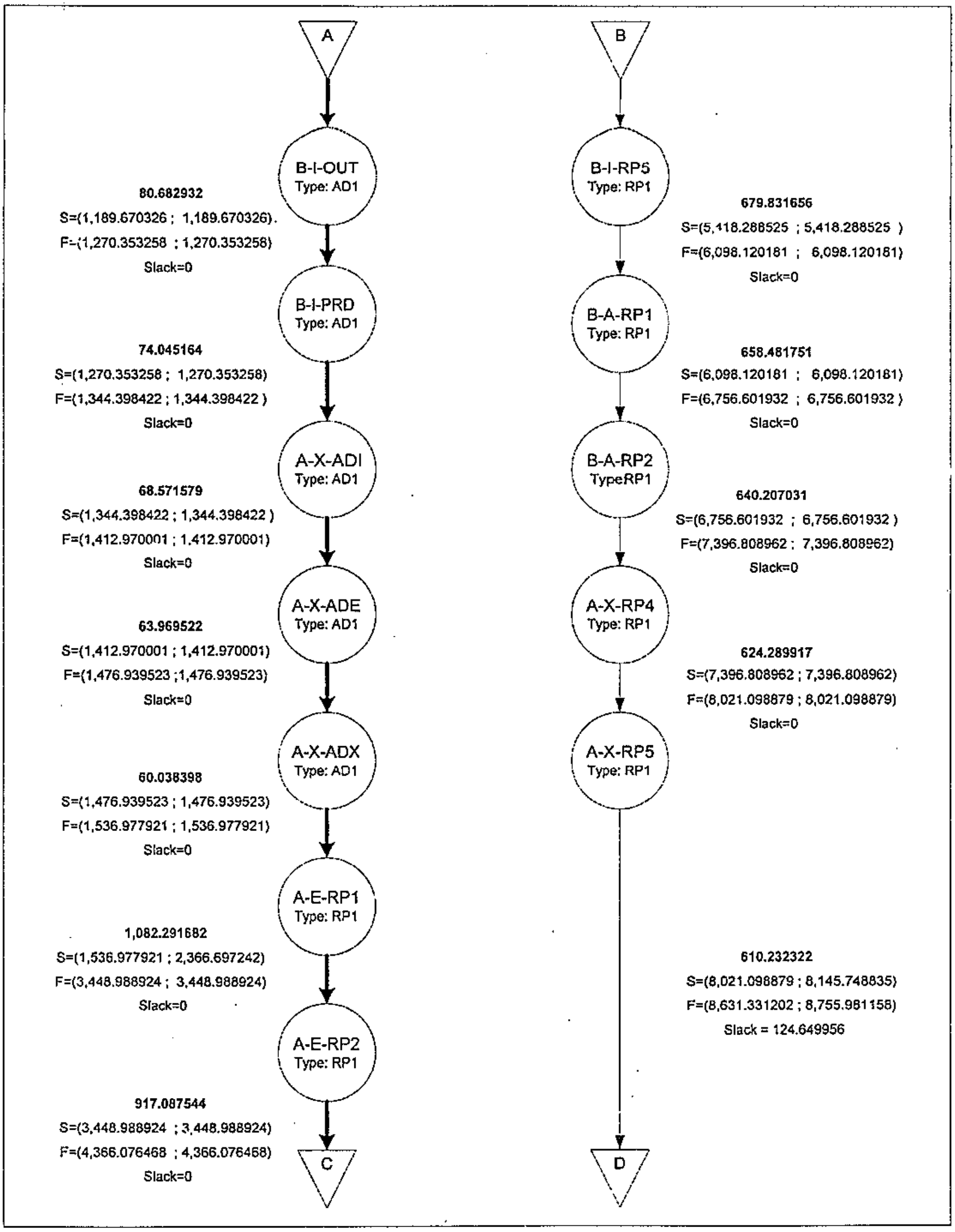
Figure 4-59

ES, EF, LF, LS and Slack Time for Job-Type Approach
Phase 2 Variant 2 (Page 1)



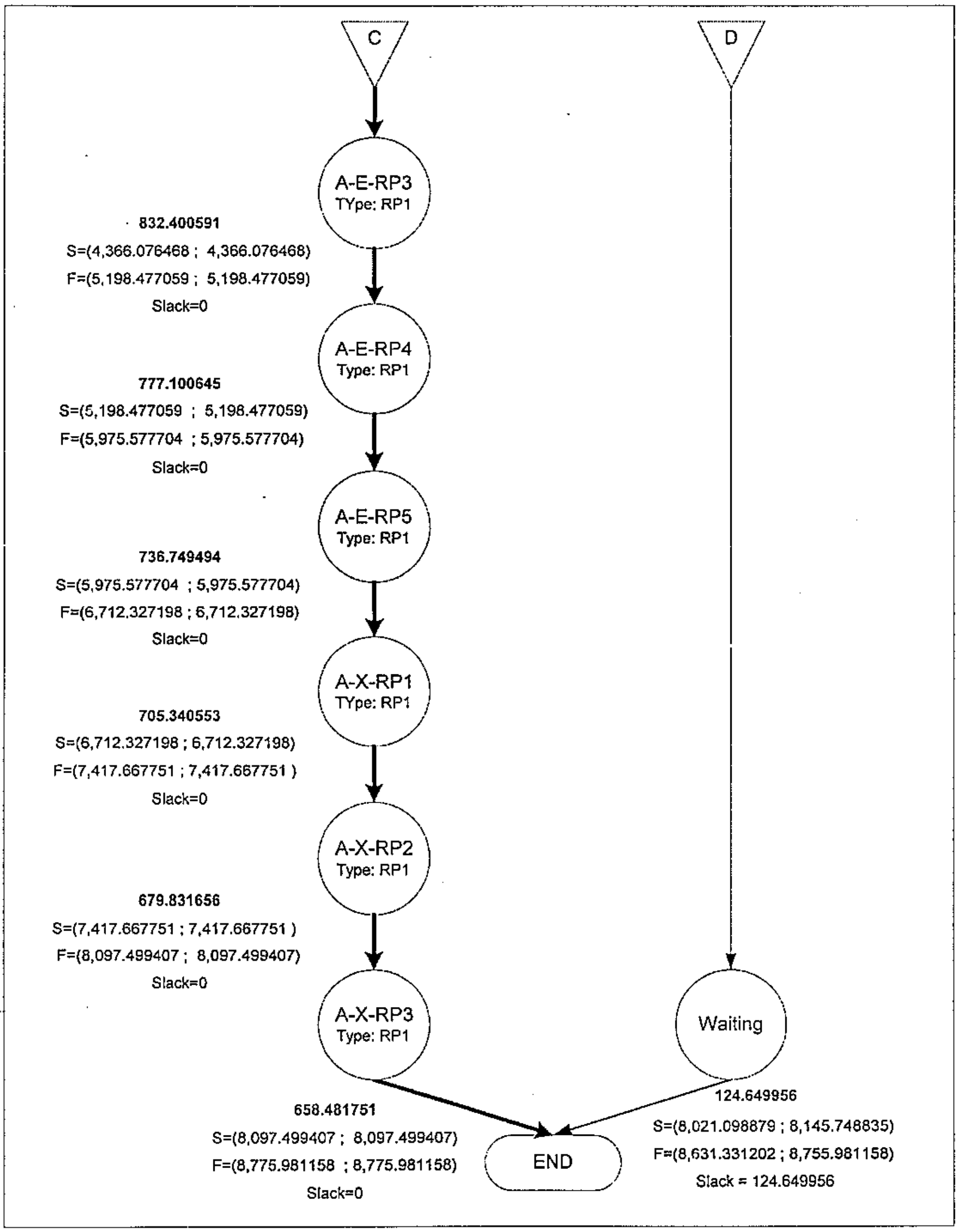
Source: Processed primary data

Figure 4-60
ES, EF, LF, LS and Slack Time for Job-Type Approach
Phase 2 Variant 2 (Page 2)



Source: Processed primary data

Figure 4-61
ES, EF, LF, LS and Slack Time for Job-Type Approach
Phase 2 Variant 2 (Page 3)



Source: Processed primary data

Job-Type Approach Variant 2 has been decided to be the most efficient way to accomplish the project. ES, EF, LS, LF and Slack time for Job-Type Approach Variant 2 are computed. The result can be examined in table 4-24 and table 4-25

Table 4-24 shows the result of ES, EF, LF, LS and Slack time computation. Programmer 1 has a waiting period at the end of the sequence. This cause 3.327921 minutes slack time. According to Stevenson, 2003, a path, which has a slack time is not the critical path. So, the path involving Programmer 1 is not the Critical Path.

Consequently, the path involving Programmer 2 is the Critical Path. Table 4-25 can be used to prove it. The first activity of Programmer 2 is Waiting, which means idle time. Programmer 2 can do nothing except waiting for Programmer 1 to complete the O-C-AD sub-module, since this sub-module is the precedence of O-C-RP module. In this case, the ES time of O-C-RP is the EF of O-C-AD sub-modules. So, this idle time cannot be considered as slack time and considered as a dummy activity. It can be evaluated that the path involving programmer 2 has no slack time. Conclusively, this path is the Critical Path for Job-Type Approach Phase 1.

Table 4-25 shows the calculation for ES, EF, LS, LF and Slack Time for Phase 2 Variant 2 of Job-Type Approach for Programmer 1 and Programmer 2. There is no Slack Time found for Programmer 1 at Job-Type Approach Phase 2 Variant 2. This indicates that this path is the Critical Path for Job-Type Approach Phase 2 Variant 2. Programmer 2 has more than 124 minutes of slack time at the end of development sequence.

4.8.5 Comparison among Development Approaches

Several estimation processes, based on two different development approaches have already been discussed. Cutting development time and total idle time are the two ultimate objective of every business. An efficient development time may lead to a better profit for the firm.

Table 4-26 shows the comparison of these three different approaches

Table 4-26

Summary of the Estimation Process

Comparison

No	Approach		Cumulative	Idle	Critical Path
1	Modular Type	Phase 1	4.570,455774	1.671,236379	4.570,455774
2	Modular Type	Phase 2	11.895,966427	4.126,609867	11.528,648411
	Total		16.466,422201	5.797,846246	16.099,104185
1	JobType Variant 1	Phase 1	4.712,947972	3.979,526399	3.103,446736
2	JobType Variant 1	Phase 2	13.143,977652	11.974,317747	13.143,977652
	Total		17.856,925624	15.953,844146	16.247,424388
1	Job Type Variant 2	Phase 1	3.100,118815	-	3.103,446736
2	Job Type Variant 2	Phase 2	8.755,981158	491,967972	8.755,981158
	Total		11.856,099973	491,967972	11.859,427894

Source: Processed primary data

Modular development approach is predicted to take 16,466.422201 minutes of development time. Idle time is predicted to be 5,797.846246 minutes. Critical Path is predicted to be 16.099,104185 minutes. The modular development process is restricted in module-by-module basis. There is only a small amount of learning rate is expected to be seen in this approach.

Job Type approach total development time is predicted to be 17,856.925624 minutes. Total idle time for both programmers is predicted to be 15,953.844146 minutes. The Critical Path is predicted to be 16.247,424388 minutes. Job Type does not restrict modular structures. Instead, it permits sub-module re-arrangement based on the job type. It is expected that learning effect will occur. Idle time is minimized. Hopefully, Critical Path is also shortened. So, the length of overall development time is expected to decline.

But since RP1 Job Type takes much longer time that AD1 Job Type, the result is not satisfactorily. Un-balanced workload cause a longer development time in a programer while idle time is found at another programmers. An optimization process is then conducted.

This optimized job sequence is expected to cut the development time to 11,856.099973 minutes and push the idle time down to 491.967972 minutes. This is the shorter development time and idle time. This also caused by learning effect. The length of Critical Path of this approach is the shortest: 11.859,427894 minutes. The Optimized Job-Type Approach (Variant 2) is proven to be most efficient development approach

It can be concluded that a shorter development time and idle time can be achieved by arranging sub-modules based on Job Type. Optimization process is required to cut the idle the down. These processes should not violate the sub-module precedence.

4.8.6 Sub-module Grouping

Table 4-26 shows the comparison between several development approaches. It is proven that Variant 2 of Job-Type Approach gives the best result. Variant 2 involved a job sequence optimization. Several sub-modules, which have the same Job-Type, were put in a group. Those groups are switched among programmers to minimize idle time. Sub-module grouping can be seen in Table 4-27 and Table 4-28.

Grouping is also essential in model building because it can distinguish series of sub-modules based on its Job-Type.

Table 4-27

Sub Module Grouping for

Job-Type Approach Phase 1 Variant 2

Sub-module Grouping

Job-Type Approach Phase 1 Variant 2

No.	Phase	Group	Seq#	Programer 1				Phase	Group	Seq#	Programmer 2			
				Sub-module	Job Type	Time	Cummulative				Sub-module	Job Type	Time	Cummulative
1	1	1	1	O-C-AD	AD1	367,318015	367,318015	1	1	1	Waiting		367,318015	367,318015
2	1	1	2	O-D-AD	AD1	221,626682	588,944697	1	2	1	O-C-RP	RP1	1.082,291682	1.449,609697
3	1	1	3	E-G-AD	AD1	164,916533	753,863231	1	2	2	E-G-RP	RP1	917,087544	2.366,697242
4	1	1	4	A-G-AD	AD1	133,721691	887,584921	1	2	3	E-C-RP	RP1	736,749494	3.103,446736
5	1	1	5	E-C-AD1	AD1	113,648665	1.001,233586							
6	1	1	6	E-C-AD2	AD1	99,506002	1.100,739588							
7	1	2	7	O-D-RP	RP1	1.082,291682	2.183,031270							
8	1	2	8	A-G-RP	RP1	917,087544	3.100,118615							
9	1	3	1	Waiting		3,327921	3.103,446736							

Source: Processed primary data

Table 4-28

Sub Module Grouping for
Job-Type Approach Phase 2 Variant 2

Sub-module Grouping

Job-Type Approach Phase 1 Variant 2

				Programer 1							Programmer 2			
No.	Phase	Group	Seq#	Sub-module	Job Type	Time	Cummulative	Phase	Group	Seq#	Sub-modul	Job Type	Time	Cummulative
1	2A	1	1	W-H-AD	AD1	367,318015	367,318015	2A	1	1	Waiting		367,318015	367,318015
2	2A	1	2	W-W-AD	AD1	221,626682	588,944697	2A	2	1	W-H-RP	RP1	1.082,291682	1.449,609697
3	2A	1	3	A-E-AD1	AD1	164,916533	753,863231	2A	2	2	W-W-RP	RP1	917,087544	2.366,697242
4	2A	1	4	A-E-AD2	AD1	133,721691	887,584921	2B	2	1	B-I-RP1	RP1	832,400591	3.199,097833
5	2A	1	5	B-I-RAW	AD1	113,646665	1.001,233586	2B	2	2	B-I-RP2	RP1	777,100645	3.976,198477
6	2A	1	6	B-I-SLC	AD1	99,506002	1.100,739588	2B	2	3	B-I-RP3	RP1	736,749494	4.712,947972
7	2A	1	7	B-I-IN	AD1	88,930737	1.189,670326	2B	2	4	B-I-RP4	RP1	705,340553	5.418,288525
8	2A	1	8	B-I-OUT	AD1	80,682932	1.270,353258	2B	2	5	B-I-RP5	RP1	679,831656	6.098,120181
9	2A	1	9	B-I-PRD	AD1	74,045164	1.344,398422	2B	2	6	B-A-RP1	RP1	658,481751	6.756,601932
10	2B	1	1	A-X-ADI	AD1	68,571579	1.412,970001	2B	2	7	B-A-RP2	RP1	640,207031	7.396,808962
11	2B	1	2	A-X-ADE	AD1	63,969522	1.476,939523	2B	2	10	A-X-RP4	RP1	624,289917	8.021,098879
12	2B	1	3	A-X-ADX	AD1	60,038398	1.536,977921	2B	2	11	A-X-RP5	RP1	610,232322	8.631,331202
13	2A	2	4	A-E-RP1	RP1	1.082,291682	3.448,988924							
14	2A	2	5	A-E-RP2	RP1	917,087544	4.366,076468							
15	2A	2	6	A-E-RP3	RP1	832,400591	5.198,477059							
16	2A	2	7	A-E-RP4	RP1	777,100645	5.975,577704							
17	2A	2	8	A-E-RP5	RP1	736,749494	6.712,327198							
18	2B	2	9	A-X-RP1	RP1	705,340553	7.417,667751							
19	2B	2	10	A-X-RP2	RP1	679,831656	8.097,499407							
20	2B	2	11	A-X-RP3	RP1	658,481751	8.755,981158				Waiting		124,649956	8.755,981158

Source: Processed primary data

4.9 Uncertainties

Uncertainties are always happen in everyday's life . Uncertainty is a situation where there are more than one probable result of a decision-making process (Salvatore, 1989)

In this situation *probabilistic approach* is needed. (Hillier and Lieberman, 2001; Stevenson, 2003; Render and Heizer; 2004). This approach needs 3 (three) time estimates for each activity:

1. Optimistic Time:

   Optimistic Time (t_0) is the length of time required to complete an activity under an optimum condition

2. Pessimistic Time:

   Pessimistic Time (t_p) is the length of time required to complete an activity under the worst condition

3. Most Likely Time:

   Most Likely Time (t_m) is the most probable length of time required to complete an activity.

Managers can make all of those estimation. PERT also assumes that the form of probability distribution is a *Beta Distribution* (Hillier and Lieberman, 2001). Although there is no real theoretical justification for using the Beta Distribution, it has certain features that make it attractive in practice: The Distribution can be symmetrical of skewed to either right or left according to the nature of particular activity. The mean and variance of the distribution can readily obtained from the three estimates described above. The distribution is Unimodal with high concentration of probability surrounding the most likely time estimate. Of special interest in network analysis are the expected time for each activity (t_e) and the variance of each activity time σ_i^2 (Stevenson, 2003).

Estimating a duration of an activity is not a simple task. Krajewski and Ritzman, 1990, suggest that 15% to 20% allowance time should be provided. Laudon and Laudon, 2000, said that Software Development usually requires 15% allowance time. Whitten, Bentley and Dittman, 2000, give a more detailed explanation. They said that there are two important people factor to be considered:

1. Efficiency: No worker performs at 100 percent efficiency.Most people do coffee breaks, lunch breaks, reading their emails, check their calendars, participate in non-project work and even engage in idle conversation. Experts differ on just how productive the average worker is. One commonly figure is 75 percent.

2. Interruptions: People experience phone calls, visitors and other unplanned interruptions. Interruption can consume 10% to 50%of programmer's time. Those interruptions will increase project time.

Whitten, Bentley and Dittman suggest that expected duration has to consider interruptions and delays. They suggest that that 75 percent efficiency and 15 percent interruption is a realistic figure. The calculation formula will be described in equation 4.9.1 and 4.9.2

$$Coeff = \frac{1}{eff} \div (1 - i) \qquad 4.9.1$$

where:
Coeff=Uncertainty coefficient

Eff=efficiency
i=interruption

$$Coeff = \frac{1}{0.75} \div (1.00 - 0.15) \tag{4.9.2}$$
$$Coeff = 1.57$$

where:
Efficiency = 75%
Interruption=15%

This means that the estimation time will increase to 157% of their original estimation value.

This research adopts the calculation mention above for most likely time. The original estimation is considered to be optimistic estimation.

The pessimistic estimation is duration estimation under the most unfavorable conditions (Hillier and Lieberman, 2001)."Guesstimate", described by Whitten, Bentley and Dittman, 2000, is considered to be the worst scenario and reflects the unfavorable condition. So, the pessimistic time, which reflect the unfavorable condition is considered to be 200% of the original estimation value.

As described in former sub-sections, Job Type Approach is proven to be a better approach compared to Modular Approach. Calculation involving uncertainties in this sub section is based on the calculation of Job Type Approach Phase 1 Variant 2 and Phase 2 Variant 2.

4.9.1 Uncertainties in Phase 1

Table 4-29 shows the three types of time estimation: optimistic estimation (t_o), most likely estimation (t_m) and pessimistic estimation (t_p). Most Likely Estimation is 157% of Optimistic Estimation. Pessimistic Estimation is 200% of Optimistic Estimation

Table 4-29

Optimistic, Most Likely and Pessimistic Time Estimates for Job Type Approach Phase 1 Variant 2

No.	Pgm	Phase	Seq	Sub Module	Job Type	Optimistic	Most Likely	Pessimistic
1	1	1	1	O-C-AD	AD1	367.318015	576.689284	734.636031
2	1	1	2	O-D-AD	AD1	221.626682	347.953890	443.253364
3	1	1	3	E-G-AD	AD1	164.918533	258.922097	329.837067
4	1	1	4	A-G-AD	AD1	133.721691	209.943055	267.443382
5	1	1	5	E-C-AD1	AD1	113.648665	178.428403	227.297329
6	1	1	6	E-C-AD2	AD1	99.506002	156.224424	199.012005
7	1	1	7	O-D-RP	RP1	1,082.291682	1,699.197941	2,164.583364
8	1	1	8	A-G-RP	RP1	917.087544	1,439.827444	1,834.175089
Total						3,100.118815	4,867.186539	6,200.237629

Source: Processed primary data

According to Stevenson (2003), Hillier and Lieberman (2001), Whitten, Bentley and Dittman (2000), the estimate time (t_e) is then calculate using the equation:

$$t_e = \frac{t_o + 4t_m + t_p}{6} \qquad (4.9.1.1)$$

Table 4-30

Estimated Time and Variance Calculation for
Job Type Approach Phase 1 Variant 2

No.	Pgm	Phase	Seq	Sub Module	Job Type	Estimated Time	Variance
1	1	1	1	O-C-AD	AD1	568.118531	322,758.664802
2	1	1	2	O-D-AD	AD1	342.782601	117,499.911659
3	1	1	3	E-G-AD	AD1	255.073998	65,062.744631
4	1	1	4	A-G-AD	AD1	206.822882	42,775.704406
5	1	1	5	E-C-AD1	AD1	175.776601	30,897.413543
6	1	1	6	E-C-AD2	AD1	153.902617	23,686.015529
7	1	1	7	O-D-RP	RP1	1,673.944468	2,802,090.082483
8	1	1	8	A-G-RP	RP1	1,418.428735	2,011,940.076627
Total						4,794.850433	5,416,710.613681

Source: Processed primary data

Stevenson, 2003, and Hillier and Lieberman, 2001, also explain the formula to calculate the Variance of the activity as follows:

$$\sigma^2 = \left[\frac{(t_p - t_o)}{6}\right]^2 = \frac{(t_p - t_o)^2}{36} \qquad (4.9.1.2)$$

The expected duration of a path (i.e the path mean, $\overline{P}$) is equal to the sum of expected time of the activities on that path. Analogously, Variance of a path is the sum of the variance activities on the path. Standard Deviation of a path can be obtained by taking the square root of the Variance of the Path (Stevenson, 2003).

According to the table 4-30, Standard Deviation of Phase 1 Variant 2 is:

$$\sigma_{path} = \sqrt{5,416,710.613681} = 2,327382782$$

Further, Stevenson, 2003, explained that the probability of a given path to be completed under a specified time (t) can be calculated as follows

$$z = \frac{t - \overline{P}}{\sigma} \qquad (4.12)$$

where z is the probability, $\overline{P}$ is the path mean and σ is the standard deviation of the path.

Table 4-31 shows probabilities of Job Type Approach Phase 1 Variant 2 to be completed under several time specifications.

Table 4-31

Job completion probabilities under several time specifications
for Job Type Approach Phase 1 Variant 2

No	Specified Time (Minutes)	Specified time (Hour)	Z Value	Probability (%)
1	3.100,118815	51,668647	(0,728171)	23,3254519
2	4.867,186539	81,119776	0,031080	51,2397364
3	6.200,237629	103,337294	0,603849	72,7027954
4	1.000,000000	16,666667	(1,630523)	5,1495525
5	2.000,000000	33,333333	(1,200856)	11,4903689
6	3.000,000000	50,000000	(0,771188)	22,0297586
7	4.000,000000	66,666667	(0,341521)	36,6355707
8	5.000,000000	83,333333	0,088146	53,5119761
9	6.000,000000	100,000000	0,517813	69,7705718
10	7.000,000000	116,666667	0,947480	82,8302995
11	8.000,000000	133,333333	1,377148	91,5766631
12	9.000,000000	150,000000	1,806815	96,4604472

Source: Processed primary data

Time specification 1 is the total amount of optimistic time. The table shows that the probability of the Job Completed under Optimistic time specification is only approximately 23, 3255%.

Time specification 2 is the total amount of Most Likely time. The table shows that the probability of the Job Completed under Most Likely time specification is only approximately 51,2397%.

Time specification 3 is the total amount of Pessimistic time. The table shows that the probability of the Job Completed under Pessimistic time specification is only approximately 72,7028%.

There rest of time specifications shows the job completion probability under several steps of time specifications. Table 4-31 show that the probability of job completion is lower than 90% until it reach approximately 8,000 minutes of working time. This means that there is a lot of uncertainties around the development time forecast of this development phase.

4.9.2 Uncertainties in Phase 2

Table 4-32 presents the optimistic estimates, most likely estimates and pessimistic estimates for Job Type Approach Phasc 2 Variant 2. Estimation criteria is the same as the criteria used in the previous section.

The estimated time (t_e) is then calculated using the equation defined in the previous sub-section. The variance (σ^2) is also calculated. The result is presented in table 4-33.

Expected path duration ($\overline{P}$) is known as the sum of the estimated time of a path. Path variance (σ) is the sum of variance of each activity in a path. The Standard Deviation of a path can be obtained by taking the square root of the Variance of the Path.

$$\sigma = \sqrt{12,547,583.441571} = 3,542.256829$$

Table 4-32

Optimistic, Most Likely and Pessimistic Time Estimates for Job Type Approach Phase 2 Variant 2

No.	Pgm	Phase	Seq	Sub Module	Job Type	Optimistic	Most Likely	Pessimistic
1	2	2A	1	W-H-AD	AD1	367.318015	576.689284	734.636031
2	2	2A	2	W-W-AD	AD1	221.626682	347.953890	443.253364
3	2	2A	3	A-E-AD1	AD1	164.918533	258.922097	329.837067
4	2	2A	4	A-E-AD2	AD1	133.721691	209.943055	267.443382
5	2	2A	5	B-I-RAW	AD1	113.648665	178.428403	227.297329
6	2	2A	6	B-I-SLC	AD1	99.506002	156.224424	199.012005
7	2	2A	7	B-I-IN	AD1	88.930737	139.621257	177.861475
8	2	2A	8	B-I-OUT	AD1	80.682932	126.672204	161.365865
9	2	2A	9	B-I-PRD	AD1	74.045164	116.250907	148.090328
10	2	2B	1	A-X-ADI	AD1	68.571579	107.657379	137.143159
11	2	2B	2	A-X-ADE	AD1	63.969522	100.432149	127.939043
12	2	2B	3	A-X-ADX	AD1	60.038398	94.260285	120.076796
13	2	2A	4	A-E-RP1	RP1	1,082.291682	1,699.197941	2,164.583364
14	2	2A	5	A-E-RP2	RP1	917.087544	1,439.827444	1,834.175089
15	2	2A	6	A-E-RP3	RP1	832.400591	1,306.868928	1,664.801182
16	2	2A	7	A-E-RP4	RP1	777.100645	1,220.048012	1,554.201289
17	2	2A	8	A-E-RP5	RP1	736.749494	1,156.696706	1,473.498988
18	2	2B	9	A-X-RP1	RP1	705.340553	1,107.384669	1,410.681107
19	2	2B	10	A-X-RP2	RP1	679.831656	1,067.335699	1,359.663311
20	2	2B	11	A-X-RP3	RP1	658.481751	1,033.816349	1,316.963502
				Total		7,926.261837	12,444.231084	15,852.523674

Source: Processed primary data

Table 4-33

Estimated Time and Variance Calculation for
Job Type Approach Phase 2 Variant 2

No.	Pgm	Phase	Seq	Sub Module	Job Type	Estimated time	Variance
1	2	2A	1	W-H-AD	AD1	568.118531	322,758.664802
2	2	2A	2	W-W-AD	AD1	342.782601	117,499.911659
3	2	2A	3	A-E-AD1	AD1	255.073998	65,062.744631
4	2	2A	4	A-E-AD2	AD1	206.822882	42,775.704406
5	2	2A	5	B-I-RAW	AD1	175.776601	30,897.413543
6	2	2A	6	B-I-SLC	AD1	153.902617	23,686.015529
7	2	2A	7	B-I-IN	AD1	137.546207	18,918.959050
8	2	2A	8	B-I-OUT	AD1	124.789602	15,572.444792
9	2	2A	9	B-I-PRD	AD1	114.523187	13,115.560326
10	2	2B	1	A-X-ADI	AD1	106.057376	11,248.166998
11	2	2B	2	A-X-ADE	AD1	98.939527	9,789.029974
12	2	2B	3	A-X-ADX	AD1	92.859389	8,622.866047
13	2	2A	4	A-E-RP1	RP1	1,673.944468	2,802,090.082483
14	2	2A	5	A-E-RP2	RP1	1,418.428735	2,011,940.076627
15	2	2A	6	A-E-RP3	RP1	1,287.446247	1,657,517.839969
16	2	2A	7	A-E-RP4	RP1	1,201.915664	1,444,601.262908
17	2	2A	8	A-E-RP5	RP1	1,139.505884	1,298,473.660546
18	2	2B	9	A-X-RP1	RP1	1,090.926722	1,190,121.113808
19	2	2B	10	A-X-RP2	RP1	1,051.472961	1,105,595.387361
20	2	2B	11	A-X-RP3	RP1	1,018.451775	1,037,244.017870
					Total	12,259.284975	12,547,583.441571

Source: Processed primary data

The probability of a given path to be completed under a specified time (t) is calculated. The result can be examined in table 4-34.

Table 4-34

Job completion probabilities under several time specifications for Job Type Approach Phase 2 Variant 2

No	Specified Time (Minutes)	Specified Time (Hour)	Z Value	Probability (%)
1	7,926.261837	132.104364	(1.223238)	11.061997
2	12,444.231084	207.403851	0.052211	52.081993
3	15,852.523674	264.208728	1.014392	84.480223
4	5,000.000000	83.333333	(2.049339)	2.021442
5	6,000.000000	100.000000	(1.767033)	3.861130
6	7,000.000000	116.666667	(1.484727)	6.880809
7	8,000.000000	133.333333	(1.202421)	11.460024
8	9,000.000000	150.000000	(0.920115)	17.875621
9	10,000.000000	166.666667	(0.637809)	26.179879
10	11,000.000000	183.333333	(0.355504)	36.110624
11	12,000.000000	200.000000	(0.073198)	47.082434
12	13,000.000000	216.666667	0.209108	58.281809
13	14,000.000000	233.333333	0.491414	68.843321
14	15,000.000000	250.000000	0.773720	78.045188
15	16,000.000000	266.666667	1.056026	85.452179
16	17,000.000000	283.333333	1.338332	90.960579
17	18,000.000000	300.000000	1.620638	94.745233
18	19,000.000000	316.666667	1.902944	97.147612
19	20,000.000000	333.333333	2.185250	98.556477

Source: Processed primary data

Time specification 1 is the total amount of optimistic time. The table shows that the probability of the Job Completed under Optimistic time specification is only approximately 11.061997%.

Time specification 2 is the total amount of Most Likely time. The table shows that the probability of the Job Completed under Most Likely time specification is only approximately 52.081993%.

Time specification 3 is the total amount of Pessimistic time. The table shows that the probability of the Job Completed under Pessimistic time specification is only approximately 84.480223%.

There rest of time specifications shows the job completion probability under several steps of time specifications. Table 4-34 show that the probability of job completion is lower than 90% until it reach approximately 17,000 minutes of working time. This means that there is a lot of uncertainties around the development time forecast of this development phase.

4.9.3 Efficiency improvement impact

It has been stated earlier that Most Likely Estimates based on 75% of work efficiency and 15% interruptions. Using these assumptions, the probability of job assignments completed under Most Likely time specification is approximately 51,2397% for Phase 1 and approximately 52.081993% for Phase 2. Obviously, further exploration to see the effect of increasing efficiency and decreasing interruption to those probability numbers will be conducted.

The combination number of efficiency and interruption will be reduced to 120% for Most Likely Estimates and 150% for Pessimistic Estimates. Table 4-35 shows the result of this modification for Phase 1 of the Job Type Approach.

Table 4-35

Optimistic, Most Likely and Pessimistic Time Estimates for
Job Type Approach Phase 1 Variant 2 (with Modified Coefficient)

No.	Pgm	Phase	Seq	Sub Module	Job Type	Optimistic	Most Likely	Pessimistic
1	1	1	1	O-C-AD	AD1	367.3180155	440.7816186	550.9770232
2	1	1	2	O-D-AD	AD1	221.6266818	265.9520181	332.4400227
3	1	1	3	E-G-AD	AD1	164.9185334	197.9022401	247.3778001
4	1	1	4	A-G-AD	AD1	133.7216908	160.4660289	200.5825362
5	1	1	5	E-C-AD1	AD1	113.6486646	136.3783975	170.4729969
6	1	1	6	E-C-AD2	AD1	99.5060024	119.4072029	149.2590036
7	1	1	7	O-D-RP	RP1	1,082.2916820	1,298.7500184	1,623.4375230
8	1	1	8	A-G-RP	RP1	917.0875443	1,100.5050531	1,375.6313164
					Total	3,100.1188147	3,720.1425776	4,650.1782220

Source: Processed primary data

Table 4-36 shows the result of Estimated Time, Path Mean, Job Variances and Path Variance of Phase 1 of Job Type Approach under a modified coefficient for Most Likely and Pessimistic Estimate.

Table 4-36

Estimated Time and Variance Calculation for
Job Type Approach Phase 1 Variant 2 (with Modified Coefficients)

No.	Pgm	Phase	Seq	Sub Module	Job Type	Estimated Time	Variance
1	1	1	1	O-C-AD	AD1	446.903585	199,722.814721
2	1	1	2	O-D-AD	AD1	269.645796	72,708.855394
3	1	1	3	E-G-AD	AD1	200.650882	40,260.776575
4	1	1	4	A-G-AD	AD1	162.694724	26,469.573143
5	1	1	5	E-C-AD1	AD1	138.272542	19,119.295850
6	1	1	6	E-C-AD2	AD1	121.065636	14,656.888278
7	1	1	7	O-D-RP	RP1	1,316.788213	1,733,931.198159
8	1	1	8	A-G-RP	RP1	1,115.789846	1,244,986.979361
					Total	3,771.811225	3,351,856.381482

Source: Processed primary data

Expected path duration ($\overline{P}$) is known as the sum of the estimated time of a path. Path variance (σ) is the sum of variance of each activity in a path. The Standard Deviation of a path can be obtained by taking the square root of the Variance of the Path.

$$\sigma = \sqrt{3{,}351{,}586381482} = 1{,}830.807576$$

The probability of a given path to be completed under a specified time (t) is calculated. The result can be examined in table 4-37.

Table 4-37

Job completion probabilities under several time specifications
for Job Type Approach Phase 1 Variant 2
(with Modified Coefficient)

No	Estimated Time (Minutes)	Estimated Time (Hour)	Z Value	Probability (%)
1	3.100,118815	51,668647	(0,366883)	35,685316
2	4.867,186539	81,119776	0,598302	72,518074
3	6.200,237629	103,337294	1,326424	90,765023
4	1.000,000000	16,666667	(1,513983)	6,501512
5	2.000,000000	33,333333	(0,967776)	16,657817
6	3.000,000000	50,000000	(0,421569)	33,666995
7	4.000,000000	66,666667	0,124638	54,959509
8	5.000,000000	83,333333	0,670845	74,884055
9	6.000,000000	100,000000	1,217052	88,820780
10	7.000,000000	116,666667	1,763259	96,107168
11	8.000,000000	133,333333	2,309467	98,954117
12	9.000,000000	150,000000	2,855674	99,785265

Source: Processed primary data

Time specification 1 is the total amount of optimistic time of the original estimation. The table shows that the probability of the Job Completed in 3.100,118815 minutes is now 35,685316%. Previously the probability under the same specified time is only approximately 23,3254519%.

Time specification 2 is the total amount of Most Likely time of the original estimation. The table shows that the probability of the Job Completed in 4.867,186539 is now 72,518074%. Previously the probability under the same specified time specification is only approximately 51,2397364%.

Time specification 3 is the total amount of Pessimistic time of the original estimation. The table shows that the probability of the Job Completed under Pessimistic is now 90,765023%. Previously the probability under the same specified time specification is only approximately 72,7027954%.

There rest of time specifications shows the job completion probability under several steps of time specifications. Table 4-37 show that the probability of job completion is lower than 90% until it reach approximately 6,000 minutes of working time. This means that there is a better probability of job completion under lower amount of working hour.

An effort to increase efficiency and reduce interruption might also improve the probability of job completion under lower working hour in Phase 2 of Job Type Approach. Modified coefficient is used to perform the recalculation. The most likely estimates uses 120% as the uncertainty coefficient, while Pessimistic estimate uses 150% as the uncertainty coefficient. Table 4-38 shows the result of the estimation recalculation using the modified uncertainty coefficient.

Time Estimates and Variances are presented in Table 4-39. Expected path duration ($\overline{P}$) is known as the sum of the estimated time of a path. Path variance (σ) is the sum of variance of each activity in a path. The Standard Deviation of a path can be obtained by taking the square root of the Variance of the Path.

$$\sigma = \sqrt{8{,}185{,}186.010204} = 2{,}786.473583$$

Table 4-38

Optimistic, Most Likely and Pessimistic Time Estimates for
Job Type Approach Phase 2 Variant 2 (with Modified Coefficient)

No.	Pgm	Phase	Seq	Sub Module	Job Type	Optimistic	Most Likely	Pessimistic
1	2	2A	1	W-H-AD	AD1	367.318015	440.781619	550.977023
2	2	2A	2	W-W-AD	AD1	221.626682	265.952018	332.440023
3	2	2A	3	A-E-AD1	AD1	164.918533	197.902240	247.377800
4	2	2A	4	A-E-AD2	AD1	133.721691	160.466029	200.582536
5	2	2A	5	B-I-RAW	AD1	113.648665	136.378398	170.472997
6	2	2A	6	B-I-SLC	AD1	99.506002	119.407203	149.259004
7	2	2A	7	B-I-IN	AD1	88.930737	106.716885	133.396106
8	2	2A	8	B-I-OUT	AD1	80.682932	96.819519	121.024399
9	2	2A	9	B-I-PRD	AD1	74.045164	88.854197	111.067746
10	2	2B	1	A-X-ADI	AD1	68.571579	82.285895	102.857369
11	2	2B	2	A-X-ADE	AD1	63.969522	76.763426	95.954283
12	2	2B	3	A-X-ADX	AD1	60.038398	72.046077	90.057597
13	2	2A	4	A-E-RP1	RP1	1,082.291682	1,298.750018	1,623.437523
14	2	2A	5	A-E-RP2	RP1	917.087544	1,100.505053	1,375.631316
15	2	2A	6	A-E-RP3	RP1	832.400591	998.880709	1,248.600886
16	2	2A	7	A-E-RP4	RP1	777.100645	932.520774	1,165.650967
17	2	2A	8	A-E-RP5	RP1	736.749494	884.099393	1,105.124241
18	2	2B	9	A-X-RP1	RP1	705.340553	846.408664	1,058.010830
19	2	2B	10	A-X-RP2	RP1	679.831656	815.797987	1,019.747484
20	2	2B	11	A-X-RP3	RP1	658.481751	790.178101	987.722627
					Total	7,926.261837	9,511.514204	11,889.392755

Source: Processed primary data

Table 4-39

Optimistic, Most Likely and Pessimistic Time Estimates for
Job Type Approach Phase 2 Variant 2 (with Modified Coefficient)

No.	Pgm	Phase	Seq	Sub Module	Job Type	Estimated Time	Variance
1	2	2A	1	W-H-AD	AD1	446,903585	199.722,814721
2	2	2A	2	W-W-AD	AD1	269,645796	72.708,855394
3	2	2A	3	A-E-AD1	AD1	200,650882	40.260,776575
4	2	2A	4	A-E-AD2	AD1	162,694724	26.469,573143
5	2	2A	5	B-I-RAW	AD1	138,272542	19.119,295850
6	2	2A	6	B-I-SLC	AD1	121,065636	14.656,888278
7	2	2A	7	B-I-IN	AD1	108,199064	11.707,037379
8	2	2A	8	B-I-OUT	AD1	98,164234	9.636,216917
9	2	2A	9	B-I-PRD	AD1	90,088283	8.115,898690
10	2	2B	1	A-X-ADI	AD1	83,428755	6.960,357129
11	2	2B	2	A-X-ADE	AD1	77,829585	6.057,444255
12	2	2B	3	A-X-ADX	AD1	73,046717	5.335,822910
13	2	2A	4	A-E-RP1	RP1	1.316,788213	1.733.931,198159
14	2	2A	5	A-E-RP2	RP1	1.115,789846	1.244.986,979361
15	2	2A	6	A-E-RP3	RP1	1.012,754052	1.025.670,770613
16	2	2A	7	A-E-RP4	RP1	945,472451	893.918.155706
17	2	2A	8	A-E-RP5	RP1	896,378551	803.494.507219
18	2	2B	9	A-X-RP1	RP1	858,164340	736.446.034237
19	2	2B	10	A-X-RP2	RP1	827,128514	684.141,579412
20	2	2B	11	A-X-RP3	RP1	801,152797	641.845,804292
					Total	9.643,618568	8.185.186,010240

Source: Processed primary data

The probability of a given path to be completed under a specified time (t) is calculated. The result can be examined in table 4-40.

Table 4-40

Job completion probabilities under several time specifications
for Job Type Approach Phase 2 Variant 2
(with Modified Coefficient)

No	Estimated Time (Minutes)	Estimated Time (Hour)	Z Value	Probability (%)
1	7.926,261837	132,104364	(0,616319)	26,884193
2	12.444,231084	207,403851	1,005074	84,256941
3	15.852.523674	264,208728	2,228230	98,706747
4	5.000,000000	83,333333	(1,666486)	4,780833
5	6.000,000000	100,000000	(1,307609)	9,550301
6	7.000,000000	116,666667	(0,948733)	17,137828
7	8.000,000000	133,333333	(0,589856)	27,764350
8	9.000,000000	150,000000	(0,230980)	40,866537
9	10.000,000000	166,666667	0,127897	55,088477
10	11.000,000000	183,333333	0,486773	68,679056
11	12.000,000000	200,000000	0,845650	80,112605
12	13.000,000000	216,666667	1,204527	88,580688
13	14.000,000000	233,333333	1,563403	94,102109
14	15.000,000000	250,000000	1,922280	97,271478
15	16.000,000000	266,666667	2,281156	98,873043
16	17.000,000000	283,333333	2,640033	99,585506
17	18.000,000000	300,000000	2,998909	99,864519
18	19.000,000000	316,666667	3,357786	99,960710
19	20.000,000000	333,333333	3,716662	99,989903

Source: Processed primary data

Time specification 1 is the total amount of optimistic time of the original estimation. The table shows that the probability of the Job Completed in

7.926,261837 minutes is now 26.884193%. Previously the probability under the same specified time is only approximately 11.061997%.

Time specification 2 is the total amount of Most Likely time of the original estimation. The table shows that the probability of the Job Completed in 12.444,231084 minutes is now 84.256941%. Previously the probability under the same specified time specification is only approximately 52.081993%.

Time specification 3 is the total amount of Pessimistic time of the original estimation. The table shows that the probability of the Job Completed under Pessimistic estimates is now 98.706747%. Previously the probability under the same specified time specification is only approximately 84.480223%.

There rest of time specifications shows the job completion probability under several steps of time specifications. Table 4-37 show that the probability of job completion is lower than 90% until it reach approximately 13,000 minutes of working time. This means that there is a better probability of job completion under lower amount of working hour.

4.10 Model Building

Several calculation has been done in previous sub-sections in order to estimate development time of certain Phase of the Biometric Time and Attendance Systems Development. Based on those calculations, a set of simple mathematical models can be build.

Systems Development Projects are usually broken down into several modules to increase the manageability aspect of the project and reduce their complexity. This process is called Work Breakdown Structure (WBS). The Work Breakdown Structure (WBS) would become the foundation of the entire process.

Once WBS is built, primary module, module and sub-module relationship and precedence can be determined. A network diagram can be drawn, reflecting sub-module relationship and precedence. Several Development Phase can be found Analyzing network diagram.

Estimated total amount of time required to accomplish the overall project can be represented by the estimated Critical development time of all Development Phase found. Suppose there are n development phase found in a project. Estimated total development time of the overall project (T) can be expressed in the following equation.

$$T = CTP_1 + CTP_2 + CTP_3 + ... + CTP_n \tag{4.13}$$

where:
T = Estimated development time of the overall project
CTP=Critical Time of a phase
n=number of phase in the project
i=CTP's index

Hillier and Lieberman (2001), suggested another form to express the kind of equation in a simpler manner as follows.

$$T = \sum_{i=1}^{n} CTP_i \tag{4.14}$$

where:
T = Estimated development time of the overall project
CTP=Critical Time of a phase
n=number of phase in the project
i=CTP's index

Estimated Critical Development Time of a Phase is the total of all sub-module groups found in a phase. Consider there are *m* number of Groups found in a Phase, the amount of Critical Development Time of a Phase can be expressed in the following equation:

$$CTP_i = TG_1 + TG_2 + TG_3 + ... + TG_m \tag{4.15}$$

$$CTP_i = \sum_{j=1}^{m} TG_m \tag{4.16}$$

where:
CTP=Critical Time of a Phase
i=CTP's index
TG=Development Time of a group
j=TG's index
m=number of sub-module group found in a phase

Sub-module Grouping is based on Job-Type similarity, sub-module precedence (see sub-section 4.8.6 for detailed explanation).

Sub-module Group consists of one of more sub-modules. Suppose there are *x* sub-modules, development time of a group can be computed as follows:

$$TG_j = TS_1 + TS_2 + TS_3 + ... + TS_x \tag{4.17}$$

$$TG_j = \sum_{y=1}^{x} TS_y \qquad (4.18)$$

where:
TG=Development Time of a Group
j=TG's index
TS=Development Time of a sub-module
y=index of TS

Development time of certain sub-module can be obtained from a forecasting table. Since a group consists of sub-modules which have a similar Job-Type, a learning effect is expected to occur. Development time of a sub-module is expected to decline based on certain learning rate. Learning rate can be obtained by conducting series of experiment. Referring to sub-section 2.6.6, time required to produce for the first unit of product is assumed to k_1. Production time of the n^{th} can be computed using the following equation:

$$k_n = k_1 n^b \qquad (4.19)$$

where:
k_1=direct labor hours for the first unit
n=cumulative number of units produced

Suppose Learning Rate discovered to be r, the value of b can be computed as follows:

$$b = \frac{\log r}{\log 2} \qquad (4.20)$$

where:
r=learning rate

Development time can be derived from general form of learning curve equation mentioned above. The initial sub-module development time (k_1) can be substituted by TS_1. The second sub-module development time (k_2) can be substituted by the value of TS_2. TS_2 can be computed using the following equation:

$$TS_2 = TS_1 \bullet 2^b \tag{4.21}$$

where:
TS_2=Development time of sub-module #2
TS_1=Development time of sub-module #1
value of b can be computed using equation 4.10.8

Third sub-module development time (k_3) can be substituted by the value of TS_3, where TS_3 can be calculated using the following equation:

$$TS_3 = TS_1 \bullet 3^b \tag{4.22}$$

where:
TS_3=Development time of sub-module #3
TS_1=Development time of sub-module #1
value of b can be computed using equation 4.10.8

Analogously, development time of sub-module number x (k_x) can be substituted by TS_x. TS_x can be computed by:

$$TS_x = TS_1 \bullet x^b \tag{4.23}$$

where:
TS_x=Development time of sub-module #x
TS_1=Development time of sub-module #1
x=The number of Sub-module sequences in a group
value of b can be computed using equation 4.10.8

So, equation number 4-17 can be rewritten to:

$$TG_j = (TS_1 \bullet 1^b) + (TS_1 \bullet 2^b) + (TS_1 \bullet 3^b) \\ +...+(TS_1 \bullet x^b) \tag{4.24}$$

where:
TG=Development Time of a Group
j=TG's index
TS_1=Development time of sub-module #1
TS_2=Development time of sub-module #2
TS_3=Development time of sub-module #3
TS_x=Development time of sub-module #x
x=Sub-module sequence number in a group
value of b can be computed using equation 4.10.8

Alternatively:

$$TG_j = \sum_{y=1}^{x}(TS_1 \bullet y^b) \qquad (4.25)$$

where:
TG=Development Time of a Group
j=TG's index
TS_1=Development Time of the first sub-module
y=index of TS
value of b can be computed using equation 4.10.8

Now, it's time to review equations which build a drill-down structure of the total estimated development time as follows:

$$T = \sum_{i=1}^{n} CTP_i$$

$$CTP_i = \sum_{j=1}^{m} TG_m$$

$$TG_j = \sum_{y=1}^{x}(TS_1 \bullet y^b)$$

Combining those equation will result to a new equation as follows:

$$T = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{y=1}^{x}(TS_1 \bullet y^b) \qquad (4.26)$$

where:
T = Estimated development time of the overall project
n=number of phase in the project
i=CTP's inde
m=number of sub-module group found in a phase
j=TG's index
y=index of TS
x=The number of Sub-module sequences in a group
value of b can be computed using equation 4.10.8

In order to anticipate uncertainties, three estimations should be constructed. Those estimation includes Optimistic Time (t_o), Most Likely Time (t_m) and

Pessimistic Time (t_p) of a development Phase. The value of *TG*, obtained from equation 4.10.5 is considered to be the base of the probabilistic estimates. In other words, the *TG* value will become the Optimistic Time (t_o).

$$t_o = \sum_{y=1}^{x}(TS_1 \bullet y^b) \tag{4.27}$$

where:
t_o=Optimistic Time Estimates
TS_1=Development Time of the first sub-module
y=index of TS
value of b can be computed using equation 4.10.8

The Most Likely Time (t_m) can be computed by multiplying the Optimistic Time (t_o) with certain coefficient (C_m). This coefficient is built based on the combination of efficiency and interruption.

$$t_m = \sum_{y=1}^{x}(TS_1 \bullet y^b \bullet C_m) \tag{4.28}$$

where:
t_m=Most Likely Time Estimates
TS_1=Development Time of the first sub-module
y=index of TS
C_m=Most Likely Estimate Coefficient
value of b can be computed using equation 4.10.8

A typical figure of 75% efficiency and 15% interruption is mentioned by Whitten, Bentley and Dittman (2000), resulting 157% as the value of C_m, can be used.

$$t_m = \sum_{y=1}^{x}(TS_1 \bullet y^b \bullet 1.57) \tag{4.29}$$

where:
t_m=Most Likely Time Estimates
TS_1=Development Time of the first sub-module
y=index of TS
value of b can be computed using equation 4.10.8

Pessimistic Time can be computed in the same manner as Most Likely Estimates. However, there is no clear reference regarding the value of the Pessimistic Time Coefficient, but it should be greater than the value of C_m.

$$t_p = \sum_{y=1}^{x}(TS_1 \bullet y^b \bullet C_p) \tag{4.30}$$

where:
t_p=Pessimistic Time Estimates
TS_1=Development Time of the first sub-module
y=index of TS
C_p=Pessimistic Time Estimate Coefficient
value of b can be computed using equation 4.10.8

A value of 200% is used as Pessimistic Coefficient (C_p). So the equation become:

$$t_p = \sum_{y=1}^{x}(TS_1 \bullet y^b \bullet 2) \tag{4.31}$$

where:
t_p=Pessimistic Time Estimates
TS_1=Development Time of the first sub-module
y=index of TS
value of b can be computed using equation 4.10.8

After Optimistic, Most Likely and Pessimistic Estimates has been constructed, the probability of project completion under a specified time can be computed using the existing CPM model.

So far, a simple model in order to estimate the development time of a Systems Development Project has been constructed. This model is based on the combination of Learning Curve and PERT/CPM Model.

4.11 PERT/CPM Analysis Conclusions

Software Development is not always simple. There are many modules to be developed. Work Breakdown Structure can be used to break a huge and complex project into small manageable modules. Work Breakdown Structure is proven to be useful in the Pilot Study, Biometric Time and Attendance Systems Development. The project is broken-down into five primary modules and many modules and sub-modules. As sub-module is the smallest development entity, network diagrams are drawn based on sub-module precedence.

There are two development approach involved in estimation process. The first approach is Modular approach, which attempt to develop sub-modules in modular basis regardless their Job-Type. Second approach is Job-Type approach, which attempt to develop sub-modules based on the Job-Type of the sub-module, regardless the module it belongs to. An optimized variant of Job-Type Approach is also included.

The optimized variant of Job-Type Approach (called Job-Type Variant 2) is expected to reduce the development time, compared to Modular Approach. Idle time is also minimized and critical path is also shortened. This result can be achieved by carefully rearrange the sequence of sub-module development without violating the sub-module precedence.

Software Development is subject to uncertainties. There are two uncertainties factors observed in this research: (1) Efficiency and (2) Interruptions. According to Whitten, Bentley and Dittman, (2000), 75% efficiency and 15% interruptions, which will lead to 157% coefficient in a realistic figure. So, this coefficient is used to calculate Most Likely Estimation, while the original estimation become the

Optimistic Estimates. Pessimistic Estimate uses 200% coefficient, where 200% coefficient is intended to reflect the most unfavorable condition.

Several cut-off value were set, which include the optimistic, most likely and pessimistic estimate value themselves. Cut-off time also includes series of value from 1,000 minutes to 20,000 minutes in 1,000 minutes incremental, depending on the development phase. Probability of works completed in specified time were computed.

In order to seek a better understanding regarding the effect of uncertainties factors described above, coefficients were modified. The Most Likely Estimate is recalculated using 120% uncertainty coefficient, while Pessimistic estimate is recalculated using 150% uncertainty coefficient. The probability of works completed series of specified time is also recalculated.

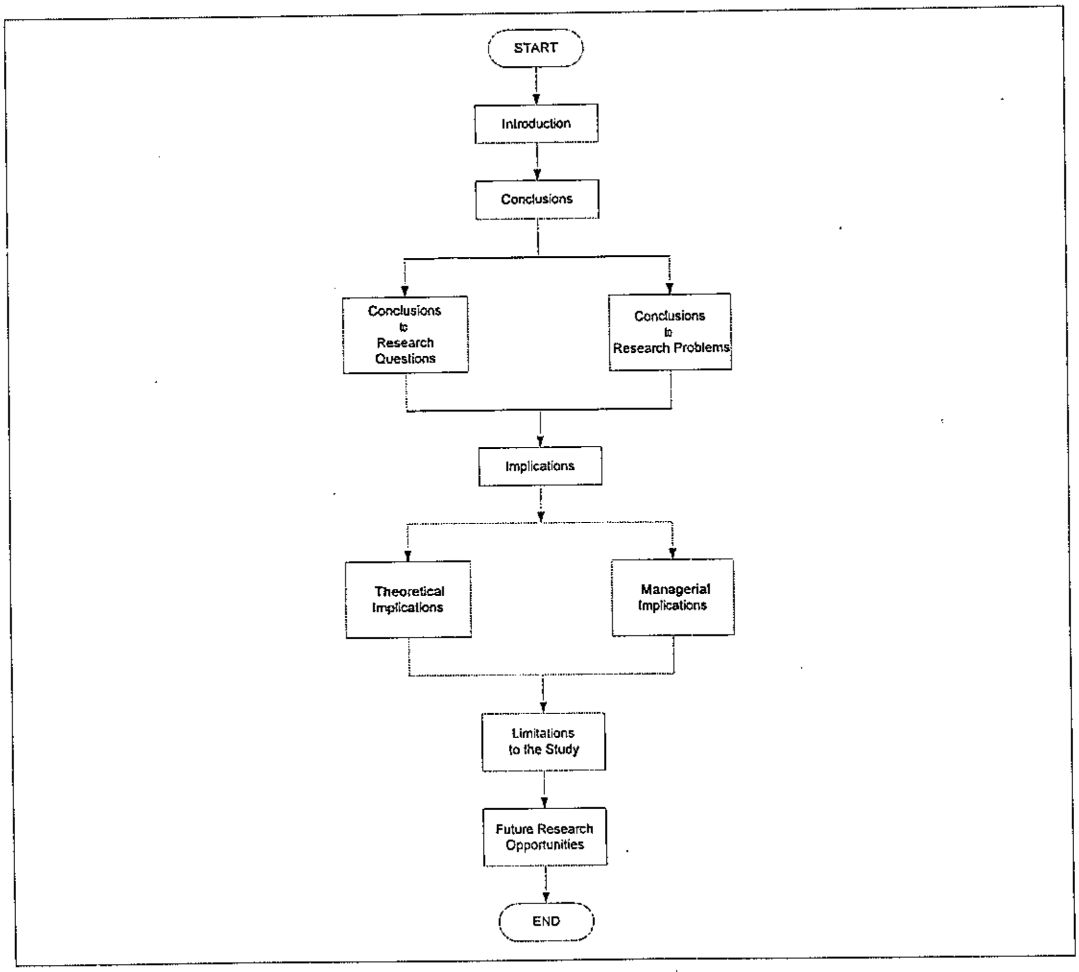
The probability result is increased. This means that a lower uncertainty coefficient will increase the probability of works completed in a specified time. Lower uncertainty coefficient can be obtained by increasing efficiency and/or decreasing interruptions.

CHAPTER V
CONCLUSION AND IMPLICATIONS

The final section of the research has been reached. This section begins with the Introduction sub-section, followed by conclusions, implications, limitations to the study and future research opportunities. Conclusions consists of two sub-sections: Conclusion to the Research Questions and Conclusion to the Research Problem. Implications consists of Theoretical Implications and Managerial Implications. Figure 5-1 describe the framework of current chapter graphically.

Figure 5-1

Conclusions and Implications Chapter Framework



Source: Developed for this thesis

5.1 Introduction

Information is very important for a company in order to struggle for life and reaching its sustainable competitive advantage. Information is one of the competitive advantage for a company (Porter, 1979). Ability to manage technology, including Information Technology, has become strength factor in SWOT Analysis (Thompson and Strickland, 2003)

Ironically, Information Technology Projects, especially Software Development are suffering from many difficulties (Tong, 1994; Krishnan, 1998; Suwardhy, et al, 2003; Clarke and Doherty, 2004; Dube, 1998; Herzwurm, 2003). Obviously, this is not a conducive atmosphere for both Software Development Companies and the companies who become the users of the Software Development Companies' products. Delays in Software Development Projects is enough to justify that the project is failed. Poor time estimating techniques and lack of Systems Development Methodology were suspected to become a dominant factor in a Systems Development failure (Whitten, Bentley and Dittman, 2000).

This research is designed to seek a scientific approach to fix the time estimation problem. Several experiments has been conducted in order to build a simple model so that a systems development project can be finished on time. Those experiments involve several existing Operation Research model and combine them to create a synergy.

There are two major parts in the analysis chapter. An effort of building a model based on several observations was done in the first part of the analysis. The first part of the study is intended to build a mathematical model which will be used in the forecasting process.

A pilot study was conducted involving a senior programmer to obtain the number of observations should be conducted. The result of the pilot study is: 14 observations should be conducted in time study.

Two novice programmer are invited to join the first part of the research. The observation follows A-B-A-B experiment pattern. The "A" type means no treatment within job assignments while the "B" type means treatment provided in each job assignment. Treatment means detailed job descriptions were provided. The Each object is carefully designed. A full description about the object is provided. The property of each object follows certain standards, which also known as Standardized Object Specifications. The standards include Control Size, positioning, color, appearance, object naming conventions, folder destinations, database, table and field attributes. Each job follows certain standards and categorized into two kind of Job-Type. Job assignments were also properly sequenced. No treatment means no or limited details provided to complete the assignments. Job assignments were not properly sequenced. This means that we leave the job to the programmers imagination to complete the job.

For identification reason only, the experiment pattern derived into segments, named A1, B1, A2, B2 . Each segment consists of 14 job assignment. So, each programmer was required to build 56 job assignments. Programmer 1 were required to build AD1 Job Type, while Programmer 2 were required to build RP1 Job Type.

The result A1 and A2 sessions for Programmer 1 indicates that the model is not fit. Learning rate was not found in Session A1. The curvilinear plot violated the underlying theory of learning curve. The was no significant value of learning observed.

Relatively small learning rate was found in Session A2. The value of the learning rate found in Session A2 was -0.907423.

Regression calculations were perform for both Linear and Log-linear model for each segment of each programmer. Several indicators, including Pearson Correlation, R Squared and Adjusted R Squared values, Durbin Watson test Value, were used to determine the "goodness of fit". Indicator values were compared between Linear and Log-linear model. Better value were selected and the model was considered have "a better fit". Linear and Curvilinear plot were also drawn for each segment of the experiment. Log-linear models were proven to have a better fit on all "B" sessions of both programmers. The coefficients of Log-linear model were converted back to their original value using Anti-Logarithm calculation.

Learning Rate were also calculated for each segment based on the best fit model. Learning Rate calculation result of each segment were compared to seek Learning Effect. Learning Effect can be observed in both "B" segments for both programmers.

An interesting phenomena called **inertia** was found in the experience. The term "inertia" was actually borrowed from physics. According to Microsoft ® Encarta ® Reference Library 2005, Inertia is the property of matter that causes it to resist any change of its motion in either direction or speed.

Gujarati (2003), has a great explanation regarding inertia in the context of economics. A salient feature in economic time series is inertia or sluggishness. In upward (or downward) swing of a growth, value of a series at one point in time is greater than its previous value. Thus there is a "momentum" built into them until something happens. Therefore, in regressions involving time series data, successive observations are likely to be interdependent. Durbin-Watson test result of Session B2 of Programmer 1 shows positive auto-correlation. The effect of learning may build a strong "momentum" that drives construction time of Programmer 1 down greater and greater in successive observations. This momentum can be explained by the formula of learning curve itself :

$$k_n = k_1 n^b$$

The power of n indicates a non-linear impact. So the phenomena supports the basic understanding of learning curve. Further explanation regarding inertia can be found in subsection 4.3.4.2 on page 174.

As the Curvilinear model was built, forecasting process can be conducted (Gaynor and Kirkpatrick, 1994). Forecast result will be used in PERT/CPM Model in the second major part of the research.

PERT/CPM became the basic model for the calculations held in the second major part of the research. Several Production and Operations Research Models, specifically Project Management Models, were also used. The Biometric Time and Attendance Systems Development Project was the Pilot Study.

First step of this second part is building a Work Breakdown Structure. Work Breakdown Structure allows us to break a large and complex project into small and manageable modules. The Biometric Time and Attendance Systems Development Project consists of five Primary Modules, named O, E, A, B and W Primary Modules. Each module was broken down into several modules. Each module can contain one or more sub-modules. Those Sub-modules will become the node of a Network Diagram. Node Relations and Precedence was built at sub-module level.

Software Development Projects include some Integration Points after several sub-modules have been built. Sub-modules were integrated and were tested together in the Integration Points (Cusumano, 1997). There are 2 integration points found in the project.

Once the hierarchy of modules successfully constructed, module sequence and precedence can be determined and a network diagram can be drawn. A sub-module represent a node and the construction time represent the arrow. At the end of this process, a PERT/CPM model is constructed. Two approaches were prepared to complete the project:

1. Modular Approach:
   attempted build sub-modules in a module by module basis regardless their job-type

2. Job-type Approach:
   attempted to build sub-modules in based on their Job-Type regardless the module they belong to.

Network diagram of each development phase of each approach were drawn based on sub-module precedence. Development was divided into two development phase, called Development Phase 1 and Development Phase 2, separated by an Integration Point. Another Integration Point was found at the end of development sessions.

Time estimation process was conducted based on the forecast data obtained from the first part of the experiment. Gantt chart of each development phase of each approach were prepared. Time estimation data were collected and then compared.

There was a chance to optimize the development sequence of Job-Type Approach since this approach rely on the Job-Type instead of the module. Time estimation data were collected and compared with the existing two sets of data. Idle time found in each set of data were analyzed. Data set which contains least idle time is considered to be the best set.

Earliest Start (ES), Earliest Finish (EF), Latest Start (LS), Latest Finish (LF) and Slack time for the best approach were computed in order to determine the Critical Path. The complete Network Diagram of the best approach was then prepared.

The optimized Job-Type Approach (called Variant 2) is proven to be the best approach. This approach can cut development time, idle time and critical path. Refer to table 4-26 for the complete comparison.

So far, deterministic time has been used in the analysis. This sound unrealistic, especially in software development project. Uncertainties may ruin the plan, which cause delays. Two uncertainties factor: Efficiency and Interruptions were observed. Those two factor were estimated and calculated to build a single Uncertainty Coefficient. The coefficient was used to build Optimistic Time, Most Likely Time and Pessimistic Time. The Most Likely estimation time was built with 75% efficiency and 15% interruptions. The coefficient was 157% (Whitten, Bentley and Dittman, 2000)."Guesstimate", described by Whitten, Bentley and Dittman (2000), was considered to be the worst scenario. So, the pessimistic time was calculated using 200% coefficient.

Several cut-off value were specified, which include the optimistic, most likely and pessimistic estimate value themselves. Cut-off time also includes series of value from 1,000 minutes to 20,000 minutes in 1,000 minutes incremental, depending on the development phase. Probability of works completed in specified time were computed. Probability of works completed at optimistic time is 11.061997%, at Most Likely Time is 52.081993% and at Pessimistic time is 84.480023%

In order to seek a better understanding regarding the effect of uncertainties factors described above, coefficients were modified. The Most Likely Estimate is recalculated using 120% uncertainty coefficient, while Pessimistic estimate is recalculated using 150% uncertainty coefficient. The probability of works completed series of specified time is also recalculated. Probability of works completed at optimistic time is 26.884193%, at Most Likely Time is 84.256941% and at Pessimistic time is 98.706747%

The probability result is increased. This means that a lower uncertainty coefficient will increase the probability of works completed in a specified time. Lower uncertainty coefficient can be obtained by increasing efficiency and/or decreasing interruptions.

5.2 Conclusion about Research Questions

Experiments conducted previously were intended to answer the Research Questions stated in sub-section 1.3. Based on each experiment conclusions, Research Questions can be answered as follows:

1. *What are Critical Time determinants in Packaged Software Development?*

Critical Time determinants found in this research are:

- Job Standardization, which include Standardized Object Specifications
- Job Sequence, as long as the sequence does not violate Job Precedence
- Learning Rate, triggered by Standardized Object Specifications and carefully designed Job Sequence.

2. *Is Standardized Object Specifications in a module can improve programmer's Learning Curve ?*

   Standardized Object Specifications is proven to improve programmer's Learning Curve. The result of B1 and B2 experiments of both programmer were the evidence.

3. *Is programmer's learning curve in building a module can improve overall Construction Time Estimation of Packaged Software Development Projects.*

   Learning Curve of a programmer can improve overall Construction Time Estimation of Packaged Software Development Project. The Job-Type Approach Variant 2 for both Phase 1 and Phase 2 in PERT/CPM Analysis can be used to support this statement.

4. *How to accommodate uncertainty in Critical Time of Packaged Software Development Projects*

   Efficiency and Interruptions has been observed as two uncertainty factors. Efficiency and Interruptions should be represented in percentage value, and combined as an uncertainty coefficient. The uncertainty coefficient will be used to build Optimistic, Most Likely and Pessimistic Value. CPM model is then used to calculate the probability of works completed in a specified time.

5. *How Standardized Object Specifications, Learning Curve and Uncertainty can be incorporated in Packaged Software Development so that construction time can be accurately estimated*

There are several steps should be done to incorporate Standardized Object Specifications, Learning Curve and Uncertainty Coefficient in Packaged Software Development as follows:

- A Standardized Object Specification should constructed as a basis of a Standardized Job-Type.
- Experiments in order to determine the Learning Rate of a programmer to accomplish specific Job-Type should be conducted. Development time of Standardized Job-Type can be forecasted using Linear Regression involving Log-linear model and certain programmer's Learning Rate.
- Sub-modules should be categorized in to Standardized Job-Type. The sub-module development sequence should be carefully constructed without violating the module precedence, based on Job-Type.
- Efficiency and Interruptions can become the source of Uncertainties. Efficiency should increased and Interruptions should be minimized in order to improve the probability of works completed in a specified time.

5.3 Conclusion about Research Problem

It has been already been stated that the research problem is:

- *How to estimate the Construction Time of a Packaged Software Development Project accurately?*

The construction time can be accurately estimated by using appropriate estimation tools and procedures. In order to estimate the Construction Time of a Packaged Software Development Project accurately several steps can be recommended as follows:

1. Standardized Object Specifications should be constructed. Standardized Object Specifications can become the excellent basis for constructing a Standardized Job Specifications.

2. Learning Rate of a programmer to accomplish a Standardized Job Specifications should be measured carefully

3. Development time of Standardized Job-Type can be forecasted using Linear Regression involving Log-linear model and certain programmer's Learning Rate.

4. Job Sequence should be constructed based on Job-Type without violating sub-module precedence. Carefully prepared Job Sequence is expected to stimulate a good learning rate.

5. Efficiency and Interruption should be incorporated as an uncertainty factor, by constructing an uncertainty coefficient. Efficiency should be increased while minimizing Interruption will result in a smaller

Uncertainty Coefficient. Smaller Uncertainty Coefficient will increase the probability of works completed within a specified time.

6. A set simple mathematical model is proposed to assists development time estimation process as follows:

$$T = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{y=1}^{x}(TS_1 \bullet y^b) \qquad (5.1)$$

where:
T = Estimated development time of the overall project
n=number of phase in the project
i=CTP's inde
m=number of sub-module group found in a phase
j=TG's index
y=index of TS
x=The number of Sub-module sequences in a group
value of b can be computed using the following equation

$$b = \frac{\log r}{\log 2} \qquad (5.2)$$

where:
r=learning rate

The equation can be used to reflect the optimistic estimates. The equation can be rewritten as follows

$$t_o = \sum_{y=1}^{x}(TS_1 \bullet y^b) \qquad (5.3)$$

where:
t_o=Optimistic Time Estimates
TS_1=Development Time of the first sub-module
y=index of TS
value of b can be computed using equation 5.3.2

Most Likely estimation can be constructed by adding an Uncertainty Coefficient (C_m) to equation 5.3.1 as follows:

$$t_m = \sum_{y=1}^{x}(TS_1 \bullet y^b \bullet C_m) \qquad (5.4)$$

where:
t_m=Most Likely Time Estimates
TS_1=Development Time of the first sub-module
y=index of TS
C_m=Most Likely Estimate Coefficient
value of b can be computed using equation 5.3.2

Pessimistic estimation can be constructed by adding an Uncertainty Coefficient (C_p) to equation 5.3.1 as follows:

$$t_p = \sum_{y=1}^{x}(TS_1 \bullet y^b \bullet C_p) \qquad (5.5)$$

where:
t_p=Pessimistic Time Estimates
TS_1=Development Time of the first sub-module
y=index of TS
C_p=Pessimistic Time Estimate Coefficient
value of b can be computed using equation 5.3.2

5.4 Theoretical Implications

Several theoretical implications can be drawn from this research as follows

1. Learning Curve can be observed in the first part of the research. Construction time of Programmer 1 and Programmer 2, both at B1 and B2 Session shows a significant decrease with calculated to be 72% to 84% learning rate. On the contrary, no learning curve observed at A sessions of both programmer. Submitting a properly sequenced job-assignments will reduce the construction time. This strengthen the Learning Curve Concept presented by Graither and Frazier (2001); Krajewski and Ritzman (1990);

Nahmias (2001); Render and Heizer (2004); Schonberger and Knod (1994); Russel and Taylor, (2003)

2. The use of Standardized Object Specification can improve Learning Curve of a programmer. This research agree that a good Learning Rate can improve the performance of a programmer in a software development project. This research agree that combining the effect of various factors, such as specialization, standardization, product re-design, improved process and methods, management can exploit experience cost opportunities to drive down the cost of production (Chambers and Johnston, 2000; and Nahmias, 2001)

3. This research suggests that Learning Curve Concept which was developed more that 80 years ago for manufacturing environments, supported by Regression Analysis can assists the development time of a sub-module in a modern Software Development Project. This fact underlines that Learning Curve Concept, initially observed by Commander of the Wright-Patterson Air Force Base in Dayton, Ohio, in 1925, presented by Graither and Frazier (2001); Krajewski and Ritzman (1990); Nahmias (2001); Render and Heizer (2004); Schonberger and Knod (1994); Russel and Taylor, (2003); is still relevant in current business environment, even though in a young, dynamic and liquid environment such as Software Development business as Software Development environment observed by Tong (1994)

3. PERT/CPM model, developed in 1950's, combined by Regression Analysis and Learning Curve Concept can be used to construct the best overall development time. This means that the Project Management materials presented by Chase, Aquilano and Jacobs (2004); Graither and

Frazier (2001); Hillier and Lieberman (2001); Krajewski and Ritzman (1990); Levine, *et. al.,* (1989); Nahmias (2001); Render and Heizer (2004); Schonberger and Knod (1994); Russel and Taylor, (2003); can be extended and implemented in Software Development area.

4. A well-designed sub-module sequence based on a valid forecasting process can improve the overall project development time. PERT/CPM model is proven to be a valuable model, but its accuracy can be improved by a set of statistically valid estimation data. This fact supports Whitten, Bentley and Dittman (2000), who said that an effective project management is necessary to ensure that the project meets the deadline. A prerequisite for a good project management is a well-defined system development process.

5. Implementation of Object Oriented Technology makes Work Breakdown Structure and Network Diagram Construction possible. Ability to breakdown the large project into several small and manageable parts means that modularity can be emphasized. The modularity and standardization supported enabled by Object Oriented Technology will decrease development time and improve the quality. The use of Object Framework and Components can resemble modular design concept in Operations Management. This means that Modularity and Standardization Concept stated by Stevenson (2003) can be extended and implemented in Software Development process. The findings also supports Ihison and Youg-Gul, (2002) who suggests that Object Oriented Technology increases the ease of building modular components.

5. This research agrees that construction time of s sub-module should be estimated using a valid statistical approach. Several statistical test which

conducted during Learning Rate calculation process may lead to a valid sub-module development time forecasts. These findings conforms with Whitten, Bentley and Dittman (2000) that poor estimating techniques by making best-calculated estimate (jokingly "guesstimate") triggers project mis-management which may lead to a total project failure

5.5 Contributions to the Knowledge

Systems Development Projects, especially Software Development Projects, has already known to be late. Difficulties in estimating the development time usually cause this problem. Several methods has already built, but they are not easily implemented.

1. A set of simple mathematical model is proposed to reduce the complexity of estimating the construction time of a software development project. The model has its root in Learning Curve and PERT/CPM model, built and combining them to perform a simple yet accurate model.

   Tong (1994) said that there is a lack of Software Development Standard. This set of simple model is expected to enrich the software development standard. A set simple model conforms parsimonious criteria described by Thomas (1996). By using a simple model, mismanagement which cause delays in Software Development is expected to be minimized. It is also expected to increase user satisfaction (Clarke and Doherty, 2004; Dube, 1998; Herzwurm, 2003; Krishnan, 1998; Suwardhy, et al, 2003; Tong, 1994; Whitten, Bentley and Dittman, 2000)

2. Software is some times considered as an art (Blackburn, *et. al.,* 1996) . The nature of Software Development with is virtual and very difficult to measure (Tong, 1994).

   This thesis proposed a set of simple mathematical models. This set of model is expected to open a new horizon of finding a more sophisticated but easy to implement models so that that software development can be managed easily instead of leaving the process as an art only.

5.6 Managerial Implications

This research has brought some managerial implications, especially regarding standardization and uncertainties as follows:

5.6.1 Standardization

This research suggest that Standardized Object Specifications and Standardized Job-Design improved the performance of a programmer. Based on this finding, the company, P.T. Marga Computindo Sarana - Systems Integration Division, should make the best effort in standardizing the job assignments. A detailed instructions should accompany every single job assignment to avoid confusion and reduce unnecessary "imagination" of a programmer.

5.6.2 Uncertainties

Uncertainties always happen everyday. Software Development Project Manager has to deal with uncertainties. There are two factors to be considered: efficiency and interruptions. As described earlier, the combination of 75%

efficiency and 15% interruption is a realistic figure. Effort to increase efficiency and reduce interruption should be conducted by the company in order to increase the number of probability of a series of job assignments to be completed under a specified time.

In order to obtain a higher probability of works completion, project manager would have to increase efficiency by reducing such contra-productive activities (such as extended coffee breaks and lunch breaks, participating in non-project works and engaging in idle conversations) and minimizing any kind of interruption (such as unnecessary phone calls, unnecessary web surfing, etc) to increase the programmers' focus.

5.7 Research Limitations

Several limitations has been realized during the research as follows:

1. The research was conducted only in a local company. A research involving more companies would be result in a better conclusion, but the number of similar companies has become the constraint. Special characteristics in Software Development might restrict the number of existing companies compared with another business type such as retail and distribution companies.

2. Lack of existing standard in software development makes difficult to justify the result of the experiments further. As an immature business but rapidly growing, existing documentation regarding the development process is difficult to find.

3. The research unit in this research is jobs submitted to the programmers. An A-B-A-B experiment design was conducted with 14 experiment each segment. Two novice programmer were involved in this research, attempting to accomplish two Job-Types. Increasing the number of Job-types and programmers involved in the research might be favorable.

4. Difficulties in finding programmers who really meet the requirement is also considered in this research. Unskilled programmer may also cause performance bias which may affect in the research. Preliminary training was done as an effort to minimize the performance bias. But, preliminary training obviously penalize the experiment time.

5.8 Future Research Opportunities

Several opportunities still available for future research in order to shape the findings in this research even better. A number of area has not been touched by the research. So, future research may include:

1. Exploring another factors which may cause Learning Curve of a programmer to be better. Several technical aspects which include the quality of development facilities, network connections, official release of newer version of the programming language etc.

2. Exploring the effect of findings in a different programming environment.

3. Exploring another uncertainty factors which influence the programmer's productivity.

4. Exploring the source of programmers such as academic institutions in order to investigate the factors which influence the quality of the programmers.

So far, there are several experiments has been conducted in order to seek a simple model in to estimate the construction time of a Packaged Software Development, involving Biometric Time and Attendance Systems Development as the pilot study. A set of mathematical models has been presented to answer the research problem. It has been realized that there are limitations in the study, but efforts to make a small contribution to knowledge has already been done. Future researchers are invited to enhance current findings.

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Biometrics Research at Michigan State University: Pattern Recognition and Image Processing Lab, Department of Computer Science and Engineering:
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