5-2000

Target Monitoring and assessment system

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TARGET MONITORING & ASSESSMENT SYSTEM FOR PRODUCTION CONTROL

TAREK MUSTAFA A/SAMAD

2000

THE AMERICAN UNIVERSITY IN CAIRO
SCHOOL OF SCIENCES AND ENGINEERING

Target Monitoring and Assessment System For Production Control

A Thesis Submitted To

The Engineering Department

in partial fulfillment of the requirements for the degree of

Masters of Science in Engineering
with concentration in:
Industrial Engineering

by

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American University in Cairo
May 2000

The American University in Cairo
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Master of Science in Engineering with Specialization in Industrial Engineering

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Dedication

"***Dream as if you'll live forever. Live as if you'll die today***."

James Dean

This work is dedicated to all my family, friends, and all people whom I love and care for. Dedicated to all the notions, ideas, words of wisdom, knowledge, and fair judgments, which have inspired my thinking. Above all, this work is dedicated to my great parents, and to close friends and colleagues: Dina Hegazy, Ahmed Zarea, Mahmoud Demillawi, Mahmoud Lashin, Ahmed Shaer, Samy Raafat, and Nader Greiss, who have shown great concern, love, and encouragement during the achievement of this work.

Tarek Mustafa Al Samad

Acknowledgement

For the development of this thesis, I would like to gratefully acknowledge the support of Dr. Yasser Hosni of the UNIVERSITY OF CENTRAL FLORIDA, USA, Dr. M. Sadek Eid of the UNIVERSITÉ DE MONCTON, Canada (currently both of the AMERICAN UNIVERSITY IN CAIRO). Their useful comments and suggestions have made this thesis possible.

I am also grateful to Dr. Nahed Sobhy for her constant help, advice, understanding and support.

I am also grateful to Dr. Quentin W. Fleming for his help, and support.

I would also like to express my gratitude and deep appreciation to Dr. Hatem El-Ayat of October University, and all my Engineering Professors and Doctors in the AUC for their encouragement, constant help and suggestions with this work.

Abstract

Monitoring and control of production projects' progress monitoring is a major task in production management. The current techniques for production project monitoring and control are poor at best. While the Line of Balance (LOB) technique has been known for years, it has never been adopted or used efficiently; due to its reliance on graphics. Project managers are in dire need for a tool through which they can assess project progress early enough, to regain control on both: project schedules and costs. Such a tool would help production manager to meet the customer's requirements in quantity, quality and delivery date with the least possible cost.

The objective of this research is to develop analytical model based on the LOB graphical technique. The model and its practical system are meant to assist project managers monitor and control repetitive types of production projects, introduce and utilize cost, as a performance measure to enable tangible assessment of malfunctions in the production cycle. The model, presented here, Target Monitoring and Assessment System for Production Control, TMAS, is translated into a computer-based system using Visual Basic with a direct link to common "of-the-shelve" MS Access Database. Along with its development in a user-friendly format, the system is amiable to be used by small and medium size industries as well as large organizations. The system helps in the creation of database for different factories, production lines and variety of products, processes and durations. This system identifies automatically the control points, which should be monitored. The graphical component of the system draws lead-time chart using the set back method. It distributes the user-entered values for idle time, storage, and delay costs over the different control points. Production orders are tracked from the database.

Users periodically "tally" production at the control points, and the system calculates the LOB values for each control point, assess the status at each (leading, lagging, or on schedule), and determines deviation and potential cost to the organization. The cost value helps the manager in assessing the severity of "bottlenecks" and in providing the proper remedial action to regain control.

The system, TMAS, was applied to three true case studies. The results are provided in the form of tables as well as in graphical representation to give valuable information for decision-making. The TMAS system results, for the three case studies, came out to be conforming to the ones calculated manually using the graphical LOB. The system should be of great value to practitioners and academicians involved in production systems as it results in substantial saving in time and effort as compared to manual calculations.

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Chapter I

INTRODUCTION

Chapter 1
Introduction

1.1 A Project Versus A Production Operation

Before defining what is Project Management, or what is Production management, it is crucial to define both terms: project and production operations. Again, before defining what is a project or an operation, it is important to differentiate between both of them. Considering it; organizations (facilities) perform work; work generally involves either operations (processes) or projects, although they may overlap. Operations and projects share many characteristics; for example, they are:

- performed by people or machines or tools;
- constrained by limited resources: e.g. cost and time; and
- planned, executed, monitored and controlled.

Operations and projects differ primarily in the nature of each; operations are ongoing and repetitive (recurring), while projects are temporary and unique. A project can thus be defined in terms of its typical characteristics. A project is a temporary enterprise in which human, material and financial resources are organized, in a narrative way, to carry out an exclusive span of work, of a known specification, within the constraints of cost and time, to achieve an advantageous change defined by quantitative and qualitative objectives undertaken to create a unique product or service. Wysocki et al. (1995) and Burke (1996) define a project as:

"a **sequence of unique, complex** and **connected activities** having **one goal** or purpose and that must be completed by a **specific time, within budget** and **according to**

specification" (Wysocki 1995). or "a group of **activities** that have been performed in a logical sequence to meet present objectives outlined by the project" (Burke 1996).

Temporary means that every project has a definite beginning and a definite end. Unique means that the product or service is different in some distinguished way from all similar products or services. Projects are undertaken on all levels of the organization. They may involve a single person or thousands. Projects may involve a single unit of one organization or may involve cross-organizational boundaries as in joint ventures and partnering. Projects are often regarded as critical components of the performing business strategy of organizations.

Now searching for the meaning of operations or processes as in production: "Operation, is (1) A job or task, consisting of one or more work elements, usually done essentially in one location. (2) The performance of any planned work or method associated with an individual, machine, process, department, or inspection. (3) One or more elements which involve one of the following: the intentional changing of an object in any of its physical or chemical characteristics; the assembling or disassembling of parts or objects; the preparation of an object for another operation, transportation, inspection, or storage; planning, calculating, or the giving or the receiving of information." (ANSI Z94 1983). As for the process it is: " a planned series of actions or operations (e.g., mechanical, electrical, chemical, inspection, test), which advances a material or procedure from one stage of completion to another." (ANSI Z94 1983)

Finally it can be concluded that projects and operations (processes) share many things in common that production operations could be dealt as a project. This technique is called managing by a project, and it will be discussed in the following section.

1.2 Project Management Field Of Knowledge

Project management can be defined as; **"making the project happen"**(Burke 1996). Project management is the application of information, skills, tools, and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project. Meeting or exceeding stakeholder needs and expectations invariably involves balancing competing demands, among which:

- Scope, time, cost, and quality.
- Stakeholders with differing needs and expectations.
- Identified requirements (needs) and unidentified requirements (expectations).

The term 'project management' is sometimes used to describe an organizational approach to the management of ongoing operations or processes. This approach, more properly called management by projects, treats many aspects of ongoing operations as projects in order to apply project management to them.

The 'Project Management Knowledge Areas' describes project management knowledge and practice in terms of its component processes. These processes have been organized into nine knowledge areas as described below and as illustrated in Figure 1-1.

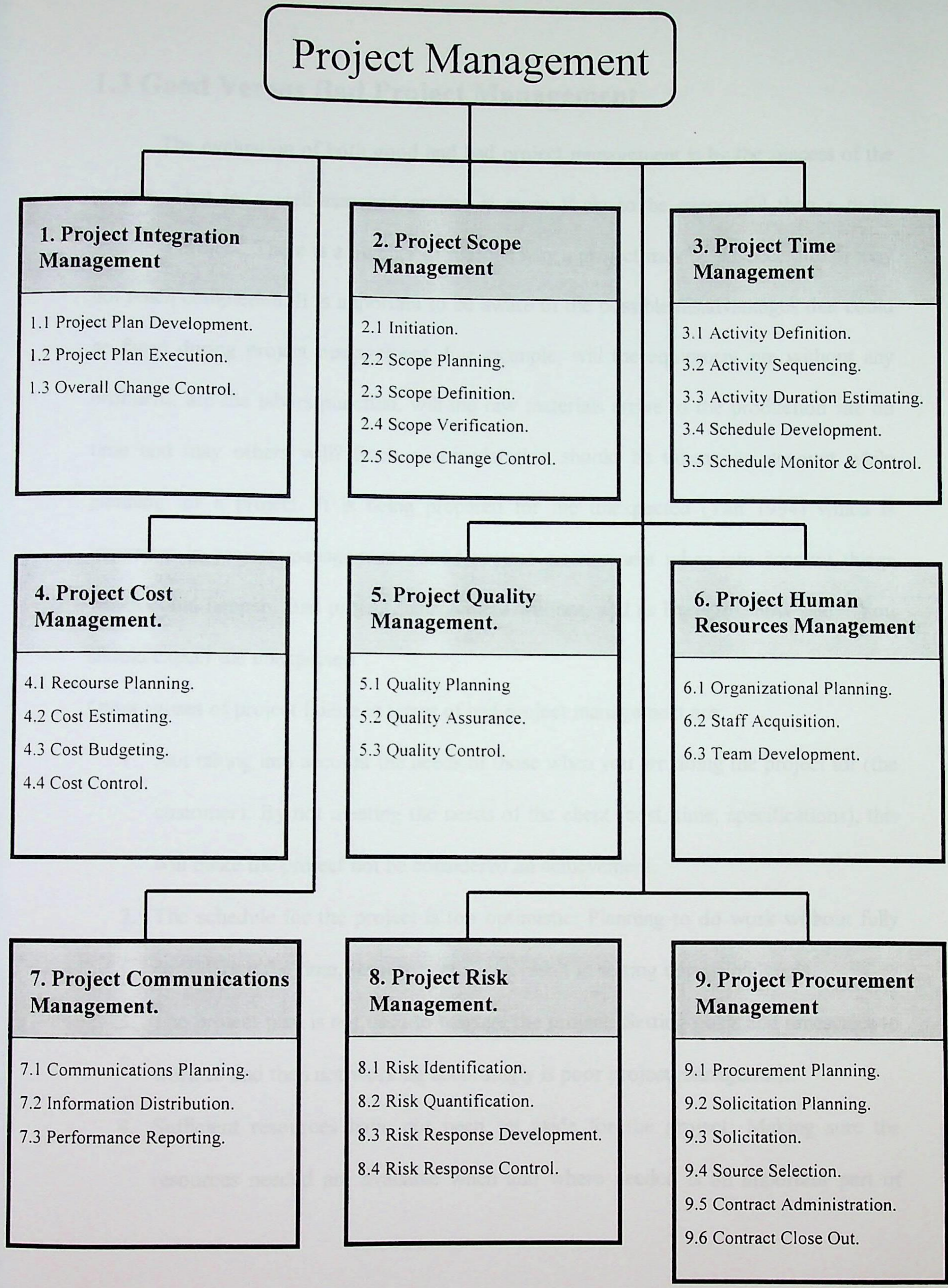


Figure 1-1 Overview of Project Management Knowledge Areas and Project Management Processes

1.3 Good Versus Bad Project Management

The evaluation of both good and bad project management is by the success of the project. That is, a well-managed project is more likely to be successful than a badly managed project. There is a number of reasons why a project may be unsuccessful or may not reach completion. It is important to be aware of the possible disadvantages that could be faced during project management. For example, will the equipment run without any problems, are the labors punctual, will the raw materials arrive to the production site on time and may others will? Such a consideration should be taken into account while planning for a project. It is being prepared for the unexpected (Tan 1994) which is important in project management. Good project management takes into account things which could happen. Bad project management will not, and as Bernard Show said " You should expect the unexpected".

Other causes of project failure in terms of bad project management are:

1. Not taking into account the needs of those when you are doing the project for (the customer): By not meeting the needs of the client (cost, time, specifications), this will make the project not be considered an achievement.
2. The schedule for the project is too optimistic: Planning to do work without fully considering the time, resources,etc., can result in setting impossible goals.
3. The project plan is not used to manage the project: Setting goals and timescales to work to and then not working accordingly is poor project management.
4. Sufficient resources have not been set aside for the project: Making sure the resources needed are available when and where needed is an important part of

project management. Unable to do so can affect the progress and the completion of the project.

5. The progress of the project is not monitored against the project plan: It is important to keep track of the progress of the project to show the direction, which the work is taking. Measuring the progress of the project is done through checking the point achieved against the project plan. This will show whether the work is progressing according to the project plan or not.

Good project management avoids these problems. It is the careful planning of a project that completes the project on time and according to the required specifications. The key to completing a project successfully is to have an effective plan, execution, monitoring and control. These will identify what needs to be done in order that the objectives of the project can be met (Tan 1994).

The careful planning, execution, monitoring, and control of a project takes into account all factors which may affect the project. In terms of the 5 factors listed above, which can cause the failure of projects; good project management will avoid such factors. Good project management will:

1. Take into account the project specification and needs.
2. Plan a realistic schedule in which deadlines and goals can be achieved.
3. The project plan is used and adhered throughout the project.
4. The availability of resources is taken into account.
5. Progress is monitored against the project plan.

Good project management is an investment. Wysocki et al. (1995) describes the 'project management pain curve' where the phrase "pay now or pay later" can be applied, meaning that if a project is not planned carefully with some initial effort (or pain), then later on the effort (or pain) required will be enormous. Good project management can then be seen as an investment, which avoids the pain of bad project management. Figure 1-2 shows giving the project management pain curve (Wysocki et al. 1995) the effort (pain) associated with good project management in comparison with that in bad project management.

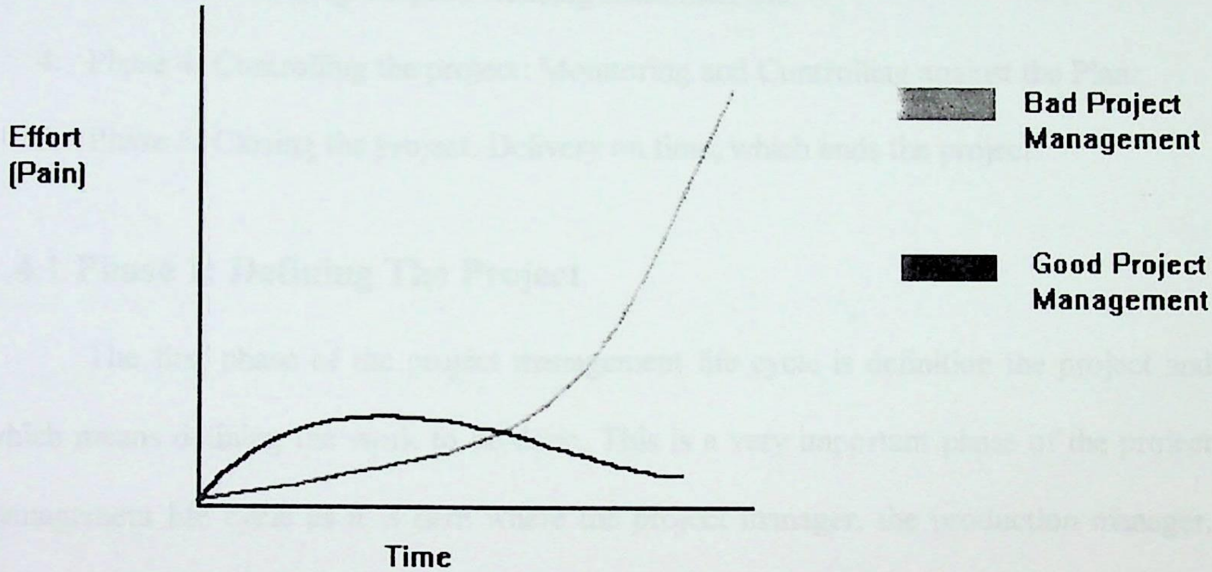


Figure 1-2: The Project Management Pain Curve (Wysocki, 1995)

In summary, good project management is:

- Well planned.
- Takes into account the unexpected.
- Takes into account time and resources.
- Refers to the original plan.
- Monitors progress against the original objectives.

Bad project management does not reflect any of these characteristics and results in an unsuccessful project.

1.4 The Project Management Life Cycle

The process of project management consists of a number of phases; which may include 5 main phases:

1. Phase 1: Defining the project: What should be produced or done?
2. Phase 2: Planning the project: Checking the available resources.
3. Phase 3: Executing the plan: Loading Machines, etc.
4. Phase 4: Controlling the project: Monitoring and Controlling against the Plan.
5. Phase 5: Closing the project: Delivery on time; which ends the project.

1.4.1 Phase 1: Defining The Project

The first phase of the project management life cycle is definition the project and which means defining the work to be done. This is a very important phase of the project management life cycle as it is here where the project manager, the production manager, and the client or customer defines the project. This first stage of the life cycle involves the definition and the agreement upon the terms of reference for the project (Tan 1994). It is at this point of the project management life cycle that the aim (what should be produced), objectives (specifications), and constraints (time, cost) are defined.

Wysocki et al. (1995) state that there are five questions that should be asked at this stage of the project management life cycle. In terms of a research project these questions are:

1. What is the product to be produced?

2. What is the goal of the project?
3. What resources are necessary in order to accomplish the goal?
4. How will the success of the project be determined?
5. Are there any risks or obstacles that may affect the completion of the project?

Considering such questions early in the project life cycle will help defining the project and what the project is about and what it is trying achieve.

1.4.2 Phase 2: Planning

Wysocki et al. (1995) state, "Some would argue that planning is a waste of time" and that once a plan is developed some factors may cause it to change. There is also the opinion that once a plan is developed it will not be used (Wysocki et al. 1995).

Project planning is a dynamic activity. The plan will change over time as tasks maybe completed on time, before the stated time (Leading), or after the deadline (Lacking). These are called slippage. A complete project plan, however, will clearly state what work is to be done. Wysocki et al. (1995) state that planning reduces uncertainty and improves efficiency.

1.4.3 Phase 3: Executing The Plan

The subsequent phase of the project management life cycle is to set the plan into action. Implementing the project plan involves the organization of resources. Implementing the project plan means executing the project plan, adhering to the plan and carrying out the tasks in the order and the time stated within the plan.

When carrying out the plan it is important to record the actual time taken to complete a task against the planned time for a task. This will show any spare time to be

reallocated or extra time required. Reallocation of time will mean making changes to the project plan.

1.4.4 Phase 4: Controlling The Project

Control of the project is an important part of project management or the product management. Monitoring the progress of the project helps ensure that the project is on schedule and that it is progressing according to plan. Tan (1994) states that "You need to monitor your performance in order to review the feasibility of your plan on an ongoing basis."

By monitoring the project progress, it will be easy to re-examine the plan of work whether it is too optimistic or too realistic and it will be clear if the plan needs to be changed or not.

The project plan as a whole is a way in which the project can be controlled. Through controlling and monitoring the work and the progress, the project is adhered to the plan. In order to carry out the project, as Burke stated, controlling and monitoring should be applied throughout the project execution phase. This could lead to changing the project plan to meet its new situation.

1.5 Project Control And Monitoring Process

Control is the process of making sure things happen in an ordered manner or according to a plan. The basic control process involves creating plans/standards, measuring performance against plans/standards, identifying deviations and taking corrective action. Monitoring is the evaluation of project status at key points along its schedule. Effective monitoring provides a number of benefits. It improves project

performance together with the management of the project. It ensures that quality of project work does not take a back seat to schedule and cost concerns and reveals developing problems early enough so that action can be taken to deal with them. The project plan when prepared in the early phases of projects provides the framework within which the project manager will gauge progress once the project is under way. The process of controlling and monitoring involves conducting regular formal and informal reviews (both managerial and technical) to monitor progress, adjust the project plan where necessary, and formally document the project status. The purpose of this process is to identify potential problems before they happen and specify necessary problem solutions.

The result of the controlling and monitoring process is a list of problems or potential problems. Managing these problems would pose putting off tasks or operations if the priorities of the problems are not managed properly. The focus should always be to solve the most important problems first. However, the priorities of the problems would change as the project progresses. Therefore, continuous evaluation, monitoring, and control are essential.

1.6 The Need For Monitoring

One phase of production planning and control involves monitoring the project or the production system to supply the necessary data for control of operations. So as perform the corrections needed to guarantee the contiguous probable conformance with the master delivery schedule or the master project plan. Management must have a steady flow of information about the status of operations and activities and the reasons for any

deviations from previously prepared plans. This feedback helps management to take corrective action and, in addition, aids in the development of future plans.

Production system management of problems have across-the-board, effects not only in production departments but also in other departments such as sales or engineering, etc. Usually, management cannot afford to wait for complaints before collecting data about production problems. The Line of Balance technique is used as an approach for gathering production information for control purposes. This is the focus of this research.

Chapter II

LITERATURE SURVEY

Chapter II
Literature Survey

2.1 History Of Development Of Line Of Balance Technique

Network analysis techniques such as CPM and PERT are generally used for scheduling projects, including production projects. However, repetitive production projects include a known set of activities or operations in a known sequence to produce a unit product. The same routing repetitively can produce all units (Moselhi and El Rayes 1993). Network analysis techniques cannot handle the correlation of such repetitive occurrence of the same activities since they assume each activity in the project network to be independent (Moder et al. 1983).

The production systems of repetitive units can be thought of as the continuous manufacturing of many units necessitating a certain period of time for each unit to be completed. Literature reveals that the Line-of-Balance technique (LOB) is the most suitable method for production projects. The LOB method is a major tool among the linear scheduling techniques and is acknowledged widely to be applicable to the scheduling of repetitive kind of projects (Reda 1990, Cole 1991)

The LOB technique was originally derived from manufacturing industry (Neale 1989). It is a graphical scheduling method that originated and was developed by a group headed by George E. Fouch. During 1941, The American Goodyear Tire & Rubber Company monitored production with LOB. It was first applied to industrial manufacturing and production control where the objective was to attain or evaluate the flow rate of finished products in a production line (Line of Balance 1962).

The LOB technique, as mentioned, can be used in projects involving activities of a repetitive nature. Many practitioners have used the LOB method in industry as a scheduling technique. In the early 1950s, the U.S. Navy successfully applied the LOB to the production planning and scheduling of the huge Navy mobilization Program of World War II (Suhail and Neale 1994). Figure (2-1), shows the first graphical representation of the LOB method.

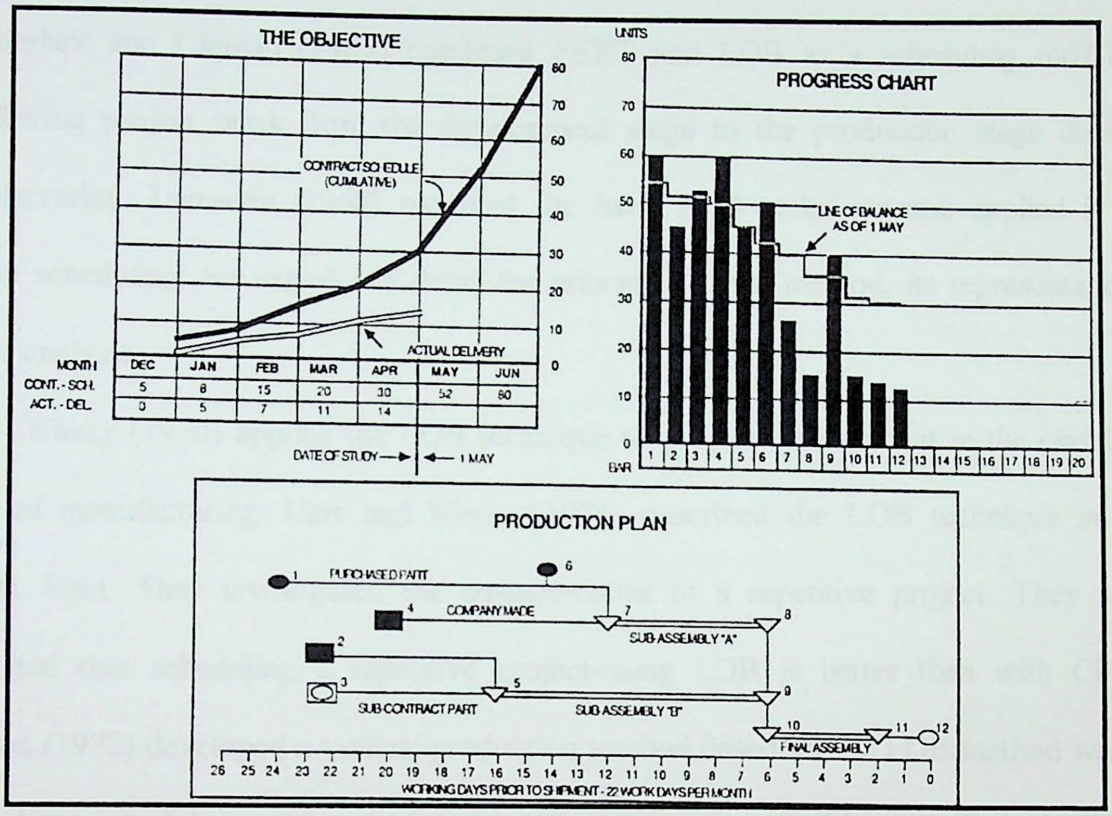


Figure 2-1: Illustration of the LOB method (Line Of Balance Technology, 1962)

LOB proved to be a valuable tool for expediting production visibility during the Korean hostilities. During this period, defense suppliers used LOB. Since then LOB has been found to be most useful for planning, scheduling and monitoring progress of simple to complex manufacturing projects. In particular, it is most appropriate for manufacturing and assembly operations, which involve a large number of diverse operations.

LOB application has been further expanded making it useable now across a whole spectrum of activities ranging from research and development through job shop and process flow operations. In its current form, LOB combines features from the Gantt chart schedule and the critical path network schedule. Both of these techniques are widely used in the majority of British, European and American companies.

Going some how far back in the history of the Line of Balance technique, Schoderbek and Digman (1967) combined PERT and LOB as a scheduling tool for transferring project work from the development stage to the production stage during manufacturing. Lumsden (1968) modified the basic LOB technique and applied it to project scheduling. He explains in detail the principles of the method, its representation, and its analysis.

Khisty (1970) applied the LOB technique to project management in the classical sense of manufacturing. Carr and Meyer (1974) described the LOB technique in its present form. They investigated the characteristics of a repetitive project. They also suggested that scheduling a repetitive project-using LOB is better than with CPM. O'Brien (1975) developed a vertical production method based on the LOB method which is used to schedule projects such as construction ones. Arditi and Albulak (1986) explained how LOB method might be used in pavement projects. Cole (1991) used six cases to illustrate the characteristics of CPM and LOB as used in site construction projects. Cole concluded that CPM is suitable for non-repetitive projects and LOB is applicable to repetitive projects. Gaither (1992) used an example to illustrate the application of the LOB method to assembly line scheduling. Lutz and Hijazi (1993) presented the current practices in using the LOB method. Suhail and Neale (1994) tried to

integrate the LOB and the CPM into a new technique. Their technique focuses on resource leveling and utilization of float times to streamline the scheduling process.

All the above stated research efforts go after a fundamental hypothesis of the LOB method which is that the same activities in adjacent units will progress continuously, and the same activities in each unit have the same lead time (Reda, 1990).

2.2 Advantages And Disadvantages Of Line Of Balance Technique

Line Of Balance (LOB) is an executive monitoring and control process for gathering, measuring and showing information concerning time, cost and achievement, all compared to a specific plan. It illustrates the process, standing, conditions, timing, and phasing of the project activities, thus supplying executive with measuring tools that help:

1. Comparing actual progress with a formal objective plan;
2. Examining only the deviations from established plans, and gauging their degree of severity with respect to the remainder of the project;
3. Receiving timely information concerning trouble areas and indicating areas where appropriate corrective action is required;
4. Forecasting future performance; and,

The next set of points sum up some advantages of the Line of Balance technique:

1. LOB is a clear-cut and tremendously effective planning and control method;
2. It creates and enforces a planning discipline, which can be used to control a delivery plan to a customer;
3. It is easily used to assess and re-evaluate lead times and cycle times;
4. The projected finishing point schedules of all parts in order are clearly obtainable;

5. It provides a scheduling tool, which can determine precedence;
6. It gives the existing status and location of each part is known;
7. It makes updating the production schedule straightforward in comparison to other monitoring approaches in a much-reduced amount of time;
8. It gives the improvement of parts along the production project in assessment to the output needed to meet the delivery schedule;
9. It gives the history of each part performance is given at each checkpoint;
10. It reveals the crash of parts to meet up projected deliveries;
11. It identifies operation at problems and roadblocks in the manufacturing process;
12. It facilitates tracing forward the future effects of current delays;
13. It points out the degree of urgency for actions needed;
14. It points out in advance any deficiencies with respect to material input;
15. The Line of Balance method is proactive not reactive.
16. It reduces panic and problems fighting before they happen.
17. All information including the schedule, the progress and deficiencies for all areas are presented clearly on one piece of paper.

Although there are many advantages, as listed above, that are pointed out by many books, and articles, there are some disadvantages, such as:

1. Kavanagh (1985) pointed out that the LOB technique is designed to model simple recurring production processes and, therefore, cannot be used for complex project management;

2. Arditi and Albulak (1986) stated that visual problems exist in the presentation of the LOB diagrams and suggested that color graphics be used to differentiate between overlapping activities;

3. Neale and Raju (1988) tried to refine the LOB in a spreadsheet format by introducing activities that run concurrently. They met head-on the complex relationships that the spreadsheet had to express and concluded that it was practically worthless to draw the output in the form of a diagram with an incomprehensible mass of flow lines.

4. Neale and Raju (1989) mentioned that the LOB could show clearly only a limited amount of information and a limited degree of complexity, especially when using the technique to monitor progress.

It can be seen from the above that the advantages out-weight the disadvantages. Based on the available literature, it is concluded that the development of a computerized model is needed to facilitate solutions using the LOB method and to overcome its disadvantages.

2.3 S Curve As A Target Monitoring Technique

The S curve is a graph of the cumulative value of percentage complete, man-hours, or cost against time. The graph acquires the form of an S shape for the reason that most projects have a slow start, pursued by a longer period of relatively constant activity at a higher rate of activity, and finally a falling off of this rate of activity to give a slow finish.

The S curve is a highly responsive tool for the analysis and control of project progress. The main advantage of S curves is that they can be used to identify trends at an

early stage, because they can monitor both the rate of project progress, and also the acceleration or deceleration of this rate. In manpower analysis the slope of the curve represents the rate of expenditure of man-hours, that is the velocity, and the rate of change of the curve represents the rate of build up or run down of the momentum of work on the project, that is, the acceleration or deceleration of the pace of work. S curves can be used to represent the project as a whole, work-breakdown structure items, and organizational or functional work packages. Figure 2-2 shows the planned percentage man-hours S curves for work on the design and construction, respectively, of a petrochemical project.

Three elements of data are required to be graphed on an S curve for effective control of man-hours. These are:

1. The planned cumulative expenditure of man-hours against time.
2. The actual cumulative expenditure of man-hours against time.
3. The cumulative man-hours equivalent of actual work completed, that is, earned value.

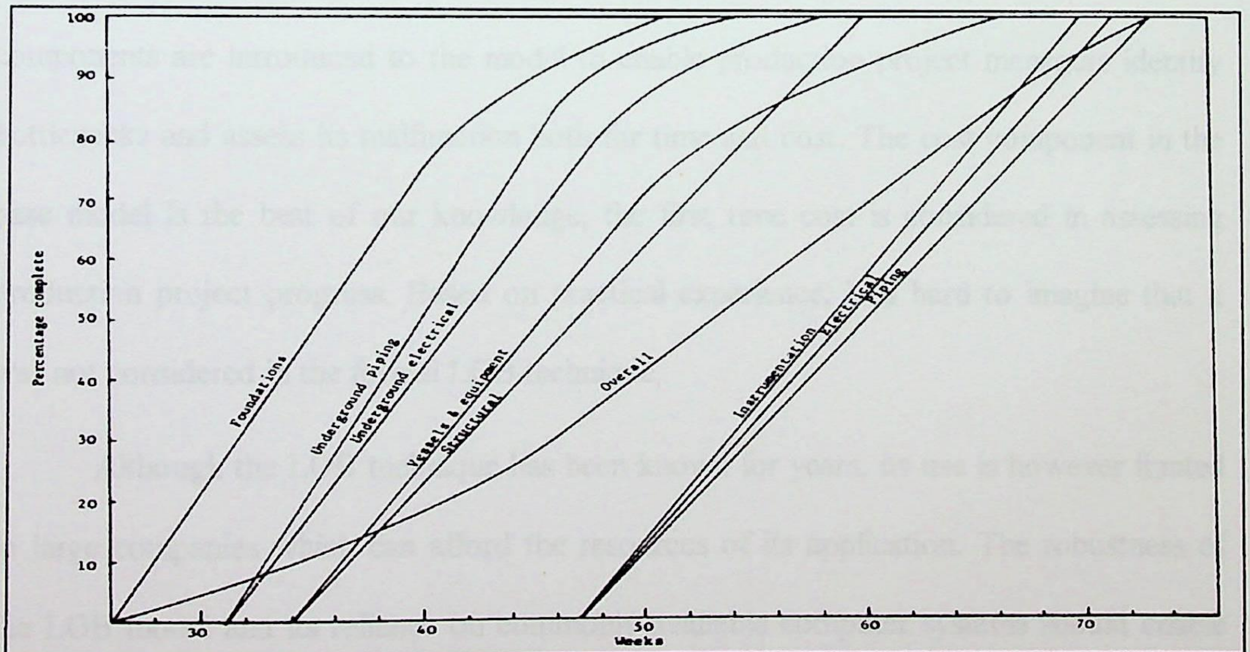


Figure 2-2: The planned percentage man-hours S curves (Gaither 1995)

The slope of the curve at the start represents the initial rate of work on the project If the gradient of the actual man-hours curve is less than planned, then it is obvious that there is too slow a start. Thereafter the first critical point is where the curve should turn up at the bottom of the S. If this critical acceleration of work on the project does not occur as planned, that is, the S curve does not turn upwards; the project is going to be delayed, no matter what is done. Once the curve does turn up, the slope of the curve shows the rate of progress. If work is not progressing as fast as planned, the slope of the actual curve very quickly and obviously becomes less than that of the planned work curve. At the top of the curve if the work does not decelerate as planned then there is going to be an overshoot This is because it is generally not possible to finish off a project without the slowing up of the pace of work, as is represented by the top of the S.

2.4 Research Objectives

This research is aimed at formalizing the graphical Line of Balance technique and developing a user-friendly computer system for production control. Both time and cost components are introduced to the model to enable production project managers identify bottlenecks and assess its malfunction both for time and cost. The cost component in the base model is the best of our knowledge, the first time cost is considered in assessing production project progress. Based on practical experience, it is hard to imagine that it was not considered in the formal LOB technique.

Although the LOB technique has been known for years, its use is however limited to large companies which can afford the resources of its application. The robustness of the LOB model and its reliance on commonly available computer systems should enable

its application for small and medium industries as well as large industries. After creating this mathematical model, computer software is to be developed using Visual Basic version 6.0. This application should provide the management with daily, weekly, monthly and yearly reports as well as charts depicting the production of all the critical machines or operations. A production analyst should be able to enter the daily production data, while the software access the necessary DB, compiles accumulated data, and integrate it to provide accurate progress graphs and reports, complete with quantitative assessment at each control point both from the schedule and cost criteria. It should also keep track of the orders, complete and pending. This should help the managers decide to allocate resources to accelerate the production and regain control.

Chapter III

MONITORING USING LINE OF BALANCE

Chapter III
Project Monitoring Using Line Of Balance

As stated before, the US Navy invented and created the Line of Balance as a graphic method used in linear industrial project scheduling. It compares the required orders counter to accomplishments.

3.1 Identification Of Line Of Balance Technique

Line of Balance is a technique of presenting a production target, the plan to attain that target, and the actual progress achieved at any point in time. It provides a type of "Early Warning" system with a way of graphically linking the project's achievements against its planned reference at any point in time. The U.S. Navy defined the LOB in their booklet as:

> "Line of Balance is a technique for assembling, selecting, interpreting, and presenting in graphic form the essential factors involved in a production process, from raw materials to completion of the end product, against a background of time. It is essentially a management-type tool, utilizing the principle of exception to show only the most important facts to its audience. It is a means of integrating the flow of materials and components into manufacture of end items in accordance with phased delivery requirements." (Navy Office of Naval Materials, 1962)

The line of Balance name is originated from the assembly "Line" production perspective, and the idea that "Optimal" production and the undeviating master schedule can be only achieved when the production rates of the processes are "Balanced" (Iannone, 1967).

3.2 The Line Of Balance Output

LOB reports the real status of parts in the production schedule relative to the planned required advance. It recognizes activities or operations which are lagging earlier before a delay in delivery schedule happens at the last operation. It connects production operations in the manufacturing process with relationships and identifies shortages in the availability of materials, parts and assemblies at selected control points along the line of production. LOB shows if the different operations of manufacturing processes are in harmony or not.

3.3 The Use Of The LOB Technique

The Line of Balance method is fundamentally used to gauge the up-to-date correlation of production development as compared to the scheduled production rates and to foresee if the required delivery will be feasible. It is a helpful tool for identifying those production areas which need to have corrective actions in order to meet the required delivery dates. As a result of these corrective actions, the master delivery plan is changed and updated. LOB is utilized as a scheduling tool of shop and purchase orders. The US Navy used LOB in a massive scale as a reporting tool and a way of communication with the contractor and sub contractors. (Burke 1997).

3.4 Line Of Balance Components

Viewing a Line of Balance chart for the first time makes it appear to be complex. The LOB chart is three diagrams in one plus a drawn (stepped) line referred to as "Striking LOB" (Burke 1997). The Line of Balance (LOB) technique is comprised of the

four components used in the succession, when performing the Line of Balance monitoring of a production process. The four components of LOB are:

1-*The Objective Chart:* a cumulative curve of planned production units over time;

2-*The Production Plan Display, or the Program:* a manufacturing setback chart;

3- *The Progress Chart, or the Program Progress:* a chart reflecting the current progress of production by individual task at a given point in time or the point of review;

4- *"Striking" Line of Balance:* a line drawn over the progress chart, which shows where the progress should be at any point in time.

Figure 3-1 is an example Line of Balance chart.

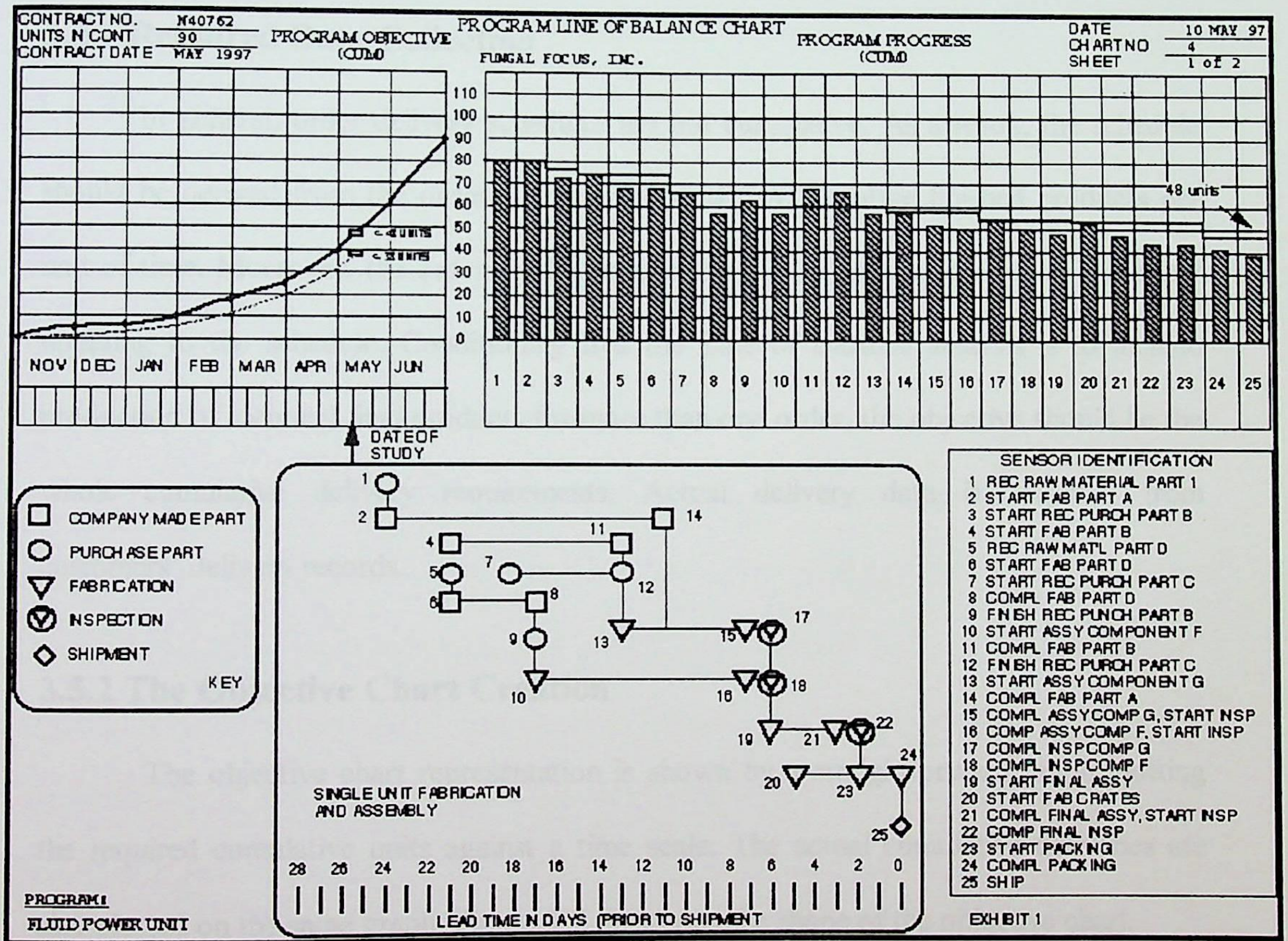


Figure 3-1: Fluid Power Unit Production Line of Balance chart (Earned Value 1999)

3.5 The Objective Chart

Using the Production Master Schedule, the required deliveries by time period are obtained and displayed in the form of a cumulative (parts) curve over time. Actual production completed is also plotted in a second cumulative curve so that the divergence between the required deliveries and actual deliveries can be clearly seen. Figure 3-1 shows an objective chart representing an order delivery of about forty-eight units during the first week of May, while the actual produced is only thirty-eight units, this means that it is lagging by 10 units. This helps show that the project is behind or lagging as of the screening period of the first week of May.

3.5.1 Required Data Collection

In general, order delivery schedules are not cumulative. As a result, the schedule should be derived from the orders and transformed to cumulative finished products per unit of time. Moreover, the orders and adjustments must be inspected cautiously for any updating to the schedule. Conditioning that the Line of Balance analysis is to include production of identical final products for more than one order, the objective should be the whole cumulative delivery requirements. Actual delivery data is acquired from customers' delivery records.

3.5.2 The Objective Chart Creation

The objective chart representation is shown by a straightforward graph plotting the required cumulative units against a time scale. The actual cumulative deliveries are also plotted on the same graph. Figure 3-2 illustrates the shape of the objective chart.

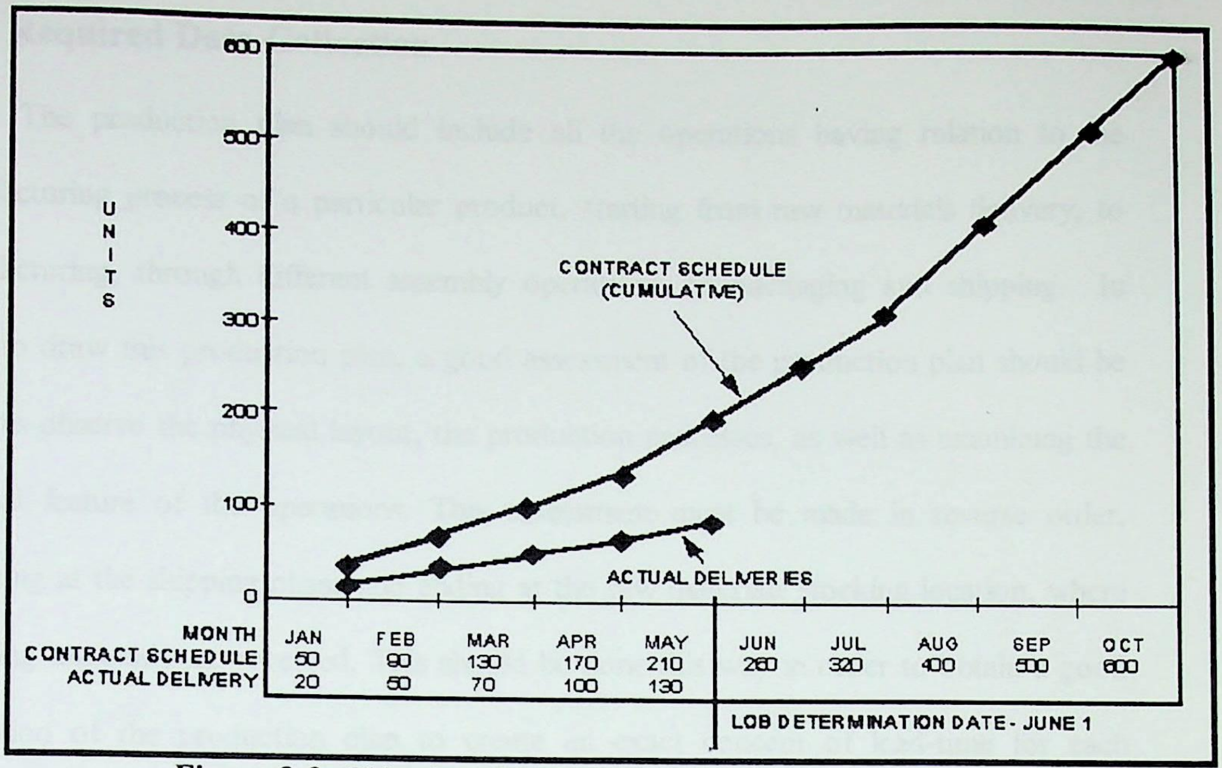


Figure 3-2: Objective Chart sample (Earned Value, 1999)

3.6 The Program Plan

The program plan is identified as the manufacturers designed process of production. The most critical phase of the Line of Balance analysis, is creating the production plan in terms of operations, activities, control points, and their lead-time relationship until reaching final stage of production.

The production nodes are steps in the production routing that can be used to monitor intermediate progress of production in the direction of its final production stage. The Drawing of the production plan is an outcome of a detailed study made by factory or project management and other representatives responsible for conducting the Line of Balance analysis. The program plan is the core of the Line of Balance analysis as it is the basis for all other production inspection techniques.

3.6.1 Required Data Collection

The production plan should include all the operations having relation to the manufacturing process of a particular product, starting from raw materials delivery, to manufacturing, through different assembly operations, to packaging and shipping. In order to draw this production plan, a good assessment of the production plan should be made to observe the physical layout, the production processes, as well as examining the physical feature of the operations. This assessment must be made in reverse order, beginning at the shipping phase and ending at the raw materials stocking location, where incoming materials are received. This should be done this way in order to obtain a good estimation of the production plan to create an exact concept of lead-time for each operation. The production plan is created out of three phases:

3.6.1.1 Defining The Operations To Be Performed

Utilizing the theory of monitoring by exception, only the strategic operations in addition to other potentially limiting activities must be taken into consideration for the production plan. Precision is required while eliminating any potential minor operations, or the "less-troublesome" operations (Burke 1997). Eliminating or grouping operations can be done only in situations such as fast successive operations of the same features or where some parts that can be united and named as a single part.

The operations or parts being monitored by the production plan need not be identical in number or amount but could change as determined by the facts of the production process or by availability of material at the time of study.

3.6.1.2 Defining The Routing Of Operations

This stage is concerned with defining the routing or cycle through which the raw materials and the sub-manufactured parts will go through until reaching the final production stage. The first thing to do is to observe the Bill of Materials, which is always set according to main assemblies, which are divided into subassemblies. A broad chronological routing of material flow can be concluded at this phase. All these information must be combined onto a flow chart to show the production process in sequence.

3.6.1.3 Defining Processing And Assembly Lead-Time

This phase is concerned with finding the total time duration between ordering and receiving raw materials, sub-contracted parts, already manufactured parts, subassemblies and the final due date of the order delivery or the shipping date to the customer. The time includes processing time, in-plant storage or handling time. The time used by each operation, subassembly, or any other activity must be placed according to the routing in a forward position of final production stage. The time units are expressed (weeks, days, hours, minutes, etc.). The operation or the activity with the longest lead-time is the one governing the lead-time for that whole production sequence while creating the production plan.

3.6.2 Creating The Production Plan

After defining the required raw materials, parts, production stages, subassemblies and assemblies for use with Line of Balance, and after knowing the sequence of operation and their lead times, these data in a graphical form. On the production plan chart, the x-

axis represents the overall lead-time in working days, hours, minutes, or seconds. To designate the type of operations being carried out at each control point, symbols, color, and numbers are used as codes on the production chart. The Control Point is defined as the starting and ending points (before and after) for each operation or activity in the production plan. It is "place-oriented" (Gaither 1995) and has its own inventory as if it was a production station. The production plan is created by locating the chosen operations for the analysis in the correct production sequence, starting with the last production phase and moving backward through the whole production process. Numbering the control points follow the order from left to right and from top to bottom. Figure 3-3, illustrates this numbering method.

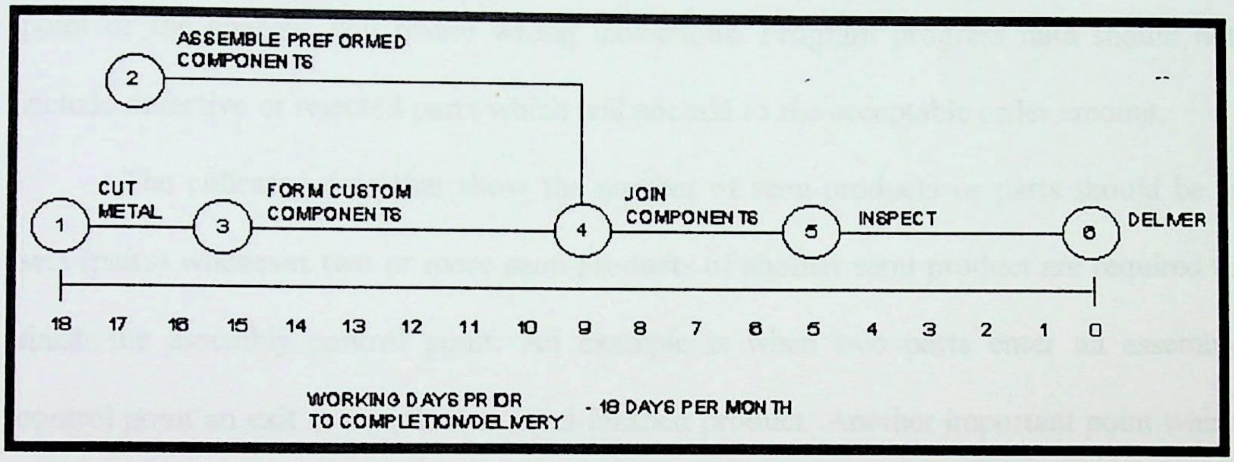


Figure 3-3: Production Plan Chart (Earned Value, 1999)

The production plan chart usually shows four or more general chronological phases: the final assembly process, preceded by major subassembly work, preceded by the manufacturing of parts, preceded by receiving and ordering of raw materials and purchased parts.

3.7 Program Progress Chart

The program progress shows the actual performance in the form of a bar chart which illustrates all the different control points under the LOB analysis and their actual achievements in terms of units produced at a given review point in time.

3.7.1 Required Data Collection

Program progress is represented in terms of quantities of materials, parts, and subassemblies, which have passed through the distinct control points of the production plan. The production monitoring or inventory personnel for each control point collect data. The data collected should represent the actual real-life situation for each control point or the analysis will reveal wrong indications. Program progress data should not include defective or rejected parts which will not add to the acceptable order amount.

The collected data that show the number of semi-products or parts should be in sets (pairs) whenever two or more semi-products of another semi-product are required to finish the assembly control point. An example is when two parts enter an assembly control point an exit as one final or semi-finished product. Another important point which should be taken into consideration while collecting such data is that whenever a control point represents the beginning of an assembly process, the quantity counted and used for that control point should be the least available component quantity for that assembly or subassembly.

3.7.2 Program Progress Chart Creation

In the program progress chart, a unified quantity scale is used as y-axis similar to the one used for the Objective Chart. The x-axis shows numbered control points

represented in the production plan. The scale numbering starts from left to right. Finally the actual collected data is plotted in Bars for each control point. Figure 3-4, shows a sample of this Progress Chart.

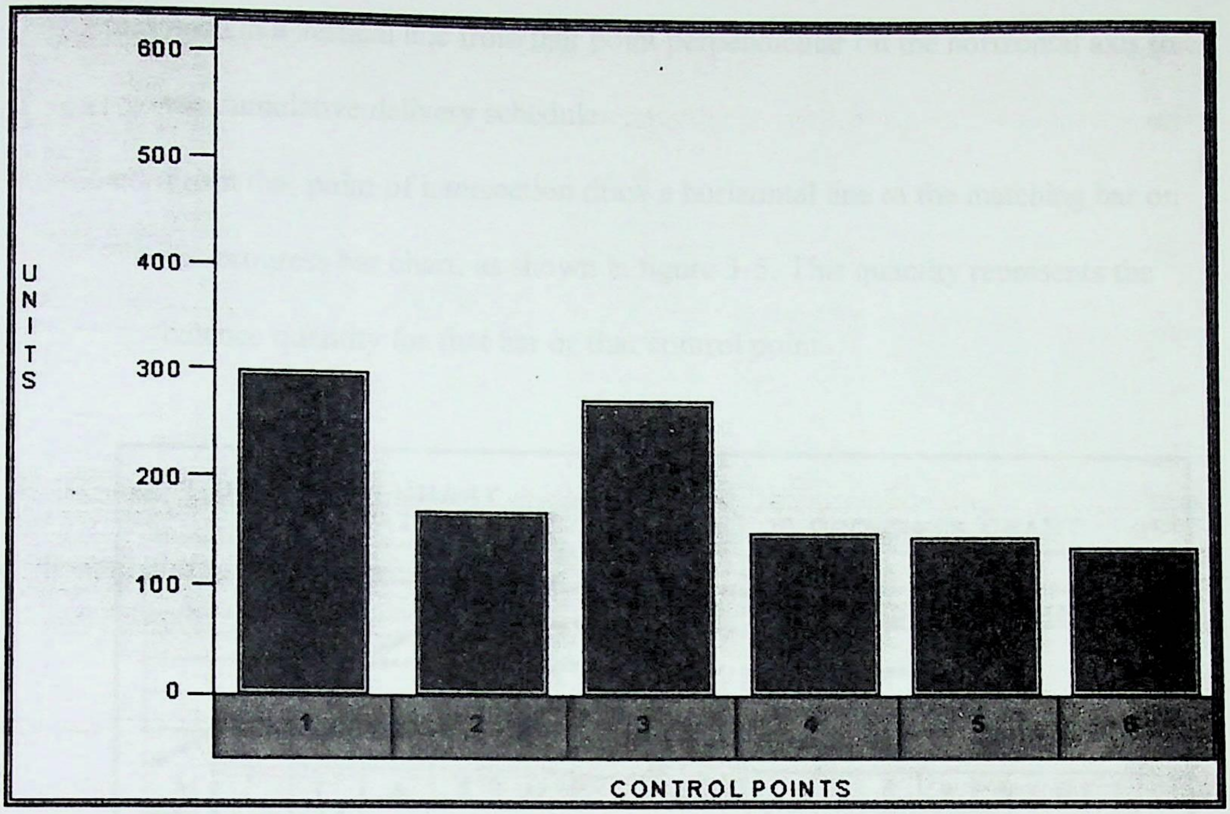


Figure 3-4: Program Progress Chart (Earned Value, 1999)

3.8 "Striking" Line Of Balance

After the creation of the objective chart, the program plan, and program progress, this ends the phase of collecting the actual physical data. The next step is to link and use all these information and charts to obtain the Line of Balance quantities, which portray the quantities for each control point that must be available at the point of review date in order to fulfill the orders due-dates schedule.

The procedure for striking the Line of Balance is as follows:

1. Plot the balance quantity for each control point.

a. Starting with the point of review date on the horizontal axis of the cumulative delivery objective chart marks off to the right the lead-time for that control point. This information is obtained from the production plan.

b. Pencil in a vertical line from that point perpendicular on the horizontal axis to the cumulative delivery schedule.

c. From that point of intersection draw a horizontal line to the matching bar on the progress bar chart, as shown in figure 3-5. This quantity represents the balance quantity for that bar or that control point.

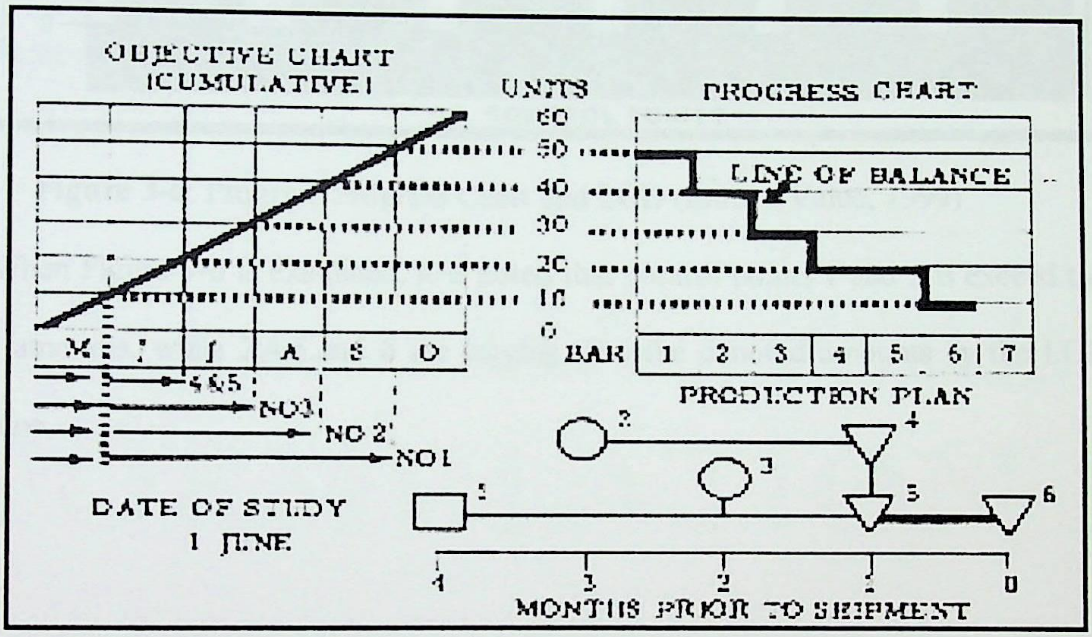


Figure 3-5: Drawing LOB (Line Of Balance Technology, 1962)

2. Join the balance quantities to form one staircase-type line over of the progress chart. Figure 3-6 illustrates the final shape of the Line of balance as it is drawn over the Program progress chart.

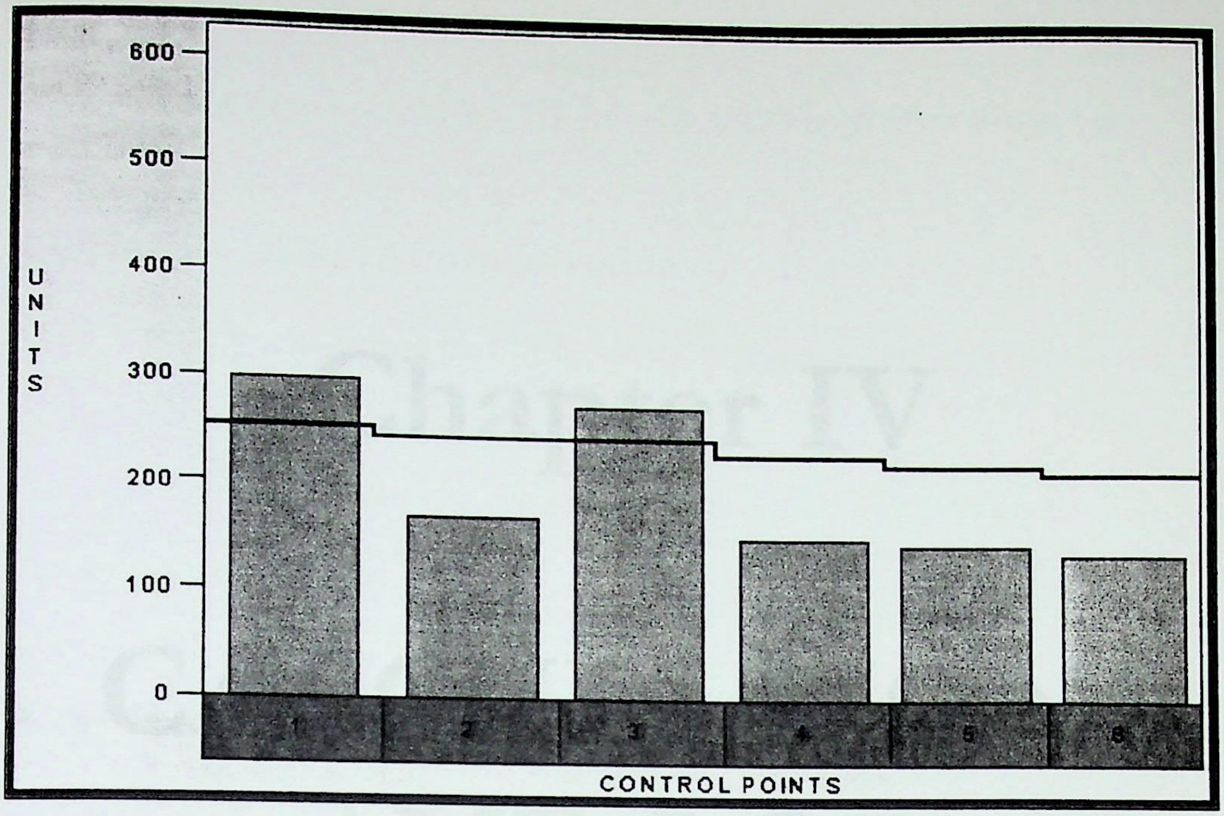


Figure 3-6: Program Progress Chart and LOB (Earned Value, 1999)

When Figure 3-6 is examined, it is noted that control points 1 and 3 is exceed the required amounts, while 2,4,5,and 6 are lagging than the denoted amounts by the LOB striking line.

Chapter IV

CALCULATIONS AND LOB MATHEMATICAL FORMULATION

Chapter IV
Calculations And LOB Mathematical Formulation

4.1 Line Of Balance Formalization

In order to enable using the LOB graphical technique, a Production Monitoring software program can prove invaluable.

The first phase of the LOB analysis, is to create a table with the quantities required and there due-dates.

Assume that:

D_i: the number of days available before the customers due date delivery.

Q_i: the number of parts or units required by the customer to be produced.

Qc_i: the cumulative number of parts or units required by the customers.

St: the Production Starting day number.

Ld: the Last order delivery day (date).

D_r: the project review day.

Qc_r: the cumulative required.

Days, D_i	Required Quantity, Q_i	Cumulative, Qc_i
D_1	Q_1	$Qc_1=Q_1$
D_2	Q_2	$Qc_2=Q_1+Q_2=Qc_1+Q_2$
D_3	Q_3	$Qc_3=Qc_2+Q_3$
D_4	Q_4	$Qc_4=Qc_3+Q_4$
D_5	Q_5	$Qc_5=Qc_4+Q_5$

Therefore,

$$Qc_i = Qc_{i-1} + Qi$$

Where i: $St < i \leq Ld$

So the Cumulative Number of Parts, Qc_i is represented by:

$$Qc_i = \sum_{i=ST}^{i} Q_i \tag{4-1}$$

Equation 4-1 can be solved by linear graphical method as follows:

1 – Place the Objective cumulative chart side-by-side with the Program Progress chart, using the same vertical scale.

2 – Get the lead-time of the required control point and add to it the point of review, either in days or weeks.

3 – On the objective chart scale, find the day which corresponds to the summation of the review point plus the control point lead time and draw a vertical line until it intersects with the Objective cumulative curve.

4 – From the point of intersection, draw a horizontal line until crossing over the analyzed control point bar in the program progress bar chart.

5 – Do the same for all the control points, and then join them in stepping line striking the bar chart.

Since the LOB analysis technique is a linear scheduling technique, we can utilize linear interpolation to find the LOB quantities for any control point at any review point required.

Assume that the review day required is D_r, and the required cumulative number of parts to be produced is Qc_r.

And $$i < r \leq i+1$$

$$D_i \rightarrow Qc_i$$
$$D_r \rightarrow Qc_r$$
$$D_{i+1} \rightarrow Qc_{i+1}$$

Knowing D_i, D_r, D_{i+1}, Qc_i, and Qc_{i+1}, calculate Qc_r using:

$$\frac{D_{i+1} - D_r}{D_{i+1} - D_i} = \frac{Qc_{i+1} - Qc_r}{Qc_{i+1} - Qc_i} \tag{4-2}$$

Simplifying the Equality:

$$Qc_{i+1} - Qc_r = \frac{(D_{i+1} - D_r) * (Qc_{i+1} - Qc_i)}{(D_{i+1} - D_i)} \tag{4-3}$$

Therefore:

$$Qc_{rvp} = Qc_{i+1} - \frac{(D_{i+1} - D_r) * (Qc_{i+1} - Qc_i)}{(D_{i+1} - D_i)} \tag{4-4}$$

4.2 Added Cost Calculation

Having calculated the Line of Balance quantities for any control point at any review point, the striking LOB line easily be drawn. The actual production progress for each control point can then be compared with the planned progress, the values that have been calculated using Equation (4-4). Subtracting the actual progress quantities from the calculated LOB quantities or the planned quantities gives the Slippage from planned. If the slippage value is negative, then the control point is lagging or lacking of the required parts supply, if the slippage value is positive, the control point is leading, indicating that excess parts have been produced. Whether there is a lead or a lag, a cost is associated with the two situations. These costs are:

1 – If the control point is (lagging), there is an idle time cost for the processes and can be assumed as machines that are dependent on that control point. This means that the next point in route will stop or will not work with its full efficiency because that control point is lagging. An idle time cost is therefore added to that control point for each part that is lagging behind schedule. This cost is per the lead-time of that process or operation because if the control point problem is solved on the spot, it will take a given time, which is the lead-time of the lagging process to finish one product.

2 – If the control point is (leading), a storage cost is added. Since this means that the exceeding number of parts will be stored for some time before they are processed by the next manufacturing process or by the next operation.

3 – The last cost added is the cost of order delay. When signing the contract, the customer specifies this penalty. It is added only in the last control point if there is lagging. This cost is per unit per the total lead-time to produce one unit. This is because if the

slipped number of parts are to be produced on the specified delivery date, it will not be ready for delivery until after the total lead time of that unit or product.

Finally, the added costs: Idle Time cost, Storage cost, and Delay Penalty cost, are included in the performance measure of the project performance. In addition, it helps pointing out control points and which one is causing more problems. It also sets priorities to each control point and relative to each operation and indicates the severity of the problem, and how important it is.

Chapter V

TMAS PROGRAM OVERVIEW

Chapter V
Computer Program Overview

The thrust of this thesis led developing a computerized software tool to be used for scheduling, monitoring and control of production projects. The Line of Balance graphical technique, which is used to schedule and monitor repetitive types of projects, is the basis of this software tool, Target Monitoring And Assessment System For Production Control, TMAS.

To measure the performance of a project or of a production plan: idle time cost, storage cost, and delay penalty cost are used as a performance measure to see how good the project performance is and to identify the control point that is most responsible for the delay.

TMAS is written in Visual Basic 6.0, with the link to Microsoft Data Access program as a data base manager. When the user runs TMAS, a welcome window is displayed showing the program name, Figure 5-1. The user security window is then displayed asking the user to enter his/her user name and password, Figure 5-2. Two types of users are permitted, an administrator level and an ordinary user type. If the user signs in as an administrator, the next screen display the user identification and the last time that user used the program, Figure 5-3. An administrator is authorized to add other user names to the users database by clicking on the "Add another users" button on the menu, Figure 5-4. The next screen provides the products tree window, Figure 5-5.

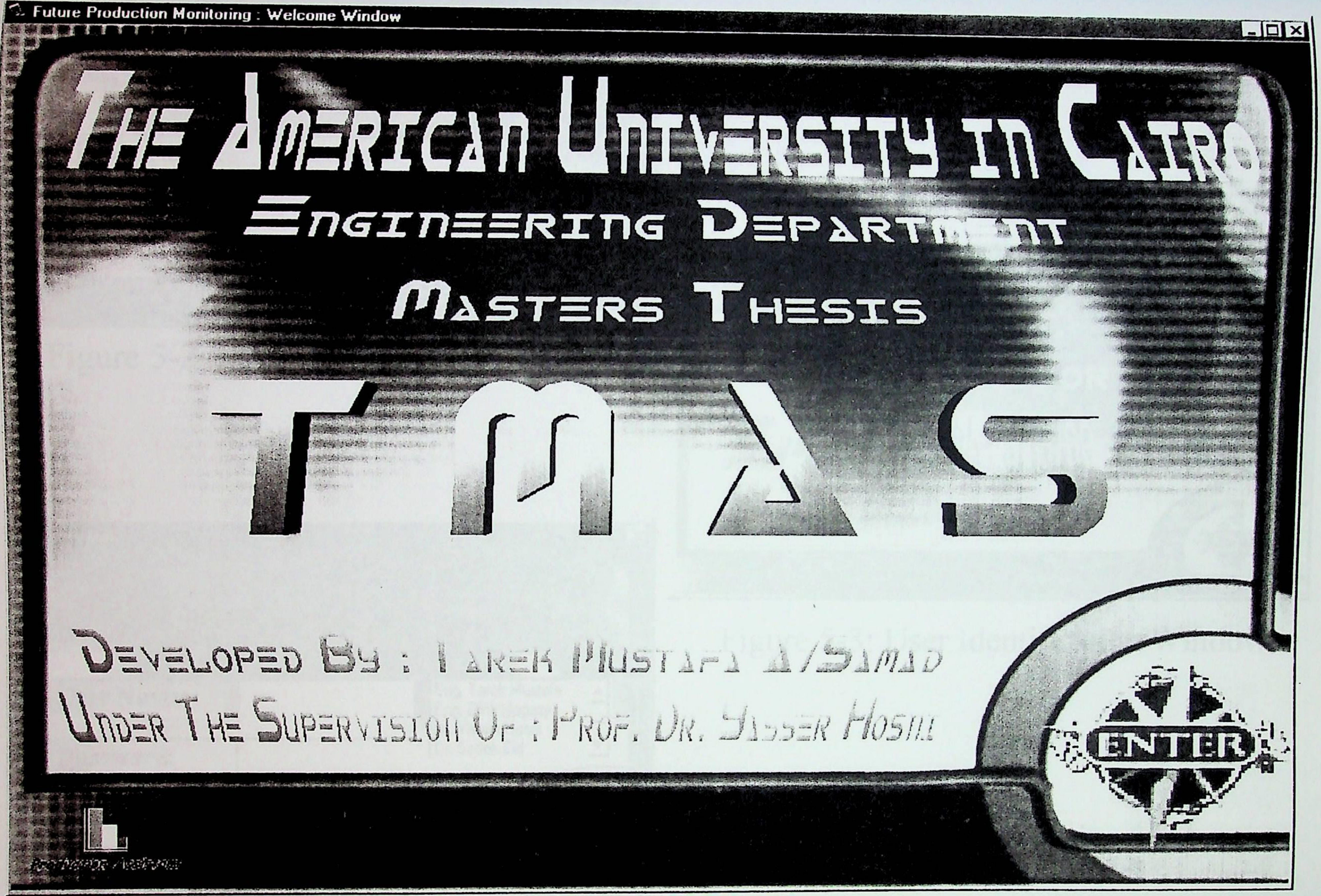


Figure 5-1: Welcome Window.

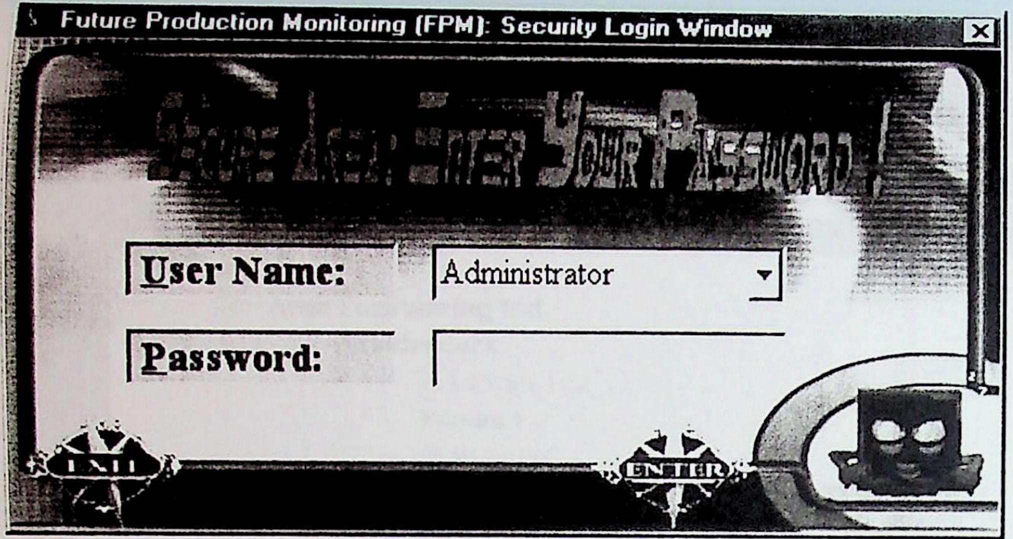


Figure 5-2: Security Login Window

Figure 5-3: User Identification Window

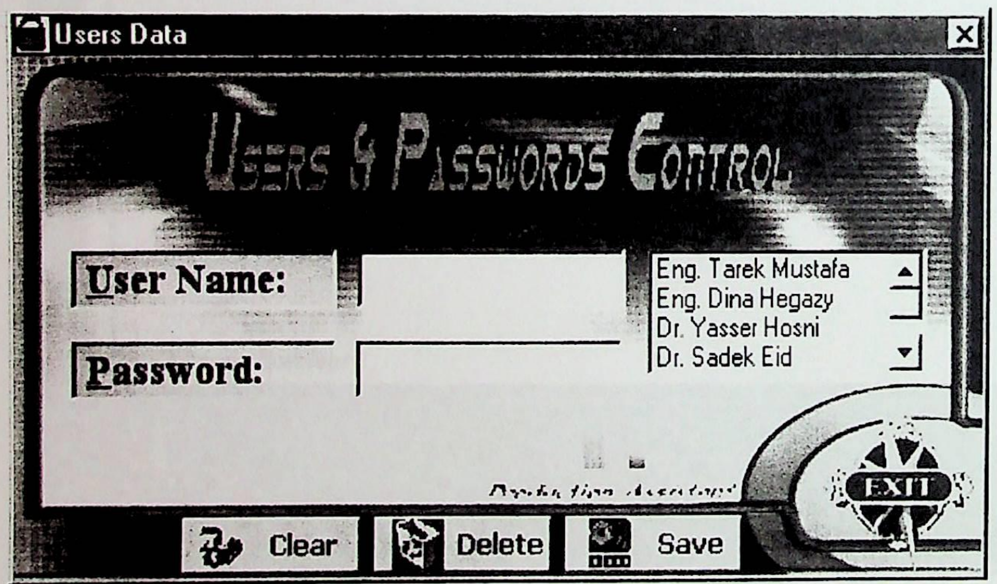


Figure 5-4: User Data Window

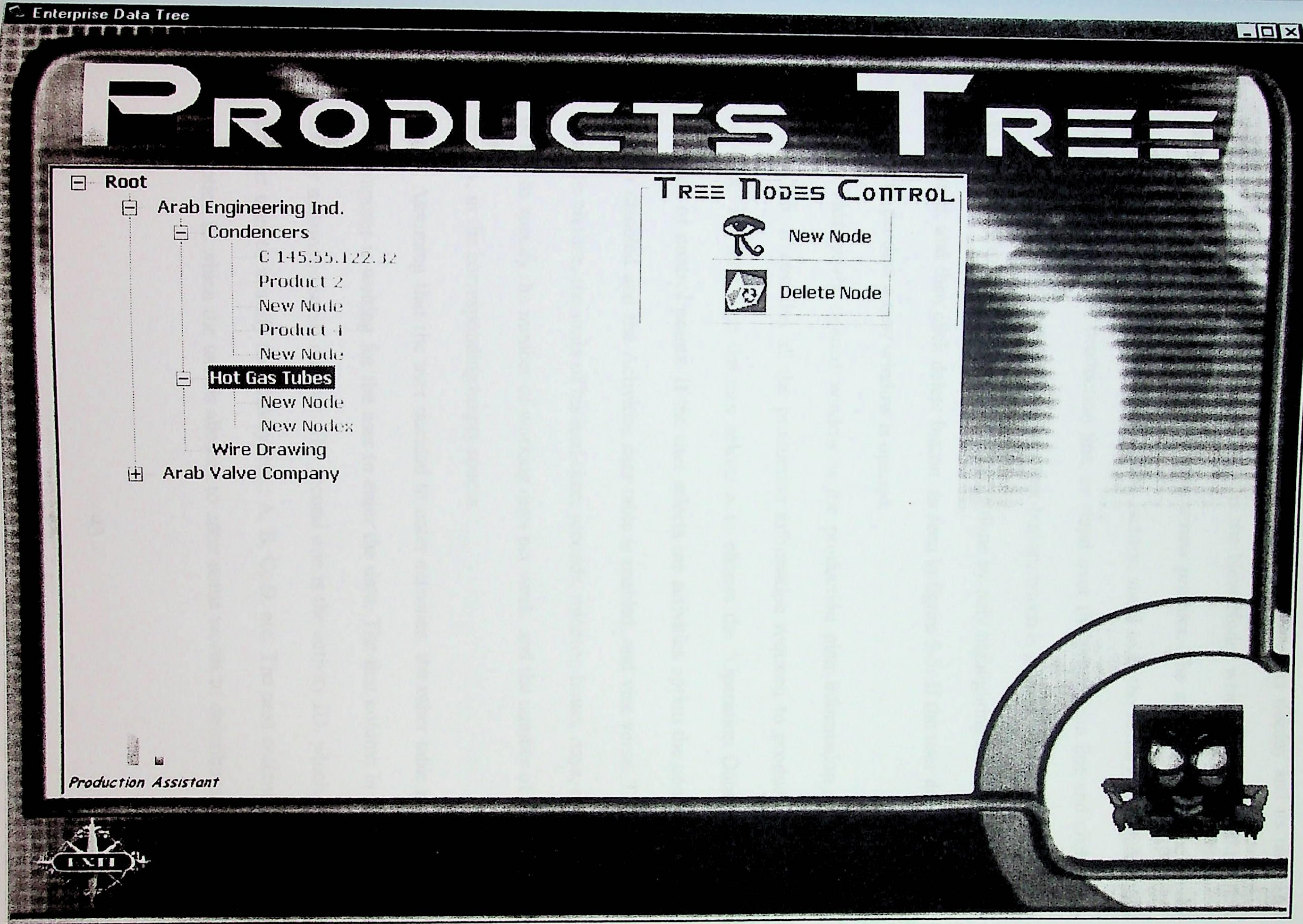


Figure 5-5: Products Data Tree

The products' tree is a database tree that contains factories, production lines, and products. Saving all these data in a tree format facilitates its display and its use. This window has two buttons. One of them is the New Node, which is used to add a new factory of a new production line or even a new product. The user just has to be on the root and click new node to make a new factory, stand over the factory and click "New Node" to create new production line, or stand over the production line and click "New Node" to create a new product. The other button, which is labeled "Delete Node", is used to delete any of the created nodes. This is done by only highlighting the node required to be deleted, and then click delete button, as seen in figure 5-5. If the user double clicks on a specific product a new window is opened.

This newly opened window is the production plan information window. See figure 5-6. It contains all the production information required to produce the required product. The first item the user selects is to choose the "Operation Data Type", either activities or control points. If the user selects the activities option the control point data table is disabled and the Activities data table is enabled, and vise versa. The user next is asked to choose, the units of his lead-time, seconds, minutes, hours, days, or weeks. Then he has to specify the number of working days per week, and the number of working hours per day, in the corresponding empty spaces.

Assuming that the user decided to enter activities, the other table is disabled, and the computer is waiting for the user to enter the data. The first column in the table is the activity automatic serial number. The second one is the activity ID, which is a unique ID the user uses to identify the activity, e.g.: A, B, C, D, etc. The next column is the activity description in which the user is allowed to enter some words to describe the activity. The

next column is the one for identifying the preceding activities. In this column, the user enters the preceding activity for each activity, separated with a (-) sign. The next column is the Process time, where the user enters the process time for each activity in Lead-time units that he identified previously in the window. The buffer time is the next column, where the user enters an amount of time for each activity per part per lead-time units. This amount of time is used, as flexibility for each operation to count for, setup time, down times, and any other. The next two columns are the storage cost and the idle time cost, which the user enters for each activity per part per lead-time units.

After entering all the activities data, the user can press the save form button to save the table in the product database, so as to be able to re-load it later. Or if the user wants to clean the table contents, he can press erase table to delete all its contents. Now it is time to find the control points and their lead times of the entered activates using the Set Back method. The user now should click on the "Find Control Point" button, and in seconds the computer will show the automatic control point serial number, numbered as A1, B3, C2, A5, where the alphabet represents the activity ID, and the number represents the automatic numbering of the control point. The next column is the control point description, where the user can identify the control point if it is before or after, or start or end of the activity. Then comes the lead-time, which is calculated using the set back method. The first value in the column represents the total lead-time required to produce one part. The units are also given in lead-time units identified above. Idle time cost column is shown next, where the value given is the multiplication of the Idle time cost in the first table with the process time. This value is only added in the after or the end of activities control points where it represents the idle time cost of that activity. The next

column is the storage cost, where the values of the storage cost that were entered in the first table for each activity are rewritten for each control point, where the after and the before have the same values. The next two columns, show the control point that depends on or precedes this control point. The last column shows the cumulative idle time cost. This cost is calculated by going to the depending control points and adding the corresponding idle time cost for each control point.

After that the user has to click on the save form button to save the data of the product. The user can make the computer draws the lead-time chart by clicking on the draw network button. Or can directly click on the calculate LOB button to go for the next screen. Of course there is an option for the user to have a hard copy by print either tables. As for help, there is a sleeping computer down in the corner, where by moving the curse over, it is awaked and it asks the user how to help him/her. If the user clicks on that computer monitor a window will open showing a glossary like help, where the user enters the word he wants to know, and the computer will seek it for him. The user can add other new words, or delete words. This glossary does not only contain words related to the program but also have over 3000 words related to project management, Figure 5-12.

When the user clicks on the "Calculate LOB" button a new window opens. Figure 5-7. This window is the customer's orders and planned versus actual production window. It contains all the orders, quantities and due dates. The user first, fills in the orders in the first grid, by pressing on the (+) sign whenever he wants to add a new order. The user should enter the order reference or serial number, date or day or week of

delivery, parts required of the product, delay penalty per part per lead-time unit, and the penalty currency. At the point of review, the user is asked to enter the date, day or week

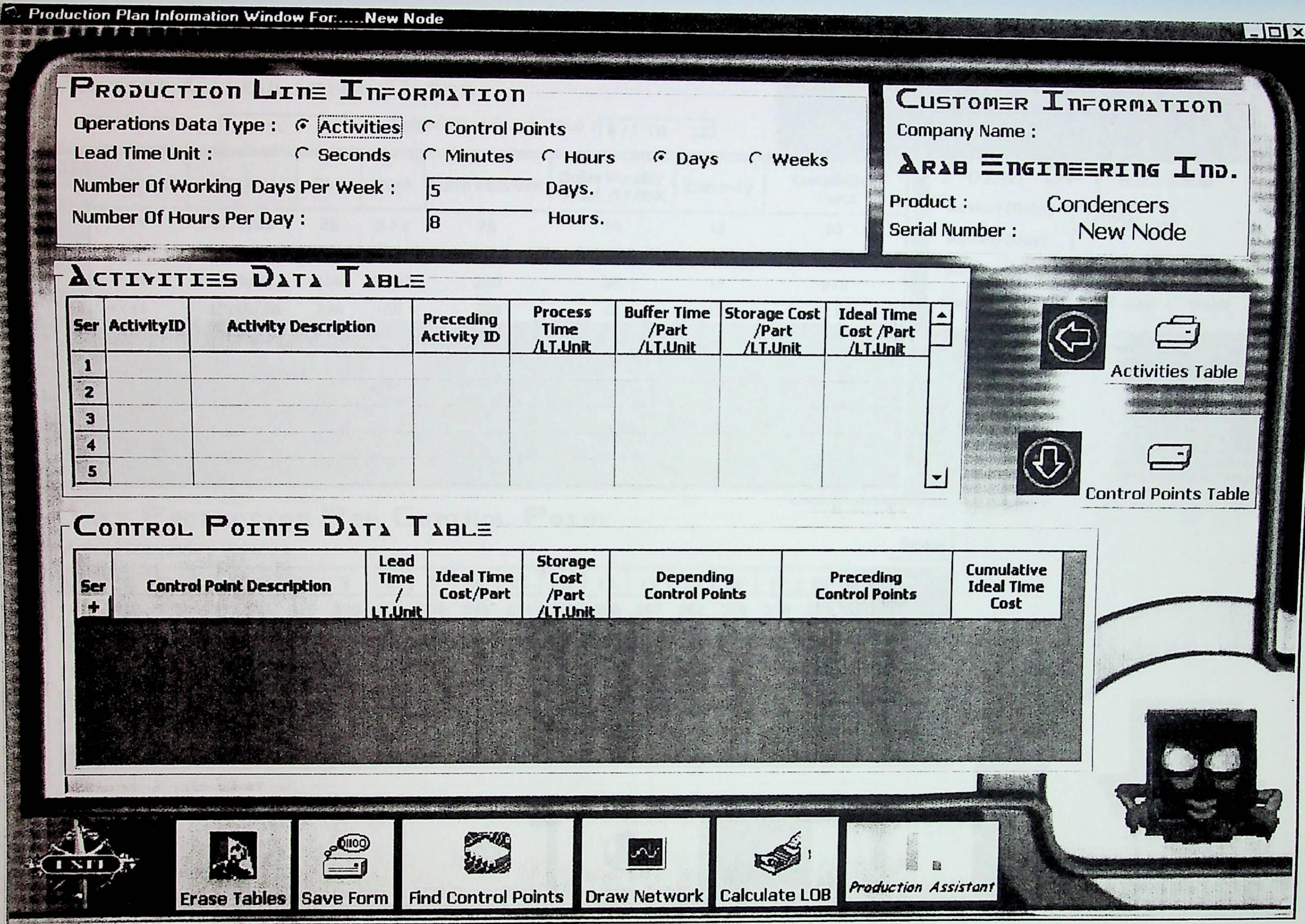


Figure 5-6: Production Plan Information Window

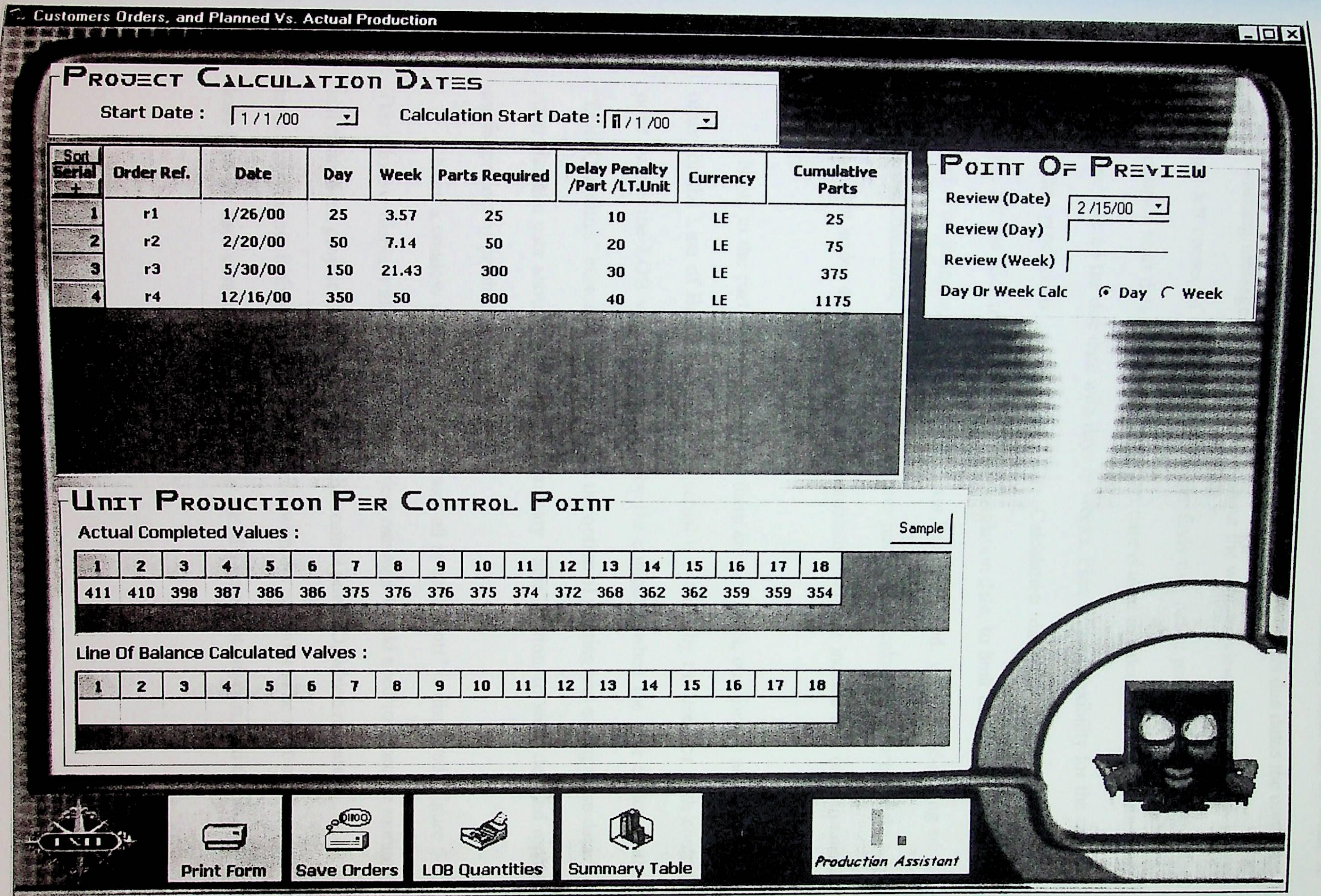
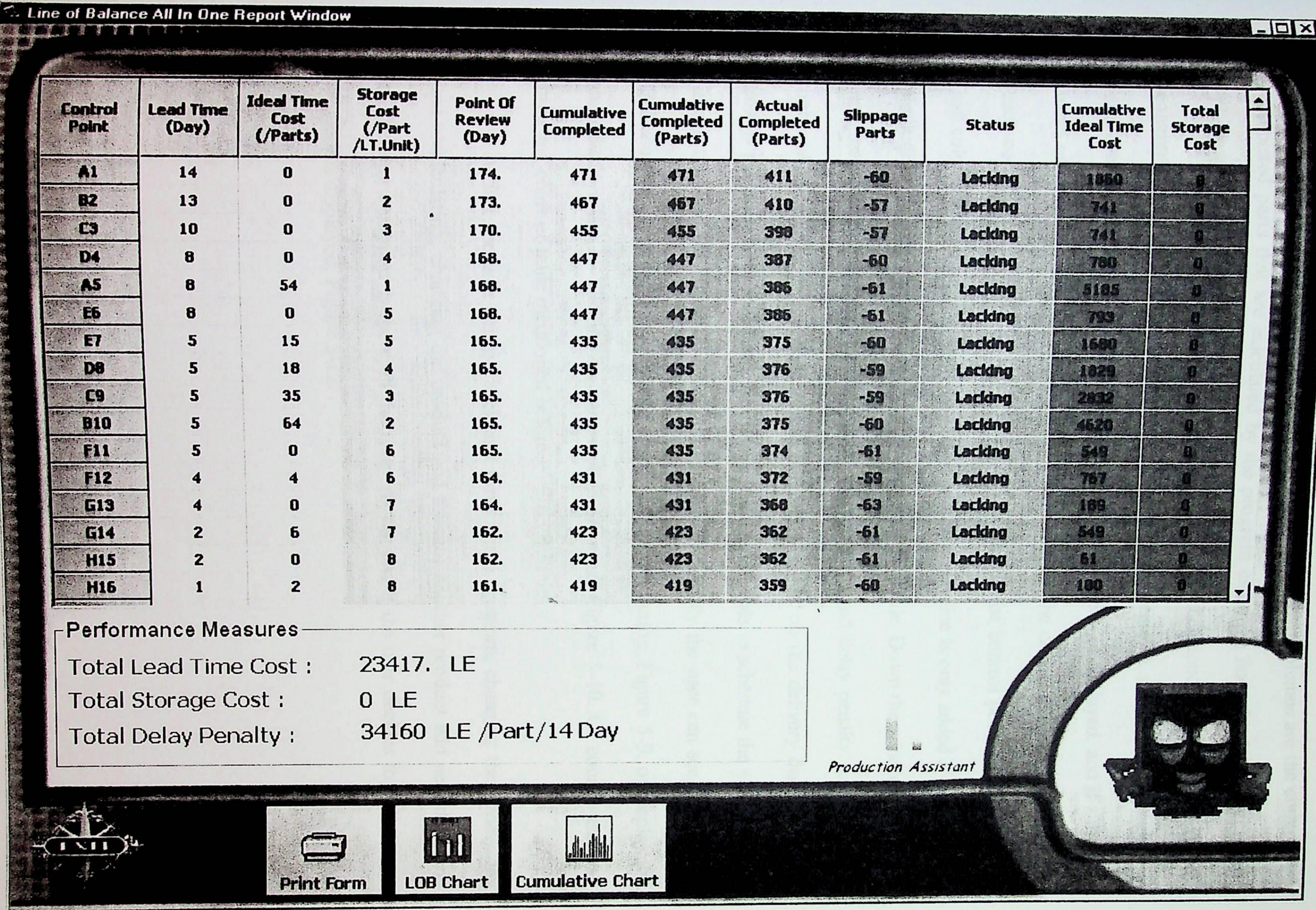


Figure 5-7: Customers Orders and Planned Vs. Actual Production

of review, and the units that the user wants to use while calculating, either day or week. If the user enters a review point that is out of the range on the orders due dates the computer gives a warning message, warning the user about the wrong review point, Figure 5-11. At the upper left corner of the window, the user finds two dates; production start date and the calculation start date. The production start date is used to calculate the due date order if the user entered the due date with days or weeks. Plus, it gives flexibility for the user to change the production starting date. The Calculation date also gives some other flexibility, for the user to change the LOB calculation date, to limit the number of orders calculated. For instance, if the first order has been delivered, why the re-adding of its value in the cumulative parts column. The user just sets the calculation starting date to a date after that order due date and all the cumulative will not include that order quantity anymore.

Now, in the part production frame, there are two grids, one for the actual and the other for the Line of Balance values. The actual is entered by the user for each control point, while the LOB value is calculated by the computer when the user clicks on the "LOB Quantities" button. The user also has the option of printing and saving these data. After that the user should click on the "Summary Table" button, to see a detailed report on the project or production progress.

Now a window called "Line of Balance all in one report" is displayed, Figure 5-8. This window displays all the data that a project manager would need to schedule monitor, and control his project. The first column is the control point ID, which repeated as in the window before the last, which deals with the activities. The next column is the lead-time for each control point. Followed by the idle time cost per part, and the storage



Control Point	Lead Time (Day)	Ideal Time Cost (/Parts)	Storage Cost (/Part /LT.Unit)	Point Of Review (Day)	Cumulative Completed	Cumulative Completed (Parts)	Actual Completed (Parts)	Slippage Parts	Status	Cumulative Ideal Time Cost	Total Storage Cost
A1	14	0	1	174.	471	471	411	-60	Lacking	1860	0
B2	13	0	2	173.	467	467	410	-57	Lacking	741	0
C3	10	0	3	170.	455	455	398	-57	Lacking	741	0
D4	8	0	4	168.	447	447	387	-60	Lacking	780	0
A5	8	54	1	168.	447	447	386	-61	Lacking	5185	0
E6	8	0	5	168.	447	447	386	-61	Lacking	793	0
E7	5	15	5	165.	435	435	375	-60	Lacking	1680	0
D8	5	18	4	165.	435	435	376	-59	Lacking	1029	0
C9	5	35	3	165.	435	435	376	-59	Lacking	2832	0
B10	5	64	2	165.	435	435	375	-60	Lacking	4620	0
F11	5	0	6	165.	435	435	374	-61	Lacking	549	0
F12	4	4	6	164.	431	431	372	-59	Lacking	767	0
G13	4	0	7	164.	431	431	368	-63	Lacking	189	0
G14	2	6	7	162.	423	423	362	-61	Lacking	549	0
H15	2	0	8	162.	423	423	362	-61	Lacking	61	0
H16	1	2	8	161.	419	419	359	-60	Lacking	180	0

Performance Measures

Total Lead Time Cost : 23417. LE

Total Storage Cost : 0 LE

Total Delay Penalty : 34160 LE /Part/14 Day

Figure 5-8: Line of Balance Report

cost per part per lead-time unit. The next column is the point of review of that control point plus its lead-time, in days or weeks. The following two columns are the cumulative completed parts that are calculated by the program using the line of balance technique. The next one is the actual produced cumulative parts for each control point. The next two columns show that slippage amounts, if the value is negative so the word lacking is displayed on the status column, if positive, the word leading is displayed, and if zero, the word on schedule is displayed. The next column shows the cumulative idle time cost for each control point. But this value is only calculated if the control point is lacking. The last column shows the total storage cost, and also this value is only added if the status is leading. And of course no value is added if it is on schedule. Down the windows, the user find the summation of all Idle time cost, storage cost, and delay penalty cost, which is only calculated for the slippage in the last control point on the delivery due date. This cost is per part/ total lead-time. Assuming that it is possible to schedule the slipped parts, it will take the total lead-time value to produce it. Finally the user can see the Line of Balance chart graphically by clicking on the LOB chart button, Figure 5-9, or display the cumulative chart by clicking its corresponding button, Figure 5-10. Of course user can print any chart or table mentioned before.

At last the user can go back and forth in the program, changing the review day and recalculating, changing the product and monitor another product add new data, and the helping computer is there all the time. At the end if the user decides to exit an exit window is displayed, Figure 5-12.

Figure 5-9: Line of Balance Program Progress Chart

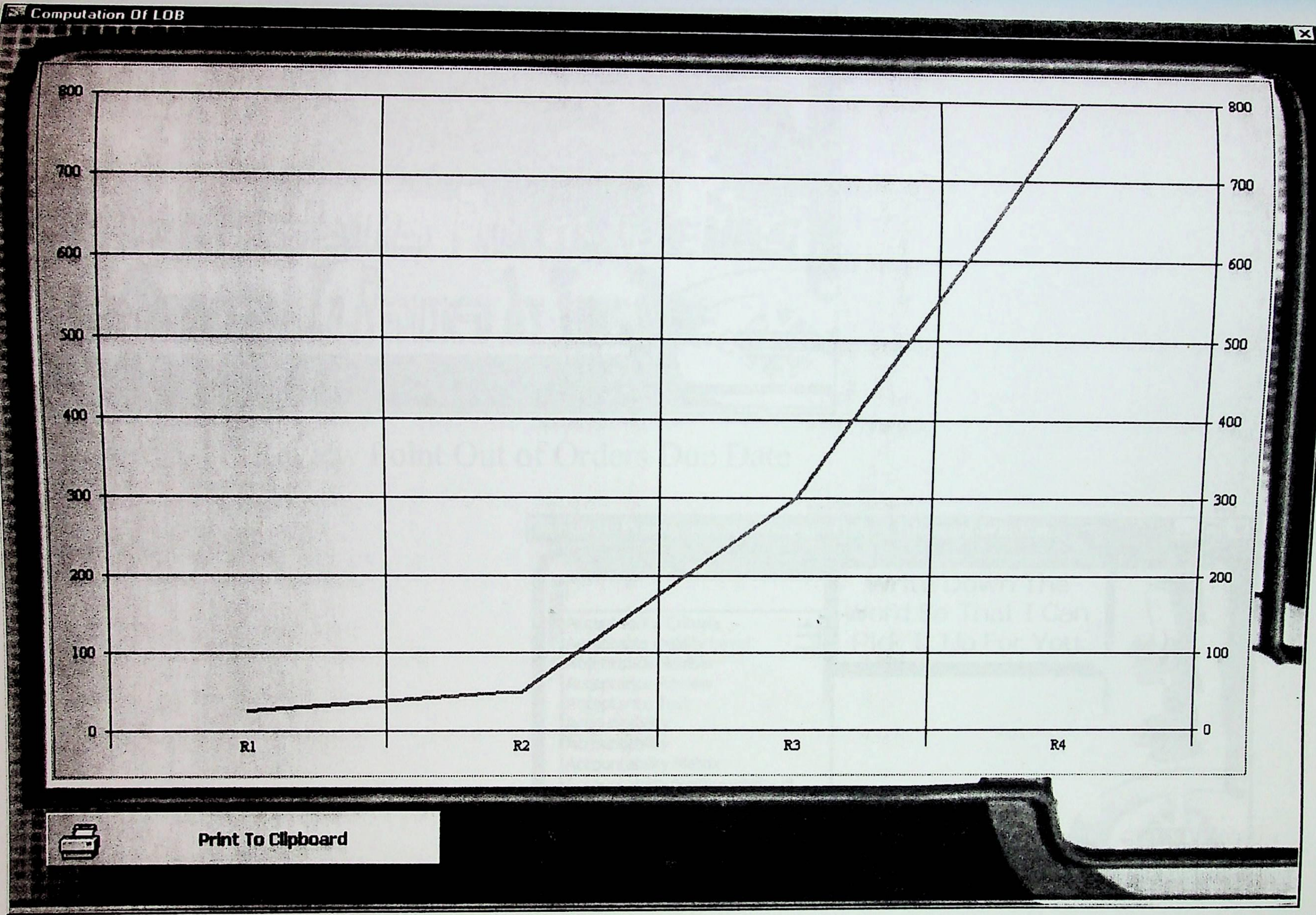


Figure 5-10: Objective Chart

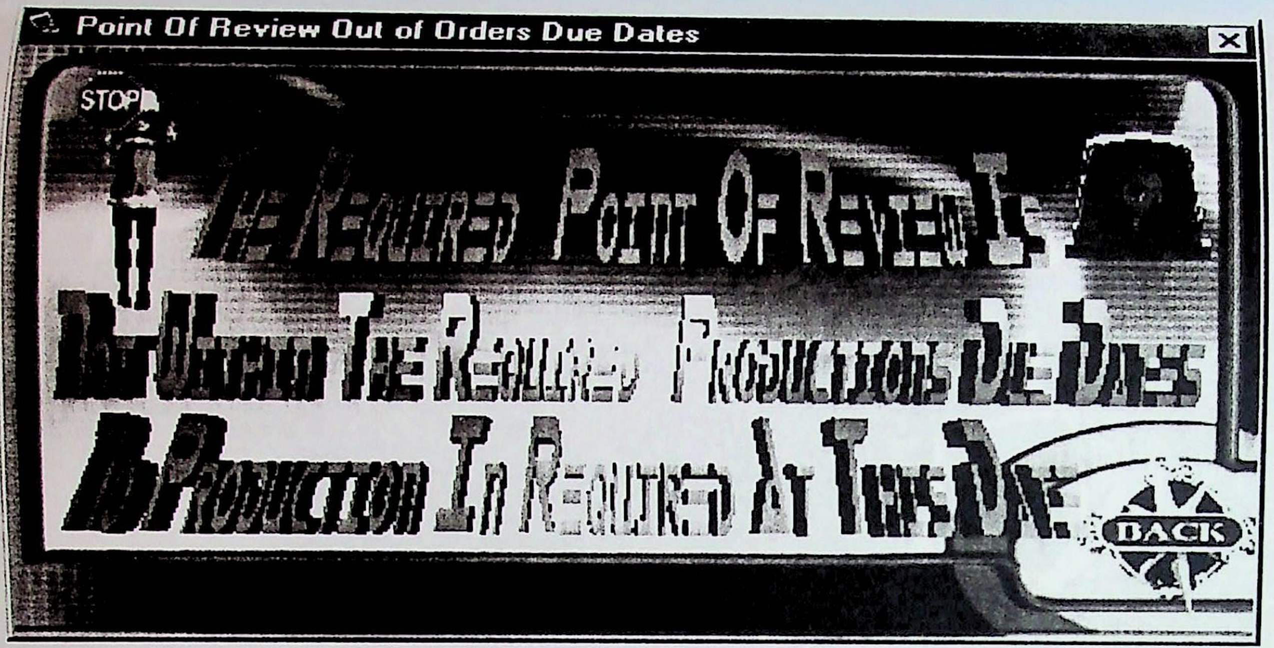


Figure 5-11: Review Point Out of Orders Due Date

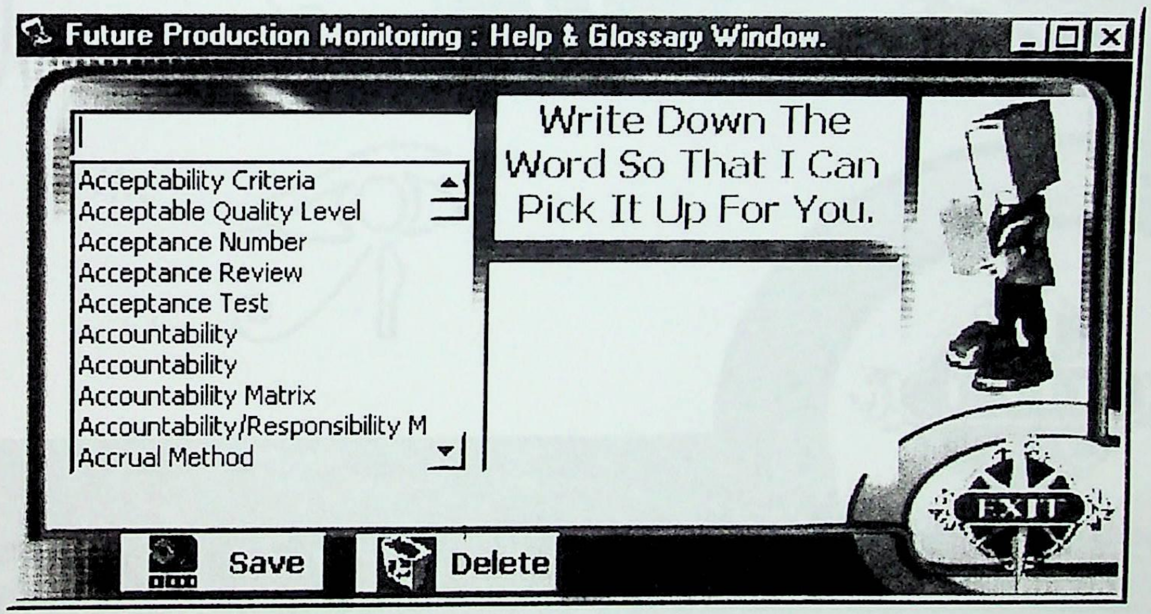


Figure 5-12: Help and Glossary Window

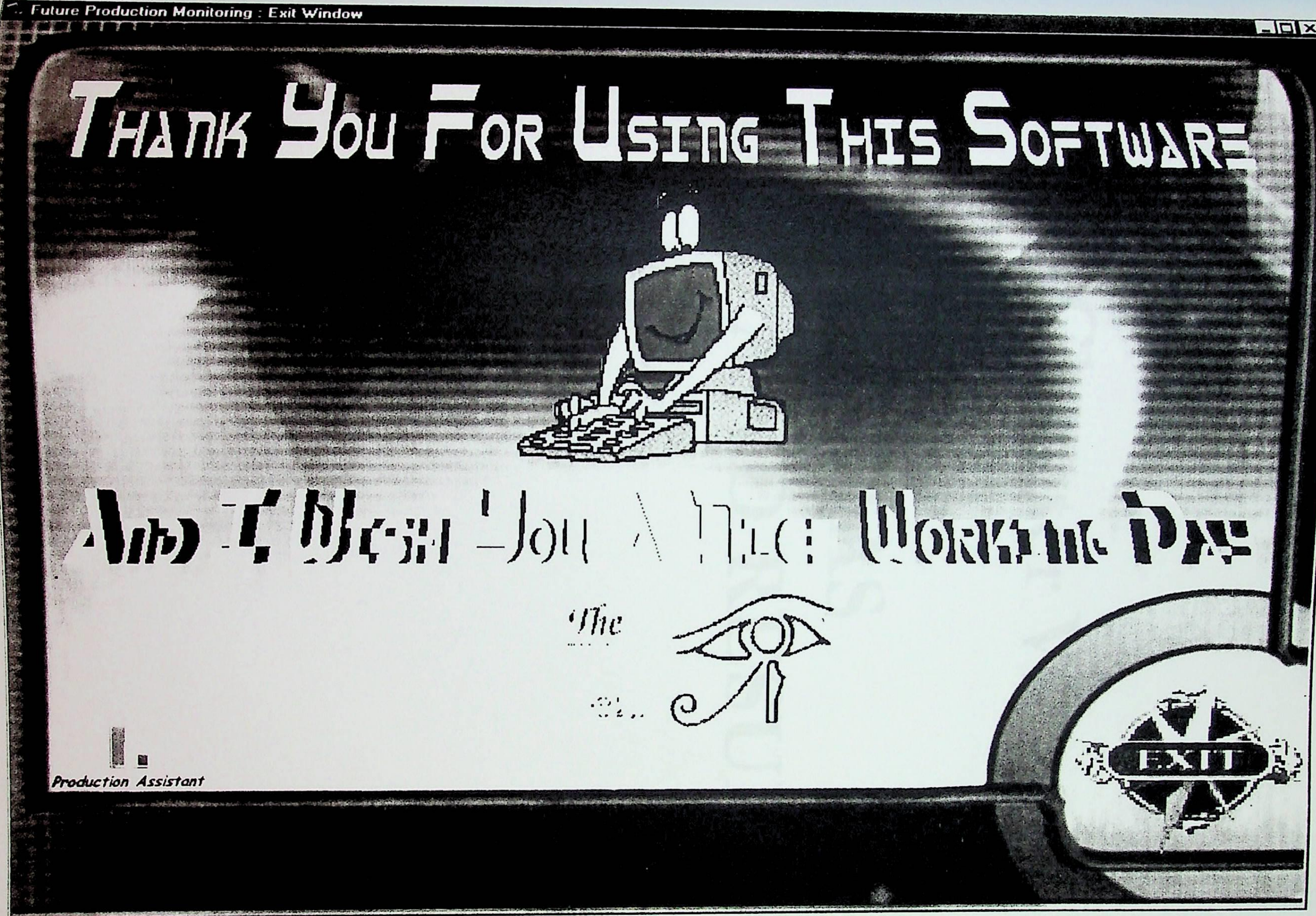


Figure 5-13: Good Bye and Thanks Window

Chapter VI

TMAS
RUNS AND RESULTS

Chapter VI
Program Runs And Results

The aim behind these program runs is to test the program ability to come up with the correct values as the ones that are already made or not. Three different program runs are made using already solved problems. Two of these runs are for the same product and they are taken from the "Integrated Production Control Systems" by Bedworth (1994). The third one is taken from the "Analysis and control of production systems" El Sayed (1994). One important thing behind these computer runs is to test the program ability to calculate the added costs, which are divided into three items.

In conclusion, the program has proven that all its functions are operating well without any bugs. Add to that, the results of the three program runs came out identical to the ones manually calculated by the above-mentioned authors. Added cost utilized in the program gave a new dimension to the results. It showed and highlighted the control points that may have major effect on production, although its slippage could be just the smallest of all.

In the next sections the program runs is shown with the actual results made by the other authors.

TMAS

RUN AND RESULTS
- 1 -

***** LINE-OF-BALANCE *****

Project: CASE EXAMPLE Activity Lead-Time information

Act. ID.	Activity Description	Preceding Act. ID's	Processing Time
A	RELEASE RAW MATERIALS		6
B	RELEASE "BUY" ASSY A-1		8
C	RELEASE "BUY" ASSY A-2		5
D	MANUF COMP MC-1	A	3
E	MANUF COMP MC-2	A	3
F	ASSEMBLE	BCDE	1
G	TEST	F	2
H	PACK	G	1
I	SHIP	H	1

Figure 6-1A: Production Plan Information. (Bedworth, 1994)

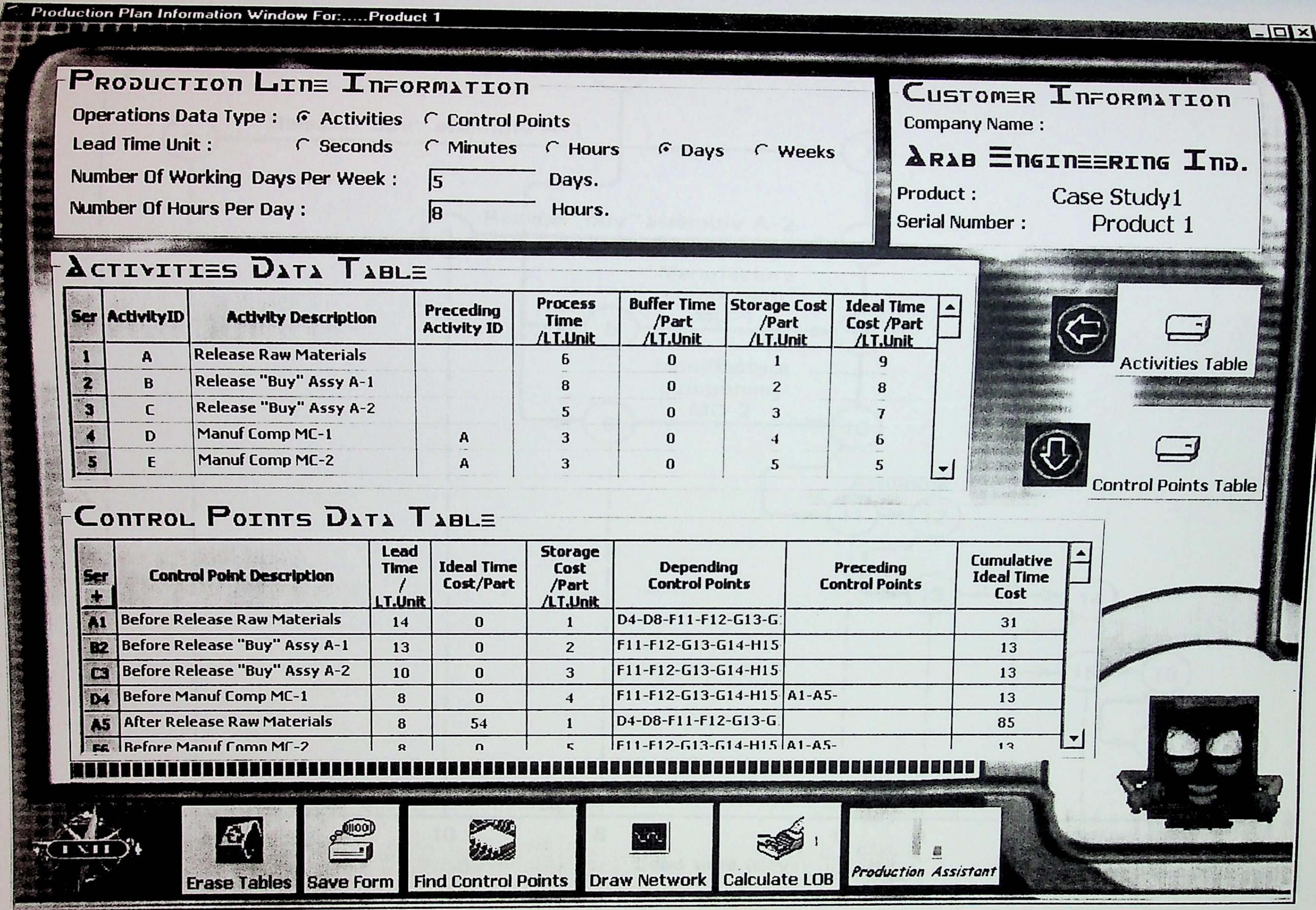


Figure 6-1: Production Plan Information.

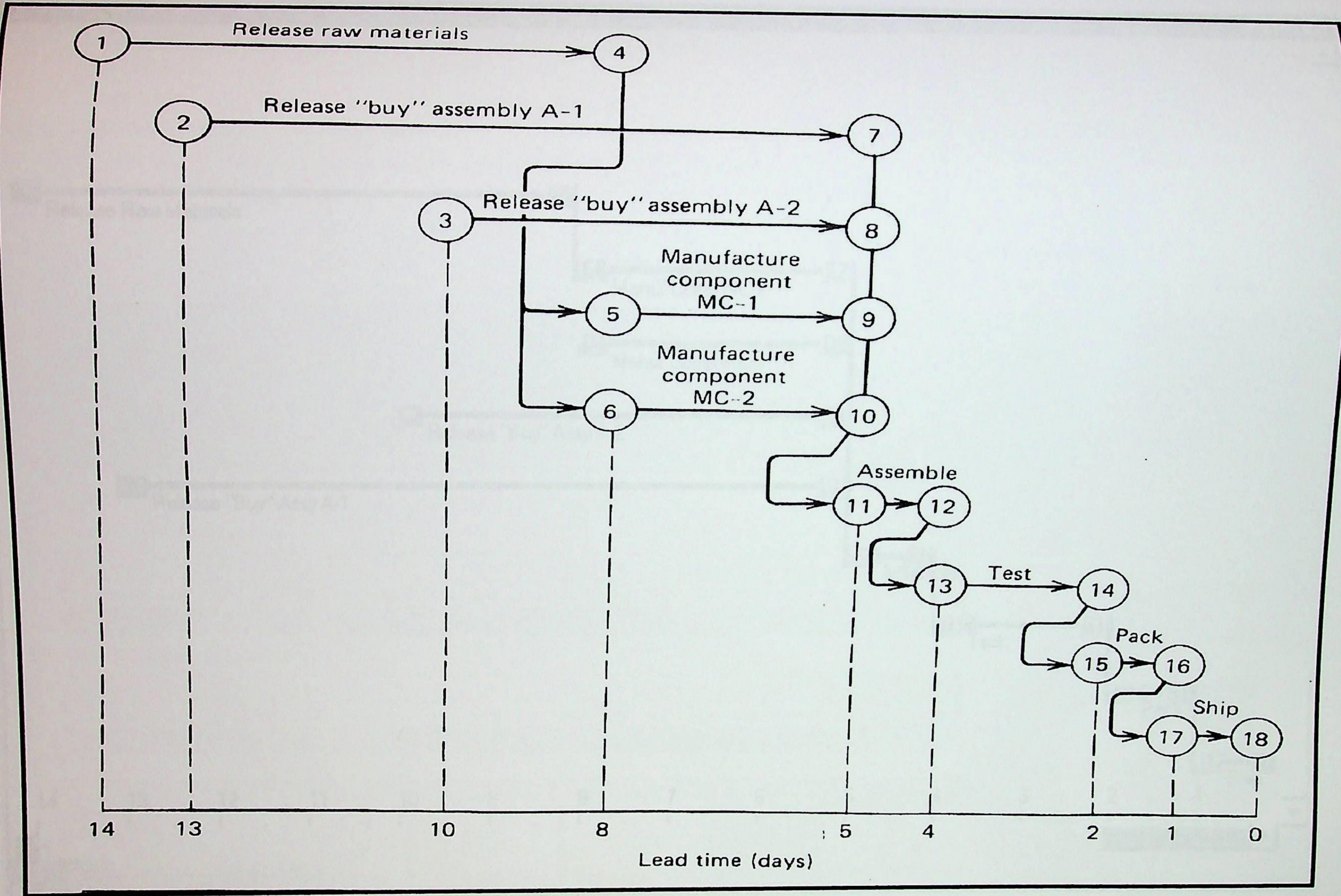


Figure 6-2A: Lead Time Chart. (Bedworth, 1994)

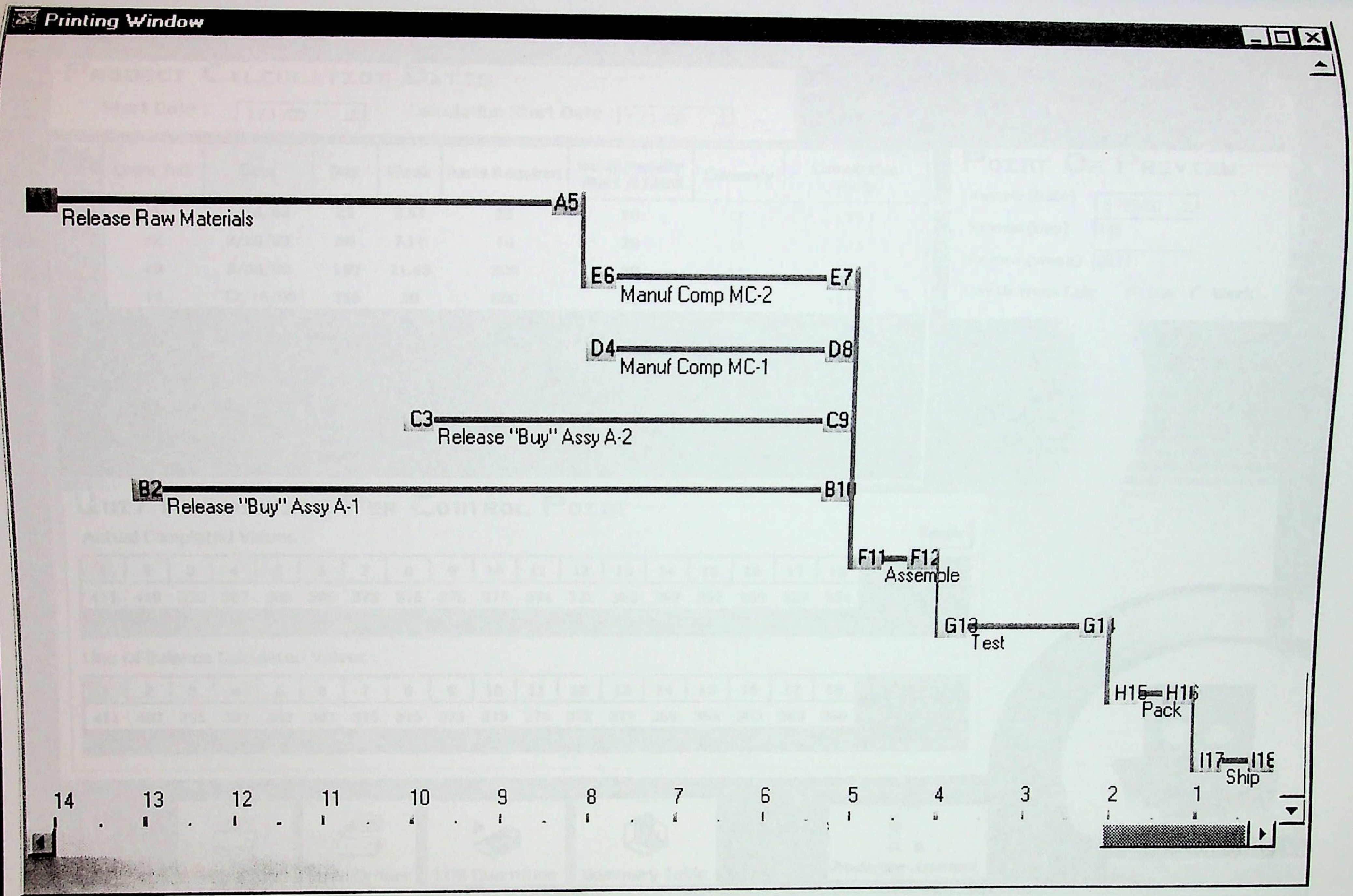


Figure 6-2: Lead Time Chart.

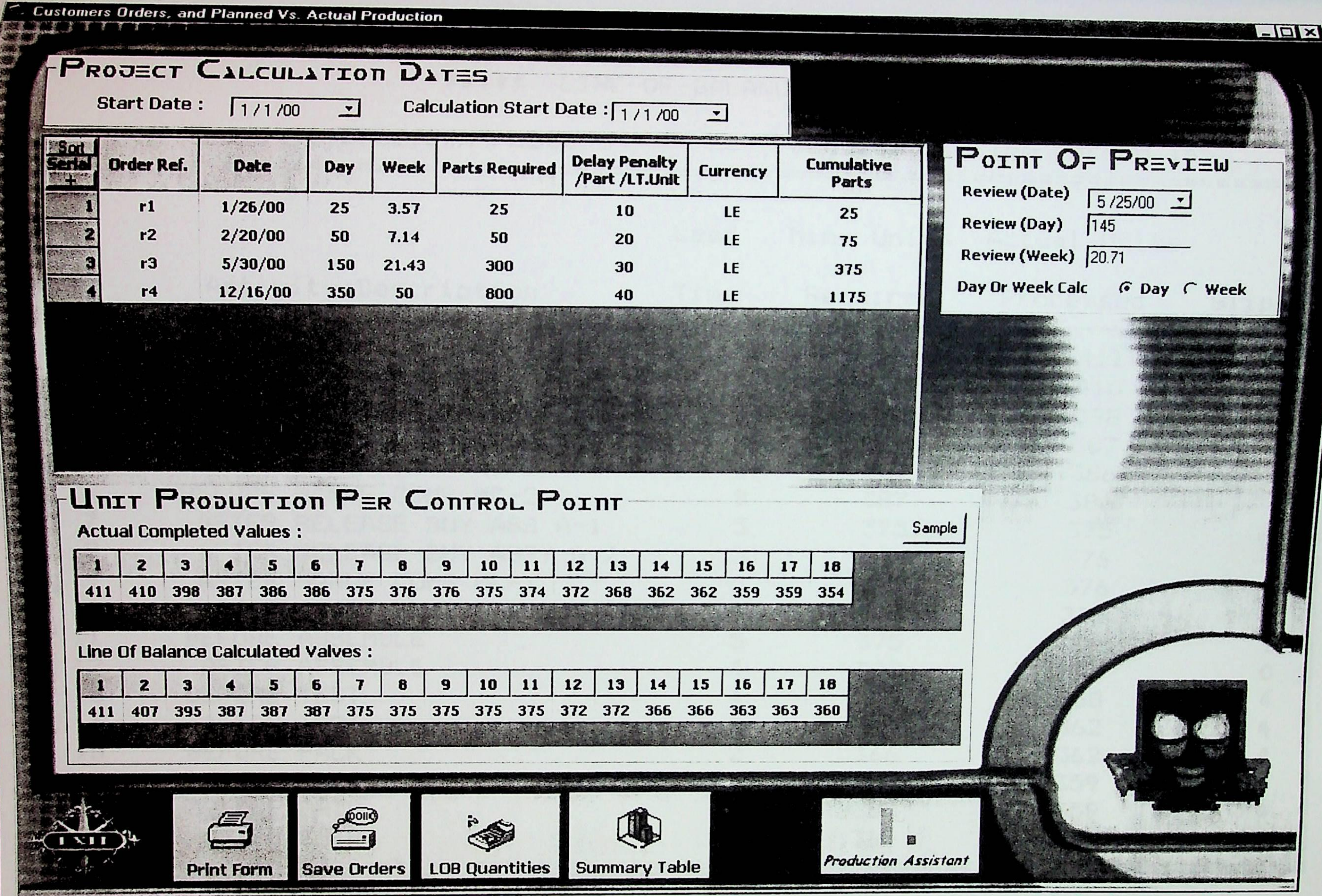


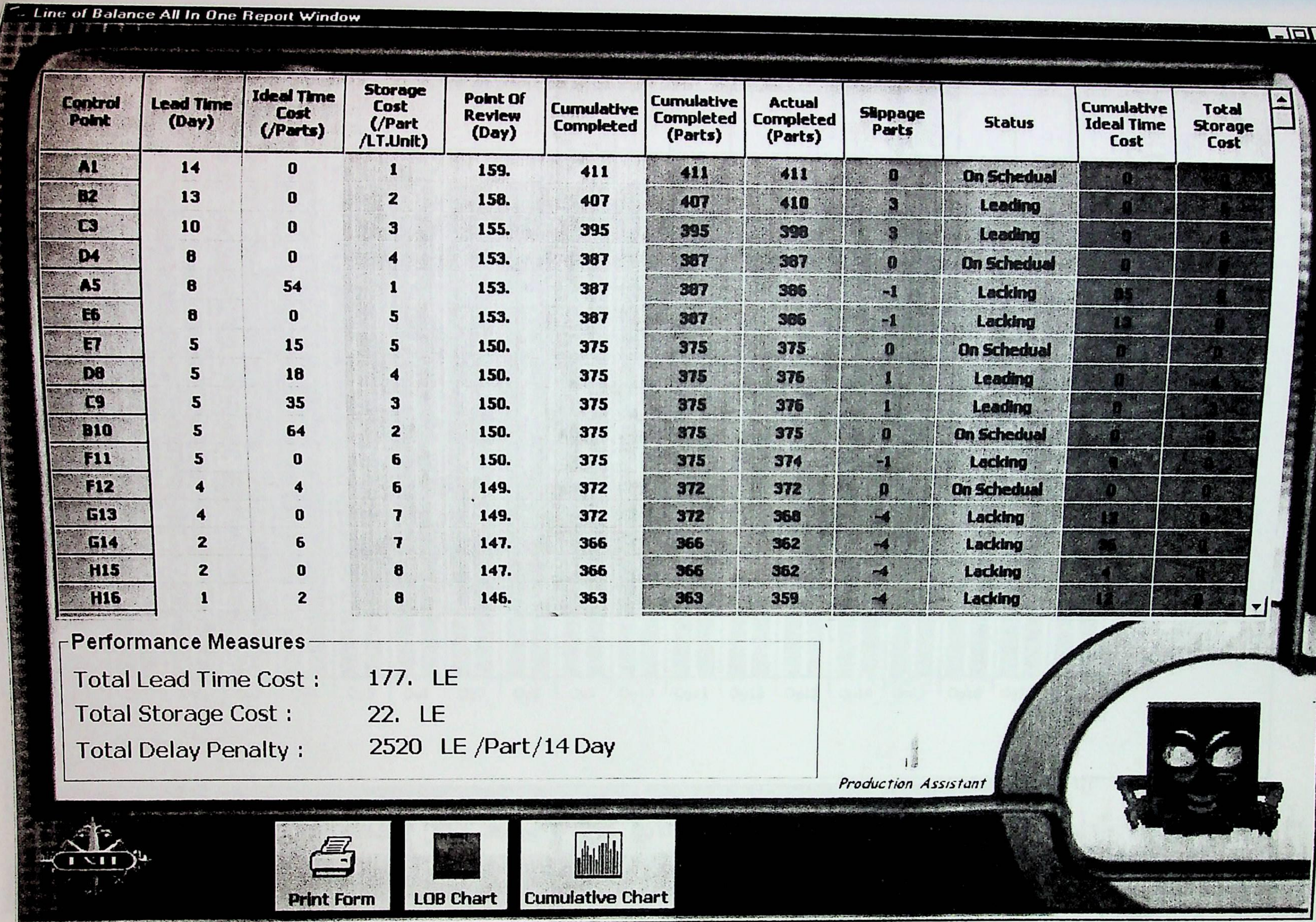
Figure 6-3: Customers Orders and Planned Vs. Actual Prodcution.

***** LINE-OF-BALANCE *****

Project: CASE EXAMPLE Progress at time period 145

Node	Activity Description	Lead Time	Min. Units Required	Actual Units Processed	Slippage
1	BEFORE RELEASE RAW MATLS	14	411	411	0
2	BEFORE RELEASE BUY ASS A-1	13	407	410	-3
3	BEFORE RELEASE BUY ASSY A-2	10	395	398	-3
4	AFTER RELEASE RAW MATLS	8	387	387	0
5	BEFORE MANUF COMP MC-1	8	387	386	1
6	BEFORE MANUF COMP MC-2	8	387	386	1
7	AFTER RELEASE BUY ASS A-1	5	375	375	0
8	AFTER RELEASE BUY ASSY A-2	5	375	376	-1
9	AFTER MANUF COMP MC-1	5	375	376	-1
10	AFTER MANUF COMP MC-2	5	375	375	0
11	BEFORE ASSEMBLE	5	375	374	1
12	AFTER ASSEMBLE	4	372	372	0
13	BEFORE TEST	4	372	368	4
14	AFTER TEST	2	366	362	4
15	BEFORE PACK	2	366	362	4
16	AFTER PACK	1	363	359	4
17	BEFORE SHIP	1	363	359	4
18	AFTER SHIP	0	360	354	6

Figure 6-4A: Line of Balance Report. (Bedworth, 1994)



Line of Balance All In One Report Window

Control Point	Lead Time (Day)	Ideal Time Cost (/Parts)	Storage Cost (/Part /LT.Unit)	Point Of Review (Day)	Cumulative Completed	Cumulative Completed (Parts)	Actual Completed (Parts)	Slippage Parts	Status	Cumulative Ideal Time Cost	Total Storage Cost
A1	14	0	1	159.	411	411	411	0	On Schedual	0	[illegible]
B2	13	0	2	158.	407	407	410	3	Leading	0	[illegible]
C3	10	0	3	155.	395	395	398	3	Leading	0	[illegible]
D4	8	0	4	153.	387	387	387	0	On Schedual	0	[illegible]
A5	8	54	1	153.	387	387	386	-1	Lacking	85	[illegible]
E6	8	0	5	153.	387	387	386	-1	Lacking	13	0
E7	5	15	5	150.	375	375	375	0	On Schedual	0	0
D8	5	18	4	150.	375	375	376	1	Leading	0	[illegible]
C9	5	35	3	150.	375	375	376	1	Leading	0	[illegible]
B10	5	64	2	150.	375	375	375	0	On Schedual	0	0
F11	5	0	6	150.	375	375	374	-1	Lacking	[illegible]	0
F12	4	4	6	149.	372	372	372	0	On Schedual	0	0
G13	4	0	7	149.	372	372	368	-4	Lacking	12	0
G14	2	6	7	147.	366	366	362	-4	Lacking	36	0
H15	2	0	8	147.	366	366	362	-4	Lacking	4	0
H16	1	2	8	146.	363	363	359	-4	Lacking	12	0

Performance Measures

Total Lead Time Cost : 177. LE

Total Storage Cost : 22. LE

Total Delay Penalty : 2520 LE /Part/14 Day

Figure 6-4: Line of Balance Report.

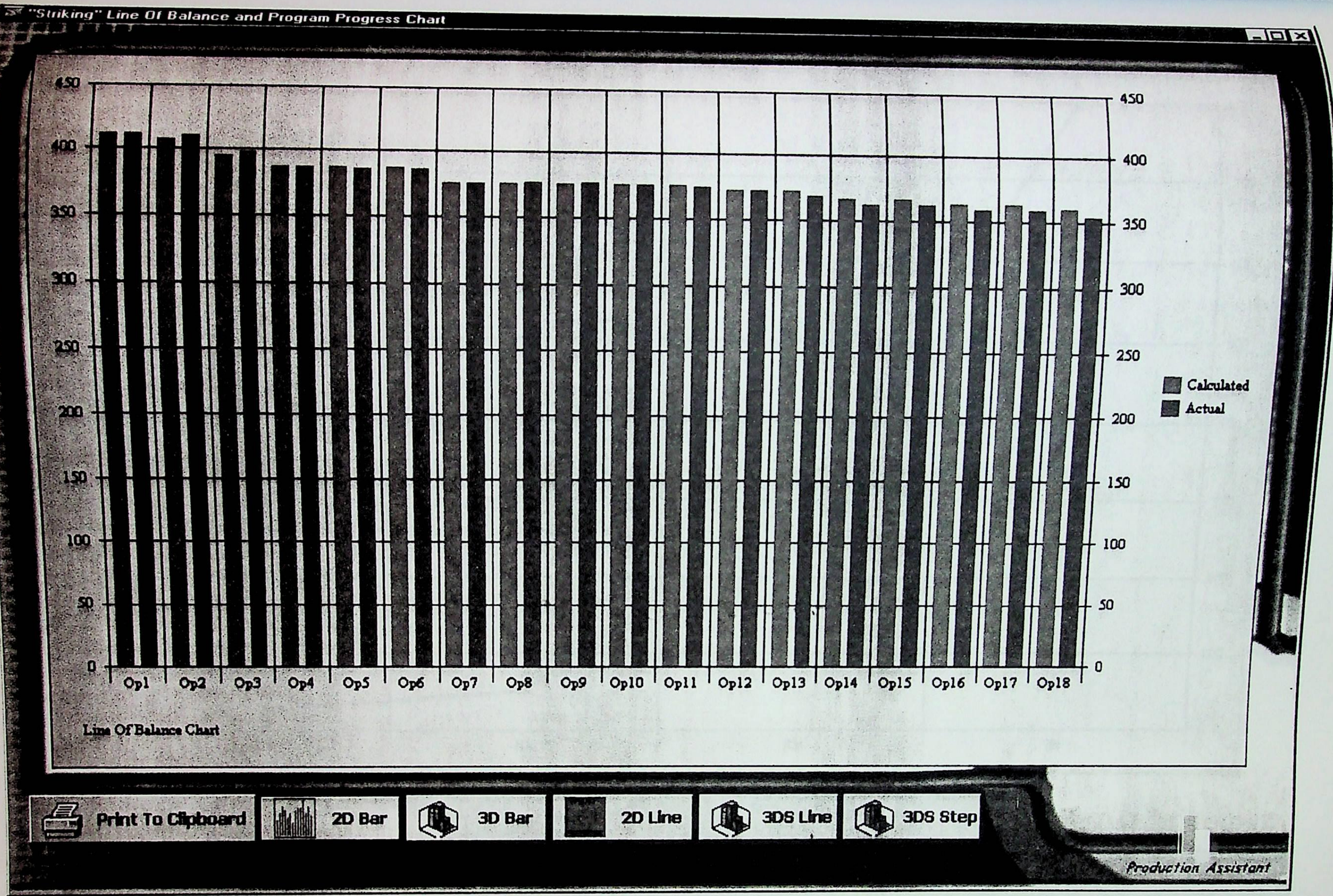


Figure 6-5: Line of Balance Chart.

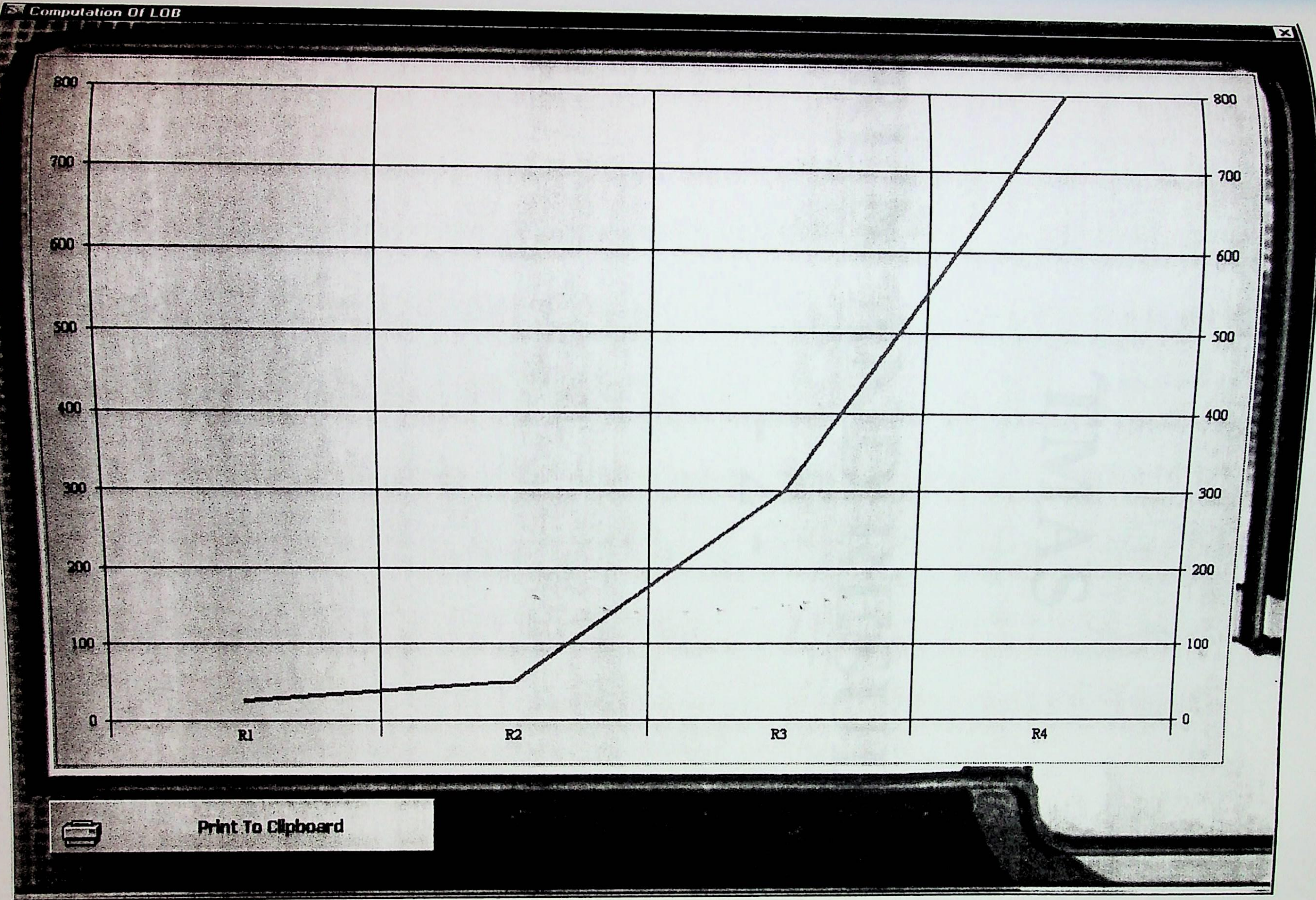


Figure 6-6: Objective Chart (Cumulative Orders).

TMAS

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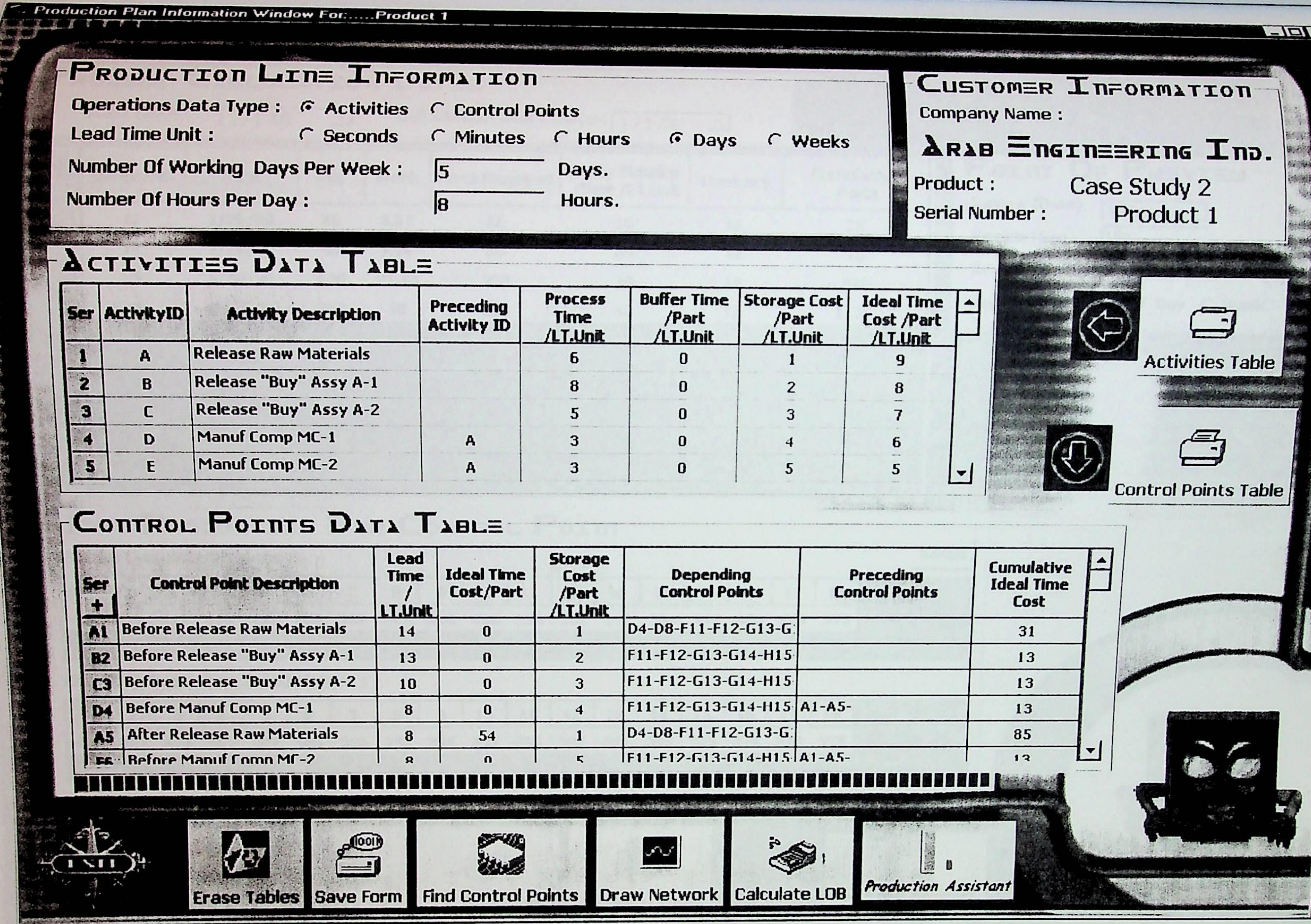


Figure 6-7: Production Plan Information.

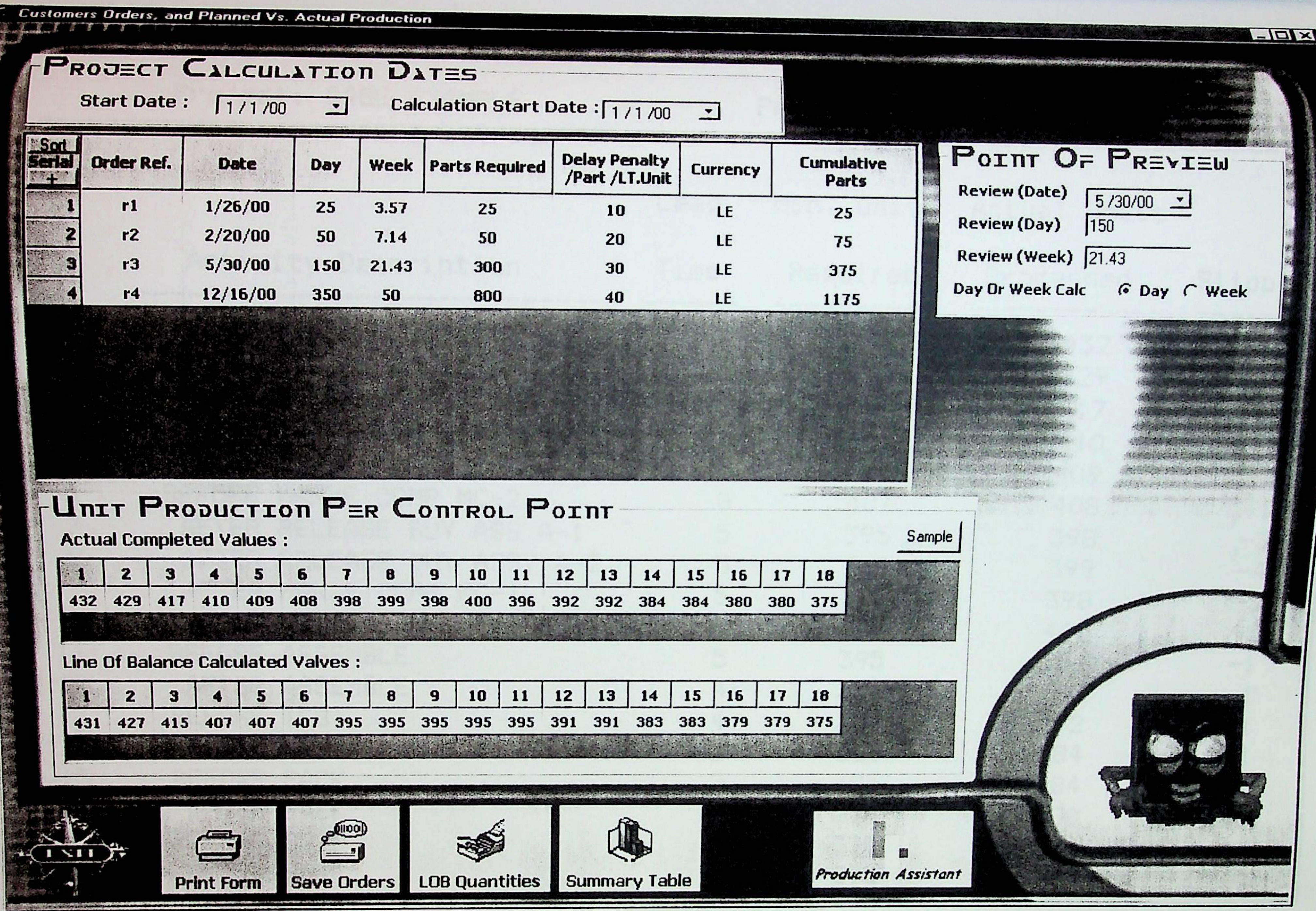


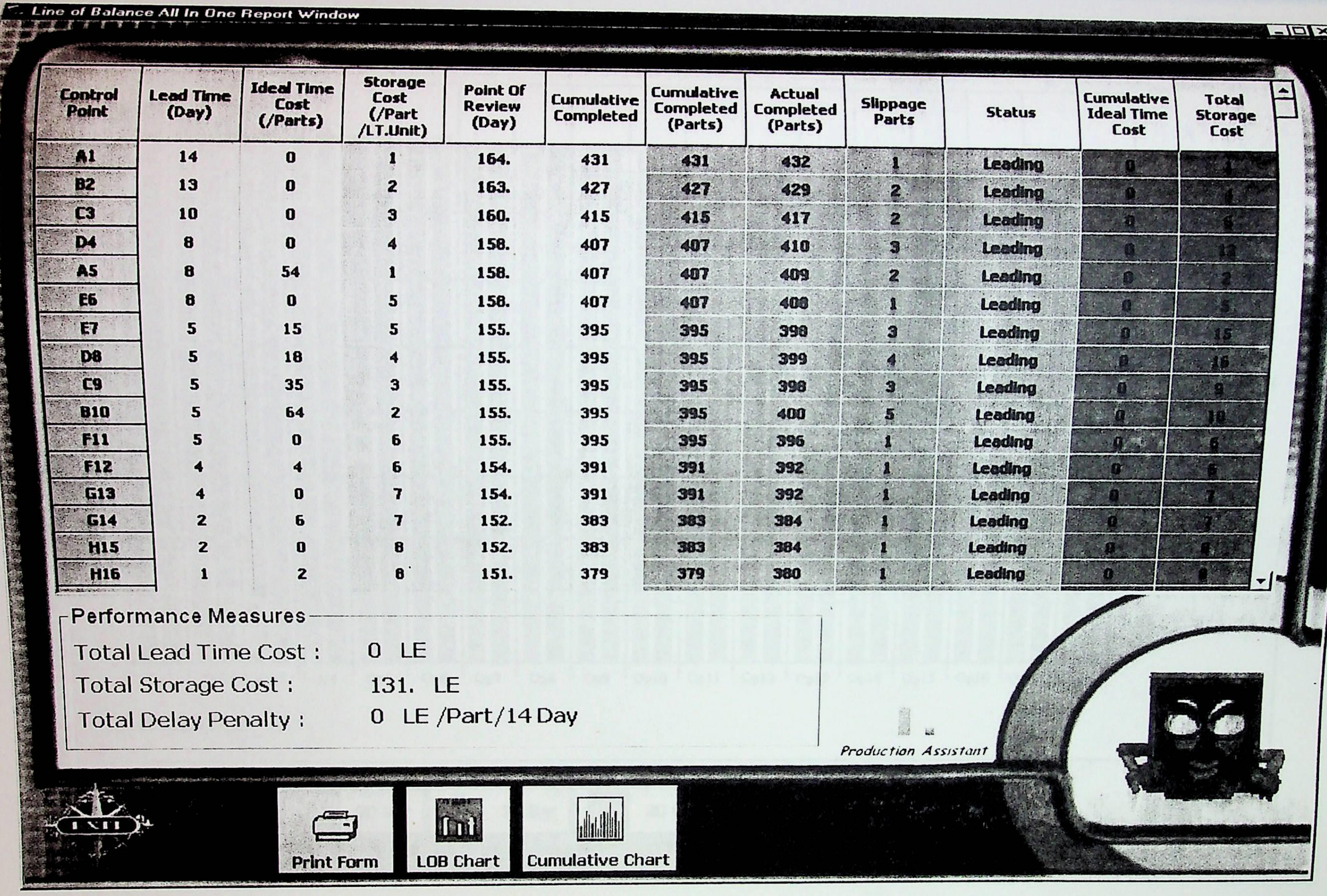
Figure 6-8: Customers Orders and Planned Vs. Actual Production.

***** LINE-OF-BALANCE *****

Project: CASE EXAMPLE — Progress at time period 150

Node	Activity Description	Lead Time	Min. Units Required	Actual Units Processed	Slippage
1	BEFORE RELEASE RAW MATLS	14	431	432	-1
2	BEFORE RELEASE BUY ASS A-1	13	427	429	-2
3	BEFORE RELEASE BUY ASSY A-2	10	415	417	-2
4	AFTER RELEASE RAW MATLS	8	407	410	-3
5	BEFORE MANUF COMP MC-1	8	407	409	-2
6	BEFORE MANUF COMP MC-2	8	407	408	-1
7	AFTER RELEASE BUY ASS A-1	5	395	398	-3
8	AFTER RELEASE BUY ASSY A-2	5	395	399	-4
9	AFTER MANUF COMP MC-1	5	395	398	-3
10	AFTER MANUF COMP MC-2	5	395	400	-5
11	BEFORE ASSEMBLE	5	395	396	-1
12	AFTER ASSEMBLE	4	391	392	-1
13	BEFORE TEST	4	391	392	-1
14	AFTER TEST	2	383	384	-1
15	BEFORE PACK	2	383	384	-1
16	AFTER PACK	1	379	380	-1
17	BEFORE SHIP	1	379	380	-1
18	AFTER SHIP	0	375	375	0

Figure 6-9A: Line of Balance Report.



Control Point	Lead Time (Day)	Ideal Time Cost (/Parts)	Storage Cost (/Part /LT.Unit)	Point Of Review (Day)	Cumulative Completed	Cumulative Completed (Parts)	Actual Completed (Parts)	Slippage Parts	Status	Cumulative Ideal Time Cost	Total Storage Cost
A1	14	0	1	164.	431	431	432	1	Leading	0	1
B2	13	0	2	163.	427	427	429	2	Leading	0	4
C3	10	0	3	160.	415	415	417	2	Leading	0	6
D4	8	0	4	158.	407	407	410	3	Leading	0	12
A5	8	54	1	158.	407	407	409	2	Leading	0	2
E6	8	0	5	158.	407	407	408	1	Leading	0	5
E7	5	15	5	155.	395	395	398	3	Leading	0	15
D8	5	18	4	155.	395	395	399	4	Leading	0	16
C9	5	35	3	155.	395	395	398	3	Leading	0	9
B10	5	64	2	155.	395	395	400	5	Leading	0	10
F11	5	0	6	155.	395	395	396	1	Leading	0	6
F12	4	4	6	154.	391	391	392	1	Leading	0	6
G13	4	0	7	154.	391	391	392	1	Leading	0	7
G14	2	6	7	152.	383	383	384	1	Leading	0	7
H15	2	0	8	152.	383	383	384	1	Leading	0	8
H16	1	2	8	151.	379	379	380	1	Leading	0	8

Figure 6-9: Line of Balance Report.

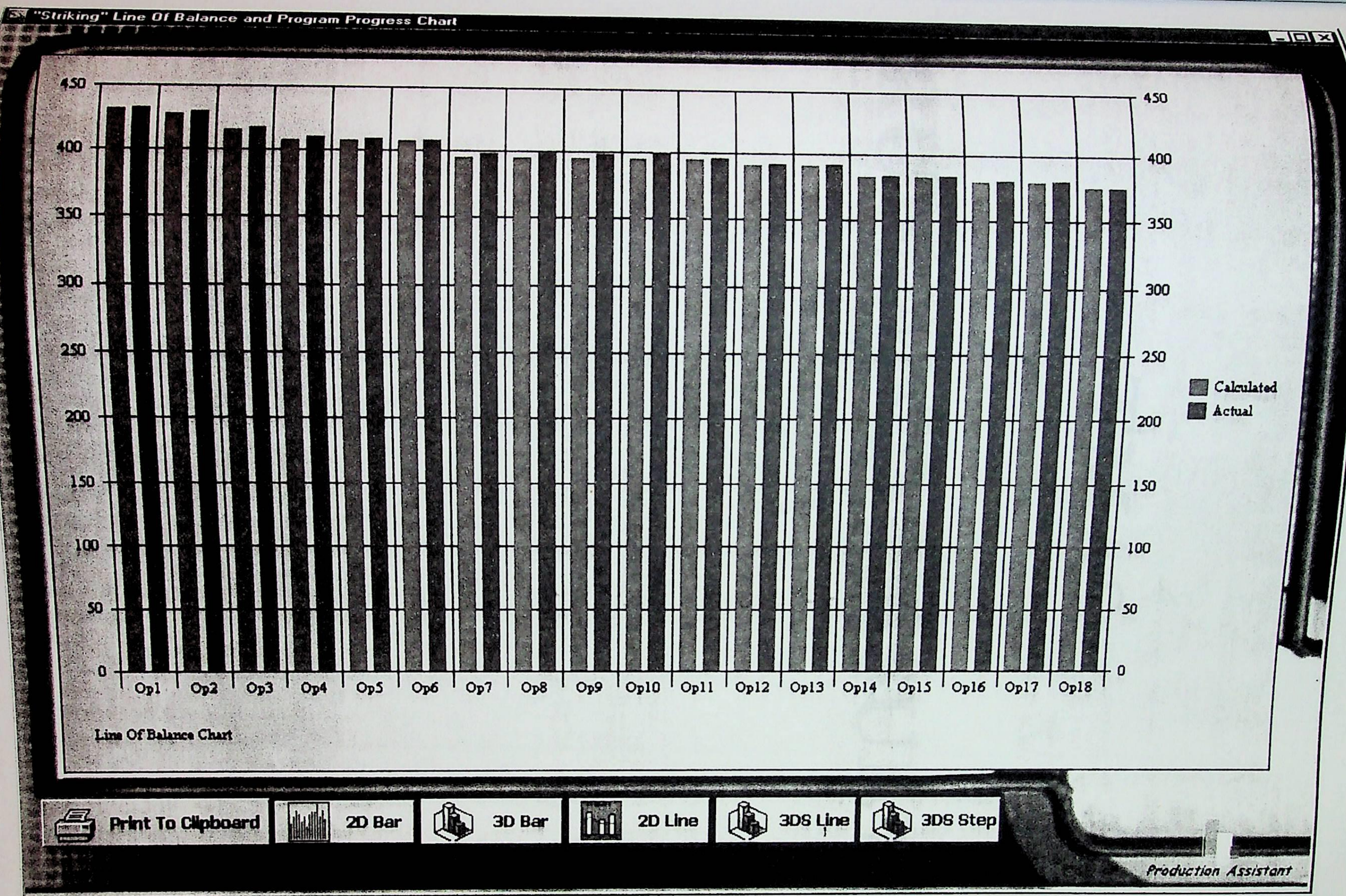


Figure 6-10: Line of Balance Chart.

TMAS

RUN AND RESULTS

- 3 -

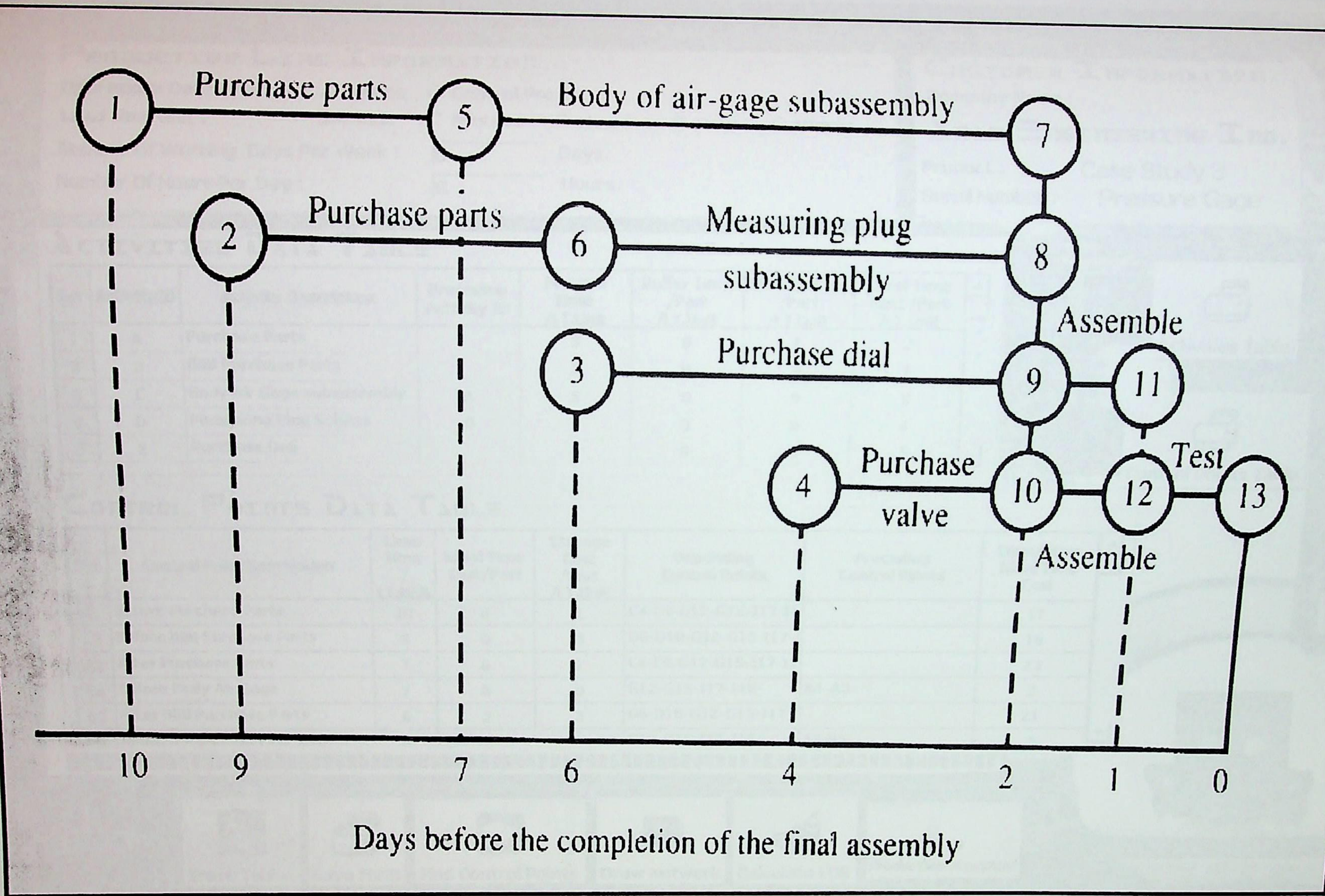


Figure 6-11A: Lead Time Chart.

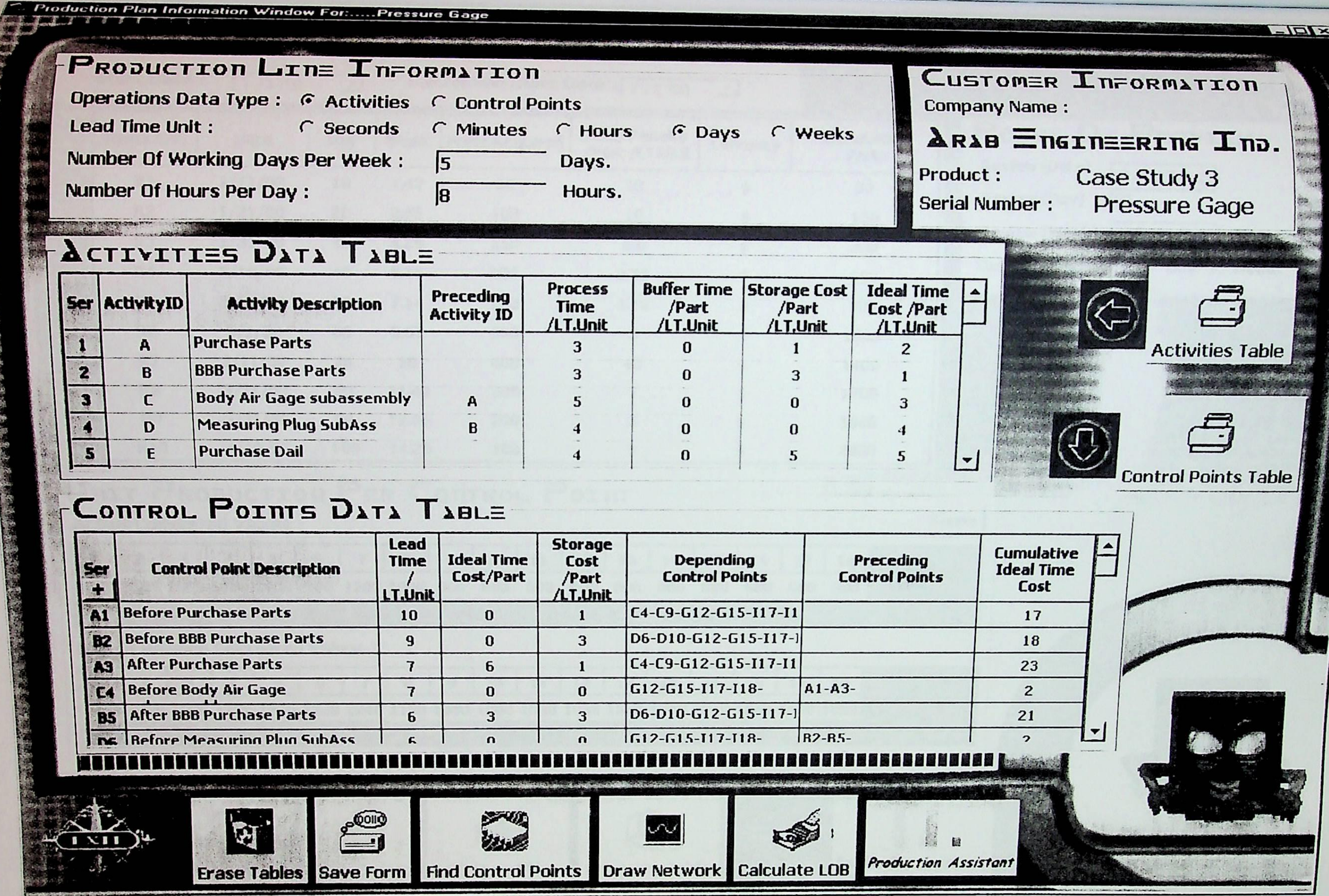


Figure 6-11: Production Plan Information.

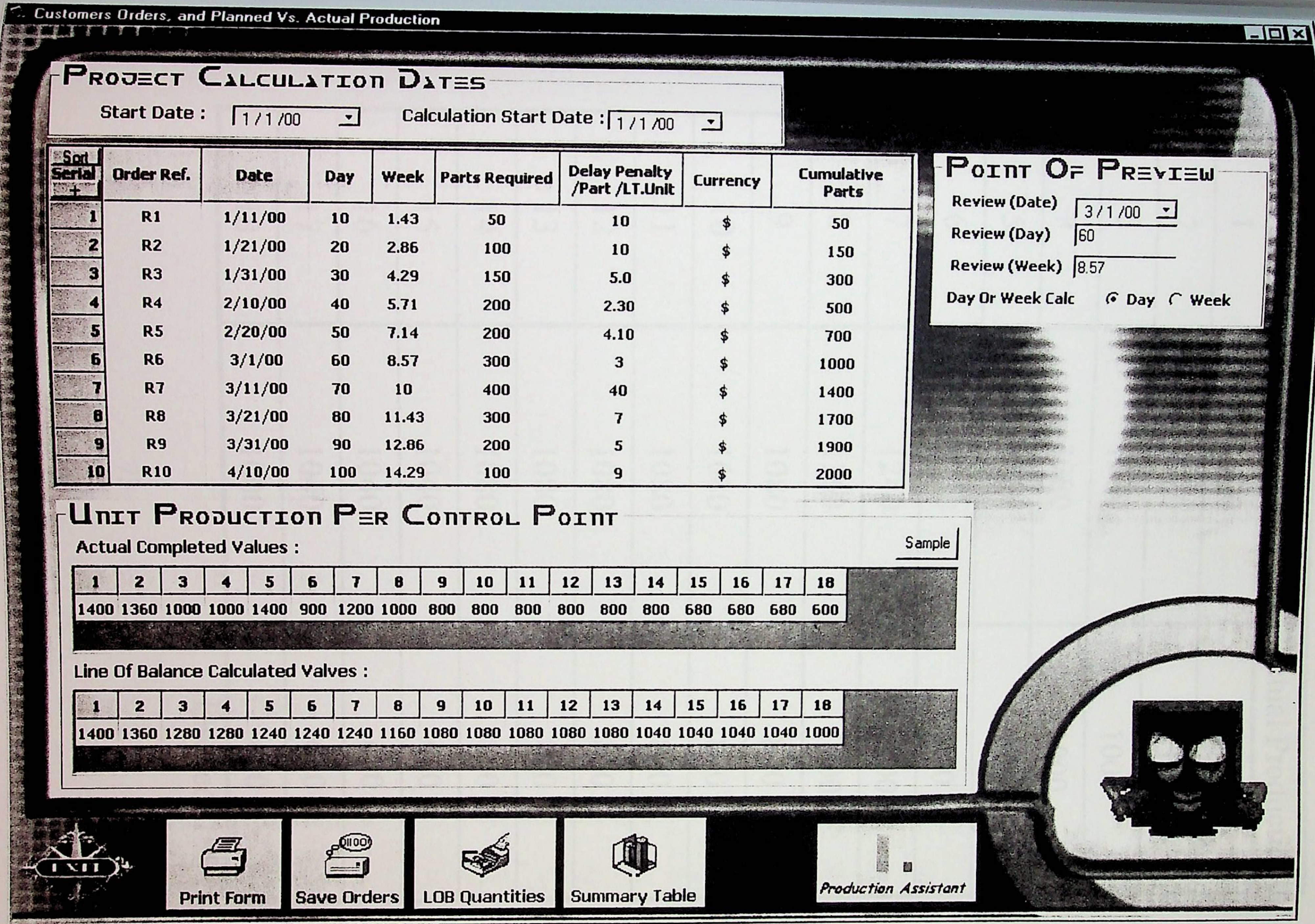
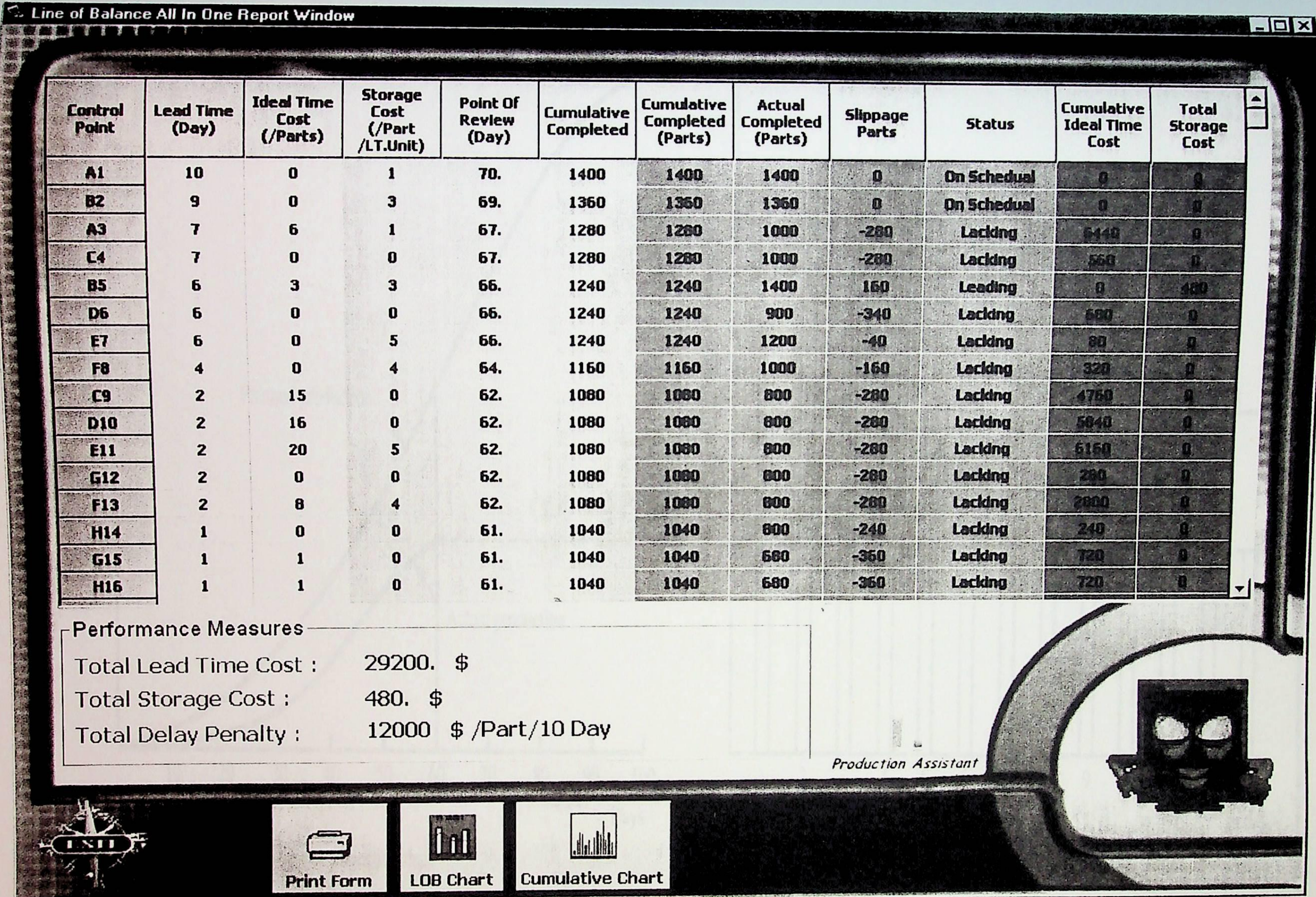


Figure 6-12: Customer orders and Planned Vs. Actual Production.

Cumulative Planned and Actual Production At Day 60

Control Point	Planned Production	Actual Production
1	1400	1400
2	1360	1360
3	1280	1000
4	1280	1000
5	1360	1400
6	1240	900
7	1240	1200
8	1160	1000
9	1080	800
10	1080	800
11	1080	800
12	1080	800
13	1080	800
14	1080	800
15	1040	680
16	1040	680
17	1040	680
18	1000	600

(Elsayed, 1994)



Line of Balance All In One Report Window

Control Point	Lead Time (Day)	Ideal Time Cost (/Parts)	Storage Cost (/Part /LT.Unit)	Point Of Review (Day)	Cumulative Completed	Cumulative Completed (Parts)	Actual Completed (Parts)	Slippage Parts	Status	Cumulative Ideal Time Cost	Total Storage Cost
A1	10	0	1	70.	1400	1400	1400	0	On Schedual	0	0
B2	9	0	3	69.	1360	1360	1360	0	On Schedual	0	0
A3	7	6	1	67.	1280	1280	1000	-280	Lacking	6440	0
C4	7	0	0	67.	1280	1280	1000	-280	Lacking	560	0
B5	6	3	3	66.	1240	1240	1400	160	Leading	0	480
D6	6	0	0	66.	1240	1240	900	-340	Lacking	680	0
E7	6	0	5	66.	1240	1240	1200	-40	Lacking	80	0
F8	4	0	4	64.	1160	1160	1000	-160	Lacking	320	0
C9	2	15	0	62.	1080	1080	800	-280	Lacking	4760	0
D10	2	16	0	62.	1080	1080	800	-280	Lacking	5840	0
E11	2	20	5	62.	1080	1080	800	-280	Lacking	6160	0
G12	2	0	0	62.	1080	1080	800	-280	Lacking	280	0
F13	2	8	4	62.	1080	1080	800	-280	Lacking	2800	0
H14	1	0	0	61.	1040	1040	800	-240	Lacking	240	0
G15	1	1	0	61.	1040	1040	680	-360	Lacking	720	0
H16	1	1	0	61.	1040	1040	680	-360	Lacking	720	0

Performance Measures

Total Lead Time Cost : 29200. $

Total Storage Cost : 480. $

Total Delay Penalty : 12000 $ /Part/10 Day

Figure 6-13: Line Of Balance Report.

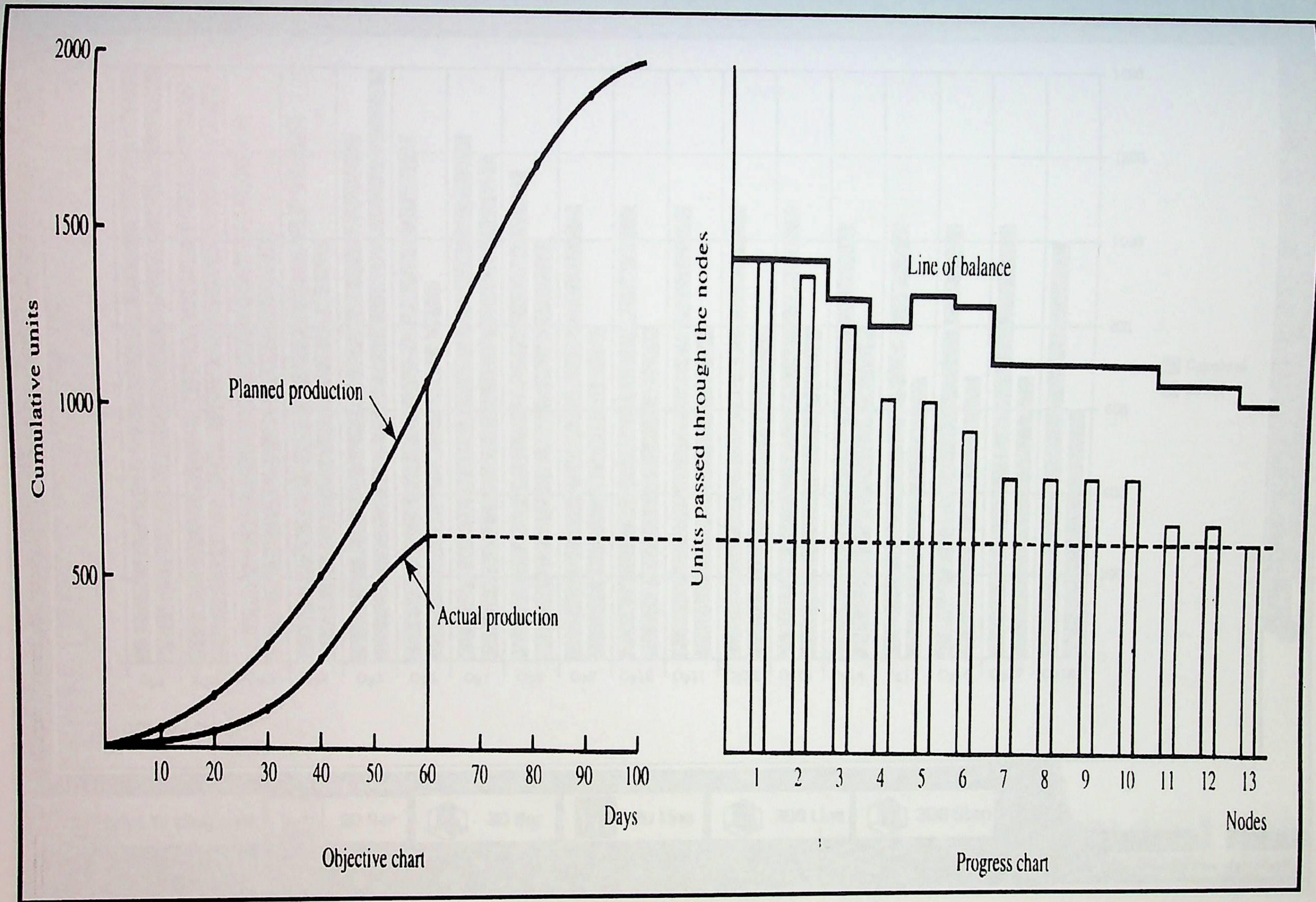


Figure 6-14A: Line Of Balance and Program Progress Chart.

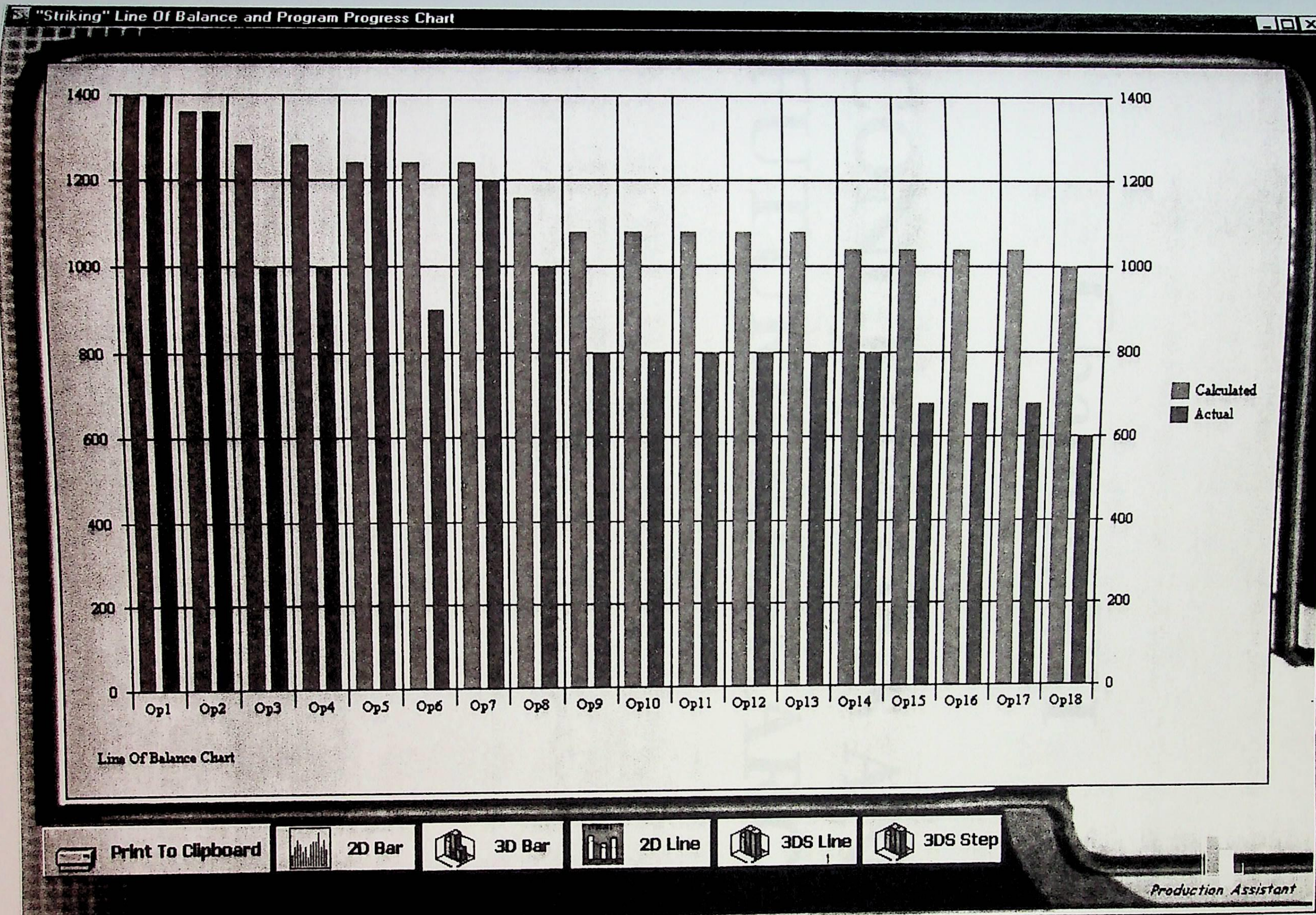


Figure 6-14: Line Of Balance and Program Progress Chart.

Chapter VII

CONCLUSIONS AND FUTURE RESEARCH

Chapter VII
Conclusions And Future Research

7.1 Conclusion

Monitoring and control of project progress are vital components in the project management area of knowledge. When it comes to production projects, where the proper quantity has to be delivered on time to the customer, it can make or break the organization. This phase of project management is considered as the backbone of any project. The one who is responsible for it should be capable of planning so as to be able to re-plan the project whenever needed.

Because the research work deal with monitoring and control of repetitive type of projects, and since this type of study would also be a very useful tool for the production sector, a merge between the project and the production operation is made. Since there are many things in common between a project and an operation as stated previously in the thesis the concept of management by project was introduced to merge the two together.

The LOB method has proven to be of great value in the management of repetitive small to large-quantity production runs, in which the design of the product is unchanged. It gives the status of the project, plan versus actual progress for any control point at any point in time. Moreover, and now with item of cost added to it, the LOB is capable of notifying management with where exactly to pay more attention and pressure and, perhaps of equal importance, where not to, because some operations may be at or ahead of their planned schedule.

The software developed here has adopted the LOB technique as the basic model for monitoring and control of production projects. The LOB method has been mathematical formulated to be able to program it. Adding the cost element as another component of performance measure has augmented the technique. Decision-maker would have a better idea on how much a delay in any given control point would cost. The cost reflects facility idle time cost, storage cost, and the final delay in delivery cost. LOB shows the manager the exact control point that is causing the problem, assessed by both delays in number of units and added costs.

The program was developed using Visual Basic 6, with a direct link to Microsoft Access database engine. It is a very user friendly made program, that there is help at any stage of the program, provided by a glossary database that contains over 3000 words related to the program and to the whole project management area of knowledge. The user is asked to enter through a secure area, to grand the security of data, then asked to enter and describe the Product tree. The product tree contains all Factories, Production lines, and products that the project manager is monitoring. For every product the manager is requested to enter the production routing, defining the activities, process time, precedence, idle time cost, storage cost. Then the computer stores this information and creates the control points for each activity. The program is also capable of drawing the Lead-time network chart. On the next screen, the user will be asked to enter the customer's orders in terms of due dates and quantities. After the computer stores the required production quantities, the user is now ready to enter the point of review day. When the user enters that point of review, a full detailed table is generated showing the status of each control point, either leading or lagging, and the accompanied added cost

due to slippage. A total idle time cost, storage cost, and delay cost is displayed. Finally, the program generates the Line of Balance chart, and the Objective chart.

In conclusion, and after testing the program with three real life case studies, and comparing the results with manually calculated ones, it was proven that it is generating correct output at a far shorter time, than the one done graphically. In addition to that, the item of cost added to the technique, made it easier for the user to highlight the control points that are the main reasons behind all tribulations.

7.2 Future Research

A number of future research points were identified in the course of this research. The following are brief description of future extensions to this research:

1. Delineating the cost item: The system relays on its user in evaluating the cost associated with delays. It should consider the integrated cost of an operation. It is believed that such information can be an accumulation of several cost elements, which can be accessed from its pertinent DB. If modified to include such delineation of the cost, the program should provide more accurate results.
2. Introducing intelligence to the system: In general, monitoring systems provide its user with a quantitative assessment of the current status. This system provide a cost assessment, however, it does not provide any remedial action. With the availability of intelligent systems, it is theoretically possible that the system may provide options to its user, on how to regain control of the project. Actions such as splitting of the orders, Shifting resources, and others

may be provided as options to the managers. Such component is not difficult to add to the system, however, in certain cases it may have to be "customized" to the organization. In certain cases, such component may be of great help, especially if the user is not familiar with remedial actions.

3. Introducing the element of uncertainty in the basic model: The system assumes that the information stored in its DB is deterministic. Such assumption may not be valid in cases of new products or orders (Case of Agile production systems). It is possible that models of uncertainty may be included in the assessment component of the model.
4. Assessing the quality: Assuming that there is a trade of between time and quality, the cost of quality may be evaluated and added to the cost element of the system. However not much thought have been given to that in this research, it is not uncommon, that the number of rejects, hence higher cost, may be generated as a result of trials to regain control on the project. A point worth investigating and if found valuable should be added to the cost equation.

REFERENCES

References

1. Arditi, D., and Albulak, M. Z. (1986). Line of balance scheduling in pavement construction. Journal of Construction Engineering and Management, 112(3), 411-424.

2. Awa, A. O. (1983). Project Management Techniques. New York: Petrocelli Books Inc.

3. Bedworth, David D., and James E. Bailey. (1994). Integrated Production Control Systems. New York: John Wiley & Sons.

4. Bittel, Lester R., ed. (1978). Network Planning Methods, in Encyclopedia of Professional Management. New York: McGraw-Hill.

5. Burke R. (1997). Project Management Planning and Control Second Edition. John Wiley and Sons. International.

6. Carr, R. L, and Meyer, W. L. (1974). Planning construction of repetitive building units. Journal of Construction Engineering and Management, 100(3), 403-412.

7. Cole, L.J.R. (1991). Construction scheduling: principles, practices, and six case studies. Journal of Construction Engineering and Management, 117(4), 579-88.

8. Earned Value. (1999). Line Of Balance. [Online]. Available: http:// www.nnh.com/draw/lob.gif. (Jan 20, 2000).

9. El Maghraby, S. E. (1964). An Algebra for the Analysis of Generalized Activity Networks. Management Science, Vol. 10, No. 3

10. Elsayed, Elsayed A., and Thomas O. Boucher. (1994). Analysis And Control Of Production Systems. New Jersey: Prentice Hall, Englewood Cliffs.

11. Fleming, Quentin W., John W. Bronn, and Gary C. Humphreys. (1997). Project and Production Scheduling. Chicago, Illinois: Produs Publishing Company.

12. Gaither, Norman. (1995). Production and Operations Management. Hinsdale, Illinois: The Dryden Press.

13. Garret, Leonard J., and Milton Silver. (1973). Production Management Analysis. New York: Harcourt Brace Jovanovich, Inc.

14. Graham, P. (1965). Profit Probability Analysis of Research and Development Expenditures. Journal of Industrial Engineering, Vol. 16, No. 3, May-June.

15. Greene, James H. (1965). Production Control Systems and Decisions. Homewood, Illinois: Richard D. Irwin, Inc.

16. Harrison, Florence Louise. (1985). Advanced Project Management. Britain: Billing & Sons Limited, Worcester.

17. Hosni, Yasser and Whitehouse, G. E. (1989). IIE Microsoft Package. IIE Press, International.

18. Iannone, Anthony L. (1967). Management Program Planning and Control with PERT MOST and LOB. New Jersey: Prentice Hall, Englewood Cliffs.

19. Kavanagh, D.P. (1985). SIREN: A Repetitive Construction Simulation Model. Journal of Construction Engineering and Management, 111(3), 308-323.

20. Kelley, James E., and M. Walker. (1959). Critical-Path Planning and Scheduling. Proceedings Eastern Joint Computer Conference.

21. Khisty, C. J. (1970). The application of the line of balance technique to the construction industry. Indian Concrete Journal, 44(7), 297-300, 319-320.

22. Lumsden, P. (1968). The Line Of Balance Method. London, U.K: Pergamon Press.

23. Lutz, J.D. and Hijazi, A. (1993). Planning repetitive construction: current practice. Construction Management and Economics, 11(2), 99-110.

24. MacCrimmon, K. R., and C. A. Ryavec. (1964). An Analytical Study of the PERT Assumptions. Operations Research, Vol. 12, Jan.-Feb.

25. McBain, N. (1997). Project Management. On campus version of the Research Student Training Programme.

26. Moder, J.J., Phillips, C.R. and Davis, E.W. (1983). Project Management with CPM, Pert and Precedence Diagramming. New York: Van Nostrand Reinhold.

27. Moselhi, O. and El Rayes, K. (1993). Scheduling of repetitive project with cost optimization. Journal of Construction Engineering and Management, 119(4), 681-97.

28. Navy Office of Naval Material. (1962). Line Of Balance Technology, NAVEXOS.

29. O'Brien, James J. (1969). Scheduling Handbook. New York: McGraw-Hill Book Company.

30. O'Brien, James J. (1984). Network scheduling variations for repetitive work. Paper Presented at the ASCE spring convention. Atlanta, Ga.

31. O'Brien, James J. (1975). VPM scheduling for high-rise buildings. Journal of Construction Engineering and Management, 101(4), 895-905.

32. Perera, S. (1982). Network planning of projects comprising repetitive activities. IAHS conference on Impact of Economy and Technology, International Association of Housing Science, Vienna, Austria, 927-985.

33. Rahbar, F. F., and Rowing, J.E. (1992). Repetitive activity scheduling process. AACE Trans., 36th Annual meeting, Orlando, Florida, O.5.1-O.5.8.

34. Reda, R.M. (1990). RPM: repetitive project modeling. Journal of construction Engineering and Management, 116(2), 316-30.

35. Russel, A.D., and Wang, C.M. (1993). New generation of planning structures. Journal of Construction Engineering and Management, 119(2), 196-214.

36. Sarraj, Z.M. Al. (1990). Formal development of Line of Balance technique. Journal of Construction Engineering and Management, 116(4), 689-704.

37. Schoderbek, P.P. and Digman, L.A. (1967). Third generation PERT/LOB. Harvard Business Review, 45(5), 100-10.

38. Selinger, S. (1980). Construction planning fro linear projects. Journal of Construction Engineering and Management, 106(CO2), 195-205.

39. Strategic Soft. (1999). Line Of Balance. [Online]. Available: http://home.Pdq.net/sbi/LINOBAL.HTM (Jan 5, 2000).

40. Suhail, S.A. and Neale, R.H. (1994). CPM/LOB: new methodology to integrate CPM and Line or Balance. Journal of Construction Engineering and Management, 120(3), 667-84.

41. Tan T.C. (1994). Level Three Project Management Guide. Version 1.2. University of Sunderland.

42. Thompson, P. (1981). Organization and economics of construction. London, England: McGraw Hill Book Company Ltd.

43. Trimble, G. (1984). Resource-oriented scheduling. Project Management Journal, 2(2), 70-74.

44. Whitehouse, G. E. (1965). Extensions, New Developments and Applications of GERT. Ph.D. dissertation, Arizona State University, Aug.

45. Whitehouse, G. E. (1973). Systems Analysis and Design Using Network Techniques. Englewood Cliffs, NJ: Prentice Hall.

46. Wiest, J. D., and F. K. Levy. (1977). A Management Guide to PERTICPM, 2nd ed. Englewood Cliffs, NJ: Prentice-Hall.

47. Wysocki RX, Beck R. and Crane D.B. (1995). Effective Project Management. How to plan, manage and deliver projects on time and within budget. International: John Wiley and Sons.