A Mathematical Modeling Approach To Energy Cost Saving In A Manufacturing Plant

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ABSTRACT

The objective of this study is to develop mathematical models that meet the finished products requirements at a minimum cost of energy used in the process subject to different operational constraints. An energy-intensive process is chosen for the study. Four different linear programming models are developed. Model 1 is the base form of the other models and focuses on minimizing total energy costs and meeting customer demands subject to operational constraints of the process. In model 2, 3 and 4, constraints of model 1 are adapted to different production and marketing circumstances. Model 2 focuses on reducing inventory-holding costs. Model 3 focuses on utilizing time capacity 100 %. Model 4 focuses on increasing production for more products also taking into account marketing circumstances. Sensitivity analysis of the models yields a better insight to the real problem and gives an idea what is now, and will be in the near future. Since the aim of the thesis is to focus on the energy costs, sensitivity analysis is related to the changes in prices of the resources and their effects on optimal production values.

ÖZ

Bu çalışmanın amacı farklı işletim kısıtları dikkate alınarak ürün gereksinimlerini minimum enerji maliyetleri ile karşılayan matematiksel modeller geliştirmektir. Çalışma için enerji sarfiyatı yoğun olan bir işletme seçilmiştir. Dört farklı lineer programlama modeli oluşturulmuştur. Model 1 diğer modellerin temel formudur ve toplam enerji maliyetlerini en alt seviyeye çekmeye ve müşteri beklentilerini karşılamaya odaklanmıştır. Model 2, 3 ve 4' de, model 1' in kısıtları farklı üretim ve pazarlama koşullarına uyarlanmıştır. Model 2 depoda ürün bulundurma maliyetlerini düşürmeye yöneliktir. Model 3 mevcut zaman kapasitesinin yüzde yüz kullanılmasına odaklanmıştır. Model 4 pazarlama şartlarını da dikkate alarak daha fazla ürün için üretimi arttırmaya yöneliktir. Modellerin duyarlılık analizleri problemin güncel haline daha iyi bir bakış açısı sağlamakta ve bugünkü konumu ile yakın gelecekteki konumu hakkında bir fikir vermektedir. Tezin amacı enerji maliyetlerine yönelmiş olduğu için duyarlılık analizi kaynakların fiyatlarındaki değişmeler ve bunların optimum üretim değerleri üzerindeki etkileri ile ilişkilidir.

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NOMENCLATURE

E_{ij} : electricity consumption to produce one unit of product j at stage i

F_{ij} : fuel oil consumption to produce one unit of product j at stage i

X_{ijk} : number of units of product j at stage i in month k

P_{tjk} : number of units of finished product j produced by method t in month k

D_{tjk} : number of units of demand for product j produced by method t in month k

I_{tjk} : number of units of product j in inventory produced by method t in month k

S_j : required set-up time to produce product j

R_j : required processing time to produce one unit of product j

C_k : available time capacity in month k

m_{oil} : mass flow-rate of oil

m_{fuel} : mass flow-rate of fuel

C : specific heat of oil

ΔT : temperature difference of oil

C_v : calorific value of fuel

Greek letters

η : boiler efficiency

Subscripts

i : number of stages, i = 1,…,5

j : number of product types, j = 1,…,7

k : number of months, k = 1,…,12

t : number of methods to produce product j, t = 1,2

CHAPTER 1
INTRODUCTION

1.1. Energy and Economy

Energy is essential and crucial to life either in one form or the other. Any kind of activity requires use of it. Chapman [1] briefly explains the importance of energy for a modern society "*A modern industrial society has been described as resting upon the tripod of materials, energy and information. All aspects of our culture involve a mix of these three basic ingredients. But they are not independent. The communication of information requires energy, energy conversion requires the use of materials and the extraction and production of useful engineering materials requires energy.*"

Energy is an indispensable factor for the social and economic development of societies. The usage level of electricity is an indication of the economic prosperity of nations. In today's world, the reasons of increasing energy consumption can be grouped in five titles [2]:

1. Total population (or growth rate of population)
2. Per capita residential energy
3. Energy content per unit good and services
4. New energy consumed by all sectors of the economy (it reflects new inventions and growth of affluence)
5. Growth of non-farm working population

Regional distribution of the world's primary energy consumption has never been uniform in the past. For instance, while North America consumes around 30% of the world's total primary energy, Africa's share remains at only 3% recently [2]. About half of the world's total has been consumed only in North America and Western Europe together and the rest in the other five regions. On the other hand, the major energy producing regions [2], the Middle East, Central and South America and Africa, consume only about 13% of the world's total energy.

The five primary energy consumer classes are given in Table 1 as follows [2]: (1) Super consumer (greater than 25.4%), (2) Major consumer (between 5.6% and 8.3%), (3) Big consumer (between 1.3% and 3.2%), (4) Medium consumer (between 0.6% and 1.2%) and (5) Small consumer (less than or equal to 0.5%).

Table 1. Primary energy consumer classes; number of countries in each class is given in parentheses [2]

Classes	Share of total (%)	Name of countries
Super (1)	>25,4	USA, EU (>16,0 %)
Major (3)	5,6-8,3	China, RF, Japan
Big (11)	1,3-3,2	Germany, Canada, India, France, UK, Brazil, Italy, South Korea, Ukraine, Mexico, Spain
Medium (13)	0,6-1,2	Australia, Iran, South Africa, Saudi Arabia, The Netherlands, Poland, Indonesia, Taiwan, Turkey, Venezuela, Argentina, Belgium, Thailand
Small (191)	≤0,5	Sweden, Egypt, Norway, United Arab Emirates, Uzbekistan, Pakistan, etc

Only the USA falls in the Super consumer class, whereas China, the Russian Federation and Japan are classified under the Major consumers. The country names of the 11 big consumers and 13 medium consumers are given in Table 1, and the remaining 191 countries are included in the Small consumers. Additionally, in the case when the 15 member countries are taken as a whole, the European Union is to be classified under the Super consumers with more than 16.0% share of the total.

The focus of today's energy world remains the effect of supply interruptions and oil price shocks on the economic performance of the major importing countries. It should not be forgotten that it was the events of the 1970s [3], including the Arab oil embargo and the Iranian revolution that generated recessions, high rates of inflation and reduced growth rates in oil importing countries.

Today the most common concern is still the possibility that new events will produce a reoccurrence of the price shocks of the 1970s [3], which were extremely large, unexpected and persistent. Perhaps, a more realistic risk, however, is the possibility of a sudden rise in oil prices in response to a short-term disruption of supplies, or the threat of such a disruption, due to political instability in a major oil producing area, especially in the Middle East. Thus, even today, the strategic *importance of energy, and oil and gas particular is by no means diminished. The world economy is as dependent, or even more so, on energy than in the 1970s. The fundamental link between economic growth and energy consumption remains in place. Even though the share of oil in the world energy mix has been reduced, oil remains a strategic commodity critical to national strategies and international politics. The reliance on imported oil and gas of the main consuming regions, including the industrialized countries and dynamic Asian economies, will increase substantially over the next 20 years.*

1.2. Energy Consumption in the World

Total world energy consumption which is given in Table 2 is expected to expand by 58 percent between 2001 and 2025, from 404 quadrillion British thermal units (Btu) in 2001 to 640 quadrillion Btu in 2025 (see *International Energy Outlook 2003*) [4] (Table 2). Much of the increment in future energy demand is projected to be for fossil fuels (oil, natural gas, and coal), because it is expected that fossil fuel prices will remain relatively low, and that the cost of generating energy from other fuels will not be competitive. It is possible, however, that as environmental programs or government policies —particularly those designed to limit or reduce greenhouse gas emissions —are implemented, the expectations might change, and non-fossil fuels (including nuclear power and renewable energy sources such as hydroelectricity, geothermal, biomass, solar, and wind power) might become more attractive. The *IEO2003* projections [4] assume that government policies or programs in place as of October 1, 2002, will remain constant over the forecast horizon.

Table 2. World energy consumption by region, 1990-2025, [4]

Region	Energy Consumption (Quadrillion Btu)			
	1990	2001	2010	2025
Industrialized Countries	**182.8**	**211.5**	**240.1**	**288.3**
EE/FSU	**76.3**	**53.3**	**65.9**	**82.3**
Developing Countries	**89.3**	**139.2**	**174.7**	**269.6**
Asia	52.5	85.0	110.1	174.6
Middle East	13.1	20.8	25.0	36.0
Africa	9.3	12.4	14.4	20.0
Central and South America	14.4	20.9	25.2	39.0
Total World	**348.4**	**403.9**	**480.6**	**640.1**

1.3. Energy Consumption in Turkey

In Turkey, the growing population, industrialization and increasing standard of living has considerably increased the dependence on imported energy. Consequently, in addition to the development of conventional energy resources, exploitation of non-conventional energy resources and energy conservation has become inevitable. Turkish energy consumption has risen dramatically over the past 20 years; and will be doubled between the years 2000 and 2010 and grow fourfold between 2000 and 2025 [5]. This rapid increase in demand is due to the combined demands of industrialization and urbanization.

Turkey's primary energy consumption has increased from 32 mtoe (million tons of oil equivalent) in 1980 to 74 mtoe in 1998. According to the planning studies [5], Turkey's final consumption of primary energy is estimated to be 130 mtoe in 2005, 171 mtoe in 2010 and 298 mtoe in 2020 (Figure 1).

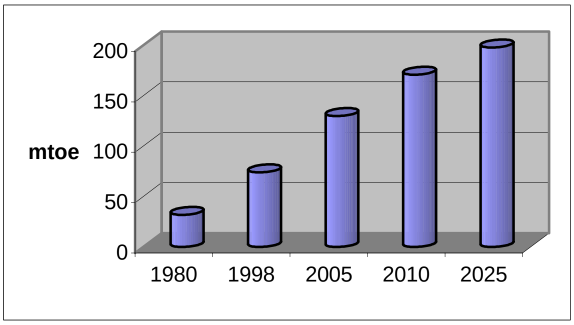

Figure 1. Primary energy consumption in Turkey

The level of Turkey's energy consumption is still low relative to similar sized countries, such as France and Germany, with gross inland consumptions of 235 and 339 mtoe in 1995 and with estimated values of 290 and 350 mtoe in 2020 [5], respectively. However, Turkey's upward trend may mean it will surpass these countries in the future.

Oil has the biggest share in total primary energy consumption. Oil demand grew at an annual average rate of 4.1% between 1979 and 1990. In the following decade, the growth slowed somewhat, and the government expects lower growth rates in the vicinity of 3% per year until 2010 [6]. The government expects oil consumption to increase fastest in the transport sector, leading to a near tripling of demand by 2020. Industrial demand is also expected to more than double by 2020. In the commercial and residential sector, oil consumption is expected to continue to increase, although less rapidly, especially because of the growing demand in agriculture. But, Turkey's oil reserves are minor. The country covered about 10% of its primary oil demand through its own production in 2000 [6], and the remainder had to be imported. As oil demand shows momentous growth, net crude oil and oil products imports also increased at a 4.2% annual average growth rate since 1990.

Turkey has chosen natural gas as the preferred fuel due to some reasons such as environmental, geographic, energy security, economic and political. On the other hand, Turkey does not have satisfactory reserves. As of the end of 1998, the known total reserves were 15.5 billion m^3, of which 12.4 billion m^3 were recoverable. The production of natural gas in Turkey began in 1976 and reached levels of 253 and 565 million m^3 in 1997 and 1998, respectively. However, this production is estimated to be 150 million m^3 by 2010 and 121 million m^3 by 2020 [5].

Turkey has large reserves of coal, particularly of lignite. The proven lignite reserves are 8.0 billion tons. The estimated total possible reserves are 30 billion tons. A majority of this lignite, mostly situated in Afsin-Elbistan, Soma, and Tunçbilek, are characterized by high ash content in the range of 14 to 42%, high moisture content ranging from 15 to 50%, and volatile matter content of 16 to 38% [6].

The production and consumption of renewable energy sources in Turkey was 11 mtoe in 1998 [5]. Renewable energy source production is the second biggest production source after coal production.

1.3.1. Energy Consumption Structure of Turkish Industrial Sector

In 1998, 38% of Turkey's final energy consumption was used by the industrial sector, 34% by the residential sector, 19% by transportation, 5% by the agricultural sector, and 3% by other sources. The share of the industrial sector in this consumption is expected to continue to grow approximately 9% per year and to reach 49% and 59% in 2010 and 2020 [5], respectively. These percentages show that the structure of the

Turkish industrial sector should be investigated from the point of energy conservation. Electricity consumption of the industrial sector is 54% of the total electricity consumption [5]. This is another priority indicator of industrial sector. Table 4 indicates the industrial sub-sectoral energy consumption and the share of the cost of energy production of Turkey.

1.4. Scope of the Work

Energy is defined as the working capacity of a system. However, this explanation describes its physical characterization. From another point of view, namely energy efficiency, it can be defined as providing ‘‘money’’ which makes life comfortable. Briefly, we can say that energy may be shortly defined as money.

The increasing demand, scarce availability of resources with existing technologies and environmental, social and technical limitations are a few and outlining aspects of today’s energy problem.

Energy system modelling may be defined as an investigation of the allocation of energy resources overtime by determining the cheapest and most efficient way of meeting final demands with available and potential resources and technologies. This idea forms the basis of this thesis.

This study examines an energy- intensive plant producing polypropylene films that can be modeled as a flow shop type production. Approximately, one-fourth of the costs belong to energy. Because of this reason, minimizing energy costs is a major problem. Dealing with this problem is the main objective of the study. Detailed information about plant features and problem definition is covered in Chapter 2. Chapter 3 gives a literature review, in which, energy management activities and conservation measures are briefly explained. Beside this, different studies that use mathematical programming to optimise energy costs are examined. Chapter 4 covers the models developed and their features. Chapter 5 gives the numerical solutions of the models. Finally, concluding remarks are outlined in Chapter 6.

Table 4. Industrial sub-sector energy consumption and the share of the cost of energy production of Turkey [5]

Industry	Rate of industrial consumption (%)	Rate of energy in total cost (%)
Iron/steel	34,9	11,5-48
Metals (except iron)	2,3	6,2-47,4
Ceramics	4,5	32,5
Cement	19,7	55
Glass	1,7	22-42
Paper and cellulose	3,4	9-30
Textile and woven	5,9	8-10
Petro chemical	4,6	28,5
Main chemicals	2,2	24
Chemical fertilizer	5,2	40
Petrol refineries	2,9	4
Dye, varnish	0,05	1,6
Medicine	0,12	1,5
Soap, cleaners	0,3	2,1
LPG	0,24	1
Others	4	-
Forest products and furniture	0,52	6
Metal furniture	0,3	4
Flour products	0,06	4
Tea	0,52	3,5
Sugar	2,99	8,5
Oil	0,99	3,7-6
Vegetable and fruit industry	0,47	6,44
Tobacco/beverage	0,77	0,7-6
Total	100	

CHAPTER 2
LITERATURE REVIEW

2.1. Energy Management Modeling

Increasing costs, demand and scarce availability of resources have made energy conservation a necessity for all energy-consuming sector. Thus, energy management has become essential and must be part of all organizations. Energy management in any industry is desirable for financial, social and environmental reasons [8]. The financial reasons focus on the profitability and potential growth of the enterprises, whereas the social and environmental reasons focus on the benefits that the enterprises, their workers and the society get from an energy management.

Energy management applies to all sorts of activities as well as measuring, analysing, controlling, monitoring, distributing and modelling of energy. Callagan and Probert defines [23] "*Energy management applies to resources as well as to supply, conversion and utilization of energy. Essentially it involves monitoring, measuring, recording, analysing, critically examining, controlling and redirecting energy and material flows through systems so that least power is expended to achieve worthwhile aims. A mixture of accurate record keeping, inspired forecasting and persuasive communication is needed.*"

The energy inputs in a plant, generally referred to utilities or power services, are:

- Electricity,
- Fuel,
- Steam,
- Compressed air,
- Refrigeration,
- Water requirements, and
- Inlet gases.

A good sound energy management requires optimum utilization of above energy inputs.

Energy conservation measures can be specified in three categories with respect to their lead times to implement conservation efforts. These are [24]:

1. *Immediate*,
2. *Medium term*, and
3. *Long term*.

Immediate term conservation efforts involve changes in daily practices of energy use, temperature settings, hours of operation, switching off the devices and so on. With these good housekeeping techniques from 5% to 15% energy saving can be made. They involve little or no capital investment, as a matter of fact; the necessary equipment is usually available from the shop floor for instrumentation.

Medium term savings efforts involve minor capital investment and require supervisory level control. These efforts may be insulation of building roof, or heated tanks, pipes and heat recovery applications. With medium term efforts up to 30% savings can be made on total energy consumption.

Long range energy saving efforts may be planned at top management level and involve in major capital investment such as installation of computer control units and process changes. Up to 50% savings have been estimated in the long range with immediate and medium term efforts.

Conservation opportunities with respect to location can be divided into three categories [24]:

1. Energy conservation outside the facility
2. Energy conservation through the building envelope
3. Energy conservation in the facility.

<u>a. Energy Conservation Opportunities Outside And Through The Building:</u>

Conservation opportunities outside and throughout the building envelope are mainly related to transportation, such as location of facility near major transportation facilities, and company transportation fleet and to comfort energy consumption, heating, ventilating and air conditioning (HVAC).

Opportunities related to outside and the envelope of industrial building are:

- *Outside the facility:*

1. Locate energy-efficient property
2. Locate facility properly on the property
3. Landscape to conserve energy
4. Consider use of underground structures
5. Design carefully company fleet
6. Orient facility for energy conservation, and
7. Engineer outside lighting

- *Through the facility envelope:*

1. Insulate well
2. Consider insulating glass or storm
3. Minimize amount of glass
4. Consider windows that can be opened
5. Minimize wall perimeter
6. Consider tinted glass
7. Consider overhangs and awnings
8. Design roof for energy conservation, and
9. Engineer wall openings.

b. Energy Conservation Opportunities Inside The Facility:

Opportunities inside building can be analyzed in two categories, opportunities requiring good house-keeping efforts and no or little capital investment, and opportunities requiring engineering efforts and capital investment. In order to achieve savings by good house-keeping efforts continuous and insistent monitoring of energy use applications are necessary. The conservation considerations requiring good house-keeping efforts may be:

1. Reduce heating temperature settings
2. Increase cooling temperature settings
3. Change lights to those with less wattage per lumen
4. Reduce lighting levels
5. Define all operations to conserve energy
6. Reduce hours of operations
7. Switching off energy consuming equipment when they are not required
8. Meter energy using devices and departments to conserve energy
9. Monitor energy use efficiency of equipment.

Major energy savings results from those, which require engineering implementation and capital expenditure, obviously, involve in cost analysis and modifications in the plant. These conservation considerations may be:

1. Product specification and material changes to eliminate or reduce energy intensive processing requirements.
2. Heat recovery applications to capture the waste heat from one process as the input heat for another process e.g. preheating, space heating in the winter
3. Materials conservation such as the recycling of energy intensive materials, aluminium, steel, and other metals or the burning of waste materials as a boiler fuel, e.g. woodchips, waste fuel.
4. Process changes to achieve better or to the same desired results with less energy.
5. Improved equipment controls to assure the most effective start up and shut down of equipment e.g. computer control.

6. Insulation of heated, cooled tank and steam pipes to prevent heat losses.
7. Electricity generation from the excess steam by using backpressure steam turbines.
8. Improved scheduling and planning of production taking into energy conservation.
9. Improved maintenance of equipment to reduce energy consumption.

Energy management is the judicious and effective use of energy to maximize profits and to enhance competitive positions through organizational measures and optimization of energy efficiency in the process [8]. The energy system consists of an integrated set of technical and economic activities within a complex socioeconomic framework [7]. Its dimensions vary from resources, through production, conversion, transportation, utilization technologies and economies to environmental and social aspects. Therefore, energy management modeling may be defined as an investigation of the allocation of energy resources over time by determining the cheapest and most efficient way of meeting final demands with available and potential resources and technologies.

Energy planning is a dynamic process based on estimates and assumptions for future conditions. There are two approaches to energy system modeling, econometric and process-oriented [7]. The process-oriented approach is employed for normative (optimization) and descriptive (assessment) purposes and uses mathematical programming techniques. In this approach energy flows are described in terms of physical units. The description is not limited to a particular technology but it covers the entire system for the production and utilization of energy. The mathematical programming techniques in modeling are generally linear, nonlinear, dynamic and integer programming. The dual solution of the problem provides a set of information as to alternative variables. A sensitivity analysis of the optimal solution also gives information about the sensitivity of solution to the changes in costs, policy and resources.

In the econometric approach, flows of economic activity, including energy flow, are described in terms of economic accounts in current and constant prices. The econometric models are usually based on the economic concept of the balancing supply and demand at a market-clearing price. The econometric models may be inefficient to analyze the system over a period of time in which demand and prices fluctuate rapidly and new investment technologies take place. For this reason the two approaches are combined, usually the result of predictive models are used as input data for the normative models. Simulation is also used extensively in modeling either on its own or as a combination with dynamic or linear programming to achieve detailed information for a few variables over a long time horizon.

2.2. Mathematical Programming and Optimizing Energy Costs

In recent years, mathematical programming has offered the necessary background for developing solutions for minimizing energy costs in industrial utility systems. Depending on different production situations and problems, various models have been developed.

Combining mathematical programming and thermodynamic analysis for solving energy integration of industrial process appears to be a tool to target minimum energy cost. In order to minimize energy costs and handle environmental constraints, Maréchal and Kalitventzeff [13] developed a new modeling approach and named EMO (effect modeling and optimization) based on mixed integer linear programming (MILP). Interrelationship that exists between energy and environmental targets forms the base structure of the model. The model represents the environmental and energy interactions both in terms of objective functions and constraints and takes into account various effects like heat exchange, mechanical power, emissions, raw material consumption etc. Application of this method showed good results concerning with optimizing energy costs and reducing chemical emissions.

Tari and Söderström [14] studied the influence on energy costs of the use of material storage. The method they developed called "Method for analysis of Industrial energy systems" (MIND) and based on mixed integer linear programming. The method determines how the existence of material stores in an industrial energy system. It can be used to make optimization models for industrial energy systems and has the ability of describing material storage in such models. But, the model does not take into account production planning.

Özdamar and Birbil [15] focused on a hierarchical production planning approach with decision support features for energy intensive industries. Their objective was not only reducing energy costs and seeking for an optimal production plan but also lot sizing. They decomposed the problem into two sub-problems. Higher-level model is an approximate model and identifies the aggregate plan over the planning horizon; second level is more detailed and resolves the issues of family lot sizing and loading in the current planning period. Planning tools are embedded within a decision support framework to result in the so-called Hierarchical Decision Support System (HDSS).

Santos and Dourado [16] used genetic algorithm for their study about multi-objective optimization that included optimizing energy costs and production rate changes. The technique and Pareto ranking method preserves the feasibility of solutions.

The problem of determining the operating schedule that minimizes the operating cost can be solved by different approaches. One of them is stochastic programming. In study of Ierapetritou et. al. [17]; power prices and product demands are known only for a portion of the desired scheduling horizon. Two-stage stochastic programming was used for the study and was based on mixed integer linear programming problem formulation. Binary variables in formulation present operation modes and switching different modes of operation. Results of the study illustrated the accuracy of forecasting and effectiveness of the stochastic optimization to account for future variability in present operating decisions.

Another approach is deterministic programming in which limits have been established. Sensitivity analysis allows going further in investigating the effects of uncertainty on the solution. Sarimveis et. al. [18] used deterministic programming in order to minimize total energy cost and evaluate the capacity for the powerhouse of pulp and paper mills. The problem was solved using standard mixed integer linear programming techniques. The optimum strategy is generated for operating the powerhouse.

Papalexandri et. al. [19] focused on multi-period optimization to explore flexible operating scenario and energy management schemes of real industrial utility systems. A multi-period modeling scheme is proposed to account for variability in energy demand. Mixed integer linear programming is used for the study. Operating issues as changes in operation, valve adjustments, shut-down's and start-up's of auxiliary equipment, etc., are modeled. This model is flexible to accommodate variable demands and robust towards modeling and/or uncertainty in operating conditions.

Örnek and Ekinci [7] studied comparison of various technologies and products of a plant from the energy consumption standpoint. A linear programming model is developed in order to obtain the optimum amount of energy usage in terms of production schedules. Sensitivity analysis allows coping with uncertainties in energy prices and product demands. The model achieves optimum production schedule for the minimum energy cost of the production and choosing alternative technological options.

CHAPTER 3

PROBLEM DEFINITION AND PLANT DESCRIPTION

3.1. Problem Definition

An energy-intensive process producing polypropylene films has been chosen for the thesis. Process has typical features of flow shops [20]:

- Layout of the process is determined by product and has a fixed routing. The production line is laid out according to the processing requirements of the product it is designed to produce.
- Specialized equipments are used and a group of closely related products can be produced.
- The products are produced in high volumes.
- Capacity for each product of the process is well-defined.
- The process has less flexibility to increase production by adding shifts or working overtime because of 7 days-24 hours working time. Thus, productive working becomes important.
- High work force is not required. Highly specialized, trained operators monitor and control process equipments. Labor cost is relatively lower than the others.
- Flow shops may need some work in process to buffer sequential operations from short-range variations in processing rates. The amount of work-in-process inventory is relatively small compared to the throughputs.
- Equipment failure or an important raw material shortage shuts down the production.

A manufacturing system should be tailored to its environment. Two topics are conspicuous in the system: energy cost and production planning. Using specialized equipments and forming some chemical reactions consumes high amounts of electricity and fuel. Besides, taking into account that approximately 25 % of costs are energy costs; problem of minimizing energy costs is put more forth rather than the other process problems.

The other important topic is production scheduling. Manufacturing runs the process via orders from marketing. Instead of products are made and put into inventory before an order is received from a customer; production plans are made based on marketing orders. This production environment puts forth production planning because of the following reasons:

1. Process is not flexible because of 7 days-24 hours working time.
2. Since they use expensive raw materials, allocation of raw material is important. They do not tend to produce products to stock.
3. There are no sub-inventories between the stages of the line.

Marketing department of the plant forecasts expected monthly customer orders in a year at the beginning of the year. Required processing time for each product in a month can be formulated as follows:

Required processing time = set-up time + capacity * production amount
(hr) (hr) (hr/kg) (kg)

If the products that are expected to be sold at the end of a month are produced in the same month, required processing times are listed below (Table 4 and Figure 2). But the system has a processing time limit for each month. Moreover, for equipment cleaning, the process should be stopped for 48 hours a month. Available capacities of the process for each month are also listed. Figure 2 indicates some situations that available capacities are not sufficient to produce the required products (i.e. in the 10^{th} month). Also for some months, production does not have enough flexibility to give reaction to unexpected orders since required processing times are very close to the capacities.

These two points have been evaluated in a plant independently. Not taking into consideration the other factors that affects the process, energy conservation methods have been used in order to minimize total energy cost. From production schedule point of view, only meeting customer demends in time have been teken into consideration. In this study these points are evaluated together as the factors that affects each other.

Table 4. Comparison of total processing time and available capacity.

Months	Total processing time (hr)	Available capacity (hr)
1	586	696
2	591	624
3	595	696
4	565	672
5	589	696
6	521	672
7	538	696
8	617	696
9	550	672
10	734	696
11	630	672
12	526	696

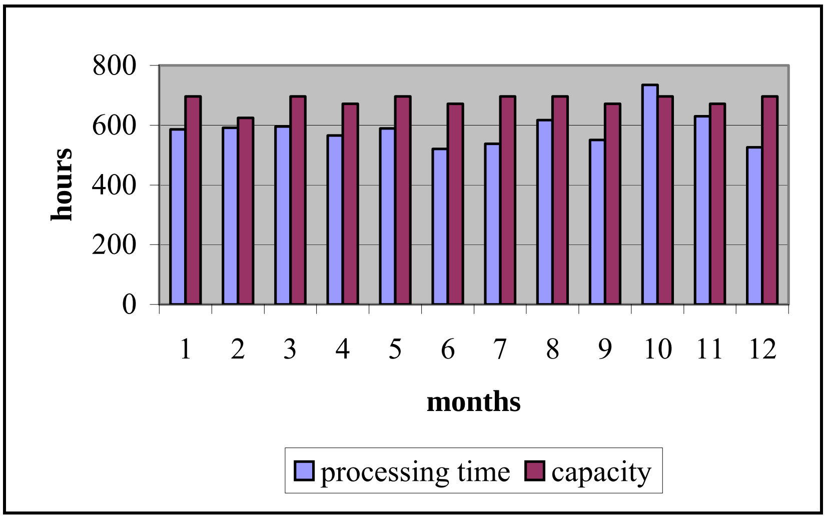

Figure 2. Comparison of processing time and capacity.

Objective of the thesis is to develop mathematical models that meet the finished product requirements at a minimum cost of energy used in the process subject to different operational constraints. In spite of the fact that all models have the same objective; some factors, such as capacity, product demands, inventory urges different models to be developed. Results clearly indicate that which model or models to be utilized is a decision to be taken by the top management.

3.2. Plant Description

The plant considered for this study consists of 5 stages. Each stage can be defined as a machine group that is used for different purposes. There is no technological option or alternative way of processing products on the layout. The production line has a fixed routine. All products are processed in first three stages. But, the way of processing in other stages depends on the type of finished products.

The energy inputs of the process are electricity and fuel. The last four stages consume only electricity to operate the mechanical devices. The first stage consumes not only electricity; but also fuel that is directly burnt in oil boiler. Figure 2 indicates the stages, their energy inputs and products processed in each stage.

Analysis of each stage with respect to energy use, products and technologies are given below:

Stage 1:

This is the first stage of the process. Raw materials and recycled materials are the material input of the stage. 2% of the products processed in stage 1 (that is illustrated as X_{1jk} in figure 2) are sent to stage 2; 98% of the products are sent to stage 3.

Stage 1 consists of chemical process-machine groups; and is the biggest consumer of energy in the process. It consumes electricity and fuel. Fuel is burnt in the oil boiler. Superheated oil is only used for chemical process in stage 1. The capacity of the boiler is 1800000 kcal/hr and the efficiency of the boiler is 90%. Total electric power expended in stage 1 is 4082,727 kW.

Stage 2:

Stage 2 can be defined as recycling unit. Wasted materials in stage 1 and stage 3 are processed (that is illustrated as X_{2jk} in figure 2) to be used in stage 1. This stage consumes electricity and its total electric power expended is 395,272 kW.

Stage 3:

The material input of stage 3 is sent from stage 1. The product processed in stage 3 is illustrated as X_{3jk} in figure 2. Approximately, 8,16% of product in stage 3 is sent to stage 2 to be recycled. Depending on what the finished product is 91,83% of X_{3jk} is sent to inventory and/or stage 4. Some product groups (X_{31k} and X_{33k}) are sent to inventory as finished products (P_{11k} and P_{13k}); but, some product groups such as X_{32k} and X_{36k} are sent to stage 4 to be processed. These product flow decisions are determined by marketing policy and chemical feature of the product. However, Some product groups such as X_{34k}, X_{35k} and X_{37k} can be sent both inventory and stage 4. The amounts of the products to be sent to inventory and stage 4 are determined by customer orders.

The energy input of stage 3 is electricity and total electric power expended is 230 kW.

Stage 4:

The input material of stage 4 is sent from stage 3. The product processed in stage 4 is illustrated as X_{4jk} in figure 2 and is sent to stage 5. There is not any waste that can be taken into account in this stage. The only energy input of the stage 4 is electricity. Its total electric power expended is 1163 kW.

Stage 5:

This is the last stage of the production line. Products sent from stage 4 are processed in this stage (that is illustrated as X_{5jk} in figure 2). Approximately, 0,48% X_{5jk} is wasted and cannot be recycled. 99,52% of X_{5jk} is sent to the inventory as finished products (P_{22k}, P_{24k}, P_{25k}, P_{26k}, P_{27k}). This stage consumes electricity and the total electric power expended is 322 kW

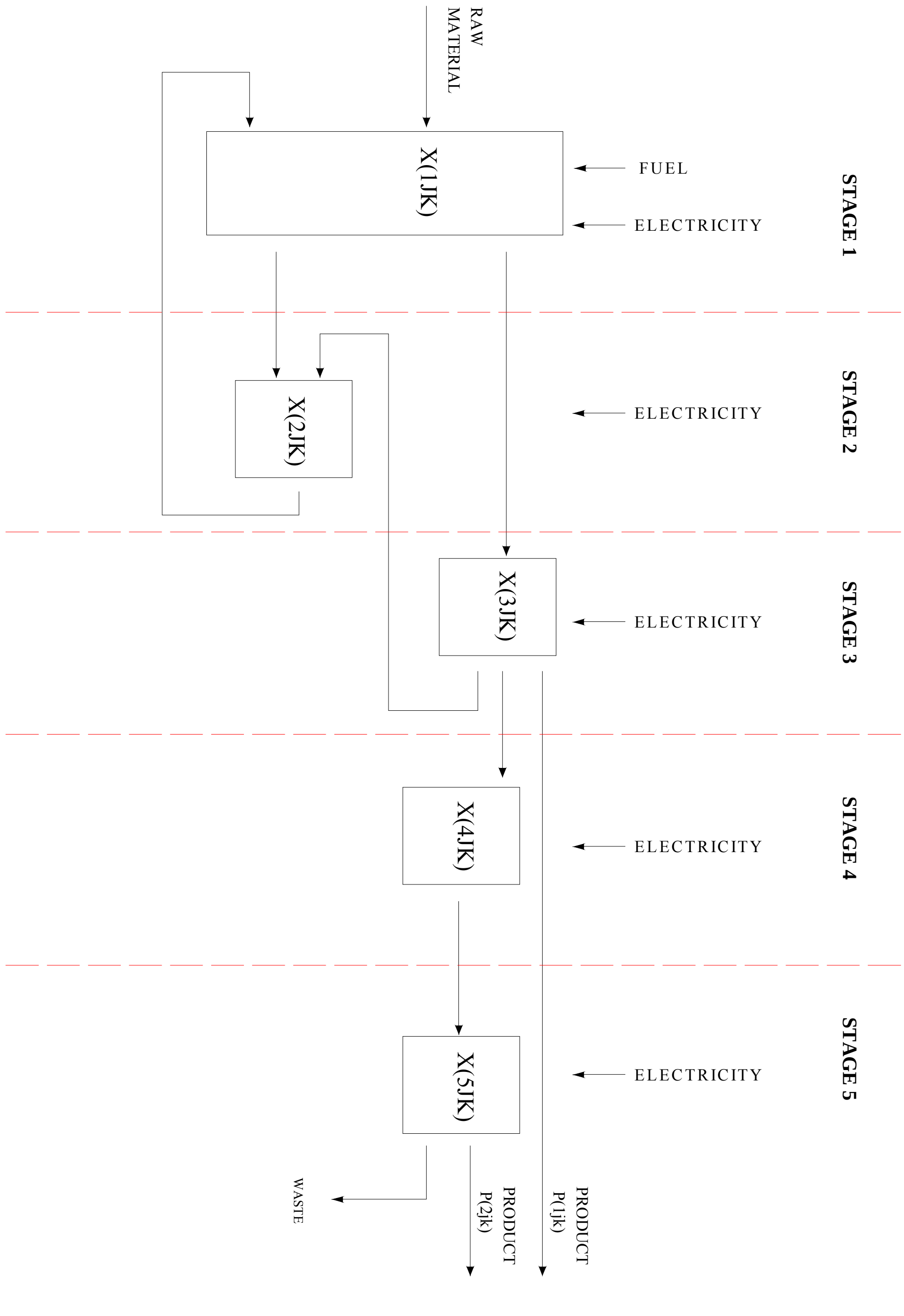

Figure 3. Production flow chart

CHAPTER 4
MODEL FORMULATION

4.1. The Models

The objective of this study is to build a mathematical model that will form a product-mix by meeting monthly customer demands and minimizing total energy costs at the same time. Nevertheless; different approaches to finished product inventory and utilization of available time capacity have supported developing four different mathematical models.

Multi-period and multi-stage linear programming is used in the development of the models. Multi-period and multi-stage models are mainly used for the analysis of process where flexibility is an important factor and is required for production scheduling. The model does not include the energy use for various areas such as lighting, ventilating, heating and miscellaneous use of energy, since as such use of energy is not directly related with the production. Material balance equations are the main feature of multi-stage linear programming and they ensure the material flows between the stages taking into account the process inventories. However, there are no process inventories between the stages since the system is a continuous process.

4.1.1. Model 1

Model 1 is the base form of all models. The aim of the model is to minimize total energy costs and form a product-mix. A conspicuous point in model 1 is inventory. In demand constraints (see equations (4.11), (4.12), (4.13) and (4.14)), finished products in inventory are classically defined, but there is no any restriction to use inventory. Nevertheless, the other important point is time capacity utilization. In time capacity constraints of the model (see equations (4.15), (4.16) and (4.17)), upper limit of processing time in a month is determined as its available capacity. Also, the model is unrestricted from available time capacity utilization point of view. Material balance equations are general expressions of material flows in the process. These constraints (see equations (4.2), (4.3), (4.4), (4.5), (4.6), (4.7), (4.8), (4.9) and (4.10)) are based on material-flows relations between the stages. Model 1 can be considered as a model that simply attains the goal of the study. Parameters such as balance between available time capacity utilization and limiting inventory utilization are not taken into account.

Objective Function

The objective function is to minimize total energy costs.

$$\text{Minimize } (Z) = \sum_{i=1}^{5} \sum_{j=1}^{7} \sum_{k=1}^{12} (E_{ij} + F_{ij}) X_{ijk} \qquad (4.1)$$

The objection function coefficients are the electricity cost *(E_{ij})* and fuel cost *(F_{ij})* per unit of product to be produced. These cost coefficients are calculated by multiplying amount of energy used to produce one unit of product (detailed information is provided in section 4.2.Data Analysis and Appendix B.2) by the cost of per unit of energy. The calculated cost coefficients are listed in Table B.6. Transferred form of objective function is given in appendix C.1.

Material Balance Equations

$$X_{2jk} = 0,02\ X_{1jk} + 0,816\ X_{3jk} \qquad (4.2)$$

$$X_{3jk} = 0,98\ X_{1jk} \qquad (4.3)$$

$$P_{1jk} = X_{3jk} - X_{4jk} \qquad (4.4)$$

$$X_{41k} = 0 \qquad (4.5)$$

$$X_{43k} = 0 \qquad (4.6)$$

$$P_{12k} = 0 \qquad (4.7)$$

$$P_{16k} = 0 \qquad (4.8)$$

$$X_{5jk} = X_{4jk} \qquad (4.9)$$

$$P_{2jk} = 0,9952\ X_{5jk} \qquad (4.10)$$

These constraints are the mathematical forms of the material flows of the process. The constraint (4.2) represents the waste material flow from stage 1 and stage 3 to stage 2 to be recycled. Constraint (4.3) represents the material flow from stage 1 to stage 3. Constraint (4.4) accounts for the material flow from stage 3 to the finished product inventory and stage 4. Constraint (4.5) and (4.6) represent that product 1 and product 3 cannot be processed in stage 4 and stage 5; and they are only sent to the finished product inventory. Constraint (4.7) and (4.8) represent that product 2 and product 6 cannot be sent to the finished product inventory after stage 3; and they are only sent to stage 4. Constraint (4.9) represents the material flow from stage 4 to stage 5. Constraint (4.10) accounts for the material flow from stage 5 to the finished product inventory.

Demand Constraints

$$P_{ij1} \geq D_{ij1} \qquad (4.11)$$

$$I_{ij1} = P_{ij1} - D_{ij1} \qquad (4.12)$$

$$I_{ijk} + P_{ij(k+1)} \geq D_{ij(k+1)} \qquad (4.13)$$

$$I_{ij(k+1)} = (\ I_{ijk} + P_{ij(k+1)}\ ) - D_{ij(k+1)} \qquad (4.14)$$

Constraint (4.12) and constraint (4.14) describe the finished products in inventory. Constraint (4.11) and constraint (4.13) ensure that the amount of finished product in inventory cannot be negative.

Time Capacity Constraints

$$\sum_{j=1}^{7} (S_j\, Y_j + R_j\, (P_{1jk} + P_{2jk})) \leq C_k \qquad (4.15)$$

$$(P_{1jk} + P_{2jk}) \leq M\, Y_j \qquad (4.16)$$

$$(P_{1jk} + P_{2jk}) \geq Y_j \qquad (4.17)$$

$$X_{ijk} \geq 0 \qquad (4.18)$$

$$Y_j = 0 \text{ or } 1 \qquad (4.19)$$

Constraint (4.15) represents that the total production time in a month cannot exceed available capacity (Table 5) in that month. In Constraint (4.15), S_j illustrates required set-up times for each product (Table A.10); and *Rj* illustrates required processing time to produce one unit of product (Table A.9). Constraint (4.16), (4.17) and (4.19) ensure that set-up times of the products are taken into account if the products are produced in that month. In order to make sure of these constraints, Y_j (that is a binary variable) and *M* (that is a big number) are used. Constraint (4.18) represents that the amount of processed products in all stages and finished products cannot be negative.

4.2. Model 2

Model 2 is the developed form of model 1. Results of model 1 indicate that product in inventory may be stored for an undesirable period of time (e.g. product 6 is held for 6 months in inventory, see Appendix C.3). In this circumstance, inventory-holding costs increase to undesirable levels. In order to prevent this, model 2 limits stored time of finished products in inventory. The products can be kept stored only for one month. This idea develops new demand constraints ((4.20.a) and (4.20.b)) for model 2. From time capacity utilization point of view, model 2 is also unrestricted like model 1. In time capacity constraints of the model (see (4.15), (4.16) and (4.17)), upper limit of processing time in a month is determined as its available capacity. Material balance equations ((4.2), (4.3), (4.4), (4.5), (4.6), (4.7), (4.8), (4.9) and (4.10)) cannot be changed in model 2 because of structure of the process. Model 2 can be considered as a stable model. Limiting stored time of finished products in inventory will have an effect on preventing fluctuations of available time capacity utilization in model 2.

Objective Function

Objective function of model 2 is the same as objective function of model 1.

$$\text{Minimize } (Z) = \sum_{i=1}^{5} \sum_{j=1}^{7} \sum_{k=1}^{12} (E_{ij} + F_{ij})\, X_{ijk} \tag{4.1}$$

Material Balance Equations

Material balance equations in model 2 are the same as in model 1.

$$X_{2jk} = 0{,}02\, X_{1jk} + 0{,}816\, X_{3jk} \tag{4.2}$$

$$X_{3jk} = 0{,}98\, X_{1jk} \tag{4.3}$$

$$P_{1jk} = X_{3jk} - X_{4jk} \tag{4.4}$$

$$X_{41k} = 0 \tag{4.5}$$

$$X_{43k} = 0 \tag{4.6}$$

$$P_{12k} = 0 \tag{4.7}$$

$$P_{16k} = 0 \tag{4.8}$$

$$X_{5jk} = X_{4jk} \tag{4.9}$$

$$P_{2jk} = 0{,}9952\, X_{5jk} \tag{4.10}$$

Demand Constraints

Demand constraint (4.11) is valid also for model 2.

$$P_{ij1} \geq D_{ij1} \qquad (4.11)$$

In model 2, the products are not allowed to be stored in finished products inventory more than one month to prevent the plant from high inventory holding costs. In order to represent this:

$$I_{ijk} + I_{ij(k+1)} = 0 \qquad (4.20.a)$$

Constraint (4.20.a) can be simplified as;

$$P_{ijk} - D_{ijk} + P_{ij(k+1)} - D_{ij(k+1)} = 0 \qquad (4.20.b)$$

Constraint (4.20.b) ensures that total amount of finished products in two months must be equal to total amounts of their demands in those two months.

Time Capacity Constraints

Time capacity constraints in model 2 are the same as in model 1.

$$\sum_{j=1}^{7} (S_j Y_j + R_j (P_{1jk} + P_{2jk})) \leq C_k \qquad (4.15)$$

$$(P_{1jk} + P_{2jk}) \leq M Y_j \qquad (4.16)$$

$$(P_{1jk} + P_{2jk}) \geq Y_j \qquad (4.17)$$

$$X_{ijk} \geq 0 \qquad (4.18)$$

$$Y_j = 0 \text{ or } 1 \qquad (4.19)$$

4.1.3. Model 3

Model 1 and model 2 indicate that time-utilizations of the models are below their available capacities. These available unused times can be utilized with the same objective of the previous models. This point causes to develop model 3. Available time capacity utilization is restricted to be used 100 % (see Constraint (4.22)). Thus, model 3 fills unused time-gaps in model 1 and 2. It gives an opportunity to increase production in the plant. Also, demand constraints ((4.21), (4.12), (4.13) and (4.14)) are adapted to fulfill unused time-gaps, but ther is no restriction which products should be producted. Model chooses the optimal one to increase production. Material balance equations ((4.2), (4.3), (4.4), (4.5), (4.6), (4.7), (4.8), (4.9) and (4.10)) cannot be changed in model 3 because of structure of the process. Different from models 1 and 2, model 3 puts forth production increase. But, managerial aspects or marketing aspects are not taken into account.

Objective Function

Objective function of model 3 is same as objective function of model 1 and model 2.

$$\text{Minimize } (Z) = \sum_{i=1}^{5} \sum_{j=1}^{7} \sum_{k=1}^{12} (E_{ij} + F_{ij})\, X_{ijk} \qquad (4.1)$$

Material Balance Equations

Material balance equations in model 3 are the same as in model 1 and model 2.

$$X_{2jk} = 0{,}02\, X_{1jk} + 0{,}816\, X_{3jk} \qquad (4.2)$$

$$X_{3jk} = 0{,}98\, X_{1jk} \qquad (4.3)$$

$$P_{1jk} = X_{3jk} - X_{4jk} \qquad (4.4)$$

$$X_{41k} = 0 \quad (4.5)$$

$$X_{43k} = 0 \quad (4.6)$$

$$P_{12k} = 0 \quad (4.7)$$

$$P_{16k} = 0 \quad (4.8)$$

$$X_{5jk} = X_{4jk} \quad (4.9)$$

$$P_{2jk} = 0{,}9952\ X_{5jk} \quad (4.10)$$

Demand Constraints

Constraint (4.21) ensures that total production of a product in a year must be equal to or greater than total demand of the product in a year. Demand constraints (4.12), (4.13) and (4.14) are the same as in model 1.

$$\sum_{k=1}^{12} P_{ijk} \geq \sum_{k=1}^{12} D_{ijk} \quad (4.21)$$

$$I_{ij1} = P_{ij1} - D_{ij1} \quad (4.12)$$

$$I_{ijk} + P_{ij(k+1)} \geq D_{ij(k+1)} \quad (4.13)$$

$$I_{ij(k+1)} = (\ I_{ijk} + P_{ij(k+1)}\ ) - D_{ij(k+1)} \quad (4.14)$$

Time Capacity Constraints

Time-utilization in a month must be equal to available time-utilization capacity in that month. Constraint (4.22) represents this point as;

$$\sum_{j=1}^{7} (S_j\, Y_j + R_j\, (P_{1jk} + P_{2jk})) = C_k \qquad (4.22)$$

Constraint (4.16), (4.17), (4.18) and (4.19) are valid also for model 3.

$$(P_{1jk} + P_{2jk}) \leq M\, Y_j \qquad (4.16)$$

$$(P_{1jk} + P_{2jk}) \geq Y_j \qquad (4.17)$$

$$X_{ijk} \geq 0 \qquad (4.18)$$

$$Y_j = 0 \text{ or } 1 \qquad (4.19)$$

4.1.4. Model 4

Model 3 tends to produce only one product to utilize unused time capacities, which is optimum for objective function. However, this is not a preferable situation for marketing. There may not be sufficient demand for that product. Instead of increasing production of one product, it would be better to spread it to all products. Also results of model 3 indicate that product in inventory may be stored for an undesirable period of time (see Appendix E.3). Under this circumstance, inventory-holding costs increase to undesirable levels. In order to prevent inventory-holding cost increase and achieve production increase for more products, model 4 is developed. Model 4 is the extention of model 2. Different from model 3, demand constraints ((4.23), (4.20.a) and (4.20.c)) limit stored time of finished products in inventory as in model 2 and determine a limitation for production increase of the process. This yield not only increasing prouction of optimum product but also the others (see constraint (4.15), (4.16) and (4.17)).Unlike model 3, from time capacity utilization point of view, model 4 is unrestricted. Because of the fact that some months in model 2 are not appropriate for production increase (e.g. time capacity utilization in month 11 is 100 % and in month 10 is 98 %), it limits production increase in certain months that utilize less capacity than the other months. The percentage of production increase and in which months available capacity utilization increase would be are determined by top management taking into account marketing and process conditions. Unlike the other models, it gives an opportunity to evaluate opinions of marketing department. Thus, model 4 can be considered as the most adaptable model to the marketing and economic conditions.

Objective Function

Objective function of model 4 is the same as objective function of previous models.

$$\text{Minimize } (Z) = \sum_{i=1}^{5} \sum_{j=1}^{7} \sum_{k=1}^{12} (E_{ij} + F_{ij}) X_{ijk} \tag{4.1}$$

Material Balance Equations

Material balance equations in model 4 are the same as in model 1, model 2 and model 3.

$$X_{2jk} = 0{,}02\ X_{1jk} + 0{,}816\ X_{3jk} \tag{4.2}$$

$$X_{3jk} = 0{,}98\ X_{1jk} \tag{4.3}$$

$$P_{1jk} = X_{3jk} - X_{4jk} \tag{4.4}$$

$$X_{41k} = 0 \tag{4.5}$$

$$X_{43k} = 0 \tag{4.6}$$

$$P_{12k} = 0 \tag{4.7}$$

$$P_{16k} = 0 \tag{4.8}$$

$$X_{5jk} = X_{4jk} \tag{4.9}$$

$$P_{2jk} = 0{,}9952\ X_{5jk} \quad (4.10)$$

Demand Constraints

In also model 4, the products are not allowed to be stored in finished products inventory more than one month to prevent the plant from high inventory holding costs. Because of this reason, Demand constraint (4.20.a) is valid for model 4. Demand coefficient, *A*, in constraints (4.23), (4.20.c) ensure that production of a product in determined months increased to *A* times of the demand of the product in those months. Management determines these parameters. In this study, the months in which production increase would be determined as month 4, 6, 7, 8 and 12. Capacity utilization in these months in model 2 is under 85 % that is total capacity utilization for a year. Production increase is determined as 15 % in these months.

$$P_{ij1} \geq A_{ij1} * D_{ij1} \quad (4.23)$$

$$I_{ijk} + I_{ij(k+1)} = 0 \quad (4.20.a)$$

Taking into consideration demand increase, constraint (4.20.a) can be adapted as;

$$P_{ijk} - A_{ij1} * D_{ijk} + P_{ij(k+1)} - A_{ij1} * D_{ij(k+1)} = 0 \quad (4.20.c)$$

Constraint (4.20.c) ensures that total amount of finished products in two months must be equal to total amounts of their demands in those two months.

Time Capacity Constraints

Time capacity constraints in model 4 are the same as in model 1 and 2.

$$\sum_{j=1}^{7} (S_j\ Y_j + R_j\ (P_{1jk} + P_{2jk})) \leq C_k \quad (4.15)$$

$$(P_{1jk} + P_{2jk}) \leq M\ Y_j \quad (4.16)$$

$$(P_{1jk} + P_{2jk}) \geq Y_j \quad (4.17)$$

$$X_{ijk} \geq 0 \quad (4.18)$$

$$Y_j = 0 \text{ or } 1 \quad (4.19)$$

4.2. Data Analysis

The necessary information about:

- ✓ Forecasts for future monthly demands,
- ✓ Current work in process,
- ✓ Capacity of the process,
- ✓ Material availability,
- ✓ Management policies,
- ✓ Power expanded at each stage, etc.

are gathered from historical records, data from management office and the process. The information is analyzed to use in mathematical formulations.

The necessary input data for the model are mainly the electricity and fuel oil used per unit of each product at each stage. The units of energy used are *kWh* of electricity and *Lt* of fuel oil.

In order to calculate the amount of fuel burnt in the boilers to heat the necessary oil required for the process a thermodynamic formula is quoted, which is:

$$\eta = \frac{m_{oil}\ C\ \Delta T}{m_{fuel}\ C_v} \quad (4.22)$$

where;

η (boiler efficiency) = 0,90

m_{oil} (mass flow-rate of oil) = 100 m^3/h

C (specific heat of oil) = 1,8 kJ/kgK

ΔT (temperature difference of oil) = 20 K

C_v (calorific value of fuel) = 8426,4832 kJ/kg

Under this circumstance;

m_{fuel} (mass flow-rate of fuel) = 0,4746 m^3/h

Obtaining the data about electric power expended, and fuel usage; units of energy consumed per unit of product can be calculated easily by dividing them with production rate. These calculations are detailed in appendix B.2. The energy cost of per unit of product is the amount of energy used to produce one unit product multiplied by the cost per unit of energy. The electricity cost per kWh is $ 0,096 and fuel oil per Lt is $ 0,473 (January 2003 data [21]). These prices are assumed to be stable for a year.

CHAPTER 5
RESULTS AND DISCUSSION

5.1. Results of Model 1

Model 1 consists of 454 variables and 1398 constraints. The minimum cost of product mix, when the electricity cost per kWh is $ 0,096 /kWh, and fuel oil is $ 0,473 /Lt, is $ 5436618 for the planned year. (Optimum production schedule for the minimum energy costs is given in appendix C.2)

In the beginning, results can be evaluated taking into account required processing times. Comparison of required processing time per month and its available time capacity is given in Table 5 and Figure 4. In months 1, 2, 4, 5, 7, 8, 9, 10, the process utilizes their available time capacities. These values are the upper bound of the time capacity utilization. In month 11, processing time is 14 hours, and utilization of time capacity decrease to 2%. This is the lower bound. In model 1, time capacity utilization fluctuates between these bounds. As it is seen in figure 4, there are unused time-gaps that are available to be used. But, these are not spread over 12 months. Because of this reason model is not flexible for unexpected customer demands or to increase production in certain months.

Table 5. Comparison of total processing time and time capacity for model 1

	Required Processing Time (hr)	Available Capacity (hr)	Capacity Utililization (%)
Month 1	696	696	100
Month 2	624	624	100
Month 3	608	696	87,3
Month 4	672	672	100
Month 5	696	696	100
Month 6	506	672	75,2
Month 7	696	696	100
Month 8	696	696	100
Month 9	672	672	100
Month 10	696	696	100
Month 11	15	672	2
Month 12	348	696	50
Toplam	6925	8184	84,6

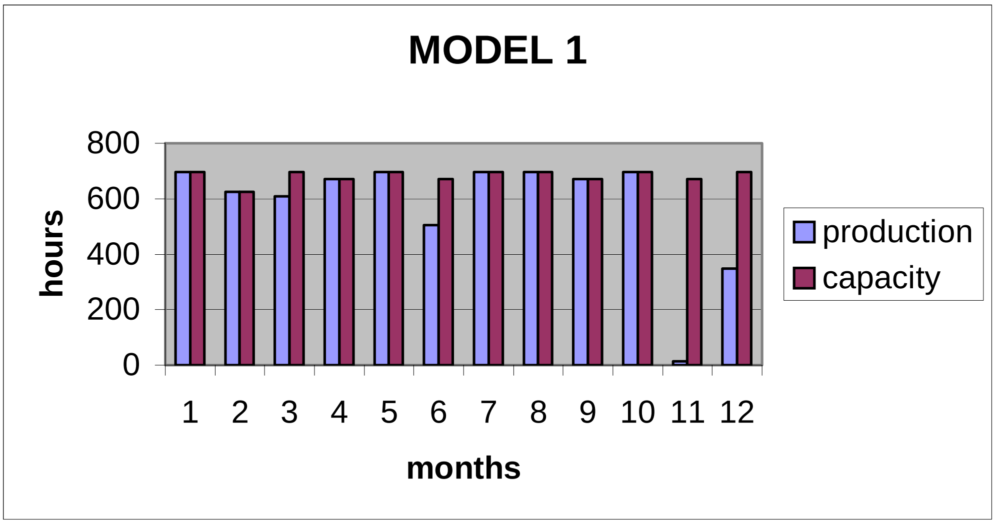

Figure 4. Comparison of total processing time and time capacity for model 1

Production, demand and inventory results of model 1 can be seen in appendix C.2 and C.3. Conspicuous point is inventory in model 1. Inventory holding costs are not evaluated in this study. But, from management point of view, it is an undesirable parameter. Finished products in inventory caused an expense-inventory holding cost. If the fact that finished products are held in inventory consecutively more than one month is considered, it is obvious that significant amount of inventory holding cost should be added to expenditure of the plant.

Results of model 1 provides optimum production mix with minimum energy cost. However, it yields unexpected result such as unstable unused time capacities and high inventory holding costs.

5.2. Results of Model 2

Model 2 consists of 492 variables and 1826 constraints. Minimum energy cost of the product mix is $ 5436618. This is equal to model 1 because of the fact that amounts of processed products are not increased or decreased. (Optimum production schedule for the minimum energy costs is given in appendix D.2)

Also in this model, required processing time is an important point to be evaluated (see table 6). There is only one month, month 11, in which required processing time is equal to its capacity. It is the upper bound of the time capacity utilization. Time capacity utilization of month 12 is 69,5%. This is the lower bound of time capacity utilization in model 2. It fluctuates between these bounds. As seen in figure 5, unused time-gaps spread over one year period as contrary of model 1. Under this circumstance, the model is more flexible to give reaction to unexpected customer orders for all months except month 11.

Table 6. Comparison of total processing time and time capacity for model 2

	Required Processing Time (hr)	Available Capacity (hr)	Capacity Utililization (%)
Month 1	628	696	90
Month 2	549	624	88
Month 3	637	696	92
Month 4	523	672	78
Month 5	631	696	91
Month 6	478	672	71
Month 7	580	696	83
Month 8	575	696	83
Month 9	592	672	88
Month 10	681	696	98
Month 11	672	672	100
Month 12	484	696	69,5
Toplam	7030	8184	85,8

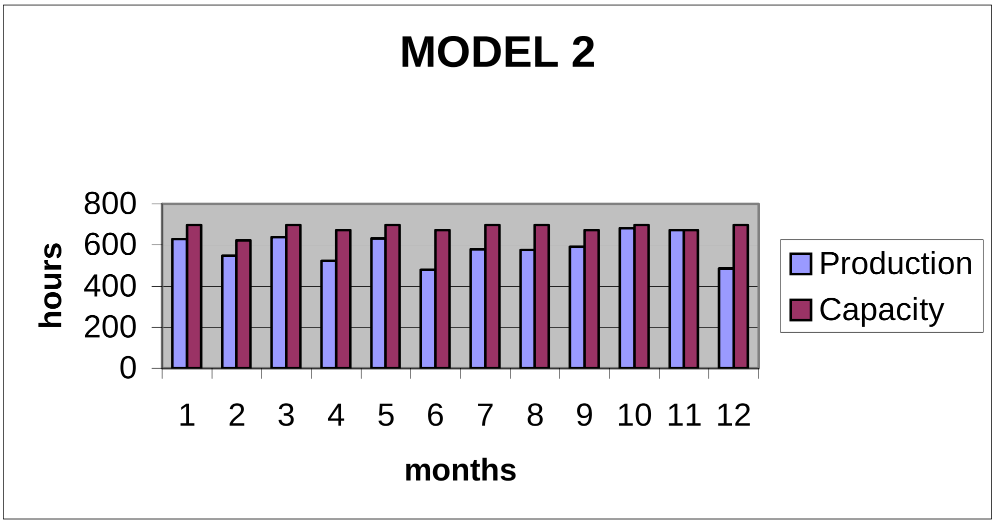

Figure 5. Comparison of total processing time and time capacity for model 2

From inventory-utilization point of view, model 2 gives better results (see appendix D.2 and figure D.3). Finished products except P 24 are not required being held in inventory. However, P24 is not held more than one month in inventory. If the results of model 2 are compared with model 1, inventory holding cost has significantly less impact on expenditure of the plant. This can be evaluated as an important advantage of the model. Developing model 2 causes portion of inventory holding costs in expenditures of the plant to decrease.

5.3. Results of Model 3

Model 3 consists of 511 variables and 1613 constraints. Results of model 3 are the answer of what would happen if time capacity utilization were 100 %. Model wants to produce the optimum product (suiting the objective function and constraints) in order to fill the time-gaps. (Optimum production schedule for the minimum energy costs is given in appendix E.2)

Table 7. Production increase in a year in model 3

	Demands (kg)	Production (kg)	Increase (%)
P 11	288577	288577	0
P 22	7000	7000	0
P 13	1118908	1118908	0
P 14	3423	3423	0
P 24	1525886	1525886	0
P 15	3043013	3043013	0
P 25	1531913	1531913	0
P 26	21723	21723	0
P 17	112177	1581389	1300
P 27	824517	824517	0
Total	8477137	9946349	17,33

In this process, the optimum product to fill the time-gaps is P17 (see appendix E.3). P17 is the third product that has least energy cost. Nevertheless, its production rate is more than production rate of first and second products. If first or second were chosen, more amounts of product would be processed, and this would cause to have more energy costs. The total forecasted demand in a year is 112177 kg. But, production of

P17 is 1581388,8 kg. Production increase is approximately 13 times of its demand. The other products are produced as their demands. Thus, total production increase is 17,33%.

Minimum energy cost of model 3 is $ 6262698. If it is compared with model 1 and 2, there is a 15.19 % energy cost increase due to increase in production.

5.4. Results of Model 4

Model 4 consists of 576 variables and 2078 constraints. Unlike model 3, time capacity utilization of model 4 is unrestricted. But, it tries to increase time capacity utilization to increase production for more products. Model 4 limits increase production amounts of products in certain months and in certain percentages that are determined by management from marketing point of view. In this study, production increase is allowed only in month 4, 6, 7, 8 and 12 and percentage of production increase for all products that is produced in those months is determined as 15 %. (Optimum production schedule for the minimum energy costs is given in appendix F.2)

Idea behind the model 4 is to increse production producing more products and reduce inventory-holding costs, which suit objective function and constraints. Comparison of required processing time per month and its available time capacity is given in table 8 and figure 6. As in model 2, the upper bound of the time capacity utilization is in month 11 by 100 % utilization. Time capacity utilization of month 12 is 81%. This is the lower bound of time capacity utilization in model 4. It fluctuates between these bounds. Production increases of the products are listed in table 9. Total production increase of all products is 6 %. For product P 22, there is no increase because there is no production for that product in month 4, 6, 7, 8 and 12. The upper bound in production increase is for P 14. It is 12 %. For the other products, it fluctuates between 4 and 8 %.

From inventory-utilization point of view, model 4 gives good results (see appendix F.2 and figure F.3). Finished products except P 25 are not required being held in inventory. However, P 25 is not held more than one month in inventory. Thus, inventory holding cost has significantly less impact on expenditure of the plant.

Minimum energy cost of the model is $ 5756370. Energy cost increase compared with model 1 and 2 is 6 %.

Model 4 can be evaluated as a stable model from production increase, capacity utilization and inventory-utilization point of view.

Table 8. Comparison of total processing time and time capacity for model 4

	Required Processing Time (hr)	Available Capacity (hr)	Capacity Utilization (%)
Month 1	628	696	90
Month 2	549	624	88
Month 3	637	696	92
Month 4	607	672	90
Month 5	631	696	91
Month 6	556	672	83
Month 7	660	696	95
Month 8	666	696	96
Month 9	592	672	88
Month 10	681	696	98
Month 11	672	672	100
Month 12	562	696	81
Total	7442	8184	91

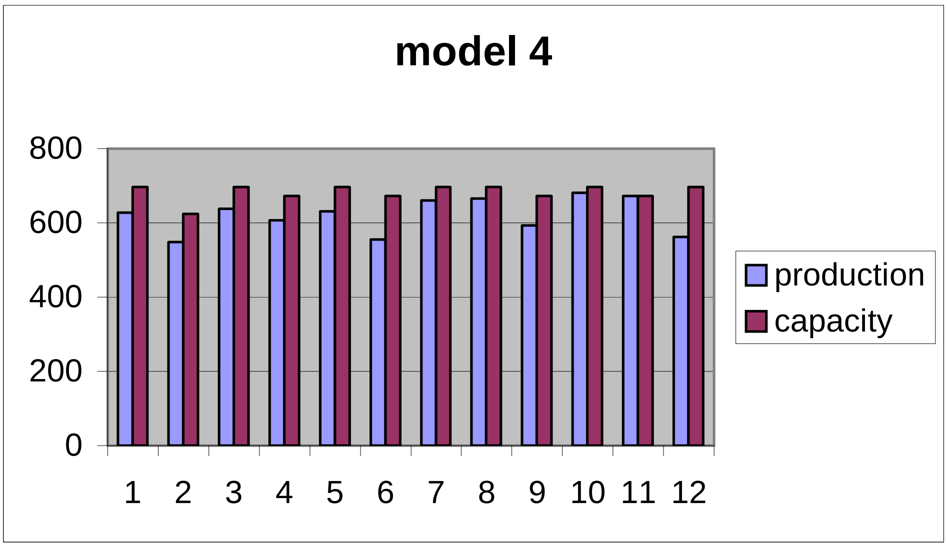

Figure 6. Comparison of total processing time and time capacity for model 4

Table 9. Production increase in a year in model 4

	Demands (kg)	Production (kg)	Increase (%)
P 11	288577	308254	7
P 22	7000	7000	0
P 13	1118908	1184114	6
P 14	3423	3819	12
P 24	1525886	1607053	5
P 15	3043013	3222732	6
P 25	1531913	161240	5
P 26	21723	22580	4
P 17	112177	118814	6
P 27	824517	888689	8
Total	8477137	8975242	6

5.5. Sensitivity Analysis.

Sensitivity analysis is important for several reasons. In many applications, the values of an linear program's (LP) parameters may change. If a parameter changes, sensitivity analysis often makes it unnecessary to solve the problem again. Knowledge of sensitivity analysis often enables the analyst to determine from the original solution how changes in an LP's parameters change the optimal solution. LINGO, the computer-software program, enables to determine the range of values for an objective function coefficients and right-hand sides of constraints within which the current basis remains optimal.

Since the aim of the study is to focus on the energy costs, sensitivity analysis is related to the changes in prices of the resources. It would be more meaningful to deal with the change in fuel oil and electricity prices separately and their effects on optimal production values. Since all cost values are used in the objective function coefficients, and changes in fuel oil prices and electricity prices have an impact on more than one coefficient; 100 % rule [11] can be useful.

To implement the rule a ratio, r, should be determined for each variable. r can be defined as the ratio of change in objective function coefficient to maximum allowable increase/decrease. The rule states that if $\Sigma r \leq 1$, it ensures that the current basis remains optimal. If $\Sigma\ r > 1$, the current basis may or may not be optimal. If the current basis remains optimal, the values of the decision variables remain unchanged, but the optimal z-value may change.

Considering these points and obtained objective function coefficient ranges from LINGO output (see Appendix C.4 for model 1, Appendix D.4 for model 2, Appendix E.4 for model 3 and Appendix F.4 for model 4), allowable price limits are determined. For model 1, it is assumed that electricity price is staying constant, fuel oil increase is calculated as \$ 0 and decrease is calculated as \$ 0,2898. Thus, current production schedule remains optimal between \$ 0,473 /Lt, and \$ 0,1832 /Lt .Same assumption is made for fuel oil price, electricity increase is calculated as \$ 0 and decrease is calculated as \$ 0,02593. Current production schedule remains optimal between \$ 0,96 /kWh and \$ 0,07 /kWh. For model 2, fuel oil price increase cannot be more than \$ 0,45 /Lt, and decrease cannot be more than \$ 0,04351 /Lt. Thus, current production schedule remains optimal, if the fuel oil price stays within the limits- \$ 0,923 /Lt and \$ 0,4294 /Lt. As for electricity prices in model 2, these limits are calculated as \$ 0,1452 /kWh and \$ 0,09485 /kWh, in which the current production schedule remains optimal. Both for model 3 and model 4, allowable fuel oil and electricity price increase and decrease are \$ 0. Any of electricity/fuel oil increase or decrease may prevent optimality of production schedule.

CHAPTER 6
CONCLUSIONS

6.1. Concluding Remarks

The energy problem is getting more critical since our increasing life standard substantially depends on it. The increasing demands for energy have required the optimum use of energy resources. New energy sources are very costly and utilization of them mainly depends on the technological developments that require substantial amounts of investment even in R&D phase. Energy is most likely the commodity whose cost is increasing faster than any of the others.

Industry is the largest user of this valuable commodity and must make the optimum use of it. Therefore, energy management in a plant is an important concept and applies to all sorts of activities ranging from daily monitoring to long term planning of energy use and activities taking into account the conservation measures.

In this thesis, a plant using electricity and fuel oil in production is considered from the energy optimization point of view in order to obtain optimum amount of energy usage in terms of production schedules. Thus, 4 different linear programming models are developed.

Model 1 can be explained as simple expression of the study. All constraints in model 1 –material balance equations, demand constraints, time capacity constraints- are in the base forms. Obtained results meet basic expectations but detailed evaluation is pointed out two problems: held finished products in inventory consecutively more than one month and unused time capacities in some months.

Model 2 is developed in order to solve inventory problem. Model 2 does not enable the products to be held in inventory more than one month. Obtained results also indicates that model 2 provides spreading unused time capacities over all months.

Model 3 is based on increased time capacity utilization 100 %. It also supports production increase. But, structure of objective function and constraints causes producing only one product that is optimum for model.

The idea of the model 4 is utilization of unused time capacities to increase production of products within determined limits and besides, reducing inventory-holding costs. Model 4 is the extention of model 2 from inventory-utilization point of view. On contrary of model 3, it encourages increasing production for more products rather than one product. Model 4 gives management an opportunity to form demand constraints taking into account market expectations.

The sensitivity analysis of linear programming problems gives a better insight to the real problem. Since costs are depicted in objective function coefficients, utilization of 100 % rule [11] is required. Obtained results indicate that model 2 is more flexible to increase or decrease electricity and fuel oil prices. Within allowable ranges, production schedule keeps its optimality.

For model 1, decrease in prices within allowable decrease limits provides keeping optimality of production schedule. As for increase in prices, there is a probability of losing that optimal condition.

Model 3 and 4 have no tolerance for increase or decrease in prices. Change in prices may end the optimum schedule. For a model, when its price level is reached, the model is solved again to obtain a new optimum solution.

This study provides management choosing the most suitable one serving 4 different models that have different features. By realizing the constraints and results, management may determine different models for different time periods. This study can be expended taking into account these point;

- It can be easily adapted adding many other constraints (e.g. budget, raw materials).

- The constraint on inventory holding of one-month in models 2 and 4 can be relaxed to extending 2 or more months. This will increase holding costs but on the other hand will give management more flexibility about production levels.
- As an important factor,inventory holding costs can be added objective functions and more realistic result can be taken.
- New investment alternatives and process changes which are under consideration could be evaluated from the energy consumption stand point taking into account the future fuel oil and electricity cost increases.
- The inclusion of labor and other major parameters affecting decision making enlarges the models realistically, and gives an opportunity to evaluate how changes in energy costs could affect other parameters by sensitivity analysis.

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APPENDIX A
OPERATIONS RESEARCH AND LINEAR PROGRAMMING

A.1. Operations Research

Operations research can be defined as follows [10]: *operations research utilizes the planned approach and an interdisciplinary team in order to represent complex functional relationships as mathematical models for the purpose of providing a quantitative basis for decision making and uncovering new problems for quantitative analysis*.

An important advantage of model building is that provides a frame of reference for consideration of the problem that is; the model indicates gaps, which are not apparent immediately. Upon testing the model, the character of the failure might give a clue to the model's deficiencies.

From a cost standpoint, a complex problem can be expressed in a mathematical model that will allow a firm to change parameters without undertaking actual construction of the project. The time factor is also involved since the results (favorable and unfavorable) can be obtained within a relatively short time as opposite to waiting a much longer time for the completion of the project and actual day-to-day operations. With the constant squeeze on profits, the cost and time savings of operations research models make them worthy of managerial adoption as a decision-making tool.

The symbolic language offers advantages in communication since it allows a precise statement of the problem as opposed to a long verbal description. The use of mathematical forms makes for better description and comprehension of the facts. It brings to light factors and uncovers relationships that were neglected in verbal description [10].

Models, which allow one to predict based upon past or present information, can be utilized for training purposes. These allow trainees to see the results of their decisions without having to make the actual decision. Models enable the trainees to distinguish between the controllable and non-controllable variables as well as to determine the relative importance of each variable. Moreover, they allow them to examine cause and affect relationships that may not be readily apparent.

When operations research is used to solve a problem of an organization, the following seven-step procedure should be followed (figure A.1.) [11]:

Step 1. Formulate the problem:

The operations research analyst first defines the organization’s problem. This includes determining such things as the appropriate objectives, the constrains on what can be done, interrelationships between the area to be studied and other areas of the organization, the possible alternative courses of action, time limits for making a decision, and so on. This process of problem formulation is a crucial one because it greatly affects how relevant the conclusions of the study will be [9]. Consequently, this phase should be executed with considerable care, and the initial formulation should be continually reexamined in the light of new insights obtained during the later phases.

Step 2. Observe the system:

Next, the analyst collects data to estimate the values of parameters that affect the organization’s problem. Basically, these data are a synthesis of the essential information in the problem. These estimates are used to develop (in step 3) and evaluate (in step 4) a mathematical model of the organization’s problem.

Step 3. Formulate a mathematical model of the problem:

Models, or idealized representations, are an integral part of everyday life. Such models are invaluable for abstracting the essence of the subject of inquiry, showing interrelationships, and facilitating analysis [9]. In this step, the analyst develops a mathematical model (or idealized representation) of the problem.

In an operations research study, perhaps the most difficult part is developing an adequate measure of the system's performance, because this measure must reflect the relative importance of many objectives involved in every management decision. These objectives are of two types [10]:

- Those which involve retaining things of value (minimize inputs, expenditures, etc.)
- Those which involve obtaining things of value (maximize outputs, income, etc.)

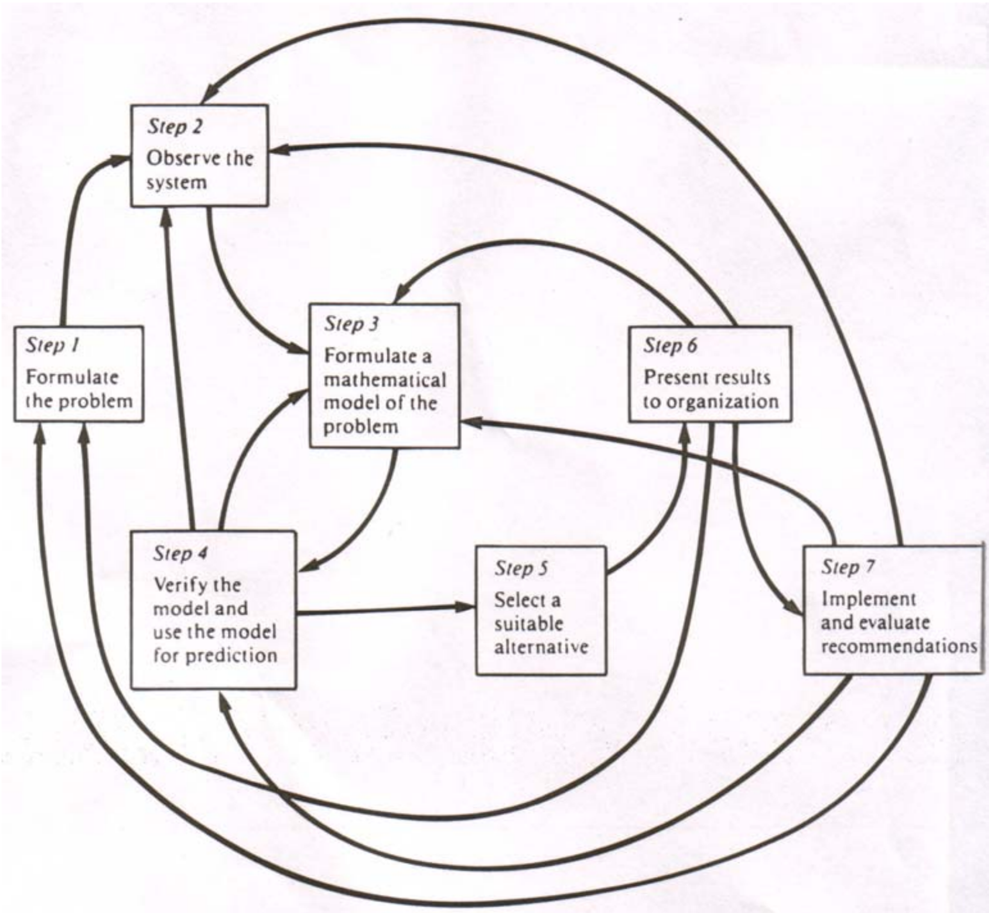

Figure A.1. The operations research methodology [11].

The "things" may be resources (like time, money, or energy) or states of the system (like market share, public acceptance, or economic activity). The restriction values of the variables in a problem, commonly called *constraints,* may be expressed in a supplementary set of equations and inequalities. The resulting formula(s) is (are) a symbolic or mathematical model that allows us to evaluate the results by varying certain elements within the constraints of the problem.

Step 4. Verify the model and use the model for prediction:

The analyst now tries to determine if the mathematical model developed in step 3 is an accurate representation of reality. To determine how well the model fits reality, one determines how valid the model is for the current situation.

A systematic approach to testing the model is to use a retrospective test. When it is applicable, this test involves using historical data to reconstruct the past and determining how well the model and the resulting solution would have performed if it had been used. Comparing the effectiveness of this hypothetical performance with what actually happened then indicates whether using this model tends to yield a significant improvement over current practice [9]. It may also indicate areas where the model has shortcomings and requires modifications.

Step 5. Select a suitable alternative:

Given a model and a set of alternatives, the analyst now chooses the alternative (if there is one) that best meets the organization's objectives. The goal of an operations research study should be to "satisfy" rather than optimize [9]. In other words, the appropriate goal is to find a good answer, one that the decision maker considers a satisfactory guide for action in a reasonable period of time, rather than to search for an optimal solution.

Step 6. Present the results and conclusions of the study to the organization:

In this step, the analyst presents the model and recommendations from step 5 to the decision-making individual or group. In some situations, one might present several alternatives and let the organization choose the one that best meets its needs. After presenting the results of the operation research study to the organization, the analyst may find that the organization does not approve of the recommendations. This may result from incorrect definition of the organization's problems or from failure to involve the decision maker from the start of the project. In this case, the analyst should return to step 1, 2, or 3.

Step 7. Implement and evaluate recommendations:

If the organization has accepted the study, the analyst aids in implementing the recommendations. The system must be constantly monitored (and updated dynamically as the environment changes) to ensure that the recommendations are enabling the organization to meet its objectives. The success of implementation phase depends upon the support of both top management and operating management (or their counterparts in non-business organizations.)

The implementation phase involves several steps [9]. First, the operations research team gives operating management a careful explanation of the solution to be adopted and how it relates to operating realities. Next, these two parties share the responsibility for developing procedures required to put this solution into operation. Operating management then sees that a detailed indoctrination is given the personnel involved, and the new course of action is initiated. If successful, the model and the solution procedure may be used periodically to provide guidance to management. With this in mind, the operations research team monitors the initial experience with the course of action taken and seeks to identify any modifications that should be made in the future.

A.2. Operations Research In Production Planning

Production planning is the activity of establishing production goals over some future time period, called *planning horizon*. The objective of production planning is to plan the optimum use of resources to meet stated production requirements or to take advantage of potential sales opportunities.

As input, production planning will use the following kinds of information [12]:

1. Current inventory levels.
2. Current backlog position.

3. Forecasts of future demand.
4. Current work in process.
5. Current work force levels.
6. Capacity of each production center.
7. Material availability.
8. Production standards.
9. Cost standards and selling prices.
10. Management policies.

This information is gathered and analyzed periodically to develop production plans. The output from this activity may take a variety of forms, specifying the following type of things for each period of the planning horizon [12]:

1. Quantities of each product to be produced.
2. Quantities of a given product to be produced by each of several alternative processes.
3. Quantities of each product to be produced by a given process (such as plant, department, line, machine, etc.).
4. Target inventory levels by product.
5. Work force level.
6. Overtime, additional shifts, unused capacity, etc.
7. Quantities of material and semi finished product to be transported between stages in a multistage (for example, multiplant) production system.
8. Subcontracting plans.
9. Purchased material requirement.

The decision made in production planning affect several cases of costs and revenues [12]:

1. Production costs.
2. Production rate change costs.
3. Capacity change costs.

4. Inventory holding costs.
5. Customer service and shortage losses.
6. Procurement costs.

For many firms, the most important decisions relating to production are those that determine the product mix for a given period of time. There may be a number of products that the company could produce and sell in the period and the problem is to decide how much of each product to schedule. The objective is to utilize limited resources to maximize the net value of the output from the production facilities. Production and sale of a given quantity of a product results in a certain contribution to overhead and profit (that is, the difference between variable sales revenue and variable production cost) and uses up certain resources, such as materials, labor, machine time at various production centers, etc. The problem is to find the production program that maximizes the total contribution to profit and overhead during the period, subject to constraints imposed by resource limitations and considering customer orders already in hand and potential sales (forecasts).

The following features characterize a product mix problem:

1. Maximization of contribution to profit and overhead.
2. Constraints resulting from resource limitations.
3. Bound constraints on planned production.

A.3. Linear Programming Formulation

The product mix problem is most naturally modeled as a mathematical programming problem. This can be illustrated by giving a linear programming model [12]:

X_i = quantity of product i, i = 1,2,…, n, produced in the period

b_k = amount of resource k, k = 1,2,…, K, available during the period

a_{ik} = number of units of resource k required to produce one unit of product i

U_i = maximum sales potential of product i in the period

L_i = required minimum production level of product i in the period

r_i = revenue, net of variable selling expense, from selling one unit of product i

c_i = unit variable cost of producing a unit of product i

$(r_i - c_i)\ X_i$ is the contribution to overhead and profit resulting from the production and sale of X_i units of product i; all production of product i up to U_i units can be sold in the period. Furthermore, production of X_i units of product i will use up $a_{ik}\ X_i$ units of resource k. The objective is to maximize the total contribution to overhead and profit, Z, from all products.

Mathematically, $X_1, X_2, \ldots, X_n$ can be chosen to maximize

$$Z = \sum_{i=1}^{n} (r_i - c_i)\ X_i \qquad \text{(A.1-a)}$$

subject to

$$\sum_{i=1}^{n} a_{ik}\ X_i \le b_k, \qquad (k = 1, 2, \ldots, K) \qquad \text{(A.1-b)}$$

$$X_i \le U_i, \qquad (i = 1, 2, \ldots, n) \qquad \text{(A.1-c)}$$

$$X_i \ge L_i, \qquad (L_i \ge 0,\ i = 1, 2, \ldots, n) \qquad \text{(A.1-d)}$$

The left-hand side of (A.1-b) is the total amount of resource k required by the production program. The lower bound constraints, (A.1-d), occur when there is a prior commitment to deliver a given amount, L_i, of a product i in the period, or when management decides to produce at least that much of the product, regardless of the economic consequences.

A.4. Brief Explanation of LINGO Software Package

LINGO is an optimization modeling language that can be used to solve linear, integer, and nonlinear programming problems. It can be applied many areas like manufacturing, scheduling, budgeting, and other industrial applications where optimization problems need to be solved. LINGO is also capable of generating large models with relatively few lines of input.

LINGO includes a number of significant enhancements and new features. Several of the enchancements focus on finding better solutions to tough nonlinear problems. This release also includes a number of modifications to significant improve performance on many linear and integer models.

It combines a series of range bounding (e.g., interval analysis and convex analysis) range reduction techniques (e.g., linear programming and constraint propagation) within a brunch-and-bound framework to find global solutions to non-convex Nonlinear Programs (NLPs). Rather than stopping after the first local optimum is found, the global solver will search until the global optimum is confirmed. The nonlinear and global licence options are required in order to utilize the global optimization capabilities with LINGO.

When limited time makes searching for the global optimum prohibitive, the Multistart feature can be a powerful tool for finding good solutions more quickly. This feature intelligently generates a set of candidate starting points in the solution space of NLPs and mixed integer NLPs. Then, the native NLP solver selects a subset of these candidate solutions to initialize a series of local optimization. For non-convex NLP models, the quality of the solution returned by the multistart solver will be superior to that of the general nonlinear solver. A user adjustable parameter controls the maximum number of multistarts to be performed. The nonlinear and global licence options are required in order to utilize the multistart feature with LINGO.

Quadratic Programming (QP) models are a common class of nonlinear model that is encountered in applications such as financial portfolio analysis. The QP recognation tool in this release of LINGO is a useful algebraic pre-processor that automatically determines if an arbitrary NLP is actually a quadratic model. QP models may then be passed to the faster quadratic solver, which is available as part of the barrier solver option.

The improved Dual Simplex solver in LINGO delivers substantially better performance. The solver is also even more robust due to improved handling of degenerate and numerically unstable models.

The Linearization capabilities of LINGO can dramatically improve performance on models with common nonsmooth functions. Linearization is a comprehensive reformulation tool that automatically converts many non-smooth functions and operators (e.g., @MAX and @ABS) to a series of linear, mathematically equivalent expressions. Many non-smooth models may be entirely linerized. This allows to linear solver to quickly find a global solution to what would have otherwise been an interactable problem.

LINGO includes a set of tools that allow you to pinpoint what is causing a model to be infeasible or unbounded. A small portion of the original model isolated as the source of the problem. This allows you to focus your attention on a subsection of the model in search of formulation or data entry errors. On infeasible models, an irreducibly inconsistent set of constraints (IIS) is reported. On unbounded models, an irreducibly unbounded set of columns (IUS) is reported.

Many large scale linear and mixed integer programs have constraint matrices that are totally decomposable into a series of independent block structures. LINGO tells the solver to check if a model can be broken into smaller independent models. If total decomposition is possible, it will solve the independent problems sequentially and report a solution for the original model. This may result in dramatic speed improvements.

APPENDIX B

DATA ANALYSIS OF THE PROCESS

B.1. Input Data

Table B.1. Demands of each product for each month (kg)

	P 11	P 22	P 13	P 14	P 24	P 15	P 25	P 26	P 17	P 27
1	0	6417	47667	495	145299	263907	140285	14199	2270	102638
2	64724	0	80248	0	100670	224906	111251	0	7389	95521
3	10551	0	34713	0	147159	236554	215639	0	20691	65669
4	21556	0	124949	0	96912	203118	111714	0	0	121917
5	24048	583	93242	285	127157	253584	127660	1810	9348	68705
6	7263	0	78488	2643	108165	200394	97080	0	2612	140055
7	0	0	129744	0	84117	226024	151989	0	15255	56490
8	22469	0	79758	0	168978	298365	70754	0	14101	89858
9	28646	0	13266	0	113230	322148	135355	0	23899	28135
10	0	0	266338	0	194190	295150	126930	0	0	12926
11	29420	0	148722	0	157070	248303	139940	0	4331	23132
12	79900	0	21773	0	82939	270560	103316	5714	12281	19471

Table B.2. Production rate for each product

	Production rate (kg/h)
Product 1	730
Product 2	957
Product 3	1173
Product 4	1193
Product 5	1277
Product 6	1270
Product 7	1268

Table B.3. Required processing time to produce one unit of product

	1/ Production rate (hr/kg)
Product 1	0,001369496
Product 2	0,001045416
Product 3	0,000852182
Product 4	0,000838193
Product 5	0,000782919
Product 6	0,000787698
Product 7	0,000788556

Table A.10. Set-up times of the process for each product (hours)

Product 1	1,5
Product 2	1
Product 3	1
Product 4	1
Product 5	1
Product 6	1
Product 7	1

B.2. Detailed Calculations Of Energy Use Of Per Unit Of Each Product

Product 1 (P 11)

- Stage 1:

Total power expanded: 4082,727 kW

Mass flow-rate of fuel: 0,4746 m^3/h

Production rate for product 1: 730,19563 kg/h

Fuel oil use per unit of product 1:

$$= \frac{0{,}4749 \text{ m}^3/\text{h}}{730{,}19563 \text{ kg/h}} = 0{,}00065 \text{ m}^3/\text{kg}$$

Electricity use per unit of product 1:

$$= \frac{4082{,}727 \text{ kW}}{730{,}19563 \text{ kg/h}} = 5{,}5912 \text{ kWh/kg}$$

- Stage 2:

Total power expanded: 395,272 kW

Production rate for product 1: 730,19563 kg/h

Electricity use per unit of product 1:

$$= \frac{395{,}272 \text{ kW}}{730{,}19563 \text{ kg/h}} = 0{,}5413 \text{ kWh/kg}$$

- Stage 3:

Total power expanded: 230 kW

Production rate for product 1: 730,19563 kg/h

Electricity use per unit of product 1:

$$= \frac{230 \text{ kW}}{730{,}19563 \text{ kg/h}} = 0{,}3149 \text{ kWh/kg}$$

Product 2 (P 22)

- Stage 1:

Total power expanded: 4082,727 kW

Mass flow-rate of fuel: 0,4746 m^3/h

Production rate for product 2: 956,55668 kg/h

Fuel oil use per unit of product 2:

$$= \frac{0{,}4749\ m^3/h}{956{,}55668\ kg/h} = 0{,}000496\ m^3/kg$$

Electricity use per unit of product 2:

$$= \frac{4082{,}727\ kW}{956{,}55668\ kg/h} = 4{,}2681\ kWh/kg$$

- Stage 2:

Total power expanded: 395,272 kW

Production rate for product 1: 956,55668 kg/h

Electricity use per unit of product 2:

$$= \frac{395{,}272\ kW}{956{,}55668\ kg/h} = 0{,}4132\ kWh/kg$$

- Stage 3:

Total power expanded: 230 kW

Production rate for product 2: 956,55668 kg/h

Electricity use per unit of product 2:

$$= \frac{230 \text{ kW}}{956{,}55668 \text{ kg/h}} = 0{,}2404 \text{ kWh/kg}$$

- Stage 4:

Total power expanded: 1163 kW

Production rate for product 2: 956,55668 kg/h

Electricity use per unit of product 2:

$$= \frac{1163 \text{ kW}}{956{,}55668 \text{ kg/h}} = 1{,}2158 \text{ kWh/kg}$$

- Stage 5:

Total power expanded: 322 kW

Production rate for product 2: 956,55668 kg/h

Electricity use per unit of product 2:

$$= \frac{322 \text{ kW}}{956{,}55668 \text{ kg/h}} = 0{,}3366 \text{ kWh/kg}$$

Product 3 (P 13)

- Stage 1:

Total power expanded: 4082,727 kW

Mass flow-rate of fuel: 0,4746 m^3/h

Production rate for product 1: 1173,4577 kg/h

Fuel oil use per unit of product 3:

$$= \frac{0,4749 \text{ m}^3/\text{h}}{1173,4577 \text{ kg/h}} = 0,000404 \text{ m}^3/\text{kg}$$

Electricity use per unit of product 3:

$$= \frac{4082,727 \text{ kW}}{1173,4577 \text{ kg/h}} = 3,4792 \text{ kWh/kg}$$

- Stage 2:

Total power expanded: 395,272 kW

Production rate for product 3: 1173,4577 kg/h

Electricity use per unit of product 3:

$$= \frac{395,272 \text{ kW}}{1173,4577 \text{ kg/h}} = 0,3368 \text{ kWh/kg}$$

- Stage 3:

Total power expanded: 230 kW

Production rate for product 3: 730,19563 kg/h

Electricity use per unit of product 3:

$$= \frac{230 \text{ kW}}{1173,4577 \text{ kg/h}} = 0,196 \text{ kWh/kg}$$

Product 4 (P 14 and P 24)

- Stage 1:

Total power expanded: 4082,727 kW

Mass flow-rate of fuel: 0,4746 m^3/h

Production rate for product 4: 1193,0429 kg/h

Fuel oil use per unit of product 4:

$$= \frac{0,4749 \text{ m}^3/\text{h}}{1193,0429 \text{ kg/h}} = 0,000398 \text{ m}^3/\text{kg}$$

Electricity use per unit of product 4:

$$= \frac{4082,727 \text{ kW}}{1193,0429 \text{ kg/h}} = 3,4221 \text{ kWh/kg}$$

- Stage 2:

Total power expanded: 395,272 kW

Production rate for product 4: 1193,0429 kg/h

Electricity use per unit of product 4:

$$= \frac{395,272 \text{ kW}}{1193,0429 \text{ kg/h}} = 0,3313 \text{ kWh/kg}$$

- Stage 3:

Total power expanded: 230 kW

Production rate for product 4: 1193,0429 kg/h

Electricity use per unit of product 4:

$$= \frac{230 \text{ kW}}{1193{,}0429 \text{ kg/h}} = 0{,}1927 \text{ kWh/kg}$$

- Stage 4:

Total power expanded: 1163 kW

Production rate for product 4: 1193,0429 kg/h

Electricity use per unit of product 4:

$$= \frac{1163 \text{ kW}}{1193{,}0429 \text{ kg/h}} = 0{,}9748 \text{ kWh/kg}$$

- Stage 5:

Total power expanded: 322 kW

Production rate for product 4: 1193,0429 kg/h

Electricity use per unit of product 4:

$$= \frac{322 \text{ kW}}{1193{,}0429 \text{ kg/h}} = 0{,}2698 \text{ kWh/kg}$$

Product 5 (P 15 and P 25)

- Stage 1:

Total power expanded: 4082,727 kW

Mass flow-rate of fuel: 0,4746 m^3/h

Production rate for product 5: 1277,2717 kg/h

Fuel oil use per unit of product 5:

$$= \frac{0{,}4749 \text{ m}^3/\text{h}}{1277{,}2717 \text{ kg/h}} = 0{,}000372 \text{ m}^3/\text{kg}$$

Electricity use per unit of product 5:

$$= \frac{4082{,}727 \text{ kW}}{1277{,}2717 \text{ kg/h}} = 3{,}1964 \text{ kWh/kg}$$

- Stage 2:

Total power expanded: 395,272 kW

Production rate for product 5: 1277,2717 kg/h

Electricity use per unit of product 5:

$$= \frac{395{,}272 \text{ kW}}{1277{,}2717 \text{ kg/h}} = 0{,}3094 \text{ kWh/kg}$$

- Stage 3:

Total power expanded: 230 kW

Production rate for product 5: 1277,2717 kg/h

Electricity use per unit of product 5:

$$= \frac{230 \text{ kW}}{1277{,}2717 \text{ kg/h}} = 0{,}18 \text{ kWh/kg}$$

- Stage 4:

Total power expanded: 1163 kW

Production rate for product 5: 1277,2717 kg/h

Electricity use per unit of product 5:

$$= \frac{1163 \text{ kW}}{1277{,}2717 \text{ kg/h}} = 0{,}9105 \text{ kWh/kg}$$

- Stage 5:

Total power expanded: 322 kW

Production rate for product 5: 1277,2717 kg/h

Electricity use per unit of product 5:

$$= \frac{322 \text{ kW}}{1277{,}2717 \text{ kg/h}} = 0{,}2521 \text{ kWh/kg}$$

Product 6 (P 26)

- Stage 1:

Total power expanded: 4082,727 kW

Mass flow-rate of fuel: 0,4746 m^3/h

Production rate for product 6: 1269,5221 kg/h

Fuel oil use per unit of product 6:

$$= \frac{0{,}4749 \text{ m}^3\text{/h}}{1269{,}5221 \text{ kg/h}} = 0{,}000374 \text{ m}^3\text{/kg}$$

Electricity use per unit of product 6:

$$= \frac{4082{,}727 \text{ kW}}{1269{,}5221 \text{ kg/h}} = 3{,}2159 \text{ kWh/kg}$$

- Stage 2:

Total power expanded: 395,272 kW

Production rate for product 6: 1269,5221 kg/h

Electricity use per unit of product 6:

$$= \frac{395{,}272 \text{ kW}}{1269{,}5221 \text{ kg/h}} = 0{,}3113 \text{ kWh/kg}$$

- Stage 3:

Total power expanded: 230 kW

Production rate for product 6: 1269,5221 kg/h

Electricity use per unit of product 6:

$$= \frac{230 \text{ kW}}{1269{,}5221 \text{ kg/h}} = 0{,}1811 \text{ kWh/kg}$$

- Stage 4:

Total power expanded: 1163 kW

Production rate for product 6: 1269,5221 kg/h

Electricity use per unit of product 6:

$$= \frac{1163 \text{ kW}}{1269{,}5221 \text{ kg/h}} = 0{,}916 \text{ kWh/kg}$$

- Stage 5:

Total power expanded: 322 kW

Production rate for product 6: 1269,5221 kg/h

Electricity use per unit of product 6:

$$= \frac{322 \text{ kW}}{1269{,}5221 \text{ kg/h}} = 0{,}2536 \text{ kWh/kg}$$

Product 7 (P 17 and P 27)

- Stage 1:

Total power expanded: 4082,727 kW

Mass flow-rate of fuel: 0,4746 m^3/h

Production rate for product 7: 1268,1401 kg/h

Fuel oil use per unit of product 7:

$$= \frac{0{,}4749 \text{ m}^3\text{/h}}{1268{,}1401 \text{ kg/h}} = 0{,}000374 \text{ m}^3\text{/kg}$$

Electricity use per unit of product 7:

$$= \frac{4082{,}727 \text{ kW}}{} = 3{,}2194 \text{ kWh/kg}$$

1268,1401 kg/h

- Stage 2:

Total power expanded: 395,272 kW

Production rate for product 7: 1268,1401 kg/h

Electricity use per unit of product 7:

$$= \frac{395{,}272 \text{ kW}}{1268{,}1401 \text{ kg/h}} = 0{,}3116 \text{ kWh/kg}$$

- Stage 3:

Total power expanded: 230 kW

Production rate for product 7: 1268,1401 kg/h

Electricity use per unit of product 7:

$$= \frac{230 \text{ kW}}{1268{,}1401 \text{ kg/h}} = 0{,}1813 \text{ kWh/kg}$$

- Stage 4:

Total power expanded: 1163 kW

Production rate for product 7: 1268,1401 kg/h

Electricity use per unit of product 7:

$$= \frac{1163 \text{ kW}}{1268{,}1401 \text{ kg/h}} = 0{,}917 \text{ kWh/kg}$$

- Stage 5:

Total power expanded: 322 kW

Production rate for product 7: 1268,1401 kg/h

Electricity use per unit of product 7:

$$= \frac{322 \text{ kW}}{1268{,}1401 \text{ kg/h}} = 0{,}2539 \text{ kWh/kg}$$

B.3. Energy Cost Coefficients

Table B.5. Energy cost coefficients of the models

		product 1 ($/kg)	product 2 ($/kg)	product 3 ($/kg)	product 4 ($/kg)	product 5 ($/kg)	product 6 ($/kg)	product 7 ($/kg)
Stage 1	E_{ij}	0,536763	0,409742	0,334006	0,328523	0,306859	0,308732	0,309068
	F_{ij}	0,307432	0,234681	0,191303	0,188162	0,175754	0,176827	0,17702
Stage 2	E_{ij}	0,051967	0,039669	0,032337	0,031806	0,029709	0,02989	0,029923
Stage 3	E_{ij}	0,030238	0,023083	0,018816	0,018507	0,017287	0,017392	0,017411
Stage 4	E_{ij}	0	0,116719	0	0,093583	0,087411	0,087945	0,088041
Stage 5	E_{ij}	0	0,032316	0	0,02591	0,024202	0,024349	0,024376

* The electricity cost per kWh is $ 0,096 and fuel oil per Lt is $ 0,473 (January 2003 data [21])

APPENDIX C

MODEL 1

C.1. Computer Program of Model 1

```
MODEL:
SETS:
 STAGE/1..5/;
 PRODUCT/1..7/;
 GROUP/1..2/;
 MOUNTH/1..12/;
 LINK1(STAGE,PRODUCT,MOUNTH):X;
 LINK2(GROUP,PRODUCT,MOUNTH):P,I;
 LINK3(PRODUCT,MOUNTH):Y;
ENDSETS

MIN=(0.8441*(@SUM(MOUNTH(K):X(1,1,K))))+(0.05196*(@SUM(MOUNTH(K):
X(2,1,K))))+(0.03023*(X(3,1,1)+X(3,1,2)+X(3,1,3)+X(3,1,4)+X(3,1,5)+X(3,1,6)+X(3,
1,7)+X(3,1,8)+X(3,1,9)+X(3,1,10)+X(3,1,11)+X(3,1,12))+(0.6444*(@SUM(MOUNT
H(K):X(1,2,K))))+(0.03966*(@SUM(MOUNTH(K):X(2,2,K))))+(0.02308*(@SUM(M
OUNTH(K):X(3,2,K))))+(0.1167*(@SUM(MOUNTH(K):X(4,2,K))))+(0.03231*(@S
UM(MOUNTH(K):X(5,2,K))))+(0.5253*(@SUM(MOUNTH(K):X(1,3,K))))+(0.03233
*(@SUM(MOUNTH(K):X(2,3,K))))+(0.01881*(@SUM(MOUNTH(K):X(3,3,K))))+(0
.5166*(@SUM(MOUNTH(K):X(1,4,K))))+(0.0318*(@SUM(MOUNTH(K):X(2,4,K)))
)+(0.0185*(@SUM(MOUNTH(K):X(3,4,K))))+(0.09358*(@SUM(MOUNTH(K):X(4,
4,K))))+(0.02591*(@SUM(MOUNTH(K):X(5,4,K))))+(0.4826*(@SUM(MOUNTH(K
):X(1,5,K))))+(0.0297*(@SUM(MOUNTH(K):X(2,5,K))))+(0.01728*(@SUM(MOUN
TH(K):X(3,5,K))))+(0.08741*(@SUM(MOUNTH(K):X(4,5,K))))+(0.0242*(@SUM(
MOUNTH(K):X(5,5,K))))+(0.4855*(@SUM(MOUNTH(K):X(1,6,K))))+(0.02989*(@
SUM(MOUNTH(K):X(2,6,K))))+(0.01739*(@SUM(MOUNTH(K):X(3,6,K))))+(0.087
94*(@SUM(MOUNTH(K):X(4,6,K))))+(0.02434*(@SUM(MOUNTH(K):X(5,6,K))))
+(0.486*(@SUM(MOUNTH(K):X(1,7,K))))+(0.02992*(@SUM(MOUNTH(K):X(2,7,
K))))+(0.01741*(@SUM(MOUNTH(K):X(3,7,K))))+(0.08804*(@SUM(MOUNTH(K)
:X(4,7,K))))+(0.02437*(@SUM(MOUNTH(K):X(5,7,K)))));
@FOR(MOUNTH(K):X(2,1,K)=0.02*X(1,1,K)+0.0816*X(3,1,K));
@FOR(MOUNTH(K):X(2,2,K)=0.02*X(1,2,K)+0.0816*X(3,2,K));
@FOR(MOUNTH(K):X(2,3,K)=0.02*X(1,3,K)+0.0816*X(3,3,K));
@FOR(MOUNTH(K):X(2,4,K)=0.02*X(1,4,K)+0.0816*X(3,4,K));
@FOR(MOUNTH(K):X(2,5,K)=0.02*X(1,5,K)+0.0816*X(3,5,K));
@FOR(MOUNTH(K):X(2,6,K)=0.02*X(1,6,K)+0.0816*X(3,6,K));
@FOR(MOUNTH(K):X(2,7,K)=0.02*X(1,7,K)+0.0816*X(3,7,K));
@FOR(MOUNTH(K):X(3,1,K)=0.98*X(1,1,K));
@FOR(MOUNTH(K):X(3,2,K)=0.98*X(1,2,K));
@FOR(MOUNTH(K):X(3,3,K)=0.98*X(1,3,K));
@FOR(MOUNTH(K):X(3,4,K)=0.98*X(1,4,K));
@FOR(MOUNTH(K):X(3,5,K)=0.98*X(1,5,K));
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@FOR(MOUNTH(K):X(3,6,K)=0.98*X(1,6,K));
@FOR(MOUNTH(K):X(3,7,K)=0.98*X(1,7,K));
@FOR(MOUNTH(K):P(1,1,K)=0.9184*X(3,1,K)-X(4,1,K));
@FOR(MOUNTH(K):P(1,2,K)=0.9184*X(3,2,K)-X(4,2,K));
@FOR(MOUNTH(K):P(1,3,K)=0.9184*X(3,3,K)-X(4,3,K));
@FOR(MOUNTH(K):P(1,4,K)=0.9184*X(3,4,K)-X(4,4,K));
@FOR(MOUNTH(K):P(1,5,K)=0.9184*X(3,5,K)-X(4,5,K));
@FOR(MOUNTH(K):P(1,6,K)=0.9184*X(3,6,K)-X(4,6,K));
@FOR(MOUNTH(K):P(1,7,K)=0.9184*X(3,7,K)-X(4,7,K));
@FOR(MOUNTH(K):X(4,1,K)=0);
@FOR(MOUNTH(K):X(4,3,K)=0);
@FOR(MOUNTH(K):P(1,2,K)=0);
@FOR(MOUNTH(K):P(1,6,K)=0);
@FOR(MOUNTH(K):X(5,1,K)=X(4,1,K));
@FOR(MOUNTH(K):X(5,2,K)=X(4,2,K));
@FOR(MOUNTH(K):X(5,3,K)=X(4,3,K));
@FOR(MOUNTH(K):X(5,4,K)=X(4,4,K));
@FOR(MOUNTH(K):X(5,5,K)=X(4,5,K));
@FOR(MOUNTH(K):X(5,6,K)=X(4,6,K));
@FOR(MOUNTH(K):X(5,7,K)=X(4,7,K));
@FOR(MOUNTH(K):P(2,1,K)=0.9952*X(5,1,K));
@FOR(MOUNTH(K):P(2,2,K)=0.9952*X(5,2,K));
@FOR(MOUNTH(K):P(2,3,K)=0.9952*X(5,3,K));
@FOR(MOUNTH(K):P(2,4,K)=0.9952*X(5,4,K));
@FOR(MOUNTH(K):P(2,5,K)=0.9952*X(5,5,K));
@FOR(MOUNTH(K):P(2,6,K)=0.9952*X(5,6,K));
@FOR(MOUNTH(K):P(2,7,K)=0.9952*X(5,7,K));
P(1,1,1)>=0;
P(2,2,1)>=6417;
P(1,3,1)>=47667;
P(1,4,1)>=495;
P(2,4,1)>=145299;
P(1,5,1)>=263907;
P(2,5,1)>=140285;
P(2,6,1)>=14199;
P(1,7,1)>=2270;
P(2,7,1)>=102638;
I(1,1,1)=P(1,1,1)-0;
I(2,2,1)=P(2,2,1)-6417;
I(1,3,1)=P(1,3,1)-47667;
I(1,4,1)=P(1,4,1)-495;
I(2,4,1)=P(2,4,1)-145299;
I(1,5,1)=P(1,5,1)-263907;
I(2,5,1)=P(2,5,1)-140285;
I(2,6,1)=P(2,6,1)-14199;
I(1,7,1)=P(1,7,1)-2270;
I(2,7,1)=P(2,7,1)-102638;
I(1,1,1)+P(1,1,2)>=64724;
I(2,2,1)+P(2,2,2)>=0;
I(1,3,1)+P(1,3,2)>=80248;
```

I(1,4,1)+P(1,4,2)>=0;
I(2,4,1)+P(2,4,2)>=100670;
I(1,5,1)+P(1,5,2)>=224906;
I(2,5,1)+P(2,5,2)>=111251;
I(2,6,1)+P(2,6,2)>=0;
I(1,7,1)+P(1,7,2)>=7389;
I(2,7,1)+P(2,7,2)>=95521;
I(1,1,2)=I(1,1,1)+P(1,1,2)-64724;
I(2,2,2)=I(2,2,1)+P(2,2,2)-0;
I(1,3,2)=I(1,3,1)+P(1,3,2)-80248;
I(1,4,2)=I(1,4,1)+P(1,4,2)-0;
I(2,4,2)=I(2,4,1)+P(2,4,2)-100670;
I(1,5,2)=I(1,5,1)+P(1,5,2)-224906;
I(2,5,2)=I(2,5,1)+P(2,5,2)-111251;
I(2,6,2)=I(2,6,1)+P(2,6,2)-0;
I(1,7,2)=I(1,7,1)+P(1,7,2)-7389;
I(2,7,2)=I(2,7,1)+P(2,7,2)-95521;
I(1,1,2)+P(1,1,3)>=10551;
I(2,2,2)+P(2,2,3)>=0;
I(1,3,2)+P(1,3,3)>=34713;
I(1,4,2)+P(1,4,3)>=0;
I(2,4,2)+P(2,4,3)>=147159;
I(1,5,2)+P(1,5,3)>=236554;
I(2,5,2)+P(2,5,3)>=215639;
I(2,6,2)+P(2,6,3)>=0;
I(1,7,2)+P(1,7,3)>=20691;
I(2,7,2)+P(2,7,3)>=65669;
I(1,1,3)=I(1,1,2)+P(1,1,3)-10551;
I(2,2,3)=I(2,2,2)+P(2,2,3)-0;
I(1,3,3)=I(1,3,2)+P(1,3,3)-34713;
I(1,4,3)=I(1,4,2)+P(1,4,3)-0;
I(2,4,3)=I(2,4,2)+P(2,4,3)-147159;
I(1,5,3)=I(1,5,2)+P(1,5,3)-236554;
I(2,5,3)=I(2,5,2)+P(2,5,3)-215639;
I(2,6,3)=I(2,6,2)+P(2,6,3)-0;
I(1,7,3)=I(1,7,2)+P(1,7,3)-20691;
I(2,7,3)=I(2,7,2)+P(2,7,3)-65669;
I(1,1,3)+P(1,1,4)>=21556;
I(2,2,3)+P(2,2,4)>=0;
I(1,3,3)+P(1,3,4)>=124949;
I(1,4,3)+P(1,4,4)>=0;
I(2,4,3)+P(2,4,4)>=96912;
I(1,5,3)+P(1,5,4)>=203118;
I(2,5,3)+P(2,5,4)>=111714;
I(2,6,3)+P(2,6,4)>=0;
I(1,7,3)+P(1,7,4)>=0;
I(2,7,3)+P(2,7,4)>=121917;
I(1,1,4)=I(1,1,3)+P(1,1,4)-21556;
I(2,2,4)=I(2,2,3)+P(2,2,4)-0;
I(1,3,4)=I(1,3,3)+P(1,3,4)-124949;

I(1,4,4)=I(1,4,3)+P(1,4,4)-0;
I(2,4,4)=I(2,4,3)+P(2,4,4)-96912;
I(1,5,4)=I(1,5,3)+P(1,5,4)-203118;
I(2,5,4)=I(2,5,3)+P(2,5,4)-111714;
I(2,6,4)=I(2,6,3)+P(2,6,4)-0;
I(1,7,4)=I(1,7,3)+P(1,7,4)-0;
I(2,7,4)=I(2,7,3)+P(2,7,4)-121917;
I(1,1,4)+P(1,1,5)>=24048;
I(2,2,4)+P(2,2,5)>=583;
I(1,3,4)+P(1,3,5)>=93242;
I(1,4,4)+P(1,4,5)>=285;
I(2,4,4)+P(2,4,5)>=127157;
I(1,5,4)+P(1,5,5)>=253584;
I(2,5,4)+P(2,5,5)>=127660;
I(2,6,4)+P(2,6,5)>=1810;
I(1,7,4)+P(1,7,5)>=9348;
I(2,7,4)+P(2,7,5)>=68705;
I(1,1,5)=I(1,1,4)+P(1,1,5)-24048;
I(2,2,5)=I(2,2,4)+P(2,2,5)-583;
I(1,3,5)=I(1,3,4)+P(1,3,5)-93242;
I(1,4,5)=I(1,4,4)+P(1,4,5)-285;
I(2,4,5)=I(2,4,4)+P(2,4,5)-127157;
I(1,5,5)=I(1,5,4)+P(1,5,5)-253584;
I(2,5,5)=I(2,5,4)+P(2,5,5)-127660;
I(2,6,5)=I(2,6,4)+P(2,6,5)-1810;
I(1,7,5)=I(1,7,4)+P(1,7,5)-9348;
I(2,7,5)=I(2,7,4)+P(2,7,5)-68705;
I(1,1,5)+P(1,1,6)>=7263;
I(2,2,5)+P(2,2,6)>=0;
I(1,3,5)+P(1,3,6)>=78488;
I(1,4,5)+P(1,4,6)>=2643;
I(2,4,5)+P(2,4,6)>=108165;
I(1,5,5)+P(1,5,6)>=200394;
I(2,5,5)+P(2,5,6)>=97080;
I(2,6,5)+P(2,6,6)>=0;
I(1,7,5)+P(1,7,6)>=2612;
I(2,7,5)+P(2,7,6)>=140055;
I(1,1,6)=I(1,1,5)+P(1,1,6)-7263;
I(2,2,6)=I(2,2,5)+P(2,2,6)-0;
I(1,3,6)=I(1,3,5)+P(1,3,6)-78488;
I(1,4,6)=I(1,4,5)+P(1,4,6)-2643;
I(2,4,6)=I(2,4,5)+P(2,4,6)-108165;
I(1,5,6)=I(1,5,5)+P(1,5,6)-200394;
I(2,5,6)=I(2,5,5)+P(2,5,6)-97080;
I(2,6,6)=I(2,6,5)+P(2,6,6)-0;
I(1,7,6)=I(1,7,5)+P(1,7,6)-2612;
I(2,7,6)=I(2,7,5)+P(2,7,6)-140055;
I(1,1,6)+P(1,1,7)>=0;
I(2,2,6)+P(2,2,7)>=0;
I(1,3,6)+P(1,3,7)>=129744;

I(1,4,6)+P(1,4,7)>=0;
I(2,4,6)+P(2,4,7)>=84117;
I(1,5,6)+P(1,5,7)>=226024;
I(2,5,6)+P(2,5,7)>=151989;
I(2,6,6)+P(2,6,7)>=0;
I(1,7,6)+P(1,7,7)>=15255;
I(2,7,6)+P(2,7,7)>=56490;
I(1,1,7)=I(1,1,6)+P(1,1,7)-0;
I(2,2,7)=I(2,2,6)+P(2,2,7)-0;
I(1,3,7)=I(1,3,6)+P(1,3,7)-129744;
I(1,4,7)=I(1,4,6)+P(1,4,7)-0;
I(2,4,7)=I(2,4,6)+P(2,4,7)-84117;
I(1,5,7)=I(1,5,6)+P(1,5,7)-226024;
I(2,5,7)=I(2,5,6)+P(2,5,7)-151989;
I(2,6,7)=I(2,6,6)+P(2,6,7)-0;
I(1,7,7)=I(1,7,6)+P(1,7,7)-15255;
I(2,7,7)=I(2,7,6)+P(2,7,7)-56490;
I(1,1,7)+P(1,1,8)>=22469;
I(2,2,7)+P(2,2,8)>=0;
I(1,3,7)+P(1,3,8)>=79758;
I(1,4,7)+P(1,4,8)>=0;
I(2,4,7)+P(2,4,8)>=168978;
I(1,5,7)+P(1,5,8)>=298365;
I(2,5,7)+P(2,5,8)>=70754;
I(2,6,7)+P(2,6,8)>=0;
I(1,7,7)+P(1,7,8)>=14101;
I(2,7,7)+P(2,7,8)>=89858;
I(1,1,8)=I(1,1,7)+P(1,1,8)-22469;
I(2,2,8)=I(2,2,7)+P(2,2,8)-0;
I(1,3,8)=I(1,3,7)+P(1,3,8)-79758;
I(1,4,8)=I(1,4,7)+P(1,4,8)-0;
I(2,4,8)=I(2,4,7)+P(2,4,8)-168978;
I(1,5,8)=I(1,5,7)+P(1,5,8)-298365;
I(2,5,8)=I(2,5,7)+P(2,5,8)-70754;
I(2,6,8)=I(2,6,7)+P(2,6,8)-0;
I(1,7,8)=I(1,7,7)+P(1,7,8)-14101;
I(2,7,8)=I(2,7,7)+P(2,7,8)-89858;
I(1,1,8)+P(1,1,9)>=28646;
I(2,2,8)+P(2,2,9)>=0;
I(1,3,8)+P(1,3,9)>=13266;
I(1,4,8)+P(1,4,9)>=0;
I(2,4,8)+P(2,4,9)>=113230;
I(1,5,8)+P(1,5,9)>=322148;
I(2,5,8)+P(2,5,9)>=135355;
I(2,6,8)+P(2,6,9)>=0;
I(1,7,8)+P(1,7,9)>=23899;
I(2,7,8)+P(2,7,9)>=28135;
I(1,1,9)=I(1,1,8)+P(1,1,9)-28646;
I(2,2,9)=I(2,2,8)+P(2,2,9)-0;
I(1,3,9)=I(1,3,8)+P(1,3,9)-13266;

I(1,4,9)=I(1,4,8)+P(1,4,9)-0;
I(2,4,9)=I(2,4,8)+P(2,4,9)-113230;
I(1,5,9)=I(1,5,8)+P(1,5,9)-322148;
I(2,5,9)=I(2,5,8)+P(2,5,9)-135355;
I(2,6,9)=I(2,6,8)+P(2,6,9)-0;
I(1,7,9)=I(1,7,8)+P(1,7,9)-23899;
I(2,7,9)=I(2,7,8)+P(2,7,9)-28135;
I(1,1,9)+P(1,1,10)>=0;
I(2,2,9)+P(2,2,10)>=0;
I(1,3,9)+P(1,3,10)>=266338;
I(1,4,9)+P(1,4,10)>=0;
I(2,4,9)+P(2,4,10)>=194190;
I(1,5,9)+P(1,5,10)>=295150;
I(2,5,9)+P(2,5,10)>=126930;
I(2,6,9)+P(2,6,10)>=0;
I(1,7,9)+P(1,7,10)>=0;
I(2,7,9)+P(2,7,10)>=12926;
I(1,1,10)=I(1,1,9)+P(1,1,10)-0;
I(2,2,10)=I(2,2,9)+P(2,2,10)-0;
I(1,3,10)=I(1,3,9)+P(1,3,10)-266338;
I(1,4,10)=I(1,4,9)+P(1,4,10)-0;
I(2,4,10)=I(2,4,9)+P(2,4,10)-194190;
I(1,5,10)=I(1,5,9)+P(1,5,10)-295150;
I(2,5,10)=I(2,5,9)+P(2,5,10)-126930;
I(2,6,10)=I(2,6,9)+P(2,6,10)-0;
I(1,7,10)=I(1,7,9)+P(1,7,10)-0;
I(2,7,10)=I(2,7,9)+P(2,7,10)-12926;
I(1,1,10)+P(1,1,11)>=29420;
I(2,2,10)+P(2,2,11)>=0;
I(1,3,10)+P(1,3,11)>=148722;
I(1,4,10)+P(1,4,11)>=0;
I(2,4,10)+P(2,4,11)>=157070;
I(1,5,10)+P(1,5,11)>=248303;
I(2,5,10)+P(2,5,11)>=139940;
I(2,6,10)+P(2,6,11)>=0;
I(1,7,10)+P(1,7,11)>=4331;
I(2,7,10)+P(2,7,11)>=23132;
I(1,1,11)=I(1,1,10)+P(1,1,11)-29420;
I(2,2,11)=I(2,2,10)+P(2,2,11)-0;
I(1,3,11)=I(1,3,10)+P(1,3,11)-148722;
I(1,4,11)=I(1,4,10)+P(1,4,11)-0;
I(2,4,11)=I(2,4,10)+P(2,4,11)-157070;
I(1,5,11)=I(1,5,10)+P(1,5,11)-248303;
I(2,5,11)=I(2,5,10)+P(2,5,11)-139940;
I(2,6,11)=I(2,6,10)+P(2,6,11)-0;
I(1,7,11)=I(1,7,10)+P(1,7,11)-4331;
I(2,7,11)=I(2,7,10)+P(2,7,11)-23132;
I(1,1,11)+P(1,1,12)>=79900;
I(2,2,11)+P(2,2,12)>=0;
I(1,3,11)+P(1,3,12)>=21773;

```
I(1,4,11)+P(1,4,12)>=0;
I(2,4,11)+P(2,4,12)>=82939;
I(1,5,11)+P(1,5,12)>=270560;
I(2,5,11)+P(2,5,12)>=103316;
I(2,6,11)+P(2,6,12)>=5714;
I(1,7,11)+P(1,7,12)>=12281;
I(2,7,11)+P(2,7,12)>=19471;
I(1,1,12)=I(1,1,11)+P(1,1,12)-79900;
I(2,2,12)=I(2,2,11)+P(2,2,12)-0;
I(1,3,12)=I(1,3,11)+P(1,3,12)-21773;
I(1,4,12)=I(1,4,11)+P(1,4,12)-0;
I(2,4,12)=I(2,4,11)+P(2,4,12)-82939;
I(1,5,12)=I(1,5,11)+P(1,5,12)-270560;
I(2,5,12)=I(2,5,11)+P(2,5,12)-103316;
I(2,6,12)=I(2,6,11)+P(2,6,12)-5714;
I(1,7,12)=I(1,7,11)+P(1,7,12)-12281;
I(2,7,12)=I(2,7,11)+P(2,7,12)-19471;
(1.5*Y(1,1)+0.0013695*(P(1,1,1)+P(2,1,1)))+(1*Y(2,1)+0.00104542*(P(1,2,1)+P(2,2,1
)))+(1*Y(3,1)+0.00085218*(P(1,3,1)+P(2,3,1)))+(1*Y(4,1)+0.00083819*(P(1,4,1)+P(2
,4,1)))+(1*Y(5,1)+0.00078292*(P(1,5,1)+P(2,5,1)))+(1*Y(6,1)+0.0007877*(P(1,6,1)+P
(2,6,1)))+(1*Y(7,1)+0.00078856*(P(1,7,1)+P(2,7,1)))<=696;
(P(1,1,1)+P(2,1,1))<=10000000000*Y(1,1);
(P(1,1,1)+P(2,1,1))>=Y(1,1);
(P(1,2,1)+P(2,2,1))<=10000000000*Y(2,1);
(P(1,2,1)+P(2,2,1))>=Y(2,1);
(P(1,3,1)+P(2,3,1))<=10000000000*Y(3,1);
(P(1,3,1)+P(2,3,1))>=Y(3,1);
(P(1,4,1)+P(2,4,1))<=10000000000*Y(4,1);
(P(1,4,1)+P(2,4,1))>=Y(4,1);
(P(1,5,1)+P(2,5,1))<=10000000000*Y(5,1);
(P(1,5,1)+P(2,5,1))>=Y(5,1);
(P(1,6,1)+P(2,6,1))<=10000000000*Y(6,1);
(P(1,6,1)+P(2,6,1))>=Y(6,1);
(P(1,7,1)+P(2,7,1))<=10000000000*Y(7,1);
(P(1,7,1)+P(2,7,1))>=Y(7,1);
(1.5*Y(1,2)+0.0013695*(P(1,1,2)+P(2,1,2)))+(1*Y(2,2)+0.00104542*(P(1,2,2)+P(2,2,2
)))+(1*Y(3,2)+0.00085218*(P(1,3,2)+P(2,3,2)))+(1*Y(4,2)+0.00083819*(P(1,4,2)+P(2
,4,2)))+(1*Y(5,2)+0.00078292*(P(1,5,2)+P(2,5,2)))+(1*Y(6,2)+0.0007877*(P(1,6,2)+P
(2,6,2)))+(1*Y(7,2)+0.00078856*(P(1,7,2)+P(2,7,2)))<=624;
(P(1,1,2)+P(2,1,2))<=10000000000*Y(1,2);
(P(1,1,2)+P(2,1,2))>=Y(1,2);
(P(1,2,2)+P(2,2,2))<=10000000000*Y(2,2);
(P(1,2,2)+P(2,2,2))>=Y(2,2);
(P(1,3,2)+P(2,3,2))<=10000000000*Y(3,2);
(P(1,3,2)+P(2,3,2))>=Y(3,2);
(P(1,4,2)+P(2,4,2))<=10000000000*Y(4,2);
(P(1,4,2)+P(2,4,2))>=Y(4,2);
(P(1,5,2)+P(2,5,2))<=10000000000*Y(5,2);
(P(1,5,2)+P(2,5,2))>=Y(5,2);
(P(1,6,2)+P(2,6,2))<=10000000000*Y(6,2);
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(P(1,6,2)+P(2,6,2))>=Y(6,2);
(P(1,7,2)+P(2,7,2))<=10000000000*Y(7,2);
(P(1,7,2)+P(2,7,2))>=Y(7,2);
(1.5*Y(1,3)+0.0013695*(P(1,1,3)+P(2,1,3)))+(1*Y(2,3)+0.00104542*(P(1,2,3)+P(2,2,3)))+(1*Y(3,3)+0.00085218*(P(1,3,3)+P(2,3,3)))+(1*Y(4,3)+0.00083819*(P(1,4,3)+P(2,4,3)))+(1*Y(5,3)+0.00078292*(P(1,5,3)+P(2,5,3)))+(1*Y(6,3)+0.0007877*(P(1,6,3)+P(2,6,3)))+(1*Y(7,3)+0.00078856*(P(1,7,3)+P(2,7,3)))<=696;
(P(1,1,3)+P(2,1,3))<=10000000000*Y(1,3);
(P(1,1,3)+P(2,1,3))>=Y(1,3);
(P(1,2,3)+P(2,2,3))<=10000000000*Y(2,3);
(P(1,2,3)+P(2,2,3))>=Y(2,3);
(P(1,3,3)+P(2,3,3))<=10000000000*Y(3,3);
(P(1,3,3)+P(2,3,3))>=Y(3,3);
(P(1,4,3)+P(2,4,3))<=10000000000*Y(4,3);
(P(1,4,3)+P(2,4,3))>=Y(4,3);
(P(1,5,3)+P(2,5,3))<=10000000000*Y(5,3);
(P(1,5,3)+P(2,5,3))>=Y(5,3);
(P(1,6,3)+P(2,6,3))<=10000000000*Y(6,3);
(P(1,6,3)+P(2,6,3))>=Y(6,3);
(P(1,7,3)+P(2,7,3))<=10000000000*Y(7,3);
(P(1,7,3)+P(2,7,3))>=Y(7,3);
(1.5*Y(1,4)+0.0013695*(P(1,1,4)+P(2,1,4)))+(1*Y(2,4)+0.00104542*(P(1,2,4)+P(2,2,4)))+(1*Y(3,4)+0.00085218*(P(1,3,4)+P(2,3,4)))+(1*Y(4,4)+0.00083819*(P(1,4,4)+P(2,4,4)))+(1*Y(5,4)+0.00078292*(P(1,5,4)+P(2,5,4)))+(1*Y(6,4)+0.0007877*(P(1,6,4)+P(2,6,4)))+(1*Y(7,4)+0.00078856*(P(1,7,4)+P(2,7,4)))<=672;
(P(1,1,4)+P(2,1,4))<=10000000000*Y(1,4);
(P(1,1,4)+P(2,1,4))>=Y(1,4);
(P(1,2,4)+P(2,2,4))<=10000000000*Y(2,4);
(P(1,2,4)+P(2,2,4))>=Y(2,4);
(P(1,3,4)+P(2,3,4))<=10000000000*Y(3,4);
(P(1,3,4)+P(2,3,4))>=Y(3,4);
(P(1,4,4)+P(2,4,4))<=10000000000*Y(4,4);
(P(1,4,4)+P(2,4,4))>=Y(4,4);
(P(1,5,4)+P(2,5,4))<=10000000000*Y(5,4);
(P(1,5,4)+P(2,5,4))>=Y(5,4);
(P(1,6,4)+P(2,6,4))<=10000000000*Y(6,4);
(P(1,6,4)+P(2,6,4))>=Y(6,4);
(P(1,7,4)+P(2,7,4))<=10000000000*Y(7,4);
(P(1,7,4)+P(2,7,4))>=Y(7,4);
(1.5*Y(1,5)+0.0013695*(P(1,1,5)+P(2,1,5)))+(1*Y(2,5)+0.00104542*(P(1,2,5)+P(2,2,5)))+(1*Y(3,5)+0.00085218*(P(1,3,5)+P(2,3,5)))+(1*Y(4,5)+0.00083819*(P(1,4,5)+P(2,4,5)))+(1*Y(5,5)+0.00078292*(P(1,5,5)+P(2,5,5)))+(1*Y(6,5)+0.0007877*(P(1,6,5)+P(2,6,5)))+(1*Y(7,5)+0.00078856*(P(1,7,5)+P(2,7,5)))<=696;
(P(1,1,5)+P(2,1,5))<=10000000000*Y(1,5);
(P(1,1,5)+P(2,1,5))>=Y(1,5);
(P(1,2,5)+P(2,2,5))<=10000000000*Y(2,5);
(P(1,2,5)+P(2,2,5))>=Y(2,5);
(P(1,3,5)+P(2,3,5))<=10000000000*Y(3,5);
(P(1,3,5)+P(2,3,5))>=Y(3,5);
(P(1,4,5)+P(2,4,5))<=10000000000*Y(4,5);

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(P(1,4,5)+P(2,4,5))>=Y(4,5);
(P(1,5,5)+P(2,5,5))<=10000000000*Y(5,5);
(P(1,5,5)+P(2,5,5))>=Y(5,5);
(P(1,6,5)+P(2,6,5))<=10000000000*Y(6,5);
(P(1,6,5)+P(2,6,5))>=Y(6,5);
(P(1,7,5)+P(2,7,5))<=10000000000*Y(7,5);
(P(1,7,5)+P(2,7,5))>=Y(7,5);
(1.5*Y(1,6)+0.0013695*(P(1,1,6)+P(2,1,6)))+(1*Y(2,6)+0.00104542*(P(1,2,6)+P(2,2,6
)))+(1*Y(3,6)+0.00085218*(P(1,3,6)+P(2,3,6)))+(1*Y(4,6)+0.00083819*(P(1,4,6)+P(2
,4,6)))+(1*Y(5,6)+0.00078292*(P(1,5,6)+P(2,5,6)))+(1*Y(6,6)+0.0007877*(P(1,6,6)+P
(2,6,6)))+(1*Y(7,6)+0.00078856*(P(1,7,6)+P(2,7,6)))<=672;
(P(1,1,6)+P(2,1,6))<=10000000000*Y(1,6);
(P(1,1,6)+P(2,1,6))>=Y(1,6);
(P(1,2,6)+P(2,2,6))<=10000000000*Y(2,6);
(P(1,2,6)+P(2,2,6))>=Y(2,6);
(P(1,3,6)+P(2,3,6))<=10000000000*Y(3,6);
(P(1,3,6)+P(2,3,6))>=Y(3,6);
(P(1,4,6)+P(2,4,6))<=10000000000*Y(4,6);
(P(1,4,6)+P(2,4,6))>=Y(4,6);
(P(1,5,6)+P(2,5,6))<=10000000000*Y(5,6);
(P(1,5,6)+P(2,5,6))>=Y(5,6);
(P(1,6,6)+P(2,6,6))<=10000000000*Y(6,6);
(P(1,6,6)+P(2,6,6))>=Y(6,6);
(P(1,7,6)+P(2,7,6))<=10000000000*Y(7,6);
(P(1,7,6)+P(2,7,6))>=Y(7,6);
(1.5*Y(1,7)+0.0013695*(P(1,1,7)+P(2,1,7)))+(1*Y(2,7)+0.00104542*(P(1,2,7)+P(2,2,7
)))+(1*Y(3,7)+0.00085218*(P(1,3,7)+P(2,3,7)))+(1*Y(4,7)+0.00083819*(P(1,4,7)+P(2
,4,7)))+(1*Y(5,7)+0.00078292*(P(1,5,7)+P(2,5,7)))+(1*Y(6,7)+0.0007877*(P(1,6,7)+P
(2,6,7)))+(1*Y(7,7)+0.00078856*(P(1,7,7)+P(2,7,7)))<=696;
(P(1,1,7)+P(2,1,7))<=10000000000*Y(1,7);
(P(1,1,7)+P(2,1,7))>=Y(1,7);
(P(1,2,7)+P(2,2,7))<=10000000000*Y(2,7);
(P(1,2,7)+P(2,2,7))>=Y(2,7);
(P(1,3,7)+P(2,3,7))<=10000000000*Y(3,7);
(P(1,3,7)+P(2,3,7))>=Y(3,7);
(P(1,4,7)+P(2,4,7))<=10000000000*Y(4,7);
(P(1,4,7)+P(2,4,7))>=Y(4,7);
(P(1,5,7)+P(2,5,7))<=10000000000*Y(5,7);
(P(1,5,7)+P(2,5,7))>=Y(5,7);
(P(1,6,7)+P(2,6,7))<=10000000000*Y(6,7);
(P(1,6,7)+P(2,6,7))>=Y(6,7);
(P(1,7,7)+P(2,7,7))<=10000000000*Y(7,7);
(P(1,7,7)+P(2,7,7))>=Y(7,7);
(1.5*Y(1,8)+0.0013695*(P(1,1,8)+P(2,1,8)))+(1*Y(2,8)+0.00104542*(P(1,2,8)+P(2,2,8
)))+(1*Y(3,8)+0.00085218*(P(1,3,8)+P(2,3,8)))+(1*Y(4,8)+0.00083819*(P(1,4,8)+P(2
,4,8)))+(1*Y(5,8)+0.00078292*(P(1,5,8)+P(2,5,8)))+(1*Y(6,8)+0.0007877*(P(1,6,8)+P
(2,6,8)))+(1*Y(7,8)+0.00078856*(P(1,7,8)+P(2,7,8)))<=696;
(P(1,1,8)+P(2,1,8))<=10000000000*Y(1,8);
(P(1,1,8)+P(2,1,8))>=Y(1,8);
(P(1,2,8)+P(2,2,8))<=10000000000*Y(2,8);
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(P(1,2,8)+P(2,2,8))>=Y(2,8);
(P(1,3,8)+P(2,3,8))<=10000000000*Y(3,8);
(P(1,3,8)+P(2,3,8))>=Y(3,8);
(P(1,4,8)+P(2,4,8))<=10000000000*Y(4,8);
(P(1,4,8)+P(2,4,8))>=Y(4,8);
(P(1,5,8)+P(2,5,8))<=10000000000*Y(5,8);
(P(1,5,8)+P(2,5,8))>=Y(5,8);
(P(1,6,8)+P(2,6,8))<=10000000000*Y(6,8);
(P(1,6,8)+P(2,6,8))>=Y(6,8);
(P(1,7,8)+P(2,7,8))<=10000000000*Y(7,8);
(P(1,7,8)+P(2,7,8))>=Y(7,8);
(1.5*Y(1,9)+0.0013695*(P(1,1,9)+P(2,1,9)))+(1*Y(2,9)+0.00104542*(P(1,2,9)+P(2,2,9
)))+(1*Y(3,9)+0.00085218*(P(1,3,9)+P(2,3,9)))+(1*Y(4,9)+0.00083819*(P(1,4,9)+P(2
,4,9)))+(1*Y(5,9)+0.00078292*(P(1,5,9)+P(2,5,9)))+(1*Y(6,9)+0.0007877*(P(1,6,9)+P
(2,6,9)))+(1*Y(7,9)+0.00078856*(P(1,7,9)+P(2,7,9)))<=672;
(P(1,1,9)+P(2,1,9))<=10000000000*Y(1,9);
(P(1,1,9)+P(2,1,9))>=Y(1,9);
(P(1,2,9)+P(2,2,9))<=10000000000*Y(2,9);
(P(1,2,9)+P(2,2,9))>=Y(2,9);
(P(1,3,9)+P(2,3,9))<=10000000000*Y(3,9);
(P(1,3,9)+P(2,3,9))>=Y(3,9);
(P(1,4,9)+P(2,4,9))<=10000000000*Y(4,9);
(P(1,4,9)+P(2,4,9))>=Y(4,9);
(P(1,5,9)+P(2,5,9))<=10000000000*Y(5,9);
(P(1,5,9)+P(2,5,9))>=Y(5,9);
(P(1,6,9)+P(2,6,9))<=10000000000*Y(6,9);
(P(1,6,9)+P(2,6,9))>=Y(6,9);
(P(1,7,9)+P(2,7,9))<=10000000000*Y(7,9);
(P(1,7,9)+P(2,7,9))>=Y(7,9);
(1.5*Y(1,10)+0.0013695*(P(1,1,10)+P(2,1,10)))+(1*Y(2,10)+0.00104542*(P(1,2,10)+
P(2,2,10)))+(1*Y(3,10)+0.00085218*(P(1,3,10)+P(2,3,10)))+(1*Y(4,10)+0.00083819*(
P(1,4,10)+P(2,4,10)))+(1*Y(5,10)+0.00078292*(P(1,5,10)+P(2,5,10)))+(1*Y(6,10)+0.0
007877*(P(1,6,10)+P(2,6,10)))+(1*Y(7,10)+0.00078856*(P(1,7,10)+P(2,7,10)))<=696;
(P(1,1,10)+P(2,1,10))<=10000000000*Y(1,10);
(P(1,1,10)+P(2,1,10))>=Y(1,10);
(P(1,2,10)+P(2,2,10))<=10000000000*Y(2,10);
(P(1,2,10)+P(2,2,10))>=Y(2,10);
(P(1,3,10)+P(2,3,10))<=10000000000*Y(3,10);
(P(1,3,10)+P(2,3,10))>=Y(3,10);
(P(1,4,10)+P(2,4,10))<=10000000000*Y(4,10);
(P(1,4,10)+P(2,4,10))>=Y(4,10);
(P(1,5,10)+P(2,5,10))<=10000000000*Y(5,10);
(P(1,5,10)+P(2,5,10))>=Y(5,10);
(P(1,6,10)+P(2,6,10))<=10000000000*Y(6,10);
(P(1,6,10)+P(2,6,10))>=Y(6,10);
(P(1,7,10)+P(2,7,10))<=10000000000*Y(7,10);
(P(1,7,10)+P(2,7,10))>=Y(7,10);
(1.5*Y(1,11)+0.0013695*(P(1,1,11)+P(2,1,11)))+(1*Y(2,11)+0.00104542*(P(1,2,11)+
P(2,2,11)))+(1*Y(3,11)+0.00085218*(P(1,3,11)+P(2,3,11)))+(1*Y(4,11)+0.00083819*(

```
P(1,4,11)+P(2,4,11)))+(1*Y(5,11)+0.00078292*(P(1,5,11)+P(2,5,11)))+(1*Y(6,11)+0.0
007877*(P(1,6,11)+P(2,6,11)))+(1*Y(7,11)+0.00078856*(P(1,7,11)+P(2,7,11)))<=672;
(P(1,1,11)+P(2,1,11))<=10000000000*Y(1,11);
(P(1,1,11)+P(2,1,11))>=Y(1,11);
(P(1,2,11)+P(2,2,11))<=10000000000*Y(2,11);
(P(1,2,11)+P(2,2,11))>=Y(2,11);
(P(1,3,11)+P(2,3,11))<=10000000000*Y(3,11);
(P(1,3,11)+P(2,3,11))>=Y(3,11);
(P(1,4,11)+P(2,4,11))<=10000000000*Y(4,11);
(P(1,4,11)+P(2,4,11))>=Y(4,11);
(P(1,5,11)+P(2,5,11))<=10000000000*Y(5,11);
(P(1,5,11)+P(2,5,11))>=Y(5,11);
(P(1,6,11)+P(2,6,11))<=10000000000*Y(6,11);
(P(1,6,11)+P(2,6,11))>=Y(6,11);
(P(1,7,11)+P(2,7,11))<=10000000000*Y(7,11);
(P(1,7,11)+P(2,7,11))>=Y(7,11);
(1.5*Y(1,12)+0.0013695*(P(1,1,12)+P(2,1,12)))+(1*Y(2,12)+0.00104542*(P(1,2,12)+
P(2,2,12)))+(1*Y(3,12)+0.00085218*(P(1,3,12)+P(2,3,12)))+(1*Y(4,12)+0.00083819*(
P(1,4,12)+P(2,4,12)))+(1*Y(5,12)+0.00078292*(P(1,5,12)+P(2,5,12)))+(1*Y(6,12)+0.0
007877*(P(1,6,12)+P(2,6,12)))+(1*Y(7,12)+0.00078856*(P(1,7,12)+P(2,7,12)))<=696;
(P(1,1,12)+P(2,1,12))<=10000000000*Y(1,12);
(P(1,1,12)+P(2,1,12))>=Y(1,12);
(P(1,2,12)+P(2,2,12))<=10000000000*Y(2,12);
(P(1,2,12)+P(2,2,12))>=Y(2,12);
(P(1,3,12)+P(2,3,12))<=10000000000*Y(3,12);
(P(1,3,12)+P(2,3,12))>=Y(3,12);
(P(1,4,12)+P(2,4,12))<=10000000000*Y(4,12);
(P(1,4,12)+P(2,4,12))>=Y(4,12);
(P(1,5,12)+P(2,5,12))<=10000000000*Y(5,12);
(P(1,5,12)+P(2,5,12))>=Y(5,12);
(P(1,6,12)+P(2,6,12))<=10000000000*Y(6,12);
(P(1,6,12)+P(2,6,12))>=Y(6,12);
(P(1,7,12)+P(2,7,12))<=10000000000*Y(7,12);
(P(1,7,12)+P(2,7,12))>=Y(7,12);
@FOR(LINK3(J,K):@BIN(Y(J,K)));
@FOR(LINK1(I,J,K):X(I,J,K)>=0);
END
```

C.2. Output of the Model 1

Optimal solution found at step: 231
Objective value: 5436618.

Variable	Value	Reduced Cost
P(1, 1, 1)	0.0000000E+00	0.0000000E+00
P(1, 1, 2)	64724.00	0.0000000E+00
P(1, 1, 3)	62968.00	0.0000000E+00
P(1, 1, 4)	450.0000	0.0000000E+00
P(1, 1, 5)	0.0000000E+00	0.0000000E+00

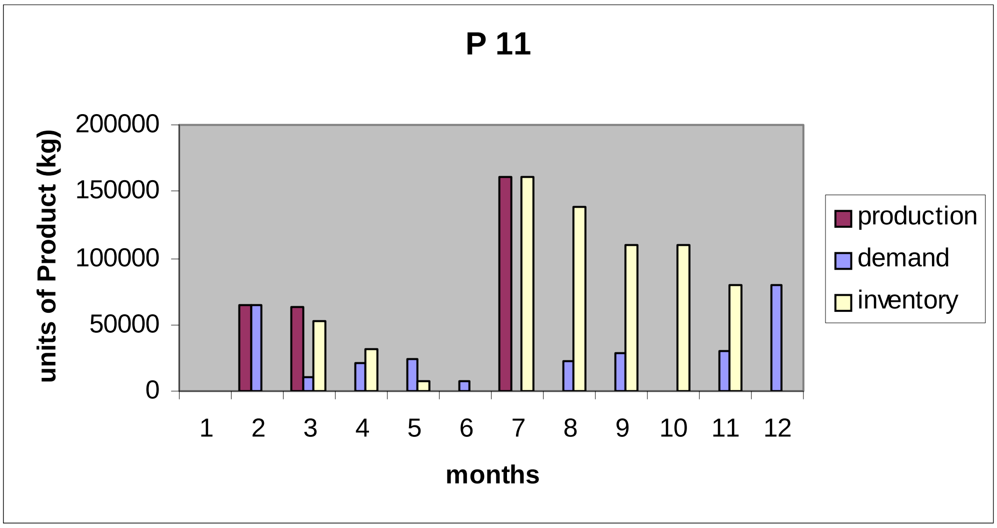
P(1, 1, 6)	0.0000000E+00	0.0000000E+00
P(1, 1, 7)	160435.0	0.0000000E+00
P(1, 1, 8)	0.0000000E+00	0.0000000E+00
P(1, 1, 9)	0.0000000E+00	0.0000000E+00
P(1, 1, 10)	0.0000000E+00	0.0000000E+00
P(1, 1, 11)	0.0000000E+00	0.0000000E+00
P(1, 1, 12)	0.0000000E+00	0.0000000E+00
P(1, 2, 1)	0.0000000E+00	0.0000000E+00
P(1, 2, 2)	0.0000000E+00	0.0000000E+00
P(1, 2, 3)	0.0000000E+00	0.0000000E+00
P(1, 2, 4)	0.0000000E+00	0.0000000E+00
P(1, 2, 5)	0.0000000E+00	0.0000000E+00
P(1, 2, 6)	0.0000000E+00	0.0000000E+00
P(1, 2, 7)	0.0000000E+00	0.0000000E+00
P(1, 2, 8)	0.0000000E+00	0.0000000E+00
P(1, 2, 9)	0.0000000E+00	0.0000000E+00
P(1, 2, 10)	0.0000000E+00	0.0000000E+00
P(1, 2, 11)	0.0000000E+00	0.0000000E+00
P(1, 2, 12)	0.0000000E+00	0.0000000E+00
P(1, 3, 1)	127915.0	0.0000000E+00
P(1, 3, 2)	0.0000000E+00	0.0000000E+00
P(1, 3, 3)	46684.18	0.0000000E+00
P(1, 3, 4)	284707.8	0.0000000E+00
P(1, 3, 5)	0.0000000E+00	0.0000000E+00
P(1, 3, 6)	0.0000000E+00	0.0000000E+00
P(1, 3, 7)	209502.0	0.0000000E+00
P(1, 3, 8)	0.0000000E+00	0.0000000E+00
P(1, 3, 9)	450099.0	0.0000000E+00
P(1, 3, 10)	0.0000000E+00	0.0000000E+00
P(1, 3, 11)	0.0000000E+00	0.0000000E+00
P(1, 3, 12)	0.0000000E+00	0.0000000E+00
P(1, 4, 1)	495.0000	0.0000000E+00
P(1, 4, 2)	0.0000000E+00	0.0000000E+00
P(1, 4, 3)	0.0000000E+00	0.0000000E+00
P(1, 4, 4)	2928.000	0.0000000E+00
P(1, 4, 5)	0.0000000E+00	0.0000000E+00
P(1, 4, 6)	0.0000000E+00	0.0000000E+00
P(1, 4, 7)	0.0000000E+00	0.0000000E+00
P(1, 4, 8)	0.0000000E+00	0.0000000E+00
P(1, 4, 9)	0.0000000E+00	0.0000000E+00
P(1, 4, 10)	0.0000000E+00	0.0000000E+00
P(1, 4, 11)	0.0000000E+00	0.0000000E+00
P(1, 4, 12)	0.0000000E+00	0.0000000E+00
P(1, 5, 1)	283545.5	0.0000000E+00
P(1, 5, 2)	205267.5	0.0000000E+00
P(1, 5, 3)	236554.0	0.0000000E+00
P(1, 5, 4)	203118.0	0.0000000E+00
P(1, 5, 5)	253584.0	0.0000000E+00
P(1, 5, 6)	232356.3	0.0000000E+00
P(1, 5, 7)	375837.7	0.0000000E+00

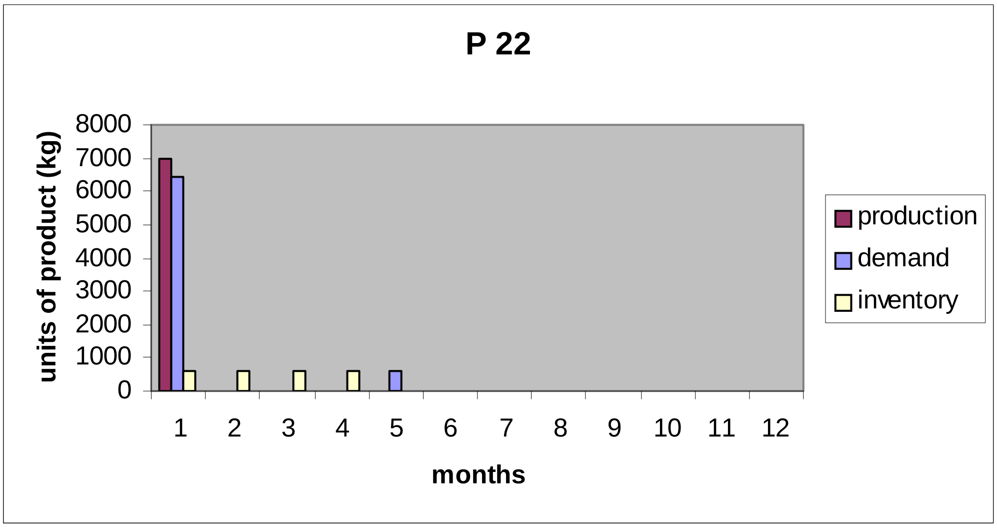
P(1, 5, 8)	208237.7	0.0000000E+00
P(1, 5, 9)	230499.3	0.0000000E+00
P(1, 5, 10)	543453.0	0.0000000E+00
P(1, 5, 11)	0.0000000E+00	0.0000000E+00
P(1, 5, 12)	270560.0	0.0000000E+00
P(1, 6, 1)	0.0000000E+00	0.0000000E+00
P(1, 6, 2)	0.0000000E+00	0.0000000E+00
P(1, 6, 3)	0.0000000E+00	0.0000000E+00
P(1, 6, 4)	0.0000000E+00	0.0000000E+00
P(1, 6, 5)	0.0000000E+00	0.0000000E+00
P(1, 6, 6)	0.0000000E+00	0.0000000E+00
P(1, 6, 7)	0.0000000E+00	0.0000000E+00
P(1, 6, 8)	0.0000000E+00	0.0000000E+00
P(1, 6, 9)	0.0000000E+00	0.0000000E+00
P(1, 6, 10)	0.0000000E+00	0.0000000E+00
P(1, 6, 11)	0.0000000E+00	0.0000000E+00
P(1, 6, 12)	0.0000000E+00	0.0000000E+00
P(1, 7, 1)	27840.66	0.0000000E+00
P(1, 7, 2)	0.0000000E+00	0.0000000E+00
P(1, 7, 3)	11857.34	0.0000000E+00
P(1, 7, 4)	0.0000000E+00	0.0000000E+00
P(1, 7, 5)	0.0000000E+00	0.0000000E+00
P(1, 7, 6)	55867.00	0.0000000E+00
P(1, 7, 7)	0.0000000E+00	0.0000000E+00
P(1, 7, 8)	0.0000000E+00	0.0000000E+00
P(1, 7, 9)	0.0000000E+00	0.0000000E+00
P(1, 7, 10)	0.0000000E+00	0.0000000E+00
P(1, 7, 11)	16612.00	0.0000000E+00
P(1, 7, 12)	0.0000000E+00	0.0000000E+00
P(2, 1, 1)	0.0000000E+00	0.0000000E+00
P(2, 1, 2)	0.0000000E+00	0.0000000E+00
P(2, 1, 3)	0.0000000E+00	0.0000000E+00
P(2, 1, 4)	0.0000000E+00	0.0000000E+00
P(2, 1, 5)	0.0000000E+00	0.0000000E+00
P(2, 1, 6)	0.0000000E+00	0.0000000E+00
P(2, 1, 7)	0.0000000E+00	0.0000000E+00
P(2, 1, 8)	0.0000000E+00	0.0000000E+00
P(2, 1, 9)	0.0000000E+00	0.0000000E+00
P(2, 1, 10)	0.0000000E+00	0.0000000E+00
P(2, 1, 11)	0.0000000E+00	0.0000000E+00
P(2, 1, 12)	0.0000000E+00	0.0000000E+00
P(2, 2, 1)	7000.000	0.0000000E+00
P(2, 2, 2)	0.0000000E+00	0.0000000E+00
P(2, 2, 3)	0.0000000E+00	0.0000000E+00
P(2, 2, 4)	0.0000000E+00	0.0000000E+00
P(2, 2, 5)	0.0000000E+00	0.0000000E+00
P(2, 2, 6)	0.0000000E+00	0.0000000E+00
P(2, 2, 7)	0.0000000E+00	0.0000000E+00
P(2, 2, 8)	0.0000000E+00	0.0000000E+00
P(2, 2, 9)	0.0000000E+00	0.0000000E+00

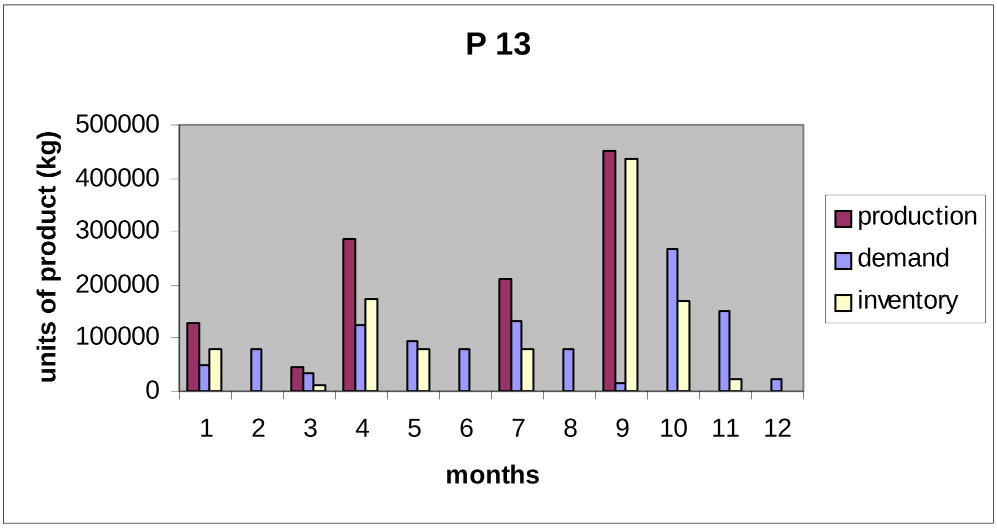
P(2, 2, 10)	0.0000000E+00	0.0000000E+00
P(2, 2, 11)	0.0000000E+00	0.0000000E+00
P(2, 2, 12)	0.0000000E+00	0.0000000E+00
P(2, 3, 1)	0.0000000E+00	0.0000000E+00
P(2, 3, 2)	0.0000000E+00	0.0000000E+00
P(2, 3, 3)	0.0000000E+00	0.0000000E+00
P(2, 3, 4)	0.0000000E+00	0.0000000E+00
P(2, 3, 5)	0.0000000E+00	0.0000000E+00
P(2, 3, 6)	0.0000000E+00	0.0000000E+00
P(2, 3, 7)	0.0000000E+00	0.0000000E+00
P(2, 3, 8)	0.0000000E+00	0.0000000E+00
P(2, 3, 9)	0.0000000E+00	0.0000000E+00
P(2, 3, 10)	0.0000000E+00	0.0000000E+00
P(2, 3, 11)	0.0000000E+00	0.0000000E+00
P(2, 3, 12)	0.0000000E+00	0.0000000E+00
P(2, 4, 1)	145299.0	0.0000000E+00
P(2, 4, 2)	247829.0	0.0000000E+00
P(2, 4, 3)	0.0000000E+00	0.0000000E+00
P(2, 4, 4)	96912.00	0.0000000E+00
P(2, 4, 5)	319439.0	0.0000000E+00
P(2, 4, 6)	0.0000000E+00	0.0000000E+00
P(2, 4, 7)	0.0000000E+00	0.0000000E+00
P(2, 4, 8)	633468.0	0.0000000E+00
P(2, 4, 9)	0.0000000E+00	0.0000000E+00
P(2, 4, 10)	0.0000000E+00	0.0000000E+00
P(2, 4, 11)	0.0000000E+00	0.0000000E+00
P(2, 4, 12)	82939.00	0.0000000E+00
P(2, 5, 1)	140285.0	0.0000000E+00
P(2, 5, 2)	111251.0	0.0000000E+00
P(2, 5, 3)	215639.0	0.0000000E+00
P(2, 5, 4)	231890.1	0.0000000E+00
P(2, 5, 5)	289121.5	0.0000000E+00
P(2, 5, 6)	38185.46	0.0000000E+00
P(2, 5, 7)	0.0000000E+00	0.0000000E+00
P(2, 5, 8)	0.0000000E+00	0.0000000E+00
P(2, 5, 9)	135355.0	0.0000000E+00
P(2, 5, 10)	287496.4	0.0000000E+00
P(2, 5, 11)	0.0000000E+00	0.0000000E+00
P(2, 5, 12)	82689.60	0.0000000E+00
P(2, 6, 1)	21273.00	0.0000000E+00
P(2, 6, 2)	0.0000000E+00	0.0000000E+00
P(2, 6, 3)	0.0000000E+00	0.0000000E+00
P(2, 6, 4)	0.0000000E+00	0.0000000E+00
P(2, 6, 5)	450.0000	0.0000000E+00
P(2, 6, 6)	0.0000000E+00	0.0000000E+00
P(2, 6, 7)	0.0000000E+00	0.0000000E+00
P(2, 6, 8)	0.0000000E+00	0.0000000E+00
P(2, 6, 9)	0.0000000E+00	0.0000000E+00
P(2, 6, 10)	0.0000000E+00	0.0000000E+00
P(2, 6, 11)	0.0000000E+00	0.0000000E+00

P(2, 6, 12)	0.0000000E+00	0.0000000E+00
P(2, 7, 1)	102638.0	0.0000000E+00
P(2, 7, 2)	95521.00	0.0000000E+00
P(2, 7, 3)	256291.0	0.0000000E+00
P(2, 7, 4)	0.0000000E+00	0.0000000E+00
P(2, 7, 5)	0.0000000E+00	0.0000000E+00
P(2, 7, 6)	314538.0	0.0000000E+00
P(2, 7, 7)	0.0000000E+00	0.0000000E+00
P(2, 7, 8)	0.0000000E+00	0.0000000E+00
P(2, 7, 9)	0.0000000E+00	0.0000000E+00
P(2, 7, 10)	55079.00	0.0000000E+00
P(2, 7, 11)	450.0000	0.0000000E+00
P(2, 7, 12)	0.0000000E+00	0.0000000E+00

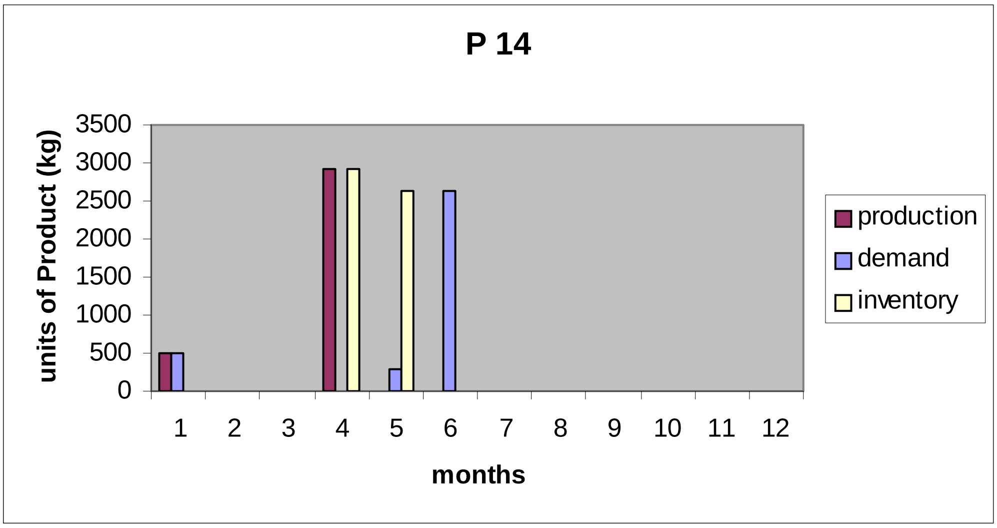
C.3. Production and Inventory Results of the Model 1



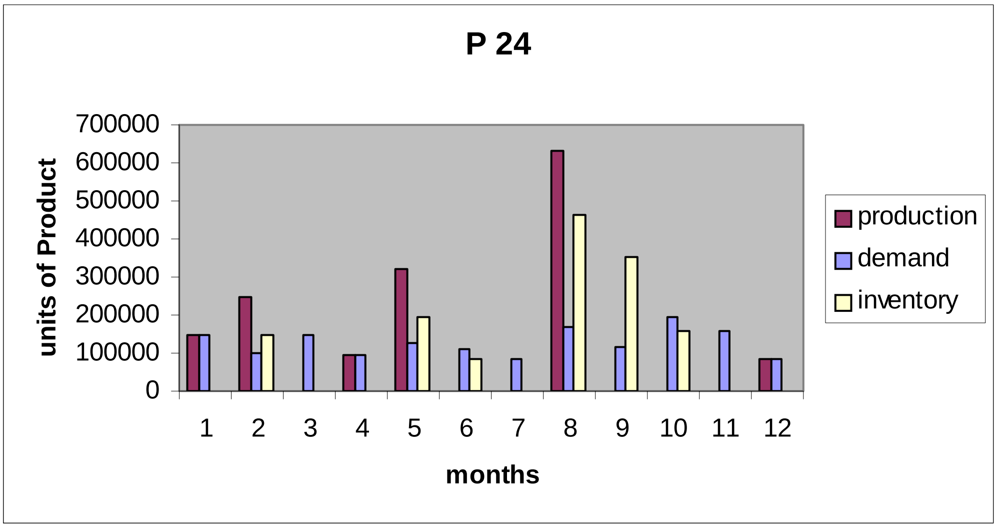




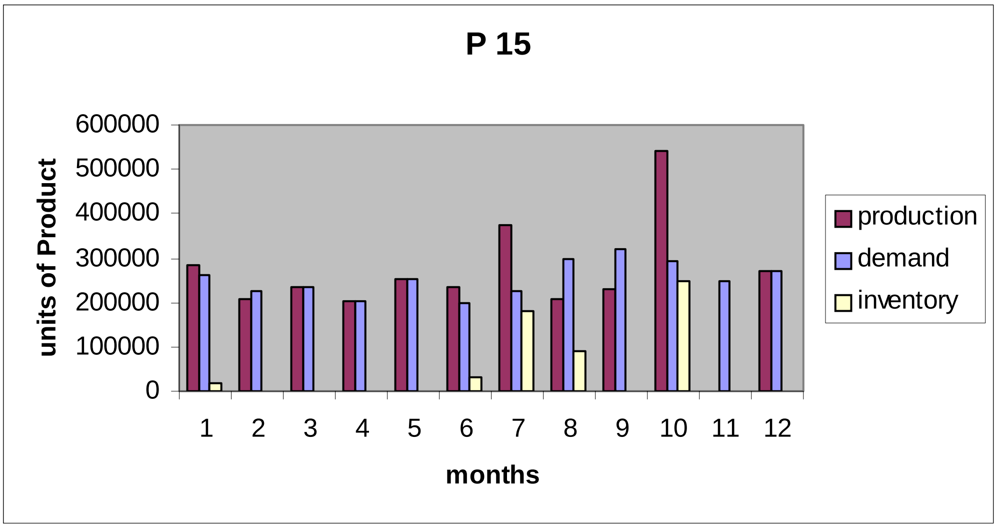
P 13
units of product (kg)
500000
400000
300000
200000
100000
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory

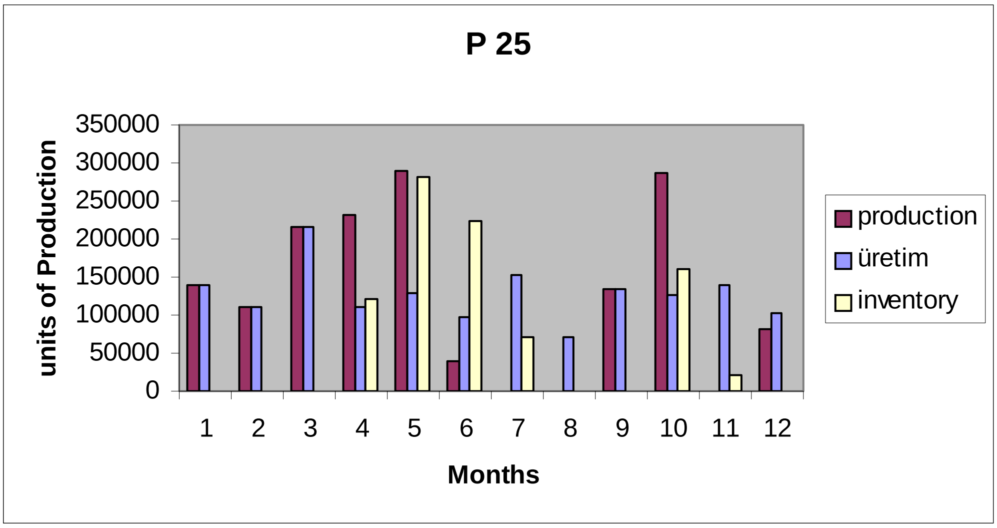


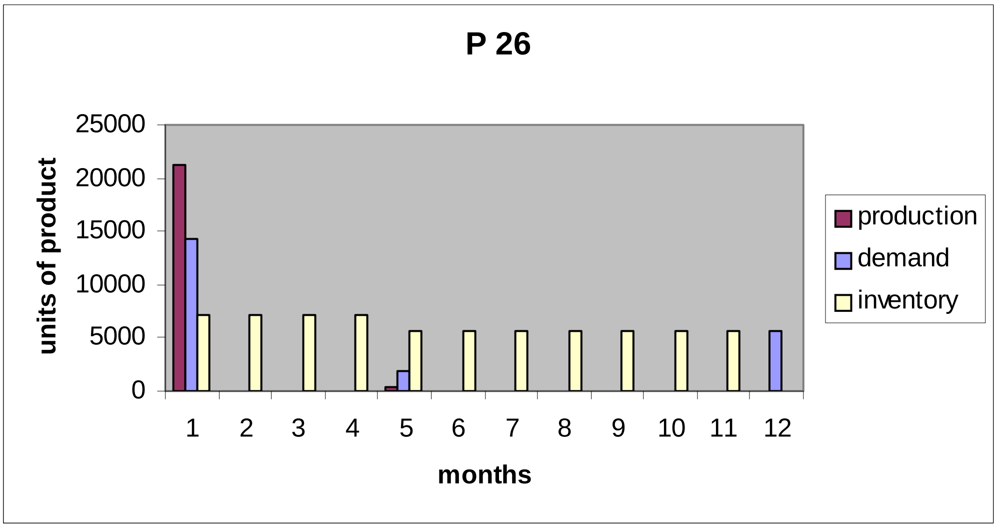
P 14
units of Product (kg)
3500
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory

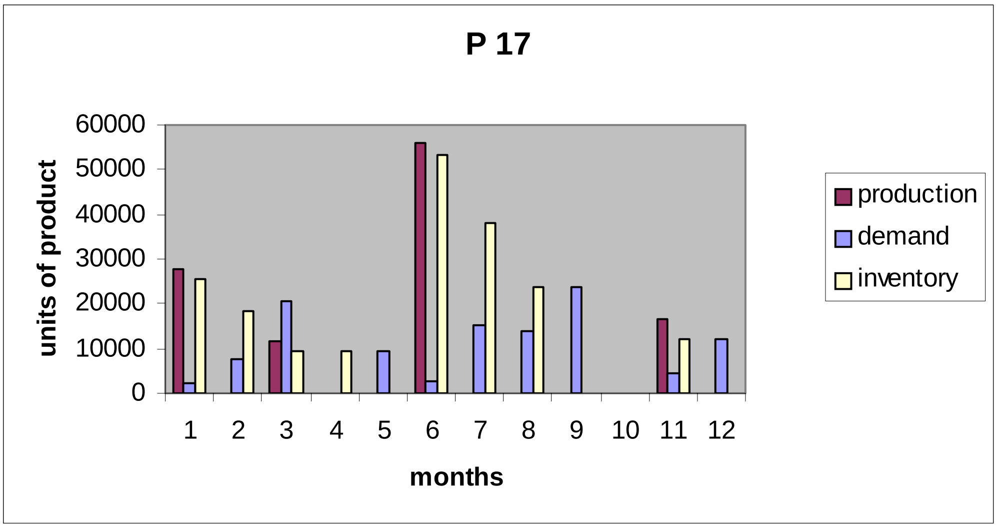


P 24
units of Product
700000
600000
500000
400000
300000
200000
100000
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory


P 15
600000
500000
400000
300000
200000
100000
0
units of Product
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory


P 25
350000
300000
250000
200000
150000
100000
50000
0
units of Production
1 2 3 4 5 6 7 8 9 10 11 12
Months
production
üretim
inventory


P 26
25000
20000
15000
10000
5000
0
units of product
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory



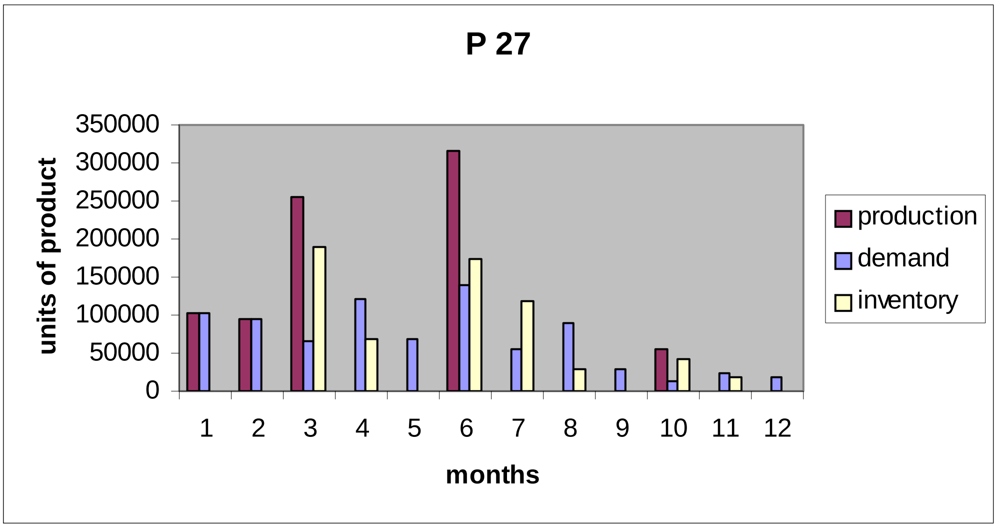


Figure C.1. Production, demand and inventory results of model 1 for each product

C. 4. Range Analysis of Model 1

Ranges in which the basis is unchanged:

Objective Coefficient Ranges

Variable	Current Coefficient	Allowable Increase	Allowable Decrease
X(1, 1, 2)	0,8441000	INFINITY	0,0
X(1, 1, 3)	0,8441000	0,0	0,0
X(1, 1, 4)	0,8441000	0,0	0,0
X(1, 1, 7)	0,8441000	0,0	0,8789198
X(1, 2, 1)	0,6444000	INFINITY	0,8050969

X(1, 3, 1)	0,5253000	0,0	0,0
X(1, 3, 3)	0,5253000	0,0	0,0
X(1, 3, 4)	0,5253000	0,0	0,0
X(1, 3, 7)	0,5253000	0,0	0,0
X(1, 3, 9)	0,5253000	0,0	0,5468658
X(1, 4, 1)	0,5166000	0,0	0,0
X(1, 4, 2)	0,5166000	0,0	0,0
X(1, 4, 4)	0,5166000	0,0	0,0
X(1, 4, 5)	0,5166000	0,0	0,0
X(1, 4, 8)	0,5166000	0,0	0,0
X(1, 4, 12)	0,5166000	0,0	0,6454538
X(1, 5, 1)	0,4826000	INFINITY	0,0
X(1, 5, 2)	0,4826000	0,0	0,0
X(1, 5, 3)	0,4826000	0,0	0,0
X(1, 5, 4)	0,4826000	0,0	0,0
X(1, 5, 5)	0,4826000	0,0	0,0
X(1, 5, 6)	0,4826000	0,0	0,0
X(1, 5, 7)	0,4826000	0,0	0,0
X(1, 5, 8)	0,4826000	0,0	0,0
X(1, 5, 9)	0,4826000	0,0	0,0
X(1, 5, 10)	0,4826000	0,0	0,0
X(1, 5, 12)	0,4826000	0,0	0,0
X(1, 6, 1)	0,4855000	0,0	0,0
X(1, 6, 5)	0,4855000	0,0	0,0
X(1, 7, 1)	0,4860000	0,0	0,0
X(1, 7, 2)	0,4860000	0,0	0,0
X(1, 7, 3)	0,4860000	0,0	0,0
X(1, 7, 6)	0,4860000	0,0	0,0
X(1, 7, 10)	0,4860000	0,0	0,0
X(1, 7, 11)	0,4860000	0,0	0,5060528
X(2, 1, 2)	0,5196000E-01	INFINITY	0,0
X(2, 1, 3)	0,5196000E-01	0,0	0,0
X(2, 1, 4)	0,5196000E-01	0,0	0,0
X(2, 1, 7)	0,5196000E-01	0,0	8,792011
X(2, 2, 1)	0,3966000E-01	INFINITY	8,053546
X(2, 3, 1)	0,3233000E-01	INFINITY	0,0
X(2, 3, 3)	0,3233000E-01	0,0	0,0
X(2, 3, 4)	0,3233000E-01	0,0	0,0
X(2, 3, 7)	0,3233000E-01	0,0	0,0
X(2, 3, 9)	0,3233000E-01	0,0	5,471408
X(2, 4, 1)	0,3180000E-01	0,0	0,0
X(2, 4, 2)	0,3180000E-01	0,0	0,0
X(2, 4, 4)	0,3180000E-01	0,0	0,0
X(2, 4, 5)	0,3180000E-01	0,0	0,0
X(2, 4, 8)	0,3180000E-01	0,0	0,0
X(2, 4, 12)	0,3180000E-01	0,0	6,456604
X(2, 5, 1)	0,2970000E-01	INFINITY	0,0
X(2, 5, 2)	0,2970000E-01	0,0	0,0
X(2, 5, 3)	0,2970000E-01	0,0	0,0
X(2, 5, 4)	0,2970000E-01	0,0	0,0

X(2, 5, 5)	0,2970000E-01	0,0	0,0
X(2, 5, 6)	0,2970000E-01	0,0	0,0
X(2, 5, 7)	0,2970000E-01	0,0	0,0
X(2, 5, 8)	0,2970000E-01	0,0	0,0
X(2, 5, 9)	0,2970000E-01	0,0	0,0
X(2, 5, 10)	0,2970000E-01	0,0	0,0
X(2, 5, 12)	0,2970000E-01	0,0	0,0
X(2, 6, 1)	0,2989000E-01	0,0	0,0
X(2, 6, 5)	0,2989000E-01	0,0	0,0
X(2, 7, 1)	0,2992000E-01	0,0	0,0
X(2, 7, 2)	0,2992000E-01	0,0	0,0
X(2, 7, 3)	0,2992000E-01	0,0	0,0
X(2, 7, 6)	0,2992000E-01	0,0	0,0
X(2, 7, 10)	0,2992000E-01	0,0	0,0
X(2, 7, 11)	0,2992000E-01	0,0	5,062148
X(3, 1, 2)	0,3023000E-01	INFINITY	0,0
X(3, 1, 3)	0,3023000E-01	0,0	0,0
X(3, 1, 4)	0,3023000E-01	0,0	0,0
X(3, 1, 7)	0,3023000E-01	0,0	0,8968569
X(3, 2, 1)	0,2308000E-01	INFINITY	0,8215274
X(3, 3, 1)	0,1881000E-01	0,0	0,0
X(3, 3, 3)	0,1881000E-01	0,0	0,0
X(3, 3, 4)	0,1881000E-01	0,0	0,0
X(3, 3, 7)	0,1881000E-01	0,0	0,0
X(3, 3, 9)	0,1881000E-01	0,0	0,5581283
X(3, 4, 1)	0,1850000E-01	0,0	0,0
X(3, 4, 2)	0,1850000E-01	0,0	0,0
X(3, 4, 4)	0,1850000E-01	0,0	0,0
X(3, 4, 5)	0,1850000E-01	0,0	0,0
X(3, 4, 8)	0,1850000E-01	0,0	0,0
X(3, 4, 12)	0,1850000E-01	0,0	0,6586263
X(3, 5, 1)	0,1728000E-01	INFINITY	0,0
X(3, 5, 2)	0,1728000E-01	0,0	0,0
X(3, 5, 3)	0,1728000E-01	0,0	0,0
X(3, 5, 4)	0,1728000E-01	0,0	0,0
X(3, 5, 5)	0,1728000E-01	0,0	0,0
X(3, 5, 6)	0,1728000E-01	0,0	0,0
X(3, 5, 7)	0,1728000E-01	0,0	0,0
X(3, 5, 8)	0,1728000E-01	0,0	0,0
X(3, 5, 9)	0,1728000E-01	0,0	0,0
X(3, 5, 10)	0,1728000E-01	0,0	0,0
X(3, 5, 12)	0,1728000E-01	0,0	0,0
X(3, 6, 1)	0,1739000E-01	0,0	0,0
X(3, 6, 5)	0,1739000E-01	0,0	0,0
X(3, 7, 1)	0,1741000E-01	0,0	0,0
X(3, 7, 2)	0,1741000E-01	0,0	0,0
X(3, 7, 3)	0,1741000E-01	0,0	0,0
X(3, 7, 6)	0,1741000E-01	0,0	0,0
X(3, 7, 10)	0,1741000E-01	0,0	0,0
X(3, 7, 11)	0,1741000E-01	0,0	0,5163805

X(4, 2, 1)	0,1167000	INFINITY	0,8945202
X(4, 4, 1)	0,9358000E-01	0,0	0,0
X(4, 4, 2)	0,9358000E-01	0,0	0,0
X(4, 4, 4)	0,9358000E-01	0,0	0,0
X(4, 4, 5)	0,9358000E-01	0,0	0,0
X(4, 4, 8)	0,9358000E-01	0,0	0,0
X(4, 4, 12)	0,9358000E-01	0,0	0,7171454
X(4, 5, 1)	0,8741000E-01	INFINITY	0,0
X(4, 5, 2)	0,8741000E-01	0,0	0,0
X(4, 5, 3)	0,8741000E-01	0,0	0,0
X(4, 5, 4)	0,8741000E-01	INFINITY	0,0
X(4, 5, 5)	0,8741000E-01	0,0	INFINITY
X(4, 5, 6)	0,8741000E-01	INFINITY	0,0
X(4, 5, 9)	0,8741000E-01	0,0	0,0
X(4, 5, 10)	0,8741000E-01	0,0	0,0
X(4, 5, 12)	0,8741000E-01	0,0	0,6699273
X(4, 6, 1)	0,8794000E-01	0,0	0,0
X(4, 6, 5)	0,8794000E-01	0,0	0,0
X(4, 7, 1)	0,8804000E-01	INFINITY	0,0
X(4, 7, 2)	0,8804000E-01	0,0	0,0
X(4, 7, 3)	0,8804000E-01	0,0	0,0
X(4, 7, 6)	0,8804000E-01	0,0	0,0
X(4, 7, 10)	0,8804000E-01	0,0	0,0
X(4, 7, 11)	0,8804000E-01	0,0	0,6746907
X(5, 2, 1)	0,3231000E-01	INFINITY	0,8945202
X(5, 4, 1)	0,2591000E-01	0,0	0,0
X(5, 4, 2)	0,2591000E-01	0,0	0,0
X(5, 4, 4)	0,2591000E-01	0,0	0,0
X(5, 4, 5)	0,2591000E-01	0,0	0,0
X(5, 4, 8)	0,2591000E-01	0,0	0,0
X(5, 4, 12)	0,2591000E-01	0,0	0,7171454
X(5, 5, 1)	0,2420000E-01	INFINITY	0,0
X(5, 5, 2)	0,2420000E-01	0,0	0,0
X(5, 5, 3)	0,2420000E-01	0,0	0,0
X(5, 5, 4)	0,2420000E-01	INFINITY	0,0
X(5, 5, 5)	0,2420000E-01	0,0	INFINITY
X(5, 5, 6)	0,2420000E-01	INFINITY	0,0
X(5, 5, 9)	0,2420000E-01	0,0	0,0
X(5, 5, 10)	0,2420000E-01	0,0	0,0
X(5, 5, 12)	0,2420000E-01	0,0	0,6699273
X(5, 6, 1)	0,2434000E-01	0,0	0,0
X(5, 6, 5)	0,2434000E-01	0,0	0,0
X(5, 7, 1)	0,2437000E-01	INFINITY	0,0
X(5, 7, 2)	0,2437000E-01	0,0	0,0
X(5, 7, 3)	0,2437000E-01	0,0	0,0
X(5, 7, 6)	0,2437000E-01	0,0	0,0
X(5, 7, 10)	0,2437000E-01	0,0	0,0
X(5, 7, 11)	0,2437000E-01	0,0	0,6746709

APPENDIX D

MODEL 2

D.1. Computer Program of Model 2

```
MODEL:
SETS:
 STAGE/1..5/;
 PRODUCT/1..7/;
 GROUP/1..2/;
 MOUNTH/1..12/;
 LINK1(STAGE,PRODUCT,MOUNTH):X;
 LINK2(GROUP,PRODUCT,MOUNTH):P;
 LINK3(PRODUCT,MOUNTH):Y;
ENDSETS

MIN=(0.8441*(@SUM(MOUNTH(K):X(1,1,K))))+(0.05196*(@SUM(MOUNTH(K):
X(2,1,K))))+(0.03023*(X(3,1,1)+X(3,1,2)+X(3,1,3)+X(3,1,4)+X(3,1,5)+X(3,1,6)+X(3,
1,7)+X(3,1,8)+X(3,1,9)+X(3,1,10)+X(3,1,11)+X(3,1,12))+(0.6444*(@SUM(MOUNT
H(K):X(1,2,K))))+(0.03966*(@SUM(MOUNTH(K):X(2,2,K))))+(0.02308*(@SUM(M
OUNTH(K):X(3,2,K))))+(0.1167*(@SUM(MOUNTH(K):X(4,2,K))))+(0.03231*(@S
UM(MOUNTH(K):X(5,2,K))))+(0.5253*(@SUM(MOUNTH(K):X(1,3,K))))+(0.03233
*(@SUM(MOUNTH(K):X(2,3,K))))+(0.01881*(@SUM(MOUNTH(K):X(3,3,K))))+(0
.5166*(@SUM(MOUNTH(K):X(1,4,K))))+(0.0318*(@SUM(MOUNTH(K):X(2,4,K)))
)+(0.0185*(@SUM(MOUNTH(K):X(3,4,K))))+(0.09358*(@SUM(MOUNTH(K):X(4,
4,K))))+(0.02591*(@SUM(MOUNTH(K):X(5,4,K))))+(0.4826*(@SUM(MOUNTH(K
):X(1,5,K))))+(0.0297*(@SUM(MOUNTH(K):X(2,5,K))))+(0.01728*(@SUM(MOUN
TH(K):X(3,5,K))))+(0.08741*(@SUM(MOUNTH(K):X(4,5,K))))+(0.0242*(@SUM(
MOUNTH(K):X(5,5,K))))+(0.4855*(@SUM(MOUNTH(K):X(1,6,K))))+(0.02989*(@
SUM(MOUNTH(K):X(2,6,K))))+(0.01739*(@SUM(MOUNTH(K):X(3,6,K))))+(0.087
94*(@SUM(MOUNTH(K):X(4,6,K))))+(0.02434*(@SUM(MOUNTH(K):X(5,6,K))))
+(0.486*(@SUM(MOUNTH(K):X(1,7,K))))+(0.02992*(@SUM(MOUNTH(K):X(2,7,
K))))+(0.01741*(@SUM(MOUNTH(K):X(3,7,K))))+(0.08804*(@SUM(MOUNTH(K)
:X(4,7,K))))+(0.02437*(@SUM(MOUNTH(K):X(5,7,K)))));
@FOR(MOUNTH(K):X(2,1,K)=0.02*X(1,1,K)+0.0816*X(3,1,K));
@FOR(MOUNTH(K):X(2,2,K)=0.02*X(1,2,K)+0.0816*X(3,2,K));
@FOR(MOUNTH(K):X(2,3,K)=0.02*X(1,3,K)+0.0816*X(3,3,K));
@FOR(MOUNTH(K):X(2,4,K)=0.02*X(1,4,K)+0.0816*X(3,4,K));
@FOR(MOUNTH(K):X(2,5,K)=0.02*X(1,5,K)+0.0816*X(3,5,K));
@FOR(MOUNTH(K):X(2,6,K)=0.02*X(1,6,K)+0.0816*X(3,6,K));
@FOR(MOUNTH(K):X(2,7,K)=0.02*X(1,7,K)+0.0816*X(3,7,K));
@FOR(MOUNTH(K):X(3,1,K)=0.98*X(1,1,K));
@FOR(MOUNTH(K):X(3,2,K)=0.98*X(1,2,K));
@FOR(MOUNTH(K):X(3,3,K)=0.98*X(1,3,K));
@FOR(MOUNTH(K):X(3,4,K)=0.98*X(1,4,K));
@FOR(MOUNTH(K):X(3,5,K)=0.98*X(1,5,K));
@FOR(MOUNTH(K):X(3,6,K)=0.98*X(1,6,K));
@FOR(MOUNTH(K):X(3,7,K)=0.98*X(1,7,K));
```

```
@FOR(MOUNTH(K):P(1,1,K)=0.9184*X(3,1,K)-X(4,1,K));
@FOR(MOUNTH(K):P(1,2,K)=0.9184*X(3,2,K)-X(4,2,K));
@FOR(MOUNTH(K):P(1,3,K)=0.9184*X(3,3,K)-X(4,3,K));
@FOR(MOUNTH(K):P(1,4,K)=0.9184*X(3,4,K)-X(4,4,K));
@FOR(MOUNTH(K):P(1,5,K)=0.9184*X(3,5,K)-X(4,5,K));
@FOR(MOUNTH(K):P(1,6,K)=0.9184*X(3,6,K)-X(4,6,K));
@FOR(MOUNTH(K):P(1,7,K)=0.9184*X(3,7,K)-X(4,7,K));
@FOR(MOUNTH(K):X(4,1,K)=0);
@FOR(MOUNTH(K):X(4,3,K)=0);
@FOR(MOUNTH(K):P(1,2,K)=0);
@FOR(MOUNTH(K):P(1,6,K)=0);
@FOR(MOUNTH(K):X(5,1,K)=X(4,1,K));
@FOR(MOUNTH(K):X(5,2,K)=X(4,2,K));
@FOR(MOUNTH(K):X(5,3,K)=X(4,3,K));
@FOR(MOUNTH(K):X(5,4,K)=X(4,4,K));
@FOR(MOUNTH(K):X(5,5,K)=X(4,5,K));
@FOR(MOUNTH(K):X(5,6,K)=X(4,6,K));
@FOR(MOUNTH(K):X(5,7,K)=X(4,7,K));
@FOR(MOUNTH(K):P(2,1,K)=0.9952*X(5,1,K));
@FOR(MOUNTH(K):P(2,2,K)=0.9952*X(5,2,K));
@FOR(MOUNTH(K):P(2,3,K)=0.9952*X(5,3,K));
@FOR(MOUNTH(K):P(2,4,K)=0.9952*X(5,4,K));
@FOR(MOUNTH(K):P(2,5,K)=0.9952*X(5,5,K));
@FOR(MOUNTH(K):P(2,6,K)=0.9952*X(5,6,K));
@FOR(MOUNTH(K):P(2,7,K)=0.9952*X(5,7,K));
P(1,1,1)>=0;
P(2,2,1)>=6417;
P(1,3,1)>=47667;
P(1,4,1)>=495;
P(2,4,1)>=145299;
P(1,5,1)>=263907;
P(2,5,1)>=140285;
P(2,6,1)>=14199;
P(1,7,1)>=2270;
P(2,7,1)>=102638;
P(1,1,1)+P(1,1,2)=64724;
P(1,1,2)+P(1,1,3)=75275;
P(1,1,3)+P(1,1,4)=32107;
P(1,1,4)+P(1,1,5)=45604;
P(1,1,5)+P(1,1,6)=31311;
P(1,1,6)+P(1,1,7)=7263;
P(1,1,7)+P(1,1,8)=22469;
P(1,1,8)+P(1,1,9)=51115;
P(1,1,9)+P(1,1,10)=28646;
P(1,1,10)+P(1,1,11)=29420;
P(1,1,11)+P(1,1,12)=109320;
P(2,2,1)+P(2,2,2)=6417;
P(2,2,2)+P(2,2,3)=0;
P(2,2,3)+P(2,2,4)=0;
P(2,2,4)+P(2,2,5)=583;
```

P(2,2,5)+P(2,2,6)=583;
P(2,2,6)+P(2,2,7)=0;
P(2,2,7)+P(2,2,8)=0;
P(2,2,8)+P(2,2,9)=0;
P(2,2,9)+P(2,2,10)=0;
P(2,2,10)+P(2,2,11)=0;
P(2,2,11)+P(2,2,12)=0;
P(1,3,1)+P(1,3,2)=127915;
P(1,3,2)+P(1,3,3)=114961;
P(1,3,3)+P(1,3,4)=159662;
P(1,3,4)+P(1,3,5)=218191;
P(1,3,5)+P(1,3,6)=171730;
P(1,3,6)+P(1,3,7)=208232;
P(1,3,7)+P(1,3,8)=209502;
P(1,3,8)+P(1,3,9)=93024;
P(1,3,9)+P(1,3,10)=279604;
P(1,3,10)+P(1,3,11)=415060;
P(1,3,11)+P(1,3,12)=170495;
P(1,4,1)+P(1,4,2)=495;
P(1,4,2)+P(1,4,3)=0;
P(1,4,3)+P(1,4,4)=0;
P(1,4,4)+P(1,4,5)=285;
P(1,4,5)+P(1,4,6)=2928;
P(1,4,6)+P(1,4,7)=2643;
P(1,4,7)+P(1,4,8)=0;
P(1,4,8)+P(1,4,9)=0;
P(1,4,9)+P(1,4,10)=0;
P(1,4,10)+P(1,4,11)=0;
P(1,4,11)+P(1,4,12)=0;
P(2,4,1)+P(2,4,2)=245969;
P(2,4,2)+P(2,4,3)=247829;
P(2,4,3)+P(2,4,4)=244071;
P(2,4,4)+P(2,4,5)=224069;
P(2,4,5)+P(2,4,6)=235322;
P(2,4,6)+P(2,4,7)=192282;
P(2,4,7)+P(2,4,8)=253095;
P(2,4,8)+P(2,4,9)=282208;
P(2,4,9)+P(2,4,10)=307420;
P(2,4,10)+P(2,4,11)=351260;
P(2,4,11)+P(2,4,12)=240009;
P(1,5,1)+P(1,5,2)=488813;
P(1,5,2)+P(1,5,3)=461460;
P(1,5,3)+P(1,5,4)=439672;
P(1,5,4)+P(1,5,5)=456702;
P(1,5,5)+P(1,5,6)=453978;
P(1,5,6)+P(1,5,7)=426418;
P(1,5,7)+P(1,5,8)=524389;
P(1,5,8)+P(1,5,9)=620513;
P(1,5,9)+P(1,5,10)=617298;
P(1,5,10)+P(1,5,11)=543453;

P(1,5,11)+P(1,5,12)=518863;
P(2,5,1)+P(2,5,2)=251536;
P(2,5,2)+P(2,5,3)=326890;
P(2,5,3)+P(2,5,4)=327353;
P(2,5,4)+P(2,5,5)=239374;
P(2,5,5)+P(2,5,6)=224740;
P(2,5,6)+P(2,5,7)=249069;
P(2,5,7)+P(2,5,8)=222743;
P(2,5,8)+P(2,5,9)=206109;
P(2,5,9)+P(2,5,10)=262285;
P(2,5,10)+P(2,5,11)=266870;
P(2,5,11)+P(2,5,12)=243256;
P(2,6,1)+P(2,6,2)=14199;
P(2,6,2)+P(2,6,3)=0;
P(2,6,3)+P(2,6,4)=0;
P(2,6,4)+P(2,6,5)=1810;
P(2,6,5)+P(2,6,6)=1810;
P(2,6,6)+P(2,6,7)=0;
P(2,6,7)+P(2,6,8)=0;
P(2,6,8)+P(2,6,9)=0;
P(2,6,9)+P(2,6,10)=0;
P(2,6,10)+P(2,6,11)=0;
P(2,6,11)+P(2,6,12)=5714;
P(1,7,1)+P(1,7,2)=9659;
P(1,7,2)+P(1,7,3)=28080;
P(1,7,3)+P(1,7,4)=20691;
P(1,7,4)+P(1,7,5)=9348;
P(1,7,5)+P(1,7,6)=11960;
P(1,7,6)+P(1,7,7)=17867;
P(1,7,7)+P(1,7,8)=29356;
P(1,7,8)+P(1,7,9)=38000;
P(1,7,9)+P(1,7,10)=23899;
P(1,7,10)+P(1,7,11)=4331;
P(1,7,11)+P(1,7,12)=16612;
P(2,7,1)+P(2,7,2)=198159;
P(2,7,2)+P(2,7,3)=161190;
P(2,7,3)+P(2,7,4)=187586;
P(2,7,4)+P(2,7,5)=190622;
P(2,7,5)+P(2,7,6)=208760;
P(2,7,6)+P(2,7,7)=196545;
P(2,7,7)+P(2,7,8)=146348;
P(2,7,8)+P(2,7,9)=117993;
P(2,7,9)+P(2,7,10)=41061;
P(2,7,10)+P(2,7,11)=36058;
P(2,7,11)+P(2,7,12)=42603;
(1.5*Y(1,1)+0.0013695*(P(1,1,1)+P(2,1,1)))+(1*Y(2,1)+0.00104542*(P(1,2,1)+P(2,2,1)))+(1*Y(3,1)+0.00085218*(P(1,3,1)+P(2,3,1)))+(1*Y(4,1)+0.00083819*(P(1,4,1)+P(2,4,1)))+(1*Y(5,1)+0.00078292*(P(1,5,1)+P(2,5,1)))+(1*Y(6,1)+0.0007877*(P(1,6,1)+P(2,6,1)))+(1*Y(7,1)+0.00078856*(P(1,7,1)+P(2,7,1)))<=696;
(P(1,1,1)+P(2,1,1))<=10000000000*Y(1,1);

```
(P(1,1,1)+P(2,1,1))>=Y(1,1);
(P(1,2,1)+P(2,2,1))<=10000000000*Y(2,1);
(P(1,2,1)+P(2,2,1))>=Y(2,1);
(P(1,3,1)+P(2,3,1))<=10000000000*Y(3,1);
(P(1,3,1)+P(2,3,1))>=Y(3,1);
(P(1,4,1)+P(2,4,1))<=10000000000*Y(4,1);
(P(1,4,1)+P(2,4,1))>=Y(4,1);
(P(1,5,1)+P(2,5,1))<=10000000000*Y(5,1);
(P(1,5,1)+P(2,5,1))>=Y(5,1);
(P(1,6,1)+P(2,6,1))<=10000000000*Y(6,1);
(P(1,6,1)+P(2,6,1))>=Y(6,1);
(P(1,7,1)+P(2,7,1))<=10000000000*Y(7,1);
(P(1,7,1)+P(2,7,1))>=Y(7,1);
(1.5*Y(1,2)+0.0013695*(P(1,1,2)+P(2,1,2)))+(1*Y(2,2)+0.00104542*(P(1,2,2)+P(2,2,2)))+(1*Y(3,2)+0.00085218*(P(1,3,2)+P(2,3,2)))+(1*Y(4,2)+0.00083819*(P(1,4,2)+P(2,4,2)))+(1*Y(5,2)+0.00078292*(P(1,5,2)+P(2,5,2)))+(1*Y(6,2)+0.0007877*(P(1,6,2)+P(2,6,2)))+(1*Y(7,2)+0.00078856*(P(1,7,2)+P(2,7,2)))<=624;
(P(1,1,2)+P(2,1,2))<=10000000000*Y(1,2);
(P(1,1,2)+P(2,1,2))>=Y(1,2);
(P(1,2,2)+P(2,2,2))<=10000000000*Y(2,2);
(P(1,2,2)+P(2,2,2))>=Y(2,2);
(P(1,3,2)+P(2,3,2))<=10000000000*Y(3,2);
(P(1,3,2)+P(2,3,2))>=Y(3,2);
(P(1,4,2)+P(2,4,2))<=10000000000*Y(4,2);
(P(1,4,2)+P(2,4,2))>=Y(4,2);
(P(1,5,2)+P(2,5,2))<=10000000000*Y(5,2);
(P(1,5,2)+P(2,5,2))>=Y(5,2);
(P(1,6,2)+P(2,6,2))<=10000000000*Y(6,2);
(P(1,6,2)+P(2,6,2))>=Y(6,2);
(P(1,7,2)+P(2,7,2))<=10000000000*Y(7,2);
(P(1,7,2)+P(2,7,2))>=Y(7,2);
(1.5*Y(1,3)+0.0013695*(P(1,1,3)+P(2,1,3)))+(1*Y(2,3)+0.00104542*(P(1,2,3)+P(2,2,3)))+(1*Y(3,3)+0.00085218*(P(1,3,3)+P(2,3,3)))+(1*Y(4,3)+0.00083819*(P(1,4,3)+P(2,4,3)))+(1*Y(5,3)+0.00078292*(P(1,5,3)+P(2,5,3)))+(1*Y(6,3)+0.0007877*(P(1,6,3)+P(2,6,3)))+(1*Y(7,3)+0.00078856*(P(1,7,3)+P(2,7,3)))<=696;
(P(1,1,3)+P(2,1,3))<=10000000000*Y(1,3);
(P(1,1,3)+P(2,1,3))>=Y(1,3);
(P(1,2,3)+P(2,2,3))<=10000000000*Y(2,3);
(P(1,2,3)+P(2,2,3))>=Y(2,3);
(P(1,3,3)+P(2,3,3))<=10000000000*Y(3,3);
(P(1,3,3)+P(2,3,3))>=Y(3,3);
(P(1,4,3)+P(2,4,3))<=10000000000*Y(4,3);
(P(1,4,3)+P(2,4,3))>=Y(4,3);
(P(1,5,3)+P(2,5,3))<=10000000000*Y(5,3);
(P(1,5,3)+P(2,5,3))>=Y(5,3);
(P(1,6,3)+P(2,6,3))<=10000000000*Y(6,3);
(P(1,6,3)+P(2,6,3))>=Y(6,3);
(P(1,7,3)+P(2,7,3))<=10000000000*Y(7,3);
(P(1,7,3)+P(2,7,3))>=Y(7,3);
```

```
(1.5*Y(1,4)+0.0013695*(P(1,1,4)+P(2,1,4)))+(1*Y(2,4)+0.00104542*(P(1,2,4)+P(2,2,4
)))+(1*Y(3,4)+0.00085218*(P(1,3,4)+P(2,3,4)))+(1*Y(4,4)+0.00083819*(P(1,4,4)+P(2
,4,4)))+(1*Y(5,4)+0.00078292*(P(1,5,4)+P(2,5,4)))+(1*Y(6,4)+0.0007877*(P(1,6,4)+P
(2,6,4)))+(1*Y(7,4)+0.00078856*(P(1,7,4)+P(2,7,4)))<=672;
(P(1,1,4)+P(2,1,4))<=10000000000*Y(1,4);
(P(1,1,4)+P(2,1,4))>=Y(1,4);
(P(1,2,4)+P(2,2,4))<=10000000000*Y(2,4);
(P(1,2,4)+P(2,2,4))>=Y(2,4);
(P(1,3,4)+P(2,3,4))<=10000000000*Y(3,4);
(P(1,3,4)+P(2,3,4))>=Y(3,4);
(P(1,4,4)+P(2,4,4))<=10000000000*Y(4,4);
(P(1,4,4)+P(2,4,4))>=Y(4,4);
(P(1,5,4)+P(2,5,4))<=10000000000*Y(5,4);
(P(1,5,4)+P(2,5,4))>=Y(5,4);
(P(1,6,4)+P(2,6,4))<=10000000000*Y(6,4);
(P(1,6,4)+P(2,6,4))>=Y(6,4);
(P(1,7,4)+P(2,7,4))<=10000000000*Y(7,4);
(P(1,7,4)+P(2,7,4))>=Y(7,4);
(1.5*Y(1,5)+0.0013695*(P(1,1,5)+P(2,1,5)))+(1*Y(2,5)+0.00104542*(P(1,2,5)+P(2,2,5
)))+(1*Y(3,5)+0.00085218*(P(1,3,5)+P(2,3,5)))+(1*Y(4,5)+0.00083819*(P(1,4,5)+P(2
,4,5)))+(1*Y(5,5)+0.00078292*(P(1,5,5)+P(2,5,5)))+(1*Y(6,5)+0.0007877*(P(1,6,5)+P
(2,6,5)))+(1*Y(7,5)+0.00078856*(P(1,7,5)+P(2,7,5)))<=696;
(P(1,1,5)+P(2,1,5))<=10000000000*Y(1,5);
(P(1,1,5)+P(2,1,5))>=Y(1,5);
(P(1,2,5)+P(2,2,5))<=10000000000*Y(2,5);
(P(1,2,5)+P(2,2,5))>=Y(2,5);
(P(1,3,5)+P(2,3,5))<=10000000000*Y(3,5);
(P(1,3,5)+P(2,3,5))>=Y(3,5);
(P(1,4,5)+P(2,4,5))<=10000000000*Y(4,5);
(P(1,4,5)+P(2,4,5))>=Y(4,5);
(P(1,5,5)+P(2,5,5))<=10000000000*Y(5,5);
(P(1,5,5)+P(2,5,5))>=Y(5,5);
(P(1,6,5)+P(2,6,5))<=10000000000*Y(6,5);
(P(1,6,5)+P(2,6,5))>=Y(6,5);
(P(1,7,5)+P(2,7,5))<=10000000000*Y(7,5);
(P(1,7,5)+P(2,7,5))>=Y(7,5);
(1.5*Y(1,6)+0.0013695*(P(1,1,6)+P(2,1,6)))+(1*Y(2,6)+0.00104542*(P(1,2,6)+P(2,2,6
)))+(1*Y(3,6)+0.00085218*(P(1,3,6)+P(2,3,6)))+(1*Y(4,6)+0.00083819*(P(1,4,6)+P(2
,4,6)))+(1*Y(5,6)+0.00078292*(P(1,5,6)+P(2,5,6)))+(1*Y(6,6)+0.0007877*(P(1,6,6)+P
(2,6,6)))+(1*Y(7,6)+0.00078856*(P(1,7,6)+P(2,7,6)))<=672;
(P(1,1,6)+P(2,1,6))<=10000000000*Y(1,6);
(P(1,1,6)+P(2,1,6))>=Y(1,6);
(P(1,2,6)+P(2,2,6))<=10000000000*Y(2,6);
(P(1,2,6)+P(2,2,6))>=Y(2,6);
(P(1,3,6)+P(2,3,6))<=10000000000*Y(3,6);
(P(1,3,6)+P(2,3,6))>=Y(3,6);
(P(1,4,6)+P(2,4,6))<=10000000000*Y(4,6);
(P(1,4,6)+P(2,4,6))>=Y(4,6);
(P(1,5,6)+P(2,5,6))<=10000000000*Y(5,6);
(P(1,5,6)+P(2,5,6))>=Y(5,6);
```

(P(1,6,6)+P(2,6,6))<=10000000000*Y(6,6);
(P(1,6,6)+P(2,6,6))>=Y(6,6);
(P(1,7,6)+P(2,7,6))<=10000000000*Y(7,6);
(P(1,7,6)+P(2,7,6))>=Y(7,6);
(1.5*Y(1,7)+0.0013695*(P(1,1,7)+P(2,1,7)))+(1*Y(2,7)+0.00104542*(P(1,2,7)+P(2,2,7)))+(1*Y(3,7)+0.00085218*(P(1,3,7)+P(2,3,7)))+(1*Y(4,7)+0.00083819*(P(1,4,7)+P(2,4,7)))+(1*Y(5,7)+0.00078292*(P(1,5,7)+P(2,5,7)))+(1*Y(6,7)+0.0007877*(P(1,6,7)+P(2,6,7)))+(1*Y(7,7)+0.00078856*(P(1,7,7)+P(2,7,7)))<=696;
(P(1,1,7)+P(2,1,7))<=10000000000*Y(1,7);
(P(1,1,7)+P(2,1,7))>=Y(1,7);
(P(1,2,7)+P(2,2,7))<=10000000000*Y(2,7);
(P(1,2,7)+P(2,2,7))>=Y(2,7);
(P(1,3,7)+P(2,3,7))<=10000000000*Y(3,7);
(P(1,3,7)+P(2,3,7))>=Y(3,7);
(P(1,4,7)+P(2,4,7))<=10000000000*Y(4,7);
(P(1,4,7)+P(2,4,7))>=Y(4,7);
(P(1,5,7)+P(2,5,7))<=10000000000*Y(5,7);
(P(1,5,7)+P(2,5,7))>=Y(5,7);
(P(1,6,7)+P(2,6,7))<=10000000000*Y(6,7);
(P(1,6,7)+P(2,6,7))>=Y(6,7);
(P(1,7,7)+P(2,7,7))<=10000000000*Y(7,7);
(P(1,7,7)+P(2,7,7))>=Y(7,7);
(1.5*Y(1,8)+0.0013695*(P(1,1,8)+P(2,1,8)))+(1*Y(2,8)+0.00104542*(P(1,2,8)+P(2,2,8)))+(1*Y(3,8)+0.00085218*(P(1,3,8)+P(2,3,8)))+(1*Y(4,8)+0.00083819*(P(1,4,8)+P(2,4,8)))+(1*Y(5,8)+0.00078292*(P(1,5,8)+P(2,5,8)))+(1*Y(6,8)+0.0007877*(P(1,6,8)+P(2,6,8)))+(1*Y(7,8)+0.00078856*(P(1,7,8)+P(2,7,8)))<=696;
(P(1,1,8)+P(2,1,8))<=10000000000*Y(1,8);
(P(1,1,8)+P(2,1,8))>=Y(1,8);
(P(1,2,8)+P(2,2,8))<=10000000000*Y(2,8);
(P(1,2,8)+P(2,2,8))>=Y(2,8);
(P(1,3,8)+P(2,3,8))<=10000000000*Y(3,8);
(P(1,3,8)+P(2,3,8))>=Y(3,8);
(P(1,4,8)+P(2,4,8))<=10000000000*Y(4,8);
(P(1,4,8)+P(2,4,8))>=Y(4,8);
(P(1,5,8)+P(2,5,8))<=10000000000*Y(5,8);
(P(1,5,8)+P(2,5,8))>=Y(5,8);
(P(1,6,8)+P(2,6,8))<=10000000000*Y(6,8);
(P(1,6,8)+P(2,6,8))>=Y(6,8);
(P(1,7,8)+P(2,7,8))<=10000000000*Y(7,8);
(P(1,7,8)+P(2,7,8))>=Y(7,8);
(1.5*Y(1,9)+0.0013695*(P(1,1,9)+P(2,1,9)))+(1*Y(2,9)+0.00104542*(P(1,2,9)+P(2,2,9)))+(1*Y(3,9)+0.00085218*(P(1,3,9)+P(2,3,9)))+(1*Y(4,9)+0.00083819*(P(1,4,9)+P(2,4,9)))+(1*Y(5,9)+0.00078292*(P(1,5,9)+P(2,5,9)))+(1*Y(6,9)+0.0007877*(P(1,6,9)+P(2,6,9)))+(1*Y(7,9)+0.00078856*(P(1,7,9)+P(2,7,9)))<=672;
(P(1,1,9)+P(2,1,9))<=10000000000*Y(1,9);
(P(1,1,9)+P(2,1,9))>=Y(1,9);
(P(1,2,9)+P(2,2,9))<=10000000000*Y(2,9);
(P(1,2,9)+P(2,2,9))>=Y(2,9);
(P(1,3,9)+P(2,3,9))<=10000000000*Y(3,9);
(P(1,3,9)+P(2,3,9))>=Y(3,9);

```
(P(1,4,9)+P(2,4,9))<=10000000000*Y(4,9);
(P(1,4,9)+P(2,4,9))>=Y(4,9);
(P(1,5,9)+P(2,5,9))<=10000000000*Y(5,9);
(P(1,5,9)+P(2,5,9))>=Y(5,9);
(P(1,6,9)+P(2,6,9))<=10000000000*Y(6,9);
(P(1,6,9)+P(2,6,9))>=Y(6,9);
(P(1,7,9)+P(2,7,9))<=10000000000*Y(7,9);
(P(1,7,9)+P(2,7,9))>=Y(7,9);
(1.5*Y(1,10)+0.0013695*(P(1,1,10)+P(2,1,10)))+(1*Y(2,10)+0.00104542*(P(1,2,10)+
P(2,2,10)))+(1*Y(3,10)+0.00085218*(P(1,3,10)+P(2,3,10)))+(1*Y(4,10)+0.00083819*(
P(1,4,10)+P(2,4,10)))+(1*Y(5,10)+0.00078292*(P(1,5,10)+P(2,5,10)))+(1*Y(6,10)+0.0
007877*(P(1,6,10)+P(2,6,10)))+(1*Y(7,10)+0.00078856*(P(1,7,10)+P(2,7,10)))<=696;
(P(1,1,10)+P(2,1,10))<=10000000000*Y(1,10);
(P(1,1,10)+P(2,1,10))>=Y(1,10);
(P(1,2,10)+P(2,2,10))<=10000000000*Y(2,10);
(P(1,2,10)+P(2,2,10))>=Y(2,10);
(P(1,3,10)+P(2,3,10))<=10000000000*Y(3,10);
(P(1,3,10)+P(2,3,10))>=Y(3,10);
(P(1,4,10)+P(2,4,10))<=10000000000*Y(4,10);
(P(1,4,10)+P(2,4,10))>=Y(4,10);
(P(1,5,10)+P(2,5,10))<=10000000000*Y(5,10);
(P(1,5,10)+P(2,5,10))>=Y(5,10);
(P(1,6,10)+P(2,6,10))<=10000000000*Y(6,10);
(P(1,6,10)+P(2,6,10))>=Y(6,10);
(P(1,7,10)+P(2,7,10))<=10000000000*Y(7,10);
(P(1,7,10)+P(2,7,10))>=Y(7,10);
(1.5*Y(1,11)+0.0013695*(P(1,1,11)+P(2,1,11)))+(1*Y(2,11)+0.00104542*(P(1,2,11)+
P(2,2,11)))+(1*Y(3,11)+0.00085218*(P(1,3,11)+P(2,3,11)))+(1*Y(4,11)+0.00083819*(
P(1,4,11)+P(2,4,11)))+(1*Y(5,11)+0.00078292*(P(1,5,11)+P(2,5,11)))+(1*Y(6,11)+0.0
007877*(P(1,6,11)+P(2,6,11)))+(1*Y(7,11)+0.00078856*(P(1,7,11)+P(2,7,11)))<=672;
(P(1,1,11)+P(2,1,11))<=10000000000*Y(1,11);
(P(1,1,11)+P(2,1,11))>=Y(1,11);
(P(1,2,11)+P(2,2,11))<=10000000000*Y(2,11);
(P(1,2,11)+P(2,2,11))>=Y(2,11);
(P(1,3,11)+P(2,3,11))<=10000000000*Y(3,11);
(P(1,3,11)+P(2,3,11))>=Y(3,11);
(P(1,4,11)+P(2,4,11))<=10000000000*Y(4,11);
(P(1,4,11)+P(2,4,11))>=Y(4,11);
(P(1,5,11)+P(2,5,11))<=10000000000*Y(5,11);
(P(1,5,11)+P(2,5,11))>=Y(5,11);
(P(1,6,11)+P(2,6,11))<=10000000000*Y(6,11);
(P(1,6,11)+P(2,6,11))>=Y(6,11);
(P(1,7,11)+P(2,7,11))<=10000000000*Y(7,11);
(P(1,7,11)+P(2,7,11))>=Y(7,11);
(1.5*Y(1,12)+0.0013695*(P(1,1,12)+P(2,1,12)))+(1*Y(2,12)+0.00104542*(P(1,2,12)+
P(2,2,12)))+(1*Y(3,12)+0.00085218*(P(1,3,12)+P(2,3,12)))+(1*Y(4,12)+0.00083819*(
P(1,4,12)+P(2,4,12)))+(1*Y(5,12)+0.00078292*(P(1,5,12)+P(2,5,12)))+(1*Y(6,12)+0.0
007877*(P(1,6,12)+P(2,6,12)))+(1*Y(7,12)+0.00078856*(P(1,7,12)+P(2,7,12)))<=696;
(P(1,1,12)+P(2,1,12))<=10000000000*Y(1,12);
(P(1,1,12)+P(2,1,12))>=Y(1,12);
```

```
(P(1,2,12)+P(2,2,12))<=10000000000*Y(2,12);
(P(1,2,12)+P(2,2,12))>=Y(2,12);
(P(1,3,12)+P(2,3,12))<=10000000000*Y(3,12);
(P(1,3,12)+P(2,3,12))>=Y(3,12);
(P(1,4,12)+P(2,4,12))<=10000000000*Y(4,12);
(P(1,4,12)+P(2,4,12))>=Y(4,12);
(P(1,5,12)+P(2,5,12))<=10000000000*Y(5,12);
(P(1,5,12)+P(2,5,12))>=Y(5,12);
(P(1,6,12)+P(2,6,12))<=10000000000*Y(6,12);
(P(1,6,12)+P(2,6,12))>=Y(6,12);
(P(1,7,12)+P(2,7,12))<=10000000000*Y(7,12);
(P(1,7,12)+P(2,7,12))>=Y(7,12);
@FOR(LINK1(I,J,K):X(I,J,K)>=0);
@FOR(LINK3(J,K):@BIN(Y(J,K)));
END
```

D.2. Output of Model 2

Optimal solution found at step: 29
Objective value: 5436618.

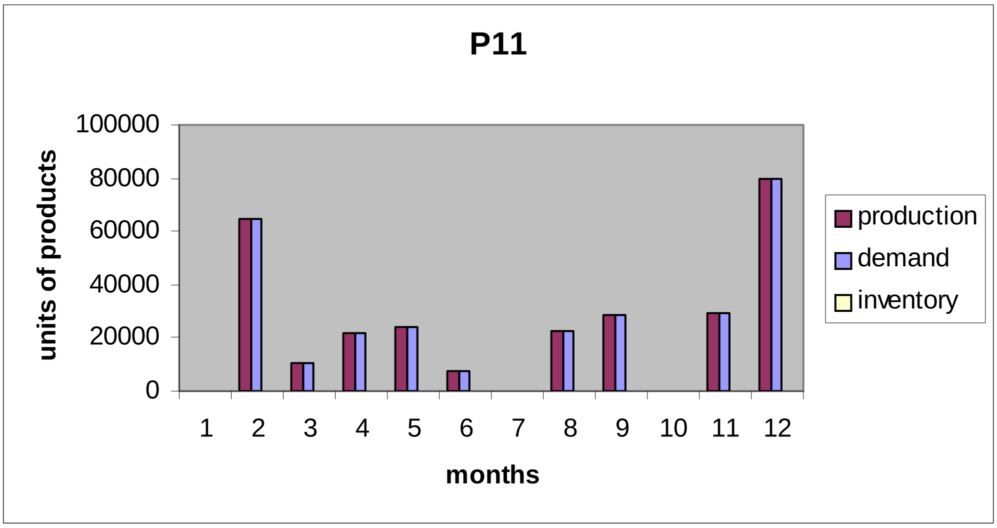
Variable	Value	Reduced Cost
P(1, 1, 1)	0.0000000E+00	0.0000000E+00
P(1, 1, 2)	64724.00	0.0000000E+00
P(1, 1, 3)	10551.00	0.0000000E+00
P(1, 1, 4)	21556.00	0.0000000E+00
P(1, 1, 5)	24048.00	0.0000000E+00
P(1, 1, 6)	7263.000	0.0000000E+00
P(1, 1, 7)	0.0000000E+00	0.0000000E+00
P(1, 1, 8)	22469.00	0.0000000E+00
P(1, 1, 9)	28646.00	0.0000000E+00
P(1, 1, 10)	0.0000000E+00	0.9765428
P(1, 1, 11)	29420.00	0.0000000E+00
P(1, 1, 12)	79900.00	0.0000000E+00
P(1, 2, 1)	0.0000000E+00	0.0000000E+00
P(1, 2, 2)	0.0000000E+00	0.0000000E+00
P(1, 2, 3)	0.0000000E+00	0.0000000E+00
P(1, 2, 4)	0.0000000E+00	0.0000000E+00
P(1, 2, 5)	0.0000000E+00	0.0000000E+00
P(1, 2, 6)	0.0000000E+00	0.0000000E+00
P(1, 2, 7)	0.0000000E+00	0.0000000E+00
P(1, 2, 8)	0.0000000E+00	0.0000000E+00
P(1, 2, 9)	0.0000000E+00	0.0000000E+00
P(1, 2, 10)	0.0000000E+00	0.0000000E+00
P(1, 2, 11)	0.0000000E+00	0.0000000E+00
P(1, 2, 12)	0.0000000E+00	0.0000000E+00
P(1, 3, 1)	69439.00	0.0000000E+00
P(1, 3, 2)	58476.00	0.0000000E+00
P(1, 3, 3)	56485.00	0.0000000E+00

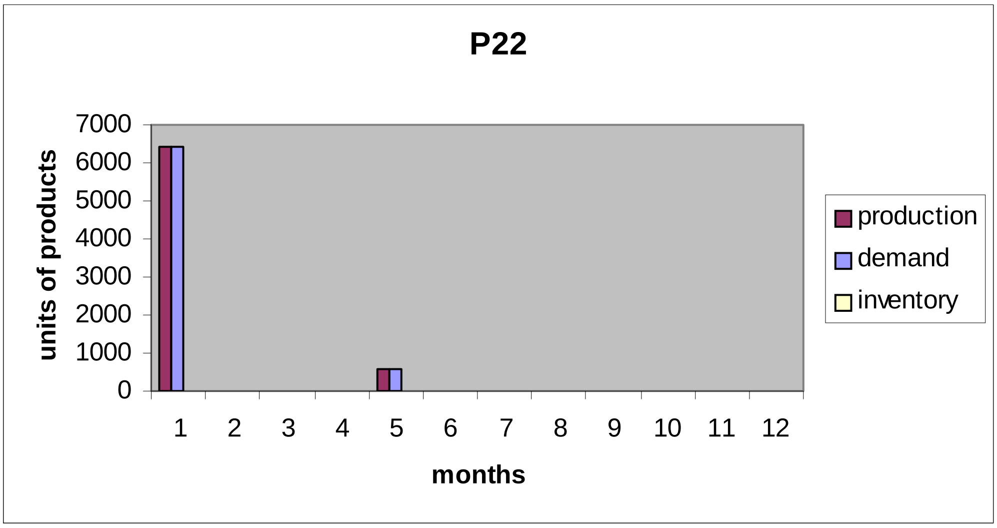
P(1, 3, 4)	103177.0	0.0000000E+00
P(1, 3, 5)	115014.0	0.0000000E+00
P(1, 3, 6)	56716.00	0.0000000E+00
P(1, 3, 7)	151516.0	0.0000000E+00
P(1, 3, 8)	57986.00	0.0000000E+00
P(1, 3, 9)	35038.00	0.0000000E+00
P(1, 3, 10)	244566.0	0.0000000E+00
P(1, 3, 11)	170494.0	0.0000000E+00
P(1, 3, 12)	1.000000	0.0000000E+00
P(1, 4, 1)	495.0000	0.0000000E+00
P(1, 4, 2)	0.0000000E+00	0.5976554
P(1, 4, 3)	0.0000000E+00	0.5976554
P(1, 4, 4)	0.0000000E+00	0.5976554
P(1, 4, 5)	285.0000	0.0000000E+00
P(1, 4, 6)	2643.000	0.0000000E+00
P(1, 4, 7)	0.0000000E+00	0.5976554
P(1, 4, 8)	0.0000000E+00	0.5976554
P(1, 4, 9)	0.0000000E+00	0.5976554
P(1, 4, 10)	0.0000000E+00	0.5976554
P(1, 4, 11)	0.0000000E+00	0.5976554
P(1, 4, 12)	0.0000000E+00	0.5976554
P(1, 5, 1)	263907.0	0.0000000E+00
P(1, 5, 2)	224906.0	0.0000000E+00
P(1, 5, 3)	236554.0	0.0000000E+00
P(1, 5, 4)	203118.0	0.0000000E+00
P(1, 5, 5)	253584.0	0.0000000E+00
P(1, 5, 6)	200394.0	0.0000000E+00
P(1, 5, 7)	226024.0	0.0000000E+00
P(1, 5, 8)	298365.0	0.0000000E+00
P(1, 5, 9)	322148.0	0.0000000E+00
P(1, 5, 10)	295150.0	0.0000000E+00
P(1, 5, 11)	248303.0	0.0000000E+00
P(1, 5, 12)	270560.0	0.0000000E+00
P(1, 6, 1)	0.0000000E+00	0.0000000E+00
P(1, 6, 2)	0.0000000E+00	0.0000000E+00
P(1, 6, 3)	0.0000000E+00	0.0000000E+00
P(1, 6, 4)	0.0000000E+00	0.0000000E+00
P(1, 6, 5)	0.0000000E+00	0.0000000E+00
P(1, 6, 6)	0.0000000E+00	0.0000000E+00
P(1, 6, 7)	0.0000000E+00	0.0000000E+00
P(1, 6, 8)	0.0000000E+00	0.0000000E+00
P(1, 6, 9)	0.0000000E+00	0.0000000E+00
P(1, 6, 10)	0.0000000E+00	0.0000000E+00
P(1, 6, 11)	0.0000000E+00	0.0000000E+00
P(1, 6, 12)	0.0000000E+00	0.0000000E+00
P(1, 7, 1)	2270.000	0.0000000E+00
P(1, 7, 2)	7389.000	0.0000000E+00
P(1, 7, 3)	20691.00	0.0000000E+00
P(1, 7, 4)	0.0000000E+00	0.5622609
P(1, 7, 5)	9348.000	0.0000000E+00

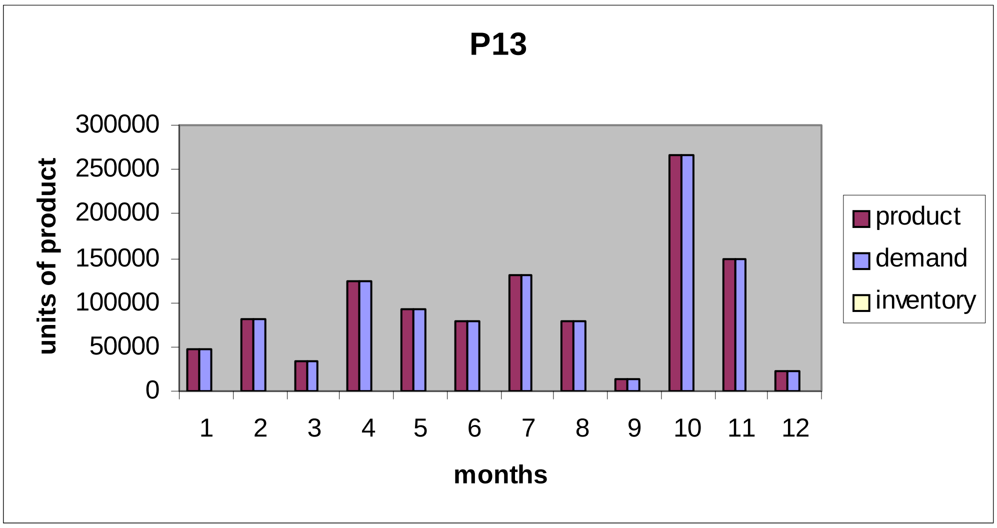
P(1, 7, 6)	2612.000	0.0000000E+00
P(1, 7, 7)	15255.00	0.0000000E+00
P(1, 7, 8)	14101.00	0.0000000E+00
P(1, 7, 9)	23899.00	0.0000000E+00
P(1, 7, 10)	0.0000000E+00	0.0000000E+00
P(1, 7, 11)	4331.000	0.0000000E+00
P(1, 7, 12)	12281.00	0.0000000E+00
P(2, 1, 1)	0.0000000E+00	0.0000000E+00
P(2, 1, 2)	0.0000000E+00	0.0000000E+00
P(2, 1, 3)	0.0000000E+00	0.0000000E+00
P(2, 1, 4)	0.0000000E+00	0.0000000E+00
P(2, 1, 5)	0.0000000E+00	0.0000000E+00
P(2, 1, 6)	0.0000000E+00	0.0000000E+00
P(2, 1, 7)	0.0000000E+00	0.0000000E+00
P(2, 1, 8)	0.0000000E+00	0.0000000E+00
P(2, 1, 9)	0.0000000E+00	0.0000000E+00
P(2, 1, 10)	0.0000000E+00	0.0000000E+00
P(2, 1, 11)	0.0000000E+00	0.0000000E+00
P(2, 1, 12)	0.0000000E+00	0.0000000E+00
P(2, 2, 1)	6417.000	0.0000000E+00
P(2, 2, 2)	0.0000000E+00	0.0000000E+00
P(2, 2, 3)	0.0000000E+00	0.0000000E+00
P(2, 2, 4)	0.0000000E+00	0.0000000E+00
P(2, 2, 5)	583.0000	0.0000000E+00
P(2, 2, 6)	0.0000000E+00	0.0000000E+00
P(2, 2, 7)	0.0000000E+00	0.8988347
P(2, 2, 8)	0.0000000E+00	0.0000000E+00
P(2, 2, 9)	0.0000000E+00	0.0000000E+00
P(2, 2, 10)	0.0000000E+00	0.0000000E+00
P(2, 2, 11)	0.0000000E+00	0.0000000E+00
P(2, 2, 12)	0.0000000E+00	0.0000000E+00
P(2, 3, 1)	0.0000000E+00	0.0000000E+00
P(2, 3, 2)	0.0000000E+00	0.0000000E+00
P(2, 3, 3)	0.0000000E+00	0.0000000E+00
P(2, 3, 4)	0.0000000E+00	0.0000000E+00
P(2, 3, 5)	0.0000000E+00	0.0000000E+00
P(2, 3, 6)	0.0000000E+00	0.0000000E+00
P(2, 3, 7)	0.0000000E+00	0.0000000E+00
P(2, 3, 8)	0.0000000E+00	0.0000000E+00
P(2, 3, 9)	0.0000000E+00	0.0000000E+00
P(2, 3, 10)	0.0000000E+00	0.0000000E+00
P(2, 3, 11)	0.0000000E+00	0.0000000E+00
P(2, 3, 12)	0.0000000E+00	0.0000000E+00
P(2, 4, 1)	161347.5	0.0000000E+00
P(2, 4, 2)	84621.54	0.0000000E+00
P(2, 4, 3)	163207.5	0.0000000E+00
P(2, 4, 4)	80863.54	0.0000000E+00
P(2, 4, 5)	143205.5	0.0000000E+00
P(2, 4, 6)	92116.54	0.0000000E+00
P(2, 4, 7)	100165.5	0.0000000E+00

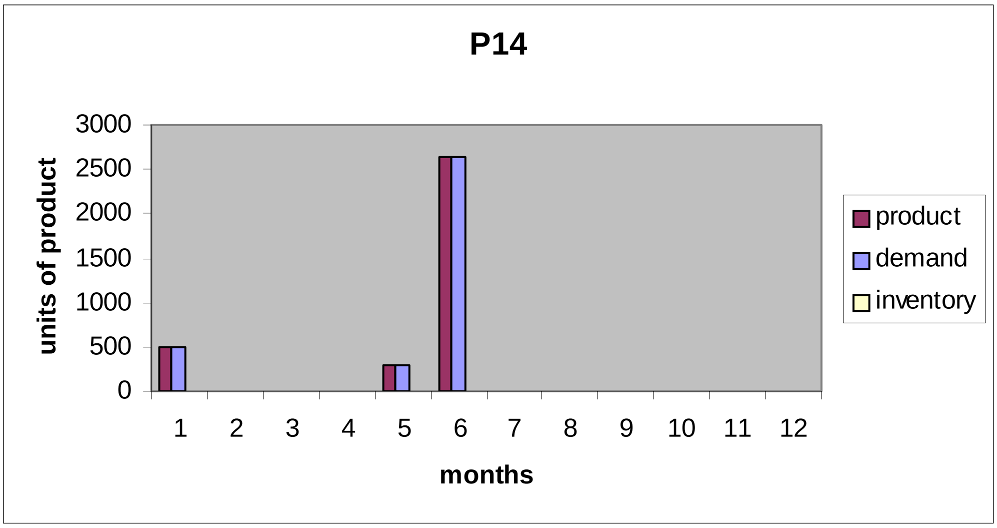
P(2, 4, 8)	152929.5	0.0000000E+00
P(2, 4, 9)	129278.5	0.0000000E+00
P(2, 4, 10)	178141.5	0.0000000E+00
P(2, 4, 11)	173118.5	0.0000000E+00
P(2, 4, 12)	66890.54	0.0000000E+00
P(2, 5, 1)	140285.0	0.0000000E+00
P(2, 5, 2)	111251.0	0.0000000E+00
P(2, 5, 3)	215639.0	0.0000000E+00
P(2, 5, 4)	111714.0	0.0000000E+00
P(2, 5, 5)	127660.0	0.0000000E+00
P(2, 5, 6)	97080.00	0.0000000E+00
P(2, 5, 7)	151989.0	0.0000000E+00
P(2, 5, 8)	70754.00	0.0000000E+00
P(2, 5, 9)	135355.0	0.0000000E+00
P(2, 5, 10)	126930.0	0.0000000E+00
P(2, 5, 11)	139940.0	0.0000000E+00
P(2, 5, 12)	103316.0	0.0000000E+00
P(2, 6, 1)	14199.00	0.0000000E+00
P(2, 6, 2)	0.0000000E+00	0.0000000E+00
P(2, 6, 3)	0.0000000E+00	0.0000000E+00
P(2, 6, 4)	0.0000000E+00	0.0000000E+00
P(2, 6, 5)	1810.000	0.0000000E+00
P(2, 6, 6)	0.0000000E+00	0.0000000E+00
P(2, 6, 7)	0.0000000E+00	0.6772109
P(2, 6, 8)	0.0000000E+00	0.0000000E+00
P(2, 6, 9)	0.0000000E+00	0.0000000E+00
P(2, 6, 10)	0.0000000E+00	0.6772109
P(2, 6, 11)	0.0000000E+00	0.0000000E+00
P(2, 6, 12)	5714.000	0.0000000E+00
P(2, 7, 1)	115563.0	0.0000000E+00
P(2, 7, 2)	82596.00	0.0000000E+00
P(2, 7, 3)	78594.00	0.0000000E+00
P(2, 7, 4)	108992.0	0.0000000E+00
P(2, 7, 5)	81630.00	0.0000000E+00
P(2, 7, 6)	127130.0	0.0000000E+00
P(2, 7, 7)	69415.00	0.0000000E+00
P(2, 7, 8)	76933.00	0.0000000E+00
P(2, 7, 9)	41060.00	0.0000000E+00
P(2, 7, 10)	1.000000	0.0000000E+00
P(2, 7, 11)	36057.00	0.0000000E+00
P(2, 7, 12)	6546.000	0.0000000E+00

D.3. Production and Inventory Results of Model 2

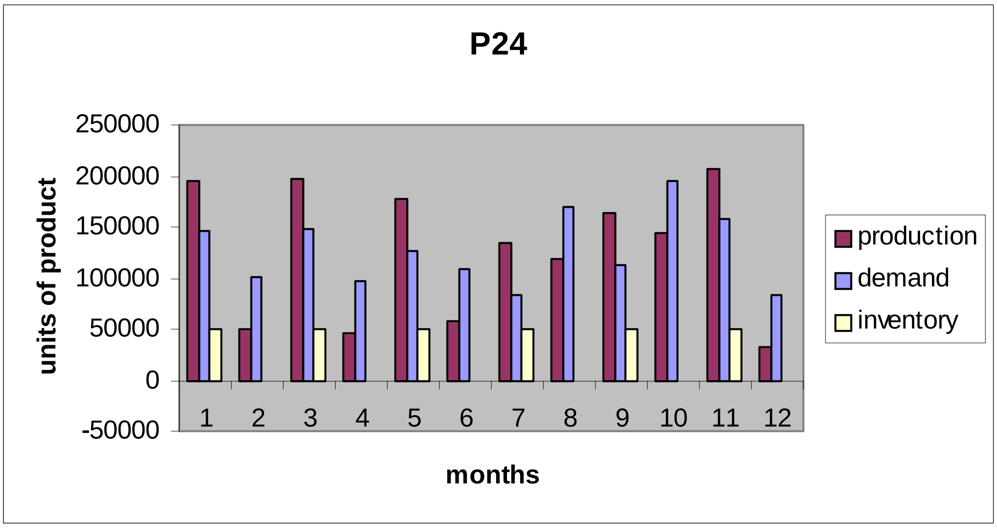




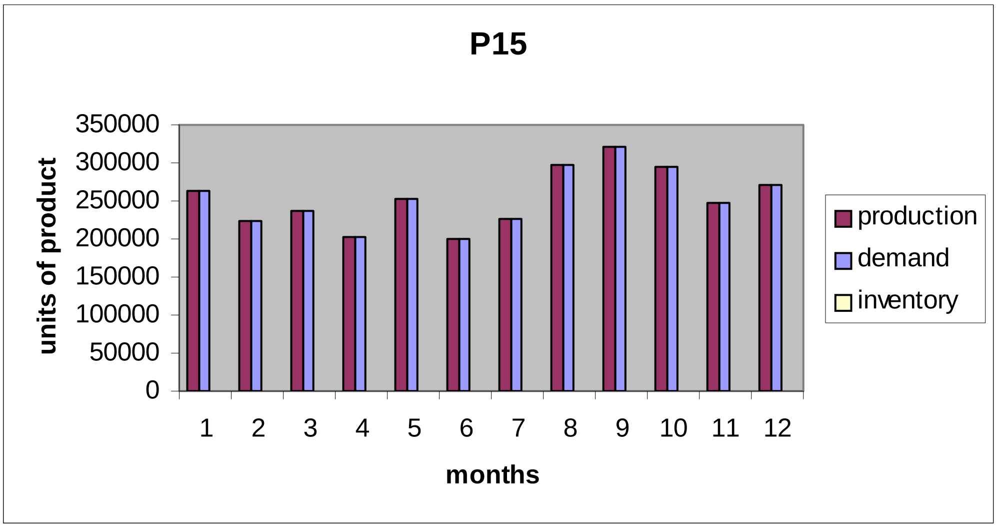




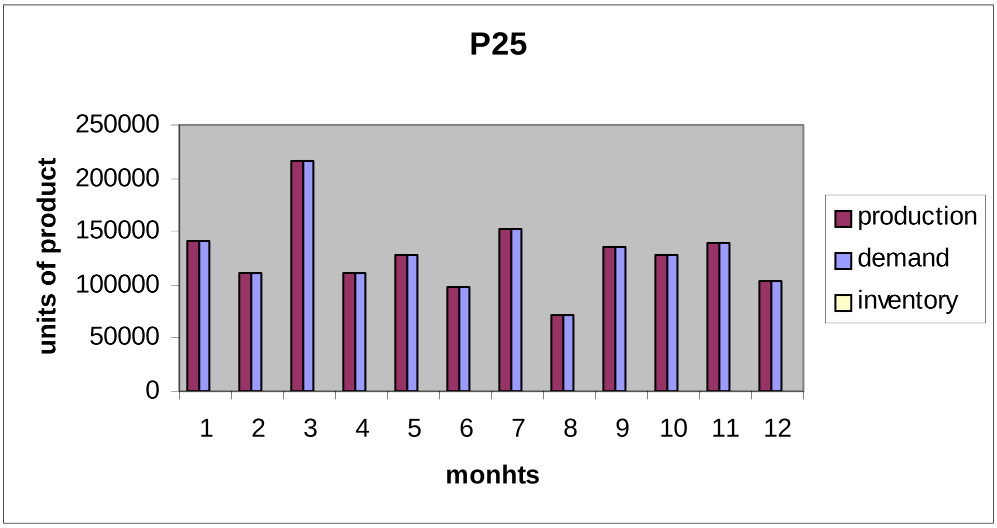
P14
units of product
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
months
product
demand
inventory

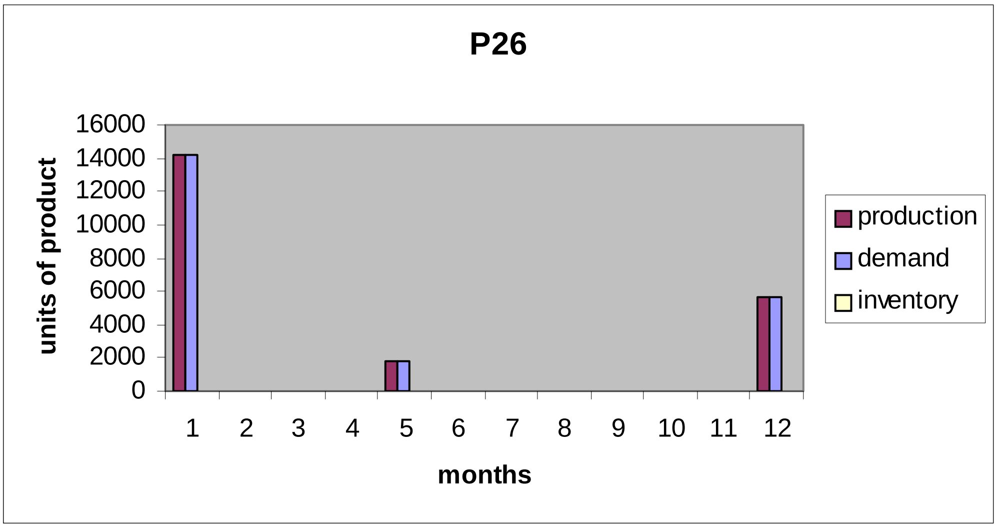


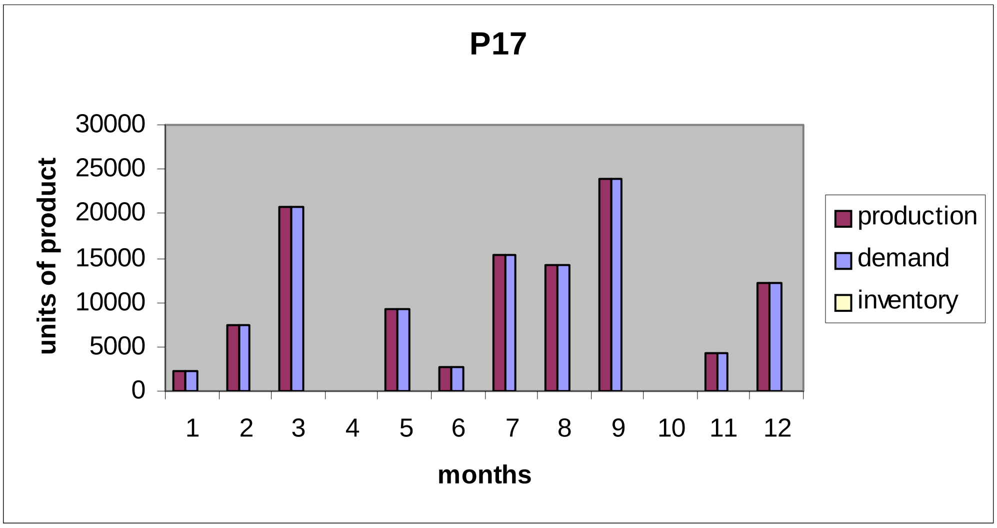
P24
units of product
250000
200000
150000
100000
50000
0
-50000
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory



P15
units of product
350000
300000
250000
200000
150000
100000
50000
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory


P25
units of product
250000
200000
150000
100000
50000
0
1
2
3
4
5
6
7
8
9
10
11
12
monhts
production
demand
inventory


P26
units of product
16000
14000
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
months
production
demand
inventory


P17
units of product
30000
25000
20000
15000
10000
5000
0
1
2
3
4
5
6
7
8
9
10
11
12
months
production
demand
inventory

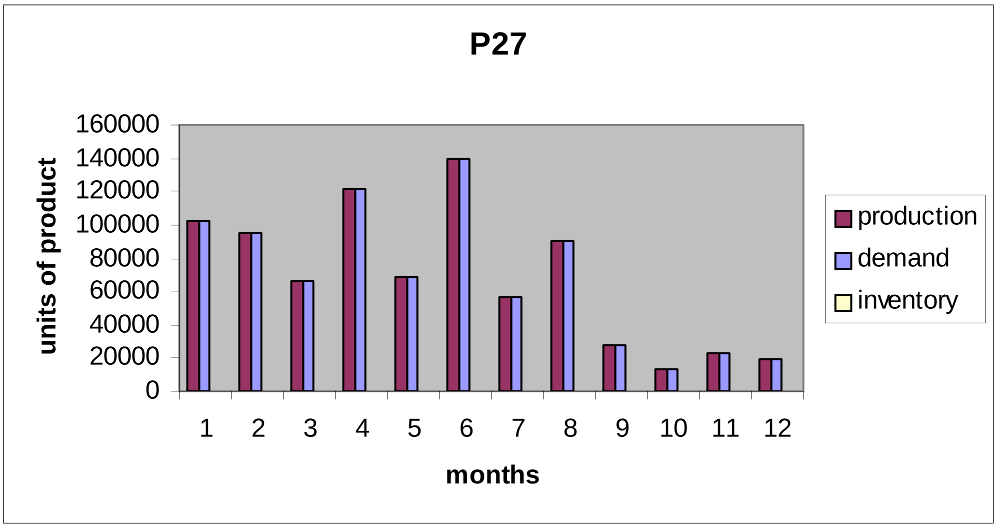


Figure D.1. Production and inventory results of model 2 for each product

D.4. Range Analysis of Model 2

Ranges in which the basis is unchanged:

Objective Coefficient Ranges

Variable	Current Coefficient	Allowable Increase	Allowable Decrease
X(1, 1, 1)	0,8441000	INFINITY	0,8441000
X(1, 1, 2)	0,8441000	0,0	INFINITY
X(1, 1, 3)	0,8441000	INFINITY	0,0
X(1, 1, 4)	0,8441000	INFINITY	0,8789198
X(1, 1, 5)	0,8441000	0,8789198	INFINITY
X(1, 1, 6)	0,8441000	INFINITY	0,8789198
X(1, 1, 7)	0,8441000	INFINITY	0,8441000
X(1, 1, 8)	0,8441000	INFINITY	0,8789198
X(1, 1, 9)	0,8441000	0,8789198	INFINITY
X(1, 1, 10)	0,8441000	INFINITY	0,8441000
X(1, 1, 11)	0,8441000	0,8789198	INFINITY
X(1, 1, 12)	0,8441000	INFINITY	0,8789198
X(1, 2, 1)	0,6444000	INFINITY	0,8050969
X(1, 2, 2)	0,6444000	INFINITY	0,6444000
X(1, 2, 3)	0,6444000	INFINITY	0,6444000
X(1, 2, 4)	0,6444000	INFINITY	0,6444000
X(1, 2, 5)	0,6444000	INFINITY	0,8050969
X(1, 2, 6)	0,6444000	INFINITY	0,6444000
X(1, 2, 7)	0,6444000	INFINITY	0,6444000
X(1, 2, 8)	0,6444000	INFINITY	0,6444000
X(1, 2, 9)	0,6444000	INFINITY	0,6444000
X(1, 2, 10)	0,6444000	INFINITY	0,6444000

X(1, 2, 11)	0,6444000	INFINITY	0,6444000
X(1, 2, 12)	0,6444000	INFINITY	0,6444000
X(1, 3, 1)	0,5253000	0,0	INFINITY
X(1, 3, 2)	0,5253000	INFINITY	0,0
X(1, 3, 3)	0,5253000	0,0	INFINITY
X(1, 3, 4)	0,5253000	INFINITY	0,0
X(1, 3, 5)	0,5253000	0,0	INFINITY
X(1, 3, 6)	0,5253000	INFINITY	0,0
X(1, 3, 7)	0,5253000	0,0	INFINITY
X(1, 3, 8)	0,5253000	INFINITY	0,0
X(1, 3, 9)	0,5253000	0,0	INFINITY
X(1, 3, 10)	0,5253000	INFINITY	0,0
X(1, 3, 11)	0,5253000	0,0	INFINITY
X(1, 3, 12)	0,5253000	INFINITY	0,0
X(1, 4, 1)	0,5166000	0,0	0,0
X(1, 4, 2)	0,5166000	0,0	0,0
X(1, 4, 3)	0,5166000	0,0	0,0
X(1, 4, 4)	0,5166000	0,0	0,0
X(1, 4, 5)	0,5166000	0,0	0,0
X(1, 4, 6)	0,5166000	0,0	0,0
X(1, 4, 7)	0,5166000	0,0	0,0
X(1, 4, 8)	0,5166000	0,0	0,0
X(1, 4, 9)	0,5166000	0,0	0,0
X(1, 4, 10)	0,5166000	0,0	0,0
X(1, 4, 11)	0,5166000	0,0	0,0
X(1, 4, 12)	0,5166000	0,0	0,0
X(1, 5, 1)	0,4826000	INFINITY	0,0
X(1, 5, 2)	0,4826000	0,0	INFINITY
X(1, 5, 3)	0,4826000	INFINITY	0,0
X(1, 5, 4)	0,4826000	0,0	INFINITY
X(1, 5, 5)	0,4826000	INFINITY	0,0
X(1, 5, 6)	0,4826000	0,0	INFINITY
X(1, 5, 7)	0,4826000	INFINITY	0,0
X(1, 5, 8)	0,4826000	0,0	INFINITY
X(1, 5, 9)	0,4826000	INFINITY	0,0
X(1, 5, 10)	0,4826000	0,0	INFINITY
X(1, 5, 11)	0,4826000	INFINITY	0,0
X(1, 5, 12)	0,4826000	0,0	INFINITY
X(1, 6, 1)	0,4855000	INFINITY	0,6065858
X(1, 6, 2)	0,4855000	INFINITY	0,4855000
X(1, 6, 3)	0,4855000	INFINITY	0,4855000
X(1, 6, 4)	0,4855000	INFINITY	0,4855000
X(1, 6, 5)	0,4855000	INFINITY	0,6065858
X(1, 6, 6)	0,4855000	INFINITY	0,4855000
X(1, 6, 7)	0,4855000	INFINITY	0,4855000
X(1, 6, 8)	0,4855000	INFINITY	0,4855000
X(1, 6, 9)	0,4855000	INFINITY	0,4855000
X(1, 6, 10)	0,4855000	INFINITY	0,4855000
X(1, 6, 11)	0,4855000	INFINITY	0,4855000
X(1, 6, 12)	0,4855000	INFINITY	0,6065858

X(1, 7, 1)	0,4860000	0,0	0,0
X(1, 7, 2)	0,4860000	0,0	0,0
X(1, 7, 3)	0,4860000	0,0	0,0
X(1, 7, 4)	0,4860000	0,0	0,0
X(1, 7, 5)	0,4860000	0,0	0,0
X(1, 7, 6)	0,4860000	0,0	0,0
X(1, 7, 7)	0,4860000	0,0	0,0
X(1, 7, 8)	0,4860000	0,0	0,0
X(1, 7, 9)	0,4860000	0,0	0,0
X(1, 7, 10)	0,4860000	0,0	0,0
X(1, 7, 11)	0,4860000	0,0	0,0
X(1, 7, 12)	0,4860000	0,0	0,0
X(2, 1, 1)	0,5196000E-01	INFINITY	0,519600E-01
X(2, 1, 2)	0,5196000E-01	0,0	INFINITY
X(2, 1, 3)	0,5196000E-01	INFINITY	0,0
X(2, 1, 4)	0,5196000E-01	INFINITY	8,792011
X(2, 1, 5)	0,5196000E-01	8,792011	INFINITY
X(2, 1, 6)	0,5196000E-01	INFINITY	8,792011
X(2, 1, 7)	0,5196000E-01	INFINITY	0,519600E-01
X(2, 1, 8)	0,5196000E-01	INFINITY	8,792011
X(2, 1, 9)	0,5196000E-01	8,792011	INFINITY
X(2, 1, 10)	0,5196000E-01	INFINITY	0,519600E-01
X(2, 1, 11)	0,5196000E-01	8,792011	INFINITY
X(2, 1, 12)	0,5196000E-01	INFINITY	8,792011
X(2, 2, 1)	0,3966000E-01	INFINITY	8,053546
X(2, 2, 2)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 2, 3)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 2, 4)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 2, 5)	0,3966000E-01	INFINITY	8,053546
X(2, 2, 6)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 2, 7)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 2, 8)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 2, 9)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 2, 10)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 2, 11)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 2, 12)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 3, 1)	0,3233000E-01	0,0	INFINITY
X(2, 3, 2)	0,3233000E-01	INFINITY	0,0
X(2, 3, 3)	0,3233000E-01	0,0	INFINITY
X(2, 3, 4)	0,3233000E-01	INFINITY	0,0
X(2, 3, 5)	0,3233000E-01	0,0	INFINITY
X(2, 3, 6)	0,3233000E-01	INFINITY	0,0
X(2, 3, 7)	0,3233000E-01	0,0	INFINITY
X(2, 3, 8)	0,3233000E-01	INFINITY	0,0
X(2, 3, 9)	0,3233000E-01	0,0	INFINITY
X(2, 3, 10)	0,3233000E-01	INFINITY	0,0
X(2, 3, 11)	0,3233000E-01	0,0	INFINITY
X(2, 3, 12)	0,3233000E-01	INFINITY	0,0
X(2, 4, 1)	0,3180000E-01	0,0	0,0
X(2, 4, 2)	0,3180000E-01	0,0	0,0

X(2, 4, 3)	0,3180000E-01	0,0	0,0
X(2, 4, 4)	0,3180000E-01	0,0	0,0
X(2, 4, 5)	0,3180000E-01	0,0	0,0
X(2, 4, 6)	0,3180000E-01	0,0	0,0
X(2, 4, 7)	0,3180000E-01	0,0	0,0
X(2, 4, 8)	0,3180000E-01	0,0	0,0
X(2, 4, 9)	0,3180000E-01	0,0	0,0
X(2, 4, 10)	0,3180000E-01	0,0	0,0
X(2, 4, 11)	0,3180000E-01	0,0	0,0
X(2, 4, 12)	0,3180000E-01	0,0	0,0
X(2, 5, 1)	0,2970000E-01	INFINITY	0,0
X(2, 5, 2)	0,2970000E-01	0,0	INFINITY
X(2, 5, 3)	0,2970000E-01	INFINITY	0,0
X(2, 5, 4)	0,2970000E-01	0,0	INFINITY
X(2, 5, 5)	0,2970000E-01	INFINITY	0,0
X(2, 5, 6)	0,2970000E-01	0,0	INFINITY
X(2, 5, 7)	0,2970000E-01	INFINITY	0,0
X(2, 5, 8)	0,2970000E-01	0,0	INFINITY
X(2, 5, 9)	0,2970000E-01	INFINITY	0,0
X(2, 5, 10)	0,2970000E-01	0,0	INFINITY
X(2, 5, 11)	0,2970000E-01	INFINITY	0,0
X(2, 5, 12)	0,2970000E-01	0,0	INFINITY
X(2, 6, 1)	0,2989000E-01	INFINITY	6,067800
X(2, 6, 2)	0,2989000E-01	INFINITY	0,298900E-01
X(2, 6, 3)	0,2989000E-01	INFINITY	0,298900E-01
X(2, 6, 4)	0,2989000E-01	INFINITY	0,298900E-01
X(2, 6, 5)	0,2989000E-01	INFINITY	6,067800
X(2, 6, 6)	0,2989000E-01	INFINITY	0,298900E-01
X(2, 6, 7)	0,2989000E-01	INFINITY	0,298900E-01
X(2, 6, 8)	0,2989000E-01	INFINITY	0,298900E-01
X(2, 6, 9)	0,2989000E-01	INFINITY	0,298900E-01
X(2, 6, 10)	0,2989000E-01	INFINITY	0,298900E-01
X(2, 6, 11)	0,2989000E-01	INFINITY	0,298900E-01
X(2, 6, 12)	0,2989000E-01	INFINITY	6,067800
X(2, 7, 1)	0,2992000E-01	0,0	0,0
X(2, 7, 2)	0,2992000E-01	0,0	0,0
X(2, 7, 3)	0,2992000E-01	0,0	0,0
X(2, 7, 4)	0,2992000E-01	0,0	0,0
X(2, 7, 5)	0,2992000E-01	0,0	0,0
X(2, 7, 6)	0,2992000E-01	0,0	0,0
X(2, 7, 7)	0,2992000E-01	0,0	0,0
X(2, 7, 8)	0,2992000E-01	0,0	0,0
X(2, 7, 9)	0,2992000E-01	0,0	0,0
X(2, 7, 10)	0,2992000E-01	0,0	0,0
X(2, 7, 11)	0,2992000E-01	0,0	0,0
X(2, 7, 12)	0,2992000E-01	0,0	0,0
X(3, 1, 1)	0,3023000E-01	INFINITY	0,302300E-01
X(3, 1, 2)	0,3023000E-01	0,0	INFINITY
X(3, 1, 3)	0,3023000E-01	INFINITY	0,0
X(3, 1, 4)	0,3023000E-01	INFINITY	0,8968569

X(3, 1, 5)	0,3023000E-01	0,8968569	INFINITY
X(3, 1, 6)	0,3023000E-01	INFINITY	0,8968569
X(3, 1, 7)	0,3023000E-01	INFINITY	0,302300E-01
X(3, 1, 8)	0,3023000E-01	INFINITY	0,8968569
X(3, 1, 9)	0,3023000E-01	0,8968569	INFINITY
X(3, 1, 10)	0,3023000E-01	INFINITY	0,302300E-01
X(3, 1, 11)	0,3023000E-01	0,8968569	INFINITY
X(3, 1, 12)	0,3023000E-01	INFINITY	0,8968569
X(3, 2, 1)	0,2308000E-01	INFINITY	0,8215274
X(3, 2, 2)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 3)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 4)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 5)	0,2308000E-01	INFINITY	0,8215274
X(3, 2, 6)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 7)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 8)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 9)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 10)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 11)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 12)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 3, 1)	0,1881000E-01	0,0	INFINITY
X(3, 3, 2)	0,1881000E-01	INFINITY	0,0
X(3, 3, 3)	0,1881000E-01	0,0	INFINITY
X(3, 3, 4)	0,1881000E-01	INFINITY	0,0
X(3, 3, 5)	0,1881000E-01	0,0	INFINITY
X(3, 3, 6)	0,1881000E-01	INFINITY	0,0
X(3, 3, 7)	0,1881000E-01	0,0	INFINITY
X(3, 3, 8)	0,1881000E-01	INFINITY	0,0
X(3, 3, 9)	0,1881000E-01	0,0	INFINITY
X(3, 3, 10)	0,1881000E-01	INFINITY	0,0
X(3, 3, 11)	0,1881000E-01	0,0	INFINITY
X(3, 3, 12)	0,1881000E-01	INFINITY	0,0
X(3, 4, 1)	0,1850000E-01	0,0	0,0
X(3, 4, 2)	0,1850000E-01	0,0	0,0
X(3, 4, 3)	0,1850000E-01	0,0	0,0
X(3, 4, 4)	0,1850000E-01	0,0	0,0
X(3, 4, 5)	0,1850000E-01	0,0	0,0
X(3, 4, 6)	0,1850000E-01	0,0	0,0
X(3, 4, 7)	0,1850000E-01	0,0	0,0
X(3, 4, 8)	0,1850000E-01	0,0	0,0
X(3, 4, 9)	0,1850000E-01	0,0	0,0
X(3, 4, 10)	0,1850000E-01	0,0	0,0
X(3, 4, 11)	0,1850000E-01	0,0	0,0
X(3, 4, 12)	0,1850000E-01	0,0	0,0
X(3, 5, 1)	0,1728000E-01	INFINITY	0,0
X(3, 5, 2)	0,1728000E-01	0,0	INFINITY
X(3, 5, 3)	0,1728000E-01	INFINITY	0,0
X(3, 5, 4)	0,1728000E-01	0,0	INFINITY
X(3, 5, 5)	0,1728000E-01	INFINITY	0,0
X(3, 5, 6)	0,1728000E-01	0,0	INFINITY

X(3, 5, 7)	0,1728000E-01	INFINITY	0,0
X(3, 5, 8)	0,1728000E-01	0,0	INFINITY
X(3, 5, 9)	0,1728000E-01	INFINITY	0,0
X(3, 5, 10)	0,1728000E-01	0,0	INFINITY
X(3, 5, 11)	0,1728000E-01	INFINITY	0,0
X(3, 5, 12)	0,1728000E-01	0,0	INFINITY
X(3, 6, 1)	0,1739000E-01	INFINITY	0,6189651
X(3, 6, 2)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 3)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 4)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 5)	0,1739000E-01	INFINITY	0,6189651
X(3, 6, 6)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 7)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 8)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 9)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 10)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 11)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 12)	0,1739000E-01	INFINITY	0,6189651
X(3, 7, 1)	0,1741000E-01	0,0	0,0
X(3, 7, 2)	0,1741000E-01	0,0	0,0
X(3, 7, 3)	0,1741000E-01	0,0	0,0
X(3, 7, 4)	0,1741000E-01	0,0	0,0
X(3, 7, 5)	0,1741000E-01	0,0	0,0
X(3, 7, 6)	0,1741000E-01	0,0	0,0
X(3, 7, 7)	0,1741000E-01	0,0	0,0
X(3, 7, 8)	0,1741000E-01	0,0	0,0
X(3, 7, 9)	0,1741000E-01	0,0	0,0
X(3, 7, 10)	0,1741000E-01	0,0	0,0
X(3, 7, 11)	0,1741000E-01	0,0	0,0
X(3, 7, 12)	0,1741000E-01	0,0	0,0
X(4, 2, 1)	0,1167000	INFINITY	0,8945202
X(4, 2, 2)	0,1167000	INFINITY	0,1167000
X(4, 2, 3)	0,1167000	INFINITY	0,1167000
X(4, 2, 4)	0,1167000	INFINITY	0,1167000
X(4, 2, 5)	0,1167000	INFINITY	0,8945202
X(4, 2, 6)	0,1167000	INFINITY	0,1167000
X(4, 2, 7)	0,1167000	INFINITY	0,1167000
X(4, 2, 8)	0,1167000	INFINITY	0,1167000
X(4, 2, 9)	0,1167000	INFINITY	0,1167000
X(4, 2, 10)	0,1167000	INFINITY	0,1167000
X(4, 2, 11)	0,1167000	INFINITY	0,1167000
X(4, 2, 12)	0,1167000	INFINITY	0,1167000
X(4, 4, 1)	0,9358000E-01	0,0	0,0
X(4, 4, 2)	0,9358000E-01	0,0	0,0
X(4, 4, 3)	0,9358000E-01	0,0	0,0
X(4, 4, 4)	0,9358000E-01	0,0	0,0
X(4, 4, 5)	0,9358000E-01	0,0	0,0
X(4, 4, 6)	0,9358000E-01	0,0	0,0
X(4, 4, 7)	0,9358000E-01	0,0	0,0
X(4, 4, 8)	0,9358000E-01	0,0	0,0

X(4, 4, 9)	0,9358000E-01	0,0	0,0
X(4, 4, 10)	0,9358000E-01	0,0	0,0
X(4, 4, 11)	0,9358000E-01	0,0	0,0
X(4, 4, 12)	0,9358000E-01	0,0	0,0
X(4, 5, 1)	0,8741000E-01	INFINITY	0,0
X(4, 5, 2)	0,8741000E-01	0,0	INFINITY
X(4, 5, 3)	0,8741000E-01	INFINITY	0,0
X(4, 5, 4)	0,8741000E-01	0,0	INFINITY
X(4, 5, 5)	0,8741000E-01	INFINITY	0,0
X(4, 5, 6)	0,8741000E-01	0,0	INFINITY
X(4, 5, 7)	0,8741000E-01	INFINITY	0,0
X(4, 5, 8)	0,8741000E-01	0,0	INFINITY
X(4, 5, 9)	0,8741000E-01	INFINITY	0,0
X(4, 5, 10)	0,8741000E-01	0,0	INFINITY
X(4, 5, 11)	0,8741000E-01	INFINITY	0,0
X(4, 5, 12)	0,8741000E-01	0,0	INFINITY
X(4, 6, 1)	0,8794000E-01	INFINITY	0,6739603
X(4, 6, 2)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 3)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 4)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 5)	0,8794000E-01	INFINITY	0,6739603
X(4, 6, 6)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 7)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 8)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 9)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 10)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 11)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 12)	0,8794000E-01	INFINITY	0,6739603
X(4, 7, 1)	0,8804000E-01	0,0	0,0
X(4, 7, 2)	0,8804000E-01	0,0	0,0
X(4, 7, 3)	0,8804000E-01	0,0	0,0
X(4, 7, 4)	0,8804000E-01	0,0	0,0
X(4, 7, 5)	0,8804000E-01	0,0	0,0
X(4, 7, 6)	0,8804000E-01	0,0	0,0
X(4, 7, 7)	0,8804000E-01	0,0	0,0
X(4, 7, 8)	0,8804000E-01	0,0	0,0
X(4, 7, 9)	0,8804000E-01	0,0	0,0
X(4, 7, 10)	0,8804000E-01	0,0	0,0
X(4, 7, 11)	0,8804000E-01	0,0	0,0
X(4, 7, 12)	0,8804000E-01	0,0	0,0
X(5, 2, 1)	0,3231000E-01	INFINITY	0,8945202
X(5, 2, 2)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 3)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 4)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 5)	0,3231000E-01	INFINITY	0,8945202
X(5, 2, 6)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 7)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 8)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 9)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 10)	0,3231000E-01	INFINITY	0,323100E-01

X(5, 2, 11)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 12)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 4, 1)	0,2591000E-01	0,0	0,0
X(5, 4, 2)	0,2591000E-01	0,0	0,0
X(5, 4, 3)	0,2591000E-01	0,0	0,0
X(5, 4, 4)	0,2591000E-01	0,0	0,0
X(5, 4, 5)	0,2591000E-01	0,0	0,0
X(5, 4, 6)	0,2591000E-01	0,0	0,0
X(5, 4, 7)	0,2591000E-01	0,0	0,0
X(5, 4, 8)	0,2591000E-01	0,0	0,0
X(5, 4, 9)	0,2591000E-01	0,0	0,0
X(5, 4, 10)	0,2591000E-01	0,0	0,0
X(5, 4, 11)	0,2591000E-01	0,0	0,0
X(5, 4, 12)	0,2591000E-01	0,0	0,0
X(5, 5, 1)	0,2420000E-01	INFINITY	0,0
X(5, 5, 2)	0,2420000E-01	0,0	INFINITY
X(5, 5, 3)	0,2420000E-01	INFINITY	0,0
X(5, 5, 4)	0,2420000E-01	0,0	INFINITY
X(5, 5, 5)	0,2420000E-01	INFINITY	0,0
X(5, 5, 6)	0,2420000E-01	0,0	INFINITY
X(5, 5, 7)	0,2420000E-01	INFINITY	0,0
X(5, 5, 8)	0,2420000E-01	0,0	INFINITY
X(5, 5, 9)	0,2420000E-01	INFINITY	0,0
X(5, 5, 10)	0,2420000E-01	0,0	INFINITY
X(5, 5, 11)	0,2420000E-01	INFINITY	0,0
X(5, 5, 12)	0,2420000E-01	0,0	INFINITY
X(5, 6, 1)	0,2434000E-01	INFINITY	0,6739603
X(5, 6, 2)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 3)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 4)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 5)	0,2434000E-01	INFINITY	0,6739603
X(5, 6, 6)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 7)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 8)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 9)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 10)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 11)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 12)	0,2434000E-01	INFINITY	0,6739603
X(5, 7, 1)	0,2437000E-01	INFINITY	0,0
X(5, 7, 2)	0,2437000E-01	0,0	0,0
X(5, 7, 3)	0,2437000E-01	0,0	0,0
X(5, 7, 4)	0,2437000E-01	0,0	0,0
X(5, 7, 5)	0,2437000E-01	0,0	0,0
X(5, 7, 6)	0,2437000E-01	0,0	0,0
X(5, 7, 7)	0,2437000E-01	0,0	0,0
X(5, 7, 8)	0,2437000E-01	0,0	0,0
X(5, 7, 9)	0,2437000E-01	0,0	0,0
X(5, 7, 10)	0,2437000E-01	0,0	0,0
X(5, 7, 11)	0,2437000E-01	0,0	0,0
X(5, 7, 12)	0,2437000E-01	0,0	0,0

APPENDIX E

MODEL 3

E.1. Computer Program of Model 3

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MODEL:
SETS:
 STAGE/1..5/;
 PRODUCT/1..7/;
 GROUP/1..2/;
 MOUNTH/1..12/;
 LINK1(STAGE,PRODUCT,MOUNTH):X;
 LINK2(GROUP,PRODUCT,MOUNTH):P,I;
 LINK3(PRODUCT,MOUNTH):Y;
ENDSETS

MIN=(0.8441*(@SUM(MOUNTH(K):X(1,1,K))))+(0.05196*(@SUM(MOUNTH(K):
X(2,1,K))))+(0.03023*(X(3,1,1)+X(3,1,2)+X(3,1,3)+X(3,1,4)+X(3,1,5)+X(3,1,6)+X(3,
1,7)+X(3,1,8)+X(3,1,9)+X(3,1,10)+X(3,1,11)+X(3,1,12))+(0.6444*(@SUM(MOUNT
H(K):X(1,2,K))))+(0.03966*(@SUM(MOUNTH(K):X(2,2,K))))+(0.02308*(@SUM(M
OUNTH(K):X(3,2,K))))+(0.1167*(@SUM(MOUNTH(K):X(4,2,K))))+(0.03231*(@S
UM(MOUNTH(K):X(5,2,K))))+(0.5253*(@SUM(MOUNTH(K):X(1,3,K))))+(0.03233
*(@SUM(MOUNTH(K):X(2,3,K))))+(0.01881*(@SUM(MOUNTH(K):X(3,3,K))))+(0
.5166*(@SUM(MOUNTH(K):X(1,4,K))))+(0.0318*(@SUM(MOUNTH(K):X(2,4,K)))
)+(0.0185*(@SUM(MOUNTH(K):X(3,4,K))))+(0.09358*(@SUM(MOUNTH(K):X(4,
4,K))))+(0.02591*(@SUM(MOUNTH(K):X(5,4,K))))+(0.4826*(@SUM(MOUNTH(K
):X(1,5,K))))+(0.0297*(@SUM(MOUNTH(K):X(2,5,K))))+(0.01728*(@SUM(MOUN
TH(K):X(3,5,K))))+(0.08741*(@SUM(MOUNTH(K):X(4,5,K))))+(0.0242*(@SUM(
MOUNTH(K):X(5,5,K))))+(0.4855*(@SUM(MOUNTH(K):X(1,6,K))))+(0.02989*(@
SUM(MOUNTH(K):X(2,6,K))))+(0.01739*(@SUM(MOUNTH(K):X(3,6,K))))+(0.087
94*(@SUM(MOUNTH(K):X(4,6,K))))+(0.02434*(@SUM(MOUNTH(K):X(5,6,K))))
+(0.486*(@SUM(MOUNTH(K):X(1,7,K))))+(0.02992*(@SUM(MOUNTH(K):X(2,7,
K))))+(0.01741*(@SUM(MOUNTH(K):X(3,7,K))))+(0.08804*(@SUM(MOUNTH(K)
:X(4,7,K))))+(0.02437*(@SUM(MOUNTH(K):X(5,7,K)))));
@FOR(MOUNTH(K):X(2,1,K)=0.02*X(1,1,K)+0.0816*X(3,1,K));
@FOR(MOUNTH(K):X(2,2,K)=0.02*X(1,2,K)+0.0816*X(3,2,K));
@FOR(MOUNTH(K):X(2,3,K)=0.02*X(1,3,K)+0.0816*X(3,3,K));
@FOR(MOUNTH(K):X(2,4,K)=0.02*X(1,4,K)+0.0816*X(3,4,K));
@FOR(MOUNTH(K):X(2,5,K)=0.02*X(1,5,K)+0.0816*X(3,5,K));
@FOR(MOUNTH(K):X(2,6,K)=0.02*X(1,6,K)+0.0816*X(3,6,K));
@FOR(MOUNTH(K):X(2,7,K)=0.02*X(1,7,K)+0.0816*X(3,7,K));
@FOR(MOUNTH(K):X(3,1,K)=0.98*X(1,1,K));
@FOR(MOUNTH(K):X(3,2,K)=0.98*X(1,2,K));
@FOR(MOUNTH(K):X(3,3,K)=0.98*X(1,3,K));
@FOR(MOUNTH(K):X(3,4,K)=0.98*X(1,4,K));
@FOR(MOUNTH(K):X(3,5,K)=0.98*X(1,5,K));
@FOR(MOUNTH(K):X(3,6,K)=0.98*X(1,6,K));
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@FOR(MOUNTH(K):X(3,7,K)=0.98*X(1,7,K));
@FOR(MOUNTH(K):P(1,1,K)=0.9184*X(3,1,K)-X(4,1,K));
@FOR(MOUNTH(K):P(1,2,K)=0.9184*X(3,2,K)-X(4,2,K));
@FOR(MOUNTH(K):P(1,3,K)=0.9184*X(3,3,K)-X(4,3,K));
@FOR(MOUNTH(K):P(1,4,K)=0.9184*X(3,4,K)-X(4,4,K));
@FOR(MOUNTH(K):P(1,5,K)=0.9184*X(3,5,K)-X(4,5,K));
@FOR(MOUNTH(K):P(1,6,K)=0.9184*X(3,6,K)-X(4,6,K));
@FOR(MOUNTH(K):P(1,7,K)=0.9184*X(3,7,K)-X(4,7,K));
@FOR(MOUNTH(K):X(4,1,K)=0);
@FOR(MOUNTH(K):X(4,3,K)=0);
@FOR(MOUNTH(K):P(1,2,K)=0);
@FOR(MOUNTH(K):P(1,6,K)=0);
@FOR(MOUNTH(K):X(5,1,K)=X(4,1,K));
@FOR(MOUNTH(K):X(5,2,K)=X(4,2,K));
@FOR(MOUNTH(K):X(5,3,K)=X(4,3,K));
@FOR(MOUNTH(K):X(5,4,K)=X(4,4,K));
@FOR(MOUNTH(K):X(5,5,K)=X(4,5,K));
@FOR(MOUNTH(K):X(5,6,K)=X(4,6,K));
@FOR(MOUNTH(K):X(5,7,K)=X(4,7,K));
@FOR(MOUNTH(K):P(2,1,K)=0.9952*X(5,1,K));
@FOR(MOUNTH(K):P(2,2,K)=0.9952*X(5,2,K));
@FOR(MOUNTH(K):P(2,3,K)=0.9952*X(5,3,K));
@FOR(MOUNTH(K):P(2,4,K)=0.9952*X(5,4,K));
@FOR(MOUNTH(K):P(2,5,K)=0.9952*X(5,5,K));
@FOR(MOUNTH(K):P(2,6,K)=0.9952*X(5,6,K));
@FOR(MOUNTH(K):P(2,7,K)=0.9952*X(5,7,K));
P(1,1,1)>=0;
P(2,2,1)>=6417;
P(1,3,1)>=47667;
P(1,4,1)>=495;
P(2,4,1)>=145299;
P(1,5,1)>=263907;
P(2,5,1)>=140285;
P(2,6,1)>=14199;
P(1,7,1)>=2270;
P(2,7,1)>=102638;
I(1,1,1)=P(1,1,1)-0;
I(2,2,1)=P(2,2,1)-6417;
I(1,3,1)=P(1,3,1)-47667;
I(1,4,1)=P(1,4,1)-495;
I(2,4,1)=P(2,4,1)-145299;
I(1,5,1)=P(1,5,1)-263907;
I(2,5,1)=P(2,5,1)-140285;
I(2,6,1)=P(2,6,1)-14199;
I(1,7,1)=P(1,7,1)-2270;
I(2,7,1)=P(2,7,1)-102638;
I(1,1,1)+P(1,1,2)>=64724;
I(2,2,1)+P(2,2,2)>=0;
I(1,3,1)+P(1,3,2)>=80248;
I(1,4,1)+P(1,4,2)>=0;
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I(2,4,1)+P(2,4,2)>=100670;
I(1,5,1)+P(1,5,2)>=224906;
I(2,5,1)+P(2,5,2)>=111251;
I(2,6,1)+P(2,6,2)>=0;
I(1,7,1)+P(1,7,2)>=7389;
I(2,7,1)+P(2,7,2)>=95521;
I(1,1,2)=I(1,1,1)+P(1,1,2)-64724;
I(2,2,2)=I(2,2,1)+P(2,2,2)-0;
I(1,3,2)=I(1,3,1)+P(1,3,2)-80248;
I(1,4,2)=I(1,4,1)+P(1,4,2)-0;
I(2,4,2)=I(2,4,1)+P(2,4,2)-100670;
I(1,5,2)=I(1,5,1)+P(1,5,2)-224906;
I(2,5,2)=I(2,5,1)+P(2,5,2)-111251;
I(2,6,2)=I(2,6,1)+P(2,6,2)-0;
I(1,7,2)=I(1,7,1)+P(1,7,2)-7389;
I(2,7,2)=I(2,7,1)+P(2,7,2)-95521;
I(1,1,2)+P(1,1,3)>=10551;
I(2,2,2)+P(2,2,3)>=0;
I(1,3,2)+P(1,3,3)>=34713;
I(1,4,2)+P(1,4,3)>=0;
I(2,4,2)+P(2,4,3)>=147159;
I(1,5,2)+P(1,5,3)>=236554;
I(2,5,2)+P(2,5,3)>=215639;
I(2,6,2)+P(2,6,3)>=0;
I(1,7,2)+P(1,7,3)>=20691;
I(2,7,2)+P(2,7,3)>=65669;
I(1,1,3)=I(1,1,2)+P(1,1,3)-10551;
I(2,2,3)=I(2,2,2)+P(2,2,3)-0;
I(1,3,3)=I(1,3,2)+P(1,3,3)-34713;
I(1,4,3)=I(1,4,2)+P(1,4,3)-0;
I(2,4,3)=I(2,4,2)+P(2,4,3)-147159;
I(1,5,3)=I(1,5,2)+P(1,5,3)-236554;
I(2,5,3)=I(2,5,2)+P(2,5,3)-215639;
I(2,6,3)=I(2,6,2)+P(2,6,3)-0;
I(1,7,3)=I(1,7,2)+P(1,7,3)-20691;
I(2,7,3)=I(2,7,2)+P(2,7,3)-65669;
I(1,1,3)+P(1,1,4)>=21556;
I(2,2,3)+P(2,2,4)>=0;
I(1,3,3)+P(1,3,4)>=124949;
I(1,4,3)+P(1,4,4)>=0;
I(2,4,3)+P(2,4,4)>=96912;
I(1,5,3)+P(1,5,4)>=203118;
I(2,5,3)+P(2,5,4)>=111714;
I(2,6,3)+P(2,6,4)>=0;
I(1,7,3)+P(1,7,4)>=0;
I(2,7,3)+P(2,7,4)>=121917;
I(1,1,4)=I(1,1,3)+P(1,1,4)-21556;
I(2,2,4)=I(2,2,3)+P(2,2,4)-0;
I(1,3,4)=I(1,3,3)+P(1,3,4)-124949;
I(1,4,4)=I(1,4,3)+P(1,4,4)-0;

I(2,4,4)=I(2,4,3)+P(2,4,4)-96912;
I(1,5,4)=I(1,5,3)+P(1,5,4)-203118;
I(2,5,4)=I(2,5,3)+P(2,5,4)-111714;
I(2,6,4)=I(2,6,3)+P(2,6,4)-0;
I(1,7,4)=I(1,7,3)+P(1,7,4)-0;
I(2,7,4)=I(2,7,3)+P(2,7,4)-121917;
I(1,1,4)+P(1,1,5)>=24048;
I(2,2,4)+P(2,2,5)>=583;
I(1,3,4)+P(1,3,5)>=93242;
I(1,4,4)+P(1,4,5)>=285;
I(2,4,4)+P(2,4,5)>=127157;
I(1,5,4)+P(1,5,5)>=253584;
I(2,5,4)+P(2,5,5)>=127660;
I(2,6,4)+P(2,6,5)>=1810;
I(1,7,4)+P(1,7,5)>=9348;
I(2,7,4)+P(2,7,5)>=68705;
I(1,1,5)=I(1,1,4)+P(1,1,5)-24048;
I(2,2,5)=I(2,2,4)+P(2,2,5)-583;
I(1,3,5)=I(1,3,4)+P(1,3,5)-93242;
I(1,4,5)=I(1,4,4)+P(1,4,5)-285;
I(2,4,5)=I(2,4,4)+P(2,4,5)-127157;
I(1,5,5)=I(1,5,4)+P(1,5,5)-253584;
I(2,5,5)=I(2,5,4)+P(2,5,5)-127660;
I(2,6,5)=I(2,6,4)+P(2,6,5)-1810;
I(1,7,5)=I(1,7,4)+P(1,7,5)-9348;
I(2,7,5)=I(2,7,4)+P(2,7,5)-68705;
I(1,1,5)+P(1,1,6)>=7263;
I(2,2,5)+P(2,2,6)>=0;
I(1,3,5)+P(1,3,6)>=78488;
I(1,4,5)+P(1,4,6)>=2643;
I(2,4,5)+P(2,4,6)>=108165;
I(1,5,5)+P(1,5,6)>=200394;
I(2,5,5)+P(2,5,6)>=97080;
I(2,6,5)+P(2,6,6)>=0;
I(1,7,5)+P(1,7,6)>=2612;
I(2,7,5)+P(2,7,6)>=140055;
I(1,1,6)=I(1,1,5)+P(1,1,6)-7263;
I(2,2,6)=I(2,2,5)+P(2,2,6)-0;
I(1,3,6)=I(1,3,5)+P(1,3,6)-78488;
I(1,4,6)=I(1,4,5)+P(1,4,6)-2643;
I(2,4,6)=I(2,4,5)+P(2,4,6)-108165;
I(1,5,6)=I(1,5,5)+P(1,5,6)-200394;
I(2,5,6)=I(2,5,5)+P(2,5,6)-97080;
I(2,6,6)=I(2,6,5)+P(2,6,6)-0;
I(1,7,6)=I(1,7,5)+P(1,7,6)-2612;
I(2,7,6)=I(2,7,5)+P(2,7,6)-140055;
I(1,1,6)+P(1,1,7)>=0;
I(2,2,6)+P(2,2,7)>=0;
I(1,3,6)+P(1,3,7)>=129744;
I(1,4,6)+P(1,4,7)>=0;

I(2,4,6)+P(2,4,7)>=84117;
I(1,5,6)+P(1,5,7)>=226024;
I(2,5,6)+P(2,5,7)>=151989;
I(2,6,6)+P(2,6,7)>=0;
I(1,7,6)+P(1,7,7)>=15255;
I(2,7,6)+P(2,7,7)>=56490;
I(1,1,7)=I(1,1,6)+P(1,1,7)-0;
I(2,2,7)=I(2,2,6)+P(2,2,7)-0;
I(1,3,7)=I(1,3,6)+P(1,3,7)-129744;
I(1,4,7)=I(1,4,6)+P(1,4,7)-0;
I(2,4,7)=I(2,4,6)+P(2,4,7)-84117;
I(1,5,7)=I(1,5,6)+P(1,5,7)-226024;
I(2,5,7)=I(2,5,6)+P(2,5,7)-151989;
I(2,6,7)=I(2,6,6)+P(2,6,7)-0;
I(1,7,7)=I(1,7,6)+P(1,7,7)-15255;
I(2,7,7)=I(2,7,6)+P(2,7,7)-56490;
I(1,1,7)+P(1,1,8)>=22469;
I(2,2,7)+P(2,2,8)>=0;
I(1,3,7)+P(1,3,8)>=79758;
I(1,4,7)+P(1,4,8)>=0;
I(2,4,7)+P(2,4,8)>=168978;
I(1,5,7)+P(1,5,8)>=298365;
I(2,5,7)+P(2,5,8)>=70754;
I(2,6,7)+P(2,6,8)>=0;
I(1,7,7)+P(1,7,8)>=14101;
I(2,7,7)+P(2,7,8)>=89858;
I(1,1,8)=I(1,1,7)+P(1,1,8)-22469;
I(2,2,8)=I(2,2,7)+P(2,2,8)-0;
I(1,3,8)=I(1,3,7)+P(1,3,8)-79758;
I(1,4,8)=I(1,4,7)+P(1,4,8)-0;
I(2,4,8)=I(2,4,7)+P(2,4,8)-168978;
I(1,5,8)=I(1,5,7)+P(1,5,8)-298365;
I(2,5,8)=I(2,5,7)+P(2,5,8)-70754;
I(2,6,8)=I(2,6,7)+P(2,6,8)-0;
I(1,7,8)=I(1,7,7)+P(1,7,8)-14101;
I(2,7,8)=I(2,7,7)+P(2,7,8)-89858;
I(1,1,8)+P(1,1,9)>=28646;
I(2,2,8)+P(2,2,9)>=0;
I(1,3,8)+P(1,3,9)>=13266;
I(1,4,8)+P(1,4,9)>=0;
I(2,4,8)+P(2,4,9)>=113230;
I(1,5,8)+P(1,5,9)>=322148;
I(2,5,8)+P(2,5,9)>=135355;
I(2,6,8)+P(2,6,9)>=0;
I(1,7,8)+P(1,7,9)>=23899;
I(2,7,8)+P(2,7,9)>=28135;
I(1,1,9)=I(1,1,8)+P(1,1,9)-28646;
I(2,2,9)=I(2,2,8)+P(2,2,9)-0;
I(1,3,9)=I(1,3,8)+P(1,3,9)-13266;
I(1,4,9)=I(1,4,8)+P(1,4,9)-0;

I(2,4,9)=I(2,4,8)+P(2,4,9)-113230;
I(1,5,9)=I(1,5,8)+P(1,5,9)-322148;
I(2,5,9)=I(2,5,8)+P(2,5,9)-135355;
I(2,6,9)=I(2,6,8)+P(2,6,9)-0;
I(1,7,9)=I(1,7,8)+P(1,7,9)-23899;
I(2,7,9)=I(2,7,8)+P(2,7,9)-28135;
I(1,1,9)+P(1,1,10)>=0;
I(2,2,9)+P(2,2,10)>=0;
I(1,3,9)+P(1,3,10)>=266338;
I(1,4,9)+P(1,4,10)>=0;
I(2,4,9)+P(2,4,10)>=194190;
I(1,5,9)+P(1,5,10)>=295150;
I(2,5,9)+P(2,5,10)>=126930;
I(2,6,9)+P(2,6,10)>=0;
I(1,7,9)+P(1,7,10)>=0;
I(2,7,9)+P(2,7,10)>=12926;
I(1,1,10)=I(1,1,9)+P(1,1,10)-0;
I(2,2,10)=I(2,2,9)+P(2,2,10)-0;
I(1,3,10)=I(1,3,9)+P(1,3,10)-266338;
I(1,4,10)=I(1,4,9)+P(1,4,10)-0;
I(2,4,10)=I(2,4,9)+P(2,4,10)-194190;
I(1,5,10)=I(1,5,9)+P(1,5,10)-295150;
I(2,5,10)=I(2,5,9)+P(2,5,10)-126930;
I(2,6,10)=I(2,6,9)+P(2,6,10)-0;
I(1,7,10)=I(1,7,9)+P(1,7,10)-0;
I(2,7,10)=I(2,7,9)+P(2,7,10)-12926;
I(1,1,10)+P(1,1,11)>=29420;
I(2,2,10)+P(2,2,11)>=0;
I(1,3,10)+P(1,3,11)>=148722;
I(1,4,10)+P(1,4,11)>=0;
I(2,4,10)+P(2,4,11)>=157070;
I(1,5,10)+P(1,5,11)>=248303;
I(2,5,10)+P(2,5,11)>=139940;
I(2,6,10)+P(2,6,11)>=0;
I(1,7,10)+P(1,7,11)>=4331;
I(2,7,10)+P(2,7,11)>=23132;
I(1,1,11)=I(1,1,10)+P(1,1,11)-29420;
I(2,2,11)=I(2,2,10)+P(2,2,11)-0;
I(1,3,11)=I(1,3,10)+P(1,3,11)-148722;
I(1,4,11)=I(1,4,10)+P(1,4,11)-0;
I(2,4,11)=I(2,4,10)+P(2,4,11)-157070;
I(1,5,11)=I(1,5,10)+P(1,5,11)-248303;
I(2,5,11)=I(2,5,10)+P(2,5,11)-139940;
I(2,6,11)=I(2,6,10)+P(2,6,11)-0;
I(1,7,11)=I(1,7,10)+P(1,7,11)-4331;
I(2,7,11)=I(2,7,10)+P(2,7,11)-23132;
I(1,1,11)+P(1,1,12)>=79900;
I(2,2,11)+P(2,2,12)>=0;
I(1,3,11)+P(1,3,12)>=21773;
I(1,4,11)+P(1,4,12)>=0;

I(2,4,11)+P(2,4,12)>=82939;
I(1,5,11)+P(1,5,12)>=270560;
I(2,5,11)+P(2,5,12)>=103316;
I(2,6,11)+P(2,6,12)>=5714;
I(1,7,11)+P(1,7,12)>=12281;
I(2,7,11)+P(2,7,12)>=19471;
I(1,1,12)=I(1,1,11)+P(1,1,12)-79900;
I(2,2,12)=I(2,2,11)+P(2,2,12)-0;
I(1,3,12)=I(1,3,11)+P(1,3,12)-21773;
I(1,4,12)=I(1,4,11)+P(1,4,12)-0;
I(2,4,12)=I(2,4,11)+P(2,4,12)-82939;
I(1,5,12)=I(1,5,11)+P(1,5,12)-270560;
I(2,5,12)=I(2,5,11)+P(2,5,12)-103316;
I(2,6,12)=I(2,6,11)+P(2,6,12)-5714;
I(1,7,12)=I(1,7,11)+P(1,7,12)-12281;
I(2,7,12)=I(2,7,11)+P(2,7,12)-19471;
(1.5*Y(1,1)+0.0013695*(P(1,1,1)+P(2,1,1)))+(1*Y(2,1)+0.00104542*(P(1,2,1)+P(2,2,1)))+(1*Y(3,1)+0.00085218*(P(1,3,1)+P(2,3,1)))+(1*Y(4,1)+0.00083819*(P(1,4,1)+P(2,4,1)))+(1*Y(5,1)+0.00078292*(P(1,5,1)+P(2,5,1)))+(1*Y(6,1)+0.0007877*(P(1,6,1)+P(2,6,1)))+(1*Y(7,1)+0.00078856*(P(1,7,1)+P(2,7,1)))=696;
(P(1,1,1)+P(2,1,1))<=10000000000*Y(1,1);
(P(1,1,1)+P(2,1,1))>=Y(1,1);
(P(1,2,1)+P(2,2,1))<=10000000000*Y(2,1);
(P(1,2,1)+P(2,2,1))>=Y(2,1);
(P(1,3,1)+P(2,3,1))<=10000000000*Y(3,1);
(P(1,3,1)+P(2,3,1))>=Y(3,1);
(P(1,4,1)+P(2,4,1))<=10000000000*Y(4,1);
(P(1,4,1)+P(2,4,1))>=Y(4,1);
(P(1,5,1)+P(2,5,1))<=10000000000*Y(5,1);
(P(1,5,1)+P(2,5,1))>=Y(5,1);
(P(1,6,1)+P(2,6,1))<=10000000000*Y(6,1);
(P(1,6,1)+P(2,6,1))>=Y(6,1);
(P(1,7,1)+P(2,7,1))<=10000000000*Y(7,1);
(P(1,7,1)+P(2,7,1))>=Y(7,1);
(1.5*Y(1,2)+0.0013695*(P(1,1,2)+P(2,1,2)))+(1*Y(2,2)+0.00104542*(P(1,2,2)+P(2,2,2)))+(1*Y(3,2)+0.00085218*(P(1,3,2)+P(2,3,2)))+(1*Y(4,2)+0.00083819*(P(1,4,2)+P(2,4,2)))+(1*Y(5,2)+0.00078292*(P(1,5,2)+P(2,5,2)))+(1*Y(6,2)+0.0007877*(P(1,6,2)+P(2,6,2)))+(1*Y(7,2)+0.00078856*(P(1,7,2)+P(2,7,2)))=624;
(P(1,1,2)+P(2,1,2))<=10000000000*Y(1,2);
(P(1,1,2)+P(2,1,2))>=Y(1,2);
(P(1,2,2)+P(2,2,2))<=10000000000*Y(2,2);
(P(1,2,2)+P(2,2,2))>=Y(2,2);
(P(1,3,2)+P(2,3,2))<=10000000000*Y(3,2);
(P(1,3,2)+P(2,3,2))>=Y(3,2);
(P(1,4,2)+P(2,4,2))<=10000000000*Y(4,2);
(P(1,4,2)+P(2,4,2))>=Y(4,2);
(P(1,5,2)+P(2,5,2))<=10000000000*Y(5,2);
(P(1,5,2)+P(2,5,2))>=Y(5,2);
(P(1,6,2)+P(2,6,2))<=10000000000*Y(6,2);
(P(1,6,2)+P(2,6,2))>=Y(6,2);

(P(1,7,2)+P(2,7,2))<=10000000000*Y(7,2);
(P(1,7,2)+P(2,7,2))>=Y(7,2);
(1.5*Y(1,3)+0.0013695*(P(1,1,3)+P(2,1,3)))+(1*Y(2,3)+0.00104542*(P(1,2,3)+P(2,2,3
)))+(1*Y(3,3)+0.00085218*(P(1,3,3)+P(2,3,3)))+(1*Y(4,3)+0.00083819*(P(1,4,3)+P(2
,4,3)))+(1*Y(5,3)+0.00078292*(P(1,5,3)+P(2,5,3)))+(1*Y(6,3)+0.0007877*(P(1,6,3)+P
(2,6,3)))+(1*Y(7,3)+0.00078856*(P(1,7,3)+P(2,7,3)))=696;
(P(1,1,3)+P(2,1,3))<=10000000000*Y(1,3);
(P(1,1,3)+P(2,1,3))>=Y(1,3);
(P(1,2,3)+P(2,2,3))<=10000000000*Y(2,3);
(P(1,2,3)+P(2,2,3))>=Y(2,3);
(P(1,3,3)+P(2,3,3))<=10000000000*Y(3,3);
(P(1,3,3)+P(2,3,3))>=Y(3,3);
(P(1,4,3)+P(2,4,3))<=10000000000*Y(4,3);
(P(1,4,3)+P(2,4,3))>=Y(4,3);
(P(1,5,3)+P(2,5,3))<=10000000000*Y(5,3);
(P(1,5,3)+P(2,5,3))>=Y(5,3);
(P(1,6,3)+P(2,6,3))<=10000000000*Y(6,3);
(P(1,6,3)+P(2,6,3))>=Y(6,3);
(P(1,7,3)+P(2,7,3))<=10000000000*Y(7,3);
(P(1,7,3)+P(2,7,3))>=Y(7,3);
(1.5*Y(1,4)+0.0013695*(P(1,1,4)+P(2,1,4)))+(1*Y(2,4)+0.00104542*(P(1,2,4)+P(2,2,4
)))+(1*Y(3,4)+0.00085218*(P(1,3,4)+P(2,3,4)))+(1*Y(4,4)+0.00083819*(P(1,4,4)+P(2
,4,4)))+(1*Y(5,4)+0.00078292*(P(1,5,4)+P(2,5,4)))+(1*Y(6,4)+0.0007877*(P(1,6,4)+P
(2,6,4)))+(1*Y(7,4)+0.00078856*(P(1,7,4)+P(2,7,4)))=672;
(P(1,1,4)+P(2,1,4))<=10000000000*Y(1,4);
(P(1,1,4)+P(2,1,4))>=Y(1,4);
(P(1,2,4)+P(2,2,4))<=10000000000*Y(2,4);
(P(1,2,4)+P(2,2,4))>=Y(2,4);
(P(1,3,4)+P(2,3,4))<=10000000000*Y(3,4);
(P(1,3,4)+P(2,3,4))>=Y(3,4);
(P(1,4,4)+P(2,4,4))<=10000000000*Y(4,4);
(P(1,4,4)+P(2,4,4))>=Y(4,4);
(P(1,5,4)+P(2,5,4))<=10000000000*Y(5,4);
(P(1,5,4)+P(2,5,4))>=Y(5,4);
(P(1,6,4)+P(2,6,4))<=10000000000*Y(6,4);
(P(1,6,4)+P(2,6,4))>=Y(6,4);
(P(1,7,4)+P(2,7,4))<=10000000000*Y(7,4);
(P(1,7,4)+P(2,7,4))>=Y(7,4);
(1.5*Y(1,5)+0.0013695*(P(1,1,5)+P(2,1,5)))+(1*Y(2,5)+0.00104542*(P(1,2,5)+P(2,2,5
)))+(1*Y(3,5)+0.00085218*(P(1,3,5)+P(2,3,5)))+(1*Y(4,5)+0.00083819*(P(1,4,5)+P(2
,4,5)))+(1*Y(5,5)+0.00078292*(P(1,5,5)+P(2,5,5)))+(1*Y(6,5)+0.0007877*(P(1,6,5)+P
(2,6,5)))+(1*Y(7,5)+0.00078856*(P(1,7,5)+P(2,7,5)))=696;
(P(1,1,5)+P(2,1,5))<=10000000000*Y(1,5);
(P(1,1,5)+P(2,1,5))>=Y(1,5);
(P(1,2,5)+P(2,2,5))<=10000000000*Y(2,5);
(P(1,2,5)+P(2,2,5))>=Y(2,5);
(P(1,3,5)+P(2,3,5))<=10000000000*Y(3,5);
(P(1,3,5)+P(2,3,5))>=Y(3,5);
(P(1,4,5)+P(2,4,5))<=10000000000*Y(4,5);
(P(1,4,5)+P(2,4,5))>=Y(4,5);

```
(P(1,5,5)+P(2,5,5))<=10000000000*Y(5,5);
(P(1,5,5)+P(2,5,5))>=Y(5,5);
(P(1,6,5)+P(2,6,5))<=10000000000*Y(6,5);
(P(1,6,5)+P(2,6,5))>=Y(6,5);
(P(1,7,5)+P(2,7,5))<=10000000000*Y(7,5);
(P(1,7,5)+P(2,7,5))>=Y(7,5);
(1.5*Y(1,6)+0.0013695*(P(1,1,6)+P(2,1,6)))+(1*Y(2,6)+0.00104542*(P(1,2,6)+P(2,2,6
)))+(1*Y(3,6)+0.00085218*(P(1,3,6)+P(2,3,6)))+(1*Y(4,6)+0.00083819*(P(1,4,6)+P(2
,4,6)))+(1*Y(5,6)+0.00078292*(P(1,5,6)+P(2,5,6)))+(1*Y(6,6)+0.0007877*(P(1,6,6)+P
(2,6,6)))+(1*Y(7,6)+0.00078856*(P(1,7,6)+P(2,7,6)))=672;
(P(1,1,6)+P(2,1,6))<=10000000000*Y(1,6);
(P(1,1,6)+P(2,1,6))>=Y(1,6);
(P(1,2,6)+P(2,2,6))<=10000000000*Y(2,6);
(P(1,2,6)+P(2,2,6))>=Y(2,6);
(P(1,3,6)+P(2,3,6))<=10000000000*Y(3,6);
(P(1,3,6)+P(2,3,6))>=Y(3,6);
(P(1,4,6)+P(2,4,6))<=10000000000*Y(4,6);
(P(1,4,6)+P(2,4,6))>=Y(4,6);
(P(1,5,6)+P(2,5,6))<=10000000000*Y(5,6);
(P(1,5,6)+P(2,5,6))>=Y(5,6);
(P(1,6,6)+P(2,6,6))<=10000000000*Y(6,6);
(P(1,6,6)+P(2,6,6))>=Y(6,6);
(P(1,7,6)+P(2,7,6))<=10000000000*Y(7,6);
(P(1,7,6)+P(2,7,6))>=Y(7,6);
(1.5*Y(1,7)+0.0013695*(P(1,1,7)+P(2,1,7)))+(1*Y(2,7)+0.00104542*(P(1,2,7)+P(2,2,7
)))+(1*Y(3,7)+0.00085218*(P(1,3,7)+P(2,3,7)))+(1*Y(4,7)+0.00083819*(P(1,4,7)+P(2
,4,7)))+(1*Y(5,7)+0.00078292*(P(1,5,7)+P(2,5,7)))+(1*Y(6,7)+0.0007877*(P(1,6,7)+P
(2,6,7)))+(1*Y(7,7)+0.00078856*(P(1,7,7)+P(2,7,7)))=696;
(P(1,1,7)+P(2,1,7))<=10000000000*Y(1,7);
(P(1,1,7)+P(2,1,7))>=Y(1,7);
(P(1,2,7)+P(2,2,7))<=10000000000*Y(2,7);
(P(1,2,7)+P(2,2,7))>=Y(2,7);
(P(1,3,7)+P(2,3,7))<=10000000000*Y(3,7);
(P(1,3,7)+P(2,3,7))>=Y(3,7);
(P(1,4,7)+P(2,4,7))<=10000000000*Y(4,7);
(P(1,4,7)+P(2,4,7))>=Y(4,7);
(P(1,5,7)+P(2,5,7))<=10000000000*Y(5,7);
(P(1,5,7)+P(2,5,7))>=Y(5,7);
(P(1,6,7)+P(2,6,7))<=10000000000*Y(6,7);
(P(1,6,7)+P(2,6,7))>=Y(6,7);
(P(1,7,7)+P(2,7,7))<=10000000000*Y(7,7);
(P(1,7,7)+P(2,7,7))>=Y(7,7);
(1.5*Y(1,8)+0.0013695*(P(1,1,8)+P(2,1,8)))+(1*Y(2,8)+0.00104542*(P(1,2,8)+P(2,2,8
)))+(1*Y(3,8)+0.00085218*(P(1,3,8)+P(2,3,8)))+(1*Y(4,8)+0.00083819*(P(1,4,8)+P(2
,4,8)))+(1*Y(5,8)+0.00078292*(P(1,5,8)+P(2,5,8)))+(1*Y(6,8)+0.0007877*(P(1,6,8)+P
(2,6,8)))+(1*Y(7,8)+0.00078856*(P(1,7,8)+P(2,7,8)))=696;
(P(1,1,8)+P(2,1,8))<=10000000000*Y(1,8);
(P(1,1,8)+P(2,1,8))>=Y(1,8);
(P(1,2,8)+P(2,2,8))<=10000000000*Y(2,8);
(P(1,2,8)+P(2,2,8))>=Y(2,8);
```

```
(P(1,3,8)+P(2,3,8))<=10000000000*Y(3,8);
(P(1,3,8)+P(2,3,8))>=Y(3,8);
(P(1,4,8)+P(2,4,8))<=10000000000*Y(4,8);
(P(1,4,8)+P(2,4,8))>=Y(4,8);
(P(1,5,8)+P(2,5,8))<=10000000000*Y(5,8);
(P(1,5,8)+P(2,5,8))>=Y(5,8);
(P(1,6,8)+P(2,6,8))<=10000000000*Y(6,8);
(P(1,6,8)+P(2,6,8))>=Y(6,8);
(P(1,7,8)+P(2,7,8))<=10000000000*Y(7,8);
(P(1,7,8)+P(2,7,8))>=Y(7,8);
(1.5*Y(1,9)+0.0013695*(P(1,1,9)+P(2,1,9)))+(1*Y(2,9)+0.00104542*(P(1,2,9)+P(2,2,9
)))+(1*Y(3,9)+0.00085218*(P(1,3,9)+P(2,3,9)))+(1*Y(4,9)+0.00083819*(P(1,4,9)+P(2
,4,9)))+(1*Y(5,9)+0.00078292*(P(1,5,9)+P(2,5,9)))+(1*Y(6,9)+0.0007877*(P(1,6,9)+P
(2,6,9)))+(1*Y(7,9)+0.00078856*(P(1,7,9)+P(2,7,9)))=672;
(P(1,1,9)+P(2,1,9))<=10000000000*Y(1,9);
(P(1,1,9)+P(2,1,9))>=Y(1,9);
(P(1,2,9)+P(2,2,9))<=10000000000*Y(2,9);
(P(1,2,9)+P(2,2,9))>=Y(2,9);
(P(1,3,9)+P(2,3,9))<=10000000000*Y(3,9);
(P(1,3,9)+P(2,3,9))>=Y(3,9);
(P(1,4,9)+P(2,4,9))<=10000000000*Y(4,9);
(P(1,4,9)+P(2,4,9))>=Y(4,9);
(P(1,5,9)+P(2,5,9))<=10000000000*Y(5,9);
(P(1,5,9)+P(2,5,9))>=Y(5,9);
(P(1,6,9)+P(2,6,9))<=10000000000*Y(6,9);
(P(1,6,9)+P(2,6,9))>=Y(6,9);
(P(1,7,9)+P(2,7,9))<=10000000000*Y(7,9);
(P(1,7,9)+P(2,7,9))>=Y(7,9);
(1.5*Y(1,10)+0.0013695*(P(1,1,10)+P(2,1,10)))+(1*Y(2,10)+0.00104542*(P(1,2,10)+
P(2,2,10)))+(1*Y(3,10)+0.00085218*(P(1,3,10)+P(2,3,10)))+(1*Y(4,10)+0.00083819*(
P(1,4,10)+P(2,4,10)))+(1*Y(5,10)+0.00078292*(P(1,5,10)+P(2,5,10)))+(1*Y(6,10)+0.0
007877*(P(1,6,10)+P(2,6,10)))+(1*Y(7,10)+0.00078856*(P(1,7,10)+P(2,7,10)))=696;
(P(1,1,10)+P(2,1,10))<=10000000000*Y(1,10);
(P(1,1,10)+P(2,1,10))>=Y(1,10);
(P(1,2,10)+P(2,2,10))<=10000000000*Y(2,10);
(P(1,2,10)+P(2,2,10))>=Y(2,10);
(P(1,3,10)+P(2,3,10))<=10000000000*Y(3,10);
(P(1,3,10)+P(2,3,10))>=Y(3,10);
(P(1,4,10)+P(2,4,10))<=10000000000*Y(4,10);
(P(1,4,10)+P(2,4,10))>=Y(4,10);
(P(1,5,10)+P(2,5,10))<=10000000000*Y(5,10);
(P(1,5,10)+P(2,5,10))>=Y(5,10);
(P(1,6,10)+P(2,6,10))<=10000000000*Y(6,10);
(P(1,6,10)+P(2,6,10))>=Y(6,10);
(P(1,7,10)+P(2,7,10))<=10000000000*Y(7,10);
(P(1,7,10)+P(2,7,10))>=Y(7,10);
(1.5*Y(1,11)+0.0013695*(P(1,1,11)+P(2,1,11)))+(1*Y(2,11)+0.00104542*(P(1,2,11)+
P(2,2,11)))+(1*Y(3,11)+0.00085218*(P(1,3,11)+P(2,3,11)))+(1*Y(4,11)+0.00083819*(
P(1,4,11)+P(2,4,11)))+(1*Y(5,11)+0.00078292*(P(1,5,11)+P(2,5,11)))+(1*Y(6,11)+0.0
007877*(P(1,6,11)+P(2,6,11)))+(1*Y(7,11)+0.00078856*(P(1,7,11)+P(2,7,11)))=672;
```

```
(P(1,1,11)+P(2,1,11))<=10000000000*Y(1,11);
(P(1,1,11)+P(2,1,11))>=Y(1,11);
(P(1,2,11)+P(2,2,11))<=10000000000*Y(2,11);
(P(1,2,11)+P(2,2,11))>=Y(2,11);
(P(1,3,11)+P(2,3,11))<=10000000000*Y(3,11);
(P(1,3,11)+P(2,3,11))>=Y(3,11);
(P(1,4,11)+P(2,4,11))<=10000000000*Y(4,11);
(P(1,4,11)+P(2,4,11))>=Y(4,11);
(P(1,5,11)+P(2,5,11))<=10000000000*Y(5,11);
(P(1,5,11)+P(2,5,11))>=Y(5,11);
(P(1,6,11)+P(2,6,11))<=10000000000*Y(6,11);
(P(1,6,11)+P(2,6,11))>=Y(6,11);
(P(1,7,11)+P(2,7,11))<=10000000000*Y(7,11);
(P(1,7,11)+P(2,7,11))>=Y(7,11);
(1.5*Y(1,12)+0.0013695*(P(1,1,12)+P(2,1,12)))+(1*Y(2,12)+0.00104542*(P(1,2,12)+
P(2,2,12)))+(1*Y(3,12)+0.00085218*(P(1,3,12)+P(2,3,12)))+(1*Y(4,12)+0.00083819*(
P(1,4,12)+P(2,4,12)))+(1*Y(5,12)+0.00078292*(P(1,5,12)+P(2,5,12)))+(1*Y(6,12)+0.0
007877*(P(1,6,12)+P(2,6,12)))+(1*Y(7,12)+0.00078856*(P(1,7,12)+P(2,7,12)))=696;
(P(1,1,12)+P(2,1,12))<=10000000000*Y(1,12);
(P(1,1,12)+P(2,1,12))>=Y(1,12);
(P(1,2,12)+P(2,2,12))<=10000000000*Y(2,12);
(P(1,2,12)+P(2,2,12))>=Y(2,12);
(P(1,3,12)+P(2,3,12))<=10000000000*Y(3,12);
(P(1,3,12)+P(2,3,12))>=Y(3,12);
(P(1,4,12)+P(2,4,12))<=10000000000*Y(4,12);
(P(1,4,12)+P(2,4,12))>=Y(4,12);
(P(1,5,12)+P(2,5,12))<=10000000000*Y(5,12);
(P(1,5,12)+P(2,5,12))>=Y(5,12);
(P(1,6,12)+P(2,6,12))<=10000000000*Y(6,12);
(P(1,6,12)+P(2,6,12))>=Y(6,12);
(P(1,7,12)+P(2,7,12))<=10000000000*Y(7,12);
(P(1,7,12)+P(2,7,12))>=Y(7,12);
@FOR(LINK3(J,K):@BIN(Y(J,K)));
@FOR(LINK1(I,J,K):X(I,J,K)>=0);
END
```

E.2. Output of Model 3

Optimal solution found at step: 256
Objective value: 6262698.

Variable	Value	Reduced Cost
P(1, 1, 1)	0.0000000E+00	0.0000000E+00
P(1, 1, 2)	64724.00	0.0000000E+00
P(1, 1, 3)	10551.00	0.0000000E+00
P(1, 1, 4)	45604.00	0.0000000E+00
P(1, 1, 5)	0.0000000E+00	0.0000000E+00
P(1, 1, 6)	167498.0	0.0000000E+00
P(1, 1, 7)	0.0000000E+00	0.0000000E+00

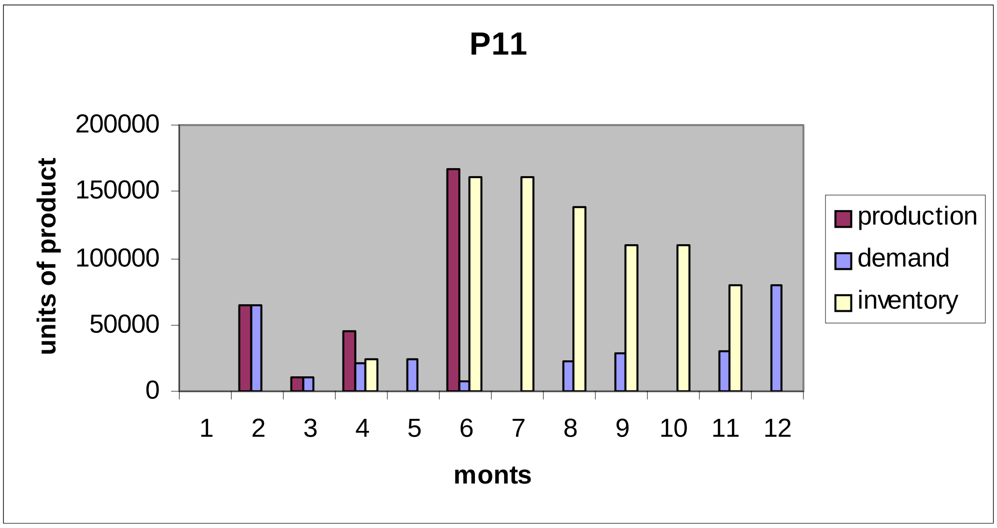
P(1, 1, 8)	100.0000	0.0000000E+00
P(1, 1, 9)	0.0000000E+00	0.0000000E+00
P(1, 1, 10)	0.0000000E+00	0.0000000E+00
P(1, 1, 11)	100.0000	0.0000000E+00
P(1, 1, 12)	0.0000000E+00	0.0000000E+00
P(1, 2, 1)	0.0000000E+00	0.0000000E+00
P(1, 2, 2)	0.0000000E+00	0.0000000E+00
P(1, 2, 3)	0.0000000E+00	0.0000000E+00
P(1, 2, 4)	0.0000000E+00	0.0000000E+00
P(1, 2, 5)	0.0000000E+00	0.0000000E+00
P(1, 2, 6)	0.0000000E+00	0.0000000E+00
P(1, 2, 7)	0.0000000E+00	0.0000000E+00
P(1, 2, 8)	0.0000000E+00	0.0000000E+00
P(1, 2, 9)	0.0000000E+00	0.0000000E+00
P(1, 2, 10)	0.0000000E+00	0.0000000E+00
P(1, 2, 11)	0.0000000E+00	0.0000000E+00
P(1, 2, 12)	0.0000000E+00	0.0000000E+00
P(1, 3, 1)	47667.00	0.0000000E+00
P(1, 3, 2)	80248.00	0.0000000E+00
P(1, 3, 3)	34713.00	0.0000000E+00
P(1, 3, 4)	124949.0	0.0000000E+00
P(1, 3, 5)	346589.8	0.0000000E+00
P(1, 3, 6)	171791.6	0.0000000E+00
P(1, 3, 7)	0.0000000E+00	0.0000000E+00
P(1, 3, 8)	0.0000000E+00	0.0000000E+00
P(1, 3, 9)	0.0000000E+00	0.0000000E+00
P(1, 3, 10)	312849.7	0.0000000E+00
P(1, 3, 11)	100.0000	0.0000000E+00
P(1, 3, 12)	0.0000000E+00	0.0000000E+00
P(1, 4, 1)	495.0000	0.0000000E+00
P(1, 4, 2)	0.0000000E+00	0.0000000E+00
P(1, 4, 3)	0.0000000E+00	0.0000000E+00
P(1, 4, 4)	0.0000000E+00	0.0000000E+00
P(1, 4, 5)	2928.000	0.0000000E+00
P(1, 4, 6)	0.0000000E+00	0.0000000E+00
P(1, 4, 7)	0.0000000E+00	0.0000000E+00
P(1, 4, 8)	0.0000000E+00	0.0000000E+00
P(1, 4, 9)	0.0000000E+00	0.0000000E+00
P(1, 4, 10)	0.0000000E+00	0.0000000E+00
P(1, 4, 11)	0.0000000E+00	0.0000000E+00
P(1, 4, 12)	0.0000000E+00	0.0000000E+00
P(1, 5, 1)	263907.0	0.0000000E+00
P(1, 5, 2)	224906.0	0.0000000E+00
P(1, 5, 3)	293017.4	0.0000000E+00
P(1, 5, 4)	400238.6	0.0000000E+00
P(1, 5, 5)	0.0000000E+00	0.0000000E+00
P(1, 5, 6)	200394.0	0.0000000E+00
P(1, 5, 7)	524289.0	0.0000000E+00
P(1, 5, 8)	100.0000	0.0000000E+00
P(1, 5, 9)	597287.5	0.0000000E+00

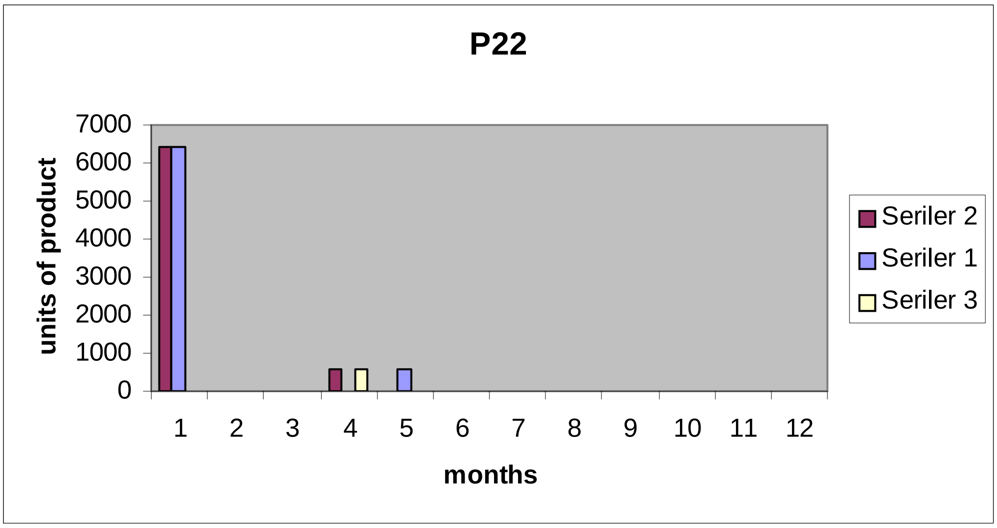
P(1, 5, 10)	538873.5	0.0000000E+00
P(1, 5, 11)	0.0000000E+00	0.0000000E+00
P(1, 5, 12)	0.0000000E+00	0.0000000E+00
P(1, 6, 1)	0.0000000E+00	0.0000000E+00
P(1, 6, 2)	0.0000000E+00	0.0000000E+00
P(1, 6, 3)	0.0000000E+00	0.0000000E+00
P(1, 6, 4)	0.0000000E+00	0.0000000E+00
P(1, 6, 5)	0.0000000E+00	0.0000000E+00
P(1, 6, 6)	0.0000000E+00	0.0000000E+00
P(1, 6, 7)	0.0000000E+00	0.0000000E+00
P(1, 6, 8)	0.0000000E+00	0.0000000E+00
P(1, 6, 9)	0.0000000E+00	0.0000000E+00
P(1, 6, 10)	0.0000000E+00	0.0000000E+00
P(1, 6, 11)	0.0000000E+00	0.0000000E+00
P(1, 6, 12)	0.0000000E+00	0.0000000E+00
P(1, 7, 1)	30150.00	0.0000000E+00
P(1, 7, 2)	100.0000	0.0000000E+00
P(1, 7, 3)	100.0000	0.0000000E+00
P(1, 7, 4)	0.0000000E+00	0.0000000E+00
P(1, 7, 5)	65115.00	0.0000000E+00
P(1, 7, 6)	0.0000000E+00	0.0000000E+00
P(1, 7, 7)	100.0000	0.0000000E+00
P(1, 7, 8)	0.0000000E+00	0.0000000E+00
P(1, 7, 9)	0.0000000E+00	0.0000000E+00
P(1, 7, 10)	0.0000000E+00	0.0000000E+00
P(1, 7, 11)	604470.4	0.0000000E+00
P(1, 7, 12)	881353.4	0.0000000E+00
P(2, 1, 1)	0.0000000E+00	0.0000000E+00
P(2, 1, 2)	0.0000000E+00	0.0000000E+00
P(2, 1, 3)	0.0000000E+00	0.0000000E+00
P(2, 1, 4)	0.0000000E+00	0.0000000E+00
P(2, 1, 5)	0.0000000E+00	0.0000000E+00
P(2, 1, 6)	0.0000000E+00	0.0000000E+00
P(2, 1, 7)	0.0000000E+00	0.0000000E+00
P(2, 1, 8)	0.0000000E+00	0.0000000E+00
P(2, 1, 9)	0.0000000E+00	0.0000000E+00
P(2, 1, 10)	0.0000000E+00	0.0000000E+00
P(2, 1, 11)	0.0000000E+00	0.0000000E+00
P(2, 1, 12)	0.0000000E+00	0.0000000E+00
P(2, 2, 1)	6417.000	0.0000000E+00
P(2, 2, 2)	0.0000000E+00	0.0000000E+00
P(2, 2, 3)	0.0000000E+00	0.0000000E+00
P(2, 2, 4)	583.0000	0.0000000E+00
P(2, 2, 5)	0.0000000E+00	0.0000000E+00
P(2, 2, 6)	0.0000000E+00	0.0000000E+00
P(2, 2, 7)	0.0000000E+00	0.0000000E+00
P(2, 2, 8)	0.0000000E+00	0.0000000E+00
P(2, 2, 9)	0.0000000E+00	0.0000000E+00
P(2, 2, 10)	0.0000000E+00	0.0000000E+00
P(2, 2, 11)	0.0000000E+00	0.0000000E+00

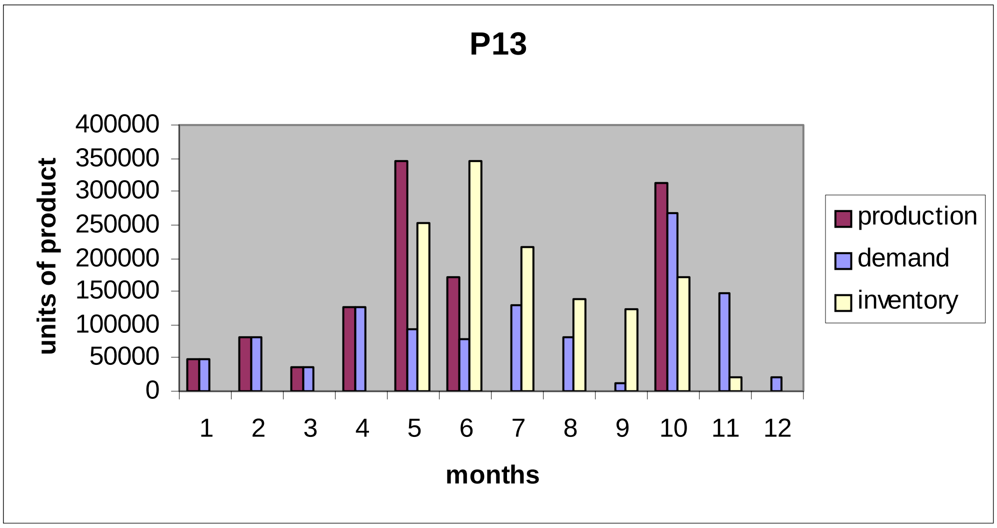
P(2, 2, 12)	0.0000000E+00	0.0000000E+00
P(2, 3, 1)	0.0000000E+00	0.0000000E+00
P(2, 3, 2)	0.0000000E+00	0.0000000E+00
P(2, 3, 3)	0.0000000E+00	0.0000000E+00
P(2, 3, 4)	0.0000000E+00	0.0000000E+00
P(2, 3, 5)	0.0000000E+00	0.0000000E+00
P(2, 3, 6)	0.0000000E+00	0.0000000E+00
P(2, 3, 7)	0.0000000E+00	0.0000000E+00
P(2, 3, 8)	0.0000000E+00	0.0000000E+00
P(2, 3, 9)	0.0000000E+00	0.0000000E+00
P(2, 3, 10)	0.0000000E+00	0.0000000E+00
P(2, 3, 11)	0.0000000E+00	0.0000000E+00
P(2, 3, 12)	0.0000000E+00	0.0000000E+00
P(2, 4, 1)	145299.0	0.0000000E+00
P(2, 4, 2)	100670.0	0.0000000E+00
P(2, 4, 3)	385351.3	0.0000000E+00
P(2, 4, 4)	0.0000000E+00	0.0000000E+00
P(2, 4, 5)	0.0000000E+00	0.0000000E+00
P(2, 4, 6)	159468.1	0.0000000E+00
P(2, 4, 7)	18690.67	0.0000000E+00
P(2, 4, 8)	528972.8	0.0000000E+00
P(2, 4, 9)	100.0000	0.0000000E+00
P(2, 4, 10)	0.0000000E+00	0.0000000E+00
P(2, 4, 11)	187334.2	0.0000000E+00
P(2, 4, 12)	0.0000000E+00	0.0000000E+00
P(2, 5, 1)	156631.1	0.0000000E+00
P(2, 5, 2)	256644.2	0.0000000E+00
P(2, 5, 3)	53899.66	0.0000000E+00
P(2, 5, 4)	111714.0	0.0000000E+00
P(2, 5, 5)	224640.0	0.0000000E+00
P(2, 5, 6)	100.0000	0.0000000E+00
P(2, 5, 7)	151989.0	0.0000000E+00
P(2, 5, 8)	317918.8	0.0000000E+00
P(2, 5, 9)	258376.2	0.0000000E+00
P(2, 5, 10)	0.0000000E+00	0.0000000E+00
P(2, 5, 11)	0.0000000E+00	0.0000000E+00
P(2, 5, 12)	0.0000000E+00	0.0000000E+00
P(2, 6, 1)	14199.00	0.0000000E+00
P(2, 6, 2)	0.0000000E+00	0.0000000E+00
P(2, 6, 3)	0.0000000E+00	0.0000000E+00
P(2, 6, 4)	0.0000000E+00	0.0000000E+00
P(2, 6, 5)	1810.000	0.0000000E+00
P(2, 6, 6)	0.0000000E+00	0.0000000E+00
P(2, 6, 7)	0.0000000E+00	0.0000000E+00
P(2, 6, 8)	0.0000000E+00	0.0000000E+00
P(2, 6, 9)	0.0000000E+00	0.0000000E+00
P(2, 6, 10)	5714.000	0.0000000E+00
P(2, 6, 11)	0.0000000E+00	0.0000000E+00
P(2, 6, 12)	0.0000000E+00	0.0000000E+00
P(2, 7, 1)	198159.0	0.0000000E+00

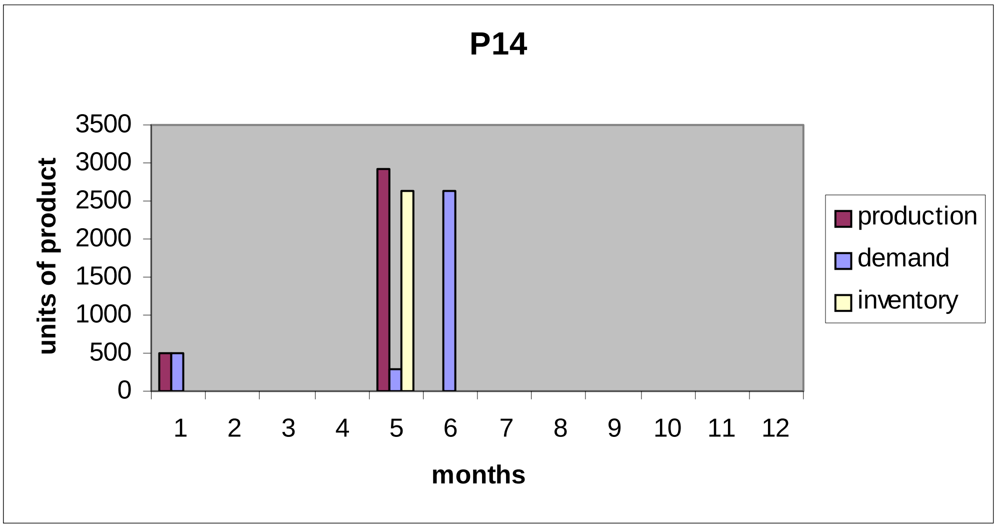
P(2, 7, 2)	0.0000000E+00	0.0000000E+00
P(2, 7, 3)	65669.00	0.0000000E+00
P(2, 7, 4)	121917.0	0.0000000E+00
P(2, 7, 5)	208660.0	0.0000000E+00
P(2, 7, 6)	100.0000	0.0000000E+00
P(2, 7, 7)	187409.0	0.0000000E+00
P(2, 7, 8)	0.0000000E+00	0.0000000E+00
P(2, 7, 9)	0.0000000E+00	0.0000000E+00
P(2, 7, 10)	0.0000000E+00	0.0000000E+00
P(2, 7, 11)	42603.00	0.0000000E+00
P(2, 7, 12)	0.0000000E+00	0.0000000E+00

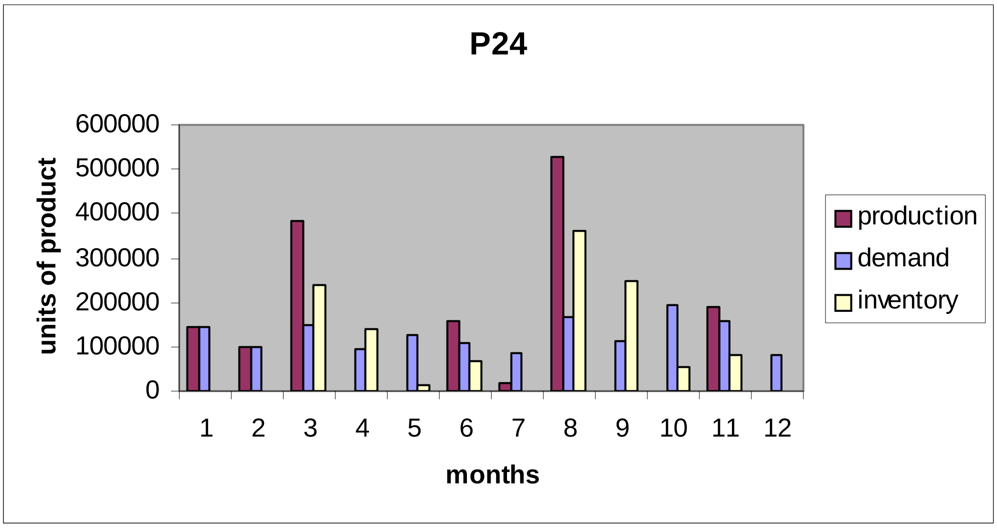
E.3. Production and Inventory Results of Model 3

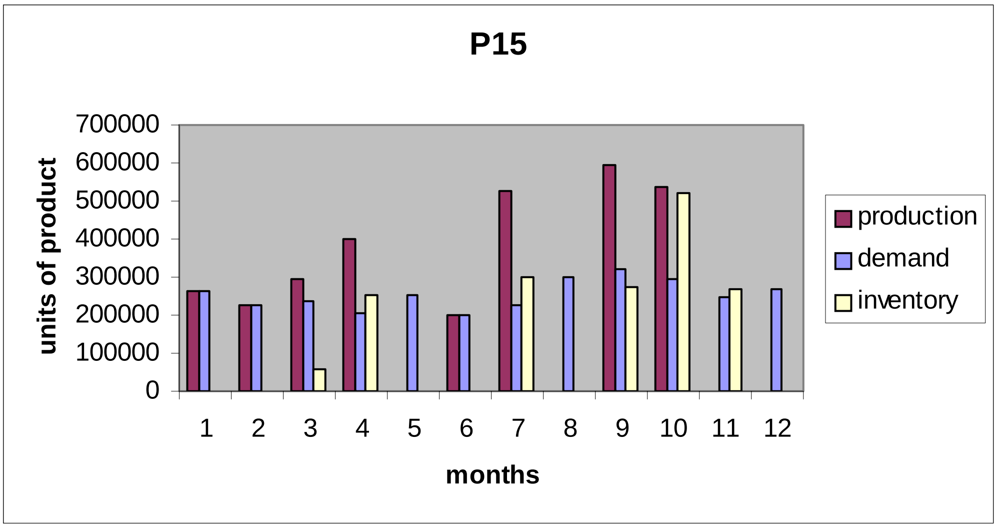


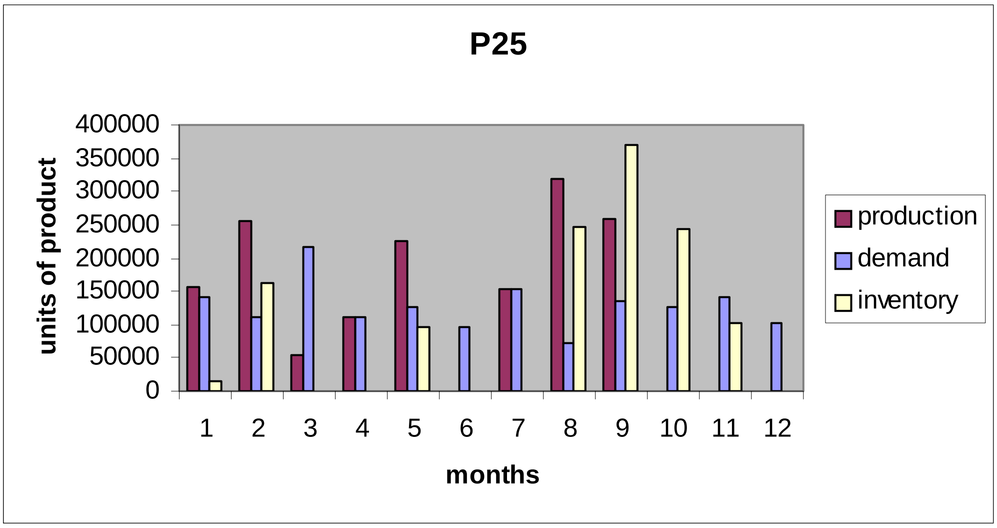


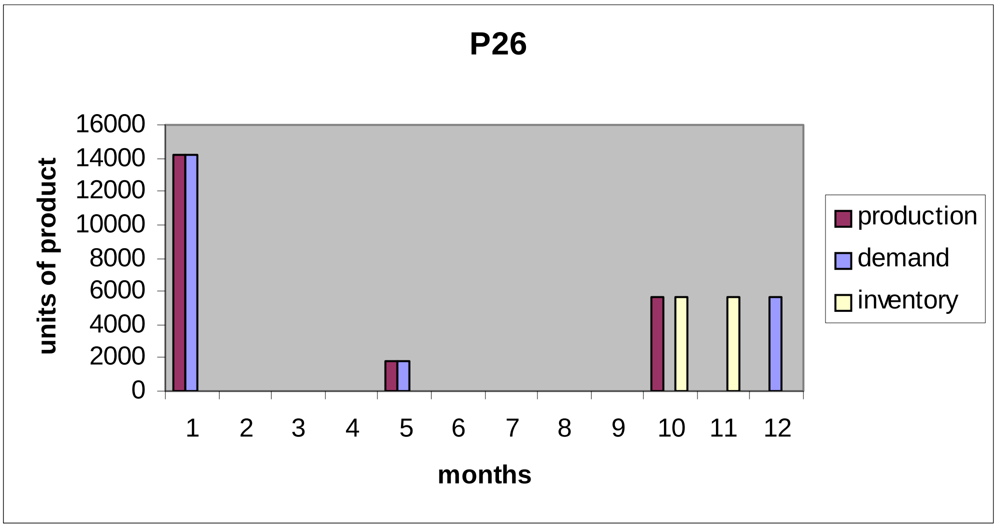

P13
units of product
400000
350000
300000
250000
200000
150000
100000
50000
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory

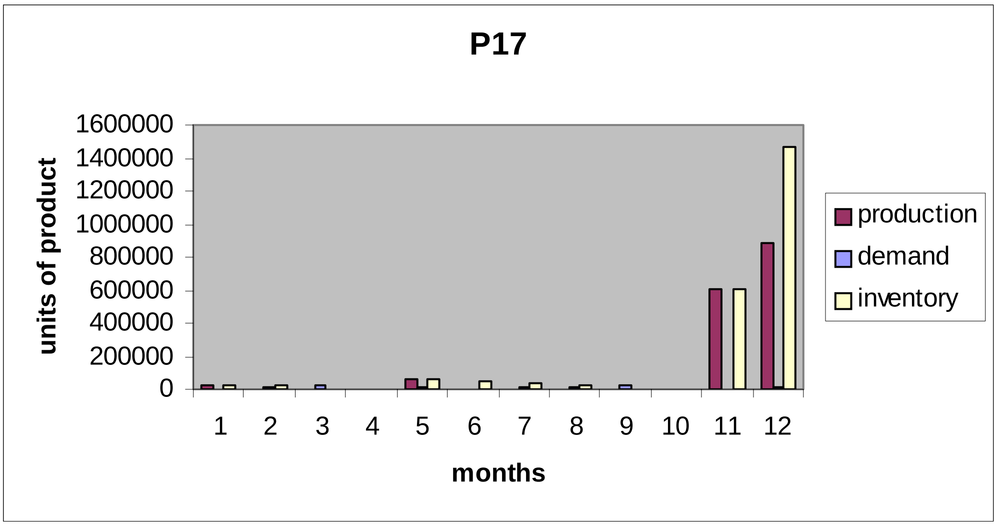

P14
units of product
3500
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory


P24
units of product
600000
500000
400000
300000
200000
100000
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory


P15
units of product
700000
600000
500000
400000
300000
200000
100000
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory


P25
units of product
400000
350000
300000
250000
200000
150000
100000
50000
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory


P26
units of product
16000
14000
12000
10000
8000
6000
4000
2000
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory



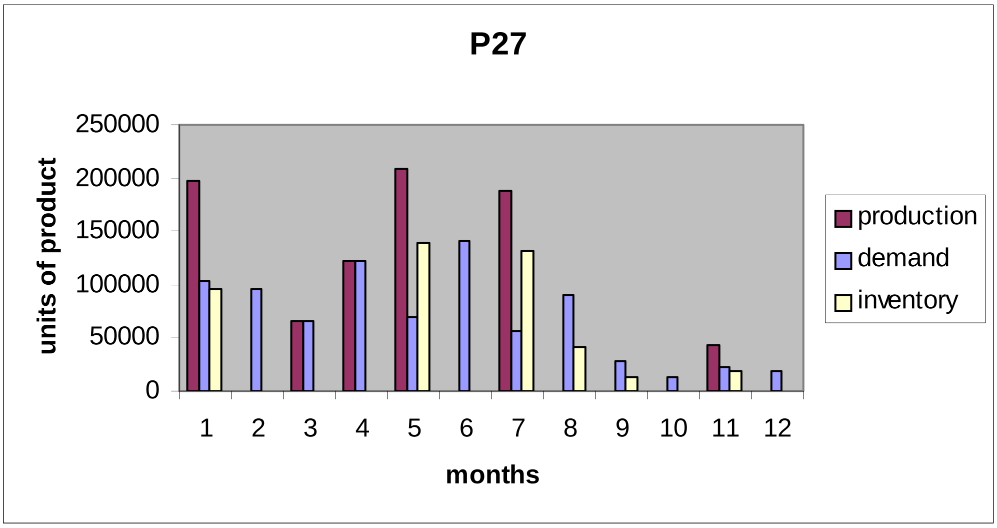


Figure E.1. Production and inventory results of model 3 for each product

E.4. Range Analysis of Model 3

Ranges in which the basis is unchanged:

Objective Coefficient Ranges

Variable	Current Coefficient	Allowable Increase	Allowable Decrease
X(1, 1, 2)	0,8441000	0,0	0,0
X(1, 1, 3)	0,8441000	INFINITY	0,0
X(1, 1, 4)	0,8441000	0,0	0,0
X(1, 1, 6)	0,8441000	0,0	0,0
X(1, 1, 8)	0,8441000	0,0	0,0
X(1, 1, 11)	0,8441000	0,0	0,0
X(1, 2, 1)	0,6444000	INFINITY	0,0

X(1, 2, 4)	0,6444000	0,0	0,1374262
X(1, 3, 1)	0,5253000	INFINITY	0,0
X(1, 3, 2)	0,5253000	0,0	0,0
X(1, 3, 3)	0,5253000	0,0	0,0
X(1, 3, 4)	0,5253000	0,0	0,0
X(1, 3, 5)	0,5253000	0,0	0,0
X(1, 3, 6)	0,5253000	0,0	0,0
X(1, 3, 10)	0,5253000	0,0	0,852346E-04
X(1, 3, 11)	0,5253000	INFINITY	0,0
X(1, 4, 1)	0,5166000	INFINITY	0,0
X(1, 4, 2)	0,5166000	0,0	0,0
X(1, 4, 3)	0,5166000	0,0	INFINITY
X(1, 4, 5)	0,5166000	0,0	0,643583E-05
X(1, 4, 6)	0,5166000	INFINITY	0,0
X(1, 4, 7)	0,5166000	0,0	0,0
X(1, 4, 8)	0,5166000	INFINITY	0,0
X(1, 4, 9)	0,5166000	INFINITY	0,0
X(1, 4, 11)	0,5166000	0,0	0,0
X(1, 5, 1)	0,4826000	INFINITY	0,0
X(1, 5, 2)	0,4826000	0,0	0,0
X(1, 5, 3)	0,4826000	0,0	0,0
X(1, 5, 4)	0,4826000	0,0	0,0
X(1, 5, 5)	0,4826000	0,0	0,0
X(1, 5, 6)	0,4826000	0,0	0,0
X(1, 5, 7)	0,4826000	0,0	0,0
X(1, 5, 8)	0,4826000	0,0	0,0
X(1, 5, 9)	0,4826000	0,0	21,44464
X(1, 5, 10)	0,4826000	0,0	0,0
X(1, 6, 1)	0,4855000	INFINITY	0,0
X(1, 6, 5)	0,4855000	0,0	0,1035
X(1, 6, 10)	0,4855000	INFINITY	0,0
X(1, 7, 1)	0,4860000	0,0	INFINITY
X(1, 7, 2)	0,4860000	0,0	0,0
X(1, 7, 3)	0,4860000	0,0	0,0
X(1, 7, 4)	0,4860000	0,0	0,0
X(1, 7, 5)	0,4860000	0,0	0,0
X(1, 7, 6)	0,4860000	INFINITY	0,0
X(1, 7, 7)	0,4860000	INFINITY	0,0
X(1, 7, 11)	0,4860000	0,0	0,0
X(2, 1, 2)	0,5196000E-01	0,0	0,0
X(2, 1, 3)	0,5196000E-01	INFINITY	0,0
X(2, 1, 4)	0,5196000E-01	0,0	0,0
X(2, 1, 6)	0,5196000E-01	0,0	0,0
X(2, 1, 8)	0,5196000E-01	0,0	0,0
X(2, 1, 11)	0,5196000E-01	0,0	0,0
X(2, 2, 1)	0,3966000E-01	INFINITY	8,053546
X(2, 2, 4)	0,3966000E-01	INFINITY	0,396600E-01
X(2, 3, 1)	0,3233000E-01	INFINITY	0,0
X(2, 3, 2)	0,3233000E-01	0,0	0,0
X(2, 3, 3)	0,3233000E-01	0,0	0,0

X(2, 3, 4)	0,3233000E-01	0,0	0,0
X(2, 3, 5)	0,3233000E-01	0,0	0,0
X(2, 3, 6)	0,3233000E-01	0,0	0,0
X(2, 3, 10)	0,3233000E-01	0,0	0,8526E-03
X(2, 3, 11)	0,3233000E-01	INFINITY	0,0
X(2, 4, 1)	0,3180000E-01	INFINITY	0,0
X(2, 4, 2)	0,3180000E-01	0,0	0,0
X(2, 4, 3)	0,3180000E-01	0,0	INFINITY
X(2, 4, 5)	0,3180000E-01	0,0	0,6437E-04
X(2, 4, 6)	0,3180000E-01	INFINITY	0,0
X(2, 4, 7)	0,3180000E-01	0,0	0,0
X(2, 4, 8)	0,3180000E-01	INFINITY	0,0
X(2, 4, 9)	0,3180000E-01	INFINITY	0,0
X(2, 4, 11)	0,3180000E-01	0,0	0,0
X(2, 5, 1)	0,2970000E-01	INFINITY	0,0
X(2, 5, 2)	0,2970000E-01	0,0	0,0
X(2, 5, 3)	0,2970000E-01	0,0	0,0
X(2, 5, 4)	0,2970000E-01	0,0	0,0
X(2, 5, 5)	0,2970000E-01	0,0	0,0
X(2, 5, 6)	0,2970000E-01	0,0	0,0
X(2, 5, 7)	0,2970000E-01	0,0	0,0
X(2, 5, 8)	0,2970000E-01	0,0	0,0
X(2, 5, 9)	0,2970000E-01	0,0	214,5151
X(2, 5, 10)	0,2970000E-01	0,0	0,0
X(2, 6, 1)	0,2989000E-01	INFINITY	0,0
X(2, 6, 5)	0,2989000E-01	0,0	1,035444
X(2, 6, 10)	0,2989000E-01	INFINITY	0,0
X(2, 7, 1)	0,2992000E-01	0,0	INFINITY
X(2, 7, 2)	0,2992000E-01	0,0	0,0
X(2, 7, 3)	0,2992000E-01	0,0	0,0
X(2, 7, 4)	0,2992000E-01	0,0	0,0
X(2, 7, 5)	0,2992000E-01	0,0	0,0
X(2, 7, 6)	0,2992000E-01	INFINITY	0,0
X(2, 7, 7)	0,2992000E-01	INFINITY	0,0
X(2, 7, 11)	0,2992000E-01	0,0	0,0
X(3, 1, 2)	0,3023000E-01	0,0	0,0
X(3, 1, 3)	0,3023000E-01	INFINITY	0,0
X(3, 1, 4)	0,3023000E-01	0,0	0,0
X(3, 1, 6)	0,3023000E-01	0,0	0,0
X(3, 1, 8)	0,3023000E-01	0,0	0,0
X(3, 1, 11)	0,3023000E-01	0,0	0,0
X(3, 2, 1)	0,2308000E-01	INFINITY	0,0
X(3, 2, 4)	0,2308000E-01	0,0	0,1402308
X(3, 3, 1)	0,1881000E-01	INFINITY	0,0
X(3, 3, 2)	0,1881000E-01	0,0	0,0
X(3, 3, 3)	0,1881000E-01	0,0	0,0
X(3, 3, 4)	0,1881000E-01	0,0	0,0
X(3, 3, 5)	0,1881000E-01	0,0	0,0
X(3, 3, 6)	0,1881000E-01	0,0	0,0
X(3, 3, 10)	0,1881000E-01	0,0	0,8697E-04

X(3, 3, 11)	0,1881000E-01	INFINITY	0,0
X(3, 4, 1)	0,1850000E-01	INFINITY	0,0
X(3, 4, 2)	0,1850000E-01	0,0	0,0
X(3, 4, 3)	0,1850000E-01	0,0	INFINITY
X(3, 4, 5)	0,1850000E-01	0,0	0,6567E-05
X(3, 4, 6)	0,1850000E-01	INFINITY	0,0
X(3, 4, 7)	0,1850000E-01	0,0	0,0
X(3, 4, 8)	0,1850000E-01	INFINITY	0,0
X(3, 4, 9)	0,1850000E-01	INFINITY	0,0
X(3, 4, 11)	0,1850000E-01	0,0	0,0
X(3, 5, 1)	0,1728000E-01	INFINITY	0,0
X(3, 5, 2)	0,1728000E-01	0,0	0,0
X(3, 5, 3)	0,1728000E-01	0,0	0,0
X(3, 5, 4)	0,1728000E-01	0,0	0,0
X(3, 5, 5)	0,1728000E-01	0,0	0,0
X(3, 5, 6)	0,1728000E-01	0,0	0,0
X(3, 5, 7)	0,1728000E-01	0,0	0,0
X(3, 5, 8)	0,1728000E-01	0,0	0,0
X(3, 5, 9)	0,1728000E-01	0,0	21,8822
X(3, 5, 10)	0,1728000E-01	0,0	0,0
X(3, 6, 1)	0,1739000E-01	INFINITY	0,0
X(3, 6, 5)	0,1739000E-01	0,0	0,1056208
X(3, 6, 10)	0,1739000E-01	INFINITY	0,0
X(3, 7, 1)	0,1741000E-01	0,0	0,0
X(3, 7, 2)	0,1741000E-01	0,0	0,0
X(3, 7, 3)	0,1741000E-01	0,0	0,0
X(3, 7, 4)	0,1741000E-01	0,0	0,0
X(3, 7, 5)	0,1741000E-01	0,0	0,0
X(3, 7, 6)	0,1741000E-01	INFINITY	0,0
X(3, 7, 7)	0,1741000E-01	INFINITY	0,0
X(3, 7, 11)	0,1741000E-01	0,0	0,0
X(4, 2, 1)	0,1167000	INFINITY	0,0
X(4, 2, 4)	0,1167000	0,0	0,1526904
X(4, 4, 1)	0,9358000E-01	INFINITY	0,0
X(4, 4, 2)	0,9358000E-01	0,0	0,0
X(4, 4, 3)	0,9358000E-01	0,0	0,0
X(4, 4, 6)	0,9358000E-01	INFINITY	INFINITY
X(4, 4, 7)	0,9358000E-01	0,0	0,0
X(4, 4, 8)	0,9358000E-01	INFINITY	0,0
X(4, 4, 9)	0,9358000E-01	INFINITY	0,0
X(4, 4, 11)	0,9358000E-01	0,0	0,0
X(4, 5, 1)	0,8741000E-01	INFINITY	0,0
X(4, 5, 2)	0,8741000E-01	0,0	0,0
X(4, 5, 3)	0,8741000E-01	0,0	0,0
X(4, 5, 4)	0,8741000E-01	0,0	0,0
X(4, 5, 5)	0,8741000E-01	0,0	0,0
X(4, 5, 6)	0,8741000E-01	0,0	0,0
X(4, 5, 7)	0,8741000E-01	INFINITY	0,0
X(4, 5, 8)	0,8741000E-01	0,0	0,0
X(4, 5, 9)	0,8741000E-01	0,0	0,114367

X(4, 6, 1)	0,8794000E-01	INFINITY	0,0
X(4, 6, 5)	0,8794000E-01	0,0	0,1150085
X(4, 6, 10)	0,8794000E-01	INFINITY	0,0
X(4, 7, 1)	0,8804000E-01	0,0	INFINITY
X(4, 7, 3)	0,8804000E-01	0,0	0,0
X(4, 7, 4)	0,8804000E-01	0,0	0,0
X(4, 7, 5)	0,8804000E-01	0,0	0,1151088
X(4, 7, 6)	0,8804000E-01	INFINITY	0,0
X(4, 7, 7)	0,8804000E-01	INFINITY	0,0
X(4, 7, 11)	0,8804000E-01	INFINITY	0,0
X(5, 2, 1)	0,3231000E-01	INFINITY	0,0
X(5, 2, 4)	0,3231000E-01	0,0	0,1526904
X(5, 4, 1)	0,2591000E-01	INFINITY	0,0
X(5, 4, 2)	0,2591000E-01	0,0	0,0
X(5, 4, 3)	0,2591000E-01	0,0	INFINITY
X(5, 4, 6)	0,2591000E-01	INFINITY	0,0
X(5, 4, 7)	0,2591000E-01	0,0	0,0
X(5, 4, 8)	0,2591000E-01	INFINITY	0,0
X(5, 4, 9)	0,2591000E-01	INFINITY	0,0
X(5, 4, 11)	0,2591000E-01	0,0	0,0
X(5, 5, 1)	0,2420000E-01	INFINITY	0,0
X(5, 5, 2)	0,2420000E-01	0,0	0,0
X(5, 5, 3)	0,2420000E-01	0,0	0,0
X(5, 5, 4)	0,2420000E-01	0,0	0,0
X(5, 5, 5)	0,2420000E-01	0,0	0,0
X(5, 5, 6)	0,2420000E-01	0,0	0,0
X(5, 5, 7)	0,2420000E-01	INFINITY	0,0
X(5, 5, 8)	0,2420000E-01	0,0	0,0
X(5, 5, 9)	0,2420000E-01	0,0	0,0
X(5, 6, 1)	0,2434000E-01	INFINITY	0,0
X(5, 6, 5)	0,2434000E-01	0,0	0,1150085
X(5, 6, 10)	0,2434000E-01	INFINITY	0,0
X(5, 7, 1)	0,2437000E-01	0,0	0,0
X(5, 7, 3)	0,2437000E-01	0,0	0,0
X(5, 7, 4)	0,2437000E-01	0,0	0,0
X(5, 7, 5)	0,2437000E-01	0,0	0,1151088
X(5, 7, 6)	0,2437000E-01	INFINITY	0,0
X(5, 7, 7)	0,2437000E-01	INFINITY	0,0
X(5, 7, 11)	0,2437000E-01	INFINITY	0,0

APPENDIX F

MODEL 4

F.1. Computer Program of Model 4

```
MODEL:
SETS:
 STAGE/1..5/;
 PRODUCT/1..7/;
 GROUP/1..2/;
 MOUNTH/1..12/;
 LINK1(STAGE,PRODUCT,MOUNTH):X;
 LINK2(GROUP,PRODUCT,MOUNTH):P;
 LINK3(PRODUCT,MOUNTH):Y;
ENDSETS
MIN=(0.8441*(@SUM(MOUNTH(K):X(1,1,K))))+(0.05196*(@SUM(MOUNTH(K):
X(2,1,K))))+(0.03023*(X(3,1,1)+X(3,1,2)+X(3,1,3)+X(3,1,4)+X(3,1,5)+X(3,1,6)+X(3,
1,7)+X(3,1,8)+X(3,1,9)+X(3,1,10)+X(3,1,11)+X(3,1,12))+(0.6444*(@SUM(MOUNT
H(K):X(1,2,K))))+(0.03966*(@SUM(MOUNTH(K):X(2,2,K))))+(0.02308*(@SUM(M
OUNTH(K):X(3,2,K))))+(0.1167*(@SUM(MOUNTH(K):X(4,2,K))))+(0.03231*(@S
UM(MOUNTH(K):X(5,2,K))))+(0.5253*(@SUM(MOUNTH(K):X(1,3,K))))+(0.03233
*(@SUM(MOUNTH(K):X(2,3,K))))+(0.01881*(@SUM(MOUNTH(K):X(3,3,K))))+(0
.5166*(@SUM(MOUNTH(K):X(1,4,K))))+(0.0318*(@SUM(MOUNTH(K):X(2,4,K)))
)+(0.0185*(@SUM(MOUNTH(K):X(3,4,K))))+(0.09358*(@SUM(MOUNTH(K):X(4,
4,K))))+(0.02591*(@SUM(MOUNTH(K):X(5,4,K))))+(0.4826*(@SUM(MOUNTH(K
):X(1,5,K))))+(0.0297*(@SUM(MOUNTH(K):X(2,5,K))))+(0.01728*(@SUM(MOUN
TH(K):X(3,5,K))))+(0.08741*(@SUM(MOUNTH(K):X(4,5,K))))+(0.0242*(@SUM(
MOUNTH(K):X(5,5,K))))+(0.4855*(@SUM(MOUNTH(K):X(1,6,K))))+(0.02989*(@
SUM(MOUNTH(K):X(2,6,K))))+(0.01739*(@SUM(MOUNTH(K):X(3,6,K))))+(0.087
94*(@SUM(MOUNTH(K):X(4,6,K))))+(0.02434*(@SUM(MOUNTH(K):X(5,6,K))))
+(0.486*(@SUM(MOUNTH(K):X(1,7,K))))+(0.02992*(@SUM(MOUNTH(K):X(2,7,
K))))+(0.01741*(@SUM(MOUNTH(K):X(3,7,K))))+(0.08804*(@SUM(MOUNTH(K)
:X(4,7,K))))+(0.02437*(@SUM(MOUNTH(K):X(5,7,K)))));
@FOR(MOUNTH(K):X(2,1,K)=0.02*X(1,1,K)+0.0816*X(3,1,K));
@FOR(MOUNTH(K):X(2,2,K)=0.02*X(1,2,K)+0.0816*X(3,2,K));
@FOR(MOUNTH(K):X(2,3,K)=0.02*X(1,3,K)+0.0816*X(3,3,K));
@FOR(MOUNTH(K):X(2,4,K)=0.02*X(1,4,K)+0.0816*X(3,4,K));
@FOR(MOUNTH(K):X(2,5,K)=0.02*X(1,5,K)+0.0816*X(3,5,K));
@FOR(MOUNTH(K):X(2,6,K)=0.02*X(1,6,K)+0.0816*X(3,6,K));
@FOR(MOUNTH(K):X(2,7,K)=0.02*X(1,7,K)+0.0816*X(3,7,K));
@FOR(MOUNTH(K):X(3,1,K)=0.98*X(1,1,K));
@FOR(MOUNTH(K):X(3,2,K)=0.98*X(1,2,K));
@FOR(MOUNTH(K):X(3,3,K)=0.98*X(1,3,K));
@FOR(MOUNTH(K):X(3,4,K)=0.98*X(1,4,K));
@FOR(MOUNTH(K):X(3,5,K)=0.98*X(1,5,K));
@FOR(MOUNTH(K):X(3,6,K)=0.98*X(1,6,K));
@FOR(MOUNTH(K):X(3,7,K)=0.98*X(1,7,K));
```

```
@FOR(MOUNTH(K):P(1,1,K)=0.9184*X(3,1,K)-X(4,1,K));
@FOR(MOUNTH(K):P(1,2,K)=0.9184*X(3,2,K)-X(4,2,K));
@FOR(MOUNTH(K):P(1,3,K)=0.9184*X(3,3,K)-X(4,3,K));
@FOR(MOUNTH(K):P(1,4,K)=0.9184*X(3,4,K)-X(4,4,K));
@FOR(MOUNTH(K):P(1,5,K)=0.9184*X(3,5,K)-X(4,5,K));
@FOR(MOUNTH(K):P(1,6,K)=0.9184*X(3,6,K)-X(4,6,K));
@FOR(MOUNTH(K):P(1,7,K)=0.9184*X(3,7,K)-X(4,7,K));
@FOR(MOUNTH(K):X(4,1,K)=0);
@FOR(MOUNTH(K):X(4,3,K)=0);
@FOR(MOUNTH(K):P(1,2,K)=0);
@FOR(MOUNTH(K):P(1,6,K)=0);
@FOR(MOUNTH(K):X(5,1,K)=X(4,1,K));
@FOR(MOUNTH(K):X(5,2,K)=X(4,2,K));
@FOR(MOUNTH(K):X(5,3,K)=X(4,3,K));
@FOR(MOUNTH(K):X(5,4,K)=X(4,4,K));
@FOR(MOUNTH(K):X(5,5,K)=X(4,5,K));
@FOR(MOUNTH(K):X(5,6,K)=X(4,6,K));
@FOR(MOUNTH(K):X(5,7,K)=X(4,7,K));
@FOR(MOUNTH(K):P(2,1,K)=0.9952*X(5,1,K));
@FOR(MOUNTH(K):P(2,2,K)=0.9952*X(5,2,K));
@FOR(MOUNTH(K):P(2,3,K)=0.9952*X(5,3,K));
@FOR(MOUNTH(K):P(2,4,K)=0.9952*X(5,4,K));
@FOR(MOUNTH(K):P(2,5,K)=0.9952*X(5,5,K));
@FOR(MOUNTH(K):P(2,6,K)=0.9952*X(5,6,K));
@FOR(MOUNTH(K):P(2,7,K)=0.9952*X(5,7,K));
P(1,1,1)>=0;
P(2,2,1)>=6417;
P(1,3,1)>=47667;
P(1,4,1)>=495;
P(2,4,1)>=145299;
P(1,5,1)>=263907;
P(2,5,1)>=140285;
P(2,6,1)>=14199;
P(1,7,1)>=2270;
P(2,7,1)>=102638;
P(1,1,1)+P(1,1,2)=64724;
P(1,1,2)+P(1,1,3)=75275;
P(1,1,3)+P(1,1,4)=35340;
P(1,1,4)+P(1,1,5)=48837;
P(1,1,5)+P(1,1,6)=32400;
P(1,1,6)+P(1,1,7)=8352;
P(1,1,7)+P(1,1,8)=25839;
P(1,1,8)+P(1,1,9)=54485;
P(1,1,9)+P(1,1,10)=28646;
P(1,1,10)+P(1,1,11)=29420;
P(1,1,11)+P(1,1,12)=121305;
P(2,2,1)+P(2,2,2)=6417;
P(2,2,2)+P(2,2,3)=0;
P(2,2,3)+P(2,2,4)=0;
P(2,2,4)+P(2,2,5)=583;
```

P(2,2,5)+P(2,2,6)=583;
P(2,2,6)+P(2,2,7)=0;
P(2,2,7)+P(2,2,8)=0;
P(2,2,8)+P(2,2,9)=0;
P(2,2,9)+P(2,2,10)=0;
P(2,2,10)+P(2,2,11)=0;
P(2,2,11)+P(2,2,12)=0;
P(1,3,1)+P(1,3,2)=127915;
P(1,3,2)+P(1,3,3)=114961;
P(1,3,3)+P(1,3,4)=178404;
P(1,3,4)+P(1,3,5)=236933;
P(1,3,5)+P(1,3,6)=183503;
P(1,3,6)+P(1,3,7)=239467;
P(1,3,7)+P(1,3,8)=240927;
P(1,3,8)+P(1,3,9)=104988;
P(1,3,9)+P(1,3,10)=279604;
P(1,3,10)+P(1,3,11)=415060;
P(1,3,11)+P(1,3,12)=173761;
P(1,4,1)+P(1,4,2)=495;
P(1,4,2)+P(1,4,3)=0;
P(1,4,3)+P(1,4,4)=0;
P(1,4,4)+P(1,4,5)=285;
P(1,4,5)+P(1,4,6)=3324;
P(1,4,6)+P(1,4,7)=3039;
P(1,4,7)+P(1,4,8)=0;
P(1,4,8)+P(1,4,9)=0;
P(1,4,9)+P(1,4,10)=0;
P(1,4,10)+P(1,4,11)=0;
P(1,4,11)+P(1,4,12)=0;
P(2,4,1)+P(2,4,2)=245969;
P(2,4,2)+P(2,4,3)=247829;
P(2,4,3)+P(2,4,4)=258608;
P(2,4,4)+P(2,4,5)=238606;
P(2,4,5)+P(2,4,6)=251547;
P(2,4,6)+P(2,4,7)=221124;
P(2,4,7)+P(2,4,8)=291059;
P(2,4,8)+P(2,4,9)=307555;
P(2,4,9)+P(2,4,10)=307420;
P(2,4,10)+P(2,4,11)=351260;
P(2,4,11)+P(2,4,12)=252450;
P(1,5,1)+P(1,5,2)=488813;
P(1,5,2)+P(1,5,3)=461460;
P(1,5,3)+P(1,5,4)=470140;
P(1,5,4)+P(1,5,5)=487170;
P(1,5,5)+P(1,5,6)=484037;
P(1,5,6)+P(1,5,7)=490381;
P(1,5,7)+P(1,5,8)=603047;
P(1,5,8)+P(1,5,9)=665268;
P(1,5,9)+P(1,5,10)=617298;
P(1,5,10)+P(1,5,11)=543453;

```
P(1,5,11)+P(1,5,12)=559447;
P(2,5,1)+P(2,5,2)=251536;
P(2,5,2)+P(2,5,3)=326890;
P(2,5,3)+P(2,5,4)=344110;
P(2,5,4)+P(2,5,5)=256131;
P(2,5,5)+P(2,5,6)=239302;
P(2,5,6)+P(2,5,7)=286429;
P(2,5,7)+P(2,5,8)=256154;
P(2,5,8)+P(2,5,9)=216722;
P(2,5,9)+P(2,5,10)=262285;
P(2,5,10)+P(2,5,11)=266870;
P(2,5,11)+P(2,5,12)=258753;
P(2,6,1)+P(2,6,2)=14199;
P(2,6,2)+P(2,6,3)=0;
P(2,6,3)+P(2,6,4)=0;
P(2,6,4)+P(2,6,5)=1810;
P(2,6,5)+P(2,6,6)=1810;
P(2,6,6)+P(2,6,7)=0;
P(2,6,7)+P(2,6,8)=0;
P(2,6,8)+P(2,6,9)=0;
P(2,6,9)+P(2,6,10)=0;
P(2,6,10)+P(2,6,11)=0;
P(2,6,11)+P(2,6,12)=6571;
P(1,7,1)+P(1,7,2)=9659;
P(1,7,2)+P(1,7,3)=28080;
P(1,7,3)+P(1,7,4)=20691;
P(1,7,4)+P(1,7,5)=9348;
P(1,7,5)+P(1,7,6)=12352;
P(1,7,6)+P(1,7,7)=20547;
P(1,7,7)+P(1,7,8)=33759;
P(1,7,8)+P(1,7,9)=40115;
P(1,7,9)+P(1,7,10)=23899;
P(1,7,10)+P(1,7,11)=4331;
P(1,7,11)+P(1,7,12)=18454;
P(2,7,1)+P(2,7,2)=198159;
P(2,7,2)+P(2,7,3)=161190;
P(2,7,3)+P(2,7,4)=205874;
P(2,7,4)+P(2,7,5)=208910;
P(2,7,5)+P(2,7,6)=229763;
P(2,7,6)+P(2,7,7)=226027;
P(2,7,7)+P(2,7,8)=168300;
P(2,7,8)+P(2,7,9)=131472;
P(2,7,9)+P(2,7,10)=41061;
P(2,7,10)+P(2,7,11)=36058;
P(2,7,11)+P(2,7,12)=45524;
(1.5*Y(1,1)+0.0013695*(P(1,1,1)+P(2,1,1)))+(1*Y(2,1)+0.00104542*(P(1,2,1)+P(2,2,1)))+(1*Y(3,1)+0.00085218*(P(1,3,1)+P(2,3,1)))+(1*Y(4,1)+0.00083819*(P(1,4,1)+P(2,4,1)))+(1*Y(5,1)+0.00078292*(P(1,5,1)+P(2,5,1)))+(1*Y(6,1)+0.0007877*(P(1,6,1)+P(2,6,1)))+(1*Y(7,1)+0.00078856*(P(1,7,1)+P(2,7,1)))<=696;
(P(1,1,1)+P(2,1,1))<=10000000000*Y(1,1);
```

```
(P(1,1,1)+P(2,1,1))>=Y(1,1);
(P(1,2,1)+P(2,2,1))<=10000000000*Y(2,1);
(P(1,2,1)+P(2,2,1))>=Y(2,1);
(P(1,3,1)+P(2,3,1))<=10000000000*Y(3,1);
(P(1,3,1)+P(2,3,1))>=Y(3,1);
(P(1,4,1)+P(2,4,1))<=10000000000*Y(4,1);
(P(1,4,1)+P(2,4,1))>=Y(4,1);
(P(1,5,1)+P(2,5,1))<=10000000000*Y(5,1);
(P(1,5,1)+P(2,5,1))>=Y(5,1);
(P(1,6,1)+P(2,6,1))<=10000000000*Y(6,1);
(P(1,6,1)+P(2,6,1))>=Y(6,1);
(P(1,7,1)+P(2,7,1))<=10000000000*Y(7,1);
(P(1,7,1)+P(2,7,1))>=Y(7,1);
(1.5*Y(1,2)+0.0013695*(P(1,1,2)+P(2,1,2)))+(1*Y(2,2)+0.00104542*(P(1,2,2)+P(2,2,2
)))+(1*Y(3,2)+0.00085218*(P(1,3,2)+P(2,3,2)))+(1*Y(4,2)+0.00083819*(P(1,4,2)+P(2
,4,2)))+(1*Y(5,2)+0.00078292*(P(1,5,2)+P(2,5,2)))+(1*Y(6,2)+0.0007877*(P(1,6,2)+P
(2,6,2)))+(1*Y(7,2)+0.00078856*(P(1,7,2)+P(2,7,2)))<=624;
(P(1,1,2)+P(2,1,2))<=10000000000*Y(1,2);
(P(1,1,2)+P(2,1,2))>=Y(1,2);
(P(1,2,2)+P(2,2,2))<=10000000000*Y(2,2);
(P(1,2,2)+P(2,2,2))>=Y(2,2);
(P(1,3,2)+P(2,3,2))<=10000000000*Y(3,2);
(P(1,3,2)+P(2,3,2))>=Y(3,2);
(P(1,4,2)+P(2,4,2))<=10000000000*Y(4,2);
(P(1,4,2)+P(2,4,2))>=Y(4,2);
(P(1,5,2)+P(2,5,2))<=10000000000*Y(5,2);
(P(1,5,2)+P(2,5,2))>=Y(5,2);
(P(1,6,2)+P(2,6,2))<=10000000000*Y(6,2);
(P(1,6,2)+P(2,6,2))>=Y(6,2);
(P(1,7,2)+P(2,7,2))<=10000000000*Y(7,2);
(P(1,7,2)+P(2,7,2))>=Y(7,2);
(1.5*Y(1,3)+0.0013695*(P(1,1,3)+P(2,1,3)))+(1*Y(2,3)+0.00104542*(P(1,2,3)+P(2,2,3
)))+(1*Y(3,3)+0.00085218*(P(1,3,3)+P(2,3,3)))+(1*Y(4,3)+0.00083819*(P(1,4,3)+P(2
,4,3)))+(1*Y(5,3)+0.00078292*(P(1,5,3)+P(2,5,3)))+(1*Y(6,3)+0.0007877*(P(1,6,3)+P
(2,6,3)))+(1*Y(7,3)+0.00078856*(P(1,7,3)+P(2,7,3)))<=696;
(P(1,1,3)+P(2,1,3))<=10000000000*Y(1,3);
(P(1,1,3)+P(2,1,3))>=Y(1,3);
(P(1,2,3)+P(2,2,3))<=10000000000*Y(2,3);
(P(1,2,3)+P(2,2,3))>=Y(2,3);
(P(1,3,3)+P(2,3,3))<=10000000000*Y(3,3);
(P(1,3,3)+P(2,3,3))>=Y(3,3);
(P(1,4,3)+P(2,4,3))<=10000000000*Y(4,3);
(P(1,4,3)+P(2,4,3))>=Y(4,3);
(P(1,5,3)+P(2,5,3))<=10000000000*Y(5,3);
(P(1,5,3)+P(2,5,3))>=Y(5,3);
(P(1,6,3)+P(2,6,3))<=10000000000*Y(6,3);
(P(1,6,3)+P(2,6,3))>=Y(6,3);
(P(1,7,3)+P(2,7,3))<=10000000000*Y(7,3);
(P(1,7,3)+P(2,7,3))>=Y(7,3);
```

(1.5*Y(1,4)+0.0013695*(P(1,1,4)+P(2,1,4)))+(1*Y(2,4)+0.00104542*(P(1,2,4)+P(2,2,4)))+(1*Y(3,4)+0.00085218*(P(1,3,4)+P(2,3,4)))+(1*Y(4,4)+0.00083819*(P(1,4,4)+P(2,4,4)))+(1*Y(5,4)+0.00078292*(P(1,5,4)+P(2,5,4)))+(1*Y(6,4)+0.0007877*(P(1,6,4)+P(2,6,4)))+(1*Y(7,4)+0.00078856*(P(1,7,4)+P(2,7,4)))<=672;
(P(1,1,4)+P(2,1,4))<=10000000000*Y(1,4);
(P(1,1,4)+P(2,1,4))>=Y(1,4);
(P(1,2,4)+P(2,2,4))<=10000000000*Y(2,4);
(P(1,2,4)+P(2,2,4))>=Y(2,4);
(P(1,3,4)+P(2,3,4))<=10000000000*Y(3,4);
(P(1,3,4)+P(2,3,4))>=Y(3,4);
(P(1,4,4)+P(2,4,4))<=10000000000*Y(4,4);
(P(1,4,4)+P(2,4,4))>=Y(4,4);
(P(1,5,4)+P(2,5,4))<=10000000000*Y(5,4);
(P(1,5,4)+P(2,5,4))>=Y(5,4);
(P(1,6,4)+P(2,6,4))<=10000000000*Y(6,4);
(P(1,6,4)+P(2,6,4))>=Y(6,4);
(P(1,7,4)+P(2,7,4))<=10000000000*Y(7,4);
(P(1,7,4)+P(2,7,4))>=Y(7,4);
(1.5*Y(1,5)+0.0013695*(P(1,1,5)+P(2,1,5)))+(1*Y(2,5)+0.00104542*(P(1,2,5)+P(2,2,5)))+(1*Y(3,5)+0.00085218*(P(1,3,5)+P(2,3,5)))+(1*Y(4,5)+0.00083819*(P(1,4,5)+P(2,4,5)))+(1*Y(5,5)+0.00078292*(P(1,5,5)+P(2,5,5)))+(1*Y(6,5)+0.0007877*(P(1,6,5)+P(2,6,5)))+(1*Y(7,5)+0.00078856*(P(1,7,5)+P(2,7,5)))<=696;
(P(1,1,5)+P(2,1,5))<=10000000000*Y(1,5);
(P(1,1,5)+P(2,1,5))>=Y(1,5);
(P(1,2,5)+P(2,2,5))<=10000000000*Y(2,5);
(P(1,2,5)+P(2,2,5))>=Y(2,5);
(P(1,3,5)+P(2,3,5))<=10000000000*Y(3,5);
(P(1,3,5)+P(2,3,5))>=Y(3,5);
(P(1,4,5)+P(2,4,5))<=10000000000*Y(4,5);
(P(1,4,5)+P(2,4,5))>=Y(4,5);
(P(1,5,5)+P(2,5,5))<=10000000000*Y(5,5);
(P(1,5,5)+P(2,5,5))>=Y(5,5);
(P(1,6,5)+P(2,6,5))<=10000000000*Y(6,5);
(P(1,6,5)+P(2,6,5))>=Y(6,5);
(P(1,7,5)+P(2,7,5))<=10000000000*Y(7,5);
(P(1,7,5)+P(2,7,5))>=Y(7,5);
(1.5*Y(1,6)+0.0013695*(P(1,1,6)+P(2,1,6)))+(1*Y(2,6)+0.00104542*(P(1,2,6)+P(2,2,6)))+(1*Y(3,6)+0.00085218*(P(1,3,6)+P(2,3,6)))+(1*Y(4,6)+0.00083819*(P(1,4,6)+P(2,4,6)))+(1*Y(5,6)+0.00078292*(P(1,5,6)+P(2,5,6)))+(1*Y(6,6)+0.0007877*(P(1,6,6)+P(2,6,6)))+(1*Y(7,6)+0.00078856*(P(1,7,6)+P(2,7,6)))<=672;
(P(1,1,6)+P(2,1,6))<=10000000000*Y(1,6);
(P(1,1,6)+P(2,1,6))>=Y(1,6);
(P(1,2,6)+P(2,2,6))<=10000000000*Y(2,6);
(P(1,2,6)+P(2,2,6))>=Y(2,6);
(P(1,3,6)+P(2,3,6))<=10000000000*Y(3,6);
(P(1,3,6)+P(2,3,6))>=Y(3,6);
(P(1,4,6)+P(2,4,6))<=10000000000*Y(4,6);
(P(1,4,6)+P(2,4,6))>=Y(4,6);
(P(1,5,6)+P(2,5,6))<=10000000000*Y(5,6);
(P(1,5,6)+P(2,5,6))>=Y(5,6);

(P(1,6,6)+P(2,6,6))<=10000000000*Y(6,6);
(P(1,6,6)+P(2,6,6))>=Y(6,6);
(P(1,7,6)+P(2,7,6))<=10000000000*Y(7,6);
(P(1,7,6)+P(2,7,6))>=Y(7,6);
(1.5*Y(1,7)+0.0013695*(P(1,1,7)+P(2,1,7)))+(1*Y(2,7)+0.00104542*(P(1,2,7)+P(2,2,7
)))+(1*Y(3,7)+0.00085218*(P(1,3,7)+P(2,3,7)))+(1*Y(4,7)+0.00083819*(P(1,4,7)+P(2
,4,7)))+(1*Y(5,7)+0.00078292*(P(1,5,7)+P(2,5,7)))+(1*Y(6,7)+0.0007877*(P(1,6,7)+P
(2,6,7)))+(1*Y(7,7)+0.00078856*(P(1,7,7)+P(2,7,7)))<=696;
(P(1,1,7)+P(2,1,7))<=10000000000*Y(1,7);
(P(1,1,7)+P(2,1,7))>=Y(1,7);
(P(1,2,7)+P(2,2,7))<=10000000000*Y(2,7);
(P(1,2,7)+P(2,2,7))>=Y(2,7);
(P(1,3,7)+P(2,3,7))<=10000000000*Y(3,7);
(P(1,3,7)+P(2,3,7))>=Y(3,7);
(P(1,4,7)+P(2,4,7))<=10000000000*Y(4,7);
(P(1,4,7)+P(2,4,7))>=Y(4,7);
(P(1,5,7)+P(2,5,7))<=10000000000*Y(5,7);
(P(1,5,7)+P(2,5,7))>=Y(5,7);
(P(1,6,7)+P(2,6,7))<=10000000000*Y(6,7);
(P(1,6,7)+P(2,6,7))>=Y(6,7);
(P(1,7,7)+P(2,7,7))<=10000000000*Y(7,7);
(P(1,7,7)+P(2,7,7))>=Y(7,7);
(1.5*Y(1,8)+0.0013695*(P(1,1,8)+P(2,1,8)))+(1*Y(2,8)+0.00104542*(P(1,2,8)+P(2,2,8
)))+(1*Y(3,8)+0.00085218*(P(1,3,8)+P(2,3,8)))+(1*Y(4,8)+0.00083819*(P(1,4,8)+P(2
,4,8)))+(1*Y(5,8)+0.00078292*(P(1,5,8)+P(2,5,8)))+(1*Y(6,8)+0.0007877*(P(1,6,8)+P
(2,6,8)))+(1*Y(7,8)+0.00078856*(P(1,7,8)+P(2,7,8)))<=696;
(P(1,1,8)+P(2,1,8))<=10000000000*Y(1,8);
(P(1,1,8)+P(2,1,8))>=Y(1,8);
(P(1,2,8)+P(2,2,8))<=10000000000*Y(2,8);
(P(1,2,8)+P(2,2,8))>=Y(2,8);
(P(1,3,8)+P(2,3,8))<=10000000000*Y(3,8);
(P(1,3,8)+P(2,3,8))>=Y(3,8);
(P(1,4,8)+P(2,4,8))<=10000000000*Y(4,8);
(P(1,4,8)+P(2,4,8))>=Y(4,8);
(P(1,5,8)+P(2,5,8))<=10000000000*Y(5,8);
(P(1,5,8)+P(2,5,8))>=Y(5,8);
(P(1,6,8)+P(2,6,8))<=10000000000*Y(6,8);
(P(1,6,8)+P(2,6,8))>=Y(6,8);
(P(1,7,8)+P(2,7,8))<=10000000000*Y(7,8);
(P(1,7,8)+P(2,7,8))>=Y(7,8);
(1.5*Y(1,9)+0.0013695*(P(1,1,9)+P(2,1,9)))+(1*Y(2,9)+0.00104542*(P(1,2,9)+P(2,2,9
)))+(1*Y(3,9)+0.00085218*(P(1,3,9)+P(2,3,9)))+(1*Y(4,9)+0.00083819*(P(1,4,9)+P(2
,4,9)))+(1*Y(5,9)+0.00078292*(P(1,5,9)+P(2,5,9)))+(1*Y(6,9)+0.0007877*(P(1,6,9)+P
(2,6,9)))+(1*Y(7,9)+0.00078856*(P(1,7,9)+P(2,7,9)))<=672;
(P(1,1,9)+P(2,1,9))<=10000000000*Y(1,9);
(P(1,1,9)+P(2,1,9))>=Y(1,9);
(P(1,2,9)+P(2,2,9))<=10000000000*Y(2,9);
(P(1,2,9)+P(2,2,9))>=Y(2,9);
(P(1,3,9)+P(2,3,9))<=10000000000*Y(3,9);
(P(1,3,9)+P(2,3,9))>=Y(3,9);

(P(1,4,9)+P(2,4,9))<=10000000000*Y(4,9);
(P(1,4,9)+P(2,4,9))>=Y(4,9);
(P(1,5,9)+P(2,5,9))<=10000000000*Y(5,9);
(P(1,5,9)+P(2,5,9))>=Y(5,9);
(P(1,6,9)+P(2,6,9))<=10000000000*Y(6,9);
(P(1,6,9)+P(2,6,9))>=Y(6,9);
(P(1,7,9)+P(2,7,9))<=10000000000*Y(7,9);
(P(1,7,9)+P(2,7,9))>=Y(7,9);
(1.5*Y(1,10)+0.0013695*(P(1,1,10)+P(2,1,10)))+(1*Y(2,10)+0.00104542*(P(1,2,10)+
P(2,2,10)))+(1*Y(3,10)+0.00085218*(P(1,3,10)+P(2,3,10)))+(1*Y(4,10)+0.00083819*(
P(1,4,10)+P(2,4,10)))+(1*Y(5,10)+0.00078292*(P(1,5,10)+P(2,5,10)))+(1*Y(6,10)+0.0
007877*(P(1,6,10)+P(2,6,10)))+(1*Y(7,10)+0.00078856*(P(1,7,10)+P(2,7,10)))<=696;
(P(1,1,10)+P(2,1,10))<=10000000000*Y(1,10);
(P(1,1,10)+P(2,1,10))>=Y(1,10);
(P(1,2,10)+P(2,2,10))<=10000000000*Y(2,10);
(P(1,2,10)+P(2,2,10))>=Y(2,10);
(P(1,3,10)+P(2,3,10))<=10000000000*Y(3,10);
(P(1,3,10)+P(2,3,10))>=Y(3,10);
(P(1,4,10)+P(2,4,10))<=10000000000*Y(4,10);
(P(1,4,10)+P(2,4,10))>=Y(4,10);
(P(1,5,10)+P(2,5,10))<=10000000000*Y(5,10);
(P(1,5,10)+P(2,5,10))>=Y(5,10);
(P(1,6,10)+P(2,6,10))<=10000000000*Y(6,10);
(P(1,6,10)+P(2,6,10))>=Y(6,10);
(P(1,7,10)+P(2,7,10))<=10000000000*Y(7,10);
(P(1,7,10)+P(2,7,10))>=Y(7,10);
(1.5*Y(1,11)+0.0013695*(P(1,1,11)+P(2,1,11)))+(1*Y(2,11)+0.00104542*(P(1,2,11)+
P(2,2,11)))+(1*Y(3,11)+0.00085218*(P(1,3,11)+P(2,3,11)))+(1*Y(4,11)+0.00083819*(
P(1,4,11)+P(2,4,11)))+(1*Y(5,11)+0.00078292*(P(1,5,11)+P(2,5,11)))+(1*Y(6,11)+0.0
007877*(P(1,6,11)+P(2,6,11)))+(1*Y(7,11)+0.00078856*(P(1,7,11)+P(2,7,11)))<=672;
(P(1,1,11)+P(2,1,11))<=10000000000*Y(1,11);
(P(1,1,11)+P(2,1,11))>=Y(1,11);
(P(1,2,11)+P(2,2,11))<=10000000000*Y(2,11);
(P(1,2,11)+P(2,2,11))>=Y(2,11);
(P(1,3,11)+P(2,3,11))<=10000000000*Y(3,11);
(P(1,3,11)+P(2,3,11))>=Y(3,11);
(P(1,4,11)+P(2,4,11))<=10000000000*Y(4,11);
(P(1,4,11)+P(2,4,11))>=Y(4,11);
(P(1,5,11)+P(2,5,11))<=10000000000*Y(5,11);
(P(1,5,11)+P(2,5,11))>=Y(5,11);
(P(1,6,11)+P(2,6,11))<=10000000000*Y(6,11);
(P(1,6,11)+P(2,6,11))>=Y(6,11);
(P(1,7,11)+P(2,7,11))<=10000000000*Y(7,11);
(P(1,7,11)+P(2,7,11))>=Y(7,11);
(1.5*Y(1,12)+0.0013695*(P(1,1,12)+P(2,1,12)))+(1*Y(2,12)+0.00104542*(P(1,2,12)+
P(2,2,12)))+(1*Y(3,12)+0.00085218*(P(1,3,12)+P(2,3,12)))+(1*Y(4,12)+0.00083819*(
P(1,4,12)+P(2,4,12)))+(1*Y(5,12)+0.00078292*(P(1,5,12)+P(2,5,12)))+(1*Y(6,12)+0.0
007877*(P(1,6,12)+P(2,6,12)))+(1*Y(7,12)+0.00078856*(P(1,7,12)+P(2,7,12)))<=696;
(P(1,1,12)+P(2,1,12))<=10000000000*Y(1,12);
(P(1,1,12)+P(2,1,12))>=Y(1,12);

```
(P(1,2,12)+P(2,2,12))<=10000000000*Y(2,12);
(P(1,2,12)+P(2,2,12))>=Y(2,12);
(P(1,3,12)+P(2,3,12))<=10000000000*Y(3,12);
(P(1,3,12)+P(2,3,12))>=Y(3,12);
(P(1,4,12)+P(2,4,12))<=10000000000*Y(4,12);
(P(1,4,12)+P(2,4,12))>=Y(4,12);
(P(1,5,12)+P(2,5,12))<=10000000000*Y(5,12);
(P(1,5,12)+P(2,5,12))>=Y(5,12);
(P(1,6,12)+P(2,6,12))<=10000000000*Y(6,12);
(P(1,6,12)+P(2,6,12))>=Y(6,12);
(P(1,7,12)+P(2,7,12))<=10000000000*Y(7,12);
(P(1,7,12)+P(2,7,12))>=Y(7,12);
@FOR(LINK1(I,J,K):X(I,J,K)>=0);
@FOR(LINK3(J,K):@BIN(Y(J,K)));
END
```

F.2. Output of Model 4

Optimal solution found at step: 575

Objective value: 5756370.

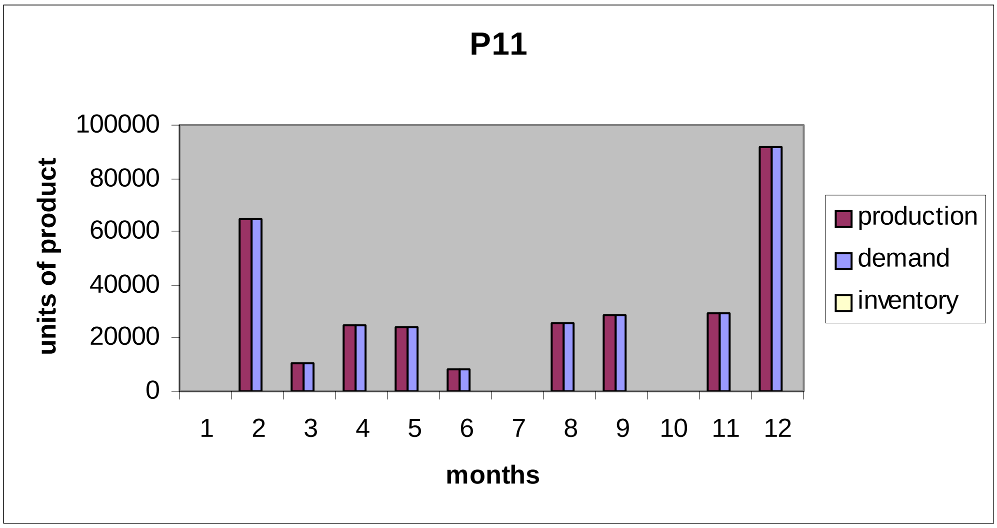
Variable	Value	Reduced Cost
P(1, 1, 1)	0.0000000E+00	0.0000000E+00
P(1, 1, 2)	64724.00	0.0000000E+00
P(1, 1, 3)	10551.00	0.0000000E+00
P(1, 1, 4)	24789.00	0.0000000E+00
P(1, 1, 5)	24048.00	0.0000000E+00
P(1, 1, 6)	8352.000	0.0000000E+00
P(1, 1, 7)	0.0000000E+00	0.0000000E+00
P(1, 1, 8)	25839.00	0.0000000E+00
P(1, 1, 9)	28646.00	0.0000000E+00
P(1, 1, 10)	0.0000000E+00	0.0000000E+00
P(1, 1, 11)	29420.00	0.0000000E+00
P(1, 1, 12)	91885.00	0.0000000E+00
P(1, 2, 1)	0.0000000E+00	0.0000000E+00
P(1, 2, 2)	0.0000000E+00	0.0000000E+00
P(1, 2, 3)	0.0000000E+00	0.0000000E+00
P(1, 2, 4)	0.0000000E+00	0.0000000E+00
P(1, 2, 5)	0.0000000E+00	0.0000000E+00
P(1, 2, 6)	0.0000000E+00	0.0000000E+00
P(1, 2, 7)	0.0000000E+00	0.0000000E+00
P(1, 2, 8)	0.0000000E+00	0.0000000E+00
P(1, 2, 9)	0.0000000E+00	0.0000000E+00
P(1, 2, 10)	0.0000000E+00	0.0000000E+00
P(1, 2, 11)	0.0000000E+00	0.0000000E+00
P(1, 2, 12)	0.0000000E+00	0.0000000E+00
P(1, 3, 1)	47667.00	0.0000000E+00

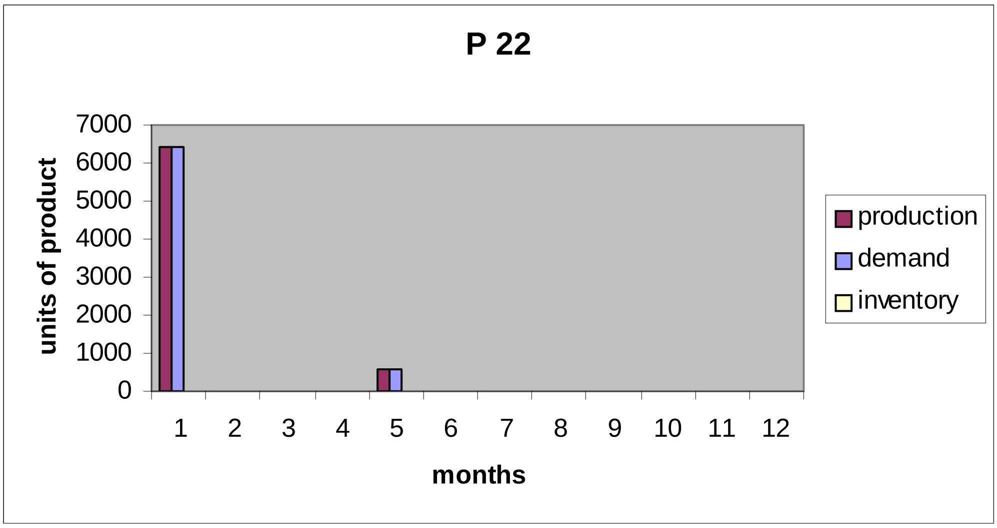
P(1, 3, 2)	80248.00	0.0000000E+00
P(1, 3, 3)	34713.00	0.0000000E+00
P(1, 3, 4)	143691.0	0.0000000E+00
P(1, 3, 5)	93242.00	0.0000000E+00
P(1, 3, 6)	90261.00	0.0000000E+00
P(1, 3, 7)	149206.0	0.0000000E+00
P(1, 3, 8)	91721.00	0.0000000E+00
P(1, 3, 9)	13267.00	0.0000000E+00
P(1, 3, 10)	266337.0	0.0000000E+00
P(1, 3, 11)	148723.0	0.0000000E+00
P(1, 3, 12)	25038.00	0.0000000E+00
P(1, 4, 1)	495.0000	0.0000000E+00
P(1, 4, 2)	0.0000000E+00	0.5976554
P(1, 4, 3)	0.0000000E+00	0.5976554
P(1, 4, 4)	0.0000000E+00	0.5976554
P(1, 4, 5)	285.0000	0.0000000E+00
P(1, 4, 6)	3039.000	0.0000000E+00
P(1, 4, 7)	0.0000000E+00	0.5976554
P(1, 4, 8)	0.0000000E+00	0.5976554
P(1, 4, 9)	0.0000000E+00	0.5976554
P(1, 4, 10)	0.0000000E+00	0.5976554
P(1, 4, 11)	0.0000000E+00	0.5976554
P(1, 4, 12)	0.0000000E+00	0.5976554
P(1, 5, 1)	263907.0	0.0000000E+00
P(1, 5, 2)	224906.0	0.0000000E+00
P(1, 5, 3)	236554.0	0.0000000E+00
P(1, 5, 4)	233586.0	0.0000000E+00
P(1, 5, 5)	253584.0	0.0000000E+00
P(1, 5, 6)	230453.0	0.0000000E+00
P(1, 5, 7)	259928.0	0.0000000E+00
P(1, 5, 8)	343119.0	0.0000000E+00
P(1, 5, 9)	322149.0	0.0000000E+00
P(1, 5, 10)	295149.0	0.0000000E+00
P(1, 5, 11)	248304.0	0.0000000E+00
P(1, 5, 12)	311143.0	0.0000000E+00
P(1, 6, 1)	0.0000000E+00	0.0000000E+00
P(1, 6, 2)	0.0000000E+00	0.0000000E+00
P(1, 6, 3)	0.0000000E+00	0.0000000E+00
P(1, 6, 4)	0.0000000E+00	0.0000000E+00
P(1, 6, 5)	0.0000000E+00	0.0000000E+00
P(1, 6, 6)	0.0000000E+00	0.0000000E+00
P(1, 6, 7)	0.0000000E+00	0.0000000E+00
P(1, 6, 8)	0.0000000E+00	0.0000000E+00
P(1, 6, 9)	0.0000000E+00	0.0000000E+00
P(1, 6, 10)	0.0000000E+00	0.0000000E+00
P(1, 6, 11)	0.0000000E+00	0.0000000E+00
P(1, 6, 12)	0.0000000E+00	0.0000000E+00
P(1, 7, 1)	2270.000	0.0000000E+00
P(1, 7, 2)	7389.000	0.0000000E+00
P(1, 7, 3)	20691.00	0.0000000E+00

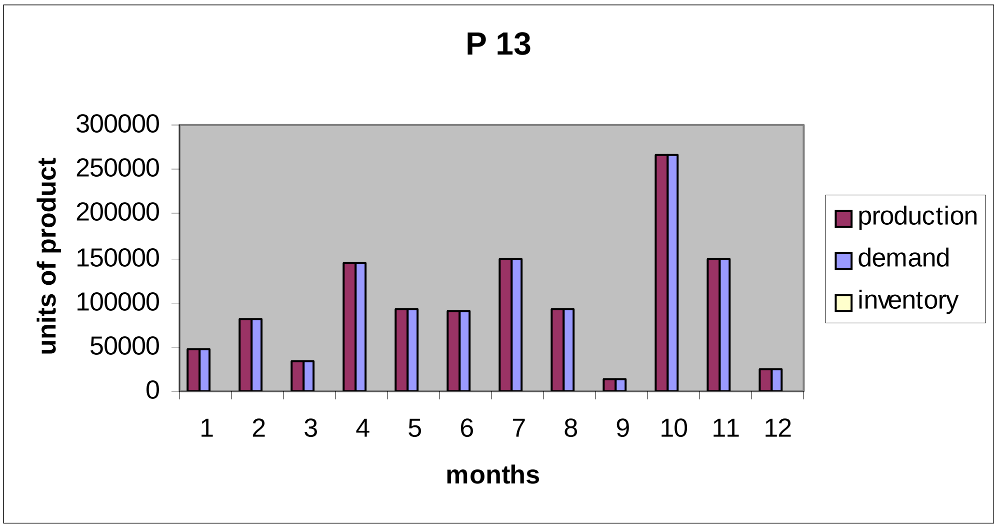
P(1, 7, 4)	0.0000000E+00	0.5622609
P(1, 7, 5)	9348.000	0.0000000E+00
P(1, 7, 6)	3004.000	0.0000000E+00
P(1, 7, 7)	17543.00	0.0000000E+00
P(1, 7, 8)	16216.00	0.0000000E+00
P(1, 7, 9)	23899.00	0.0000000E+00
P(1, 7, 10)	0.0000000E+00	0.0000000E+00
P(1, 7, 11)	4331.000	0.0000000E+00
P(1, 7, 12)	14123.00	0.0000000E+00
P(2, 1, 1)	0.0000000E+00	0.0000000E+00
P(2, 1, 2)	0.0000000E+00	0.0000000E+00
P(2, 1, 3)	0.0000000E+00	0.0000000E+00
P(2, 1, 4)	0.0000000E+00	0.0000000E+00
P(2, 1, 5)	0.0000000E+00	0.0000000E+00
P(2, 1, 6)	0.0000000E+00	0.0000000E+00
P(2, 1, 7)	0.0000000E+00	0.0000000E+00
P(2, 1, 8)	0.0000000E+00	0.0000000E+00
P(2, 1, 9)	0.0000000E+00	0.0000000E+00
P(2, 1, 10)	0.0000000E+00	0.0000000E+00
P(2, 1, 11)	0.0000000E+00	0.0000000E+00
P(2, 1, 12)	0.0000000E+00	0.0000000E+00
P(2, 2, 1)	6417.000	0.0000000E+00
P(2, 2, 2)	0.0000000E+00	0.0000000E+00
P(2, 2, 3)	0.0000000E+00	0.0000000E+00
P(2, 2, 4)	0.0000000E+00	0.0000000E+00
P(2, 2, 5)	583.0000	0.0000000E+00
P(2, 2, 6)	0.0000000E+00	0.0000000E+00
P(2, 2, 7)	0.0000000E+00	0.8988347
P(2, 2, 8)	0.0000000E+00	0.0000000E+00
P(2, 2, 9)	0.0000000E+00	0.0000000E+00
P(2, 2, 10)	0.0000000E+00	0.0000000E+00
P(2, 2, 11)	0.0000000E+00	0.0000000E+00
P(2, 2, 12)	0.0000000E+00	0.0000000E+00
P(2, 3, 1)	0.0000000E+00	0.0000000E+00
P(2, 3, 2)	0.0000000E+00	0.0000000E+00
P(2, 3, 3)	0.0000000E+00	0.0000000E+00
P(2, 3, 4)	0.0000000E+00	0.0000000E+00
P(2, 3, 5)	0.0000000E+00	0.0000000E+00
P(2, 3, 6)	0.0000000E+00	0.0000000E+00
P(2, 3, 7)	0.0000000E+00	0.0000000E+00
P(2, 3, 8)	0.0000000E+00	0.0000000E+00
P(2, 3, 9)	0.0000000E+00	0.0000000E+00
P(2, 3, 10)	0.0000000E+00	0.0000000E+00
P(2, 3, 11)	0.0000000E+00	0.0000000E+00
P(2, 3, 12)	0.0000000E+00	0.0000000E+00
P(2, 4, 1)	145299.0	0.0000000E+00
P(2, 4, 2)	100670.0	0.0000000E+00
P(2, 4, 3)	147159.0	0.0000000E+00
P(2, 4, 4)	111449.0	0.0000000E+00
P(2, 4, 5)	127157.0	0.0000000E+00

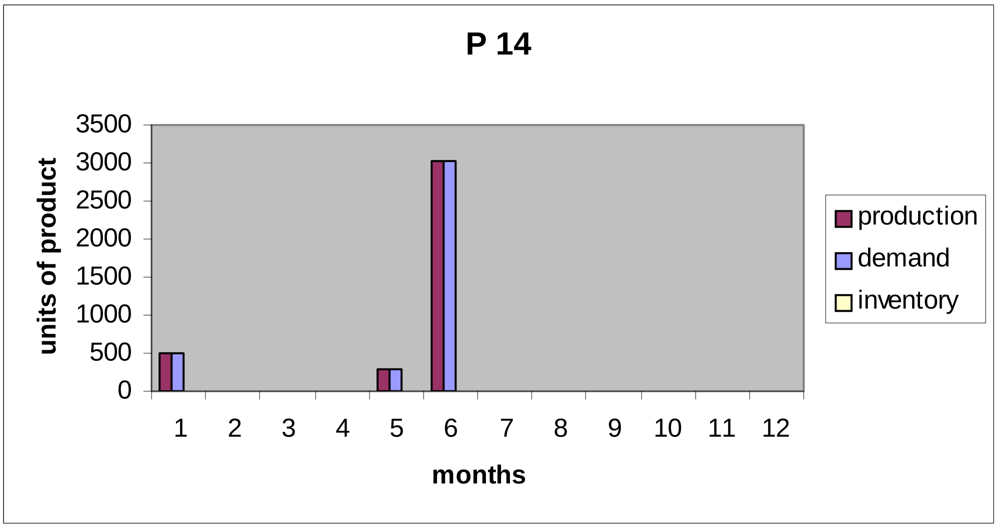
P(2, 4, 6)	124390.0	0.0000000E+00
P(2, 4, 7)	96734.00	0.0000000E+00
P(2, 4, 8)	194325.0	0.0000000E+00
P(2, 4, 9)	113230.0	0.0000000E+00
P(2, 4, 10)	194190.0	0.0000000E+00
P(2, 4, 11)	157070.0	0.0000000E+00
P(2, 4, 12)	95380.00	0.0000000E+00
P(2, 5, 1)	194174.4	0.0000000E+00
P(2, 5, 2)	57361.59	0.0000000E+00
P(2, 5, 3)	269528.4	0.0000000E+00
P(2, 5, 4)	74581.59	0.0000000E+00
P(2, 5, 5)	181549.4	0.0000000E+00
P(2, 5, 6)	57752.59	0.0000000E+00
P(2, 5, 7)	228676.4	0.0000000E+00
P(2, 5, 8)	27477.59	0.0000000E+00
P(2, 5, 9)	189244.4	0.0000000E+00
P(2, 5, 10)	73040.59	0.0000000E+00
P(2, 5, 11)	193829.4	0.0000000E+00
P(2, 5, 12)	64923.59	0.0000000E+00
P(2, 6, 1)	14199.00	0.0000000E+00
P(2, 6, 2)	0.0000000E+00	0.0000000E+00
P(2, 6, 3)	0.0000000E+00	0.0000000E+00
P(2, 6, 4)	0.0000000E+00	0.0000000E+00
P(2, 6, 5)	1810.000	0.0000000E+00
P(2, 6, 6)	0.0000000E+00	0.0000000E+00
P(2, 6, 7)	0.0000000E+00	0.6772109
P(2, 6, 8)	0.0000000E+00	0.0000000E+00
P(2, 6, 9)	0.0000000E+00	0.0000000E+00
P(2, 6, 10)	0.0000000E+00	0.6772109
P(2, 6, 11)	0.0000000E+00	0.0000000E+00
P(2, 6, 12)	6571.000	0.0000000E+00
P(2, 7, 1)	102638.0	0.0000000E+00
P(2, 7, 2)	95521.00	0.0000000E+00
P(2, 7, 3)	65669.00	0.0000000E+00
P(2, 7, 4)	140205.0	0.0000000E+00
P(2, 7, 5)	68705.00	0.0000000E+00
P(2, 7, 6)	161058.0	0.0000000E+00
P(2, 7, 7)	64969.00	0.0000000E+00
P(2, 7, 8)	103331.0	0.0000000E+00
P(2, 7, 9)	28141.00	0.0000000E+00
P(2, 7, 10)	12920.00	0.0000000E+00
P(2, 7, 11)	23138.00	0.0000000E+00
P(2, 7, 12)	22386.00	0.0000000E+00

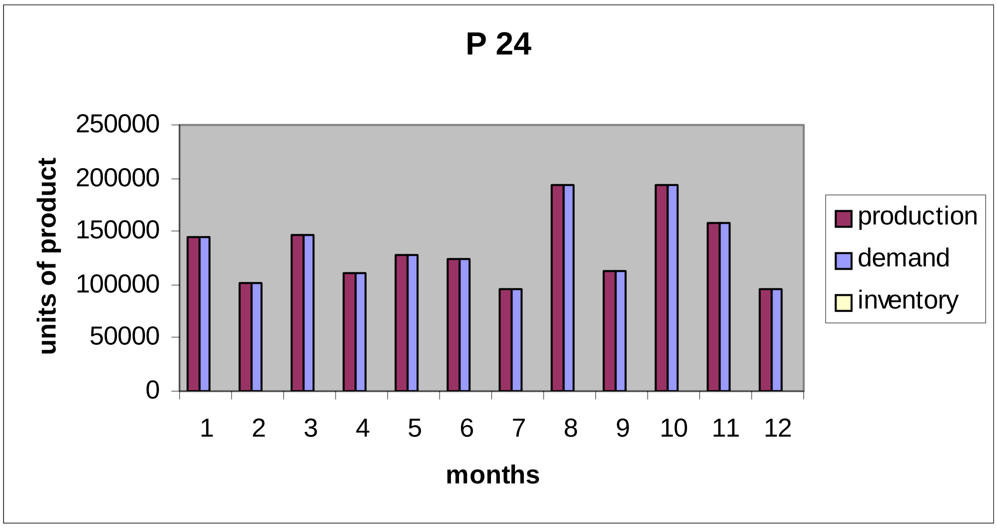
F.3. Production and Inventory Results of Model 4

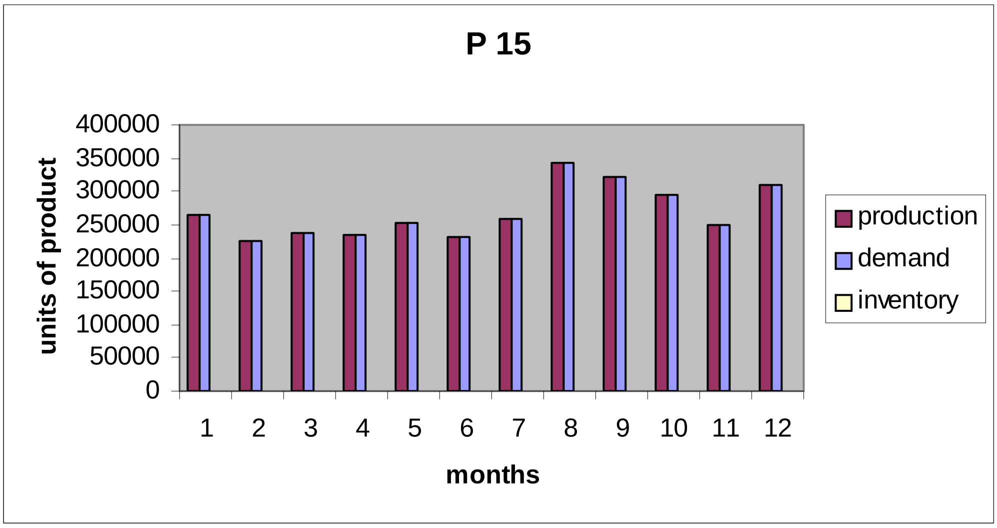


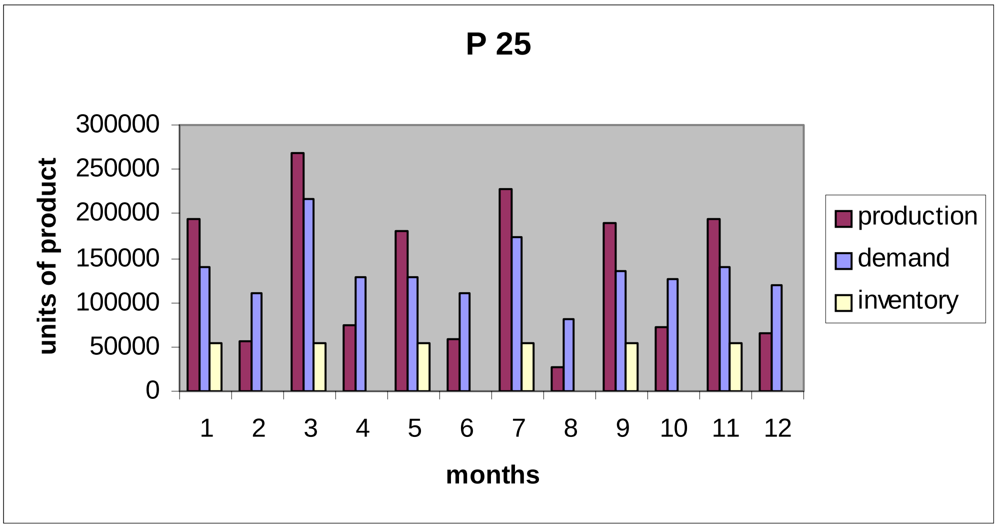


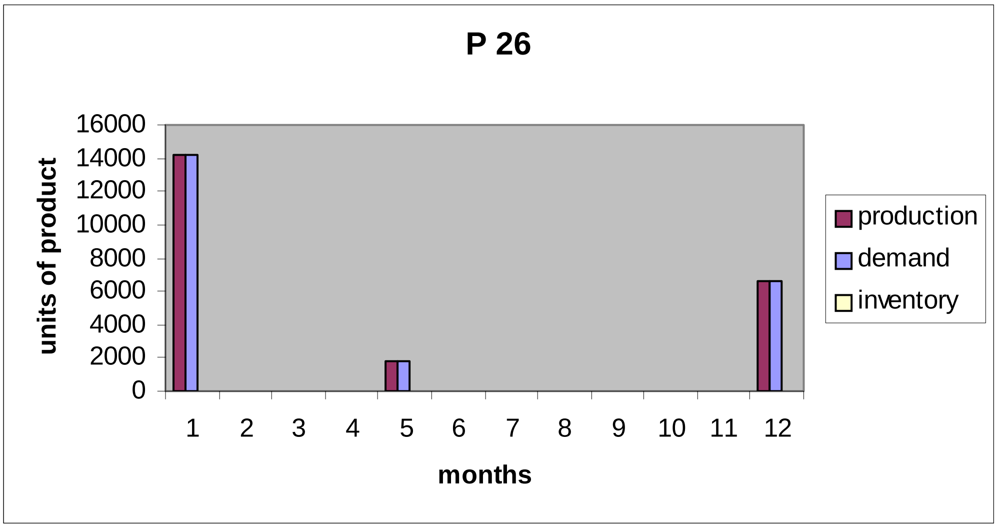


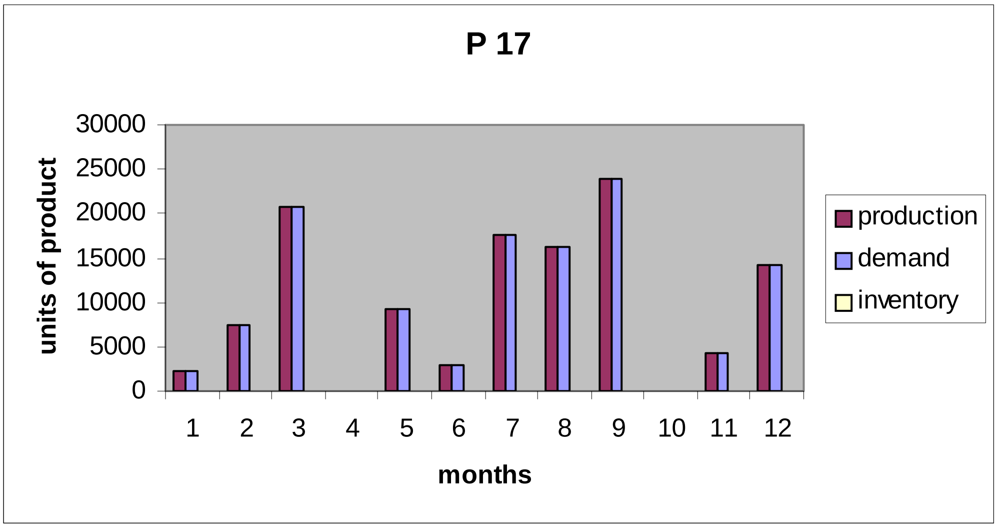

P 14
units of product
3500
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory


P 24
units of product
250000
200000
150000
100000
50000
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory


P 15
units of product
400000
350000
300000
250000
200000
150000
100000
50000
0
1 2 3 4 5 6 7 8 9 10 11 12
months
production
demand
inventory


P 25
units of product
300000
250000
200000
150000
100000
50000
0
1
2
3
4
5
6
7
8
9
10
11
12
months
production
demand
inventory


P 26
units of product
16000
14000
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
months
production
demand
inventory


P 17
units of product
30000
25000
20000
15000
10000
5000
0
1
2
3
4
5
6
7
8
9
10
11
12
months
production
demand
inventory

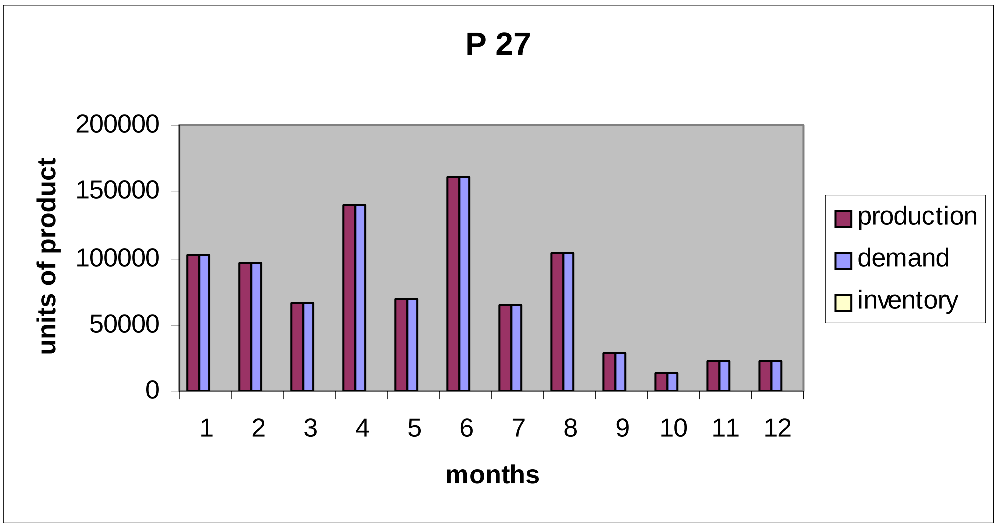


Figure F.1. Production and inventory results of model 4 for each product

F.4. Range Analysis of Model 4

Ranges in which the basis is unchanged:

Objective Coefficient Ranges

Variable	Current Coefficient	Allowable Increase	Allowable Decrease
X(1, 1, 1)	0,8441000	INFINITY	0,0
X(1, 1, 2)	0,8441000	0,0	0,199843E-15
X(1, 1, 3)	0,8441000	0,1998473E-15	0,199843E-15
X(1, 1, 4)	0,8441000	0,1998473E-15	0,0
X(1, 1, 5)	0,8441000	0,0	0,0
X(1, 1, 6)	0,8441000	0,0	0,0
X(1, 1, 7)	0,8441000	INFINITY	0,199843E-15
X(1, 1, 8)	0,8441000	INFINITY	0,0
X(1, 1, 9)	0,8441000	INFINITY	0,0
X(1, 1, 10)	0,8441000	0,0	0,0
X(1, 1, 11)	0,8441000	INFINITY	0,0
X(1, 1, 12)	0,8441000	0,0	INFINITY
X(1, 2, 1)	0,6444000	INFINITY	0,198880E-15
X(1, 2, 2)	0,6444000	INFINITY	0,198880E-15
X(1, 2, 3)	0,6444000	0,0	0,994439E-14
X(1, 2, 4)	0,6444000	INFINITY	0,0
X(1, 2, 5)	0,6444000	INFINITY	0,0
X(1, 2, 6)	0,6444000	INFINITY	0,0
X(1, 2, 7)	0,6444000	INFINITY	0,994439E-14
X(1, 2, 8)	0,6444000	INFINITY	0,0
X(1, 2, 9)	0,6444000	0,0	INFINITY
X(1, 2, 10)	0,6444000	INFINITY	0,0

X(1, 2, 11)	0,6444000	INFINITY	0,0
X(1, 2, 12)	0,6444000	INFINITY	0,0
X(1, 3, 1)	0,5253000	INFINITY	0,0
X(1, 3, 2)	0,5253000	0,0	0,999233E-16
X(1, 3, 3)	0,5253000	INFINITY	0,0
X(1, 3, 4)	0,5253000	INFINITY	0,0
X(1, 3, 5)	0,5253000	0,0	0,0
X(1, 3, 6)	0,5253000	INFINITY	0,0
X(1, 3, 7)	0,5253000	0,0	0,0
X(1, 3, 8)	0,5253000	0,0	0,0
X(1, 3, 9)	0,5253000	INFINITY	0,0
X(1, 3, 10)	0,5253000	0,0	0,0
X(1, 3, 11)	0,5253000	0,0	0,0
X(1, 3, 12)	0,5253000	0,0	0,0
X(1, 4, 1)	0,5166000	0,0	0,994439E-14
X(1, 4, 2)	0,5166000	INFINITY	0,0
X(1, 4, 3)	0,5166000	0,0	0,0
X(1, 4, 4)	0,5166000	0,0	0,0
X(1, 4, 5)	0,5166000	0,0	0,0
X(1, 4, 6)	0,5166000	INFINITY	0,0
X(1, 4, 7)	0,5166000	0,0	0,0
X(1, 4, 8)	0,5166000	INFINITY	0,0
X(1, 4, 9)	0,5166000	0,0	0,0
X(1, 4, 10)	0,5166000	INFINITY	0,0
X(1, 4, 11)	0,5166000	INFINITY	0,0
X(1, 4, 12)	0,5166000	0,0	0,0
X(1, 5, 1)	0,4826000	INFINITY	0,0
X(1, 5, 2)	0,4826000	0,0	0,0
X(1, 5, 3)	0,4826000	0,0	0,918024E-16
X(1, 5, 4)	0,4826000	0,0	0,0
X(1, 5, 5)	0,4826000	0,0	0,0
X(1, 5, 6)	0,4826000	0,0	0,0
X(1, 5, 7)	0,4826000	INFINITY	0,994439E-14
X(1, 5, 8)	0,4826000	0,0	0,0
X(1, 5, 9)	0,4826000	0,0	0,0
X(1, 5, 10)	0,4826000	0,0	0,0
X(1, 5, 11)	0,4826000	0,0	0,0
X(1, 5, 12)	0,4826000	0,0	0,0
X(1, 6, 1)	0,4855000	INFINITY	0,0
X(1, 6, 2)	0,4855000	0,0	0,198880E-15
X(1, 6, 3)	0,4855000	INFINITY	0,0
X(1, 6, 4)	0,4855000	INFINITY	0,0
X(1, 6, 5)	0,4855000	INFINITY	0,0
X(1, 6, 6)	0,4855000	INFINITY	0,0
X(1, 6, 7)	0,4855000	INFINITY	0,994439E-14
X(1, 6, 8)	0,4855000	0,0	INFINITY
X(1, 6, 9)	0,4855000	INFINITY	0,0
X(1, 6, 10)	0,4855000	INFINITY	0,0
X(1, 6, 11)	0,4855000	INFINITY	0,0
X(1, 6, 12)	0,4855000	INFINITY	0,0

X(1, 7, 1)	0,4860000	0,0	0,0
X(1, 7, 2)	0,4860000	0,0	0,0
X(1, 7, 3)	0,4860000	0,0	0,0
X(1, 7, 4)	0,4860000	0,0	0,994439E-14
X(1, 7, 5)	0,4860000	0,0	0,0
X(1, 7, 6)	0,4860000	0,0	0,0
X(1, 7, 7)	0,4860000	INFINITY	0,994439E-14
X(1, 7, 8)	0,4860000	0,0	0,0
X(1, 7, 9)	0,4860000	INFINITY	0,0
X(1, 7, 10)	0,4860000	0,0	0,0
X(1, 7, 11)	0,4860000	INFINITY	0,0
X(1, 7, 12)	0,4860000	INFINITY	0,0
X(2, 1, 1)	0,5196000E-01	INFINITY	0,0
X(2, 1, 2)	0,5196000E-01	0,0	0,199912E-14
X(2, 1, 3)	0,5196000E-01	0,1999112E-14	0,199912E-14
X(2, 1, 4)	0,5196000E-01	0,1999112E-14	0,0
X(2, 1, 5)	0,5196000E-01	0,0	0,0
X(2, 1, 6)	0,5196000E-01	0,0	0,0
X(2, 1, 7)	0,5196000E-01	INFINITY	0,199912E-14
X(2, 1, 8)	0,5196000E-01	INFINITY	0,0
X(2, 1, 9)	0,5196000E-01	INFINITY	0,0
X(2, 1, 10)	0,5196000E-01	0,0	0,0
X(2, 1, 11)	0,5196000E-01	INFINITY	0,0
X(2, 1, 12)	0,5196000E-01	0,0	INFINITY
X(2, 2, 1)	0,3966000E-01	INFINITY	0,198951E-14
X(2, 2, 2)	0,3966000E-01	INFINITY	0,198951E-14
X(2, 2, 3)	0,3966000E-01	0,0	0,994758E-15
X(2, 2, 4)	0,3966000E-01	INFINITY	0,0
X(2, 2, 5)	0,3966000E-01	INFINITY	0,0
X(2, 2, 6)	0,3966000E-01	INFINITY	0,0
X(2, 2, 7)	0,3966000E-01	INFINITY	0,994758E-15
X(2, 2, 8)	0,3966000E-01	INFINITY	0,0
X(2, 2, 9)	0,3966000E-01	0,0	INFINITY
X(2, 2, 10)	0,3966000E-01	INFINITY	0,0
X(2, 2, 11)	0,3966000E-01	INFINITY	0,0
X(2, 2, 12)	0,3966000E-01	INFINITY	0,0
X(2, 3, 1)	0,3233000E-01	INFINITY	0,0
X(2, 3, 2)	0,3233000E-01	0,0	0,0
X(2, 3, 3)	0,3233000E-01	INFINITY	0,994758E-15
X(2, 3, 4)	0,3233000E-01	INFINITY	0,0
X(2, 3, 5)	0,3233000E-01	0,0	0,0
X(2, 3, 6)	0,3233000E-01	INFINITY	0,0
X(2, 3, 7)	0,3233000E-01	0,0	0,0
X(2, 3, 8)	0,3233000E-01	0,0	0,0
X(2, 3, 9)	0,3233000E-01	INFINITY	0,0
X(2, 3, 10)	0,3233000E-01	0,0	0,0
X(2, 3, 11)	0,3233000E-01	0,0	0,0
X(2, 3, 12)	0,3233000E-01	0,0	0,0
X(2, 4, 1)	0,3180000E-01	0,0	0,994758E-15
X(2, 4, 2)	0,3180000E-01	INFINITY	0,0

X(2, 4, 3)	0,3180000E-01	0,0	0,0
X(2, 4, 4)	0,3180000E-01	0,0	0,0
X(2, 4, 5)	0,3180000E-01	0,0	0,0
X(2, 4, 6)	0,3180000E-01	INFINITY	0,0
X(2, 4, 7)	0,3180000E-01	0,0	0,0
X(2, 4, 8)	0,3180000E-01	INFINITY	0,0
X(2, 4, 9)	0,3180000E-01	0,0	0,0
X(2, 4, 10)	0,3180000E-01	INFINITY	0,0
X(2, 4, 11)	0,3180000E-01	INFINITY	0,0
X(2, 4, 12)	0,3180000E-01	0,0	0,0
X(2, 5, 1)	0,2970000E-01	INFINITY	0,0
X(2, 5, 2)	0,2970000E-01	0,0	0,0
X(2, 5, 3)	0,2970000E-01	0,0	0,918318E-15
X(2, 5, 4)	0,2970000E-01	0,0	0,0
X(2, 5, 5)	0,2970000E-01	0,0	0,0
X(2, 5, 6)	0,2970000E-01	0,0	0,0
X(2, 5, 7)	0,2970000E-01	INFINITY	0,994758E-15
X(2, 5, 8)	0,2970000E-01	0,0	0,0
X(2, 5, 9)	0,2970000E-01	0,0	0,0
X(2, 5, 10)	0,2970000E-01	0,0	0,0
X(2, 5, 11)	0,2970000E-01	0,0	0,0
X(2, 5, 12)	0,2970000E-01	0,0	0,0
X(2, 6, 1)	0,2989000E-01	INFINITY	0,0
X(2, 6, 2)	0,2989000E-01	0,0	0,198956E-14
X(2, 6, 3)	0,2989000E-01	INFINITY	0,0
X(2, 6, 4)	0,2989000E-01	INFINITY	0,0
X(2, 6, 5)	0,2989000E-01	INFINITY	0,0
X(2, 6, 6)	0,2989000E-01	INFINITY	0,0
X(2, 6, 7)	0,2989000E-01	INFINITY	0,994758E-15
X(2, 6, 8)	0,2989000E-01	0,0	INFINITY
X(2, 6, 9)	0,2989000E-01	INFINITY	0,0
X(2, 6, 10)	0,2989000E-01	INFINITY	0,0
X(2, 6, 11)	0,2989000E-01	INFINITY	0,0
X(2, 6, 12)	0,2989000E-01	INFINITY	0,0
X(2, 7, 1)	0,2992000E-01	0,0	0,0
X(2, 7, 2)	0,2992000E-01	0,0	0,0
X(2, 7, 3)	0,2992000E-01	0,0	0,994758E-15
X(2, 7, 4)	0,2992000E-01	0,0	0,0
X(2, 7, 5)	0,2992000E-01	0,0	0,0
X(2, 7, 6)	0,2992000E-01	0,0	0,0
X(2, 7, 7)	0,2992000E-01	INFINITY	0,994758E-15
X(2, 7, 8)	0,2992000E-01	0,0	0,0
X(2, 7, 9)	0,2992000E-01	INFINITY	0,0
X(2, 7, 10)	0,2992000E-01	0,0	0,0
X(2, 7, 11)	0,2992000E-01	INFINITY	0,0
X(2, 7, 12)	0,2992000E-01	INFINITY	0,0
X(3, 1, 1)	0,3023000E-01	INFINITY	0,302300E-01
X(3, 1, 2)	0,3023000E-01	0,0	INFINITY
X(3, 1, 3)	0,3023000E-01	INFINITY	0,0
X(3, 1, 4)	0,3023000E-01	INFINITY	0,8968569

X(3, 1, 5)	0,3023000E-01	0,8968569	INFINITY
X(3, 1, 6)	0,3023000E-01	INFINITY	0,8968569
X(3, 1, 7)	0,3023000E-01	INFINITY	0,302300E-01
X(3, 1, 8)	0,3023000E-01	INFINITY	0,8968569
X(3, 1, 9)	0,3023000E-01	0,8968569	INFINITY
X(3, 1, 10)	0,3023000E-01	INFINITY	0,302300E-01
X(3, 1, 11)	0,3023000E-01	0,8968569	INFINITY
X(3, 1, 12)	0,3023000E-01	INFINITY	0,8968569
X(3, 2, 1)	0,2308000E-01	INFINITY	0,8215274
X(3, 2, 2)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 3)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 4)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 5)	0,2308000E-01	INFINITY	0,8215274
X(3, 2, 6)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 7)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 8)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 9)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 10)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 11)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 2, 12)	0,2308000E-01	INFINITY	0,230800E-01
X(3, 3, 1)	0,1881000E-01	0,0	INFINITY
X(3, 3, 2)	0,1881000E-01	INFINITY	0,0
X(3, 3, 3)	0,1881000E-01	0,0	INFINITY
X(3, 3, 4)	0,1881000E-01	INFINITY	0,0
X(3, 3, 5)	0,1881000E-01	0,0	INFINITY
X(3, 3, 6)	0,1881000E-01	INFINITY	0,0
X(3, 3, 7)	0,1881000E-01	0,0	INFINITY
X(3, 3, 8)	0,1881000E-01	INFINITY	0,0
X(3, 3, 9)	0,1881000E-01	0,0	INFINITY
X(3, 3, 10)	0,1881000E-01	INFINITY	0,0
X(3, 3, 11)	0,1881000E-01	0,0	INFINITY
X(3, 3, 12)	0,1881000E-01	INFINITY	0,0
X(3, 4, 1)	0,1850000E-01	0,0	0,0
X(3, 4, 2)	0,1850000E-01	0,0	0,0
X(3, 4, 3)	0,1850000E-01	0,0	0,0
X(3, 4, 4)	0,1850000E-01	0,0	0,0
X(3, 4, 5)	0,1850000E-01	0,0	0,0
X(3, 4, 6)	0,1850000E-01	0,0	0,0
X(3, 4, 7)	0,1850000E-01	0,0	0,0
X(3, 4, 8)	0,1850000E-01	0,0	0,0
X(3, 4, 9)	0,1850000E-01	0,0	0,0
X(3, 4, 10)	0,1850000E-01	0,0	0,0
X(3, 4, 11)	0,1850000E-01	0,0	0,0
X(3, 4, 12)	0,1850000E-01	0,0	0,0
X(3, 5, 1)	0,1728000E-01	INFINITY	0,0
X(3, 5, 2)	0,1728000E-01	0,0	INFINITY
X(3, 5, 3)	0,1728000E-01	INFINITY	0,0
X(3, 5, 4)	0,1728000E-01	0,0	INFINITY
X(3, 5, 5)	0,1728000E-01	INFINITY	0,0
X(3, 5, 6)	0,1728000E-01	0,0	INFINITY

X(3, 5, 7)	0,1728000E-01	INFINITY	0,0
X(3, 5, 8)	0,1728000E-01	0,0	INFINITY
X(3, 5, 9)	0,1728000E-01	INFINITY	0,0
X(3, 5, 10)	0,1728000E-01	0,0	INFINITY
X(3, 5, 11)	0,1728000E-01	INFINITY	0,0
X(3, 5, 12)	0,1728000E-01	0,0	INFINITY
X(3, 6, 1)	0,1739000E-01	INFINITY	0,6189651
X(3, 6, 2)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 3)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 4)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 5)	0,1739000E-01	INFINITY	0,6189651
X(3, 6, 6)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 7)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 8)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 9)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 10)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 11)	0,1739000E-01	INFINITY	0,173900E-01
X(3, 6, 12)	0,1739000E-01	INFINITY	0,6189651
X(3, 7, 1)	0,1741000E-01	0,0	0,0
X(3, 7, 2)	0,1741000E-01	0,0	0,0
X(3, 7, 3)	0,1741000E-01	0,0	0,0
X(3, 7, 4)	0,1741000E-01	0,0	0,0
X(3, 7, 5)	0,1741000E-01	0,0	0,0
X(3, 7, 6)	0,1741000E-01	0,0	0,0
X(3, 7, 7)	0,1741000E-01	0,0	0,0
X(3, 7, 8)	0,1741000E-01	0,0	0,0
X(3, 7, 9)	0,1741000E-01	0,0	0,0
X(3, 7, 10)	0,1741000E-01	0,0	0,0
X(3, 7, 11)	0,1741000E-01	0,0	0,0
X(3, 7, 12)	0,1741000E-01	0,0	0,0
X(4, 2, 1)	0,1167000	INFINITY	0,8945202
X(4, 2, 2)	0,1167000	INFINITY	0,1167000
X(4, 2, 3)	0,1167000	INFINITY	0,1167000
X(4, 2, 4)	0,1167000	INFINITY	0,1167000
X(4, 2, 5)	0,1167000	INFINITY	0,8945202
X(4, 2, 6)	0,1167000	INFINITY	0,1167000
X(4, 2, 7)	0,1167000	INFINITY	0,1167000
X(4, 2, 8)	0,1167000	INFINITY	0,1167000
X(4, 2, 9)	0,1167000	INFINITY	0,1167000
X(4, 2, 10)	0,1167000	INFINITY	0,1167000
X(4, 2, 11)	0,1167000	INFINITY	0,1167000
X(4, 2, 12)	0,1167000	INFINITY	0,1167000
X(4, 4, 1)	0,9358000E-01	0,0	0,0
X(4, 4, 2)	0,9358000E-01	0,0	0,0
X(4, 4, 3)	0,9358000E-01	0,0	0,0
X(4, 4, 4)	0,9358000E-01	0,0	0,0
X(4, 4, 5)	0,9358000E-01	0,0	0,0
X(4, 4, 6)	0,9358000E-01	0,0	0,0
X(4, 4, 7)	0,9358000E-01	0,0	0,0
X(4, 4, 8)	0,9358000E-01	0,0	0,0

X(4, 4, 9)	0,9358000E-01	0,0	0,0
X(4, 4, 10)	0,9358000E-01	0,0	0,0
X(4, 4, 11)	0,9358000E-01	0,0	0,0
X(4, 4, 12)	0,9358000E-01	0,0	0,0
X(4, 5, 1)	0,8741000E-01	INFINITY	0,0
X(4, 5, 2)	0,8741000E-01	0,0	INFINITY
X(4, 5, 3)	0,8741000E-01	INFINITY	0,0
X(4, 5, 4)	0,8741000E-01	0,0	INFINITY
X(4, 5, 5)	0,8741000E-01	INFINITY	0,0
X(4, 5, 6)	0,8741000E-01	0,0	INFINITY
X(4, 5, 7)	0,8741000E-01	INFINITY	0,0
X(4, 5, 8)	0,8741000E-01	0,0	INFINITY
X(4, 5, 9)	0,8741000E-01	INFINITY	0,0
X(4, 5, 10)	0,8741000E-01	0,0	INFINITY
X(4, 5, 11)	0,8741000E-01	INFINITY	0,0
X(4, 5, 12)	0,8741000E-01	0,0	INFINITY
X(4, 6, 1)	0,8794000E-01	INFINITY	0,6739603
X(4, 6, 2)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 3)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 4)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 5)	0,8794000E-01	INFINITY	0,6739603
X(4, 6, 6)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 7)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 8)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 9)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 10)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 11)	0,8794000E-01	INFINITY	0,879400E-01
X(4, 6, 12)	0,8794000E-01	INFINITY	0,6739603
X(4, 7, 1)	0,8804000E-01	0,0	0,0
X(4, 7, 2)	0,8804000E-01	0,0	0,0
X(4, 7, 3)	0,8804000E-01	0,0	0,0
X(4, 7, 4)	0,8804000E-01	0,0	0,0
X(4, 7, 5)	0,8804000E-01	0,0	0,0
X(4, 7, 6)	0,8804000E-01	0,0	0,0
X(4, 7, 7)	0,8804000E-01	0,0	0,0
X(4, 7, 8)	0,8804000E-01	0,0	0,0
X(4, 7, 9)	0,8804000E-01	0,0	0,0
X(4, 7, 10)	0,8804000E-01	0,0	0,0
X(4, 7, 11)	0,8804000E-01	0,0	0,0
X(4, 7, 12)	0,8804000E-01	0,0	0,0
X(5, 2, 1)	0,3231000E-01	INFINITY	0,8945202
X(5, 2, 2)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 3)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 4)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 5)	0,3231000E-01	INFINITY	0,8945202
X(5, 2, 6)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 7)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 8)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 9)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 10)	0,3231000E-01	INFINITY	0,323100E-01

X(5, 2, 11)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 2, 12)	0,3231000E-01	INFINITY	0,323100E-01
X(5, 4, 1)	0,2591000E-01	0,0	0,0
X(5, 4, 2)	0,2591000E-01	0,0	0,0
X(5, 4, 3)	0,2591000E-01	0,0	0,0
X(5, 4, 4)	0,2591000E-01	0,0	0,0
X(5, 4, 5)	0,2591000E-01	0,0	0,0
X(5, 4, 6)	0,2591000E-01	0,0	0,0
X(5, 4, 7)	0,2591000E-01	0,0	0,0
X(5, 4, 8)	0,2591000E-01	0,0	0,0
X(5, 4, 9)	0,2591000E-01	0,0	0,0
X(5, 4, 10)	0,2591000E-01	0,0	0,0
X(5, 4, 11)	0,2591000E-01	0,0	0,0
X(5, 4, 12)	0,2591000E-01	0,0	0,0
X(5, 5, 1)	0,2420000E-01	INFINITY	0,0
X(5, 5, 2)	0,2420000E-01	0,0	INFINITY
X(5, 5, 3)	0,2420000E-01	INFINITY	0,0
X(5, 5, 4)	0,2420000E-01	0,0	INFINITY
X(5, 5, 5)	0,2420000E-01	INFINITY	0,0
X(5, 5, 6)	0,2420000E-01	0,0	INFINITY
X(5, 5, 7)	0,2420000E-01	INFINITY	0,0
X(5, 5, 8)	0,2420000E-01	0,0	INFINITY
X(5, 5, 9)	0,2420000E-01	INFINITY	0,0
X(5, 5, 10)	0,2420000E-01	0,0	INFINITY
X(5, 5, 11)	0,2420000E-01	INFINITY	0,0
X(5, 5, 12)	0,2420000E-01	0,0	INFINITY
X(5, 6, 1)	0,2434000E-01	INFINITY	0,6739603
X(5, 6, 2)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 3)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 4)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 5)	0,2434000E-01	INFINITY	0,6739603
X(5, 6, 6)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 7)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 8)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 9)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 10)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 11)	0,2434000E-01	INFINITY	0,243400E-01
X(5, 6, 12)	0,2434000E-01	INFINITY	0,6739603
X(5, 7, 1)	0,2437000E-01	INFINITY	0,0
X(5, 7, 2)	0,2437000E-01	0,0	0,0
X(5, 7, 3)	0,2437000E-01	0,0	0,0
X(5, 7, 4)	0,2437000E-01	0,0	0,0
X(5, 7, 5)	0,2437000E-01	0,0	0,0
X(5, 7, 6)	0,2437000E-01	0,0	0,0
X(5, 7, 7)	0,2437000E-01	0,0	0,0
X(5, 7, 8)	0,2437000E-01	0,0	0,0
X(5, 7, 9)	0,2437000E-01	0,0	0,0
X(5, 7, 10)	0,2437000E-01	0,0	0,0
X(5, 7, 11)	0,2437000E-01	0,0	0,0
X(5, 7, 12)	0,2437000E-01	0,0	0,0