APPLICATION OF THE CRITICAL PATH METHOD TO THE PLANNING OF A TECHNOLOGY TRANSFER PROJECT USING LINEAR PROGRAMMING

A THESIS
SUBMITTED TO THE DEPARTMENT OF MANAGEMENT
AND THE GRADUATE SCHOOL OF BUSINESS
ADMINISTRATION OF BILKENT UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER
OF BUSINESS ADMINISTRATION

By
ELİF EMİRLİ
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MAY, 1993

I certify that I have read this thesis and in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Business Administration.

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ABSTRACT

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ELİF EMİRLİ

Master of Business Administration

Supervisor: Assoc. Prof. ERDAL EREL

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The main purpose of this thesis is to utilize the critical path method in the planning of a technology transfer project by using linear programming. LINDO software is practiced in establishing the linear programming formulation and a matrix generator is written in C language to input the formulation into LINDO format. In this way, the schedule of the project is created, the completion time of the project is calculated and the activities forming the critical path are determined. Also by applying a parametric analysis to the right-hand sides of the constraints (activity durations) for the noncitical activities, the times when the critical activities became critical are determined.

Keywords : Critical Path Method, Planning and

Scheduling, Technology Transfer, Parametric Analysis.

ÖZET

BİR TEKNOLOJİ TRANSFERİ PROJESİNİN PLANLANMASINDA DOĞRUSAL PROGRAMLAMA KULLANILARAK KRİTİK YOL METODUNUN UYGULANMASI

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Bu çalışmanın amacı, bir teknoloji transferi projesinin planlanmasında doğrusal programlama kullanılarak kritik yol metodunun uygulanmasıdır. Doğrusal programlama formülasyonunun oluşturulmasında LINDO yazılımı kullanılmış ve formülasyonu LINDO formatına çevirmek için de C dilinde bir program yazılmıştır. Bu şekilde, projenin aktivite zamanları, proje bitiş zamanı hesaplandı ve kritik yolu oluşturan aktiviteler belirlenmiştir. Ayrıca kritik olmayan aktivitelerin zamanlarına parametrik analiz yapılarak bunların kritik yola girme zamanları elde edilmiştir.

Anahtar Kelimeler: Kritik Yol Metodu, Proje Planlama ve Aktivite Zamanlarını Belirleme, Teknoloji Transferi, Parametrik Analiz.

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INTRODUCTION

1.1.Scope of the Study

"Project management is not only a science but also an art. It is a science because it makes use of scientific techniques that have been proven to enhance management processes. It is an art because it relies on the judgment, expertise and personal intuition of the project management people." (Whitehouse,1973,1989)

Leaving the art side of the project management aside, the emphasis is on science part of it in this thesis.

Most of the scientific techniques available to project management people are handled with the help of computer hardware and software. Although project management makes use of computers in many areas such as project planning and organization, project coordination, project control, budget analysis and project communications; activity scheduling and resource allocation are the areas where computers are utilized most.

And the scope of this study is limited to project scheduling with critical path method (CPM) by making use of linear programming software LINDO. The discussions are also applied to a technology transfer project as an illustration.

1.2.An Overview of the Technology Transfer Concept

The fast development of global industrialization has brought a new approach to the concept of ownership in law in the last centuries and consequently besides tangible rights, intangible rights also emerged. Technological knowledge, which is gained either as a result of experience or as a result of systematic research, had become something that is sold in return of money. It has long been a very common behavior to buy the results that some other company developed by paying a suitable fee which is called transfer of technology. The transfer of technical information related with the design, engineering, manufacturing, and production techniques for hardware systems using recorded and/or documented information of a scientific or technical nature is called technology transfer. (the Defense Systems Management College Publications,1987)

With the rapid widening of the technological gap between the developed and developing countries, the transfer of technology has become a matter of decisive importance. This importance is not restricted to the developing countries alone, but to the developed ones as well, since no industrial, trade or cultural relations can be built up and maintained between the two, without bridging, or at any rate reducing this gap. (Bhattasali,1972) Hence, although technology transfers may be among companies from different countries or among companies from the same country, the most common type is the one which includes different countries. In other words, transfer of technology is an integral part of national development.

Technology transfer is indeed an extremely broad subject and it is perceived as an increasingly important ingredient in the development of industrial resources and wealth. Technology transfer enables companies to make better use of their scarce resources of research and development for donor companies in that it provides additional income to be derived from R & D. On the other hand, it represents a source of new and improved products in an increasingly competitive world for the recipient companies.

1.2.2.Types of Technology Transfer Channels

Although technology transfers vary in their scope, there exists methods such as trademark license transfer, patent/patent license transfer and technical information (know-how) license transfer for them.

1.2.2.1.Trademark Transfer

Trademark is a sign which is put onto a product or to its package in order to distinguish it from the similar products. Trademarks are registered by the government to hinder unfair competition by counterfeiting. (Milli Prodüktivite Merkezi,1975) Any other company can obtain the rights to use the registered trademark of a company by paying a suitable fee to the owner of the trademark.

Contracts are made between the companies for the transfer of trademarks. These contracts should also be approved by the government office which registered the trademark. In these contracts there exists issues such as the term of the agreement, the products for which the trademark can be used and whether the trademark is transferable or not.

1.2.2.2.Patent/Patent License Transfer

Patent is a grant of specific monopoly rights given by a government to an inventor for his invention that is valid for a certain period of time and only within the territorial limits of the country in which it is granted. (the Defense Systems Management College Publications,1987) These rights can be transferred in return of a fee which is called patent transfer. If only the rights to use the patent but not the rights to transfer, are transferred then this is called patent license transfer. (Milli Prodüktivite Merkezi Yayınları, 1975)

In patent/patent license transfer contracts , there exists topics such as what portion of the patent is transferred, if the licensee is given the right to transfer and whether the developments, if any, will also be transferred to the licensee.

The monopoly granted to the patentee rules the others out from using the particular invention in the sense that it provides redress by giving the right to bring suit but it cannot prevent the direct violations.

1.2.2.3.Technical Information (know-how) Transfer

Know-how is an American term which is receiving growing acceptance in international contracts. It is a generic term and it includes trade secrets, manufacturing procedures and techniques, specifications, charts, formulae, drawings and graphs, marketing techniques and professional advice and the like except patents and trademarks. Actually know-how can be anything which is not readily known or available to the public.

The Restatement of Torts defines know-how as "any formula, device or compilation of information which is used in one's business and which gives an opportunity to gain an advantage over competitors who do not know or use it." (the Defense Systems Management College Publications, 1987)

Therefore, know-how can be similar to a patent in the sense that it grants some kind of monopoly by preventing those who do not posses it from using it. But it is also differentiated from patents in the following issues (the Defense Systems Management College Publications,1987) :

- The monopoly is de facto as opposed to de jure.
- The monopoly is maintained indefinitely unless the know-how is made public.
- What is essential to the value of know-how is some extent of secrecy.

There is a current trend of switching from patent system to know-how rights to protect the unpatented rights and processes among the companies in recent years. Furthermore, know-how is generally necessary to utilize the patents licensed in an agreement. As a result of this, another common behavior in this area has been to contain only know-how without patents in the licensing agreements.

The companies that are successful in transferring technologies to other companies have a common belief in general. This belief is that the beginning of a successful local production is not at the time of contract signature between two parties, but it is as early as the time the design goals for a new product or system to be transferred later are being defined. One design goal of such a product is that it must be producible in foreign countries autonomously, free of bottlenecks and hindrances. In order to do this, the product should be designed taking the availability of components in the world market into consideration. Furthermore, the local manufacturing philosophy should be structured in a modular way to enable the company receiving the technology to increase the local manufacturing content step by step thus achieving the implementation of the full know-how transfer to a 100% autonomy in subsequent modules, parts and components at the earliest time possible.

1.3.An Overview of the Project

The Project is mainly a license and know-how transfer of a defense product from a European company and subsequent manufacturing of it in the licensee's facilities and then selling it to a customer in Turkey. The licensee company is a Turkish company and the project duration is 7 years. The overall project involves 3 agreements and a contract, namely License and Know-how Transfer Agreement, Hardware Supply Agreement, Unique to Type Test Equipment (UTTE) Agreement and Sales Contract. While the three agreements are between the licenser which is a multinational company and the licensee ; the contract is between the end customer and the licensee.

In this program, the licenser is selected by the customer from a number of foreign companies which are manufacturing the product the customer desires to buy. The licenser possesses some specific proprietary rights, manufacturing rights and certain engineering and production know-how essential to or helpful in the manufacturing the product. Following the selection of the licenser, the customer has opened a domestic tender for the local production and delivery of the product. It obligated the bidders for the tender to locally manufacture the product under the license of the product and provide the necessary support.

A contract is signed between the customer and the winner of the domestic tender. The licensee has been nominated by the customer for the local manufacturing of the product and had obtained the rights to use, to manufacture, to sell and to provide maintenance for the product and subassemblies of the product in accordance with the License and Know-how Transfer Agreement.

Although the validity of the agreements in consideration lasts 7 years, only the activities of the first 3 years will be studied in this thesis due to the data available at hand. Besides, activities after the third year will be a repetition of the first 3-year activities.

Since the project is in the defense industry, confidentiality agreements are made between the two parties to protect the proprietary rights. And because of these agreements, the name of the licenser and the licensee, the name of the product any other information about it will not be disclosed within the thesis.

1.3.1.License and Know-how Transfer Activities

These are the activities of the License and Know-how Transfer Agreement signed between the licensee and the licenser company. They mainly consist of training courses at different phases of the project, technical assistance programs and delivery of technical and manufacturing data package activities. This technology transfer is planned be completed by the end of 1997. In order for the licensee to be able to manufacture the product in its own facilities, the timing of the activities in the technology transfer must be closely monitored. Namely, the success of the project depends on the timely and successful progress of technology transfer activities.

1.3.2.Hardware Supply Activities

These are activities of the Hardware Supply Agreement signed between the licensee and the licenser company. While the license and know-how transfer continues between the two parties, the procurement of necessary kits and components from the licenser also continues according to the provisions of the Supply Agreement.

In general, they consist of procurement programs of ready made units (RMU), semi-knocked down kits (SKD), partly knocked down kits (PKD) and components. In the early phases of the program, a number of RMUs will be procured from the licenser and will be sold to the customer without giving any additional value to them since necessary technology will not be present in the facilities of the licensee by that time.

In the second phase, a certain amount of equipment will be delivered to the licensee in SKD kit form. Semi-knocked down kits are mainly processed mechanical parts, assembled and tested modules, component set for final-/sub-assembly. SKD kits will be tested, assembled, integrated, final tested in the licensee's facilities. Following these activities is the manufacturing out of SKD phase before selling them to end users. (See figure 1.1.)

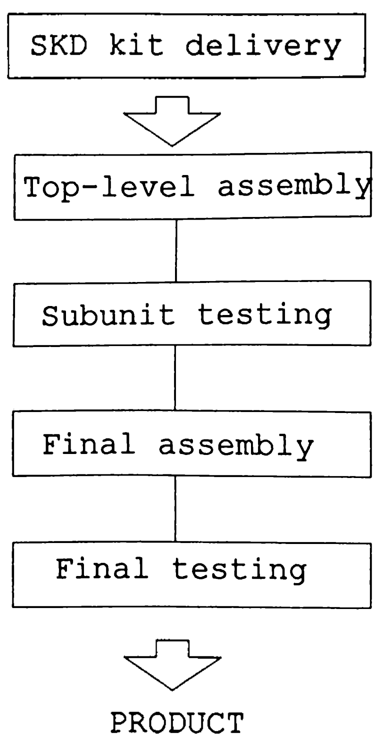

Figure 1.1. Flow chart of SKD phase production

In the third phase, a certain amount of equipment will be delivered to the licensee in PKD kit form. PKD kits are parts of the SKD modules in unassembled form. They are mainly prefabricated parts, component set for modules. Modules are assembled, tested and built into subunits, tested and then final assembled and tested. (See figure 1.2.)

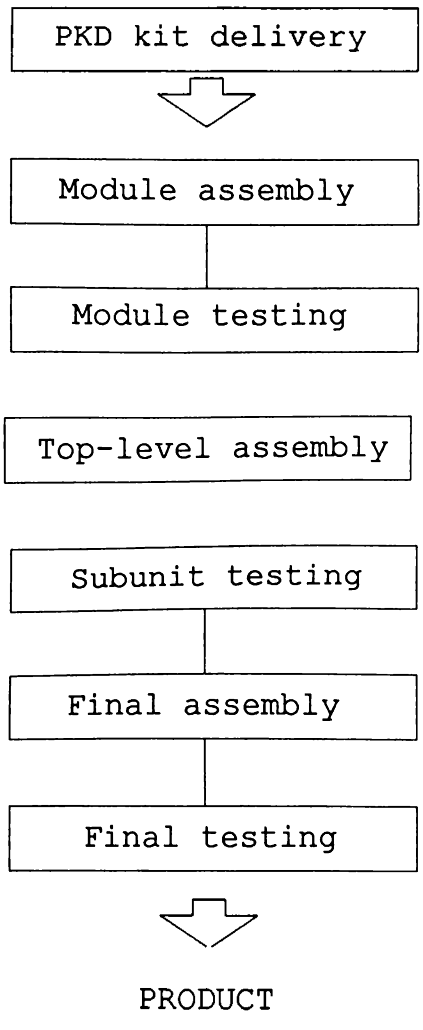

Figure 1.2. Flow chart of PKD phase production

In the last phase of the supply program, some must-buy items will be procured from the licenser and other material will be procured from other vendors. Items delivered in this phase are mainly raw material for prefabricated parts and modules and some component kits.

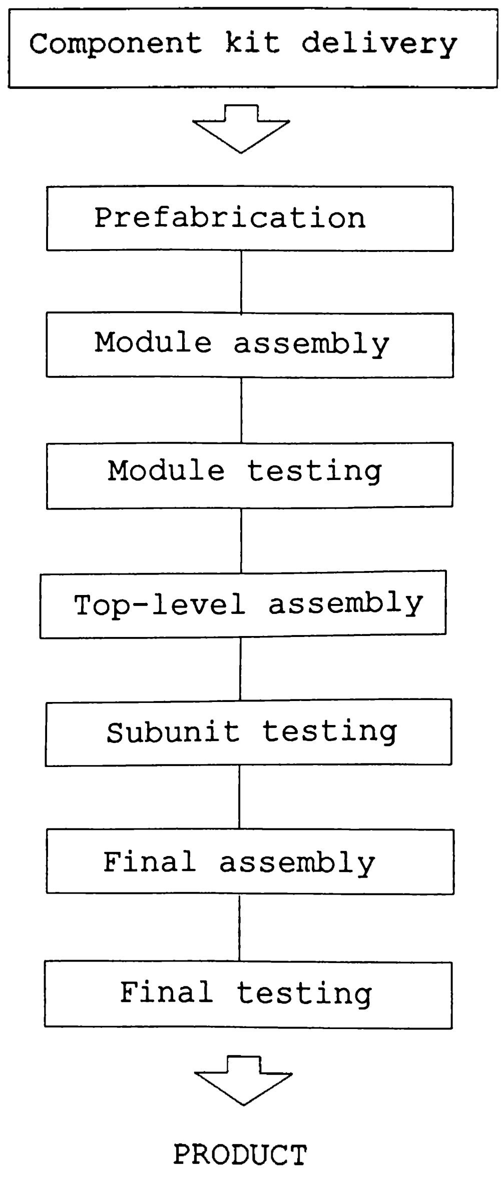

Figure 1.3. Flow Chart of Production from Component

Component kits delivered in this phase are prefabricated and built into modules. Then the same operations as in PKD phase are performed from this stage onwards. (See figure 1.3)

When the term of the agreements expired, the complete purchasing of materials will be done by the licensee. The received material from the suppliers will be tested in the incoming inspection department of the licensee. But the scope of this thesis covers only the activities during the first 3 years of the agreement. However, the success of this independent local production phase depends on the timely and successful transfer of technology satisfying the requirements of the original product.

1.3.3.UTTE Supply Activities

These are the activities of the Unique to Type Test Equipment Agreement. They mainly consist of the procurement of the special equipment which are not components of the product but are specially used in the manufacturing and testing of the product.

1.3.4.Sales Contract Activities with the Customer

These are the activities of the contract signed between the licensee and the customer. They mainly consist of the deliveries of the product in batches beginning in 1992, ending in 1994, and operator training, field level maintenance training and depot level maintenance training programs that will be given to the customer.

1.3.5.Activities inside the company

These are the insider activities that will be performed by the licensee in addition to the other agreement and contract activities. They mainly consist of the procurement of standard equipment, procurement from the other vendors, building SKD production set-up, building PKD production set-up, building local production set-up, building UTTE production set-up and local production phase.

1.4.Purpose of the Thesis

Technology transfer projects, like other projects, consists of a number of activities. But the feature that differentiates technology transfer projects from others is the existence of strict deadlines to be satisfied. Therefore, they necessitate close monitoring. For example, in order to complete the technology transfer project subject to this thesis and to perform the subsequent local manufacturing phase on time and with success, bottlenecks and potential problem areas should be identified before they occur. For this concern CPM is one of the useful and economical methods in scheduling. The purpose of this thesis is to show how CPM using linear programming can be applied to the scheduling of a technology transfer project.

1.5. Outline of the Thesis

In this chapter, first of all, technology transfer concept is explained and then some brief information is given about the particular technology transfer project. Following this chapter, project management concept is explained including its functions. One of these functions which is project scheduling is the subject of the third chapter giving the literature survey on the different scheduling methods such as bar charts, PERT and CPM in a comparative way. In the fourth chapter, network models in scheduling is explained with emphasis on Activity on Arc (AOA) method which is the one used in CPM. These led the discussion in chapter four to finding a critical path by making use of linear programming. In the fifth chapter, the methodology used in the particular application is explained. The critical path for the project is determined and parametric analysis on the schedule is conducted in this chapter. Conclusion and recommendations are given in the sixth chapter.

CHAPTER 2

PROJECT MANAGEMENT

2.1.Historical Background

Although project management has been used in industrial capital projects for more than 50 years, it gained widespread usage in many areas such as construction, banking, manufacturing, marketing, healthcare, sales, transportation, and research and development as well as academic, legal, political and government establishments in the recent 10 years of time due to the successful results obtained in the capital projects field.

Project management applications were initially concentrated on defense-related and construction projects and many of the important developments in project management area occurred during and immediately after the World War II. One of the first publicized successes of the project management was the famous Manhattan project. It started early in the 1940s to develop the atom bomb under the direction of General Leslie Groves who is qualified as the first project manager. (Ritz, 1990)

Following World War II, substantial improvements on the capital projects side are realized both in size and monetary value. This was nothing but a result of the post-war economical boom which is seen all over the world. As a result of the trials to reconstruct Europe and to meet restrained demand because of wartime restrictions, capital project investment spending is increased substantially. Consequently, project management studies accelerated in order to meet the huge demand for new plants.

The 60s was the period which had taken the most of capital project increases of the post-war era especially with the construction of office buildings, airports, power plants, chemical plants, holiday centers and the like. Whereas in the 70s, the economical expansion continued with runaway inflation added to the trend. Also there was a growth in overseas projects of US. (Project Management Institute, 1981)

This era of super- and mega projects faded with the recession of 1981-82 and industrial plant usage declined to 70% from 85%. Nevertheless, the most important advantage gained from this era was that the top management people accepted the need for project management. (Cleland, 1983)

In the 80s, market expansion is observed in high-tech field which includes electronics, foreign autos, foods, biotechnology and the like. Accordingly, the size of capital markets lessened and the subject of them became much more specialized. Hence they necessitated more detailed project scheduling methods and expertised manpower.

The historical background of project managers indicates that the subject of project management is subject to sudden changes. Thus it requires a continuous awareness toward change and sufficient flexibility in order to adapt to the environment on time.

2.2.Overview of Project Management

Project management is the process of managing, allocating, and timing resources in order to achieve a given objective in a expedient manner. The objective may be in terms of time, monetary or technical results. The term project involves several functions within itself such as project planning, project scheduling, resource management and project control.

Project planning is the first step in a systematical project management study. It involves the identification of the work to be done and establishment of a baseline plan. (Kerzner, 1984) During the preparation phase, this baseline plan is subject to many changes until it satisfies the overall objectives of the project. Project planning is performed in three organizational levels consecutively which are strategic planning, operational planning and planning by the line and stuff personnel. (Cleland, 1983) Strategic planning involves the high level selection of the project objectives by the top management or whoever the strategic planners in the company. Operational planning involves the detailed planning required to meet the strategic objectives. Finally planning by the line and stuff personnel puts the operational plan on a time scale by the strategic objectives enabling the execution of the project.

Project scheduling is the establishment of a timetable to do work. It puts all the work activities onto a timeline beginning at the project start date and ending at the completion date. (Ritz, 1990; Levine, 1986) In order to achieve this objective, the schedule should contain not only the list and duration of tasks but also the dependency relationship among tasks.

Experienced project management people favors the top down approach in scheduling. In top down approach first of all the list of major activities in the project is determined. Then these macro activities are broken down into sub macro activities and finally these sub macro activities are split into individual tasks forming the overall project.

Top down approach in scheduling is very advantageous especially when there is a substantial amount of activities in the project because it helps people manage the overall project in a modular way without getting lost in the sea of tasks. Furthermore, it prevents people from missing some details while trying to cope with the whole bunch of activities at the same time.

After the project schedule is created, the sequence of tasks in the project is established taking the planned duration of tasks and their dependency relationships into consideration. Before doing this, it is quite helpful to determine the immediate predecessors and successors of the individual tasks. Following the determination of the immediate predecessor and successor relationships, all these are connected in order to form the overall project schedule.

Upon establishing the project schedule, some milestones are defined on the schedule. Milestones are zero duration tasks showing the beginning or end of some phases in the project schedule. They are powerful indicators of the achievements in the project and help the project management people evaluate the progress or delay of the overall project. (DOD and NASA Guide, 1972)

Resources are the people and equipment needed to get the tasks of the project done. And resource management is the process of assigning and allocating resources to the individual tasks so as to meet the functional requirements of the project objectives. (Badiru, 1989) While doing this, not only currently available resources but also the resources to be procured must be identified. After that, the time-based availability of resources should be specified so that resources could be allocated in a timely manner with no overloads or deficiencies.

Resource management plays a very important role especially in resource-driven projects and should be closely monitored because in such projects the structure and hence the performance of the project is determined by the resources. (Fleming, 1987; Badiru, 1989)

Ensuing the schedule establishment and resource allocation, the costs of the tasks and resources in the project is determined. Unexpected costs, in case of contingency situations, should also be taken into consideration while making the budget of the project.

After all these phases are completed, the project plan is reviewed. After this review, the ideas and approvals of the related personnel is taken. Final stage in project management involves the project control activities.

This chapter has given a summary of project management and its functions in order to reveal where this particular study stands in the overall project management subject. Narrowing down the topic, a literature survey on project scheduling techniques is the subject matter of the next chapter.

CHAPTER 3

LITERATURE SURVEY

3.1.Project Scheduling Techniques

Two basic project scheduling techniques are bar charts and logic-diagram-based schedules. Both methods have their own advantages and disadvantages. Therefore, selecting which technique to use is a very important decision since it also affects the success of the controlling phase of the project.

3.2.Bar Charts

Bar charts first came into use on capital projects in the early twenties. The forerunner to the bar chart was developed by an industrial engineer, Henry L. Gannt for scheduling production/operations during World War II. Therefore, bar chart are the oldest and the simplest of the scheduling techniques.

One of the advantages of the bar charts is their being cheap and simple to prepare, easy to read and update. People with a little schedule training can easily understand their reasoning. However, their main disadvantage is their inability to show enough detail to cover all the activities and their interaction on larger, complex projects. That is the reason why they become unmanageable on projects with as few as 100 activities. (Ritz, 1990)

Furthermore, bar charts cannot show clearly the interaction between early start and late finish dates of activities and the resulting float of non critical activities. Hence, there is no clear identification of the critical path through the project.

3.3.Logic-Diagram-Based Schedules

Although bar charts are simple and effective progress reporting tools, they are weak in planning. This, along with the fact that the size and complexity of the projects grew in the late fifties and sixties obliged project management people add logical relationships to Gannt charts. DuPont Company together with Remington Rand (Univac) developed CPM (Critical Path Method) in 1957-1958 for planning and scheduling of plant maintenance and construction programs where the dominant emphasis was on controlling cost and having schedule flexible. (Ritz, 1990; Project Mangement Institute, 1981)

At about the same type, a very similar method of PERT (Program Evaluation and Review Technique) was invented by the Special Projects Office of the US. Navy in 1957-1958, and developed by Booz, Allen and Hamilton in conjunction with Lockheed Missiles Systems Division on the Polaris Fleet Ballistic Missile Program. (Project Mangement Institute, 1981) The dominant emphasis in this program was on meeting closely determined schedules for internationally strategic reasons and taking a rather flexible view of cost control.

Today, the distinction between PERT and CPM had been disappeared and the two became nearly identical methods with slight variations in network format and activity duration estimation. In the PERT, the duration of an activity is calculated by assessing an optimistic and a pessimistic time and then calculating the average of the two. (Moder,1983) Whereas in CPM, there is only one value for each activity duration and it is the most likely time for the activity duration. Therefore, estimating the activity duration is a very important part in CPM scheduling since it directly affects the critical path and the slack times. This indicates the importance of getting the most sophisticated estimates from the most experienced specialists. Activity duration estimates should neither be all pessimistic nor all optimistic because this would skew the schedule too far one way or to the other.

3.3.1. Advantages/Drawbacks of CPM over Bar Charts

CPM is capable of handling many work activities on complex projects. However, one should not use more activities than necessary just because it is easy to do so. In such a situation, the scheduler might get lost in the details and use the activities in a less efficient way. (Busch,1991) Actually, this was the trap that almost killed CPM in its early years. One way to get rid of this may be to use bar-charts for less complicated areas in the schedule.

Another advantage of CPM is that it establishes an intangible force on the project team to divide the project into all its working parts and form an early analysis of the individual work activities as early as possible. (Moder,1983)

Disadvantages of CPM are a few in number and can be avoided if proper attention is paid to. One of these disadvantages is the necessity of the project people be trained in CPM techniques which is something costly. All the people in the project team should receive at least a basic understanding of CPM. This training includes all project management team including people from various functional departments.

On top of this, CPM generates more data than bar charting. That means unit cost of the data in CPM is low. However, if the data are not used or are being improperly used, then the unit cost of the data is not low any more and the project team is not getting the worth from the particular investment on CPM. (Ritz,1990)

This chapter has given a comparative literature survey on the project scheduling techniques. Next chapter further narrows down the topic to give activity relationships in scheduling. It also introduces how LP can be relevant in a project scheduling study in finding the critical path and performing parametric analysis.

CHAPTER 4

NETWORK MODELS IN SCHEDULING

4.1.Critical Path Identification

Identifying the critical path of a project is actually nothing but an optimization problem because the aim here is to minimize the time project takes to finish. Most of the optimization problems can best be analyzed by making use of a network representation. Among these network models are shortest route problems, maximum flow problems, minimum spanning tree problems, CPM-PERT project scheduling models.

If the duration of each activity is known with certainty, CPM can be used to determine the length of time required to complete a project. CPM can also be used to determine how long each activity in the project can be delayed without delaying the completion of the project. If the duration of the activities is not known with certainty, PERT can be used to estimate the probability that the project will be completed by a given deadline. (Winston,1991)

As the goal in this thesis is to identify the critical path in a project, CPM-PERT project scheduling methods can be used. Furthermore, as the duration of the activities in this particular project can be estimated quite certainly, CPM is chosen as the more appropriate method to utilize in scheduling the project activities.

Before discussing the CPM project scheduling, some basic terms used in describing network models will be explained.

4.2.Basic Definitions

Activity : A project operation or process that requires resources and consumes some amount of time to complete.

Critical Path : The sequence of activities which determines the total completion time for the project.

Dummy Activity : A logical link or a constraint representing no specific operation. It is an activity which absorbs neither time nor resources.

Duration : The estimated or actual time required to complete an activity.

Event : The completion of an activity, or a series of activities at a particular point in time.

Finish-to-start (F-S) : The condition that the start of an activity depends on the finish of its predecessors.

Finish-to-finish (F-F) : The condition that the finish of an activity depends on the finish of its predecessors.

Float : A time available for an activity or path in addition to its duration. It is the difference between the time necessary and the time available for an activity.

Network : The set of all project activities graphically interrelated through the precedence relationships.

Path : A series of connected activities between two events.

Predecessor : A set of activities that must be completed before an activity begins.

Successor : A set of activities which can only begin after an activity ends.

Start-to-start (S-S) : The condition that the start of an activity depends on the start of its predecessors.

4.3. CPM Scheduling

After identifying the list of activities that make up the project and their duration, it is time to begin scheduling part of the baseline plan by establishing activity relationships. Precedence diagrams and precedence matrix are two of the methods used to show these relationships. The activity relationship method affects the schedule times to a great extent. Hence, choosing which activity relationship method to use in scheduling is an important decision.

4.3.1. Activity Relationship Methods

There are three basic activity relationship methods which are AOA (activity on arc), AON (activity on node) and the precedence method. CPM makes use of AOA method in scheduling. Since the objective of this thesis is to utilize CPM in project scheduling, AOA method will be discussed in more detail.

4.3.1.1. AOA Method

In the AOA, activities are represented by directed arcs, and nodes are used to depict the completion of a set of activities. In the arrow process, every activity has a start event and an end event. The events are numbered sequentially and the activity is identified by the beginning and ending event numbers. These numbers are designated as the i-j number. (Lockyear,1984) With these definitions, a single activity in AOA is as in figure 4.1.

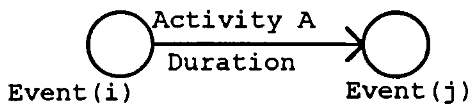

Figure 4.1. Single activity in AOA format

Each activity has an elapsed time necessary to accomplish the work involved. The estimated elapsed time for the activity must consider the scope of the activity and any historical data available from previous similar activities. If there are no historical data on the activity to estimate the activity duration, then scheduling is done by using the estimates of the people experienced in performing the activity.

In the AOA format any activity may either precede, succeed, or be performed concurrently with any other activity. A more complex situation depicted in figure 4.2. specifies that A and B are prerequisites for activity D, but that only A is required to start activity C. A dummy activity is drawn between event 3 and event 4 to establish the specified logic constraints.

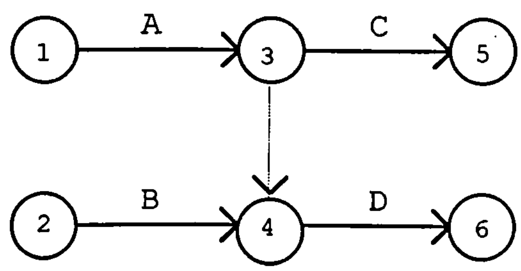

Figure 4.2. Activities with a Dummy Constraint

In figure 4.2. there are four real activities, indicated as 1-3, 2-4, 3-5, and 4-6, plus one dummy activity, designated 3-4. A, B, C, and D are just activity descriptions. Dummy activities are usually indicated by a dotted line on the precedence diagram.

The following rules apply to the construction of a project network or precedence diagram in AOA format :

1. Node 1 represents the start of the project. An arc should lead from node 1 to represent each activity that has no predecessors.

2. A node representing the completion of the project should be included in the network.

3. Number the nodes in the network so that the node representing the completion of an activity has a larger number than the node representing the beginning

of an activity.

4. An activity should not be represented by more than one arc in the network.

5. Two nodes can be connected by at most one arc. (Winston, 1991)

Another use of dummy activities is to avoid the violation of rules 4 and 5. For example, suppose that activities A and B are both predecessors of activity C and can begin at the same time. In the absence of rule 5, activity representation could be as in figure 4.3. However, since nodes 1 and 2 are connected by more than one arc, figure 4.3. violates rule 5.

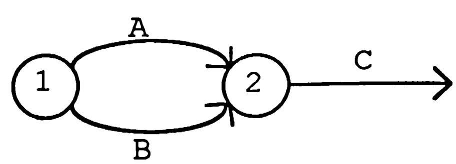

Figure 4.3. Violation of Rule 5

By using a dummy activity as in figure 4.4., A and B both can be represented as the predecessors of C. Figure 4.4. guarantees that activity C cannot begin until both activities A and B are completed without violating rule 5.

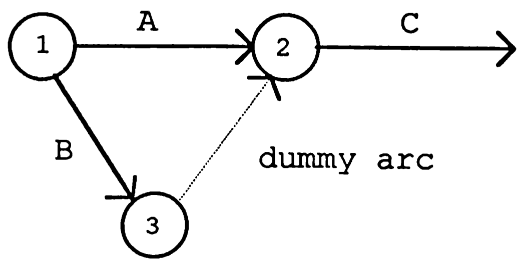

Figure 4.4. Use of Dummy Activity

4.3.1.2.AON Method

In AON method the nodes of the network are used to represent the activities. This method is widely preferred in the recently developed project management programs prepared for microcomputers. (Levine, 1986)

Having activities represented in the nodes in AON format eliminates the need to use dummy activities for unique relationships. Figure 4.5. illustrates the same relationships that were shown in figure 4.2., but this time in AON format without any dummy activities.

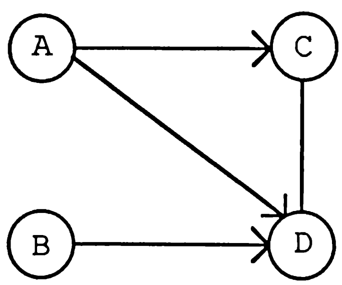

Figure 4.5. AON format

4.3.1.3. The Precedence Method

The Precedence method is more complex than the AOA and AON methods. Nevertheless, it permits a more precise description of activity relationships in that it supports two additional types of relationships in addition to the traditional finish-to-start (F-S) relationships. These are start-to-start (S-S) and finish-to-finish (F-F). (Bennett, 1977) Besides this, the precedence method adds an element called " lag ", which is the time duration for the relationship itself. (Moder, 1983) Lag is used either to indicate a delay between the finish of one activity and the start of another, or the delay between two starts or two finishes.

In the precedence diagram shown in figure 4.6., the start of task B is delayed for two weeks after task A is completed. Task C can start after task A is completed, but must be completed one week before task B can be finished. Task D can start one week after task C starts and must be completed before task B is done.

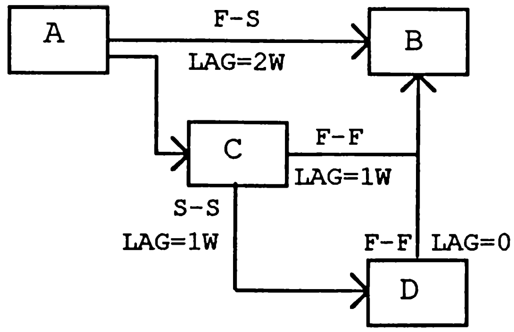

Figure 4.6. PDM Format

4.4. Finding a Critical Path

Now that the list of activities making up the project is identified and AOA is chosen as the activity relationship method as a requirement of CPM, it is time to establish the project schedule and find the critical path.

4.4.1. Critical Path Identification with LP

One of the ways of determining the length of the critical path in a project is by making use of linear programming. Linear programming (LP) is a mathematical decision-making procedure for determining optimal allocation of resources. It has found practical application in many areas of business.

In all LP problems the maximization or minimization of some quantity is the objective and there are also some restrictions or constraints that limit the degree to which the objective can be pursued. For most of the LP problems, there are two important types of objects. The first type is limited resources which can be time, money or labor and the second type is set of activities. Each activity consumes some amount or contributes additional amounts of resources. The problem in LP formulation is to determine the best combination of activity levels and which does not use more resources than actually available. (Schrage, 1991)

The problem to be solved is defined as the objective function, z in LP formulation and it can be either a minimization or a maximization situation as explained above. The objective function is defined using variables which are called decision variables. These variables are all restricted to nonnegative values. The activities consuming resources and the scarcity of the resources are given as the constraints.

The solutions that satisfy all the constraints are referred to as feasible solutions and the best one among the feasible solutions is the optimal solution. The standard format of LP formulation is as follows :

Min (or Max) z = objective function

subject to (s.t.)

constraint_1

$constraint_2$

$constraint_n$

all variables are nonnegative

LP applies only to situations in which the effects of the different activities which are engaged in are linear. Linearity requirements are as follows :

1. Proportionality : Contribution of each variable in the objective function or its usage of resources are directly proportional to the level of the activity.

2. Additivity : There should be no cross-product terms in the formulation.

3. Certainty : All the parameters are known constants.

4. Activity units can be divided into any fractional levels. (Schrage ,1991 ; Winston , 1991)

4.4.2. Applying Linear Programming to the Schedule

While applying linear programming, first of all, a variable called x_j is defined where x_j is the time that the event corresponding to node j occurs. For each activity (i,j), we know that before node j occurs, node i must occur and activity (i,j) must be completed. This implies that for each arc (i,j) in the project network ,

$x_j >= x_i + t_{ij}$ where t_{ij} is the duration of activity (i,j).

Above relationships are defined for each activity and these constitute the constraints in the linear programming model. Since the goal is to minimize the time required to complete the project, the objective function in this linear programming model would be as follows :

$z = x_f - x_1$ where x_f is node that represents the completion of the project.

Hence the complete linear programming model would be in the following form :

Min $z = x_f - x_1$

st

$x_j >= x_i + t_{ij}$

for i=1 to n, j=1 to n & i not equal to j

where n = number of events(nodes)

All variables integer

After including all of the project activity relationship constraints and the objective function into the linear programming model, it is time to solve the LP model to find the critical path. The process of finding the critical path requires a large number of calculations for projects with hundreds of activities. Therefore, instead of manual calculation the model is run on a computer using a linear programming software. In this thesis, LINDO is utilized as the linear programming software package. (See Appendix A)

After the model is executed on a computer, the results of the model are used to determine the critical path. Dual prices column of constraints is examined to find the critical path. The critical path for a project network consists of a path from the start of the project to the finish in which each arc in the path corresponds to a constraint with a dual price of -1. As explained in Appendix A, for each constraint with a dual price of -1, increasing the duration of the activity corresponding to that constraint by X days will increase the duration of the project by X days. Decreasing the activity duration will do the reverse effect as long as the activity remains critical.

4.4.3.Matrix Generators

Many linear programming models contain thousands of decision variables. In such large LPs, it is impractical to manually enter all the coefficients and constraints of the LP. Instead of manual entering, it is very useful to write an auxiliary computer program called a matrix generator to simplify the inputting of the LP. This program reads the problem description in an arbitrary format from either a file or from the terminal and then generates the corresponding LP formulation depending on the given information. There are two approaches in writing a matrix generator program :

a. to use a general purpose programming language such as FORTRAN, PASCAL or C.

b. to use a special purpose language designed for generating LP formulations. These special purpose languages are frequently available from vendors of LP optimization packages.

4.5.Parametric Analysis

After determining the critical path depending upon the solution of the LINDO formulation, performing parametric analysis may be quite helpful during the planning stage since it helps visualize the situation when assumptions upon which the model is based, is changed. Parametric analysis or parametric programming is the term applied to tracing out how the solution changes as a specific coefficient (the parameter) changes over a wide range.(Schrage, 1991) Most of the LP computer packages have special commands for performing this analysis. In LINDO, PARA command is used for parametric analysis.(See Appendix A)

4.5.1. Types of Parametric Analysis

There may be two kinds of parametric changes in an LP formulation : change in objective function parametrics and change in right-hand side parametrics. These two parametric changes allow three different perspectives from which one might wish to view the effects of a parametric change :

1. How does the objective function change ?

2. How does the optimal value and reduced cost of a specific decision variable change as the parameter changes ?

3. How does the dual price and slack of a specific constraint change as the parameter changes ? (Schrage, 1991)

This chapter has introduced activity relationship methods, and then explained LP formulation methodology to find the critical path and perform parametric analysis. Next chapter is the application of the discussion conducted in this chapter to the technology transfer project subject to this thesis.

CHAPTER 5

APPLICATION OF CPM TO THE TECHNOLOGY TRANSFER PROJECT

5.1. Identifying Activities/Estimating Their Duration

Different methods are used to identify the project activities and to estimate their duration in this project. There are mainly three types of activities in the project. First type is the delivery activities by the licenser company or by other vendors. Among them are license and know-how transfer documentation packages and hardware deliveries. The duration estimations of such deliveries are based on the information given by the licenser company and are bounded by the related contracts made between the two parties.

The second types of activities are the manufacturing and assembly activities of the delivered items. Since the local production will be performed for the first-time, the duration of this class of activities are based on the experience of the licenser company engineers. Thereafter, these estimations are revised by the licensee company engineers taking special situations into consideration. Such revisions on the manufacturing duration are made during project management meetings conducted in both licenser and licensee's facilities.

The third type of activities is the delivery of the finished products to the end customer by the licensee during the lifetime of the project. The duration of such activities are estimated by the licensee company regarding the current capabilities of the company. These are also bounded by the contract.

As a result of these efforts, the first 3 years of the total project is broken down to 186 individual activities. Each of these activities represents a task to be accomplished and was identified by an activity name.

After determining the activities and their duration, identification of the immediate predecessor(s) and successor(s) of each activity and the whole precedence relationships of the project should be done. These relationships are determined using the same methods as used in estimating the activities and their duration, i.e. using a combination of know-how received from the licenser company and the experience of the licensee company.

In order to determine immediate predecessor and successor activities, the following questions were answered for each activity :

-Which activities should be completed in order to start the activity?

-Which activities can be done in parallel to the activity?

-Which activities cannot start before the particular activity is finished?

According to the answers given to these three questions, precedence list including the detailed predecessor and successor activities for 186 individual activities in the project schedule is shown in Appendix C. The activity duration information is also included in the list. Additional to these 186 activities, there are 23 dummy activities and that makes a total of 209 activity relationships.

5.2.Preparing the Schedule

After determining activities, their estimated duration and the precedence relationships among them, the schedule in LP format can be prepared. To do this, first of all, activities should be numbered. In numbering the activities, rules for constructing an AOA project diagram which were explained in section

4.3.1.1. of this study, were taken into consideration. Besides this, since schedule preparation requires repetitive passes on the tentative schedule, gaps should be left in the sequence of activity numbering in order to allow later insertion of activities.

Then these precedence relationships were converted into LP formulation constraints. 186 constraints are formed for the individual activities and 23 constraints were established for the dummy activities. And the objective function is formulated so as to minimize the total project time as explained in the previous chapter.

Since there is a total of 209 logical relationships in the formulation, manual entering is inefficient. Besides, performing some changes in the formulation necessitates too much effort in the LINDO environment. These two reasons led to the result of using a matrix generator for inputting LP formulations. C which is a general purpose programming language is preferred to write the matrix generator. The reason why a general purpose programming language is used is that LINDO formulation in this thesis is too large to execute on a PC, and therefore is executed on SUN computers of Bilkent University that uses UNIX operating system environment. And a special purpose software package designed for generating LP formulation in UNIX environment was not available. Therefore, a simple C program was written to input the objective function and the constraints of the LP formulation. (See Appendix B)

The times when the activities occur and when the project is completed was attained from the solution of the LINDO formulation. The times when activities start was found by looking at the values of the variables representing the begin node of the activities. In the same way, the times when activities finish was found by looking at the variables representing the end node of the activities. (See Appendix D) In this manner, the schedule was prepared.

5.3. Identifying the Critical Path Activities

In this stage, critical path activities were determined by making use of the solution of the LINDO formulation. The critical path consists of the activities which are represented by constraints with a dual price of -1. (See Appendix D) This means that lengthening the duration of such activities will lengthen the total project duration accordingly. And shortening the duration of critical activities will shorten the total project time in the same amount as long as they remain on the critical path.

As a result of these efforts twenty-two activities which constitute the critical path were determined which are respectively "Issuing Letter of Credit for UTTE", "Notification of UTTE Delivery for SKD Production", "Acceptance Tests of UTTE Delivery for SKD Production", "Sign of Acceptance/Rejection of UTTE Delivery for SKD Production", "Delivery of UTTE for SKD Production", "SKD Set-up", "2nd Batch SKD Delivery", "3rd Batch SKD Delivery", "4th Batch SKD Delivery", "5th Batch SKD Delivery", "PKD Delivery", "Delivery of Electrical and Mechanical Parts-I", "Delivery of Electrical and Mechanical Parts-II", "Manufacturing of Electrical and Mechanical Parts-II", "Module and Printed Board Assembly/Test Phase", "Unit Assembly/Test Phase-VI", "Final Assembly-VI", "Final Assembly-VII", "Final Assembly-VIII", "Final Assembly/Test-IX", "Customer Acceptance Tests for the ´94 4th Batch Delivery", "´94 4th Batch Delivery".

Since the critical path activities determine the total project time, any delays in one of them will delay the completion time of the project. Therefore, special attention should be paid to monitoring the critical path activities.

5.4.Applying Parametric Analysis to the Activities

After the determination of the critical path activities of the particular project using LINDO solution, parametric analysis was performed on the results of this solution. The type of the parametric change applied is the change of the right-hand side of the constraints related with non critical activities. The aim here is to see the effects of a change in the duration of a non critical activity on the whole project schedule and to settle when these activities enter into the critical path.

With this idea in mind, right-hand sides of the non critical activity constraints were increased, one at a time, from their current value to a maximum number which depends on the original duration of the activities. (See Appendix E) While giving a new value for the right-hand side, the results of the sensitivity analysis conducted after finding the optimal solution, are used. (See Appendix D) Namely, the values of the right-hand side are increased beyond their allowable increases calculated in right-hand side ranges of the sensitivity analysis. Very large amount of increases may seem irrational at the first glance. But the idea is to see the exact time when a non critical activity becomes critical. Among these changes, the realistic ones will be given more attention during the execution phase of the project to take preemptive action for contingency situations beforehand.

As a result of these efforts in parametric analysis, the non critical activities represented by constraints with a float of less than three days were diagnosed as potential critical path activities.

5.5. Discussion and Evaluation of the Implementation

Application has been developed based on the methodology described in Chapter 4 of this study. All of the preset objectives defined in this section have been actualized in that critical path activities are identified and parametric analysis is applied to the right-hand sides of the formulation constraints. It is realized that first part of the critical path are SKD production related activities which is the first type of production to be performed in the licensee's facilities. Other type of critical activities are the delivery of the manufacturing material from the licenser. Lastly, there are also some critical activities related with the manufacturing from component level phase in the licensee's facilities.

After determining the critical path activities, parametric analysis is applied to the non critical activities. By decreasing their duration, the times when the non critical activities become critical were determined in the parametric analysis part. In this way the extent to which these critical activities have float times was observed from the results of the parametric analysis to take measures accordingly. (See Appendix E) The float time of a non critical activity is the difference between the right-hand side value of the related constraint when the activity just becomes critical and the original value of the right-hand side.

The only problematic situation in this study had been the time-consuming feature of performing parametric analysis. Since the optimal solution should be found by executing ´GO´ command prior to each execution of the ´PARA´ command, making a parametric analysis for all the project activities necessitates patience and time. But the advantages of performing a parametric analysis in taking preemptive action for contingency situations compensates this drawback a lot.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1.Conclusion

In this thesis, CPM is applied to a technology transfer project. The project was broken down to 186 individual activities and 23 dummy activities. An LP constraint is formulated for each relationship and objective function is defined so as to minimize the total time project takes to finish. A matrix generator program is written to input the objective function and the constraints. Then the LINDO formulation is executed to develop the solution and determine the critical path activities accordingly. Critical activities determine the total time project takes to finish. They constitute the longest path in the project which indicates the expected completion time for the project. While activities forming the critical path have all zero floats, non critical activities have positive float, i.e. a flexibility in their starting dates. Therefore, critical activities determined from the LINDO solution should be closely monitored since they affect the timely execution of the project to a great extent. But that is not sufficient for a comprehensive scheduling study. Namely, not only the critical activities but also the non critical activities must be in the scope of the project control and monitoring. Although these activities do not determine the critical path, lack of progressing in these activities beyond their floats may turn them into critical activities.

Hence, in addition to determining the critical path activities, parametric analysis is applied to right-hand side of the constraints related with non critical activities in the LINDO formulation to be alert for critical activity candidates. Right-hand side of the non critical activities are increased to observe when they become critical, i.e. when they run out of float times. The float of all the non critical activities can be seen from the parametric analysis results in Appendix E. It is the difference between the right-hand side of the related constraint when the activity just enters the critical path and the original right-hand side value. Activities with positive float time can be delayed according to their float times.

In this study, time was the major constraint when compared to other resources like money or labor since penalty should be paid to the end customer for each day of delay in deliveries.

Critical path identification using LINDO software necessitates more theoretical knowledge when compared with most of the traditional project management packages. However, the significance of this study lies in the fact that it is developed with the aim to make both the theoretical and practical world benefit from the study. Therefore, necessary information about LINDO package is given in the appendices part which may be skipped if the user is already literate on the subject. This thesis is developed in a way to make the study comprehensive and clear for the prospective users irrespective of their background whether they are from engineering or management disciplines.

This study offers the following advantages to the real life project management group :

- It is a realistic application in that LINDO formulation of the schedule is developed by using actual estimations. Therefore, the results found in the LINDO solution about the completion date computations are realistic and can be utilized in the practical world as an alternative to the traditional project management software packages.

- Although this study is utilized in the planning phase of a project, it can also be used in the implementation phase by entering the actual activity duration for the completed activities and by correcting the scheduled duration for the progressing activities.

- The potential problem situations can be foreseen from the results of the parametric analysis.

- If the project management group wants to carry the completion time of the project developed in the LINDO solution to an earlier date in the planning / contractual phase, then some resource transfer can be realized from the non critical activities to the critical ones according to the type of the resource (time, money or labor) used by the particular activity.

- The scheme above can be utilized not only in the planning but also in the execution phase in possible delay situations. If a delay in a critical activity results in delaying the whole project, this can be corrected by transferring some resources from non critical activities to the critical ones.

- In this study, all the LINDO formulation constraints are related with time because of the existence of the strict delivery times to be met. However, it is also possible to add budget constraints to the formulation in addition to the time constraints during later phases of the project whenever necessary.

- Extra resource constraints can also be added to the formulation if necessary.

- All these expansion opportunities in the developed schedule guarantees that the schedule is not a one-time study, i.e. a snapshot of the critical path at a definite time. On the contrary, it is flexible in that it is suitable to apply any kind of change whether it be a change in the activity duration or addition / deleting of constraints to the schedule. Besides this, using a matrix generator enables this change process to be easy and quick.

- Furthermore, current formulation can be manipulated so as to make a crashing by adding extra resources to the project activities if the time required to complete the project exceeds the time available. In such a situation, the activities on the critical path can be analyzed to determine whether their times can be reduced or whether some of the activities can be performed concurrently.

LINDO formulation can handle this situation by defining a new objective function to minimize the cost of crashing and with the addition of new constraints indicating the range of crashing for each activity as illustrated in the formulation below.

The cost per day of reducing the duration of an activity, x_{ij} is given as follows :

Event	x_{12}	x_{13}	x_{35}	...	x_{1n}
Cost	10	20	3	...	40

Let us define :

d_{12} = number of days by which duration of activity x_{12} is reduced

d_{1n} = number of days by which duration of activity x_{1n} is reduced

Then the new formulation can be in the following form :

$$\text{Min } z = 10\, d_{12} + 20\, d_{13} + 3\, d_{35} + 40\, d_{1n}$$

st

$$x_2 >= x_1 + t_{12} - d_{12}$$

$$x_3 >= x_1 + t_{13} - d_{13}$$

$$x_5 >= x_3 + t_{35} - d_{35}$$

$$x_n >= x_1 + t_{1n} - d_{1n}$$

All variables integer

Furthermore, if there is a limited time, say D in which the project should be completed, then this fact might also be added to the formulation as an extra constraint as shown in the following equality :

$$x_{end\ node} - x_{begin\ node} <= D$$

When the time required by the critical path is shortened to less than that of a path with non critical activities, then that path becomes critical. In this occasion, the activities of the new critical path can in turn be analyzed to determine how that path can be shortened. This process continues until a schedule is developed to complete the project by the desired or directed date.

- The schedule also provides a solid framework for communication between the people from different functional departments in the project group including engineering, production, procurement and etc. One difficulty to cope with here is the necessity of making a brief training on the logic of critical path method which is given as a summary in the fourth chapter of this thesis. In this occasion, there may be the question whether the motivation to learn the critical path logic will be there or not. However, it would be the responsibility of the project manager and his/her colleagues to create the motivation if it does not exist.

Finally, this study also constitutes an alternative to the traditional project management packages. When CPM using LINDO package is compared with CPM using traditional project management packages, it is observed that traditional packages have a more widespread usage.

One reason for this is that CPM using linear programming is a mathematical model which consists of some numbers. And these numbers are meaningful only when the user knows the CPM logic so that he/she is able to make comments on them. Otherwise, the model is nothing but a bunch of numbers without an apparent meaning about the activities constituting the critical path. One solution that might help here is to use graphic programs and visual aids to support the LINDO solution. These may help people in the project group from different departments visualize the critical path more clearly. Besides, some supplementary programs can also be written providing logistic support to LINDO. The matrix generator in this thesis is a simple example for this kind of supplementary programs.

Another reason why traditional project management packages are more popular when compared with LINDO is that they are more user friendly. A person who does not know the CPM logic can learn and use them easily. However, their danger also lies in that point. They calculate the critical path depending upon the user inputs regarding the activities and relationships among them. But if the user is completely illiterate about CPM logic, then he/she may come up with a wrong critical path calculated by the program. Therefore, although these programs have a reputation of being very easy-to-use for the new beginners, they may calculate an incomplete or even wrong critical path as a result of inadequate user inputs.

From these points, this study gives a reason why people should make use of linear programming (particularly the LINDO package) in critical path identification or should not when compared with the other project management programs. In short, critical path method by using linear programming obligates the knowledge of the CPM logic but it guarantees the correctness of the critical path. However, the user friendly traditional project management packages require not much literacy in CPM logic, nevertheless they can not ensure the accuracy of the calculated critical path due to incompetent users. Therefore, which one to use is very much dependent on the particular situation.

6.2.Suggestions for Further Research

In this thesis, the outcomes of changing only one right-hand side coefficient at a time had been observed. Namely, the effects of changing only one of the activity duration, on the critical path of the whole project was investigated. One further study related with this thesis might be to examine the effects of simultaneously varying several right-hand side coefficients at a time to observe the consequence of changes in more than one activity duration.

But the crucial feature of parametric analysis is the ability to vary a single coefficient. One way to get rid off this restraint can be to introduce a new variable into the constraints whose right-hand side coefficients are to be changed and then define a new constraint for this variable as shown below.

Original Formulation

Min $z = x_{1390} - x_{10}$

st

$- x_{10} + x_{20} >= 5$

$- x_{10} + x_{30} >= 30$

$x_{30} + x_{100} >= 0$

$- x_{10} + x_{35} >= 30$

and etc.

Modified Formulation Which Allows Simultaneous Change in Right-hand Side of the Constraints

Min $z = x_{1390} - x_{10}$

st

$- x_{10} + x_{20} + 2y >= 5$

$- x_{10} + x_{30} + y >= 30$

$- x_{30} + x_{100} + 0y >= 0$

$- x_{10} + x_{35} + 5y >= 30$

and etc.

$y = f$

Where f is the parameter to be varied.

Therefore, the problem would be reduced to analyzing the effects of changing a single right-hand side coefficient which is equal to the new variable.

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APPENDIX A

LINDO COMPUTER PACKAGE

A.1.Introduction

LINDO (Linear, INteractive, Discrete Optimizer) is a software package available both for mainframes and PCs to solve linear, integer and quadratic programming problems. The main purpose of LINDO is to allow a user to input an LP formulation; solve it; assess the correctness or appropriateness of the formulation based on the solution and then if necessary, make modifications to the formulation and repeat the process.

LINDO is an interactive and command-oriented program. Therefore, it asks the user what is to be done next, and waits for the response of the user. There is a wide range of commands for the user to choose and then LINDO checks whether a particular command makes sense in a particular situation. The following is a step-by-step execution of LINDO program.

1. The user command "LINDO" when typed at user prompt, causes the LINDO program to be loaded from the floppy disk, or hard disk of the computer or from a network.

2. LINDO starts by sending the symbol "?" to indicate that it is waiting for an instruction from the user.

3. The user types the objective function as it appears in the mathematical statement of the problem.

4. Then LINDO sends the symbol "?" to show that it is waiting for additional input for the LP problem.

5. The user input "ST" stands for "subject to" notifying the program that information about constraints is to follow.

6. After inputting each of the constraints with the symbol < or >, which is interpreted as less than or equal to and greater than or equal to by LINDO, the user inputs "END" to signal that the date input is complete.

7. LINDO again responds with ":" to indicate that it is waiting for an instruction.

8. The user inputs the optional instruction "LOOK ALL" which results in the computer printing the LP formulation that LINDO is ready to solve.

"LOOK ALL" is not a required instruction, but using it provides an easy check on the accuracy of the input data. (Anderson,1988)

In the computer package the objective function is identified as row 1. Then comes the "SUBJECT TO" heading. This row is followed by the constraints identified as row 2, row 3 and etc. LINDO package proceeds to develop the solution of the problem when given the command "GO".

A.2.Interpretation of LINDO Computer Output

In the LINDO output shown in figure, the number under the "OBJECTIVE FUNCTION COEFFICIENT VALUE" heading shows the solution of LP problem.

The information in the column labeled "REDUCED COST" indicates how much the objective function coefficient of each decision variable would have to improve before it would be possible for that variable to assume a positive value in the solution. Improvement here is defined as getting bigger in a max problem and getting smaller in a minimization problem. Therefore, if a decision variable is already positive in the optimal solution, its reduced cost is zero.

The column labeled "DUAL PRICES" contains information about the improvement in the optimal value of the objective function resulting from a one-unit increase in the right hand side value for the constraint. Negative dual price tells us that the objective function will not improve if the value of the right hand side is increased by one unit. Hence, if the dual price is negative, reducing the right hand side of the constraint should be tried to improve the objective function value. The dual price for a <=

constraint is always greater than or equal to 0 because increasing the righthand side cannot make the value of the objective function worse. With the same reasoning, the dual price for a >= constraint is always less than or equal to 0 since increasing the righthand side cannot improve the value of the objective function.

A.3.Sensitivity Analysis

After finding the the optimal solution to the original linear programming problem, LINDO program can also conduct sentivity analysis. Because of this, sensitivity analysis is often referred to as postoptimality analysis.

In the first part of sensitivity analysis, LINDO output shows the ALLOWABLE INCREASE AND ALLOWABLE DECREASE for the objective function coefficients. From this data, range of optimality can be calculated by adding the allowable increase and subtracting allowable decrease. It is the range of values over which an objective function coefficient may vary without causing any change in the values of the decision variables in the optimal solution.

In the second part, LINDO output shows ALLOWABLE INCREASE and ALLOWABLE DECREASE for the right hand side ranges. From here range of feasibility can be calculated by adding allowable increase and subtracting allowable decrease from the current righthand side values. Range of feasibility is defined as the range of values over which a righthand side value may vary without changing the value and interpretation of the dual price.

A.4.Parametric Analysis

The command 'PARA' is executed to perform parametric analysis. Upon execution, LINDO asks for which row the RHS is to be changed. After the row number is typed, LINDO asks for the new RHS value. This is inputted by the user. Then LINDO presents if there occurs a basis change or not, if so, which variable is entering into basis and which variable is departing from the basis and the pivot row. It also shows new RHS, dual price, dual price before pivot, objective function value. One important point about parametric analysis the necessity of finding the optimal solution each time a parametric analysis is conducted. Namely, 'GO' command should be executed prior to execution of 'PARA' command.

APPENDIX B

MATRIX GENERATOR PROGRAM FOR LINDO FORMULATION

```
# include   <stdio.h>

# define          MAX_FILE_NAME           500

main( )
{

     int   x,  y,  z ;
     FILE  *fpi , *fpo , *fopen() ;
     char finame (MAX_FILE_NAME)   ,  foname (MAX_FILE_NAME) ;


     printf("Enter file name for input : ");
     scanf("%s",finame);

     if  (fpi = fopen(finame,"r")) == NULL  )
     {
          printf("Could not find the file \n");
          exit( 1 );
     }

     printf("Enter file name for output : ");
     scanf("%s",foname);

     if  (fpo = fopen(finame,"w")) == NULL  )
     {
          printf("Could not open the file \n");
          exit( 1 );
     }

     fscanf(fpi,"%d %d",&x,&y);
     fprintf(fpo,"MIN -X%d + X%d\n",x,y);
     fprintf(fpo,"st\n");

     while ( fscanf(fpi,"%d %d %d",&x,&y,&z) !=EOF )
     {
          fprintf(fpo,"- X%d + X%d >= %d\n",x,y,z);
     }

     fprintf(fpo,"END\n");

     fclose(fpi);
     fcose(fpo);
}
```

The Execution of the Matrix Generator

The generator program asks for a data file to take inputs. The data file was created by using an editor. For this application, VI editor is used. The first line of the data file contains the subscript numbers of the activities in the objective function. The following lines contain the subscript numbers and duration information for the activity constraints. These numbers should be separated by one or more space characters. After entering this information about the objective function and the constraints, each on a separate line, the creation of the data file is complete.

The generator program is executed by typing "Lin". Upon execution, the generator asks for the name of the input file from the terminal. After this is entered, the program asks for the name of the output file to write the LINDO formulation.

At this stage, the mission of the generator program is over and the LINDO formulation is ready in the prepared output file. When entered the command "LINDO", the formulation can be reached typing "Take <filename>" command.

APPENDIX C

ACTIVITY LIST

The following is a detailed list of activities in the LINDO formulation excluding the dummy relationships. For each activity, the related LINDO constraint number activity name, duration in days, start and finish node numbers in the formulation predecessor and successor activity information is given.

Constraint No/Task Name **Duration**
2.Notification of the delivery of the 1st batch RMUs 5
Start Node **Finish Node**
10 20
Predecessors
none
Successors
Acceptance tests of the 1st batch RMUs

Constraint No/Task Name **Duration**
3.Issuing letter of credit for the 1st batch RMUs 30
Start Node Finish Node
10 30
Predecessors
none
Successors
Delivery of the 1st batch RMUs

Constraint No/Task Name **Duration**
5.Issuing performance bond for the UTTE 30
Start Node **Finish Node**
10 35
Predecessors
none
Successors
Notification of the delivery of UTTE to be used in SKD production

---

Constraint No/Task Name **Duration**
7.Issuing letter of credit for UTTE 30
Start Node **Finish Node**
10 40
Predecessors
none
Successors
Notification of the delivery of UTKE to be used in SKD production

---

Constraint No/Task Name **Duration**
8.Issuing performance bond for the RMUs 30
Start Node **Finish Node**
10 50
Predecessors
none
Successors
Notification of the delivery of the 2nd batch RMUs

Constraint No/Task Name **Duration**
10.Sending proforma invoice for SKD and PKD 10
Start Node **Finish Node**

10	60
Predecessors	
none	
Successors	
Issuance of letter of credit for SKD and PKD kits	

Constraint No/Task Name	**Duration**
11.In-house preparation to the trainings	14
Start Node	**Finish Node**
10	70
Predecessors	
none	
Successors	
General information on SKD training	

Constraint No/Task Name	**Duration**
12.Issuing bank guarantee for license and documentation	30
Start Node	**Finish Node**
10	80
Predecessors	
none	
Successor(s)	
Master document list delivery	

Constraint No/Task Name	**Duration**
13.Acceptance tests of the 1st batch RMUs	15
Start Node	**Finish Node**
20	90
Predecessors	
Notification of the delivery of the 1st batch RMUs	
Successors	
Field tests of the 1st batch RMUs	

Constraint No/Task Name	**Duration**
14.Field tests of the 1st batch RMUs	3
Start Node	**Finish Node**
90	100
Predecessors	
Acceptance tests of the 1st batch RMUs	
Successors	
Delivery of the 1st batch RMUs Delivery of the operator´s manual by the seller	

Constraint No/Task Name	**Duration**
15.Delivery of the 1st batch RMUs	30
Start Node	**Finish Node**
100	110
Predecessors	
Field tests of the 1st batch RMUs	
Successors	
Payment of the 1st batch RMUs Notification of the delivery of the 1st batch RMUs	

Constraint No/Task Name	**Duration**
16.Notification of the delivery of the 2nd batch RMUs	5
Start Node	**Finish Node**
110	120
Predecessors	
Delivery of the 2nd batch RMUs	
Successors	
Acceptance tests of the 2nd batch RMUs	

Constraint No/Task Name	**Duration**
17.Acceptance tests of the 2nd batch RMUs	15
Start Node	**Finish Node**

120	130
Predecessors	
Notification of the delivery of the 2nd batch RMUs	
Successors	
Delivery of the 2nd batch RMUs	

Constraint No/Task Name	**Duration**
18.Delivery of the 2nd batch RMUs	30
Start Node	**Finish Node**
130	140
Predecessors	
Acceptance tests of the 2nd batch RMUs	
Successors	
Payment for the 2nd batch RMUs	

Constraint No/Task Name	**Duration**
19.Operator training-I to the customer	12
Start Node	**Finish Node**
140	141
Predecessors	
Delivery of the 2nd batch RMUs	
Successors	
Delivery of the field level maintenance manual by the seller	

Constraint No/Task Name	**Duration**
20.Delivery of the operator´s manual by the seller	30
Start Node	**Finish Node**
100	139
Predecessors	
Field tests of the 1st batch RMUs	
Successors	
Delivery of the operator´s manual by the company	

Constraint No/Task Name	**Duration**
21.Delivery of the operator´s manual by the company	30
Start Node	**Finish Node**
139	140
Predecessors	
Delivery of the operator´s manual by the seller	
Successors	
Operator training-I to the customer	

Constraint No/Task Name	**Duration**
22.Delivery of the field level maintenance manual by the seller	40
Start Node	**Finish Node**
141	360
Predecessors	
Operator training-I to the customer	
Successors	
Preparations on the field level maintenance manual	

Constraint No/Task Name	**Duration**
23.Preparations on the field level maintenance manual	180
Start Node	**Finish Node**
360	370
Predecessors	
Delivery of the field level maintenance manual by the seller	
Successors	
Delivery of the field level maintenance manual to the customer	

Constraint No/Task Name	**Duration**
24.Delivery of the field level maintenance manual	30

to the customer

Start Node 370 | **Finish Node** 380

Predecessors
Delivery of the field level maintenance manual by the seller

Successors
Field level maintenance training to the customer

Constraint No/Task Name | **Duration**
25.Delivery of the depot level maintenance manual by the seller | 30

Start Node 360 | **Finish Node** 390

Predecessors
Delivery of the field level maintenance manual by the seller

Successors
Preparation on the depot level maintenance manual

Constraint No/Task Name | **Duration**
26.Preparation on the depot level maintenance manual | 180

Start Node 390 | **Finish Node** 400

Predecessors
Delivery of the depot level maintenance manual by the seller

Successors
Delivery of the depot level maintenance manual to the customer
Operator´s training-II to the customer

Constraint No/Task Name | **Duration**
27.Delivery of the depot level maintenance manual to the customer | 30

Start Node 400 | **Finish Node** 870

Predecessors
Preparation on the depot level maintenance manual

Successors
´93 1st batch delivery

Constraint No/Task Name | **Duration**
28.Operator´s training-II to the customer | 12

Start Node 400 | **Finish Node** 401

Predecessors
.Preparation on the depot level maintenance manual
.Delivery of the training simulator

Successors
Field level maintenance training to the customer

Constraint No/Task Name | **Duration**
30.Field level maintenance training to the customer | 15

Start Node 401 | **Finish Node** 870

Predecessors
Operator´s training-II to the customer

Successors
´93 1st batch delivery

Constraint No/Task Name | **Duration**
31.Depot level maintenance training from the licenser | 90

Start Node 390 | **Finish Node** 391

Predecessors

Delivery of the depot level maintenance manual by the seller
Successors
Delivery of the depot level maintenance manual to the customer
Operator´s training-II to the customer

Constraint No/Task Name	**Duration**
33.Notification of the delivery of the UTTE to be used in SKD production	5
Start Node	**Finish Node**
40	150

Predecessors
Issuance of letter of credit for UTTE to be used in SKD production
Successors
Acceptance tests of UTTE to be used in SKD production

Constraint No/Task Name	**Duration**
34.Acceptance tests of UTTE to be used in SKD production	15
Start Node	**Finish Node**
150	160

Predecessors
Notification of the delivery of the UTTE to be used in SKD production
Successors
Signing of acceptance / rejection of the UTTE to be used

Constraint No/Task Name	**Duration**
35.Signing of acceptance / rejection of the UTTE to be used in SKD production	5
Start Node	**Finish Node**
160	170

Predecessors
Acceptance tests of UTTE to be used in SKD production
Successors
Delivery of UTTE to be used in SKD production

Constraint No/Task Name	**Duration**
36.Delivery of UTTE to be used in SKD production	100
Start Node	**Finish Node**
170	180

Predecessors
Signing of acceptance / rejection of the UTTE to be used in SKD production
Successors
Payment for the UTTE to be used in SKD production
SKD set-up

Constraint No/Task Name	**Duration**
37.Insider activities-I	40
Start Node	**Finish Node**
880	890

Predecessors
´93 1st batch delivery
Successors
Insider activities-II

Constraint No/Task Name	**Duration**
38.Notification of the delivery of UTTE to be used in PKD production	15
Start Node	**Finish Node**
40	150

Predecessors
Issuance of letter of guarantee for UTTE
Successors

Acceptance tests of the UTTE to be used on PKD production

Constraint No/Task Name — **Duration**
39.Acceptance tests of the UTTE to be used on PKD production — 15
Start Node — **Finish Node**
190 — 200
Predecessors
Notification of the delivery of UTTE to be used in PKD production
Successors
Sign of acceptance / rejection of the UTTE to be used in PKD production

---

Constraint No/Task Name — **Duration**
40.Sign of acceptance / rejection of the UTTE to be used in PKD production — 5
Start Node — **Finish Node**
200 — 210
Predecessors
Acceptance tests of the UTTE to be used on PKD production
Successors
Delivery of the UTTE to be used in PKD production

Constraint No/Task Name — **Duration**
41.Insider activities-II — 20
Start Node — **Finish Node**
890 — 900
Predecessors
. ´93 2nd batch delivery
. Insider activities-I
Successors
. Insider activities-III

Constraint No/Task Name — **Duration**
42.Notification of the delivery of training simulator — 15
Start Node — **Finish Node**
40 — 220
Predecessors
Issuance of letter of guarantee for UTTE
Successors
Acceptance tests of the training simulator

Constraint No/Task Name — **Duration**
43.Acceptance tests of the training simulator — 15
Start Node — **Finish Node**
220 — 230
Predecessors
Notification of the delivery training simulator
Successors
Sign of acceptance / rejection of the training simulator

Constraint No/Task Name — **Duration**
44.Sign of acceptance / rejection of the training simulator — 5
Start Node — **Finish Node**
230 — 240
Predecessors
Acceptance tests of the training simulator
Successors
Delivery of the training simulator

Constraint No/Task Name — **Duration**
45.Insider activities-III — 140
Start Node — **Finish Node**
900 — 920

Predecessors
. ´94 1st batch delivery
. Insider activities-II
Successors
. Insider activities-IV

Constraint No/Task Name 46.Delivery of the training simulator
Duration 30
Start Node 240
Finish Node 400
Predecessors
Sign of acceptance / rejection of the training simulator
Successors
. Delivery of the depot level maintenance manual to the customer
. Payment for the training simulator
. Operator´s training-II to the customer

Constraint No/Task Name 47.Notification of the delivery of local oscillator
Duration 15
Start Node 40
Finish Node 250
Predecessors
Issuance of letter of guarantee for UTTE
Successors
Acceptance tests of the local oscillator

Constraint No/Task Name 48.Acceptance tests of the local oscillator
Duration 15
Start Node 250
Finish Node 260
Predecessors
Notification of the delivery of the local oscillator
Successors
Sign of acceptance / rejection of the local oscillator

Constraint No/Task Name 49.Sign of acceptance / rejection of the local oscillator
Duration 5
Start Node 260
Finish Node 270
Predecessors
Acceptance tests of the local oscillator
Successors
Delivery of the local oscillator

Constraint No/Task Name 50.Insider activities-IV
Duration 70
Start Node 920
Finish Node 1140
Predecessors
. ´94 2nd batch delivery
. Insider activities-III
Successors
Insider activities-V

Constraint No/Task Name 51.Delivery of the local oscillator
Duration 30
Start Node 270
Finish Node 580
Predecessors
Sign of acceptance / rejection of the local oscillator
Successors
Payment for the local oscillator

Manufacturing test of the 1st batch SKD kits

Constraint No/Task Name — **Duration**
52.Notification of the delivery of the servo drive — 15
Start Node — **Finish Node**
40 — 280
Predecessors
Issuance of letter of guarantee for UTTE
Successors
Acceptance tests of the servo drive

Constraint No/Task Name — **Duration**
53.Acceptance tests of the servo drive — 15
Start Node — **Finish Node**
280 — 290
Predecessors
Notification of the delivery of the servo drive
Successors
Sign of acceptance / rejection of the servo drive

Constraint No/Task Name — **Duration**
54.Sign of acceptance / rejection of the servo drive — 5
Start Node — **Finish Node**
290 — 300
Predecessors
Acceptance tests of the servo drive
Successors
Delivery of the servo drive

Constraint No/Task Name — **Duration**
55.Insider activities-V — 100
Start Node — **Finish Node**
1140 — 1390
Predecessors
. ´94 3rd batch delivery
Insider activities-IV
Successors
NONE

Constraint No/Task Name — **Duration**
56.Delivery of the servo drive — 30
Start Node — **Finish Node**
300 — 580
Predecessors
Sign of acceptance / rejection of the servo drive
Successors
Payment for the servo drive
Manufacturing test of the 1st batch SKD kits

Constraint No/Task Name — **Duration**
57.Notification of the delivery of the reference units — 15
Start Node — **Finish Node**
40 — 310
Predecessors
Issuance of letter of guarantee for UTTE
Successors
Acceptance tests of the reference units

Constraint No/Task Name — **Duration**
58.Acceptance tests of the reference units — 15
Start Node — **Finish Node**
310 — 320
Predecessors
Notification of the delivery of the reference units
Successors
Sign of acceptance / rejection of the reference units

Constraint No/Task Name | **Duration**
59.Sign of acceptance / rejection of the reference units | 5
Start Node | **Finish Node**
320 | 330
Predecessors
Acceptance tests of the servo drive
Successors
Delivery of the reference units

Constraint No/Task Name | **Duration**
60.PKD training on mechanical and and electrical inspection | 35
Start Node | **Finish Node**
770 | 801
Predecessors
PKD training - general information
Successors
Manufacturing out of PKD

Constraint No/Task Name | **Duration**
61.Delivery of the reference units | 30
Start Node | **Finish Node**
330 | 580
Predecessors
Sign of acceptance / rejection of the reference units
Successors
Payment for the reference units
Manufacturing test of the 1st batch SKD kits

Constraint No/Task Name | **Duration**
62.Issuance letter of credit for SKD and PKD | 30
Start Node | **Finish node**
60 | 340
Predecessors
Sending proforma invoice for SKD and PKD
Successors
1st Batch SKD delivery

Constraint No/Task Name | **Duration**
63.1st Batch SKD delivery | 30
Start Node | **Finish node**
340 | 550
Predecessors
Issuance of letter of credit for SKD and PKD
Successors
Payment for the 1st batch SKD delivery
Acceptance tests of the 1st batch RMU delivery
Manufacturing out of the 1st batch SKD
2nd batch SKD delivery

Constraint No/Task Name | **Duration**
65.SKD training - general information | 14
Start Node | **Finish node**
70 | 420
Predecessors
In-house preparation to the trainings
Successors
SKD training on industrial engineering
SKD training on purchasing
SKD training on in-process control and handling
SKD training on quality control

Constraint No/Task Name | **Duration**
66.SKD training on industrial engineering | 24
Start Node | **Finish Node**
420 | 430

Predecessors
SKD training - general information
Successors
SKD training on manufacturing

Constraint No/Task Name 68.SKD training on purchasing
Duration 30
Start Node 420
Finish Node 440
Predecessors
SKD training - general information
Successors
SKD training on systems and principles

Constraint No/Task Name 69.SKD training on in-process control and handling
Duration 10
Start Node 420
Finish Node 460
Predecessors
SKD training - general information
Successors
SKD training on systems and principles

Constraint No/Task Name 70.SKD training on quality control
Duration 10
Start Node 420
Finish Node 450
Predecessors
SKD training - generalk information
Successors
SKD training on systems and principles

Constraint No/Task Name 72.SKD training on manufacturing
Duration 33
Start Node 440
Finish Node 500
Predecessors
SKD training on purchasing
SKD training on industrial engineering
Successors
SKD training on rework touch-up

Constraint No/Task Name 73.SKD training on rework touch-up
Duration 7
Start Node 500
Finish Node 560
Predecessors
SKD training on manufacturing
Successors
Manufacturing out of 1st batch SKD kit

Constraint No/Task Name 74.SKD training on systems and principles
Duration 21
Start Node 460
Finish Node 470
Predecessors
SKD training on quality control
SKD training on in-process control and handling
Successors
SKD training on maintenance

Constraint No/Task Name 75.SKD training on maintenance
Duration 7
Start Node 470
Finish Node 480
Predecessors
SKD training on systems and principles

Successors
SKD training on test engineeering support
SKD training on production testing

Constraint No/Task Name	**Duration**
76.SKD training on test engineeering support	30
Start Node	**Finish Node**
480	560

Predecessors
SKD training on maintenance
Successors
Manufacturing out of 1st batch SKD kits

Constraint No/Task Name	**Duration**
77.SKD training on production testing	60
Start Node	**Finish Node**
480	490

Predecessors
SKD training on maintenance
Successors
Manufacturing out of 1st batch SKD kits

Constraint No/Task Name	**Duration**
79.Delivery of master document list by the seller	15
Start Node	**Finish Node**
80	510

Predecessors
Issuance of bank guarantee for license and documentation
Successors
. Delivery of technical data package by the seller excluding test document
. Delivery of manufacturing data package by the seller excluding test document
. Delivery of additional data package by the seller excluding test document
. Delivery of documentation for UTTE required for final assembly

---

Constraint No/Task Name	**Duration**
80.Delivery of technical data package by the seller excluding test document	150
Start Node	**Finish Node**
510	560

Predecessors
Delivery of master document list by the seller
Successors
Manufacturing out of 1st batch SKD kit

Constraint No/Task Name	**Duration**
81.Delivery of manufacturing data package by the seller excluding test document	140
Start Node	**Finish Node**
510	530

Predecessors
Delivery of master document list by the seller
Successors
Manufacturing out of 1st batch SKD kit

Task Name	**Duration**
83.Delivery of additional data package by the seller excluding test document	130
Start Node	**Finish Node**
510	540

Predecessors
Delivery of master document list by the seller
Successors
Manufacturing out of 1st batch SKD kit

Constraint No/Task Name	Duration
85.Delivery of documentation for UTTE required for final assembly	30
Start Node	**Finish Node**
510	520
Predecessors	
Delivery of master document list by the seller	
Successors	
Preparation on documentation for UTTE required for final assembly	

Constraint No/Task Name	Duration
86.Preparation on documentation for UTTE required for final assembly	90
Start Node	**Finish Node**
520	560
Predecessors	
Delivery of documentation for UTTE required for final assembly	
Successors	
Manufacturing out of 1st batch SKD kit	

Constraint No/Task Name	Duration
87.SKD set-up	60
Start Node	**Finish Node**
180	560
Predecessors	
Delivery of UTTE to be used in SKD production	
Successors	
Manufacturing out of 1st batch SKD kit	

Constraint No/Task Name	Duration
88.Acceptance tests of the 1st batch SKD kit	90
Start Node	**Finish Node**
550	570
Predecessors	
Delivery of the 1st batch SKD kits	
Successors	
Sign of acceptance / rejection for the delivery of the 1st batch SKD kits	

Constraint No/Task Name	Duration
89.Sign of acceptance / rejection for the delivery of the 1st batch SKD kits	5
Start Node	**Finish Node**
570	850
Predecessors	
Acceptance tests of the 1st batch SKD kit	
Successors	
Customer acceptance tests of the '93 1st batch delivery	

Constraint No/Task Name	Duration
90.Payment for the 1st batch SKD kits	30
Start Node	**Finish Node**
550	850
Predecessors	
1st batch SKD delivery	
Successors	
Customer acceptance tests of the '93 1st batch delivery	

Constraint No/Task Name	Duration
91.Manufacturing out of 1st batch SKD kit	90
Start Node	**Finish Node**
560	580

Predecessors
. SKD set-up
. SKD training on rework touch-up
. SKD training on test engineering support
. SKD training on production testing
. Delivery of technical data package by the seller excluding test document
. Delivery of manufacturing data package by the seller excluding test document
. Delivery of additional data package by the seller excluding test document
. Delivery of documentation for UTTE required for final assembly
Successors
Manufacturing test of 1st batch SKD kit

Constraint No/Task Name — **Duration**
92.Manufacturing test of the 1st batch SKD kits — 30
Start Node — **Finish Node**
580 — 850
Predecessors
Manufacturing out of 1st batch SKD kits
Successors
Customer acceptance tests of the '93 1st batch delivery

Constraint No/Task Name — **Duration**
94.2nd batch SKD delivery — 30
Start Node — **Finish Node**
560 — 590
Predecessors
1st batch SKD delivery
Successors
Acceptance tests of the 2nd batch SKD kits

Constraint No/Task Name — **Duration**
95.Acceptance tests of the 2nd batch SKD kits — 90
Start Node — **Finish Node**
590 — 600
Predecessors
2nd batch SKD delivery
Successors
Sign of acceptance / rejection for the delivery of 2nd batch SKD kits

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Constraint No/Task Name — **Duration**
96.Sign of acceptance / rejection for the delivery of 2nd batch SKD kits — 5
Start Node — **Finish Node**
600 — 850
Predecessors
Acceptance tests of the 2nd batch SKD kits
Successors
Customer acceptance tests for the '93 1st batch delivery

Constraint No/Task Name — **Duration**
97.Payment for the 2nd batch SKD kits — 30
Start Node — **Finish Node**
590 — 850
Predecessors
2nd batch SKD delivery
Successors
Customer acceptance tests for the '93 1st batch delivery

Constraint No/Task Name — **Duration**
98.Manufacturing out of 2nd batch SKD kits — 90
Start Node — **Finish Node**

590	610
Predecessors	
2nd batch SKD delivery	
Successors	
Manufacturing tests of 2nd batch SKD kits	

Constraint No/Task Name	**Duration**
99.Manufacturing test of 2nd batch SKD kits	30
Start Node	**Finish Node**
610	850
Predecessors	
Manufacturing out of 2nd batch SKD kits	
Successors	
Customer acceptance tests for the ´93 1st batch delivery	

Constraint No/Task Name	**Duration**
100.3rd batch SKD delivery	30
Start Node	**Finish Node**
590	620
Predecessors	
2nd batch SKD delivery	
Successors	
Acceptance test of the 3rd batch SKD kits	

Constraint No/Task Name	**Duration**
101.Acceptance test of the 3rd batch SKD kits	90
Start Node	**Finish Node**
620	630
Predecessors	
3rd batch SKD delivery	
Successors	
Sign of acceptance / rejection for the delivery of 3rd batch SKD kits	

Constraint No/Task Name	**Duration**
102.Sign of acceptance / rejection for the delivery of 3rd batch SKD kits	5
Start Node	**Finish Node**
630	850
Predecessors	
Acceptance tests of the 3rd batch SKD kits	
Successors	
Customer acceptance tests for the ´93 1st batch delivery	

Constraint No/Task Name	**Duration**
103.Payment for the 3rd batch SKD kits	30
Start Node	**Finish Node**
620	850
Predecessors	
3rd batch SKD kit delivery	
Successors	
Customer acceptance tests for the ´93 1st batch delivery	

Constraint No/Task Name	**Duration**
104.Manufacturing out of 3rd batch SKD kits	90
Start Node	**Finish Node**
620	640
Predecessors	
3rd batch SKD delivery	
Successors	
Manufacturing test of 3rd batch SKD kits	

Constraint No/Task Name	**Duration**
105.Manufacturing test of 3rd batch SKD kits	30
Start Node	**Finish Node**
640	650
Predecessors	

Manufacturing out of 3rd batch SKD kits
Successors
Customer acceptance tests for the ´93 1st batch delivery

Constraint No/Task Name — **Duration**
107.Customer acceptance tests for the ´93 1st batch delivery — 15
Start Node — **Finish Node**
850 — 870
Predecessors
. Sign of acceptance / rejection for thge delivery of 1st batch SKD kits
. Payment for the 1st batch SKD kits
. Manufacturing test of the 1st batch SKD kits
. Sign of acceptance / rejection for thge delivery of 2nd batch SKD kits
. Payment for the 2nd batch SKD kits
. Manufacturing test of the 2nd batch SKD kits
. Sign of acceptance / rejection for thge delivery of 3rd batch SKD kits
. Payment for the 3rd batch SKD kits
. Manufacturing test of the 3rd batch SKD kits
Successors
´93 1st batch delivery

Constraint No/Task Name — **Duration**
108.´93 1st batch delivery — 10
Start Node — **Finish Node**
870 — 880
Predecessors
Customer acceptance tests for the ´93 1st batch delivery
Successors
Insider activities-I

Constraint No/Task Name — **Duration**
109.4th batch delivery — 30
Start Node — **Finish Node**
620 — 660
Predecessors
3rd batch SKD delivery
Successors
Acceptance tests of the 4th batch SKD kit

Constraint No/Task Name — **Duration**
110.Acceptance tests of the 4th batch SKD kit — 90
Start Node — **Finish Node**
660 — 670
Predecessors
4th batch SKD delivery
Successors
Sign of acceptance / rejection for the delivery of 4th batch SKD kits

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Constraint No/Task Name — **Duration**
111.Sign of acceptance / rejection for the delivery of 4th batch SKD kits — 5
Start Node — **Finish Node**
670 — 690
Predecessors
Acceptance tests of the 4th batch SKD kit
Successors
Customer acceptance tests for the ´93 2nd batch delivery

Constraint No/Task Name	Duration
112.Payment for the 4th batch SKD kits	30
Start Node	**Finish Node**
660	690

Predecessors
4th batch SKD delivery
Successors
Customer acceptance tests for the ´93 2nd batch delivery

Constraint No/Task Name	Duration
113.Manufacturing out of 4th batch SKD kits	90
Start Node	**Finish Node**
660	680

Predecessors
4th batch SKD delivery
Successors
Manufacturing test of 4th batch SKD kits

Constraint No/Task Name	Duration
114.Manufacturing test of 4th batch SKD kits	30
Start Node	**Finish Node**
680	690

Predecessors
Manufacturing out of 4th batch SKD kits
Successors
Customer acceptance tests for the ´93 2nd batch delivery

Constraint No/Task Name	Duration
115.Customer acceptance tests for the ´93 2nd batch delivery	15
Start Node	**Finish Node**
690	700

Predecessors
. Sign of acceptance / rejection for the delivery of the 4th batch SKD kits
. Payment for the 4th batch SKD kits
. Manufacturing test of 4th batch SKD kits
Successors
´93 2nd batch delivery

Constraint No/Task Name	Duration
116.´93 2nd batch delivery	30
Start Node	**Finish Node**
700	890

Predecessors
Customer acceptance tests for the ´93 2nd batch delivery
Successors
Insider activities-II

Constraint No/Task Name	Duration
117.Receiving technical assistance from the licenser	180
Start Node	**Finish Node**
560	740

Predecessors
Same as manufacturing out of 1st batch SKD kits
Successors
Manufacturing test of the 5th batch SKD delivery

Constraint No/Task Name	Duration
118.5th batch SKD delivery	30
Start Node	**Finish Node**
660	720

Predecessors
4th batch SKD delivery

Successors
Acceptance tests of the 5th batch SKD kit

Constraint No/Task Name | **Duration**
119.Acceptance tests of the 5th batch SKD kit | 90
Start Node | **Finish Node**
720 | 730
Predecessors
5th batch SKD delivery
Successors
Sign of acceptance /rejection for the delivery of 5th batch SKD kits

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Constraint No/Task Name | **Duration**
120.Sign of acceptance /rejection for the delivery of 5th batch SKD kits | 5
Start Node | **Finish Node**
730 | 750
Predecessors
Acceptance tests of the 5th batch SKD kits
Successors
Customer acceptance tests for the ´94 1st batch delivery

Constraint No/Task Name | **Duration**
121.Payment for the 5th batch SKD kits | 30
Start Node | **Finish Node**
720 | 750
Predecessors
5th batch SKD delivery
Successors
Customer acceptance tests for the ´94 1st batch delivery

Constraint No/Task Name | **Duration**
122.Manufacturing out of 5th batch SKD kits | 90
Start Node | **Finish Node**
720 | 740
Predecessors
5th batch SKD deliveryu
Successors
Manufacturing test of the 5th batch SKD kits

Constraint No/Task Name | **Duration**
123.Manufacturing test of the 5th batch SKD kits | 30
Start Node | **Finish Node**
740 | 750
Predecessors
Manufacturing out of 3rd batch SKD kits
Successors
Customer acceptance tests for the ´94 1st batch delivery

Constraint No/Task Name | **Duration**
124.Customer acceptance tests for the ´94 1st batch delivery | 15
Start Node | **Finish Node**
750 | 760
Predecessors
. Sign of acceptance /rejection for the delivery of 5th batch SKD kits
. Manufacturing test of the 5th batch SKD kits
. Payment for the 5th batch SKD kits
Successors
´94 1st batch delivery

Constraint No/Task Name | **Duration**
125.´94 1st batch delivery | 30

Start Node | **Finish Node**
760 | 900
Predecessors
Customer acceptance tests for the ´94 1st batch delivery
Successors
Insider activities-III

Constraint No/Task Name | **Duration**
126.PKD training - general information | 7
Start Node | **Finish Node**
560 | 770
Predecessors
. SKD training on rework touch-up
. SKD training on test engineering support
. SKD training on production testing
. Delivery of technical data package by the seller excluding test document
. Delivery of manufacturing data package by the seller excluding test document
. Delivery of additional data package by the seller excluding test document
. Delivery of documentation for UTTE required for final assembly
. 1st batch SKD delivery
Successors
. PKD training on mechanical and and electrical inspection
. PKD training on manufacturing
. PKD training on cable harness
. PKD training on production testing

Constraint No/Task Name | **Duration**
127.PKD training on manufacturing | 51
Start Node | **Finish Node**
770 | 780
Predecessors
PKD training - general information
Successors
Manufacturing out of PKD

Constraint No/Task Name | **Duration**
129.PKD training on cable harness | 35
Start Node | **Finish Node**
770 | 790
Predecessors
PKD training - general information
Successors
Manufacturing out of PKD

Constraint No/Task Name | **Duration**
131.PKD training on production testing | 44
Start Node | **Finish Node**
770 | 800
Predecessors
PKD training - general information
Successors
Manufacturing out of PKD

Constraint No/Task Name | **Duration**
133.Delivery of the UTTE to be used in PKD production | 30
Start Node | **Finish Node**
210 | 710
Predecessors
Sign of acceptance / rejection of the UTTE to be used in PKD production

Successors
PKD set-up
Payment for the UTTE to be used in PKD production

Constraint No/Task Name — **Duration**
134.PKD set-up — 90
Start Node — **Finish Node**
710 — 801
Predecessors
Delivery of UTTE to be used in PKD production
Successors
Manufacturing out of PKD kits

Constraint No/Task Name — **Duration**
136.PKD delivery — 30
Start Node — **Finish Node**
720 — 721
Predecessors
5th batch SKD delivery
Successors
Acceptance tests of the PKD kits

Constraint No/Task Name — **Duration**
137.Acceptance tests of the PKD kits — 90
Start Node — **Finish Node**
721 — 820
Predecessors
PKD delivery
Successors
Sign of acceptance / rejection for the delivery of PKD kits

Constraint No/Task Name — **Duration**
138.Sign of acceptance / rejection for the delivery of PKD kits — 5
Start Node — **Finish Node**
820 — 840
Predecessors
Acceptance tests of the PKD kits
Successors
Customer acceptance tests for the ´94 2nd batch delivery

Constraint No/Task Name — **Duration**
139.Customer acceptance tests for the ´94 2nd batch delivery — 15
Start Node — **Finish Node**
840 — 910
Predecessors
. Sign of acceptanec /rejection for the delivery of PKD kits
. Payment for the 1st batch SKD kits
. Manufacturing test of PKD kits
Successors
´94 2nd batch delivery

Constraint No/Task Name — **Duration**
140.´94 2nd batch delivery — 30
Start Node — **Finish Node**
910 — 920
Predecessors
Customer acceptance tests for the ´94 2nd batch delivery
Successors
Insider activities-IV

Constraint No/Task Name — **Duration**
141.Payment for the PKD kits — 30

Start Node 721 | **Finish Node** 840

Predecessors
5th batch SKD delivery
Successors
Customer acceptance tests for the ´94 2nd batch delivery

Constraint No/Task Name 142.Manufacturing out of PKD kits | **Duration** 210

Start Node 801 | **Finish Node** 830

Predecessors
PKD delivery
Successors
Manufacturing test of PKD kits

Constraint No/Task Name 143.Manufacturing test of PKD kits | **Duration** 30

Start Node 830 | **Finish Node** 840

Predecessors
Manufacturing out of PKD kits
Successors
Customer acceptance tests for the ´94 2nd batch delivery

Constraint No/Task Name 144.Delivery of electrical and mechanical piece parts-1 | **Duration** 30

Start Node 721 | **Finish Node** 940

Predecessors
PKD delivery
Successors
Manufacturing of mechanical and electrical piece parts-1

Constraint No/Task Name 145.Delivery of components to be used in module assembly phase-1 | **Duration** 30

Start Node 940 | **Finish Node** 950

Predecessors
Delivery of electrical and mechanical piece parts-1
Successors
. Delivery of components to be used in unit assembly phase-1
. Module and printed board assembly / test phase-I

Constraint No/Task Name 146.Delivery of must-buy items-B -1 | **Duration** 30

Start Node 940 | **Finish Node** 960

Predecessors
Delivery of electrical and mechanical piece parts-1
Successors
. Delivery of must-buy items-A -1
. Module and printed board assembly / test phase-I
. Delivery of must-buy items-B -1b

Constraint No/Task Name 147.Manufacturing of mechanical and electrical piece parts-1 | **Duration** 60

Start Node 940 | **Finish Node** 970

Predecessors
Delivery of electrical and mechanical piece parts-1
Successors

Constraint No/Task Name | **Duration**
148.Module and printed board assembly/test phase-I | 50
Start Node | **Finish Node**
970 | 980
Predecessors
. Manufacturing of mechanical and electrical piece parts-1
. Delivery of must-buy items-B -1
. Delivery of components to be used in module assembly phase-1
Successors
Unit asssembly/test phase-I

Constraint No/Task Name | **Duration**
149.Delivery of must-buy items-A -1 | 30
Start Node | **Finish Node**
960 | 980
Predecessors
Delivery of must-buy items-B -1
Successors
. Unit assembly /test phase-I
. Delivery of must-buy items-A -1b

Constraint No/Task Name | **Duration**
150.Delivery of components to be used in unit assembly phase-1 | 30
Start Node | **Finish Node**
950 | 980
Predecessors
Delivery of components to be used in module assembly phase-1
Successors
Unit assembly / test-I

Constraint No/Task Name | **Duration**
151.Unit assembly / test-I | 60
Start Node | **Finish Node**
980 | 990
Predecessors
. Module and printed board assembly / test -I
. Delivery of must-buy items-A -1
. Delivery of components to be used in unit assembly phase-1
Successors
Final assembly-I

Constraint No/Task Name | **Duration**
152.Final assembly-I | 30
Start Node | **Finish Node**
990 | 1030
Predecessors
Unit assembly / test phase-II
Successors
Final test-I
Final assembly-II

Constraint No/Task Name | **Duration**
153.Final test-I | 30
Start Node | **Finish Node**
1030 | 1120
Predecessors
Final assembly-I
Unit assembly / test phase-II
Successors
Customer acceptance tests for the ′94 3rd batch delivery

Constraint No/Task Name	Duration
156.Delivery of must-buy items-B -1b	30
Start Node	**Finish Node**
960	1050

Predecessors
Delivery of must-buy items-B -1
Successors
Module and printed board assembly/test phase-III

Constraint No/Task Name	Duration
157.Delivery of must-buy items-A -1b	30
Start Node	**Finish Node**
980	1060

Predecessors
Delivery of must-buy items-A -1
Successors
Unit assembly/test phase-III

Constraint No/Task Name	Duration
158.Preparation to ´94 2nd batch of manufacturing out of component	10
Start Node	**Finish Node**
970	1010

Predecessors
Manufacturing of electrical and mechanical piece parts-1
Successors
Module and printed assembly / test -II

Constraint No/Task Name	Duration
159.Module and printed assembly / test phase-II	90
Start Node	**Finish Node**
1010	1020

Predecessors
Preparation to ´94 2nd batch of manufacturing out of component
Successors
Unit assembly / test phase-II

Constraint No/Task Name	Duration
160.Unit assembly / test phase-II	60
Start Node	**Finish Node**
1020	1030

Predecessors
Module and printed assembly / test phase-II
Successors
Final test-II

Constraint No/Task Name	Duration
161.Final assembly-II	30
Start Node	**Finish Node**
1030	1070

Predecessors
. Unit assembly / test phase-II
. Final assembly-I
Successors
. Final test-II
. Final assembly-III

Constraint No/Task Name	Duration
162.Final test-II	30
Start Node	**Finish Node**
1070	1120

Predecessors
Final assembly-II
Unit assembly-III
Successors

Customer acceptance tests for the ´94 3 batch delivery

Constraint No/Task Name — **Duration**
163.Preparation to ´94 3rd batch of manufacturing out of component — 10
Start Node — **Finish Node**
1010 — 1050
Predecessors
Preparation to ´94 2nd batch of manufacturing out of component
Successors
Module and printed board assembly / test phase-III

Constraint No/Task Name — **Duration**
164.Module and printed board assembly / test phase-III — 90
Start Node — **Finish Node**
1050 — 1060
Predecessors
Preparation to 3rd batch of manufacturing out of component
Delivery of must-buy items-B -1b
Successors
Unit assembly / test phase-III

Constraint No/Task Name — **Duration**
165.Unit assembly / test phase-III — 60
Start Node — **Finish Node**
1060 — 1070
Predecessors
Module and printed board assembly / test phase-III
Delivery of must-buy items-B -1b
Successors
Final assembly-III
Final test-II

Constraint No/Task Name — **Duration**
166.Final assembly-III — 30
Start Node — **Finish Node**
1070 — 1110
Predecessors
Final assembly-II
Unit assembly-III
Successors
Final assembly / test-IV
Final test-III

Constraint No/Task Name — **Duration**
167.Final assembly / test-IV — 30
Start Node — **Finish Node**
1110 — 1120
Predecessors
Unit assembly / test phase-IV
Final assembly / test phase-III
Successors
Customer acceptance tests for the ´94 3rd batch delivery

Constraint No/Task Name — **Duration**
168.Preparation to ´94 4th batch of manufacturing out of component — 10
Start Node — **Finish Node**
1050 — 1090
Predecessors
Preparation to ´94 3rd batch of manufacturing out of component
Successors

Module and printed board assembly/test phase-IV

Constraint No/Task Name	Duration
169.Module and printed board assembly/test phase-IV	90
Start Node	**Finish Node**
1090	1100

Predecessors
Preparation to 4th batch of manufacturing out of component
Successors
Unit assembly / test phase-IV

Constraint No/Task Name	**Duration**
170.Unit assembly / test phase-IV	60
Start Node	**Finish Node**
1100	1110

Predecessors
Module and printed board assembly / test phase-IV
Successors
Final assembly / test-IV
Final test-III

Constraint No/Task Name	**Duration**
171.Final test-III	30
Start Node	**Finish Node**
1110	1119

Predecessors
Unit assembly / test phase-IV
Final assembly / test phase-III
Successors
Customer acceptance tests for the ´94 3rd batch delivery

Constraint No/Task Name	**Duration**
172.Customer acceptance tests for the ´94 3rd batch delivery	15
Start Node	**Finish Node**
1120	1130

Predecessors
Final test-I
Final test-II
Final test-III
Final assembly / test-IV
Successors
´94 3rd batch delivery

Constraint No/Task Name	**Duration**
173.´94 3rd batch delivery	30
Start Node	**Finish Node**
1130	1140

Predecessors
Customer acceptance tests for the ´94 3rd batch delivery
Successors
Insider activities-V

Constraint No/Task Name	**Duration**
174.Delivery of electrical/mechanical piece parts-2	30
Start Node	**Finish Node**
940	1150

Predecessors
Delivery of electrical and mechanical piece parts-1
Successors
Manufacturing of mechanical and electrical piece parts-2

Constraint No/Task Name	**Duration**
175.Manufacturing of mechanical and electrical piece parts-2	60

Start Node 1150 — **Finish Node** 1180

Predecessors
Delivery of electrical and mechanical piece parts-2
Successors
Module and printed board assembly / test phase-V

Constraint No/Task Name 176.Module and printed board assembly/test phase-V — **Duration** 60
Start Node 1180 — **Finish Node** 1190

Predecessors
. Manufacturing of mechanical and electrical piece parts-2
. Delivery of must-buy items-B -2
. Delivery of components to be used in module assembly phase-2
Successors
Unit asssembly/test phase-V

Constraint No/Task Name 177.Delivery of must-buy items(B) -2 — **Duration** 30
Start Node 1150 — **Finish Node** 1160

Predecessors
Delivery of electrical and mechanical piece parts-2
Successors
. Delivery of must-buy items(A) -2
. Module and printed board assembly / test phase-V
. Delivery of must-buy items(B) -2b

Constraint No/Task Name 179.Delivery of must-buy items(A) -2 — **Duration** 30
Start Node 1160 — **Finish Node** 1190

Predecessors
Delivery of must-buy items(B) -2
Successors
. Unit assembly /test phase-V
. Delivery of must-buy items(A) -2b

Constraint No/Task Name 180.Delivery of components to be used in module assembly phase-2 — **Duration** 30
Start Node 1150 — **Finish Node** 1170

Predecessors
Delivery of electrical and mechanical piece parts-2
Successors
. Delivery of components to be used in unit assembly phase-2
. Module and printed board assembly / test phase-V

Constraint No/Task Name 182.Delivery of components to be used in unit assembly phase-2 — **Duration** 30
Start Node 1170 — **Finish Node** 1190

Predecessors
Delivery of components to be used in module assembly phase-2
Successors
Unit assembly / test phase-V

Constraint No/Task Name 183.Unit assembly / test phase-V — **Duration** 45
Start Node — **Finish Node**

1190 1200

Predecessors

. Module and printed board assembly / test phase-V

. Delivery of must-buy items(A)-2

. Delivery of components to be used in unit assembly phase-2

Successors

Final assembly-V

Constraint No/Task Name 184.Final assembly-V | **Duration** 30

Start Node 1200 | **Finish Node** 1240

Predecessors

Unit assembly / test phase-V

Successors

Final test-V

Final assembly-VI

Constraint No/Task Name 185.Final test-V | **Duration** 30

Start Node 1240 | **Finish Node** 1370

Predecessors

Final assembly-V

Unit assembly / test phase-VI

Successors

Customer acceptance tests for the ´94 4th batch delivery

Constraint No/Task Name 186.Preparation to ´94 6th batch of manufacturing out of component | **Duration** 10

Start Node 1180 | **Finish Node** 1220

Predecessors

Manufacturing of electrical and mechanical piece parts-2

Successors

Module and printed assembly / test phase-VI

Constraint No/Task Name 187.Delivery of must-buy items-B -2b | **Duration** 30

Start Node 1160 | **Finish Node** 1260

Predecessors

Delivery of must-buy items-B -2

Successors

Module and printed assembly / test phase-VII

Constraint No/Task Name 146.Delivery of must-buy items-A -2b | **Duration** 30

Start Node 1190 | **Finish Node** 1270

Predecessors

Delivery of must-buy items-B -1

Successors

Unit assembly/test phase-VII

Constraint No/Task Name 189.Module and printed assembly / test phase-VI | **Duration** 90

Start Node 1220 | **Finish Node** 1230

Predecessors

Preparation to ´94 6th batch of manufacturing out of component

Successors

Unit assembly / test phase-VI

Constraint No/Task Name | **Duration**
190.Unit assembly / test phase-VI | 60
Start Node | **Finish Node**
1230 | 1240
Predecessors
Module and printed assembly / test phase-VI
Successors
Final test-VI

Constraint No/Task Name | **Duration**
191.Final assembly-VI | 30
Start Node | **Finish Node**
1240 | 1280
Predecessors
. Unit assembly / test phase-VI
. Final assembly-V
Successors
. Final test-VI
. Final assembly-VII

Constraint No/Task Name | **Duration**
192.Final test-VI | 30
Start Node | **Finish Node**
1280 | 1370
Predecessors
Final assembly-VI
Unit assembly / test phase-VII
Successors
Customer acceptance tests for the ´94 4th batch delivery

Constraint No/Task Name | **Duration**
193.Preparation to ´94 7th batch of manufacturing out of component | 10
Start Node | **Finish Node**
1220 | 1260
Predecessors
Preparation to ´94 6th batch of manufacturing out of component
Successors
Module and printed board assembly / test phase-VII

Constraint No/Task Name | **Duration**
194.Module and printed board assembly/test phase-VII | 90
Start Node | **Finish Node**
1260 | 1270
Predecessors
. Preparation to ´94 7th batch of manufacturing out of component
. Delivery of must-buy items(B) -2 b
Successors
Unit assembly / test phase-VII

Constraint No/Task Name | **Duration**
195.Unit assembly / test phase-VII | 60
Start Node | **Finish Node**
1270 | 1280
Predecessors
. Module and printed board assembly / test phase-VII
. Delivery of must-buy items(A) -2b
Successors
Final assembly-VII
Final test-VI

Task Name | **Duration**
196.Final assembly-VII | 30
Start Node | **Finish Node**

1280 | 1320

Predecessors

Final assembly-VI

Unit assembly / test phase-VII

Successors

Final assembly-VIII

Final test-VII

Constraint No/Task Name | **Duration**

197.Final test-VII | 30

Start Node | **Finish Node**

1320 | 1370

Predecessors

Final assembly-VII

Unit assembly / test phase-VIII

Successors

Customer acceptance tests for the ′94 4th batch delivery

Constraint No/Task Name | **Duration**

198.Preparation to ′94 8th batch of manufacturing out of component | 10

Start Node | **Finish Node**

1260 | 1300

Predecessors

Preparation to ′94 7th batch of manufacturing out of component

Successors

Module and printed board assembly / test phase-VIII

Task Name | **Duration**

199.Module and printed board assembly/test phase-VIII | 90

Start Node | **Finish Node**

1300 | 1310

Predecessors

Preparation to ′94 8th batch of manufacturing out of component

Successors

Unit assembly / test phase-VIII

Constraint No/Task Name | **Duration**

200.Unit assembly / test phase-VIII | 60

Start Node | **Finish Node**

1310 | 1320

Predecessors

Module and printed board assembly / test phase-VIII

Successors

Final assembly-VIII

Final test-VII

Constraint No/Task Name | **Duration**

201.Final assembly-VIII | 30

Start Node | **Finish Node**

1320 | 1360

Predecessors

Unit assembly / test phase-VIII

Final assembly-VII

Successors

Final assembly / test-IX

Final test-VIII

Constraint No/Task Name | **Duration**

202.Final test-VIII | 30

Start Node | **Finish Node**

1360 | 1369

Predecessors

Unit assembly / test phase-IX

Final assembly-VIII

Successors
Customer acceptance tests for the ´94 4th batch delivery

Constraint No/Task Name — **Duration**
203.Preparation to 9th batch of manufacturing out of component — 10
Start Node — **Finish Node**
1300 — 1340
Predecessors
Preparation to ´94 8th batch of manufacturing out of component
Successors
Module and printed board assembly / test phase-IX

Constraint No/Task Name — **Duration**
204.Module and printed board assembly/test phase-IX — 90
Start Node — **Finish Node**
1340 — 1350
Predecessors
Preparation to ´94 9th batch of manufacturing out of component
Successors
Unit assembly / test phase-IX

Constraint No/Task Name — **Duration**
205.Unit assembly / test phase-IX — 60
Start Node — **Finish Node**
1350 — 1360
Predecessors
Module and printed board assembly / test phase-IX
Successors
Final assembly / test -IX
Final test-VIII

Constraint No/Task Name — **Duration**
206.Final assembly / test-IX — 60
Start Node — **Finish Node**
1360 — 1370
Predecessors
Unit assembly / test phase-IX
Final assembly-VIII
Successors
Customer acceptance tests for the ´94 4th batch delivery

Task Name — **Duration**
207.Customer acceptance tests for the ´94 4th batch delivery — 15
Start Node — **Finish Node**
1370 — 1380
Predecessors
Final test-V
Final test-VI
Final test-VII
Final test-VIII
Final assembly / test-IX
Successors
´94 4th batch delivery

Constraint No/Task Name — **Duration**
208.´94 4th batch delivery — 30
Start Node — **Finish Node**
1380 — 1390
Predecessors
Customer acceptance tests for the ´94 4th batch delivery
Successors

NONE

APPENDIX D

LINDO FORMULATION

The constraints associated with the critical activities are marked in **bold** for the convenience of the reader.

MIN - X10 + X1390
SUBJECT TO
2) - X10 + X20 >= 5
3) - X10 + X30 >= 30
4) - X30 + X100 >= 0
5) - X10 + X35 >= 30
6) - X35 + X40 >= 0
7) - X10 + X40 >= 30
8) - X10 + X50 >= 30
9) - X50 + X110 >= 0
10) - X10 + X60 >= 10
11) - X10 + X70 >= 14
12) - X10 + X80 >= 30
13) - X20 + X90 >= 15
14) X100 - X90 >= 3
15) - X100 + X110 >= 30
16) - X110 + X120 >= 5
17) - X120 + X130 >= 15
18) - X130 + X140 >= 30
19) - X140 + X141 >= 12
20) - X100 + X139 >= 30
21) X140 - X139 >= 30
22) - X141 + X360 >= 40
23) - X360 + X370 >= 180
24) - X370 + X380 >= 30
25) - X360 + X390 >= 30
26) - X390 + X400 >= 180
27) - X400 + X870 >= 30
28) - X400 + X401 >= 12
29) - X380 + X401 >= 0
30) X870 - X401 >= 15
31) - X390 + X391 >= 90
32) X400 - X391 >= 0
33) - X40 + X150 >= 5
34) - X150 + X160 >= 15
35) - X160 + X170 >= 5
36) - X170 + X180 >= 100
37) - X880 + X890 >= 49
38) - X40 + X190 >= 15
39) - X190 + X200 >= 15
40) - X200 + X210 >= 5
41) - X890 + X900 >= 29
42) - X40 + X220 >= 15
43) - X220 + X230 >= 15
44) - X230 + X240 >= 5
45) - X900 + X920 >= 149
46) X400 - X240 >= 30

47) - X40 + X250 >= 15
48) - X250 + X260 >= 15
49) - X260 + X270 >= 5
50) - X920 + X1140 >= 79
51) - X270 + X331 >= 30
52) - X40 + X280 >= 15
53) - X280 + X290 >= 15
54) - X290 + X300 >= 5
55) X1390 - X1140 >= 109
56) X331 - X300 >= 30
57) - X40 + X310 >= 15
58) - X310 + X320 >= 15
59) - X320 + X330 >= 5
60) - X770 + X801 >= 35
61) X331 - X330 >= 30
62) - X60 + X340 >= 30
63) - X340 + X550 >= 30
64) - X331 + X580 >= 0
65) - X70 + X420 >= 14
66) - X420 + X430 >= 24
67) - X430 + X440 >= 0
68) - X420 + X440 >= 30
69) - X420 + X460 >= 10
70) - X420 + X450 >= 10
71) X460 - X450 >= 0
72) - X440 + X500 >= 33
73) - X500 + X560 >= 7
74) - X460 + X470 >= 21
75) - X470 + X480 >= 7
76) X560 - X480 >= 30
77) - X480 + X490 >= 60
78) X560 - X490 >= 0
79) - X80 + X510 >= 15
80) X560 - X510 >= 150
81) - X510 + X530 >= 140
82) X560 - X530 >= 0
83) - X510 + X540 >= 130
84) X560 - X540 >= 0
85) - X510 + X520 >= 30
86) X560 - X520 >= 90
87) - X180 + X560 >= 60
88) - X550 + X570 >= 90
89) - X570 + X850 >= 5
90) - X550 + X850 >= 30
91) X580 - X560 >= 90
92) - X580 + X850 >= 30
93) - X550 + X560 >= 0
94) - X560 + X590 >= 30
95) - X590 + X600 >= 90
96) X850 - X600 >= 5
97) X850 - X590 >= 30
98) - X590 + X610 >= 90
99) X850 - X610 >= 30
100) - X590 + X620 >= 30
101) - X620 + X630 >= 90
102) X850 - X630 >= 5
103) X850 - X620 >= 30
104) - X620 + X640 >= 90
105) - X640 + X650 >= 30
106) X850 - X650 >= 0
107) X870 - X850 >= 15

108) - X870 + X880 >= 10
109) - X620 + X660 >= 30
110) - X660 + X670 >= 90
111) - X670 + X690 >= 5
112) - X660 + X690 >= 30
113) - X660 + X680 >= 90
114) X690 - X680 >= 30
115) - X690 + X700 >= 15
116) X890 - X700 >= 30
117) - X560 + X740 >= 180
118) - X660 + X720 >= 30
119) - X720 + X730 >= 90
120) - X730 + X750 >= 5
121) - X720 + X750 >= 30
122) X740 - X720 >= 90
123) - X740 + X750 >= 30
124) - X750 + X760 >= 15
125) X900 - X760 >= 30
126) X770 - X560 >= 7
127) - X770 + X780 >= 51
128) X801 - X780 >= 0
129) - X770 + X790 >= 35
130) X801 - X790 >= 0
131) - X770 + X800 >= 44
132) X801 - X800 >= 0
133) - X210 + X710 >= 30
134) X801 - X710 >= 90
135) X801 - X721 >= 0
136) - X720 + X721 >= 30
137) - X721 + X820 >= 90
138) - X820 + X840 >= 5
139) - X840 + X910 >= 15
140) X920 - X910 >= 30
141) - X721 + X840 >= 30
142) - X801 + X830 >= 210
143) X840 - X830 >= 30
144) - X721 + X940 >= 30
145) - X940 + X950 >= 30
146) - X940 + X960 >= 30
147) - X940 + X970 >= 60
148) - X970 + X980 >= 50
149) - X960 + X980 >= 30
150) - X950 + X980 >= 30
151) - X980 + X990 >= 60
152) - X990 + X1030 >= 30
153) - X1030 + X1120 >= 30
154) - X960 + X970 >= 0
155) - X950 + X970 >= 0
156) - X960 + X1050 >= 30
157) - X980 + X1060 >= 30
158) - X970 + X1010 >= 10
159) - X1010 + X1020 >= 70
160) X1030 - X1020 >= 60
161) - X1030 + X1070 >= 30
162) X1120 - X1070 >= 30
163) X1050 - X1010 >= 10
164) - X1050 + X1060 >= 70
165) - X1060 + X1070 >= 60
166) - X1070 + X1110 >= 30
167) X1120 - X1110 >= 30
168) - X1050 + X1090 >= 10

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169) - X1090 + X1100 >=  70
170)   X1110 - X1100 >=  30
171) - X1110 + X1119 >=  30
172) - X1120 + X1130 >=  15
173)   X1140 - X1130 >=  30
174) - X940 + X1150 >=  30
175) - X1150 + X1180 >=  60
176) - X1180 + X1190 >=  60
177) - X1150 + X1160 >=  30
178)   X1180 - X1160 >=  0
179)   X1190 - X1160 >=  30
180) - X1150 + X1170 >=  30
181)   X1180 - X1170 >=  0
182)   X1190 - X1170 >=  30
183) - X1190 + X1200 >=  45
184) - X1200 + X1240 >=  30
185) - X1240 + X1370 >=  30
186) - X1180 + X1220 >=  10
187) - X1160 + X1260 >=  30
188) - X1190 + X1270 >=  30
189) - X1220 + X1230 >=  90
190) - X1230 + X1240 >=  60
191) - X1240 + X1280 >=  30
192)   X1370 - X1280 >=  30
193) - X1220 + X1260 >=  10
194) - X1260 + X1270 >=  90
195) - X1270 + X1280 >=  60
196) - X1280 + X1320 >=  30
197)   X1370 - X1320 >=  30
198) - X1260 + X1300 >=  10
199) - X1300 + X1310 >=  90
200)   X1320 - X1310 >=  60
201) - X1320 + X1360 >=  30
202) - X1360 + X1369 >=  30
203) - X1300 + X1340 >=  10
204) - X1340 + X1350 >=  90
205)   X1360 - X1350 >=  60
206)   X1370 - X1360 >=  60
207) - X1370 + X1380 >=  15
208)   X1390 - X1380 >=  30
209)   X1120 - X1119 >=  0
210)   X1370 - X1369 >=  0
END

LP OPTIMUM FOUND AT STEP    186

      OBJECTIVE FUNCTION VALUE

      1)      840.00000
```

VARIABLE	VALUE	REDUCED COST
X10	0.000000	0.000000
X1390	840.000000	0.000000
X20	5.000000	0.000000
X30	30.000000	0.000000
X100	30.000000	0.000000
X35	30.000000	0.000000
X40	30.000000	0.000000
X50	68.000000	0.000000
X110	68.000000	0.000000
X60	10.000000	0.000000

X70	14.000000	0.000000
X80	30.000000	0.000000
X90	27.000000	0.000000
X120	73.000000	0.000000
X130	88.000000	0.000000
X140	118.000000	0.000000
X141	130.000000	0.000000
X139	60.000000	0.000000
X360	170.000000	0.000000
X370	350.000000	0.000000
X380	380.000000	0.000000
X390	200.000000	0.000000
X400	380.000000	0.000000
X870	410.000000	0.000000
X401	395.000000	0.000000
X391	290.000000	0.000000
X150	35.000000	0.000000
X160	50.000000	0.000000
X170	55.000000	0.000000
X180	155.000000	0.000000
X880	425.000000	0.000000
X890	474.000000	0.000000
X190	45.000000	0.000000
X200	60.000000	0.000000
X210	65.000000	0.000000
X900	503.000000	0.000000
X220	45.000000	0.000000
X230	60.000000	0.000000
X240	350.000000	0.000000
X920	652.000000	0.000000
X250	45.000000	0.000000
X260	60.000000	0.000000
X270	65.000000	0.000000
X1140	731.000000	0.000000
X331	365.000000	0.000000
X280	45.000000	0.000000
X290	60.000000	0.000000
X300	65.000000	0.000000
X310	45.000000	0.000000
X320	60.000000	0.000000
X330	65.000000	0.000000
X770	314.000000	0.000000
X801	365.000000	0.000000
X340	185.000000	0.000000
X550	215.000000	0.000000
X580	365.000000	0.000000
X420	28.000000	0.000000
X430	52.000000	0.000000
X440	58.000000	0.000000
X460	38.000000	0.000000
X450	38.000000	0.000000
X500	91.000000	0.000000
X560	215.000000	0.000000
X470	59.000000	0.000000
X480	66.000000	0.000000
X490	126.000000	0.000000
X510	65.000000	0.000000
X530	205.000000	0.000000
X540	195.000000	0.000000
X520	95.000000	0.000000
X570	305.000000	0.000000

X850	395.000000	0.000000
X590	245.000000	0.000000
X600	335.000000	0.000000
X610	335.000000	0.000000
X620	275.000000	0.000000
X630	365.000000	0.000000
X640	365.000000	0.000000
X650	395.000000	0.000000
X660	305.000000	0.000000
X670	395.000000	0.000000
X690	425.000000	0.000000
X680	395.000000	0.000000
X700	440.000000	0.000000
X740	428.000000	0.000000
X720	335.000000	0.000000
X730	453.000000	0.000000
X750	458.000000	0.000000
X760	473.000000	0.000000
X780	365.000000	0.000000
X790	365.000000	0.000000
X800	358.000000	0.000000
X710	95.000000	0.000000
X721	365.000000	0.000000
X820	600.000000	0.000000
X840	605.000000	0.000000
X910	622.000000	0.000000
X830	575.000000	0.000000
X940	395.000000	0.000000
X950	455.000000	0.000000
X960	445.000000	0.000000
X970	455.000000	0.000000
X980	506.000000	0.000000
X990	566.000000	0.000000
X1030	596.000000	0.000000
X1120	686.000000	0.000000
X1050	475.000000	0.000000
X1060	545.000000	0.000000
X1010	465.000000	0.000000
X1020	535.000000	0.000000
X1070	626.000000	0.000000
X1110	656.000000	0.000000
X1090	485.000000	0.000000
X1100	555.000000	0.000000
X1119	686.000000	0.000000
X1130	701.000000	0.000000
X1150	425.000000	0.000000
X1180	485.000000	0.000000
X1190	570.000000	0.000000
X1160	480.000000	0.000000
X1170	485.000000	0.000000
X1200	615.000000	0.000000
X1240	645.000000	0.000000
X1370	795.000000	0.000000
X1220	495.000000	0.000000
X1260	510.000000	0.000000
X1270	600.000000	0.000000
X1230	585.000000	0.000000
X1280	675.000000	0.000000
X1320	705.000000	0.000000
X1300	520.000000	0.000000
X1310	645.000000	0.000000

X1360	735.000000	0.000000
X1369	765.000000	0.000000
X1340	530.000000	0.000000
X1350	620.000000	0.000000
X1380	810.000000	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	0.000000	0.000000
3)	0.000000	0.000000
4)	0.000000	0.000000
5)	0.000000	0.000000
6)	0.000000	0.000000
7)	**0.000000**	**-1.000000**
8)	38.000000	0.000000
9)	0.000000	0.000000
10)	0.000000	0.000000
11)	0.000000	0.000000
12)	0.000000	0.000000
13)	7.000000	0.000000
14)	0.000000	0.000000
15)	8.000000	0.000000
16)	0.000000	0.000000
17)	0.000000	0.000000
18)	0.000000	0.000000
19)	0.000000	0.000000
20)	0.000000	0.000000
21)	28.000000	0.000000
22)	0.000000	0.000000
23)	0.000000	0.000000
24)	0.000000	0.000000
25)	0.000000	0.000000
26)	0.000000	0.000000
27)	0.000000	0.000000
28)	3.000000	0.000000
29)	15.000000	0.000000
30)	0.000000	0.000000
31)	0.000000	0.000000
32)	90.000000	0.000000
33)	**0.000000**	**-1.000000**
34)	**0.000000**	**-1.000000**
35)	**0.000000**	**-1.000000**
36)	**0.000000**	**-1.000000**
37)	0.000000	0.000000
38)	0.000000	0.000000
39)	0.000000	0.000000
40)	0.000000	0.000000
41)	0.000000	0.000000
42)	0.000000	0.000000
43)	0.000000	0.000000
44)	285.000000	0.000000
45)	0.000000	0.000000
46)	0.000000	0.000000
47)	0.000000	0.000000
48)	0.000000	0.000000
49)	0.000000	0.000000
50)	0.000000	0.000000
51)	270.000000	0.000000
52)	0.000000	0.000000
53)	0.000000	0.000000
54)	0.000000	0.000000

55)	0.000000	0.000000
56)	270.000000	0.000000
57)	0.000000	0.000000
58)	0.000000	0.000000
59)	0.000000	0.000000
60)	16.000000	0.000000
61)	270.000000	0.000000
62)	145.000000	0.000000
63)	0.000000	0.000000
64)	0.000000	0.000000
65)	0.000000	0.000000
66)	0.000000	0.000000
67)	6.000000	0.000000
68)	0.000000	0.000000
69)	0.000000	0.000000
70)	0.000000	0.000000
71)	0.000000	0.000000
72)	0.000000	0.000000
73)	117.000000	0.000000
74)	0.000000	0.000000
75)	0.000000	0.000000
76)	119.000000	0.000000
77)	0.000000	0.000000
78)	89.000000	0.000000
79)	20.000000	0.000000
80)	0.000000	0.000000
81)	0.000000	0.000000
82)	10.000000	0.000000
83)	0.000000	0.000000
84)	20.000000	0.000000
85)	0.000000	0.000000
86)	30.000000	0.000000
87)	**0.000000**	**-1.000000**
88)	0.000000	0.000000
89)	85.000000	0.000000
90)	150.000000	0.000000
91)	60.000000	0.000000
92)	0.000000	0.000000
93)	0.000000	0.000000
94)	**0.000000**	**-1.000000**
95)	0.000000	0.000000
96)	55.000000	0.000000
97)	120.000000	0.000000
98)	0.000000	0.000000
99)	30.000000	0.000000
100)	**0.000000**	**-1.000000**
101)	0.000000	0.000000
102)	25.000000	0.000000
103)	90.000000	0.000000
104)	0.000000	0.000000
105)	0.000000	0.000000
106)	0.000000	0.000000
107)	0.000000	0.000000
108)	5.000000	0.000000
109)	**0.000000**	**-1.000000**
110)	0.000000	0.000000
111)	25.000000	0.000000
112)	90.000000	0.000000
113)	0.000000	0.000000
114)	0.000000	0.000000
115)	0.000000	0.000000

116)	4.000000	0.000000
117)	33.000000	0.000000
118)	**0.000000**	**-1.000000**
119)	28.000000	0.000000
120)	0.000000	0.000000
121)	93.000000	0.000000
122)	3.000000	0.000000
123)	0.000000	0.000000
124)	0.000000	0.000000
125)	0.000000	0.000000
126)	92.000000	0.000000
127)	0.000000	0.000000
128)	0.000000	0.000000
129)	16.000000	0.000000
130)	0.000000	0.000000
131)	0.000000	0.000000
132)	7.000000	0.000000
133)	0.000000	0.000000
134)	180.000000	0.000000
135)	0.000000	0.000000
136)	**0.000000**	**-1.000000**
137)	145.000000	0.000000
138)	0.000000	0.000000
139)	2.000000	0.000000
140)	0.000000	0.000000
141)	210.000000	0.000000
142)	0.000000	0.000000
143)	0.000000	0.000000
144)	**0.000000**	**-1.000000**
145)	30.000000	0.000000
146)	20.000000	0.000000
147)	0.000000	0.000000
148)	1.000000	0.000000
149)	31.000000	0.000000
150)	21.000000	0.000000
151)	0.000000	0.000000
152)	0.000000	0.000000
153)	60.000000	0.000000
154)	10.000000	0.000000
155)	0.000000	0.000000
156)	0.000000	0.000000
157)	9.000000	0.000000
158)	0.000000	0.000000
159)	0.000000	0.000000
160)	1.000000	0.000000
161)	0.000000	0.000000
162)	30.000000	0.000000
163)	0.000000	0.000000
164)	0.000000	0.000000
165)	21.000000	0.000000
166)	0.000000	0.000000
167)	0.000000	0.000000
168)	0.000000	0.000000
169)	0.000000	0.000000
170)	71.000000	0.000000
171)	0.000000	0.000000
172)	0.000000	0.000000
173)	0.000000	0.000000
174)	**0.000000**	**-1.000000**
175)	**0.000000**	**-1.000000**
176)	25.000000	0.000000

177)	25.000000	0.000000
178)	5.000000	0.000000
179)	60.000000	0.000000
180)	30.000000	0.000000
181)	0.000000	0.000000
182)	55.000000	0.000000
183)	0.000000	0.000000
184)	0.000000	0.000000
185)	120.000000	0.000000
186)	**0.000000**	**-1.000000**
187)	0.000000	0.000000
188)	0.000000	0.000000
189)	**0.000000**	**-1.000000**
190)	**0.000000**	**-1.000000**
191)	**0.000000**	**-1.000000**
192)	90.000000	0.000000
193)	5.000000	0.000000
194)	0.000000	0.000000
195)	15.000000	0.000000
196)	**0.000000**	**-1.000000**
197)	60.000000	0.000000
198)	0.000000	0.000000
199)	35.000000	0.000000
200)	0.000000	0.000000
201)	**0.000000**	**-1.000000**
202)	0.000000	0.000000
203)	0.000000	0.000000
204)	0.000000	0.000000
205)	55.000000	0.000000
206)	**0.000000**	**-1.000000**
207)	**0.000000**	**-1.000000**
208)	**0.000000**	**-1.000000**
209)	0.000000	0.000000
210)	30.000000	0.000000

NO. ITERATIONS= 186

SENSITIVITY ANALYSIS

RANGES IN WHICH THE BASIS IS UNCHANGED:

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	5.000000	7.000000	5.000000
3	30.000000	8.000000	7.000000
4	0.000000	8.000000	7.000000
5	30.000000	0.000000	INFINITY
6	0.000000	0.000000	INFINITY
7	30.000000	INFINITY	0.000000
8	30.000000	38.000000	INFINITY
9	0.000000	38.000000	INFINITY
10	10.000000	145.000000	10.000000
11	14.000000	89.000000	14.000000
12	30.000000	20.000000	30.000000
13	15.000000	7.000000	INFINITY
14	3.000000	7.000000	INFINITY
15	30.000000	8.000000	INFINITY
16	5.000000	8.000000	INFINITY
17	15.000000	8.000000	INFINITY
18	30.000000	8.000000	INFINITY

19	12.000000	8.000000	INFINITY
20	30.000000	28.000000	60.000000
21	30.000000	28.000000	INFINITY
22	40.000000	8.000000	INFINITY
23	180.000000	15.000000	350.000000
24	30.000000	15.000000	380.000000
25	30.000000	8.000000	15.000000
26	180.000000	8.000000	15.000000
27	30.000000	8.000000	3.000000
28	12.000000	3.000000	INFINITY
29	0.000000	15.000000	INFINITY
30	15.000000	3.000000	INFINITY
31	90.000000	90.000000	290.000000
32	0.000000	90.000000	INFINITY
33	5.000000	INFINITY	8.000000
34	15.000000	INFINITY	8.000000
35	5.000000	INFINITY	8.000000
36	100.000000	INFINITY	8.000000
37	49.000000	5.000000	INFINITY
38	15.000000	180.000000	45.000000
39	15.000000	180.000000	60.000000
40	5.000000	180.000000	65.000000
41	29.000000	4.000000	INFINITY
42	15.000000	285.000000	45.000000
43	15.000000	285.000000	60.000000
44	5.000000	285.000000	INFINITY
45	149.000000	3.000000	INFINITY
46	30.000000	285.000000	INFINITY
47	15.000000	270.000000	45.000000
48	15.000000	270.000000	60.000000
49	5.000000	270.000000	65.000000
50	79.000000	2.000000	INFINITY
51	30.000000	270.000000	INFINITY
52	15.000000	270.000000	45.000000
53	15.000000	270.000000	60.000000
54	5.000000	270.000000	65.000000
55	109.000000	1.000000	9.000000
56	30.000000	270.000000	INFINITY
57	15.000000	270.000000	45.000000
58	15.000000	270.000000	60.000000
59	5.000000	270.000000	65.000000
60	35.000000	16.000000	INFINITY
61	30.000000	270.000000	INFINITY
62	30.000000	145.000000	INFINITY
63	30.000000	145.000000	INFINITY
64	0.000000	270.000000	INFINITY
65	14.000000	89.000000	28.000000
66	24.000000	6.000000	52.000000
67	0.000000	6.000000	INFINITY
68	30.000000	117.000000	6.000000
69	10.000000	0.000000	INFINITY
70	10.000000	89.000000	0.000000
71	0.000000	89.000000	0.000000
72	33.000000	117.000000	91.000000
73	7.000000	117.000000	INFINITY
74	21.000000	89.000000	59.000000
75	7.000000	89.000000	66.000000
76	30.000000	119.000000	INFINITY
77	60.000000	89.000000	126.000000
78	0.000000	89.000000	INFINITY
79	15.000000	20.000000	INFINITY

80	150.000000	20.000000	10.000000
81	140.000000	10.000000	205.000000
82	0.000000	10.000000	INFINITY
83	130.000000	20.000000	195.000000
84	0.000000	20.000000	INFINITY
85	30.000000	30.000000	95.000000
86	90.000000	30.000000	INFINITY
87	60.000000	INFINITY	8.000000
88	90.000000	85.000000	305.000000
89	5.000000	85.000000	INFINITY
90	30.000000	150.000000	INFINITY
91	90.000000	60.000000	INFINITY
92	30.000000	60.000000	INFINITY
93	0.000000	145.000000	85.000000
94	30.000000	INFINITY	8.000000
95	90.000000	55.000000	335.000000
96	5.000000	55.000000	INFINITY
97	30.000000	120.000000	INFINITY
98	90.000000	30.000000	335.000000
99	30.000000	30.000000	INFINITY
100	30.000000	INFINITY	8.000000
101	90.000000	25.000000	365.000000
102	5.000000	25.000000	INFINITY
103	30.000000	90.000000	INFINITY
104	90.000000	5.000000	8.000000
105	30.000000	5.000000	8.000000
106	0.000000	5.000000	8.000000
107	15.000000	5.000000	8.000000
108	10.000000	5.000000	INFINITY
109	30.000000	INFINITY	5.000000
110	90.000000	25.000000	395.000000
111	5.000000	25.000000	INFINITY
112	30.000000	90.000000	INFINITY
113	90.000000	4.000000	25.000000
114	30.000000	4.000000	25.000000
115	15.000000	4.000000	440.000000
116	30.000000	4.000000	INFINITY
117	180.000000	33.000000	INFINITY
118	30.000000	INFINITY	4.000000
119	90.000000	28.000000	INFINITY
120	5.000000	28.000000	INFINITY
121	30.000000	93.000000	INFINITY
122	90.000000	3.000000	INFINITY
123	30.000000	3.000000	INFINITY
124	15.000000	3.000000	INFINITY
125	30.000000	3.000000	INFINITY
126	7.000000	92.000000	INFINITY
127	51.000000	92.000000	7.000000
128	0.000000	92.000000	7.000000
129	35.000000	16.000000	INFINITY
130	0.000000	16.000000	INFINITY
131	44.000000	7.000000	358.000000
132	0.000000	7.000000	INFINITY
133	30.000000	180.000000	95.000000
134	90.000000	180.000000	INFINITY
135	0.000000	2.000000	92.000000
136	30.000000	INFINITY	3.000000
137	90.000000	145.000000	INFINITY
138	5.000000	145.000000	INFINITY
139	15.000000	2.000000	INFINITY
140	30.000000	2.000000	INFINITY

141	30.000000	210.000000	INFINITY
142	210.000000	2.000000	145.000000
143	30.000000	2.000000	145.000000
144	30.000000	INFINITY	2.000000
145	30.000000	30.000000	INFINITY
146	30.000000	20.000000	INFINITY
147	60.000000	1.000000	9.000000
148	50.000000	1.000000	INFINITY
149	30.000000	31.000000	INFINITY
150	30.000000	21.000000	INFINITY
151	60.000000	1.000000	9.000000
152	30.000000	1.000000	9.000000
153	30.000000	60.000000	INFINITY
154	0.000000	10.000000	INFINITY
155	0.000000	30.000000	21.000000
156	30.000000	20.000000	10.000000
157	30.000000	9.000000	INFINITY
158	10.000000	1.000000	9.000000
159	70.000000	1.000000	535.000000
160	60.000000	1.000000	INFINITY
161	30.000000	1.000000	9.000000
162	30.000000	30.000000	INFINITY
163	10.000000	10.000000	9.000000
164	70.000000	21.000000	9.000000
165	60.000000	21.000000	INFINITY
166	30.000000	1.000000	9.000000
167	30.000000	1.000000	0.000000
168	10.000000	71.000000	485.000000
169	70.000000	71.000000	555.000000
170	30.000000	71.000000	INFINITY
171	30.000000	0.000000	INFINITY
172	15.000000	1.000000	9.000000
173	30.000000	1.000000	9.000000
174	30.000000	9.000000	1.000000
175	60.000000	9.000000	1.000000
176	60.000000	25.000000	INFINITY
177	30.000000	25.000000	INFINITY
178	0.000000	5.000000	INFINITY
179	30.000000	60.000000	INFINITY
180	30.000000	30.000000	INFINITY
181	0.000000	30.000000	55.000000
182	30.000000	55.000000	INFINITY
183	45.000000	5.000000	5.000000
184	30.000000	5.000000	5.000000
185	30.000000	120.000000	INFINITY
186	10.000000	5.000000	1.000000
187	30.000000	25.000000	5.000000
188	30.000000	5.000000	5.000000
189	90.000000	5.000000	1.000000
190	60.000000	5.000000	1.000000
191	30.000000	9.000000	1.000000
192	30.000000	90.000000	INFINITY
193	10.000000	5.000000	INFINITY
194	90.000000	5.000000	5.000000
195	60.000000	15.000000	INFINITY
196	30.000000	9.000000	1.000000
197	30.000000	60.000000	INFINITY
198	10.000000	35.000000	520.000000
199	90.000000	35.000000	INFINITY
200	60.000000	35.000000	INFINITY
201	30.000000	9.000000	1.000000

202	30.000000	30.000000	765.000000
203	10.000000	55.000000	530.000000
204	90.000000	55.000000	620.000000
205	60.000000	55.000000	INFINITY
206	60.000000	9.000000	1.000000
207	15.000000	9.000000	1.000000
208	30.000000	9.000000	1.000000
209	0.000000	0.000000	INFINITY
210	0.000000	30.000000	INFINITY

LP OPTIMUM FOUND AT STEP 186

APPENDIX E

PARAMETRIC ANALYSIS RESULTS OF THE NONCRITICAL PATH ACTIVITIES

	VAR OUT	VAR IN	PIVOT ROW	RHS VAL	DUAL PRICE BEFORE PIVOT	OBJ VAL
CONSTRAINT 2						
				5.00000	0.	840.000
	SLK 13	SLK 3	13	12.0000	0.	840.000
	SLK 15	SLK 104	94	20.0000	0.	840.000
	SLK 108	SLK 7	106	25.0000	0.	840.000
				30.0000	-1.00000	845.000
CONSTRAINT 3						
				30.0000	0.	840.000
	SLK 13	SLK 7	33	43.0000	0.	840.000
				60.0000	-1.00000	857.000
CONSTRAINT 5						
				30.0000	0.	840.000
	SLK 5	SLK 7	5	30.0000	0.	840.000
				60.0000	-1.00000	870.000
CONSTRAINT 8						
				30.0000	0.	840.000
	SLK 8	SLK 3	8	60.0000	0.	840.000
	SLK 9	SLK 7	16	73.0000	0.	840.000
				100.000	-1.00000	867.000
CONSTRAINT 10						
				10.0000	0.	840.000
	SLK 62	SLK 7	62	155.000	0.	840.000
				200.000	-1.00000	885.000
CONSTRAINT 11						
				14.0000	0.	840.000
	SLK 11	SLK 7	11	103.000	0.	840.000
				200.000	-1.00000	937.000
CONSTRAINT 12						
				30.0000	0.	840.000
	SLK 80	SLK 7	11	50.0000	0.	840.000
				60.0000	-1.00000	850.000
CONSTRAINT 13						
				15.0000	0.	840.000
	SLK 13	SLK 3	11	22.0000	0.	840.000
	SLK 26	SLK 104	11	30.0000	0.	840.000
	SLK 108	SLK 7	108	35.0000	0.	840.000
				50.000	-1.00000	855.000
CONSTRAINT 14						
				3.00000	0.	840.000
	SLK 13	SLK 3	108	10.0000	0.	840.000
	SLK 16	SLK 7	16	23.0000	0.	840.000
				30.0000	-1.00000	847.000
CONSTRAINT 15						
				30.0000	0.	840.000
	SLK 19	SLK 135	16	41.0000	0.	840.000

	SLK	50	SLK	7	122	43.0000	0.	840.000
						60.0000	-1.00000	857.000
CONSTRAINT 16								
						5.00000	0.	840.000
	SLK	19	SLK	122	100	15.0000	0.	840.000
	SLK	45	SLK	7	122	18.0000	0.	840.000
						20.0000	-1.00000	842.000
CONSTRAINT 17								
						15.0000	0.	840.000
	SLK	19	SLK	7	100	28.0000	0.	840.000
						30.0000	-1.00000	842.000
CONSTRAINT 18								
						30.0000	0.	840.000
	SLK	26	SLK	135	100	41.0000	0.	840.000
	SLK	50	SLK	147	17	43.0000	0.	840.000
	SLK	55	SLK	7	21	43.0000	0.	840.000
						50.0000	-1.00000	847.000
CONSTRAINT 19								
						12.0000	0.	840.000
	SLK	17	SLK	7	17	25.0000	0.	840.000
						30.0000	-1.00000	845.000
CONSTRAINT 20								
						30.0000	0.	840.000
	SLK	21	SLK	15	21	50.0000	0.	840.000
	SLK	19	SLK	113	100	59.0000	0.	840.000
	SLK	41	SLK	135	118	61.0000	0.	840.000
	SLK	50	SLK	7	135	63.0000	0.	840.000
						100.000	-1.00000	877.000
CONSTRAINT 21								
						30.0000	0.	840.000
	SLK	21	SLK	15	21	50.0000	0.	840.000
	SLK	25	SLK	7	135	63.0000	0.	840.000
						100.000	-1.00000	877.000
CONSTRAINT 22								
						30.0000	0.	840.000
	SLK	19	SLK	7	65	53.0000	0.	840.000
						60.0000	-1.00000	847.000
CONSTRAINT 23								
						180.000	0.	840.000
	SLK	23	SLK	25	29	195.000	0.	840.000
	SLK	19	SLK	113	100	204.000	0.	840.000
	SLK	41	SLK	122	41	205.000	0.	840.000
	SLK	45	SLK	147	23	207.000	0.	840.000
	SLK	55	SLK	7	164	208.000	0.	840.000
						240.000	-1.00000	872.000
CONSTRAINT 24								
						30.0000	0.	840.000
	SLK	24	SLK	28	29	50.0000	0.	840.000
	SLK	30	SLK	104	108	53.0000	0.	840.000
	SLK	108	SLK	7	87	58.0000	0.	840.000
						60.0000	-1.00000	842.000
CONSTRAINT 25								
						30.0000	0.	840.000
	SLK	19	SLK	7	87	43.0000	0.	840.000
						50.0000	0.	847.000
CONSTRAINT 26								
						180.000	0.	840.000
	SLK	19	SLK	113	35	189.000	0.	840.000
	SLK	41	SLK	147	41	192.000	0.	840.000
	SLK	55	SLK	7	191	193.000	0.	840.000
						240.000	-1.00000	887.000

CONSTRAINT 27

					30.0000	0.	840.000
SLK	3	SLK	104	35	38.0000	0.	840.000
SLK	108	SLK	135	108	41.0000	0.	840.000
SLK	50	SLK	7	50	43.0000	0.	840.000
					50.0000	-1.00000	847.000

CONSTRAINT 28

					12.0000	0.	840.000
SLK	30	SLK	104	35	23.0000	0.	840.000
SLK	108	SLK	7	108	28.0000	0.	840.000
					30.0000	-1.00000	842.000

CONSTRAINT 30

					15.0000	0.	840.000
SLK	28	SLK	104	35	26.0000	0.	840.000
SLK	37	SLK	113	108	27.0000	0.	840.000
SLK	41	SLK	7	41	31.0000	0.	840.000
					50.0000	-1.00000	859.000

CONSTRAINT 31

					90.0000	0.	840.000
SLK	31	SLK	26	32	180.000	0.	840.000
SLK	19	SLK	7	7	193.000	0.	840.000
					200.000	-1.00000	847.000

CONSTRAINT 32

					60.0000	0.	840.000
SLK	31	SLK	7	114	103.000	0.	840.000
					120.000	-1.00000	857.000

CONSTRAINT 37

					49.0000	0.	840.000
SLK	107	SLK	189	136	54.0000	0.	840.000
					60.0000	-1.00000	840.000

CONSTRAINT 38

					15.0000	0.	840.000
SLK	40	SLK	135	40	195.000	0.	840.000
SLK	139	SLK	33	196	197.000	0.	840.000
					200.000	-1.00000	843.000

CONSTRAINT 39

					15.0000	0.	840.000
SLK	133	SLK	135	133	195.000	0.	840.000
SLK	50	SLK	33	144	197.000	0.	840.000
					200.000	-1.00000	843.000

CONSTRAINT 40

					5.00000	0.	840.000
SLK	133	SLK	135	111	185.000	0.	840.000
SLK	139	SLK	33	64	187.000	0.	840.000
					200.000	-1.00000	853.000

CONSTRAINT 41

					29.0000	0.	840.000
SLK	113	SLK	118	141	33.0000	0.	840.000
					60.0000	-1.00000	867.000

CONSTRAINT 42

					15.0000	0.	840.000
SLK	46	SLK	33	63	305.000	0.	840.000
					315.000	-1.00000	850.000

CONSTRAINT 43

					15.0000	0.	840.000
SLK	43	SLK	33	133	305.000	0.	840.000
					315.000	-1.00000	850.000

CONSTRAINT 44

					5.00000	0.	840.000
SLK	46	SLK	104	64	290.000	0.	840.000
SLK	108	SLK	33	107	295.000	0.	840.000

					300.000	-1.00000	845.000

CONSTRAINT 45

					30.0000	0.	840.000
SLK	122	SLK	135	73	150.000	0.	840.000
SLK	50	SLK	136	201	152.000	0.	840.000
					200.000	-1.00000	888.000

CONSTRAINT 46

					30.0000	0.	840.000
SLK	42	SLK	122	22	317.000	0.	840.000
SLK	45	SLK	33	201	320.000	0.	840.000
					330.000	-1.00000	850.000

CONSTRAINT 47

					15.0000	0.	840.000
SLK	51	SLK	147	5	289.000	0.	840.000
SLK	55	SLK	33	201	290.000	0.	840.000
					300.000	-1.00000	850.000

CONSTRAINT 48

					15.0000	0.	840.000
SLK	51	SLK	147	51	289.000	0.	840.000
SLK	55	SLK	33	201	290.000	0.	840.000
					300.000	-1.00000	850.000

CONSTRAINT 49

					5.00000	0.	840.000
SLK	51	SLK	147	51	279.000	0.	840.000
SLK	55	SLK	33	201	280.000	0.	840.000
					300.000	-1.00000	860.000

CONSTRAINT 50

					79.0000	0.	840.000
SLK	50	SLK	144	201	81.0000	0.	840.000
					100.000	-1.00000	859.000

CONSTRAINT 51

					30.0000	0.	840.000
SLK	51	SLK	147	51	304.000	0.	840.000
SLK	55	SLK	33	201	305.000	0.	840.000
					310.000	-1.00000	845.000

CONSTRAINT 52

					15.0000	0.	840.000
SLK	56	SLK	147	56	289.000	0.	840.000
SLK	55	SLK	33	201	290.000	0.	840.000
					300.000	-1.00000	850.000

CONSTRAINT 53

					15.0000	0.	840.000
SLK	56	SLK	147	56	289.000	0.	840.000
SLK	55	SLK	33	201	290.000	0.	840.000
					300.000	-1.00000	850.000

CONSTRAINT 54

					5.00000	0.	840.000
SLK	56	SLK	147	56	279.000	0.	840.000
SLK	55	SLK	33	201	280.000	0.	840.000
					300.000	-1.00000	860.000

CONSTRAINT 55

					30.0000	0.	840.000
SLK	55	SLK	174	201	110.000	0.	840.000
					150.000	-1.00000	880.000

CONSTRAINT 56

					30.0000	0.	840.000
SLK	56	SLK	147	56	304.000	0.	840.000
SLK	55	SLK	33	201	305.000	0.	840.000
					310.000	-1.00000	845.000

CONSTRAINT 57

					15.0000	0.	840.000

	SLK	61	SLK	147	61	289.000	0.	840.000
	SLK	55	SLK	33	201	290.000	0.	840.000
						320.000	-1.00000	870.000
CONSTRAINT 58								
						15.0000	0.	840.000
	SLK	61	SLK	147	61	289.000	0.	840.000
	SLK	55	SLK	33	201	290.000	0.	840.000
						320.000	-1.00000	870.000
CONSTRAINT 59								
						5.00000	0.	840.000
	SLK	61	SLK	147	61	279.000	0.	840.000
	SLK	55	SLK	33	201	280.000	0.	840.000
						310.000	-1.00000	870.000
CONBSTRAINT 60								
						30.0000	0.	840.000
	SLK	60	SLK	127	127	51.0000	0.	840.000
	SLK	126	SLK	147	126	144.000	0.	840.000
	SLK	55	SLK	94	201	145.000	0.	840.000
						150.000	-1.00000	845.000
CONSTRAINT 61								
						30.0000	0.	840.000
	SLK	61	SLK	147	61	304.000	0.	840.000
	SLK	55	SLK	33	201	305.000	0.	840.000
						310.000	-1.00000	845.000
CONSTRAINT 62								
						30.0000	0.	840.000
	SLK	10	SLK	7	45	175.000	0.	840.000
						180.000	-1.00000	845.000
CONSTRAINT 63								
						30.0000	0.	840.000
	SLK	93	SLK	7	32	175.000	0.	840.000
						180.000	-1.00000	845.000
CONSTRAINT 65								
						14.0000	0.	840.000
	SLK	11	SLK	7	11	103.000	0.	840.000
						110.000	-1.00000	847.000
CONSTRAINT 66								
						24.0000	0.	840.000
	SLK	66	SLK	7	67	147.000	0.	840.000
						150.000	-1.00000	843.000
CONSTRAINT 68								
						30.0000	0.	840.000
	SLK	68	SLK	7	68	147.000	0.	840.000
						150.000	-1.00000	843.000
CONSTRAINT 69								
						10.0000	0.	840.000
	SLK	69	SLK	70	69	10.0000	0.	840.000
	SLK	11	SLK	7	11	99.0000	0.	840.000
						200.000	-1.00000	941.000
CONSTRAINT 70								
						10.0000	0.	840.000
	SLK	65	SLK	7	68	99.0000	0.	840.000
						100.000	-1.00000	841.000
CONSTRAINT 72								
						33.0000	0.	840.000
	SLK	68	SLK	70	79	61.0000	0.	840.000
	SLK	11	SLK	7	43	150.000	0.	840.000
						160.000	-1.00000	850.000
CONSTRAINT 73								
						7.00000	0.	840.000
	SLK	68	SLK	7	68	124.000	0.	840.000

						130.000	-1.00000	846.000
CONSTRAINT 74						21.0000	0.	840.000
	SLK	11	SLK	7	11	110.000	0.	840.000
						120.000	-1.00000	850.000
CONSTRAINT 75						21.0000	0.	840.000
	SLK	70	SLK	7	70	96.0000	0.	840.000
						100.000	-1.00000	844.000
CONSTRAINT 76						30.0000	0.	840.000
	SLK	76	SLK	7	174	149.000	0.	840.000
						150.000	-1.00000	841.000
CONSTRAINT 77						60.0000	0.	840.000
	SLK	78	SLK	7	87	149.000	0.	840.000
						150.000	-1.00000	841.000
CONSTRAINT 79						15.0000	0.	840.000
	SLK	79	SLK	7	79	35.0000	0.	840.000
						50.000	-1.00000	855.00
CONSTRAINT 80						150.000	0.	840.000
	SLK	12	SLK	7	79	170.000	0.	840.000
						180.000	-1.00000	850.000
CONSTRAINT 81						140.000	0.	840.000
	SLK	81	SLK	7	79	170.000	0.	840.000
						180.000	-1.00000	850.000
CONSTRAINT 83						130.000	0.	840.000
	SLK	83	SLK	7	79	170.000	0.	840.000
						180.000	-1.00000	850.000
CONSTRAINT 85						30.0000	0.	840.000
	SLK	85	SLK	7	85	80.0000	0.	840.000
						100.000	-1.00000	860.000
CONSTRAINT 86						90.0000	0.	840.000
	SLK	85	SLK	7	25	140.000	0.	840.000
						150.000	-1.00000	850.000
CONSTRAINT 88						90.0000	0.	840.000
	SLK	89	SLK	93	106	175.000	0.	840.000
	SLK	10	SLK	104	85	320.000	0.	840.000
	SLK	107	SLK	7	88	325.000	0.	840.000
						350.000	-1.00000	865.000
CONSTRAINT 89						5.00000	0.	840.000
	SLK	89	SLK	104	25	235.000	0.	840.000
	SLK	108	SLK	7	92	240.000	0.	840.000
						250.000	-1.00000	850.000
CONSTRAINT 90						30.0000	0.	840.000
	SLK	90	SLK	93	88	180.000	0.	840.000
	SLK	10	SLK	104	3	325.000	0.	840.000
	SLK	107	SLK	7	40	330.000	0.	840.000
						350.000	-1.00000	860.000
CONSTRAINT 91						90.0000	0.	840.000
	SLK	91	SLK	104	91	150.000	0.	840.000

	SLK	107	SLK	94	107	155.000	0.	840.000
						160.000	-1.00000	845.000
CONSTRAINT 92								
						30.0000	0.	840.000
	SLK	91	SLK	104	91	90.0000	0.	840.000
	SLK	108	SLK	94	32	95.0000	0.	840.000
						100.000	-1.00000	845.000
CONSTRAINT 95								
						90.0000	0.	840.000
	SLK	95	SLK	100	95	150.000	0.	840.000
						160.000	-1.00000	850.000
CONSTRAINT 96								
						5.00000	0.	840.000
	SLK	95	SLK	100	95	65.0000	0.	840.000
						70.0000	-1.00000	845.000
CONSTRAINT 97								
						30.0000	0.	840.000
	SLK	97	SLK	100	97	155.000	0.	840.000
						180.000	-1.00000	865.000
CONSTRAINT 98								
						90.0000	0.	840.000
	SLK	98	SLK	100	109	125.000	0.	840.000
						150.000	-1.00000	865.000
CONSTRAINT 99								
						30.0000	0.	840.000
	SLK	99	SLK	100	132	65.0000	0.	840.000
						80.0000	-1.00000	855.000
CONSTRAINT 101								
						90.0000	0.	840.000
	SLK	101	SLK	109	108	120.000	0.	840.000
						130.000	-1.00000	850.000
CONSTRAINT 102								
						5.00000	0.	840.000
	SLK	102	SLK	104	29	30.0000	0.	840.000
	SLK	108	SLK	109	108	35.0000	0.	840.000
						50.0000	-1.00000	855.000
CONSTRAINT 103								
						30.0000	0.	840.000
	SLK	103	SLK	104	103	121.000	0.	840.000
	SLK	210	SLK	109	108	125.000	0.	840.000
						150.000	-1.00000	865.000
CONSTRAINT 104								
						90.0000	0.	840.000
	SLK	108	SLK	109	108	95.0000	0.	840.000
						100.000	-1.00000	845.000
CONSTRAINT 105								
						30.0000	0.	840.000
	SLK	108	SLK	109	108	35.0000	0.	840.000
						50.0000	-1.00000	855.000
CONSTRAINT 107								
						15.0000	0.	840.000
	SLK	108	SLK	109	108	20.0000	0.	840.000
						50.0000	-1.00000	870.000
CONSTRAINT 108								
						10.0000	0.	840.000
	SLK	108	SLK	109	108	15.0000	0.	840.000
						30.0000	-1.00000	855.000
CONSTRAINT 110								
						90.0000	0.	840.000
	SLK	110	SLK	118	142	119.000	0.	840.000
						120.000	-1.00000	841.000

CONSTRAINT 111

					5.00000	0.	840.000
SLK	110	SLK	118	142	34.0000	0.	840.000
					40.0000	-1.00000	846.000

CONSTRAINT 112

					30.0000	0.	840.000
SLK	112	SLK	118	112	124.000	0.	840.000
					150.000	-1.00000	866.000

CONSTRAINT 113

					90.0000	0.	840.000
SLK	113	SLK	118	119	94.0000	0.	840.000
					100.000	-1.00000	846.000

CONSTRAINT 114

					30.0000	0.	840.000
SLK	115	SLK	135	32	32.0000	0.	840.000
SLK	50	SLK	118	166	34.0000	0.	840.000
					50.0000	-1.00000	856.000

CONSTRAINT 115

					15.0000	0.	840.000
SLK	115	SLK	135	166	17.0000	0.	840.000
SLK	50	SLK	118	32	19.0000	0.	840.000
					30.0000	-1.00000	851.000

CONSTRAINT 116

					30.0000	0.	840.000
SLK	115	SLK	135	32	32.0000	0.	840.000
SLK	50	SLK	118	166	34.0000	0.	840.000
					50.0000	-1.00000	856.000

CONSTRAINT 117

					180.000	0.	840.000
SLK	117	SLK	135	174	211.000	0.	840.000
SLK	50	SLK	94	132	213.000	0.	840.000
					220.000	-1.00000	847.000

CONSTRAINT 119

					90.0000	0.	840.000
SLK	119	SLK	122	119	115.000	0.	840.000
SLK	125	SLK	147	159	117.000	0.	840.000
SLK	213	SLK	136	154	118.000	0.	840.000
					120.000	-1.00000	842.000

CONSTRAINT 120

					5.00000	0.	840.000
SLK	119	SLK	122	119	30.0000	0.	840.000
SLK	125	SLK	147	159	32.0000	0.	840.000
SLK	55	SLK	136	154	33.0000	0.	840.000
					50.0000	-1.00000	857.000

CONSTRAINT 121

					30.0000	0.	840.000
SLK	121	SLK	122	121	120.000	0.	840.000
SLK	125	SLK	147	159	122.000	0.	840.000
SLK	55	SLK	136	154	123.000	0.	840.000
					130.000	-1.00000	847.000

CONSTRAINT 122

					90.0000	0.	840.000
SLK	125	SLK	147	154	92.0000	0.	840.000
SLK	55	SLK	136	159	93.0000	0.	840.000
					100.000	-1.00000	847.000

CONSTRAINT 123

					30.0000	0.	840.000
SLK	125	SLK	147	154	32.0000	0.	840.000
SLK	55	SLK	136	159	33.0000	0.	840.000
					40.0000	-1.00000	847.000

CONSTRAINT 124

					15.0000	0.	840.000
	SLK	125	SLK	147	154	17.0000	0.	840.000
	SLK	55	SLK	136	159	18.0000	0.	840.000
						20.0000	-1.00000	842.000
CONSTRAINT 125								
						30.0000	0.	840.000
	SLK	125	SLK	147	159	32.0000	0.	840.000
	SLK	55	SLK	136	154	33.0000	0.	840.000
						40.0000	-1.00000	847.000
CONSTRAINT 126								
						7.00000	0.	840.000
	SLK	126	SLK	147	126	100.000	0.	840.000
	SLK	55	SLK	94	159	101.000	0.	840.000
						150.000	-1.00000	889.000
CONSTRAINT 127								
						51.0000	0.	840.000
	SLK	127	SLK	147	126	144.000	0.	840.000
	SLK	55	SLK	94	32	145.000	0.	840.000
						150.000	-1.00000	845.000
CONSTRAINT 129								
						35.0000	0.	840.000
	SLK	129	SLK	127	129	51.0000	0.	840.000
	SLK	126	SLK	94	126	145.000	0.	840.000
						150.000	-1.00000	845.000
CONSTRAINT 131								
						44.0000	0.	840.000
	SLK	132	SLK	135	132	143.000	0.	840.000
	SLK	142	SLK	94	174	143.000	0.	840.000
						150.000	-1.00000	845.000
CONSTRAINT 133								
						30.0000	0.	840.000
	SLK	40	SLK	135	40	210.000	0.	840.000
	SLK	139	SLK	33	166	212.000	0.	840.000
						220.000	-1.00000	848.000
CONSTRAINT 134								
						90.0000	0.	840.000
	SLK	40	SLK	135	40	270.000	0.	840.000
	SLK	143	SLK	147	166	271.000	0.	840.000
	SLK	55	SLK	33	79	272.000	0.	840.000
						300.000	-1.00000	868.000
CONSTRAINT 137								
						90.0000	0.	840.000
	SLK	137	SLK	135	137	235.000	0.	840.000
	SLK	139	SLK	144	189	237.000	0.	840.000
						250.000	-1.00000	853.000
CONSTRAINT 138								
						5.00000	0.	840.000
	SLK	138	SLK	144	126	152.000	0.	840.000
						160.000	-1.00000	848.000
CONSTRAINT 139								
						15.0000	0.	840.000
	SLK	135	SLK	144	137	17.0000	0.	840.000
						50.0000	-1.00000	873.000
CONSTRAINT 140								
						30.0000	0.	840.000
	SLK	143	SLK	147	156	31.0000	0.	840.000
	SLK	55	SLK	144	166	32.0000	0.	840.000
						60.0000	-1.00000	868.000
CONSTRAINT 141								
						30.0000	0.	840.000
	SLK	141	SLK	144	141	242.000	0.	840.000

						250.000	-1.00000	848.000
CONSTRAINT 142								
						210.000	0.	840.000
	SLK	135	SLK	144	166	212.000	0.	840.000
						250.000	-1.00000	878.000
CONSTRAINT 143								
						30.0000	0.	840.000
	SLK	135	SLK	144	166	32.0000	0.	840.000
						50.0000	-1.00000	858.000
CONSTRAINT 145								
						30.0000	0.	840.000
	SLK	145	SLK	174	145	61.0000	0.	840.000
						70.0000	-1.00000	849.000
CONSTRAINT 146								
						30.0000	0.	840.000
	SLK	146	SLK	174	146	61.0000	0.	840.000
						70.0000	-1.00000	849.000
CONSTRAINT 147								
						60.0000	0.	840.000
	SLK	147	SLK	174	156	61.0000	0.	840.000
						70.0000	-1.00000	849.000
CONSTRAINT 148								
						50.0000	0.	840.000
	SLK	148	SLK	158	148	50.0000	0.	840.000
	SLK	173	SLK	174	156	51.0000	0.	840.000
	SLK	163	SLK	156	163	51.0000	0.	840.000
						100.000	-1.00000	889.000
CONSTRAINT 149								
						30.0000	0.	840.000
	SLK	149	SLK	156	149	50.0000	0.	840.000
	SLK	146	SLK	147	146	80.0000	0.	840.000
	SLK	171	SLK	174	171	81.0000	0.	840.000
						100.000	-1.00000	859.000
CONSTRAINT 150								
						30.0000	0.	840.000
	SLK	150	SLK	155	148	50.0000	0.	840.000
	SLK	145	SLK	147	145	80.0000	0.	840.000
	SLK	171	SLK	174	171	81.0000	0.	840.000
						100.000	-1.00000	859.000
CONSTRAINT 151								
						60.0000	0.	840.000
	SLK	148	SLK	158	148	60.0000	0.	840.000
	SLK	173	SLK	174	156	61.0000	0.	840.000
	SLK	163	SLK	156	163	70.0000	-1.00000	849.000
CONSTRAINT 152								
						30.0000	0.	840.000
	SLK	148	SLK	158	148	30.0000	0.	840.000
	SLK	173	SLK	174	156	31.0000	0.	840.000
	SLK	163	SLK	156	163	40.0000	-1.00000	849.000
CONSTRAINT 153								
						30.0000	0.	840.000
	SLK	153	SLK	174	153	91.0000	0.	840.000
						100.000	-1.00000	849.000
CONSTRAINT 156								
						30.0000	0.	840.000
	SLK	165	SLK	154	165	40.0000	0.	849.000
	SLK	146	SLK	147	146	70.0000	0.	840.000
	SLK	173	SLK	174	156	71.0000	-1.00000	849.000
						100.000	-1.00000	869.000
CONSTRAINT 157								
						30.0000	0.	840.000

SLK	157	SLK	151	157	60.0000	0.	840.000
SLK	148	SLK	158	148	60.0000	-1.00000	849.000
SLK	171	SLK	174	174	61.0000	-1.00000	849.000
					100.000	-1.00000	869.000
CONSTRAINT 158							
					10.0000	0.	840.000
SLK	171	SLK	174	171	11.0000	0.	840.000
					50.0000	-1.00000	879.000
CONSTRAINT 159							
					70.0000	0.	840.000
SLK	171	SLK	174	171	71.0000	0.	840.000
					90.0000	-1.00000	859.000
CONSTRAINT 160							
					60.0000	0.	840.000
SLK	171	SLK	174	171	61.0000	0.	840.000
					80.0000	-1.00000	859.000
CONSTRAINT 161							
					30.0000	0.	840.000
SLK	173	SLK	174	156	31.0000	0.	840.000
					50.0000	-1.00000	859.000
CONSTRAINT 162							
					30.0000	0.	840.000
SLK	162	SLK	166	162	60.0000	0.	840.000
SLK	173	SLK	174	156	61.0000	0.	840.000
					100.000	-1.00000	879.000
CONSTRAINT 163							
					10.0000	0.	840.000
SLK	163	SLK	156	163	20.0000	0.	840.000
SLK	165	SLK	159	165	30.0000	0.	840.000
SLK	173	SLK	174	156	31.0000	-1.00000	849.000
					50.0000	-1.00000	859.000
CONSTRAINT 164							
					70.0000	0.	840.000
SLK	156	SLK	154	154	80.0000	0.	840.000
SLK	163	SLK	159	163	90.0000	0.	840.000
SLK	173	SLK	174	165	91.0000	0.	840.000
					100.000	-1.00000	849.000
CONSTRAINT 165							
					60.0000	0.	840.000
SLK	156	SLK	154	154	71.0000	0.	840.000
SLK	163	SLK	174	156	81.0000	0.	840.000
SLK	157	SLK	151	157	90.0000	-1.00000	859.000
CONSTRAINT 166							
					30.0000	0.	840.000
SLK	159	SLK	174	163	31.0000	0.	840.000
					50.0000	-1.00000	859.000
CONSTRAINT 167							
					30.0000	0.	840.000
SLK	173	SLK	174	156	31.0000	0.	840.000
					50.0000	-1.00000	859.000
CONSTRAINT 168							
					10.0000	0.	840.000
SLK	168	SLK	164	165	60.0000	0.	840.000
SLK	156	SLK	154	154	71.0000	0.	840.000
SLK	163	SLK	174	156	80.0000	0.	840.000
					100.000	-1.00000	859.000
CONSTRAINT 169							
					70.0000	0.	840.000
SLK	168	SLK	164	165	120.000	0.	840.000
SLK	156	SLK	154	154	131.000	0.	840.000
SLK	163	SLK	174	156	141.000	0.	840.000

					150.000	-1.00000	849.000

CONSTRAINT 170

					30.0000	0.	840.000
SLK	168	SLK	164	165	80.0000	0.	840.000
SLK	156	SLK	154	154	91.0000	0.	840.000
SLK	163	SLK	174	156	101.000	0.	840.000
					150.000	-1.00000	889.000

CONSTRAINT 171

					30.0000	0.	840.000
SLK	173	SLK	174	156	31.0000	0.	840.000
					50.0000	-1.00000	859.000

CONSTRAINT 172

					15.0000	0.	840.000
SLK	173	SLK	174	156	16.0000	0.	840.000
					50.0000	-1.00000	874.000

CONSTRAINT 173

					30.0000	0.	840.000
SLK	173	SLK	174	156	31.0000	0.	840.000
					50.0000	-1.00000	859.000

CONSTRAINT 176

					60.0000	0.	840.000
SLK	176	SLK	186	191	85.0000	0.	840.000
					100.000	-1.00000	855.000

CONSTRAINT 177

					30.0000	0.	840.000
SLK	178	SLK	175	208	60.0000	0.	840.000
					70.0000	-1.00000	850.000

CONSTRAINT 179

					30.0000	0.	840.000
SLK	177	SLK	175	179	115.000	0.	840.000
					150.000	-1.00000	875.000

CONSTRAINT 180

					30.0000	0.	840.000
SLK	180	SLK	175	180	60.0000	0.	840.000
					100.000	-1.00000	880.000

CONSTRAINT 182

					30.0000	0.	840.000
SLK	182	SLK	181	184	85.0000	0.	840.000
SLK	180	SLK	175	180	115.000	0.	840.000
					150.000	-1.00000	875.000

CONSTRAINT 183

					45.0000	0.	840.000
SLK	184	SLK	186	154	70.0000	0.	840.000
					100.000	-1.00000	870.000

CONSTRAINT 184

					30.0000	0.	840.000
SLK	176	SLK	186	156	55.0000	0.	840.000
					70.0000	-1.00000	855.000

CONSTRAINT 185

					30.0000	0.	840.000
SLK	185	SLK	191	185	150.000	0.	840.000
					200.000	-1.00000	890.000

CONSTRAINT 187

					30.0000	0.	840.000
SLK	187	SLK	175	196	70.0000	0.	840.000
					100.000	-1.00000	870.000

CONSTRAINT 188

					30.0000	0.	840.000
SLK	188	SLK	183	195	35.0000	0.	840.000
SLK	176	SLK	187	154	60.0000	0.	840.000
SLK	195	SLK	186	208	70.0000	0.	840.000

						100.000	-1.00000	870.000
CONSTRAINT 192								
						30.0000	0.	840.000
	SLK	192	SLK	196	192	120.000	0.	840.000
						150.000	-1.00000	870.000
CONSTRAINT 193								
						10.0000	0.	840.000
	SLK	193	SLK	189	200	30.0000	0.	840.000
						50.0000	-1.00000	860.000
CONSTRAINT 194								
						90.0000	0.	840.000
	SLK	195	SLK	189	200	110.000	0.	840.000
						150.000	-1.00000	880.000
CONSTRAINT 195								
						60.0000	0.	840.000
	SLK	195	SLK	189	56	80.0000	0.	840.000
						100.000	-1.00000	860.000
CONSTRAINT 197								
						30.0000	0.	840.000
	SLK	195	SLK	201	197	90.0000	0.	840.000
						100.000	-1.00000	850.000
CONSTRAINT 198								
						10.0000	0.	840.000
	SLK	198	SLK	189	199	50.0000	0.	840.000
						100.000	-1.00000	890.000
CONSTRAINT 199								
						90.0000	0.	840.000
	SLK	198	SLK	189	199	130.000	0.	840.000
						150.000	-1.00000	860.000
CONSTRAINT 200								
						60.0000	0.	840.000
	SLK	198	SLK	189	199	100.000	0.	840.000
						150.000	-1.00000	890.000
CONSTRAINT 202								
						30.0000	0.	840.000
	SLK	210	SLK	206	210	60.0000	0.	840.000
						100.000	-1.00000	880.000
CONSTRAINT 203								
						10.0000	0.	840.000
	SLK	203	SLK	199	203	30.0000	0.	840.000
	SLK	198	SLK	189	199	70.0000	0.	840.000
						100.000	-1.00000	870.000
CONSTRAINT 204								
						90.0000	0.	840.000
	SLK	204	SLK	189	199	150.000	0.	840.000
						200.000	-1.00000	890.000
CONSTRAINT 205								
						60.0000	0.	840.000
	SLK	204	SLK	189	199	120.000	0.	840.000
						150.000	-1.00000	870.000

VITA

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