SUPPLIER SELECTION PROBLEM
- AN APPLICATION OF GOAL PROGRAMMING IN A FIRM -

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by

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İZMİR

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ABSTRACT

Companies often rely on outside suppliers for many of their components and materials. In a competitive market there are many suppliers available for these inputs of the firm. The question of 'who to buy from and how much' is simply the supplier selection problem that every firm faces. In this problem, there is more than one concern that the decision maker needs to deal with. Some of these concerns are the quality, lead-time and price aspects of the parts to be purchased. Also, there can be other concerns depending on the firms strategies.

As can be seen, supplier selection problem is a multiple-objective problem in nature and hence need careful analysis. This thesis presents a goal programming approach to solve the supplier selection problem of a company operating in textile industry in Turkey, Sun Tekstil.

Sun Tekstil faces supplier selection in two different activities of the firm. One is materials' purchasing and the other is outsourcing. These two problems are handled separately in this study. The proposed approach determines the companies' objectives and assigns their relative importances. Weighted goal programming approach is used to develop mathematical models concerning firm's objectives and their relative importance weights. Four alternative models are developed. First two models have no restrictions on the number of suppliers selected for each item where the last two restricts the number by two suppliers. Also, two of these models use the weights assigned by analytic hierarchy process and the other two use the weights determined by firm's managers subjectively. All models are solved by the Lingo Optimization Software to give the selected suppliers and the quantities to be ordered from them.

In the result, the operating system in Sun Tekstil is compared with the solutions of the models in terms of the objectives determined at the beginning.

ÖZET

Firmalar pek çok malzeme için dış tedarikçilere başvururlar. Rekabetçi piyasa koşullarında her malzeme için birden fazla tedarikçi bulunabilir. 'Hangi tedarikçiden ve ne kadar' alınacağı sorusu kısaca tüm firmaların karşılaştığı tedarikçi seçimi problemidir. Bu problemde karar vericinin karşısına birden fazla sorun çıkar. Bulardan bazıları satın alınacak malzemelerin kalitesi, fiyatları ve ulaştırma süresidir. Bunların dışında firma stratejilerine göre başka amaçlar da olabilir.

Görüldüğü gibi, tedarikçi seçimi projesi çok hedefli bir problemdir ve dikkatli analiz edilmesi gerekir. Bu çalışma Türkiye'de tekstil sektöründe faaliyet gösteren Sun Tekstil'in tedarikçi seçimi projesini incelemektedir.

Sun Tekstil iki ayrı bölümünde tedarikçi seçimiyle karşı karşıya gelmektedir. Birincisi malzeme satınalmasında, ikincisi ise fason üretiminde. Bu iki problem bu tezde ayrı ayrı ele alınmıştır. Önerilen yöntem ilk olarak firmanın amaçlarını belirler ve bunların birbirlerine göre önemlerini saptar. Bu amaçları ve önem derecelerini göz önünde tutan matematiksel modeller ağırlıklı hedef programlama yaklaşımı ile oluşturulmuştur. Dört farklı model kurulmuştur. İlk iki modelde malzemeler için seçilen tedarikçi sayısı sınırlandırılmamıştır, diğer iki modelde ise her malzeme için yalnızca iki tedarikçi seçilmiştir. Ayrıca modellerden ikisi analitik hiyerarşi yöntemi ile belirlenen ağırlıkları kullanmış, diğer ikisi ise firma yöneticilerinin öznel görüşlerine göre belirledikleri ağırlıkları kullanmıştır. Matematiksel modeller, Lingo Optimizasyon Yazılımı ile çözülmüştür. Çözümler seçilen tedarikçileri ve bunlara atanan miktarları verir.

Sonuçlar, Sun Tekstil'in şu andaki sistemiyle başta belirlenen amaçlar doğrultusunda karşılaştırılmıştır.

CONTENTS

CHAPTER FOUR

SUPPLIER SELECTION APPLICATION IN SUN TEKSTİL

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER ONE
INTRODUCTION

1.1 Supplier Selection And Goal Programming

Decision making is not a straight forward approach most of the time. It is rather a complicated process because in many cases, the alternatives conflict with each other. There exist trade-offs among them. Choosing one of the alternatives may provide benefits to the decision maker in a certain area but take away other benefits in another area. In other words the decision maker has more than one objective and most of the time these objectives are conflicting.

This problem is simply called multi-objective decision making problem. One example to this kind of problem could be supplier selection problem. The purchasing activities of a company constitute a very important part in the overall operation of the company. The quality and the delivery capabilities of any manufacturing firm depend heavily on the performance of its suppliers. (Watts et al., 1995)

In addition, a large amount of the product's total cost is made up of the purchasing cost of its materials. Therefore effective purchasing is of crucial importance and can bring competitive advantages to the firm.

In supplier selection problems, the conflicting objectives are often quality, lead-time and cost. A supplier which provides highest quality or shortest lead-time may have the highest costs. In addition, a supplier with a shorter lead-time may supply materials of lower quality. In these circumstances, before making a decision of which suppliers to chose, all suppliers should be carefully analyzed in terms of the

company's needs and strategies. This is the reason why each supplier selection problem is unique.

In order to solve supplier selection problems, goal programming (GP) can be used like in many other multi-objective decision making problems. The advantage of GP over other multi-objective programming techniques is that it only tries to reach the target values that are satisfactory for the decision maker. Other techniques try to chose the best solution among a large number of efficient solutions. Therefore GP is a more effective method compared to other traditional multi-objective programming techniques. (Cabarello et al., 1996)

GP considers many objectives at the same time and tries to work them out together. That is GP sets acceptable levels for all goals and tries to satisfy these levels. If one or more objectives does not reach the target levels, then the deviations from these target levels are tried to be minimized. At this point, the decision maker should be able to clarify which goals are more important.

GP offers two different approaches. If the goals are can be listed in the order of importance, then preemptive GP is a suitable method to solve the problem. In preemptive GP, the highest priority goal is first satisfied. Then the second goal is tried to be satisfied while maintaining the first one and the procedure goes on in the same manner.

On the other hand, if the relative importance of the goals can be found, then weighted GP can be used. In weighted GP, all goals are expressed in the same objective function with their weights computed. Hence, only one mathematical model is solved.

1.2 Aim Of The Thesis

The purpose of this study is to solve the supplier selection problem of Sun Tekstil, which is a company operating in textile industry. In this problem, there is more than one objective to be met. Therefore GP, which is a multi-objective programming

technique, is decided to be used to handle the problem. The details of GP is discussed in chapter 2. Different approaches and applications of GP are explained in this chapter. Chapter 3 explains supplier selection problems and solution processes. A literature survey in this area is also given in chapter 3. In chapter 4, the proposed approach to supplier selection problem of Sun Tekstil is explained. Finally, chapter 5 gives the results obtained and recommendations about the study.

In Sun Tekstil, there are two different purchasing problems. The first one is for the materials. Four main goals are determined and their relative importance are calculated by analytic hierarchy process. All suppliers are analyzed in terms of these goals. The mathematical model developed selects the best suppliers and simultaneously allocates the quantities to be ordered to them.

Some of the finished products are outsourced by Sun Tekstil. The second purchasing problem exists in outsourcing. The methodology followed for this problem is similar to the previous one. In this case, nine goals are determined. All alternative suppliers for outsourcing are studied and a mathematical model is developed using the weighted GP approach. In the end, best suppliers are chosen and the quantities to be ordered from them are found by the model.

CHAPTER 2
GOAL PROGRAMMING

2.1 Introduction To Goal Programming

In real life organizations, decision makers often face problems where they have to deal with many conflicting objectives. In these cases, the decision maker needs a multiple-objective programming technique. This is where goal programming enters the stage.

Goal programming (GP) was first introduced by Charnes and Cooper in 1961. In 1965 Ijiri used 'a generalized inverse technique' and in 1968 Cantini brought together uncertainty conditions and goal programming. In the following years, Lee and Jaaskelainen applied goal programming in many different areas such as hospital administration, media solutions, production planning etc. (Wu & Coppins 1981)

The major reasoning behind goal programming is that it realizes many objectives at the same time and tries to work them out together. Most of the time, all of the objectives cannot be satisfied together. Even trying to increase/decrease one of them may do an inverse effect on the other. In this case objectives are given priorities by the decision maker. The highest priority represents the most important objective of the manager and the other objectives are listed accordingly. Goal programming tries to achieve all the objectives taking into account their priorities.

2.2 Mathematical Models Of Goal Programming

The need for a GP model arises from a linear programming model which has no feasible solution. When some constraints in a linear programming model (LP) cannot be satisfied, two different approaches can be used. One is to release the constraints, getting away from the target values, until feasibility is reached. The second

alternative is to set different levels of values by trial and error to get feasible solutions which is not an efficient way at all. What is more logical and faster is to start a GP model.

In a GP model, constraints are turned into goals and the objective is to minimize both the positive and negative deviations from the goals. This can simply be represented mathematically as follows:

$$\text{Minimize} \quad z = \sum_{i=1}^{n} (u_i + v_i)$$

$$\text{Subject to} \quad \sum_{j=1}^{m} a_{ij} x_j + u_i - v_i = b_i \qquad \forall i=1..n \qquad (1)$$

$$\text{All variables} \geq 0$$

where

z : Objective function

u_i : Negative deviation from the goal

v_i : Positive deviation from the goal

m : Number of decision variables

n : Number of goals

a_{ij} : Technological coefficient of the j^{th} decision variable x_j in goal i

b_i : Target level of i^{th} goal

In this formulation, only the goal constraints are shown. These constraints are also called soft constraints. Number of products to be produced, the desired profit etc. can be examples of this type of constraints. Deviations from the target values may occur and they are reflected to the objective function.

In addition to this formulation are the system constraints also called the hard constraints. These are not shown in (1). They are the constraints that cannot be violated and have to be settled before the goal constraints. Time and manpower capacities are examples of system constraints.

Also there is another assumption made in (1). That is all the positive and negative deviations from the target values are considered in the objective function and penalized equally. However, in real life cases the situation is more complex. Sometimes, only the positive or the negative deviations may be desirable alone. Table 2.1 below shows the different types of goal constraints.

Table 2.1 Types of goal constraints (Schniederjans,1984,p.70)

Goal Constraint	Deviational Variable in Objective Function	Possible Deviation	Unrestricted Deviation	Desired Usage of Right-Hand-Side Value
$a_{ij} x_j + u_i = b_i$	u_i	Negative	None	Equal to b_i
$a_{ij} x_j - v_i = b_i$	v_i	Positive	None	Equal to b_i
$a_{ij} x_j + u_i - v_i = b_i$	u_i	Negative and Positive	Positive	b_i or more
$a_{ij} x_j + u_i - v_i = b_i$	v_i	Negative and Positive	Negative	b_i or less
$a_{ij} x_j + u_i - v_i = b_i$	u_i and v_i	Negative and Positive	None	Equal to b_i
$a_{ij} x_j = b_i$	None	None	None	Exactly b_i

Also, some of the goals may be more important compared to the others. Their penalties may be different or organizations may choose to set priorities to these goals according to their specific needs. Therefore different approaches exist in goal programming to deal with different situations. These approaches are non-preemptive (weighted) goal programming and preemptive goal programming.

2.3 Non-preemptive Goal Programming

In non-preemptive (weighted) goal programming model, weights are assigned to the deviations from the target values. By this way the relative importance of the goals are identified. The mathematical model becomes

$$\text{Minimize} \quad z = \sum_{i=1}^{n} (c_{1i} u_i + c_{2i} v_i)$$

$$\text{Subject to} \quad \sum_{j=1}^{m} a_{ij} x_j + u_i - v_i = b_i \qquad \forall i=1..n \qquad (2)$$

$$\text{All variables} \geq 0$$

where

c_{1i} : Numerical coefficient assigned to negative deviations

c_{2i} : Numerical coefficient assigned to positive deviations

AHP is an effective way to calculate the weights of the objectives in non-preemptive goal programming. Though non-preemptive GP has still one major disadvantage. That is the solution might not meet any of the goals totally. The goals may be overachieved or underachieved according to their weights. But, in certain situations an approach which will satisfy the goals totally in the order of priority may be necessary. This approach is called Preemptive Goal Programming.

2.4 Preemptive Goal Programming

In this approach also known as lexicographic GP, priorities are assigned to each of the goal defined. The most desirable objective of the organization is given the highest priority (P_1), and the least desirable objective is given the smallest priority (P_n).

The goals are worked in the order of priority and satisfied fully without disturbing the previous goals.

This procedure can be implemented by setting up a separate objective function for each priority. Then each of the linear programming models are solved sequentially. (Winston, 1993)

To clarify preemptive GP, formulation 3 will be considered where there are n goals and only negative deviational variables.

$$\text{Minimize} \quad z = \sum_{i=1}^{n} P_i u_i$$

$$\text{Subject to} \quad \sum_{j=1}^{m} a_{ij} x_j + u_i = b_i \qquad \forall i=1..n \qquad (3)$$

$$\text{All variables} \geq 0$$

where

P_i : The priority of the i^{th} goal.

Let these goals be represented by A_1 to A_n from the most desirable to the least respectively. Table 2.2 below shows the goals and their priorities. The smaller the priority (mathematically), the more important the goal. Therefore:

$P_1 < P_2 < P_3 <.....< P_n \Rightarrow A_1 > A_2 > A_3 >.....> A_n$

Table 2.2 Goal - priority notation

Goal	Priority
A_1	P_1
A_2	P_2
A_3	P_3
.....	.....
A_n	P_n

In the solution procedure, goal A_1 is handled first and the linear programming model below is solved.

$$\text{Minimize} \quad z = P_1 u_1$$

$$\text{Subject to} \quad \sum_{j=1}^{m} a_{ij} x_j + u_i = b_i \qquad \forall i=1..n \qquad (4)$$

$$\text{All variables} \geq 0$$

When model 4 is solved, u_1 takes a certain value, say K_1(constant). In the second step of the procedure, A_2 is handled alone but taking into account the value of u_1. That is:

$$\text{Minimize} \quad z = P_2 u_2$$

$$\text{Subject to} \quad u_1 = K_1$$

$$\sum_{j=1}^{m} a_{ij} x_j + u_i = b_i \qquad \forall i=1..n \qquad (5)$$

$$\text{All variables} \geq 0$$

By this way the second goal is tried to be satisfied without disturbing the first. The procedure goes on like this until all the goals are worked. The solution of the last LP model will be the solution of the whole approach.

Graphical Approach To Preemptive GP

In order to explain preemptive GP graphically, a model with two decision variables (x_1,x_2), and two goals (A_1,A_2) is handled. As explained before there are two types of constraints in a GP model. The system constraints which cannot be violated are graphed first. Figure 2.1 shows the feasible region shaded (Region AOCB)

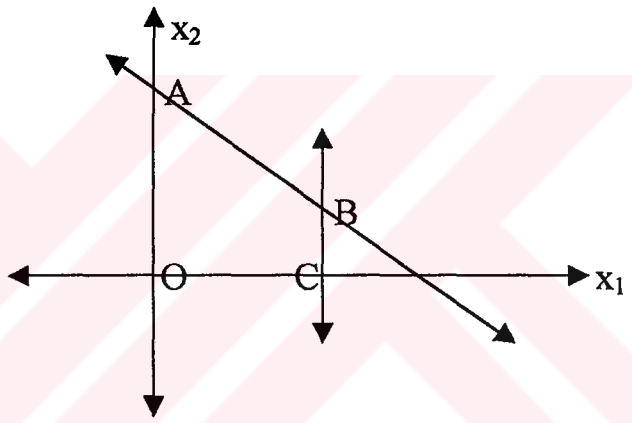

Figure 2.1 The two system constraints are drawn on the graph.

To this figure the goal constraints are added n order of priority. The highest priority goal A_1 is added first. In figure 2.2, to the right of line ED v_1 (the positive deviation) is positive and u_1 (negative deviation) is 0. To the left of ED, v_1 is 0 and u_1 is positive. Since, in this case, u_1 is trying to be minimized, the feasible region is narrowed down to EDBC.

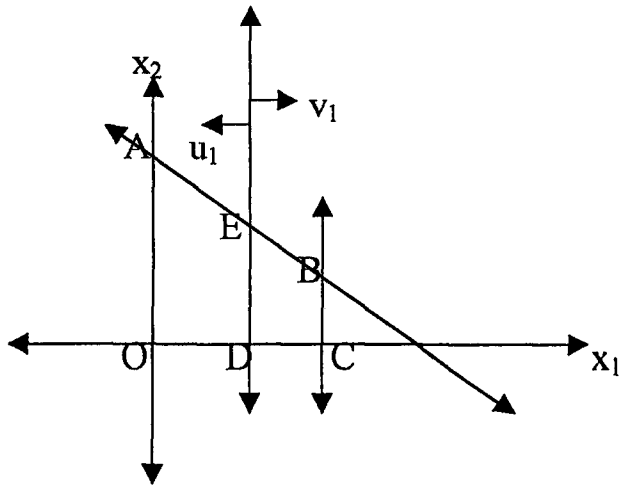

Figure 2.2 Goal A_1 is added to the graph. (Line ED)

In the last step, goal A_2 is added to the graph as shown in figure 2.3.To the bottom of line *k*, u_2 is positive. There are no points that satisfy the second goal without disturbing the first. Therefore a parallel line to *k* which hits the feasible region at point E (line *l*) gives the optimum solution to the problem.

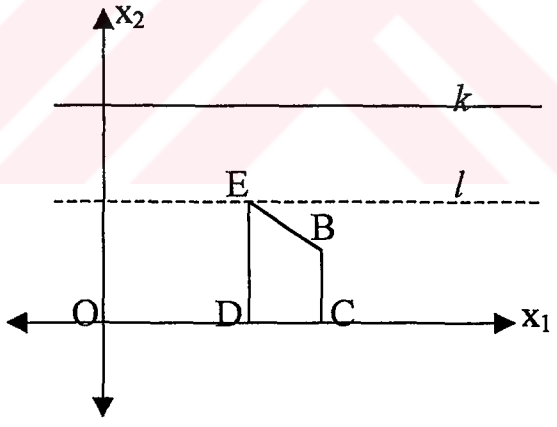

Figure 2.3 The solution is at point E.

2.5 Analytic Hierarchy Process (AHP)

In weighted GP problems Analytic Hierarchy Process, which is a methodology developed by Thomas Saaty in 1980, is a powerful tool to be used. It is used to compare all defined objectives in pairs and calculate their relative importance. It has been applied in decision making in many areas such as finance, marketing, energy

resource planning, microcomputer selection, sociology, architecture, political science etc.

Most of the time AHP is used in the choice phase of decision making. Afterwards other techniques such as linear programming, queuing, multiple objective decision making are used to solve the problem. In fact the duty of AHP is to combine quantitative factors to evaluate all the objectives. (Saaty, 1994)

The procedure of AHP :

1. Identify the objectives and the alternatives that exist.

2. Generate the pairwise comparison matrix; That is the matrix where the relative importance of each objective is identified against others. If there are n objectives, the pairwise comparison matrix (say matrix A) will be an (nxn) matrix. The entry in row i and column j of matrix A (a_{ij}) shows how much more important objective i is than objective j.(Winston, 1993)

Importance is measured by a scale between 1 and 9. Table 2.3 below shows the importance level of each number.

Table 2.3 Interpratation of entries in a pairwise comparison matrix.(Winston1993,p.799)

Value of a_{ij}	**Interpretation**
1	Objectives i and j are of equal importance
3	Objective i is weakly more important than objective j
5	Experience and judgment indicate that objective i is strongly more important than objective j
7	Objective i is very strongly or demonstrably more important than objective j
9	Objective i is absolutely more important than objective j
2, 4, 6, 8	Intermediate values- for example, a value of 8 means that objective i is midway between strongly or absolutely more important than objective j

3. Create the weights of the objectives: Let w_i be the weight given to objective i. Then assuming the decision maker is perfectly consistent, the pairwise comparison matrix will be as follows.

$$A=\begin{bmatrix} w_1/w_1 & w_1/w_2 & \ldots\ldots\ldots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \ldots\ldots\ldots & w_2/w_n \\ \ldots\ldots & & & \\ w_n/w_1 & w_n/w_2 & \ldots\ldots\ldots & w_n/w_n \end{bmatrix}$$

However, most of the time the decision maker may not be perfectly consistent. In this case,

- ❖ First, divide each entry in column I of matrix A by the sum of the entries in column i. Repeat this for all columns to get normalized matrix A (A_{norm}).
- ❖ Average the entries in row i of A_{norm} to give an estimate for w_i.

4. Check for consistency: If the inconsistency ratio is 0 then this means that the decision maker is perfectly consistent. As the ratio increases the trustability of the weights decreases. If this ratio is higher than 0.1 then serious inconsistencies may exist and AHP may not give meaningful results. In such a case some of the pairwise comparisons should be revised.

5. Find the overall score of an alternative: Each of the alternatives defined at first hand are evaluated according to the objectives and their overall scores are calculated. The best alternative is chosen. However, as mentioned before, this step may be replaced by other techniques like linear programming or goal programming.

2.6 Some Variations of Goal Programming

Goal Programming has been a very powerful technique in multiple objective problems since its very first used by Charnes and Cooper in 1961. As more research

and study is carried out on GP, new techniques which are variations of GP have arisen. Integer goal programming, interactive goal programming and fuzzy goal programming are among these techniques.

Integer goal programming is the form of GP where integer decision variables are added into the models. These models are mostly used in selection and assignment problems. They help to deal with order quantity assignments.

Interactive goal programming has been developed because of the need for flexibility in GP models. GP models need to be revised and rerun every time the target values are changed. Interactive GP provides the decision maker easily change the target values and see the tradeoffs between them. The model does not need to be reformulated. An extension of interactive GP is the visual interactive GP (VIG) developed by Korhonen. This is a decision support system which enables the user relax or tighten the constraints on the screen and shows the tradeoffs between the goals graphically. It uses strong visual aids.

Another technique used to increase the flexibility of GP is fuzzy goal programming. Fuzzy set theory was first applied into goal programming by Narasimhan in 1980. This technique allows the decision maker to adopt his/her qualitative observations into the model. Fuzzy values are used instead of deterministic values. Constraints of the model are called 'flexible goals'. All the feasible solutions are defined. Among these, there are some solutions such that no other feasible solution yields an improvement in a goal without degrading the value of at least one other goal.(Karpak et al., 2001) These solutions are called 'non-dominated' solutions and constitute the results of the fuzzy GP model.

CHAPTER 3
PURCHASING AND SUPPLIER SELECTION

3.1 Introduction to Purchasing and Supplier Selection

Quality and cost aspects of a production process start with purchasing. Therefore companies spend considerable time and money for purchasing. Companies often rely on outside suppliers for many of their inputs. Therefore purchasing spends a large percentage of the money in its suppliers. Since of about 30 to 60 percent of the revenue in manufacturing organizations is spent on purchasing goods, suppliers have a great impact on the organization. Figure 1 shows the distribution of costs in large manufacturing companies (The overhead costs include the energy, depreciation costs, the payrolls of the management etc.). However, this percentage is found through a regular accounting discipline. If only the direct manufacturing costs are considered, this percentage would approach to 80s.

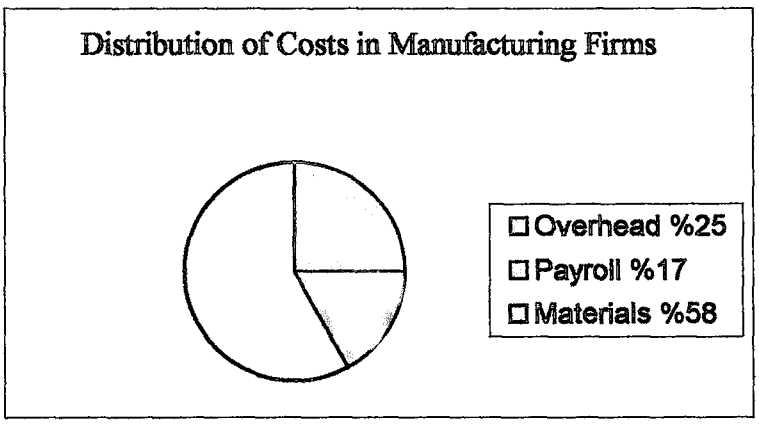

Figure 3.1 Source, U.S. Department of commerce, Bureau of the Census, 1982 Census of Manufacturers: General Summary

When talking about supplier selection, one point should be made clear. That is the market of the material to be purchased is not a monopoly. In case of a monopoly, there can be no selection. It is assumed that at least there exist two different suppliers for any of the materials. All the topics discussed in this chapter is valid under this assumption.

The purchaser asks from its suppliers to meet its desired quality, quantity, delivery requirements with reasonable price and acceptable service level. Some of the important attributes related to the firm's objectives are past history, facilities, technical strength, financial status, organization and management, reputation, systems, procedural compliance, communications, labor relations and location.(Leenders & Fearon, 2000)

Most techniques applied in a purchasing decision use a number of criteria. Each of the existing suppliers is evaluated for these criteria and ranked. The decision is made according to the rankings.

When the alternative suppliers are evaluated, three different situations may occur among them:

1. The suppliers are similar in all aspects. Small differences exist.
2. The suppliers differ from each other a lot. But one of them is superior to others in all aspects.
3. The suppliers differ from each other a lot. Some perform better under some circumstance whereas others perform better in other circumstances.

In the first two cases, the supplier selection is an easy decision and does not require much effort. However, in the third situation careful analysis and study is needed to make the right decision. This is summarized in Table 3.1 below. During the study of the first case, mistakes done in the analysis of suppliers will not change the result much since all the suppliers perform about the same. Whereas in the second case, selecting one of the worse suppliers would result in

disastrous performance. Lastly in the third case, probability of error is high since there is uncertainty, and the result cannot be forecasted.

Table 3.1 Classification of Supplier Selection Decisions, Source:Supplier Selection Strategies William R. Soukup, Journal of Purchasing and Materials Management, Summer 1987.

Condition	Probability of error	Consequences of error	Decision mode
Suppliers are similar in all conditions	High	Very Small	Routine
Suppliers differ significantly, one supplier superior in all conditions	Low	High	Routine
Suppliers differ significantly, best supplier depends on the conditions	High	Unknown	Complex

Usually, in real life organizations, the third case arises. Therefore supplier selection decisions can be considered as decision making under uncertainty. The decision tree in Figure 3.2 represents a one stage two vendor supplier selection decision. In order to use the decision tree effectively, the criteria should be evaluated and the probabilities of success (p, q) and failure (1-p, 1-q) should be calculated.

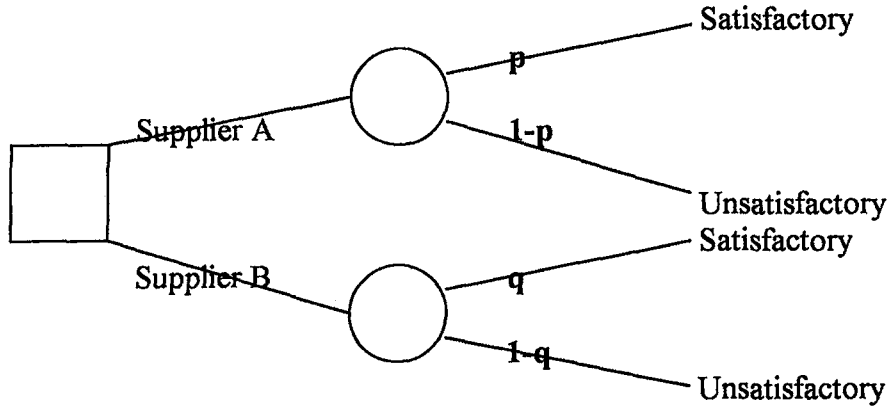

Figure 3.2 A simple one stage supplier selection decision, Source: Purchasing and Supply Management, Leenders & Fearon, 2000, page 221.

3.2 Supplier Selection Procedure

The question of 'who to buy from and how much to buy' is simply the ***Supplier Selection Problem.*** At this point two situations can be considered for a firm. In the first, one supplier can fulfill all the requirements of a firm. In this case the managers only decide 'which supplier is the best one and order from it. This situation is called single-sourcing. In the second situation, which is the real life case most of the time, more than one supplier is necessary to fulfill the requirements of the firm. This is called multiple-sourcing and in this case managers have more work to do. Which suppliers to choose and how much to order from each of the selected suppliers should be decided. According to the purchasing strategies of the firms, both single sourcing and multiple sourcing is employed in today's business world. Each strategy has its own advantages and disadvantages. These are discussed below:

Advantages of Single Sourcing:

- The order may be so small that it is not worthwhile to be divided. Splitting the order may increase fixed purchasing costs.
- Concentrating purchases may make possible certain discounts or lower freight rates that could not be had otherwise.
- The supplier will be more cooperative, more interested and more willing to please if it has all the buyer's business.
- Deliveries may be more easily scheduled.
- Effective supplier relations require considerable resources and time. Therefore the fewer supplier the better.

Advantages of Multiple Sourcing:

- Knowing that competitors are getting some of the business may tend to keep the supplier more alert to the need for giving good prices and service.

- Assurance of supply is increased. In case of fires, accidents, breakdowns, deliveries can still be obtained.
- Supplier dependence is avoided.
- More flexibility is achieved since the unused capacity of all suppliers is available.
- Strategic reasons such as military preparedness and supply security may require multiple sourcing.
- Capacity of a single supplier may not be enough to carry out the current or future needs of the firm. (Leenders & Fearon, 2000)

In both cases, most of the time buyers do not spend much time and thinking about this question. The common thought appears to be 'I have a shortlist of three suppliers and am confident that any of the three can do the job, why should I think about it?'. However, selection offers enormous potential for decreased costs and effective control of resources. Many people who spent considerable time on this subject agree that selecting the sources of supply is the most important function of purchasing department. Dobler, Lee and Burt express this issue in their book with the following words: "Selecting capable suppliers is one of a purchasing manager's most important responsibilities." (Dobler et al.,1984 pp.)

In today's world of technology and competence, what is more important than cost leadership is quality and on-time deliveries. Therefore to survive in today's business world, firms must be able to select the right suppliers and handle manufacturing together with them.

In order to select the right suppliers, the procedure to be followed is: (Dobler & Burt, 1996)

- Develop and maintain a viable supplier base.
- Address the appropriate strategic and tactical issues.
- Ensure the potential suppliers are carefully evaluated and that they have the potential to be satisfactory supply partners.

- Decide whether to use competitive bidding or negotiation as the basis of source selection.
- Select the appropriate source.
- Manage the selected supplier to ensure timely delivery of the required quality at the right price.

1. Develop and maintain a viable supplier base: A regular manufacturing system has many inputs. These inputs consist of hundreds of different raw materials and/or components. Each material/component may be supplied by a single source or by two or more suppliers. This equation gives a huge number of suppliers to be dealt with in each manufacturing organization. Therefore information belonging to each supplier should be kept and a neat supplier base should be created in the organization.

2. Address the appropriate strategic and tactical issues: In some organizations technology and quality may be of greatest importance while in some others on-time deliveries may be given the highest ranking. According to the organizations needs, customer demand and the conditions of the market it is in, each firm should identify its own strategic and tactical decisions.

For example a laptop computer manufacturer may wish to incorporate a larger 'higher resolution display' than currently exists. In order to do so the display should be innovated. Developing this component will require intense interaction between the buyer and the supplier. In this case quality and the reliability of the supplier is very important. And hence, selecting the right supplier is an important strategic decision. Another example can be given from Regal Marine Corporation which is an organization manufacturing boats and yatches. Regal Marine spends $14 Million per year on boat engines. The firm holds engines in the inventory of value $719 000 daily. This is about a 14 day inventory. If the inventory on hand can be decreased even by one day, $3000 will be saved from the interest expense. In this case on-time deliveries are what Regal Marine is trying to achieve.

As seen in the above mentioned examples, organizations have different objectives and strategic issues should be identified accordingly.

3. Ensure the potential suppliers are carefully evaluated and that they have the potential to be satisfactory supply partners: After identifying the firms needs, the suppliers which cannot meet the desired criteria are eliminated. The nominee suppliers are chosen by this way.

4. Decide whether to use competitive bidding or negotiation as the basis of source selection:

Competitive Bidding: Each of the potential suppliers are asked for an offer. Competitive bidding is where suppliers know about the others' offers and make changes in their own offers. In the end the one(s) which make the best offer(s) win the contract.

Negotiation: In negotiation the suppliers to be worked with are chosen first. Then the suppliers and the firm negotiates on prices and other conditions.

The firm must choose one of these procedures from the beginning and act according to this decision.

5. Select the appropriate source: Whether the firm chooses to use competitive bidding or negotiation, the most appropriate suppliers should be selected. At this step many different methods may be applied. Listing and ranking the suppliers, linear programming, goal programming, fuzzy logic goal programming are among these methods.

6. Manage the selected supplier to ensure timely delivery of the required quality at the right price: As the suppliers are chosen and the contracts are made, the contact with the suppliers should be kept from the order time to the

delivery of the materials. Accurate and on-time information flow between the suppliers and the buyer should be assured. So that, any unexpected demand or situation can be compensated by the supplier. By this way, materials are delivered at

- the right amount
- the right time
- the required quality
- and the price.

As seen above, supplier selection is not a one-step easy procedure. Since the decision of 'who to buy from' is strategic in nature and effects the companies overall performance, it should depend on objective and measurable criteria. Also the evaluation and selection is not a matter of instance. Including the time frame -past, present and future- brings in more complexity into the decision. Therefore supplier selection should not be a subjective matter. The reasoning behind must be logical and acceptable by everyone in the company. However, if these decisions are based on an objective procedure, no human error would be realized and therefore the risk of deterioration in the firm's performance in purchasing will be minimized.

3.3 Evaluation of Suppliers

For most organizations, the purchasing objectives are:

- Reducing the costs of purchased materials and transportation
- Keeping inventories as low as possible so that less capital will be tied up in inventories
- Assuring on-time deliveries so that the continuity of supply and the on-going production would not be disrupted
- Assuring good quality. Poor quality items would cause unexpected costs later in the production process
- Having good supplier relations. By this way, any sudden changes in demand would be satisfied by the suppliers.

In order to satisfy these objectives the supply partners should be selected carefully. Hence the evaluation criteria to identify the suppliers should be settled. Many researchers have studied these criteria. G.W. Dickson found out 23 criteria to evaluate suppliers. Table 1 is a list of these criteria. The mean rating gives the importance of criteria. As the rank increases the importance also increases.

Table 3.2 Dickson's supplier selection Criteria (Weber et al.,1991 p.4)

Rank	Factor	Mean Rating	Rank	Factor	Mean Rating
1	Quality	3.508	13	Management and Organization	2.216
2	Delivery	3.417	14	Operating Costs	2.211
3	Performance History	2.998	15	Repair Service	2.187
4	Warranties and Claim Policies	2.849	16	Attitude	2.120
5	Production Facilities & Capacity	2.775	17	Impression	2.054
6	Price	2.758	18	Packaging Ability	2.009
7	Technical Capability	2.545	19	Labor Relations Record	2.003
8	Financial Position	2.514	20	Geographical Location	1.872
9	Procedural Compliance	2.488	21	Amount of Past Business	1.597
10	Communication System	2.426	22	Training Aids	1.537
11	Position in Industry	2.412	23	Reciprocal Arrangements	0.610
12	Desire for Business	2.256			

As seen from the table, quality and on-time deliveries are given the highest ranking. Also performance history, warranties and production facilities are considered to be quite important. Surprisingly, price factor has taken its place as the sixth in the list which shows that quality and delivery are much more important than lower prices in today's world.

Another classification is done by Ram Narasimhan. Narasimhan displays a broader perspective. Figure 3.3 shows 'the decision hierarchy for supplier selection'. The evaluation criteria consists four main categories: Pricing Structure, Delivery, Quality and Service. Under these categories are given dimensions for each.

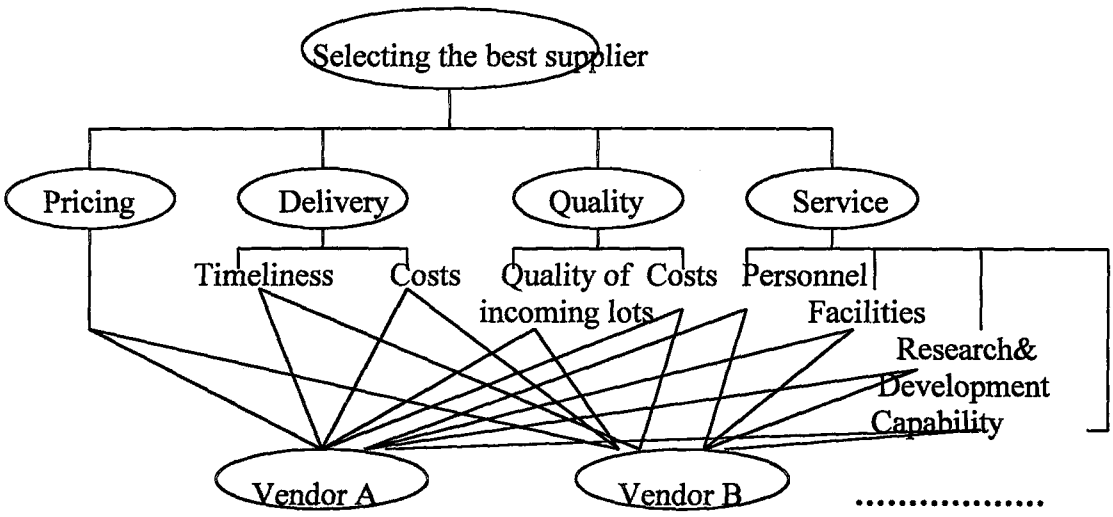

Figure 3.3 Decision hierarchy for supplier selection. Source: Ram Narasimhan, 'An Analytical Approach to Supplier Selection', Journal of Purchasing and Materials Management, 1983, p.28.

The delivery and quality dimensions are straight-forward. Personnel dimension of service denotes the abilities of the vendors' workforce; facilities denote the quality and upkeep of the vendors' physical plant. R&D refers to the technical resources of the supplier devoted to developing new products. Finally, capability represents the ability to perform the current job and the flexibility to perform future work.

A study for the Turkish Industry about the supplier selection problem was done by Gülay Barbarosoğlu and Tülin Yazgaç (1997). The criteria were examined under three main categories: Performance Assessment, Business Structure/Manufacturing Capability Assessment and Quality System Assessment. Table 3.2 gives a list of the criteria of this study and their priorities. Analytic Hierarchy Process was used to determine the priorities.

Table 3.3 Source 'An Application of the AHP to the Supplier Selection Problem, Production and Inventory Management Journal, First Quarter, 1997.

Primary Objective	Criterion	Priority
Performance Assessment	Shipment Quality	0,268
	Delivery	0,268
	Cost Analysis	0,089
Business Structure / Manufacturing Capability Assessment	Technical Cooperation	0,047
	Financial Status	0,017
	Employee Profile	0,006
	Equipment	0,020
	Manufacturing	0,047
Quality System Assessment	Management Commitment	0,094
	Product Development	0,005
	Process Improvement	0,013
	Quality Planning	0,019
	Quality Assurance in Supply	0,029
	Quality Assurance in Production	0,029
	Inspection and Experimentation	0,041
	Quality Staff	0,008

3.4 History and Literature Survey About Purchasing and Supplier Selection

The importance of purchasing function in a firm was first realized in the early 1970s. With the oil crises in 1973-74, raw material shortages appeared. This situation brought the purchasing function as a strategic problem. Porter identified the buyers and the suppliers as two of the critical forces in his 'Note on the Structural Analysis of Industries'. (Harvard Business School Note, 1975)

In 1976, Kiser asks the leading questions for a purchasing strategy. These are 'which supplier markets to enter when making a purchasing decision' and 'whether to make or buy the materials'. (Elements of Purchasing Strategy, 1976)

Afterwards, Jain and Laric (1979) presents a purchasing strategy to keep the costs lowest in the market to be compatible (A model for Purchasing Strategy, 1979). The

traditional strategy to keep the materials costs low is to ensure competition among the suppliers. Therefore multiple sourcing, short term contracting, competitive bidding were applied to the suppliers. However, these strategies resulted in higher operating costs for the suppliers because of uncertainty in their demands. And hence, in long term buyers turned out to be less profitable. That is why factors other than the prices to be considered in purchasing decisions.

Cameron and Shinsey (1985) identified quality and reliable delivery together with the prices as the most important criteria to be considered in materials purchasing. Watts, Hahn and Kim presented a new strategy in which the companies and their suppliers had a partnership like relationship. In this strategy single sourcing and continuous improvement in cost, quality and service was favored. (Costs of Competition, 1986)

Robert E. Gregory was another supporter of this idea. He stated that "Whenever a supplier selection decision is made, the customer normally establishes a set of evaluation criteria that can be used to compare potential sources. The objective of the firm is to find the optimal supplier, not necessarily the one who offers the lowest price, the quickest delivery or the best service"(Gregory, 1986, pp.24-29).

With the selection criteria on-hand, there are many different studies carried out for supplier selection problems. Section 3.4.1 gives some of the studies in the literature about this subject.

3.4.1 Literature Survey

In this section, methodologies followed by models worked and studies about the supplier selection subject will briefly be introduced.

In 1987,William R. Soukup developed a supplier performance matrix to evaluate suppliers from the view of prices offered. In this matrix the expected requirements and their probabilities as well as the suppliers and their offers are listed. The expected cost for each supplier is calculated by multiplying the volume, the offered

price (for that volume) and the probability (of that volume). The lowest expected cost and the corresponding supplier is chosen for that order. (Supplier Selection Strategies, 1987)

Mazurak, Rao and Scotton (1985) made a study about using spreadsheet software in purchasing decisions. In this study, Lotus 1-2-3 software was used to deal with many purchasing decisions as well as vendor selection. Different vendors are evaluated with four main criteria. Their product quality, price, service and financial condition is analyzed according to past performances. Each factor is given a weight which add up to 100. The best supplier in a category is given the top score and the others are scored proportional to the best one. In the end, each vendor had a grade over 100. The one with the highest score is chosen for future orders.

A similar study is carried out by Gregory in 1986. A sourcing worksheet is used to evaluate suppliers. In this sheet all criteria, their weights and the performance measures of each supplier is listed. The measures of the suppliers are determined rather subjectively. The weighted total scores are then computed. At this point appears the difference of this study from the Mazurak, Rao and Scotton. Instead of choosing only the highest scorer, the orders are split between two of the best suppliers. The share of each supplier is calculated proportional to their scores on the worksheet. This study applies multiple sourcing rather than single sourcing.

There also exist other methods to allocate the order quantities between different vendors. Chaudry, Forst and Zydiak (1991) used an integer goal programming model in a vendor selection problem of a blended gasoline purchaser. Four goals are identified. These are quality, lead time, service and price goal with the written order priorities. The model is solved using the Lindo software.

In many cases, a lot of qualitative factors as well as quantitative ones appear in supplier selection problems. Korhonen and Wallenius (1990) used analytic hierarchy process (AHP) to quantify the qualitative data on hand. Then they applied multiple objective linear programming approach to solve the supplier selection problem. The

implementation is done using multiple criteria decision support system developed by Korhonen called the visual interactive goal programming (VIG). VIG sees the constraints of the problem as goals. They are called inflexible goals whereas the objectives are called flexible goals. The approach starts with finding the best possible value for the flexible goals. This solution may not be feasible yet. For this reason, the inflexible goals (constraints) which are violated by the initial solution (if there are) are relaxed and turned into flexible goals one by one. By this way the solution becomes feasible.

VIG is also used in many other studies. One of these is 'Multi-Objective Decision Making in Supplier Selection' by Karpak, Kasuganti and Kumcu (1999). They applied VIG in two different examples: Single Product Multiple Vendor Supplier Selection and Multiple Replenishment Supplier Selection. In these examples the models end up with both which vendors to select and the quantities to be ordered to them.

Houshyar and Lyth (1992) presented a systematic procedure in a supplier selection problem. In this procedure, the factors are classified into three: Critical, objective and subjective factors. The critical factors are the ones which take a supplier into the choice list or throw out totally. The objective and subjective factors are the quantitative and the qualitative factors respectively. The first step in the procedure is to define all three types of factors. Then the suppliers which pass the critical factors are listed. The second step is to evaluate the suppliers in the list in terms of objective and subjective factors using the matrix approach and AHP respectively. The two different measures are brought together with the desired weights. The last step is to list the suppliers from the highest to the lowest according to the overall scores. Whether to employ single or multiple sourcing is left upto the decision maker.

Akınç (1993) proposed three different models for a vendor selection problem where there are four objectives. The objectives are to minimize the material costs, to reduce the number of suppliers and to maximize delivery and quality performances.

The first model only minimizes the materials costs subject to the target values of delivery and quality. The second model only minimizes the number of suppliers subject to the same constraints. The third model is in between the two extreme solutions. It finds out the tradeoffs between the costs and the number of suppliers. To solve the problems set covering models and heuristics are employed.

Weber and Current (1993) employed a multi objective approach to solve vendor selection problem of a Fortune 500 company. Three objectives are identified which are to minimize the purchasing costs, total late deliveries and total rejected units. A linear combination of these objectives become the objective function. Mixed integer problem is developed and solved. Another study of Weber and Current (1994) is about the application of Facility Location Modeling to supplier selection problems. In this study, Weber and Current showed that the mathematical formulations of simple plant, p–median and set covering location problems can also be used to solve vendor selection and quantity allocation problems.

Umur, Barbarosoğlu, and Yazgaç (1995) applied analytic hierarchy process for supplier selection in Türkiye Elektrik Endüstrisi. A four level model is built and the alternative suppliers are compared in the fourth level. This is done for several different components. For the solution, a generalized software is developed to deal with large–scaled analytic hierarchy process models and used.

Ghodsypour and Brien (1998) also employed AHP to deal with both qualitative and quantitative factors. In their methodology, first the criteria for supplier selection is defined and their weights are computed using AHP. All the suppliers are evaluated and their total scores are achieved. In the last step, a linear programming model is built and solved. The objective is to maximize the total value purchased which is found by multiplying the suppliers overall scores and the quantity to be ordered from that supplier. The constraints are the capacity, quality and the demand. AHP is applied using Expert Choice Software package and the linear programming model is solved using Microsoft Excel Solver.

Kasilingan And Lee (1996) also studied supplier selection problem. A mixed integer–programming model is built considering the demand as stochastic. The quality factor is considered as to minimize the cost of poor quality parts. This cost is included in the objective function as well as the purchasing, transportation costs and the fixed cost of establishing suppliers.

Seyhan (2000) presented an integrated approach of analytic hierarchy process and goal programming to solve the supplier selection problem of a TV manufacturing company. The implementation is a multi-item multiple sourcing problem. The study first settles the criteria to evaluate suppliers. AHP is used to figure out the weights of the factors. Then a GP model is developed which selects the vendors and allocates the orders among them. Lingo software package is used to solve the GP model.

Ulusam and Kurt (2002) applied fuzzy goal programming in a hydraulic gear pump purchasing problem. They defined cost, quality, delivery reliability goals as fuzzy goals. These are transformed into a linear programming form and Lindo is used to find the results.

As it can be seen, there is a strong challenge moving from single sourcing to multiple sourcing. The first studies used to solve supplier selection were choosing only one supplier and placing the orders from it. However, as science evolved and new methods are developed, a supplier selection problem became not only choosing the suppliers but also allocating order quantities among them.

CHAPTER 4
SUPPLIER SELECTION APPLICATION IN SUN TEKSTİL

4.1 Company Presentation

Sun Tekstil is producing sport outer clothing of knitted fabric. The in-plant capacity reaches 400,000 pieces per month. Total closed and open operating area is 35,000 m^2 and around 1000 employees are employed by the company.

Sun Tekstil started its quality and system studies in 1994 and received the ISO 9001 Certificate in 1996. Since 1999, it has been applying work excellence model of KAL-DER EFQM (Kalite Derneği–European Foundation Of Quality Management). Sun Tekstil has developed its own brand name of Jimmy Key. As well as this brand Sun Tekstil is one of the producers of brand names such as Tommy Hilfiger, Adidas, Diesel, Best Seller and Puma. About 6% of the total yearly production is made for Jimmy Key where rest of production is made based on orders coming from the above customers. The orders are treated either in-plant or given to outsourcing firms.

Manufacturing process starts with the cutting operation followed by printing and/or embroidering. Cutting facilities are performed by NC cutters. The capacity of cutting division is 25,000,000 articles per day. After cutting, all articles are monitored on the computer by means of the barcode system.

Printing facilities have a monthly capacity of 20,000 pieces. There are four printing machines and two fixing machines available. All designing works have been carried out through computer integration with the printing facilities of ten to twelve colors. All the embroidering machines are under control of the central computer system. The monthly capacity of embroidering division is 250,000 stiches, and 8,000 embroidered articles can be produced per day.

The last operation before packaging is sewing. The daily capacity of the inner sewing departments of Sun Tekstil is 86,000 minutes of sewing per day. An average of 400,000 articles may be produced per month.

All manufacturing operations, as well as the quality, procurement and stock control systems are controlled by a specially designed computer program called EDS (Enformasyon Destek Sistemi).

4.2 Problem Definition

In Sun Tekstil, there is no defined procedure used for materials purchasing. The requirements are ordered from traditionally accustomed suppliers. However, these suppliers are not tested or observed by quantitative measures. As a result company faced many problems such as higher costs, delayed production, low customer satisfaction etc. In today's world, quality is a must and on-time delivery is a differentiating criterion for firms competing in the global market. Sun Tekstil aims to be world class manufacturer with perfect quality and on-time deliveries. Therefore company should not tolerate late delivery of materials or rejected lots.

When the current system is analyzed, it is seen that late delivery of products occur due to two specific reasons.

- Delivery of materials are late or delivered lots are rejected: Late materials causes delays in the production schedule. Also, when lots are rejected, purchasing department orders them again and the production schedule is delayed depending on the lead-time of materials.
- The lots outsourced are late or rejected: Sun Tekstil works with outsourcing firms for some of its products. Fabric and the necessary

accessories are sent to the outsourcing firm. The firm produces final products and delivers them to Sun Tekstil. Often, these finished product lots are delivered late and sometimes, they are rejected because of low quality. This causes late delivery of products to Sun Tekstil's customers.

In the light of these situations, the problem can be split into two parts. First one is of materials' suppliers. Second is of outsourcing suppliers. Hence, the solution procedure should consider these two parts separately.

Another aspect of this problem is for total quality purposes. Sun Tekstil wants to be able to measure its suppliers' performances quantitatively and develop a supplier selection procedure. Therefore it is decided to study the supplier selection problem of Sun Tekstil and develop a solution.

4.3 Aim Of The Study

Aim of this study is to minimize the number of late deliveries and rejected lots of Sun Tekstil. In order to do this an effective supplier selection procedure is necessary. The problem contains many items, each of which is supplied from more than one supplier. Therefore it is a multi item multiple sourcing supplier selection problem.

As explained in section 4.2, the problem is studied in two parts as the materials supplier selection and outsourcing supplier selection. The firm aims to decrease the delays in the production schedule due to late delivery of materials and rejected lots for both problems. In addition, the suppliers which employ a higher capacity for Sun Tekstil are preferred by the company. These goals are common for both problems. Moreover, Sun Tekstil has objectives in its outsourcing activities other than its materials purchasing activities. Among these are the productivity maximization of suppliers and minimization of damaged units delivered by suppliers. Also, the suppliers are asked for their number of university graduated employees. Suppliers with more university graduated personnel are favored.

Since there are many goals to be considered at the same time, weighted goal programming model is used. Mathematical models are built and solved to select effective suppliers in terms of Sun Tekstil needs and the quantities ordered to these suppliers are found. In conclusion, it is proved that the proposed approach in this thesis is stronger over the current system in terms of the goals determined at the beginning.

The two major problems defined in section 4.2 are solved independent from each other but using the same methodology.

4.4 The Methodology Of The Proposed Approach

The proposed approach in this study uses weighted goal programming and analytic hierarchy process to solve the problem. First thing to be done is to collect necessary data from the system in order to evaluate the alternative suppliers in terms of the criteria determined by the firm. Once data collection ends, the goals of the firm should be determined. In weighted goal programming, the important part is to determine the goals as well as their relative importances to the firm. To assign these relative importances, i.e. the weights, to the goals Analytic Hierarchy Process (AHP) is used which is one of the multi-criteria decision making aids. At this step, Expert Choice computer program which is an AHP software is used. Then, performance measures, associated with the selection criteria, and the target values, associated with the goals, are calculated.

The next phase is modeling. Four different mathematical models for this specific problem are developed and solved. Two of these models assign the weights to the goals using AHP, the other two assigns the weights determined by company managers. In addition two of the models limit the number of suppliers selected by two, the others do not pose any restrictions on the number of suppliers. The last step is to find the results of the model and compare them with the current system.

In summary, the methodology is as follows:

- Data collection

- Determination of selection criteria.
- Determination of firm's goals
- Determination of weights of the goals
- Calculation of performance measures
- Determination of target values
- Formulating the alternative mathematical models
- Solving the models
- Compare the results with the current system.

Each of these headings will be discussed in the following sections both for materials' supplier selection and outsourcing supplier selection.

4.5 Data Collection

All records of ordering and purchasing activities in Sun Tekstil are recorded in EDS which was installed in June 2001. Different modules are built to keep records of purchasing and outsourcing.

For materials purchasing, records between June 2001 and April 2002 are downloaded. The data starts with June 2001 because this is the date of installation of EDS. For all orders between June 2001 and April 2002, quantities ordered, quantities received, unit costs, request date of orders and delivery date of orders are obtained. For outsourcing activities, the current system is observed from February 2002 to July 2002. All orders within this time frame, their request and delivery dates, ordered and received quantities, in-line and final inspection reports are obtained. In addition, information of outsourcing suppliers are collected including their number of blue collar and white collar employees, university graduates and capacities.

In Sun Tekstil the major material is fabric among materials. Fabric is purchased from Ekoten Inc., which is a branch of Sun Group Companies, located in Aegean Free Zone. Since there is no alternative supplier for fabric, the materials' supplier selection does not consider fabric. The list of materials analyzed is given in table 4.1.

Table 4.1 List of Materials

No	Material Name	No	Material Name	No	Material Name
1	Zip	11	Packaging Box Label	21	Packaging Tape
2	Print	12	Polyester Coil	22	Adicomp Label
3	Nylon Bag	13	Weaving Ribbon	23	Sticker
4	Mercerized Coil	14	Press Button	24	Buckram
5	Label	15	Elastic Band	25	UPC Label
6	Sized Label	16	Separator	26	Packaging Paper
7	Hanger	17	Plastic String	27	Tab
8	Washing Instruction	18	Button	28	Packaging Ring
9	Packaging Box	19	Time Label	29	Ring Clip
10	Sized Washing Instruction	20	Tape		

According to the data, first an ABC analysis is performed. Total purchasing values of foreign materials were in USD. These values are turned into TL using exchange rates on the delivery date of that order. The results of the ABC analysis are given in table 4.2.

Table 4.2 ABC Analysis

	Material	Total Value (TL)	Ratio to Total	%		Class
1	Zip	210.644.156.058 TL	0,190	18,96	18,96	A
2	Print	201.848.028.470 TL	0,182	18,17	37,13	A
3	Nylon Bag	106.100.201.900 TL	0,096	9,55	46,68	A
4	Mercerized Coil	103.608.286.150 TL	0,093	9,33	56,01	A
5	Label	96.655.027.560 TL	0,087	8,70	64,71	A
6	Sized Label	55.066.462.727 TL	0,050	4,96	69,67	A
7	Hanger	50.516.154.210 TL	0,045	4,55	74,22	A
8	Washing Instruction	50.361.289.850 TL	0,045	4,53	78,75	A
9	Packaging Box	39.491.791.000 TL	0,036	3,56	82,30	A
10	Sized Washing Instruction	38.507.136.795 TL	0,035	3,47	85,77	A
11	Packaging Box Label	35.706.229.806 TL	0,032	3,21	88,99	A
12	Polyester Coil	32.027.602.000 TL	0,029	2,88	91,87	A
13	Weaving Ribbon	26.806.088.948 TL	0,024	2,41	94,28	B
14	Press Button	20.401.458.720 TL	0,018	1,84	96,12	B
15	Elastic Band	8.850.081.868 TL	0,008	0,80	96,92	B
16	Separator	8.398.054.000 TL	0,008	0,76	97,67	B
17	Plastic String	7.295.639.050 TL	0,007	0,66	98,33	B
18	Button	4.069.728.670 TL	0,004	0,37	98,69	B
19	Time Label	2.672.325.000 TL	0,002	0,24	98,93	B
20	Tape	2.385.970.000 TL	0,002	0,21	99,15	B
21	Packaging Tape	2.087.445.000 TL	0,002	0,19	99,34	B
22	Adicomp Label	1.960.291.100 TL	0,002	0,18	99,51	B
23	Sticker	1.751.135.500 TL	0,002	0,16	99,67	B
24	Buckram	1.676.695.000 TL	0,002	0,15	99,82	B
25	UPC Label	1.077.566.200 TL	0,001	0,10	99,92	B
26	Packaging Paper	747.710.000 TL	0,001	0,07	99,99	B
27	Tab	87.710.000 TL	0,000	0,01	99,99	C
28	Packaging Ring	30.686.400 TL	0,000	0,00	100,00	C
29	Ring Clip	25.630.000 TL	0,000	0,00	100,00	C
	Sum	**1.110.856.581.981 TL**	**1,00**	**100**		

As seen from the table, the materials that make up 91.87% of the overall purchasing cost are set to be A class materials. This group contains 12 materials. From 91.87% to 99,99% materials are called class B. There are 14 types of materials in B. The rest three items, which have negligibly small cost, are in class C. As a nature of textile industry, number of materials is quite low whereas product variety is quite high. Therefore both A and B class materials will be considered in supplier selection. Among these 26 types, buckrams, time labels and Adicomp labels are supplied by a single-source. These three materials are taken out leaving 23 to be included in selection approach.

These 23 items are supplied from 57 suppliers. Of these 57 suppliers 13 are foreign suppliers and 44 of them are local suppliers. A form is designed (given in appendix A1) together with the purchasing department specialists and sent to all suppliers local and abroad. The products and the corresponding capacities of all suppliers are obtained with these forms. The materials, their suppliers and the capacities are given in appendix A2. In the rest of the study the materials will be considered with their numbers given as in appendix A2.

The outsourcing problem is handled similarly. The items ordered to outsourcing firms are the finished products of Sun Tekstil. Some of the items ordered to Sun Tekstil by its customers such as Diesel, Tommy Hillfiger etc. are manufactured by Sun Tekstil plants. Some of them are outsourced.

There are 30 different types of products purchased from 8 different outsourcing suppliers in the data taken from the system. The suppliers are all located in İzmir. Sun Tekstil employs inspection specialists who work with the outsourcing suppliers and keep in-line and final inspection reports. The list of outsourcing suppliers, their capacities and number of employees are given in Appendix A3.

An ABC analysis is performed in order to see the most important items to the company. Table 4.3 gives the results of ABC analysis. According to the table, items that make up 93.07% of the total value are A class items. There are 15 items in this

class. Items that make up the next 5.16% of the total value (from93.07% to 99.13%) are B class items. This group contains 9 types of items. The rest 6 items are class C.

Table 4.3 ABC Analysis of Items Outsourced

	Model	Total (Amount (TL)	Ratio To Total	%	Cumulative %	Class
1	Panel Block	96.150.037.500 TL	0,152	15,17	15,17	A
2	Sparkle Flag	91.525.656.300 TL	0,144	14,44	29,61	A
3	Emily	80.361.105.800 TL	0,127	12,68	42,29	A
4	Coral Garden	60.019.604.000 TL	0,095	9,47	51,76	A
5	Dilliards	57.150.139.500 TL	0,090	9,02	60,77	A
6	Service Collar	49.603.813.800 TL	0,078	7,83	68,60	A
7	Traditional	41.378.729.800 TL	0,065	6,53	75,13	A
8	Embossed	27.091.318.500 TL	0,043	4,27	79,40	A
9	Sideflag	22.247.292.600 TL	0,035	3,51	82,91	A
10	Leather Crew	17.196.768.600 TL	0,027	2,71	85,63	A
11	Stamp Front	14.920.215.600 TL	0,024	2,35	87,98	A
12	Hipstar	13.965.288.000 TL	0,022	2,20	90,18	A
13	Face Off	11.751.927.000 TL	0,019	1,85	92,04	A
14	Anna	6.568.583.400 TL	0,010	1,04	93,07	A
15	Liberty	5.715.167.300 TL	0,009	0,90	93,98	A
16	Soccer	5.378.521.000 TL	0,008	0,85	94,82	B
17	Pintuck	4.998.038.400 TL	0,008	0,79	95,61	B
18	Starbright	4.772.760.000 TL	0,008	0,75	96,37	B
19	Plam Tree	3.330.999.000 TL	0,005	0,53	96,89	B
20	Flip Flop	3.259.536.800 TL	0,005	0,51	97,41	B
21	Ferry crew	3.166.151.900 TL	0,005	0,50	97,91	B
22	Scrimmage	2.927.663.600 TL	0,005	0,46	98,37	B
23	Colorblocked	2.539.113.700 TL	0,004	0,40	98,77	B
24	Flona Top	2.306.325.400 TL	0,004	0,36	99,13	B
25	Rainbow	1.993.934.000 TL	0,003	0,31	99,45	C
26	Allaamerikan	1.834.551.600 TL	0,003	0,29	99,74	C
27	Stars Scribble	710.614.800 TL	0,001	0,11	99,85	C
28	Purple Hearts	556.898.800 TL	0,001	0,09	99,94	C
29	Hang Ten	220.029.600 TL	0,000	0,03	99,97	C
30	Scumber Party	184.362.000 TL	0,000	0,03	100,00	C
	Sum	**633.825.148.300 TL**				

In this study, only A class items will be considered. Therefore there will be 15 items in the selection process. But, item 12, Hipstar is taken out because there is only one supplier for Hipstar leaving 14 items to be considered in the outsourcing model. The items taken into consideration, their suppliers and the sequence numbers of the suppliers are given in Appendix A4. All items and outsourcing suppliers will be referred later in this thesis with their numbers as in the appendix.

4.6 Model Development

4.6.1 Determining The Selection Criteria

Decisions related to selection criteria should match to company's needs. Number of meeting has been made with the company managers. As a result of these meetings, selection criteria can be divided into two groups. These two main criteria groups are named as 'work results' and 'resources'.

a) Selection Criteria For Materials' Supplier Selection

Work results contain quality, lead-time and delivery performance. Resources contain percent utilization of capacity for Sun Tekstil. Table 4.4 lists the selection criteria. Each criterion will be referred later in this text with the letters in the parenthesis.

Table 4.4 Selection Criteria for materials' suppliers.

Work Results	Resources
Quality (K): Ratio of accepted units in the incoming quality control.	**Capacity Utilization (R) :** Ratio of the capacity of the supplier used for Sun Tekstil.
Lead-Time (L): Ratio of units arriving on-time.	
Delivery Performance (D): Ratio of delivered units to ordered units.	

- Quality (K) : Some of the lots are rejected in the incoming quality control due to low quality of the material. This criterion measures the percentage of accepted units in the total units received.
- Lead-Time (L) : This criterion measures the percentage of units that are received not later than the due date in the total units received.
- Delivery Performance (D) : The quantity of some of the lots received may be less than the quantity ordered. This criterion measures the percentage of received units in the total ordered units.
- Capacity Utilization (R) : This criterion measures the utilization percentage of the capacity of supplier with Sun Tekstil orders.

b) Selection Criteria For Outsourcing Supplier Selection

Work results contain:

- Quality

K1- Ratio of approval of the production samples at the first trial: Sun Tekstil requires a sample product from the outsourcing firm before placing the order. The supplier delivers the sample and starts producing the order if the sample is accepted. If sample is returned, then the supplier produces another sample until it is accepted. For every order the number of trials of the sample is recorded. This criterion is the ratio of first trial approvals to the total number of samples delivered by the outsourcing supplier.

K2- Ratio of accepted units in the incoming quality control: All received lots go through inspection in the incoming quality control. Some lots are rejected here. This criterion is the ratio of accepted units to the total number of incoming units.

K3- Comparison of in-line and final inspection: Sun Tekstil employs quality control specialists who follow the production at the outsourcing supplier. The in-line final inspection results are recorded. This criterion is defined as follows:

$$C = \left(\frac{\text{Number of damages appeared in in-line inspection} - \text{Number of damages appeared in final inspection}}{\text{Number of damages appeared in in-line inspection}} \right)$$

If all the damages appeared in in-line inspection are repaired then the value of this criterion is defined as 1.

K4- Ratio of non-damaged items: Sun Tekstil sends fabric and accessories to its outsourcing suppliers necessary for the order. In other words, if an order of 1000 units is placed, Sun Tekstil sends fabric and accessories sufficient for about 1100 units. Some of the

materials sent may be damaged during production. This criterion is the ratio of delivered units from the supplier to the amount sent by Sun Tekstil.

- Lead-Time

  L: Ratio of units arriving on-time to total number of units received.

- Delivery Performance

  D: Ratio of delivered units to ordered units.

- Productivity

  V: The standard times for all products are set by Sun Tekstil. Productivity is defined as the ratio of standard time for an order to its actual completion time. Actual completion time is the time between order request date and delivery date. Daily 8 hours of work is assumed. There may be more than one job processed at the suppliers' facilities during this time. For this reason, total man*hours is multiplied by the percentage of supplier's capacity used for Sun Tekstil. (Refer to criterion R1)

Resources contain:

R1- Percentage of the capacity of a supplier used for Sun Tekstil.

R2- Ratio of university graduates to the total number of employees.

4.6.2 Determining The Company's Goals

According to the selection criteria defined in the previous section, goals are determined.

a) Goals For Materials' Supplier Selection

- Quality: Maximize the number of accepted units.
- Lead-Time: Maximize the number of units arriving on-time.
- Delivery Performance: Maximize the number of delivered units.
- Resources: Maximize the ratio of capacity utilization of suppliers.

b) Goals For Outsourcing Supplier Selection

- Quality:

  Maximize the number of first trial approved samples

Maximize the number of accepted units in the incoming quality control

Minimize the final inspection damages

Maximize the number of non-damaged items

- Lead-Time: Maximize the number of units arriving on-time
- Delivery Performance: Maximize the number of delivered units
- Maximize productivity
- Resources:

  Maximize the capacity utilization of outsourcing firms

  Maximize the number of university graduates among all employees

4.6.3 Determining The Weights Of The Goals

Two different sets of weights are defined. The first set is determined directly by the subjective opinion of firm's purchasing managers. The second method used to find out weights is AHP and Expert Choice software.

a) Weights Belonging To Materials' Supplier Selection

The weights determined by company managers are presented in the table below.

Table 4.5 Firm's Weights

Work Results	Resources
Quality (K): 0,3	**Capacity Utilization (R) :** 0,2
Lead-Time (L): 0,3	
Delivery Performance (D): 0,2	

To compute the second weight set, the preference matrix entered into Expert Choice is given in table 4.6. This preference matrix is developed by subjective

judgments of purchasing managers. However, AHP turns these subjective judgments into objective values of weights.

Table 4.6 Preference Matrix

i / j	L	D	R
K	2	3	4
L		3	4
D			4

Row element i is a_{ij} times more important than the column element j. That is the quality goal is twice, three times, four times as important as lead time, delivery performance and resource goals respectively. The weights computed by Expert Choice are:

Table 4.7 AHP Weights

Work Results	Resources
Quality (K): 0,443	Capacity Utilization (R): 0,072
Lead-Time (L): 0,316	
Delivery Performance (D): 0,169	

The inconsistency ratio is found out to be 0,05. This is a acceptable value since it is less than 0,1. So, both the firm weights and the AHP weights will be considered in the modeling phase.

b) Weights Belonging To Outsourcing Supplier Selection

Table 4.8 Weights assigned to goals decided by firm managers

Work Results	K1	0.06
	K2	0.12
	K3	0.06
	K4	0.13
	L	0.3
	D	0.13
	V	0.1
Resources	R1	0.05
	R2	0.05

Also, using Expert Choice Software, the other set of weights is computed. Table 4.9 is the preference matrix entered into Expert Choice and the corresponding weights are given in table 4.10.

Table 4.9 Preference Matrix

	K2	K3	K4	L	D	V	R1	R2
K1	1	1	1	-2	-2	2	3	4
K2		1	1	2	2	2	3	4
K3			1	-2	-2	2	3	4
K4				2	2	2	3	4
L					2	2	3	4
D						2	3	4
V							3	4
R1								4

Table 4.10 Weights assigned to goals found by AHP

Work Results	K1	0.117
	K2	0.162
	K3	0.117
	K4	0.162
	L	0.153
	D	0.132
	V	0.08
Resources	R1	0.049
	R2	0.028

The inconsistency ratio calculated by Expert Choice is 0.05. Inconsistency values less than 0.1 are acceptable. Therefore this weight set is also acceptable. Hence there will be two alternative goal programming models for the weights determined by firm managers and weights calculated using AHP.

4.6.4 Calculation Of Performance Measures

Performance measures are necessary in order to evaluate the suppliers in terms of the selection criteria.

a) Performance Measures Of Materials' Supplier Selection

There exist four performance measures for four selection criteria. The formulation of performance measures are given below. All terms are over the same time interval, the 11 months from June 2001 to April 2002.

- Quality (K): Ratio of accepted units in the incoming quality control:

$$K_{ij} = \frac{\text{Number of accepted units of material i (delivered by supplier j)}}{\text{Total units (of material i) delivered by supplier j}}$$

- Lead-Time (L)=Ratio of units arriving on-time :

$$L_{ij} = \frac{\text{Number of units of material i on-time (delivered by supplier j)}}{\text{Total units (of material i) delivered by supplier j}}$$

- Delivery Performance (D): Ratio of delivered units to ordered units.

$$D_{ij} = \frac{\text{Total units of material i (delivered by supplier j)}}{\text{Total units (of material i) ordered to supplier j}}$$

- Resources (R): Capacity percentage of the supplier used for Sun Tekstil.

$$R_{ij} = \frac{\text{Total units received of material i (from supplier j)}}{\text{Yearly capacity of supplier j (for material i) *(11/12)}}$$

The data used to calculate these measures are for 11 months but the capacities of suppliers are yearly. Therefore the denominator is multiplied by (11/12) to reduce both terms to the same interval.

All suppliers are analyzed according to the selection criteria for each material they supply to Sun Tekstil. Appendix B1 gives the performance measures.

b) Performance Measures Of Outsourcing Supplier Selection

There are nine different performance measures for nine selection criteria. These are:

- Quality

K1: Ratio of samples that are approved at the first trial to the total number of samples

$$K1_{ij} = \frac{\text{Number of first trial approvals of item i (delivered by supplier j)}}{\text{Total samples (of item i) delivered by supplier j}}$$

K2: Ratio of accepted units in the incoming quality control

$$K2_{ij} = \frac{\text{Number of accepted units of item i (delivered by supplier j)}}{\text{Total units (of item i) delivered by supplier j}}$$

K3: Comparison of in-line and final inspection: Term C was defined in section 4.6.1.b.

$$K3_{ij} = \left(\sum_{\forall \text{ item i orders of supplier j}} [C] \right) / \text{Number of item i orders of supplier j}$$

K4: Ratio of non-damaged items

$$G = \frac{\text{Quantity received}}{\text{Quantity that Sun Tekstil sent material for}}$$

$$K4_{ij} = \left(\sum_{\forall \text{ item i orders of supplier j}} [G] \right) / \text{Number of item i orders of supplier j}$$

- Lead-Time

L: Ratio of units arriving on-time

$$L_{ij} = \frac{\text{Number of units of item i on-time (delivered by supplier j)}}{\text{Total units (of item i) delivered by supplier j}}$$

- Delivery Performance

D: Ratio of delivered units to ordered units.

$$D_{ij} = \frac{\text{Total units of item i (delivered by supplier j)}}{\text{Total units (of item i) ordered to supplier j}}$$

- Productivity

V: Ratio of total standard time to actual time of an order

$$E = \frac{\text{Standard time} * \text{Quantity received}}{\text{(Delivery Date-Request Date)} * 8 * 60 * \text{No. of workers} * [\text{Capacity utilization}^{1}]}$$

(Denominator of term E is the total man*minutes throughout order processing time. Daily 8 hours of work is assumed. There may be more than one job processed at the same time. This means time of the outsourcing suppliers may be used not only for Sun Tekstil but also for other customers. For this reason, total man*minutes is multiplied by capacity utilization to find the actual time spent only for Sun Tekstil. Capacity utilization is performance measure of R1.)

$$V_{ij} = (\sum_{\forall \text{ item i orders of supplier j}} [E]) \; / \; \text{Number of item i orders of supplier j}$$

[1] Refer to performance measure R1

- Resources

R1: Capacity percentage used for Sun Tekstil.

$$R1_j = \frac{\text{Total units received (from supplier j)}}{\text{Yearly capacity of supplier j} * (6/12)}$$

(Time interval of orders received is 6 months. Therefore the capacity of the supplier is for 6 months.)

R2: Ratio of university graduates to total number of employees.

$$R2_j = \frac{\text{Number of university graduates of supplier j}}{\text{Total number of employees of supplier j}}$$

Each outsourcing supplier is analyzed in terms of these performance measures. All values of performance measures are given in Appendix B2.

4.6.5 Determination Of Target Values

Once the performance measures are calculated, the firm should determine the target levels to be achieved for these performance measures. Target values represent the desired levels of performance measures. That is the level Sun Tekstil wants its outsourcing suppliers to reach. The company managers decided to set the target values according to the performance measures of the best two suppliers. Target value for each criterion is determined to be computed by adding 80% of the best performance value and %20 of the second best performance value.

a) Target Values Of Materials' Supplier Selection

Determination of the delivery performance target value for the second type material, label, is given as an example:

Material	Supplier	D	
Label	Borneman	0,917	
	Wah Sing	0,973	
	Desan	0,861	
	Akın Etiketçilik	0,964	
	Öztek Etiket	0,995	
	Teslo	0,987	
	Dizayn	0,998	→ 2nd Best Performance
	Eticart	0,977	
	New Yuen	0,997	
	Wing Tak	1	→ Best Performance

TK_i= Quality target value for material i=0,8*Best Performance+0,2*Second Performance

TK_2 =0,8*1 +0,2*0,998 = 0,9996 ≅ 1

The values used throughout this study are approximated to three digits after comma. All the target values are found in the same way and are given in appendix B3.

b) Target Values Of Outsourcing Supplier Selection

The target value for the K1 criterion of outsourcing supplier selection is given as an example.

$TK1_i$= Target value of K1 for item i=0,8*Best Performance +0,2*Second Performance

Target values for other criteria (K2, K3, K4, L ,D, V, R1, R2) calculated in the same way and all are given in Appendix B4.

4.6.6 Mathematical Model Formulation

There are four alternative goal programming models. Main differences of the alternative models are defined as follows:

- Alternative Model 1: Model 1 uses the weights determined by AHP in the weighted goal programming approach.
- Alternative Model 2: Model 2 uses the weights determined by company managers.

- Alternative Model 3: Model 3 again uses the weights determined by AHP. In addition to model one formulation, exactly 2 suppliers are chosen for each material every month.
- Alternative Model 4: Model 4 uses the weights determined by company managers and selects exactly 2 suppliers for each material every month.

This section lists the assumptions made, the decision variables and the deviational variables of the model, the notation used for performance measures and target values, the objective function and the constraints.

a) Formulation Of Materials' Supplier Selection Models

23 types of materials, 4 goals and 11 periods are concerned in all models.

i- Alternative Model 1

Model 1 applies weighted goal programming approach to solve this supplier selection problem. The solution gives the selected suppliers and the quantities ordered to them. The weights are the ones found by AHP in section 4.6.3.a.

a. Assumptions:

- Weights assigned to goals are found by AHP.
- If an item is not purchased in one period from a certain supplier, then its purchasing cost is unknown in that period. But, still this supplier is included in the alternative suppliers. In this case that supplier's cost for that item is assumed to be equal to the maximum purchasing cost among the other suppliers' costs.

b. Indices

- $i_1, i_2, i_3, \ldots i_{23}$: Number of suppliers for materials from the first to the 23^{rd} respectively.

Table 4.11 The number of suppliers for each material.

i_1	i_2	i_3	i_4	i_5	i_6	i_7	i_8	i_9	i_{10}	i_{11}	i_{12}	i_{13}	i_{14}	i_{15}	i_{16}	i_{17}	i_{18}	i_{19}	i_{20}	i_{21}	i_{22}	i_{23}
2	10	3	4	7	2	6	2	5	2	7	7	2	3	3	2	2	4	2	2	3	2	3

- k: Number of periods , k=1..11
- j: Number of material types, j=1..23

c. Decision Variables:

$Y1(i_1,k)$: units of first material ordered from i_1^{th} supplier in month k.

Similarly there exist $Y2(i_2,k)$ through $Y23(i_{23},k)$.

d. Deviational Variables:

$sa(1,j,k)$:Negative deviation from the quality goal of j^{th} material on month k.

$se(1,j,k)$:Positive deviation from the quality goal of j^{th} material on month k.

$sa(2,j,k)$:Negative deviation from the lead time goal of j^{th} material on month k.

$se(2,j,k)$:Positive deviation from the lead time goal of j^{th} material on month k.

$sa(3,j,k)$:Negative deviation from the del. per. goal of j^{th} material on month k.

$se(3,j,k)$:Positive deviation from the del. performance goal of j^{th} material on month k.

$sa(4,j,k)$:Negative deviation from the cap. utilization goal of j^{th} material on month k.

$se(4,j,k)$:Positive deviation from the cap. utilization goal of j^{th} material on month k.

e. Performance Measures:

$K(i,j)$: Ratio of lots accepted of supplier i for material j.

$L(i,j)$: Ratio of lots delivered by supplier i of material j on time.

$D(i,j)$: Mean units performance of supplier i for material j.

$R(i,j)$: Capacity utilization ratio of supplier i for material j.

Where $i= i_1, i_2, i_3,\ldots i_{23}$ for $j=1,2,3,\ldots 23$ respectively.

f. Target Values:

TK(j): Target value for the ratio of lots accepted for material j.

TL(j): Target value for the ratio of lots delivered of material j on time.

TD(j): Target value for the delivery performance for material j.

TR(j): Target value for the capacity utilization ratio for material j.

Where i= i_1, i_2, i_3,...i_{23} for j=1,2,3,...23 respectively.

g. Other Variables:

TY1(i_1)= Total number of units of first material ordered to supplier i_1.

$$= \sum_{k=1}^{11} Y1(i_1,k) \qquad \forall i_1, k$$

TY2(i_2) , TY3(i_3) ,.... TY23(i_{23}) are defined in the same manner.

MR(i,j): Monthly capacity of supplier i for material j where i= i_1, i_2, i_3,...i_{23} for j=1,2,3,...23 respectively.

QD(j,k): Quantity demanded of material j in month k. The demand of each material is calculated by adding the incoming quantities on monthly basis. The demands are given in Appendix B5.

P1(i_1,k): Purchasing cost of material 1 bought from supplier i_1 in month k. The costs are the monthly average costs for each supplier and material. Also there exists P2 to P23 for the purchasing costs of material 2 to material 23. The purchasing costs are given in Appendix B6.

h. Objective Function: The objective function minimizes the weighted sum of positive deviations from the goals for all materials and over all periods.

Minimize

$$z= \sum_{j=1}^{23} \left(\sum_{k=1}^{11} (w_1*sa(1,j,k)+w_2*sa(2,j,k)+w_3*sa(3,j,k)+w_4*sa(4,j,k)) \right)$$

where the set [w_1 w_2 w_3 w_4] is the AHP weight set of [0,443 0,316 0,169 0,072].

i. Goal Constraints: The following goal constraints are valid for all 23 materials with the corresponding target values. For simplicity, only the constraints for the first material are given.

Quality Goal:

$$\sum_{i_1=1}^{2} (Y1(i_1,k)*K(i_1,1)) + sa(1,1,k) - se(1,1,k) = TK(1)* \sum_{i_1=1}^{2} Y1(i_1,k) \quad \forall k$$

Lead Time Goal:

$$\sum_{i_1=1}^{2} (Y1(i_1,k)*L(i_1,1)) + sa(2,1,k) - se(2,1,k) = TL(1)* \sum_{i_1=1}^{2} Y1(i_1,k) \quad \forall k$$

Delivery Performance Goal:

$$\sum_{i_1=1}^{2} (Y1(i_1,k)*D(i_1,1)) + sa(3,1,k) - se(3,1,k) = TD(1)* \sum_{i_1=1}^{2} Y1(i_1,k) \quad \forall k$$

Capacity Utilization Goal:

$$\sum_{i_1=1}^{2} (Y1(i_1,k)*R(i_1,1)) + sa(4,1,k) - se(4,1,k) = TR(1)* \sum_{i_1=1}^{2} Y1(i_1,k) \quad \forall k$$

j. System Constraints:

Demand Constraints: The sum of ordered quantities to the suppliers should exactly be equal to the quantity demanded for all materials.

$$\sum_{i_1=1}^{2} Y1(i_1,k) = QD(1,k) \quad \forall k$$

Capacity Constraints: The quantity ordered to a supplier in a month should not be greater than its monthly capacity

$$MR(i_1,1) >= Y1(i_1,k) \quad \forall i_1,k$$

The monthly capacities of suppliers are far larger than the total demand for all materials. Since the capacity constraints will be redundant, they are not included in the model. The only exceptions to this situation are labels, sized labels, washing instructions and sized washing instructions.

Labels, sized labels, washing instructions, and sized washing instructions are manufactured through the same facilities and hence share the capacity value. In other words, the total monthly manufactured quantity of these materials should not exceed the supplier's monthly capacity. The capacity constraints for these four materials are not redundant and are given below. The capacity of suppliers for materials 2, 7, 9 and 11 are given in table 4.12.

Table 4.12 The suppliers sequence for each material given in columns.

Material / Supplier	Label 2	Sized Label 7	Washing Instruction 9	Sized Washing Instruction 11	Monthly Capacity (units)
Borneman	1	3	-	4	833333
Wah Sing	2	5	5	2	208333
Paxar	-	4	-	7	1000000
Akın	4	-	3	1	833333
Öztek	5	6	2	5	125000
Teslo	6	1	4	-	166666
Dizayn	7	2	-	-	83333

According to table 4.12, the numbers in the cells are the sequence numbers of suppliers in the rows for the materials in columns. Sign (-) means that supplier does not produce the material coming across.

The capacity constraints are as follows:

Borneman ➡ $Y2(1,K)+Y7(3,K)+Y11(4,K)<=833333 \quad \forall K$

Wah Sing ➡ $Y2(2,K)+Y7(5,K)+Y9(5,K)+Y11(2,K)<=208333 \quad \forall K$

Paxar ➡ $Y7(4,K)+Y11(7,K)<=1000000 \quad \forall K$

Akın ➡ Y2(4,K)+Y9(3,K)+Y11(1,K)<=833333 ∀K

Öztek ➡ Y2(5,K)+Y7(6,K)+Y9(2,K)+Y11(5,K)<=125000 ∀K

Teslo ➡ Y2(6,K)+Y7(1,K)+Y9(4,K)<=166666 ∀K

Dizayn ➡ Y2(7,K)+Y7(2,K)<=83333 ∀K

Integer Constraints: Y1, Y2, …., Y23 are integer variables.

ii-Alternative Model 2

The only difference of this model from model 1 is the goal weights. This model uses the weights given directly by the firm managers. Therefore only the objective function differs.

Objective Function Of Model 2:

Minimize

$$z=\sum_{j=1}^{23}\left(\sum_{k=1}^{11}\left(w_1*sa(1,j,k)+w_2*sa(2,j,k)+w_3*sa(3,j,k)+w_4*sa(4,j,k)\right)\right)$$

where the set [w_1 w_2 w_3 w_4] is equal to [0, 3 0,3 0,2 0,2] which is the set determined by firm managers.

iii-Alternative Model 3

Model 3 again uses the weights found by AHP. It is similar to model 1 but adds some more assumptions to the system. These are:

- Two suppliers should be chosen for each material in each month.
- At least 10% of the minimum demand of each material (among all months' demands) should be ordered from a selected supplier.

The reason why these assumptions are included is because in real life, working with too few or too many suppliers both have negative effects on the company. Too few suppliers may cause long delays in case of any accidents or disasters at the supplier's plant. Too many suppliers may decrease the suppliers trust to the company and the willingness of high quality service. Therefore in order to see the primary and the secondary suppliers, these assumptions are included and the model is modified accordingly.

In addition to model 1 formulation, the decision variables and system constraints below are used.

Additional Decision Variables:

$$X1(i_1,k): \begin{cases} 1 & \text{if } i^{th} \text{ supplier is chosen for the first material in month k} \\ 0 & \text{otherwise} \end{cases}$$

$X2(i_2,k)$, $X3(i_3,k)$, $X4(i_4,k)$,....., $X23(i_{23},k)$ are defined similarly.

Additional System Constraints:

All the constraints are given only for the first material. But all 23 materials are considered in the whole model.

- Number of suppliers is 2.

$$\sum_{i_1=1}^{2} X1(i_1,k) = 2 \qquad \forall k$$

- If a supplier is not selected, quantity ordered to that supplier should be 0. (M is a very large number)

$$X1(i_1,k)*M >= Y1(i_1,k) \quad \forall i_1,k$$

- Minimum number of units ordered from a selected supplier is at least 10% of minimum demand. These constraints will be valid for months that the demand is nonzero.

$$25*X1(i_1,k) <= Y1(i_1,k) \ \forall i_1, \forall k=1..9$$

Minimum number of units to be ordered from a selected supplier for all materials are:

Table 4.13 The minimum amounts that should be placed to a selected supplier.

Material No.	1	2	3	4	5	6	7	8	9	10	11	12
Min. Units	2	86	350	1000	30	15	3300	480	39	100	730	9000
Material No.	13	14	15	16	17	18	19	20	21	22	23	
Min. Units	150	2000	100	25	7500	440	2	6	10	290	4	

- X1....X23 are binary variables.

iv-Alternative Model 4

The last alternative model is generated using model 3 assumptions and the weights given by company managers. The objective function of model 2 and the constraints of model 3 together give out model 4.

b)Formulation Of Outsourcing Supplier Selection Models

There are 14 items concerned in the models according to the ABC analysis performed. Also, 6 time periods and 9 goals are included in the model.

i-Alternative Model 1

Model 1 is the very first model developed and there are no assumptions made on the system for model 1. The weights used in the objective function are the ones found by AHP in section 4.6.3.b. The solution gives the selected suppliers and the quantities ordered to them.

a. Indices

- $i_1, i_2, i_3, \ldots i_{14}$: Number of outsourcing suppliers for items from the 1^{st} to the 14^{th} respectively.

Table 4.14 The number of outsourcing suppliers for each item.

i_1	i_2	i_3	i_4	i_5	i_6	i_7	i_8	i_9	i_{10}	i_{11}	i_{12}	i_{13}	i_{14}
3	2	4	2	4	3	3	2	2	4	2	4	3	3

- k: Number of periods , k=1..6
- j: Number of items, j=1..14

b. Decision Variables:

$Y1(i_1,k)$: units of first item ordered from i_1^{th} supplier in month k.

Similarly there exist $Y2(i_2,k)$ through $Y14(i_{14},k)$.

c. Deviational Variables:

$sa(1,j,k)$: Negative deviation from the quality K1 goal of j^{th} item on month k.

$se(1,j,k)$: Positive deviation from the quality K1 goal of j^{th} item on month k.

$sa(2,j,k)$: Negative deviation from the quality K2 goal of j^{th} item on month k.

$se(2,j,k)$: Positive deviation from the quality K2 goal of j^{th} item on month k.

$sa(3,j,k)$: Negative deviation from the quality K3 goal of j^{th} item on month k.

$se(3,j,k)$: Positive deviation from the quality K3 goal of j^{th} item on month k.

$sa(4,j,k)$: Negative deviation from the quality K4 goal of j^{th} item on month k.

$se(4,j,k)$: Positive deviation from the quality K4 goal of j^{th} item on month k.

$sa(5,j,k)$: Negative deviation from the lead time goal of j^{th} item on month k.

$se(5,j,k)$: Positive deviation from the lead time goal of j^{th} item on month k.

$sa(6,j,k)$: Negative deviation from the delivery performance goal of j^{th} item on month k.

$se(6,j,k)$: Positive deviation from the delivery performance goal of j^{th} item on month k.

$sa(7,j,k)$: Negative deviation from the productivity goal of j^{th} item on month k.

$se(7,j,k)$: Positive deviation from the productivity goal of j^{th} item on month k.

$sa(8,j,k)$: Negative deviation from the capacity utilization goal of j^{th} item on month k.

$se(8,j,k)$: Positive deviation from the capacity utilization goal of j^{th} item on month k.

$sa(9,j,k)$: Negative deviation from the university graduates goal of j^{th} item on month k.

$se(9,j,k)$: Positive deviation from the university graduates goal of j^{th} item on month k.

d. Performance Measures

$K1(i,j)$: Ratio of approval of the samples at first trial for item j of supplier i.

$K2(i,j)$: Ratio of lots accepted of supplier i for item j.

$K3(i,j)$: Comparison of mid-inspection and final inspection defects

$K4(i,j)$: Ratio of non-damaged units.

$L(i,j)$: Ratio of lots delivered by supplier i of item j on time.

$D(i,j)$: Mean units performance of supplier i for item j.

$V(i,j)$: Productivity of supplier i for item j.

$R1(i)$: Capacity utilization ratio of supplier i.

$R2(i)$: Percentage of university graduates among the personnel of supplier i.

where $i= i_1, i_2, i_3,\ldots i_{14}$ for $j=1,2,3,\ldots 14$ respectively.

e. Target Values

$TK1(j)$: Target value for the ratio of approval of the samples at first trial for item j.

$TK2(j)$: Target value for the ratio of lots accepted for item j.

$TK3(j)$: Target value for the comparison of mid-inspection and final inspection defects

$TK4(j)$: Target value for the ratio of non-damaged units.

$TL(j)$: Target value for the ratio of lots delivered for item j on time.

$TD(j)$: Target value for the mean units performance for item j.

$TV(j)$: Target value for the productivity for item j.

$TR1(j)$: Target value for the capacity utilization ratio for item j.

$TR2(j)$: Target value for the percentage of university graduates among the personnel for item j.

where $i= i_1, i_2, i_3,\ldots i_{14}$ for $j=1,2,3,\ldots 14$ respectively.

f. Other Variables

$TY1(i_1)$= Total number of units of first item ordered to supplier i_1.

$$= \sum_{k=1}^{11} Y1(i_1,k) \qquad \forall i_1, k$$

$TY2(i_2)$, $TY3(i_3)$,.... $TY14(i_{14})$ are defined in the same manner.

MR(i): Monthly capacity of supplier i.

QD(j,k): Quantity demanded of item j in month k. All demand are given in Appendix B7 on monthly basis.

where i= i_1, i_2, i_3,...i_{14} for j=1,2,3,...14 respectively.

g. Objective Function: The objective function minimizes the weighted sum of positive deviations from the goals for all materials and over all periods.

Minimize

$$z=\sum_{j=1}^{14} \left(\sum_{k=1}^{6} (w_1*sa(1,j,k)+ w_2*sa(2,j,k)+ w_3*sa(3,j,k)+ w_4*sa(4,j,k)+ w_5*sa(5,j,k)+ w_6*sa(6,j,k)+ w_7*sa(7,j,k)+ w_8*sa(8,j,k)+ w_9*sa(9,j,k))\right)$$

where the set [w_1 w_2 w_3 w_4 w_5 w_6 w_7 w_8 w_9] is the weight set found by AHP which is [0.117 0.162 0.117 0.162 0.153 0.132 0.08 0.049 0.028].

h. Goal Constraints: The following goal constraints are valid for all 14 items with the corresponding target values. For simplicity, only the constraints for the first material are given.

Quality Goals:

K1:

$$\sum_{i_1=1}^{3} (Y1(i_1,k)*K1(i_1,1))+ sa(1,1,k)- se(1,1,k)= TK1(1)* \sum_{i_1=1}^{3} Y1(i_1,k) \quad \forall k$$

K2:

$$\sum_{i_1=1}^{3} (Y1(i_1,k)*K2(i_1,1))+ sa(2,1,k)- se(2,1,k)= TK2(1)* \sum_{i_1=1}^{3} Y1(i_1,k) \quad \forall k$$

K3:

$$\sum_{i_1=1}^{3} (Y1(i_1,k)*K3(i_1,1))+ sa(3,1,k)- se(3,1,k)= TK3(1)* \sum_{i_1=1}^{3} Y1(i_1,k) \quad \forall k$$

K4:

$$\sum_{i_1=1}^{3} (Y1(i_1,k)*K4(i_1,1))+ sa(4,1,k)- se(4,1,k)= TK4(1)* \sum_{i_1=1}^{3} Y1(i_1,k) \quad \forall k$$

Lead Time Goal:

$$\sum_{i_1=1}^{3} (Y1(i_1,k)*L(i_1,1))+ sa(5,1,k)- se(5,1,k)= TL(1)* \sum_{i_1=1}^{3} Y1(i_1,k) \quad \forall k$$

Delivery Performance Goal:

$$\sum_{i_1=1}^{3} (Y1(i_1,k)*D(i_1,1))+ sa(6,1,k)- se(6,1,k)=TD(1)* \sum_{i_1=1}^{3} Y1(i_1,k) \quad \forall k$$

Productivity Goal:

$$\sum_{i_1=1}^{3} (Y1(i_1,k)*V(i_1,1))+sa(7,1,k)- se(7,1,k)= TV(1)* \sum_{i_1=1}^{3} Y1(i_1,k) \quad \forall k$$

Capacity Utilization Goal:

$$\sum_{i_1=1}^{3} (Y1(i_1,k)*R1(i_1,1))+sa(8,1,k)-se(8,1,k)= TR1(1)* \sum_{i_1=1}^{3} Y1(i_1,k) \quad \forall k$$

University Graduates Goal:

$$\sum_{i_1=1}^{3} (Y1(i_1,k)*R2(i_1,1))+sa(9,1,k)- se(9,1,k)=TR2(1)* \sum_{i_1=1}^{3} Y1(i_1,k) \quad \forall k$$

i. System Constraints:

Demand Constraints: The sum of ordered quantities to the suppliers should exactly be equal to the quantity demanded for all materials.

$$\sum_{i_1=1}^{3} Y1(i_1,k) = QD(1,k) \quad \forall k$$

Capacity Constraints: The quantity ordered to a supplier in a month should not be greater than its monthly capacity.

$$MR(i_1,1) >= Y1(i_1,k) \quad \forall i_1,k$$

All items are manufactured by the same processes. Therefore the capacity is distributed between all items. At this circumstance, the monthly quantities of all items ordered to an outsourcing supplier should not exceed its monthly capacity. The capacity constraints are transformed into the following form:

For Supplier Aysan:

Aysan produces items 3 (Panel Block), 5 (Embossed), 8 (Leather Crew), 10 (Service Collar), 12 (Sparkle Flag), and 14 (Traditional). Its in the first sequence for all items. (The sequences can be found in Appendix A4.) The monthly capacity is 50,000 units. Therefore the monthly quantities of items 3, 5, 8, 10, 12 and 14 ordered to Aysan should not exceed 50,000 units.

$$Y3(1,K)+Y5(1,K)+Y8(1,K)+Y10(1,K)+Y12(1,K)+Y14(1,K))<=50000 \quad \forall K$$

For Supplier Canbaz:

Canbaz produces items 4 (Anna-1st sequence), 5 (2nd sequence), 11 (Side Flag-1st sequence), and 13 (Stamp Front-1st sequence). Its monthly capacity is 20,833 units. Therefore the monthly quantities of items 4, 5, 11, and 13 ordered to Canbaz should not exceed 20,833 units.

$$Y4(1,K)+Y5(2,K)+Y11(1,K)+Y13(1,K))<=20833 \quad \forall K$$

For Supplier Çağ:

Çağ produces items 3(2nd sequence), 6(Emily-1st sequence), 7(Face off-1st sequence), 12(2nd sequence) and 13(2nd sequence). Monthly capacity is 10,000 units. Therefore the monthly quantities of items 3, 4, 7, 12 and 13 ordered to Çağ should not exceed 10,000 units.

$$Y3(2,K)+Y6(1,K)+Y7(1,K)+Y12(2,K)+Y13(2,K))<=10000 \quad \forall K$$

For Supplier FB:

FB produces items 1(Coral Garden-1st sequence), 8(2nd sequence), 9(Liberty-1st sequence)and 10(2nd sequence) and its capacity is 8,333 units per month. Therefore the monthly quantities of items 1, 8, 9, and 10 ordered to FB should not exceed 8,333 units.

$$Y1(1,K)+Y8(2,K)+Y9(1,K)+Y10(2,K))<=8333 \quad \forall K$$

For Supplier Kinex:

Kinex produces items 10(3rd sequence), 11(2nd sequence) and 14 (2nd sequence). Therefore the monthly quantities of items 10, 11, and 14 ordered to Kinex should not exceed 12,500 units which is its monthly capacity.

$$Y10(3,K)+Y11(2,K)+Y14(2,K))<=12500 \quad \forall K$$

For Supplier Sesil:

Sesil produces items 3 (3rd sequence), 5 (3rd sequence), 6 (2nd sequence), 7(2nd sequence), 10 (4th sequence), 12 (3rd sequence) and 14 (3rd sequence). Therefore the

monthly quantities of these items ordered to Sesil should not exceed its monthly capacity of 83,333 units.

Y3(3,K)+Y5(3,K)+Y6(2,K)+Y7(2,K)+Y10(4,K)+Y12(3,K)+Y14(3,K))
<=83333
∀K

For Supplier User:

User produces items 1(2nd sequence), 2(Dilliards-1st sequence), 4(2nd sequence), 9(2nd sequence), 12(4th sequence) and 13(3rd sequence). The monthly quantities of these items ordered to User should not exceed its monthly capacity of 70,333 units.

Y1(2,K)+Y2(1,K)+Y4(2,K)+Y9(2,K)+Y12(4,K)+Y13(3,K))<=70833
∀K

For Supplier Zitex:

Zitex produces items 1(3rd sequence), 2(2nd sequence), 3(4th sequence), 5(4th sequence), 6(3rd sequence, and 7(3rd sequence). The monthly quantities of these items ordered to Zitex should not exceed its monthly capacity of 100,000 units.

Y1(3,K)+Y2(2,K)+Y3(4,K)+Y5(4,K)+Y6(3,K)+Y7(3,K))<=100000 ∀K

Integer Constraints: Y1 through Y14 are integer variables.

ii-Alternative Model 2

In alternative model 2, the weights assigned to goals are the ones determined by the company manager subjectively. Therefore only the objective function differs.

Objective Function Of Model 2:

Minimize

$$z=\sum_{j=1}^{14}\ (\sum_{k=1}^{6}\ (w_1*sa(1,j,k)+ w_2*sa(2,j,k)+ w_3*sa(3,j,k)+ w_4*sa(4,j,k)+ w_5*sa(5,j,k)+ w_6*sa(6,j,k)+ w_7*sa(7,j,k)+ w_8*sa(8,j,k)+ w_9*sa(9,j,k)))$$

where the set [w_1 w_2 w_3 w_4 w_5 w_6 w_7 w_8 w_9] is [0.06 0.12 0.06 0.13 0.3 0.13 0.1 0.05 0.05]

iii-Alternative Model 3

Alternative model 3 again uses the weights found by AHP. This model is similar to model 1 but adds some more assumptions to the system. To identify the primary and the secondary suppliers of Sun Tekstil, number of suppliers outsourced for each item is set to 2 in this model.

Additional Assumptions:

- Number of suppliers outsourced for each item every month is 2.
- At least 10% of the minimum demand of each item (among all months' demands) should be ordered from a selected supplier.

Additional Decision Variables:

$$X1(i_1,k): \begin{cases} 1 & \text{if } i_1^{st} \text{ supplier is chosen for the first item in month k} \\ 0 & \text{otherwise} \end{cases}$$

Also there exist $X2(i_2,k)$, $X3(i_3,k)$, $X4(i_4,k)$,....., $X14(i_{14},k)$ defined similarly.

Additional System Constraints:

The constraints below are only for the first item. But, there exist constraints for all 14 items in the model.

- Number of suppliers is 2.

$$\sum_{i_1=1}^{3} X1(i_1,k) = 2 \qquad \forall k$$

- If a supplier is not selected, quantity ordered to that supplier should be 0. (M is a very large number.)

$$X1(i_1,k) * M >= Y1(i_1,k) \quad \forall i_1,k$$

- Minimum number of units outsourced from a selected supplier is at least 10% of minimum demand. These constraints will be valid for months that the demand is nonzero.

$240*X1(i_1,k) <= Y1(i_1,k) \qquad \forall i_1, \forall k=1..9$

Minimum number of units to be ordered from a selected supplier for all items are:

Table 4.15 The minimum amounts that should be placed to a selected supplier.

Material No.	1	2	3	4	5	6	7
Min. Units	240	210	540	75	130	120	200
Material No.	8	9	10	11	12	13	14
Min. Units	230	3	130	85	160	310	800

- X1....X14 are binary variables.

iv-Alternative Model 4

The last alternative model is generated using model 3 assumptions and the weights given by company managers. In other words, the objective function of model 2 and the constraints of model 3 give out model 4.

4.6.7. Solution To The Mathematical Models

All the mathematical models are written in Lingo 3.1 Optimization Software and solved.

Goal constraints are first simplified at three steps and then written in Lingo. In the materials supplier selection model, the simplification of the quality goal constraint of the first material is given as an example. Lead time, delivery performance and capacity utilization goal constraints are simplified in the same manner.

Step 1: The constraint is in its original form as given in model formulation in section 4.6.6.a.

$Y1(1,k)*K(1,1)+Y1(2,k)*K(2,1)+sa(1,1,k) - se(1,1,k) = TK(1)*[Y1(1,k)+Y1(2,k)]$

Step 2: Right hand side value is subtracted from both sides.

[K(1,1)-TK(1)]*Y1(1,k) + [K(2,1)-TK(1)]*Y1(2,k) + sa(1,1,k) - se(1,1,k) = 0

Step 3: The multiplication factors of Y1(1,k) and Y1(2,k) are called $Coefficient_K(1,1)$ and $Coefficient_K(2,1)$ respectively.

$Coefficient_K(1,1)$* Y1(1,k) + $Coefficient_K(2,1)$* Y1(2,k) + sa(1,1,k) - se(1,1,k) = 0

Similarly, all the goal constraints of the outsourcing supplier selection models are simplified. Simplification of the quality K1 goal constraint of the first item is shown as an example.

Step 1:Y1(1,k)* K1(1,1) + Y1(2,k)*K1(2,1) + sa(1,1,k) - se(1,1,k) = TK1(1)*[Y1(1,k)+Y1(2,k)]

Step 2: [K1(1,1)-TK1(1)]*Y1(1,k) + [K1(2,1)-TK1(1)]*Y1(2,k) + sa(1,1,k) - se(1,1,k) = 0

Step 3:$Coefficient_{K1}(1,1)$* Y1(1,k) + $Coefficient_{K1}(2,1)$* Y1(2,k) + sa(1,1,k) - se(1,1,k) = 0

All coefficients are calculated for every supplier and item. The coefficients of materials supplier selection models are given in appendix B8 and the coefficients of outsourcing supplier selection models are given in Appendix B9.

In addition to the model formulation given in the previous section, in order to be able to compare the results with the current situation, three measures are determined. These measures are the number of units accepted, the number of units on-time and total cost. The first two of these measures are already the goals determined by the firm. That means the actual system is compared with the proposed in terms of firm's goals. The third measure, total cost, is not one of the company objectives. But costs are an inevitable part of manufacturing. Therefore to observe the effect of the proposed system on costs, total purchasing cost is calculated in all solutions.

a) Comparison Measures For Materials' Supplier Selection Models

The results are compared in terms of number of units accepted (K goal), number of units on-time (L goal) and total purchasing costs. The actual values of these measures are calculated from the data collected. The proposed system values are calculated as defined below.

1. Number Of Units Accepted Of Material j (TQ(j)): The suppliers quality performance measure (K value) is multiplied by the total quantity ordered to that supplier. This term is found for all the suppliers of material j and added to give the total number of units accepted of material j.

The number of units accepted of polyester coil in model 1 is calculated as a sample.

$$TQ(1) = \sum_{k=1}^{11} Y1(1,k)*K(1,1) + \sum_{k=1}^{11} Y1(2,k)*K(2,1)$$

$$= TY1(1)*K(1,1) + TY1(2)*K(2,1)$$

$$= 3807*0,962 + 14261*1 = 17923$$ (Can be seen in Table D2.1)

2. Number Of Units Arriving On-Time Of Material j (TT(j)): For each material, the quantity ordered to a supplier is multiplied by its lead-time performance measure. The terms achieved by this way for all suppliers are added which gives the number of units on-time.

The number of on-time units for polyester coil in model 1 is:

$$TT(1) = \sum_{k=1}^{11} Y1(1,k)*L(1,1) + \sum_{k=1}^{11} Y1(2,k)*L(2,1)$$

$$= TY1(1)*L(1,1) + TY1(2)*L(2,1)$$

$$= 3807*0,697 + 14261*0,656 = 12009$$ (Can be seen in Table D2.2)

3. Total Purchasing Cost of Material j (Cost(j)): The purchasing costs of each material is given in Appendix B6 on monthly basis. The total cost is the purchasing cost of the material throughout the 11 months considered.

The total cost of polyester coil in model 1 is:

$$Cost(1)= \sum_{k=1}^{11} [Y1(1,k) * P1(1,k)] + \sum_{k=1}^{11} [Y1(2,k) * P1(2,k)]$$

where P1 is the purchasing cost matrix of material 1 with the suppliers on the rows and months on the columns. The calculation can be seen in the table below. The monthly sum is the multiplication of the quantity ordered by the purchasing cost.

Month	Quantity Ordered From First Supplier	Purchasing Cost	Monthly Sum	Quantity Ordered From Second Supplier	Purchasing Cost	Monthly Sum
1	64	1500	96000	238	1500	357000
2	55	1523	83765	203	1500	304500
3	506	1540	779240	1897	1485	2817045
4	151	1500	226500	563	1500	844500
5	492	1765	868380	1844	1691	3118204
6	581	1822	1058582	2179	1822	3970138
7	1012	1800	1821600	3794	1450	5501300
8	275	1781	489775	1031	1850	1907350
9	644	1813	1167572	2415	1813	4378395
10	22	1850	40700	82	1850	151700
11	5	1850	9250	15	1850	27750
		Sum	6641364		Sum	23377882

The total cost is simply the addition of the sums belonging to two suppliers given the table.

Cost(1)= 6641364 + 23377882 =30.019.246 TL (All values are in 000's. Can be seen in Table D2.3)

These measures can be computed by the Lingo solver when included in the model. The additional statements for these measures can be seen in the last part of Lingo formulation given in Appendix C1.

b) Comparison Measures For Outsourcing Supplier Selection Models

The results of the proposed goal programming models are compared with the current system in terms of quality K2 goal (number of units accepted) and lead-time goal L(number of units on-time). In addition, total purchasing costs are compared. Number of units accepted and on-time are calculated in Lingo as defined below.

1. Number Of Units Accepted Of Item j (TQ(j)): The outsourcing suppliers' quality performance measure (K2 value) is multiplied by the total quantity ordered to that supplier. This term is found for all the suppliers of item j and added to give the total number of units accepted of item j.

The number of units accepted of Coral Garden in model 1 is calculated as an example.

$$TQ(1)=\sum_{k=1}^{6} Y1(1,k)*K2(1,1)+\sum_{k=1}^{6} Y1(2,k)*K2(2,1)+\sum_{k=1}^{6} Y1(3,k)*K2(3,1)$$

$$= TY1(1)*K2(1,1) + TY1(2)*K2(2,1) + TY1(3)*K2(3,1)$$

2. Number Of Units Arriving On-Time Of Item j (TT(j)): For each item, the quantity ordered to an outsourcing supplier is multiplied by its lead-time performance measure (L value). The terms achieved by this way for all suppliers are added which gives the number of units on-time.

The number of on-time units for Coral Garden in model 1 is:

$$TT(1)=\sum_{k=1}^{6} Y1(1,k)*L(1,1)+\sum_{k=1}^{6} Y1(2,k)*L(2,1)+\sum_{k=1}^{6} Y1(3,k)*L(3,1)$$

$$= TY1(1)*L(1,1) + TY1(2)*L(2,1) + TY1(3)*L(3,1)$$

The additional statements for these two measures can be seen in the last part of Lingo formulation given in Appendix C2.

Other than these measures, total purchasing costs for all items are found. Sun Tekstil applies a certain pricing policy for all suppliers outsourced. The price offered to every supplier is same. It is based on the standard minutes of the item purchased and the quantity ordered. The price of one minute of sewing is 90,000TL. This is

multiplied by the total standard minutes of the item to give the service price. Upon the unit service price, 240,000TL is added for packaging. The last term added to the price is called the responsibility share price. As the quantity ordered increases responsibility share price decreases. The amount of responsibility shares are given in table 4.16.

Table 4.16 Responsibility Share Price

Quantity Ordered Between	Additional Price (TL)
[0-999]	375,000
[1000-2499]	235,000
[2500-4999]	155,000
[5000-9999]	90,000
[10000-]	60,000

An example cost calculation is given below.

The number of Coral Garden units ordered to FB in February 2002 is 7327 according to model 1. The standard time of Coral Garden is 7.59minutes. The unit price offered for this lot is found by adding the following three terms.

1st Term - Unit Service Price = (7.59) * 90,000 = 683,100 TL
2nd Term - Packaging = 240,000 TL
3rd Term - Responsibility Share = 90,000 TL (From Table 4.16)
Unit Price = (683,100) + (240,000) + (90,000) = 1,013,000 TL

The units price offered to the supplier is the unit purchasing costs of Sun Tekstil. Therefore the total purchasing costs are found by multiplying the unit costs by the quantities of the lots.

4.7 Results And Comparison With The Current System

All the alternative models are solved. The selected suppliers and the quantities ordered to them are found.

4.7.1 Results Of Materials' Supplier Selection Models

The results of models 1, 2, 3 and 4 are given in appendix D1. The comparison measures (Number of units accepted, on-time and total purchasing cost) calculated from the solutions are given in appendix D2. The overall results are given in table 4.18. The description of the models is shortly as follows:

Table 4.17 The alternative models developed.

Model 1	AHP Weights
Model 2	Firm Weights
Model 3	AHP Weights, NOS=2
Model 4	Firm Weights, NOS=2

Table 4.18 Comparison of alternative models with the actual values in terms of total number of units accepted, on-time and purchasing cost.

	Model 1	Model 2	Model 3	Model 4	Actual
Total Number Of Units Accepted	19,212,015	19,196,158	19,216,374	19,177,976	18,629,421
Total Number Of Units On-Time	18,106,064	18,006,108	18,083,523	17,957,087	15,167,296
Total Purchasing Cost (000 TL)	1,051,583,144	1,011,418,362	1,078,297,171	1,051,590,818	1,104,403,086

In order to see the improvements clearly, the graphs of total units accepted, total units on-time and total cost are drawn comparatively within alternative models.

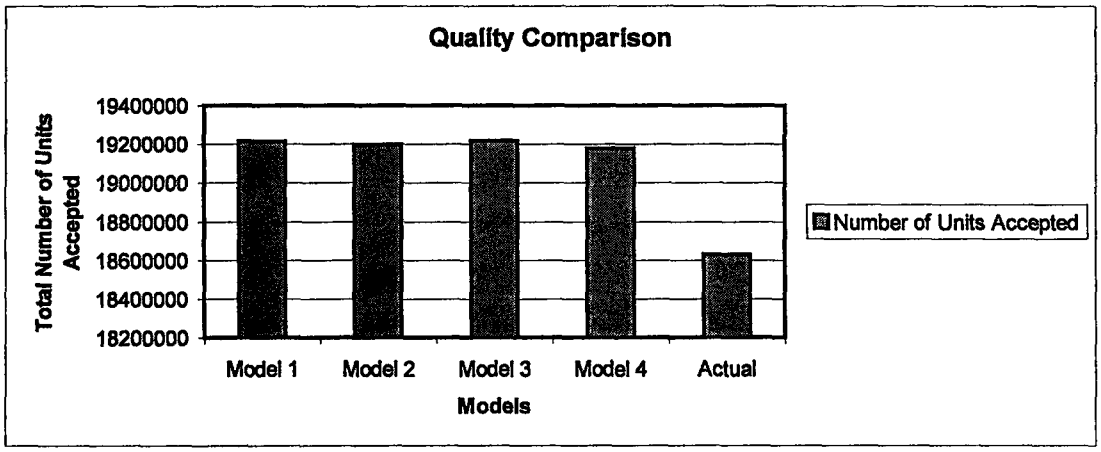

Figure 4.1 Quality comparison of the proposed model and the current system in terms of the number of units accepted. (Source: Table 4.18)

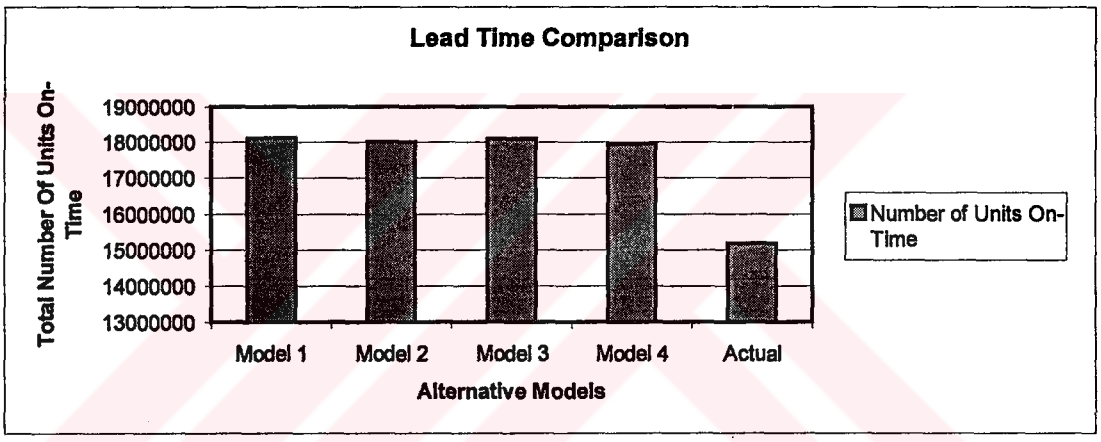

Figure 4.2 Lead-Time comparison of the proposed model and the current system in terms of the number of units accepted. (Source: Table 4.18)

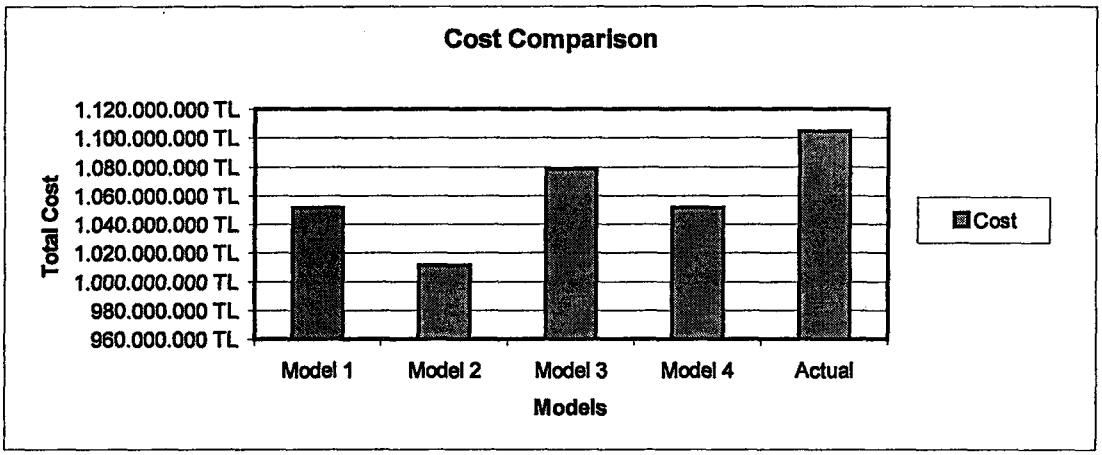

Figure 4.3 Cost comparison of the proposed models and the current system. (Source: Table 4.18)

When the current situation and the model results are compared, there is quite an increase in the total number of units accepted and the total number of units on-time in all four models. This shows the proposed methods are much powerful compared to current system. The total number of units accepted increases from around 18,6 millions to around 19 millions. The total number of units on-time increased from around 15 millions to around 18 millions. In addition to this, even though there is no cost objective among the firm's goals, the purchasing costs decreased slightly. The overall cost decreased about 50 billion TL.

In appendix D3, the percent changes in units accepted, on-time and cost measures occurred in the alternative models are given for all items. Below, are the graphical representations of these changes.

Figures 4.4 , 4.5 and 4.6 show the percent changes in the units accepted, units on-time and costs on material basis.

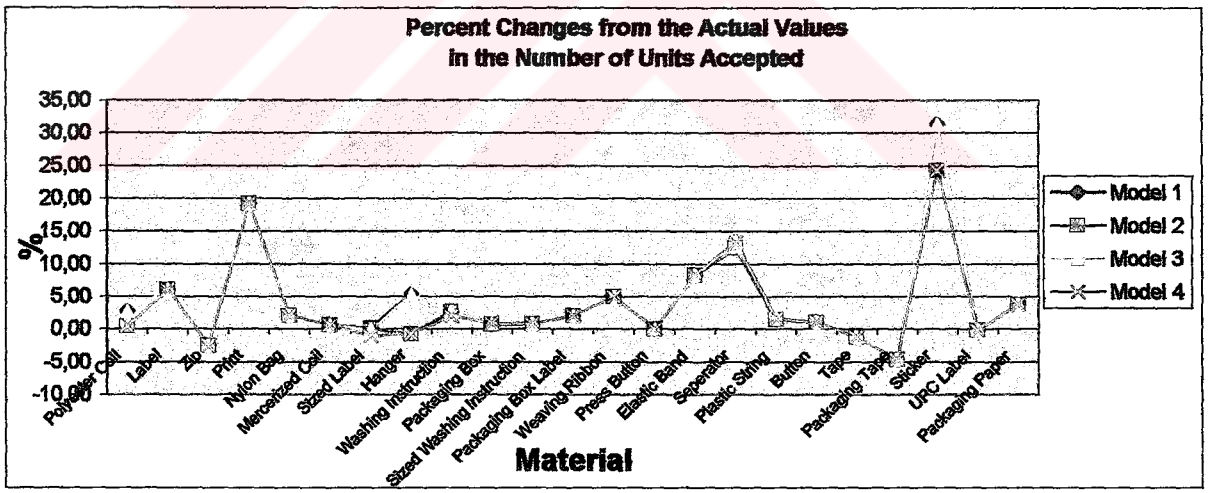

Figure 4.4 The percent change in the results of each model from the actual values in terms of number of units accepted. (Source: Table D3.1)

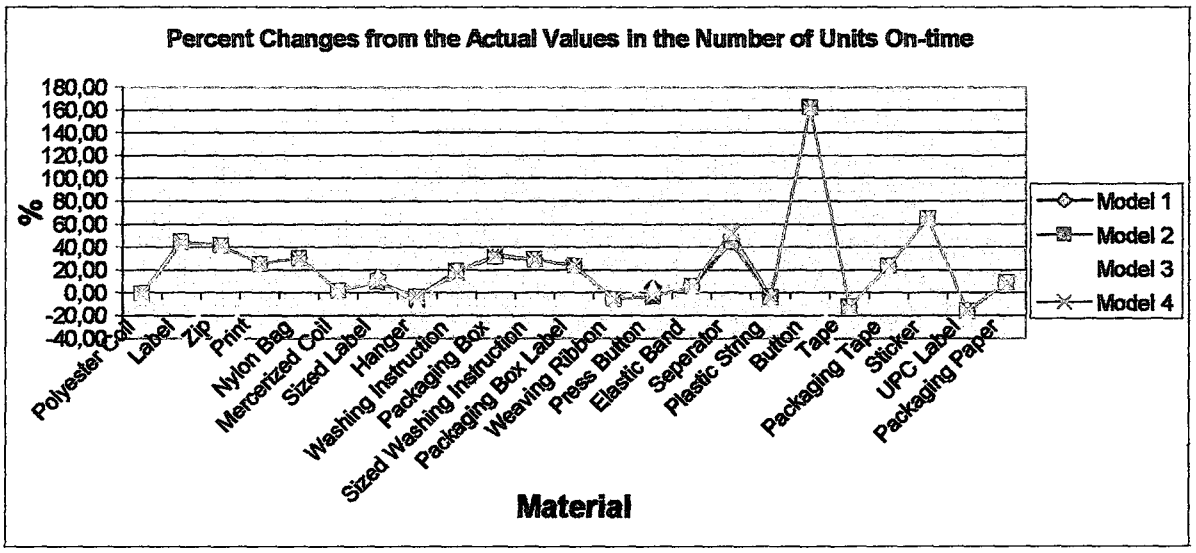

Figure 4.5: The percent change in the results of each model from the actual values in terms of number of units on-time. (Source: Table D3.2)

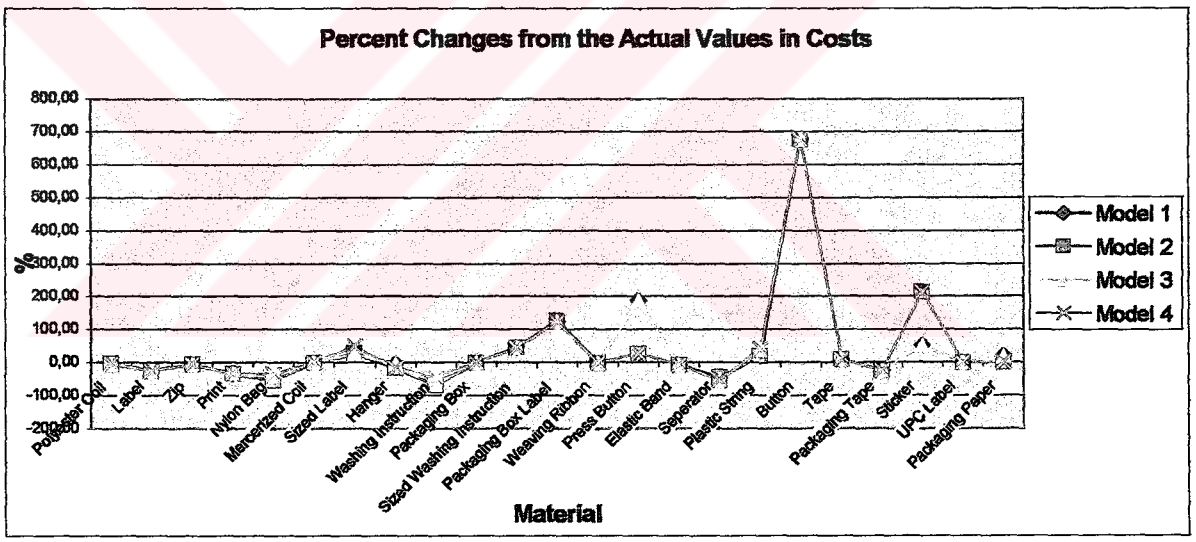

Figure 4.6: The percent change in the results of each model from the actual values in terms of total purchasing costs. (Source: Table D3.3)

In all graphs, positive points represent that the proposed model values are greater than the actual values whereas negative points mean the proposed values are decreased compared to actual values. In figure 4.4 and 4.5, positive points are favored. However, in figure 4.6, positive points show the increments in purchasing costs and are not favored. It can be clearly seen in figure 4.4, number of units accepted deteriorate only in 3 of the materials (zips, tapes and packaging tapes) and

the values of the other 20 materials show improvements. In figure 4.5, it is seen that, number of units on-time also decreased for only 3 of the materials (hangers, tapes and UPC labels). The values for the rest of the materials either stayed about the same as the actual values or improved.

When the purchasing costs are considered, it is seen in figure 4.6, quite many of the materials' costs have increased. Especially the purchasing cost of buttons increased by 700%.

But, certainly there is a tradeoff between increasing the quality and lead-time performances against the purchasing costs. Therefore the cost increase in some of the materials is considered to be reasonable since the overall decrements in costs overweigh increments.

The results of proposed models are also compared with the current system in terms of the number of suppliers selected. In the operating system, Sun Tekstil works with 57 suppliers of which 13 are foreign suppliers. Table 4.19 below gives the number of local and foreign suppliers selected by the proposed models. It is seen in the table that the number of selected suppliers decreases in a recognizable way. That means many of the suppliers do not perform well enough for Sun Tekstil objectives. Firm can meet its desired levels of goals with a fewer number of suppliers. In the first and third models, 14 local and 5 foreign suppliers are eliminated from the supplier base, in the second model 6 foreign suppliers are eliminated instead of 5. The largest number of selected suppliers is given by model 4 where the number of local and foreign suppliers is decreased by 8 and 5 compared to the current system.

Table 4.19 Number of suppliers selected in each model.

	Model 1	Model 2	Model 3	Model 4	Actual
Local Suppliers	28	28	28	32	44
Foreign Suppliers	8	7	8	8	13
Total	36	35	36	40	57

It is shown upto this point that all the proposed models work properly and are beneficial compared to the operating system at Sun Tekstil. Another perspective is to compare the alternative models within themselves.

First of all, models 1 and 2 provide better solutions than models 3 and 4 in terms of all three measures. This is an expected result because models 3 and 4 involve more constraints and hence a smaller feasible region is formed. However, the firm may prefer models 3 or 4 to models 1 and 2 according to their purchasing strategies. Especially, in economic markets where there is a high degree of uncertainty, setting the number of selected suppliers to a certain number can be more advantageous.

Secondly, model 1 performs better than model 2, and model 3 performs better than model 4 in terms of all three comparison measures. This is also an expected result since the firm's weights for quality and lead-time goals are lower than the AHP weights. But, still the firm may chose to use model 2 or 4 solutions since the weights of goals, so the solutions, are for their desires and purposes.

4.7.2 Results Of Outsourcing Supplier Selection Models

The suppliers to be used for outsourcing and the quantities ordered to them are given in Appendix D4. The comparative results of four models according to the number of units accepted, number of units on-time and total purchasing costs are given in appendix D5. Table 4.19 gives a short description of all four models and table 4.20 compares the overall results of alternative models with the actual system.

Table 4.20 Main description of alternative models.

Model 1	AHP Weights
Model 2	Firm Weights
Model 3	AHP Weights, NOS=2
Model 4	Firm Weights, NOS=2

Table 4.21 Comparison of alternative models.

	Model 1	Model 2	Model 3	Model 4	Actual
Total Number Of Units Accepted	522,327	517,979	522,226	518,089	464,752
Total Number Of Units On-Time	299,786	302,371	299,290	301,888	175,628
Total Purchasing Cost (000 TL)	574,639,805	574,536,885	575,462,305	575,931,640	581,680,360

It can be seen from the table that the proposed models increased the number of units accepted and on-time in a noticeable amount which was intended at the beginning of the project. In addition, the purchasing costs have decreased which will bring more benefits to Sun Tekstil. In order to show the improvements made by the models more clearly, graphs below are drawn.

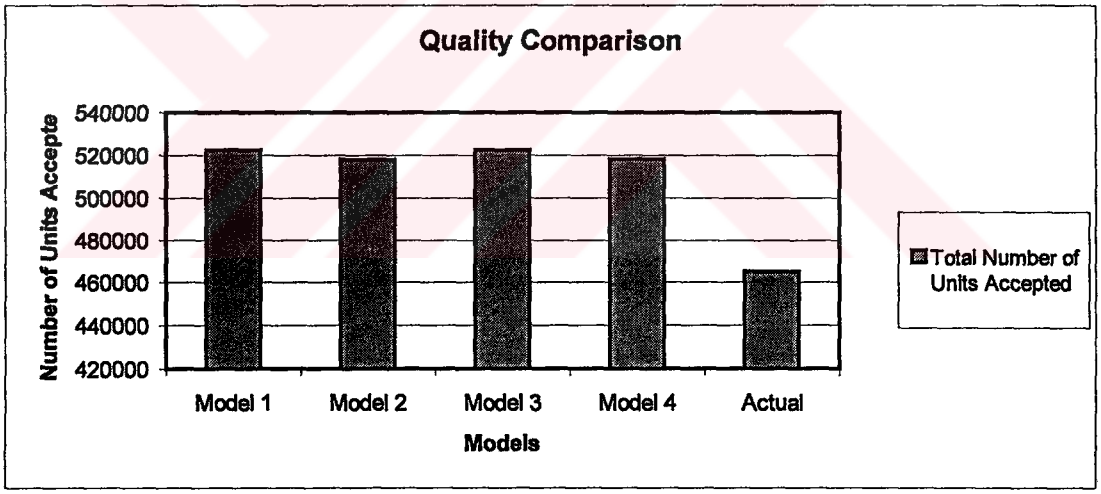

Figure 4.7 Total number of units accepted achieved by the models and the actual value. (Source: Table 4.21)

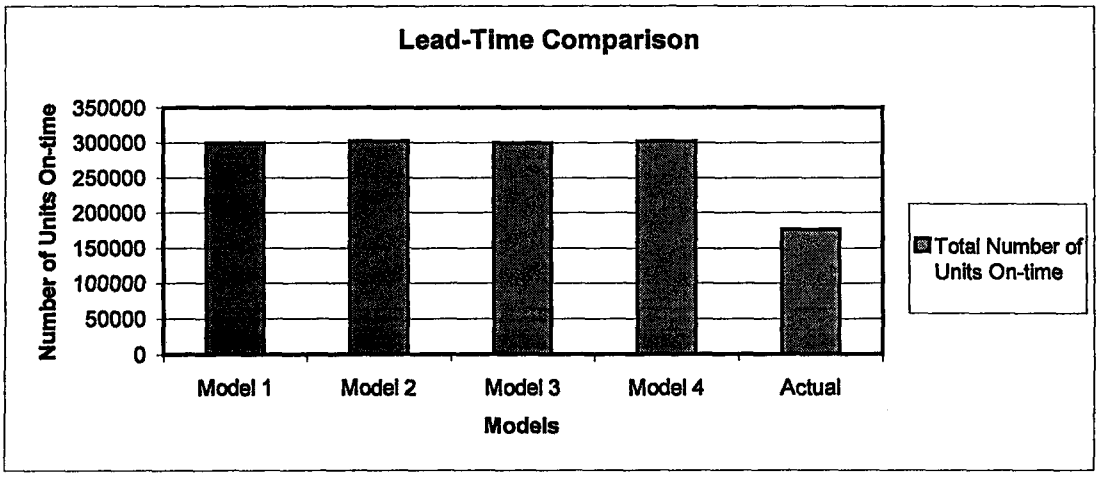

Figure 4.8 Total number of units on-time achieved by the models and the actual value. (Source: Table 4.21)

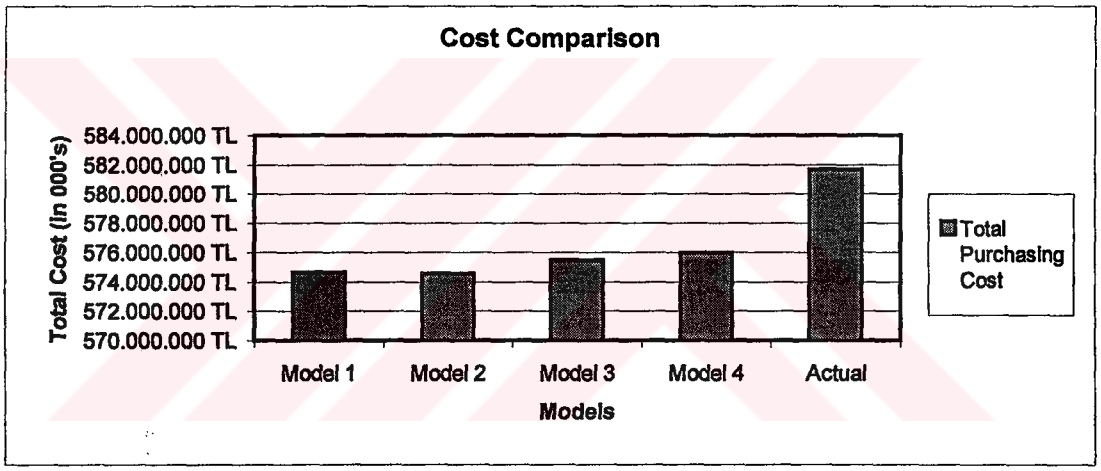

Figure 4.9 Total purchasing costs achieved by the models and the actual value. (Source: Table 4.21)

Figures 4.7, 4.8 and 4.9 show that there is not much difference among the alternative model results. But, still all of them achieved quite good improvements when compared with the current system. The improvements made can also be seen by the percent changes of alternative model values from the actual values. The changes achieved in the units accepted, units on-time and total cost are given in appendix D6. To study results item by item, the graphs belonging to percent changes are drawn.

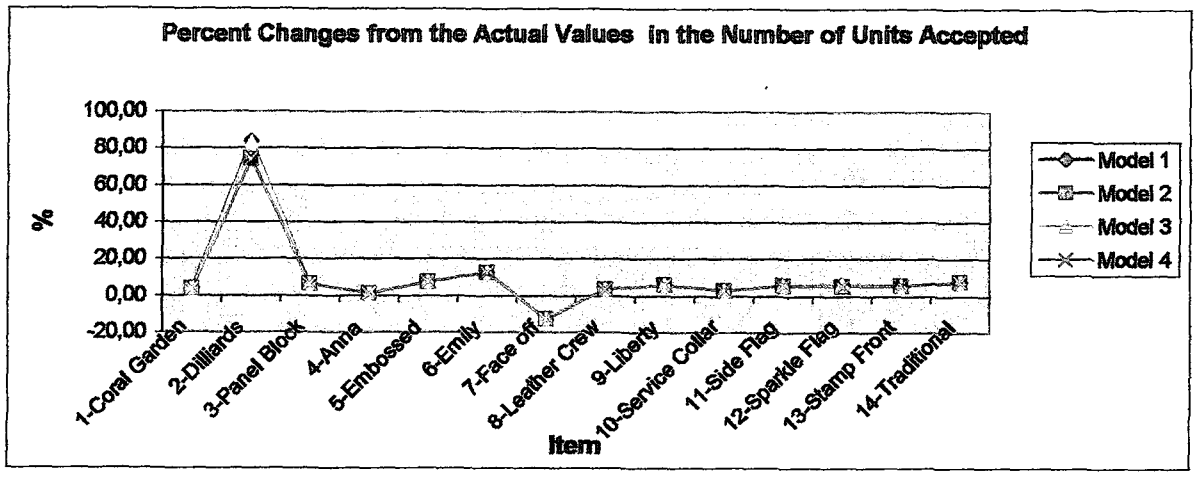

Figure 4.10 Percent changes in number of units accepted item by item.

(Source: Table D6.1)

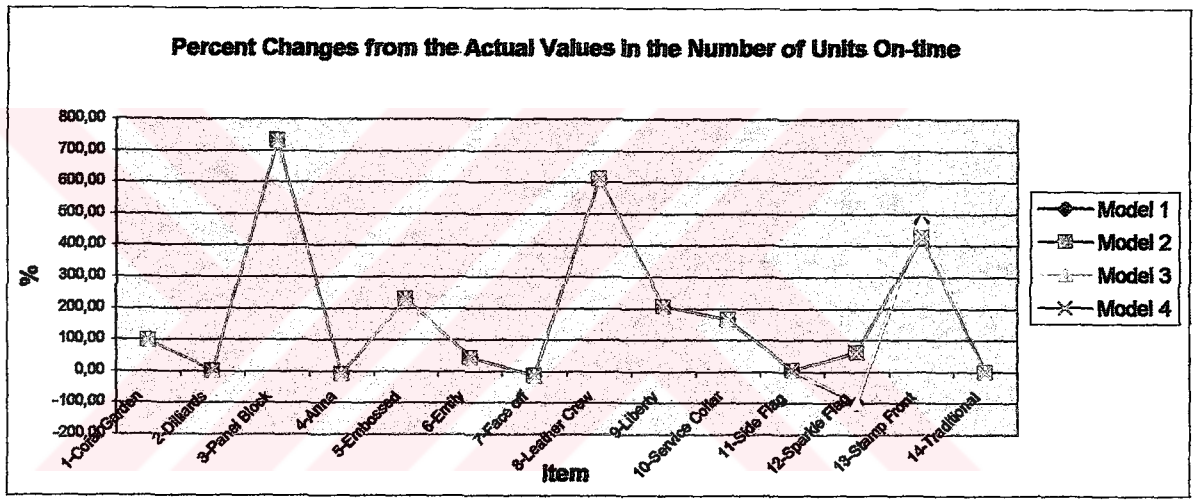

Figure 4.11 Percent changes in number of units on-time item by item.

(Source: Table D6.2)

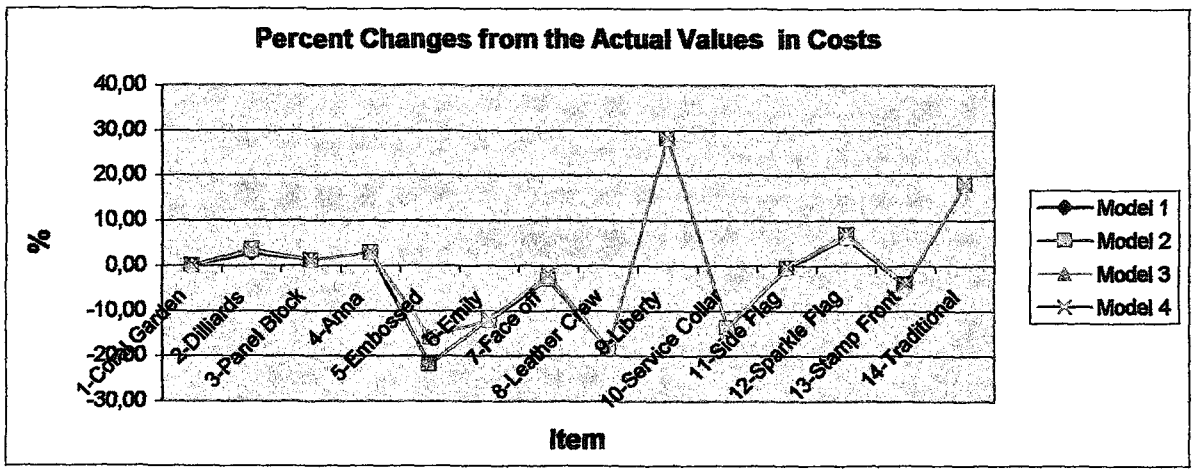

Figure 4.12 Percent changes in purchasing costs item by item. (Source: Table D6.3)

As can be seen in figure 4.10, only one of the items (Face off) showed a decrement in its number of units accepted. There is also a single item which deteriorated in terms of number of units on-time. That is Sparkle Flag. When the purchasing costs are considered, 7 of the items have decreased costs and the other 7 have increased costs compared to the current system. But, in overall perspective, purchasing costs are decreased.

Upto this point, it is seen that all the proposed models are stronger over the current system. This means a great deal of the problems faced by Sun Tekstil will be solved with the proposed system.

Another important discussion is which model to select and use. When models 1 and 2 are compared with models 3 and 4 respectively, it is seen that models 1 and 2 perform better than 3 and 4. This is an expected result because models 3 and 4 add the assumption of using exactly 2 suppliers. Sun Tekstil may still prefer to use one of these models if the managers decide to base their purchasing strategy on a constant number of suppliers.

On the other hand, when the difference in the goal weights are considered (Model 1 vs. Model 2, Model 3 vs. Model 4), it can be said that there is no certain superiority of one over the other. There is a trade-off between the number of units accepted and on-time. Using the weights found by AHP, a larger value of number of units accepted is achieved. That means model 1 (3) perform better than model 2 (4) in terms of number of units accepted. However, using the weights determined by the company managers, a larger value of number of units on-time is achieved. That means model 2 (4) perform better than model 1 (3) in terms of number of units on-time. This situation can be seen in figure 4.13.

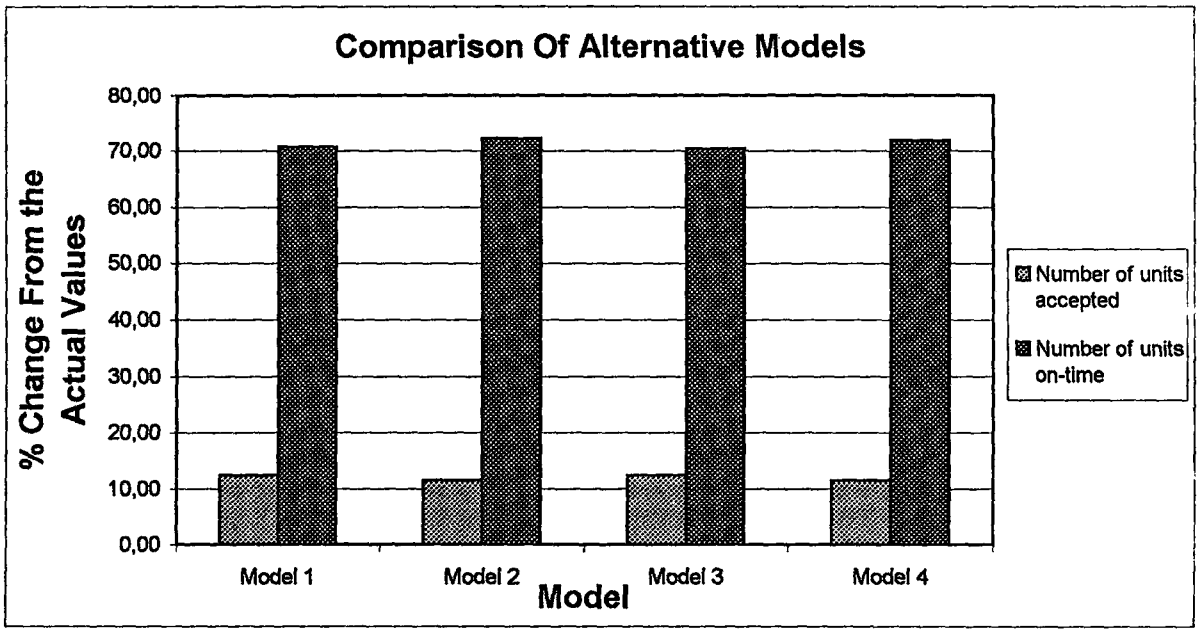

Figure 4.13 Alternative models are compared in terms of units accepted and on-time.

When deciding on which model to use, this trade-off between the two measures should be taken into account. According to the future marketing strategy, Sun Tekstil may prefer either 'higher number of units accepted' plan or 'higher number of units on-time' plan.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study proposes a solution for the supplier selection problem of Sun Tekstil which is a company operating in the textile industry producing sports outfit. The problem is studied in two sub-modules: Supplier selection for materials purchasing and supplier selection for outsourcing suppliers. The methodology followed for both problems is similar. The solution approach used weighted goal programming. The proposed model selects the best suppliers considering Sun Tekstil objectives and allocates the amounts to be purchased from them. Four alternative models are developed, two of which uses the weights found by AHP (Model 1 and 3) and the other two models uses the weights determined by the company managers (Model 2 and 4). Also, of these four models, two of them do not pose any restrictions on the number of suppliers selected (Model 1 and 2) whereas the other two selects exactly two suppliers for each item (Model 3 and 4).

All alternative models are solved by Lingo. In order to compare the results, the number of units accepted and on-time are calculated for all solutions generated by alternative models. These two measures are among the main objectives of Sun Tekstil. In addition to these measures, also total purchasing cost of each purchasing plan is computed.

The proposed models achieved quite good improvements in materials' purchasing. Table 5.1 shows the values of the number of units accepted, on-time and total costs achieved by alternative models as well as their actual values.

Table 5.1 Comparison of alternative models with the actual values in terms of total number of units accepted, on-time and purchasing cost.

	Model 1	Model 2	Model 3	Model 4	Actual
Total Number Of Units Accepted	19,212,015	19,196,158	19,216,374	19,177,976	18,629,421
Total Number Of Units On-Time	18,106,064	18,006,108	18,083,523	17,957,087	15,167,296
Total Purchasing Cost (000 TL)	1,051,583,144	1,011,418,362	1,078,297,171	1,051,590,818	1,104,403,086

According to the table, all alternative model solutions has improved the number of units accepted, on-time and purchasing costs over the current system. Furthermore, it can be seen that the best improvement in terms of units accepted is achieved by model 3 which uses the weights found by AHP and selects exactly 2 suppliers for each item. The best improvement in terms of units on-time is achieved by model 1 which again uses the weights of AHP and does not have a limit on the number of suppliers selected. On the other hand, the smallest purchasing cost is given by model 2 which uses the weights determined by firm's managers and does not have restrict the number of suppliers. Different purchasing plans are presented to Sun Tekstil by these four alternative models. The company will surely decide to employ the one which fits its future purchasing strategy best. In conclusion, the proposed system is proved to be more powerful than the current one and it will bring many benefits to Sun Tekstil.

In the outsourcing problem, the solutions found by the proposed models again performed well in terms of number of units accepted, on-time and total purchasing costs. The values of these three measures obtained by the proposed models and their actual values are given in table 5.2. (All alternative models are defined similar to materials' purchasing with respect to the weights assigned and the restrictions on the number of suppliers selected.)

Table 5.2 Comparison of alternative models.

	Model 1	Model 2	Model 3	Model 4	Actual
Total Number Of Units Accepted	522,327	517,979	522,226	518,089	464,752
Total Number Of Units On-Time	299,786	302,371	299,290	301,888	175,628
Total Purchasing Cost (000 TL)	574,639,805	574,536,885	575,462,305	575,931,640	581,680,360

As can be seen from the table, model 1 performs best in terms of number of units accepted, model 2 performs best in terms of number of units on-time and purchasing cost. In addition, all four models achieved good improvements in he number of units accepted and on-time. Also, all models showed reasonable decrements in purchasing costs. This situation shows that the proposed system is beneficial for Sun Tekstil in its outsourcing activities.

5.2 Recommendations

In the further steps of this study, target levels can be changed. New solutions can be generated based on different target levels. These solutions can be compared with each other according to their performances of units accepted, on-time and costs. The effect of target increase/decrease on the performance of the system can be analyzed.

Data values used in this study should be hold for a longer time and more systematically. Using these data, new performance measures, target values should be calculated accordingly. Also, the constraints arising from technological changes and interior activities of the firm should be added to the mathematical model formulations. Taking into consideration all these aspects, a dynamic programming model can be built and solved to give the selected suppliers and the quantities ordered to them.

The solutions found in this study are not permanent. The performance measures, target values, demand figures etc. should be updated periodically and the mathematical model should be resolved. In order to make this procedure easier, a decision support system can be incorporated. This system can be integrated into the EDS software in Sun Tekstil.

By the help of this decision support system, performance measures of suppliers can be updated automatically every month (or 3 months) based on the past period's data of purchasing. Also, the target values, coefficients in the goal programming model can be updated automatically. Demand requirements in the model should be the forecasted demand figures for the following period. When all necessary values are installed from the decision support system, the model can be resolved. The solutions of the model, that is selected suppliers and the quantities to be ordered to them, can be loaded to the decision support system. In this way, the proposed approach in this thesis will consume less time. Hence the purchasing decisions will both be more effective and efficient.

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APPENDICES

APPENDIX A1

SUPPLIER INFORMATION FORM

Date:

Name of the Firm:

Address:

Telephone number:

Fax Number:

e-mail:

Tax Number:

Registered Tax Office:

Authorized Person:

Product Groups: Please, specify whether the products are produced in plant or subcontracted

.....

.....

.....

.....

	Production in Plant	**Subcontracting or Retail**
Sales		
Production Capacity (Monthly):		
Product 1:		
Product 2:		
Product 3:		

Applied Interest Rate(Monthly): (%)

Means of Distribution, Number of Vehicles:

Hours of Distribution:

Certificates Owned:

Communication Using Internet:

Follow-up of Orders Using Internet

Geographical Location:

Time in which the Sample is Supplied:

Shipping Information:

Contact with the Customer during Production of Order:

References:

APPENDIX A2

Material - Supplier Information

Material Number	Material	Supplier Number	Supplier	Yearly Capacity (units)
1	Polyester Coil	1	Muteks	None
		2	Coats	100000
2	Label	1	Borneman	10000000
		2	Wah Sing	2500000
		3	Desan	5000000
		4	Akın Etiketçilik	10000000
		5	Öztek Etiket	1500000
		6	Teslo	2000000
		7	Dizayn	1000000
		8	Eticart	1000000
		9	New Yuen	2500000
		10	Wing Tak	2500000
3	Zip	1	YKK	11000000
		2	Muteks	None
		3	Opti Fermuar	2500000
4	Print	1	Heat Seal	250000000
		2	Printec	25000000
		3	Chris Kay	225000000
		4	Rapid Transfer	62500000
5	Nylon Bag	1	Emek Plastik	6000000
		2	Ada Plastik	4666667
		3	Gürdemir Plastik	1000000
		4	Selda Plastik	1000000
		5	Muteks	None
		6	Altın	1533333
		7	Bora Tekstil	3333333
6	Mercerized Coil	1	Muteks	None
		2	Coats	
7	Sized Label	1	Teslo	*
		2	Dizayn	*
		3	Borneman	*
		4	Paxar	12000000
		5	Wah Sing	*
		6	Öztek Etiket	*
8	Hanger	1	Tam Plastik	9000000
		2	Randy Hangers	10000000
9	Washing Instruction	1	Intermat	2500000
		2	Öztek Etiket	*
		3	Akın Etiketçilik	*
		4	Teslo	*
		5	Wah Sing	*
10	Packaging Box	1	Onurcan Ambalaj	571429
		2	Orsan Ambalaj	428571
11	Sized Washing Instruction	1	Akın Etiketçilik	*
		2	Wah Sing	*
		3	Ayrıntı	800000
		4	Borneman	*
		5	Öztek Etiket	*
		6	Kuloğlu	1000000
		7	Paxar	*

Material Number	Material	Supplier Number	Supplier	Yearly Capacity (units)
12	Packaging Box Label	1	Borneman	12000000
		2	Hobby Etiket	4000000
		3	İstanbul Etiket	1500000
		4	Grafficart	2000000
		5	RVL	2500000
		6	Profit	2000000
		7	Kwan Tat	2000000
13	Weaving Ribbon	1	Muteks	None
		2	Suner	5000
14	Press Button	1	Scovill	600000
		2	Ching Fung	1500000
		3	YKK	2500000
15	Elastic Band	1	Bam Tekstil	1000000
		2	Muteks	None
		3	Armoni	10000000
16	Separator	1	Onurcan Ambalaj	10000000
		2	Özgün Ambalaj	1500000
17	Plastic String	1	Şık Düğme	180000000
		2	Muteks	None
18	Button	1	Primoda	2000000
		2	Muteks	None
		3	Lauragel	150000000
		4	Banner	150000000
19	Tape	1	Özgül Kırtasiye	None
		2	Baran Kırtasiye	None
20	Packaging Tape	1	Megabant	15000
		2	Atılım Ambalaj	25000
21	Sticker	1	Merve	250000
		2	Vipeks	500000
		3	Primoda	500000
22	UPC Label	1	Softek	1500000
		2	Santra	2500000
23	Packaging Paper	1	Bayramoğlu	100000
		2	Merve	150000
		3	Softek	150000

* : Capacity for labels, sized labels, washing instructions, and sized washing instructions are shared.

Capacity of signed supplier is given in the previous materials.

None: These suppliers are not producers, instead they are traders. There is no capacity limitation.

Darkened suppliers are foreign suppliers.

APPENDIX A3

Outsoutcers' Information

	Yearly Capacity (units)	White Collar	Blue Collar	Total Number of Employees	University Graduates
Aysan	600000	12	65	77	8
Şanbaz	250000	28	187	215	17
Çağ	120000	16	48	64	10
FB	100000	8	43	51	6
Klnex	150000	18	52	70	12
Sesil	1000000	84	453	537	61
User	850000	37	267	304	33
Zitex	1200000	98	475	573	69

APPENDIX A4

Item - Outsourcer

Item No	Item Name	Outsourcer Sequence No	Outsourcer
1	Coral Garden	1	FB
		2	User
		3	Zitex
2	Dilliards	1	User
		2	Zitex
3	Panel Block	1	Aysan
		2	Çağ
		3	Sesil
		4	Zitex
4	Anna	1	Canbaz
		2	User
5	Embossed	1	Aysan
		2	Canbaz
		3	Sesil
		4	Zitex
6	Emily	1	Çağ
		2	Sesil
		3	Zitex
7	Face-off	1	Çağ
		2	Sesil
		3	Zitex
8	Leather crew	1	Aysan
		2	FB
9	Liberty	1	FB
		2	User
10	Service collar	1	Aysan
		2	FB
		3	Kinex
		4	Sesil
11	Side Flag	1	Canbaz
		2	Kinex
12	Sparkle Flag	1	Aysan
		2	Çağ
		3	Sesil
		4	User
13	Stamp Front	1	Canbaz
		2	Çağ
		3	User
14	Traditional	1	Aysan
		2	Kinex
		3	Sesil

APPENDIX B1

PERFORMANCE MEASURES OF MATERIALS' SUPPLIERS

			Quality	Lead Time	Delivery Performance	Resources
	Material	Supplier	K	L	D	R
	Polyester Coil	Muteks	0,962	0,697	0,99	*
		Coats	1	0,656	0,984	0,139
	Label	Borneman	0,983	0,746	0,917	0,083
		Wah Sing	1	0,462	0,973	0,107
		Desan	1	0,909	0,861	0,009
		Akın Etiketçilik	0,95	0,85	0,964	0,032
		Öztek Etiket	1	0,5	0,995	0,262
		Teslo	1	0,756	0,987	0,157
		Dizayn	1	1	0,998	0,066
		Eticart	1	1	0,977	0,030
		New Yuen	1	0	0,997	0,024
		Wing Tak	1	0,4	1	0,042
	Zip	YKK	0,957	0,534	0,996	0,063
		Muteks	0,96	0,735	0,97	*
		Opti Fermuar	0,931	0,931	0,967	0,015
	Print	Heat Seal	1	1	0,918	0,000
		Printec	0,929	0,821	0,946	0,014
		Chris Kay	0,95	0,591	0,945	0,016
		Rapid Transfer	1	1	0,754	0,000
	Nylon Bag	Emek Plastik	1	0,954	0,957	0,011
		Ada Plastik	0,968	0,79	0,951	0,009
		Gürdemir Plastik	0,938	0,688	0,878	0,002
5		Selda Plastik	1	1	0,83	0,031
		Muteks	1	1	0,996	*
		Altın	1	0,667	0,92	0,095
		Bora Tekstil	1	1	0,918	0,059
6	Mercerized Coil	Muteks	0,953	0,634	0,971	*
		Coats	0,918	0,753	0,940	0,139
	Sized Label	Teslo	1	0,85	0,924	0,074
		Dizayn	1	1	0,864	0,032
7		Borneman	0,975	0,654	0,835	0,058
		Paxar	0,941	0,941	0,814	0,028
		Wah Sing	1	0,5	0,979	0,020
		Öztek Etiket	1	0,857	0,998	0,192
8	Hanger	Tam Plastik	0,905	0,952	0,982	0,065
		Randy Hangers	1	0,833	1	0,053
	Washing Instruction	Intermat	0,896	0,604	1	0,155
		Öztek Etiket	0,943	0,6	0,994	0,218
9		Akın Etiketçilik	0,978	0,769	0,949	0,006
		Teslo	0,973	0,713	0,996	0,003
		Wah Sing	0,971	0,6	0,89	0,278
10	Packaging Box	Onurcan Ambalaj	0,978	0,679	0,932	0,121
		Orsan Ambalaj	1	0,912	0,942	0,148

		Quality	Lead Time	Delivery Performance	Resources
Material	Supplier	K	L	D	R
Sized Washing Instruction	Akın Etiketçilik	0,952	0,744	0,936	0,058
	Wah Sing	1	0,462	1	0,012
	Ayrıntı	0,923	0,615	0,698	0,005
	Borneman	1	0,667	0,979	0,001
	Öztek Etiket	1	0,75	0,963	0,202
	Kuloğlu	1	1	1	0,233
	Paxar	1	1	1	0,049
Packaging Box Label	Borneman	0,972	0,806	0,977	0,027
	Hobby Etiket	1	0,6	0,983	0,005
	İstanbul Etiket	1	0,829	0,96	0,020
	Grafficart	1	1	0,945	0,009
	RVL	1	1	1	0,007
	Profit	1	0,8	0,596	0,436
	Kwan Tat	1	1	0,749	0,016
Weaving Ribbon	Muteks	0,958	0,753	0,971	*
	Suner	1	0,6	0,971	0,655
Press Button	Scovill	1	0,878	0,996	0,211
	Ching Fung	1	1	1	0,020
	YKK	1	0,5	1	0,031
Elastic Band	Bam Tekstil	1	1	1	0,013
	Muteks	1	1	0,999	*
	Armoni	0,5	0,5	1	0,000
Seperator	Onurcan Ambalaj	0,949	0,657	0,933	0,011
	Özgün Ambalaj	1	1	1	0,107
Plastic String	Şık Düğme	0,967	0,9	0,936	0,006
	Muteks	1	0,8	0,914	*
Button	Primoda	1	0,75	0,772	0,006
	Muteks	0,95	0,55	0,999	*
	Lauragel	1	1	0,945	0,020
	Banner	1	1	0,868	0,000
Tape	Özgül Kırtasiye	0,9	0,9	0,883	*
	Baran Kırtasiye	1	0,875	0,971	*
Packaging Tape	Megabant	0,935	0,871	0,84	0,055
	Atılım Ambalaj	1	0	0,692	0,298
Sticker	Merve	0,933	1	1	0,058
	Vipeks	1	1	0,913	0,030
	Primoda	1	0,5	0,806	0,119
UPC Label	Softek	0,966	1	0,96	0,003
	Santra	1	0	0,879	0,002
Packaging Paper	Bayramoğlu	0,955	0,545	0,562	0,021
	Merve	1	1	0,983	0,034
	Softek	1	1	1	0,001

: Ratio of accepted units in the incoming quality control
: Ratio of units arriving on-time
: Ratio of delivered units to ordered units
: Ratio of the capacity of the supplier used for Sun Tekstil
: These suppliers are traders, not producers.Therefore no capacity utilization is defined.

APPENDIX B2

PERFORMANCE MEASURES OF OUTSOURCERS

			QUALITY				LEAD-TIME	DELIVERY PERF.	PRODUCTIVITY	RESOURCES	
No	Item	Outsourcer	K1	K2	K3	K4	L	D	V	R1	R2
1	Coral Garden	FB	0,5	1	1	0,963	0	1	0,857	0,515	0,118
		User	0,6	1	1	0,962	0,055	1	0,350	0,366	0,109
		Zitex	1	1	1	0,984	0,679	1	0,266	0,258	0,120
2	Dilliards	User	0,75	0,479	0,675	0,954	1	0,985	0,454	0,366	0,109
		Zitex	0,5	1	1	0,992	1	1	0,197	0,258	0,120
3	Panel Block	Aysan	1	1	1	0,99	0	1	0,797	0,233	0,104
		Çağ	0,6	1	1	0,97	0,365	1	0,675	0,272	0,156
		Sesil	1	1	1	0,99	0	1	0,551	0,392	0,114
		Zitex	1	1	1	0,952	0,858	1	0,306	0,258	0,120
4	Anna	Canbaz	1	1	1	0,911	0,856	1	0,191	0,255	0,079
		User	0	1	1	0,977	1	1	0,166	0,366	0,109
5	Embossed	Aysan	1	1	1	0,96	1	1	0,183	0,233	0,104
		Canbaz	1	1	1	0,981	0	1	0,324	0,255	0,079
		Sesil	1	1	1	0,996	0,776	1	0,203	0,392	0,114
		Zitex	1	1	1	0,988	0,159	1	0,144	0,258	0,120
6	Emily	Çağ	1	1	1	0,941	0,896	1	0,280	0,272	0,156
		Sesil	0,5	1	1	0,987	0	1	0,120	0,392	0,114
		Zitex	0,65	1	1	0,965	0,529	1	0,499	0,258	0,120
7	Face-off	Çağ	0,75	1	1	0,965	1	1	0,457	0,272	0,156
		Sesil	0,5	1	1	0,993	0,716	1	0,170	0,392	0,114
		Zitex	0,75	1	1	0,924	0,647	1	0,159	0,258	0,120
8	Leather crew	Aysan	0,75	1	1	0,978	0,944	1	0,431	0,233	0,104
		FB	1	1	1	0,991	0	1	0,491	0,515	0,118
9	Liberty	FB	1	1	1	0,923	0,655	1	0,649	0,515	0,118
		User	0,7	1	1	0,973	0,009	1	0,120	0,366	0,109

			QUALITY				LEAD-TIME	DELIVERY PERF.	PRODUCTIVITY	RESOURCES	
No	Item	Outsourcer	K1	K2	K3	K4	L	D	V	R1	R2
10	Service collar	Aysan	0	1	1	0,992	0	1	0,266	0,233	0,104
		FB	0,5	1	1	0,982	0	1	0,523	0,515	0,118
		Kinex	1	1	1	0,954	1	1	0,498	0,197	0,171
		Sesil	1	1	1	0,958	0,352	1	0,182	0,392	0,114
11	Side Flag	Canbaz	0,5	1	1	0,992	0,437	1	0,556	0,255	0,079
		Kinex	0,8	1	1	0,913	0,525	1	0,530	0,197	0,171
12	Sparkle Flag	Aysan	0,5	1	1	0,956	0	1	0,584	0,233	0,104
		Çağ	0,75	0,751	0,273	0,985	0,411	0,934	0,523	0,272	0,156
		Sesil	1	0,938	0,917	0,969	0,232	0,993	0,259	0,392	0,114
		User	1	1	1	0,999	0	1	0,199	0,366	0,109
13	Stamp Front	Canbaz	1	1	1	0,912	1	1	0,339	0,255	0,079
		Çağ	0,5	1	1	0,988	0	1	0,554	0,272	0,156
		User	0,75	1	1	0,976	0,127	1	0,179	0,366	0,109
14	Traditional	Aysan	1	1	1	0,982	0	1	0,659	0,233	0,104
		Kinex	1	1	1	0,988	0	1	0,666	0,197	0,171
		Sesil	1	1	1	0,946	0	1	0,122	0,392	0,114

K1: *Ratio of approval of the production samples at the first trail*
K2: *Ratio of accepted units in the incoming quality control*
K3: *Comparison of in-line and final inspection*
K4: *Ratio of non-damaged items*
L: *Ratio of units arriving on-time to total number of units received*
D: *Ratio of delivered units to ordered units*
V: *Ratio of standard time for an order to its actual completion time*
R1: *Percentage of the capacity of a supplier used for Sun Tekstil*
R2: *Ratio of university graduates to the total number of employees*

APPENDIX B3

TARGET VALUES OF MATERIALS

	TARGET VALUES= 0,8*BEST PERFORMANCE+0,2*SECOND BEST PERFORMANCE			
Material	Target K	Target L	Target D	Target R
Polyester Coil	0,992	0,689	0,989	0,139
Label	1,000	1,000	1,000	0,231
Zip	0,959	0,892	0,991	0,053
Print	1,000	1,000	0,946	0,016
Nylon Bag	1,000	1,000	0,988	0,088
Mercerized Coil	0,946	0,729	0,965	0,139
Sized Label	1,000	0,988	0,994	0,168
Hanger	0,981	0,928	0,996	0,063
Washing Instruction	0,977	0,758	0,999	0,266
Packaging Box	0,996	0,865	0,940	0,143
Sized Washing Instruction	1,000	1,000	1,000	0,227
Packaging Box Label	1,000	1,000	0,997	0,354
Weaving Ribbon	0,992	0,722	0,971	0,655
Press Button	1,000	0,976	1,000	0,175
Elastic Band	1,000	1,000	1,000	0,010
Seperator	0,990	0,931	0,987	0,088
Plastic String	0,993	0,880	0,932	0,006
Button	1,000	1,000	0,998	0,009
Tape	0,980	0,895	0,953	*
Packaging Tape	0,992	0,759	0,962	0,250
Sticker	1,000	1,000	0,983	0,107
UPC Label	1,000	0,800	0,944	0,003
Packaging Paper	1,000	1,000	0,997	0,031

: Since the suppliers of tape are both traders, there is no target for capacity utilization.
rformance values can be found from Appendix A3

APPENDIX B4

TARGET VALUES OF ITEMS OUTSOURCED

		TARGET VALUES= 0,8*BEST PERFORMANCE+0,2*SECOND BEST PERFORMANCE								
No	Item	Target K1	Target K2	Target K3	Target K4	Target L	Target D	Target V	Target R1	Target R2
1	Coral Garden	0,920	1,000	1,000	0,980	0,554	1,000	0,755	0,485	0,120
2	Dilliards	0,700	0,896	0,935	0,984	1,000	0,997	0,403	0,344	0,118
3	Panel Block	1,000	1,000	1,000	0,990	0,759	1,000	0,773	0,368	0,149
4	Anna	0,800	1,000	1,000	0,964	0,971	1,000	0,186	0,344	0,103
5	Embossed	1,000	1,000	1,000	0,994	0,955	1,000	0,300	0,365	0,119
6	Emily	0,930	1,000	1,000	0,983	0,823	1,000	0,455	0,368	0,149
7	Face-off	0,750	1,000	1,000	0,987	0,943	1,000	0,397	0,368	0,149
8	Leather crew	0,950	1,000	1,000	0,988	0,755	1,000	0,479	0,459	0,115
9	Liberty	0,940	1,000	1,000	0,963	0,526	1,000	0,543	0,485	0,116
10	Service collar	1,000	1,000	1,000	0,990	0,870	1,000	0,518	0,490	0,161
11	Side Flag	0,740	1,000	1,000	0,976	0,507	1,000	0,551	0,243	0,153
12	Sparkle Flag	1,000	1,000	1,000	0,996	0,375	1,000	0,572	0,387	0,148
13	Stamp Front	0,950	1,000	1,000	0,986	0,825	1,000	0,511	0,347	0,147
14	Traditional	1,000	1,000	1,000	0,987	0,000	1,000	0,665	0,360	0,160

APPENDIX B5

DEMAND DATA OF MATERIALS ON MONTHLY BASIS

	(In units)	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11	2001-12	2002-01	2002-02	2002-03	2002-04	Total
1	Polyester Coil	302	258	2403	714	2336	2760	4806	1306	3059	104	20	18068
2	Label	33660	119782	136737	205171	313197	600038	434081	165325	308572	860	0	2317423
3	Zip	15475	34376	11929	23438	88156	28964	15244	29477	3536	0	0	250595
4	Print	17280	10833	77809	18002	84992	338648	41923	99150	324110	0	0	1012747
5	Nylon Bag	118351	442892	254664	301160	771232	849403	418180	338347	211330	313	0	3705872
6	Mercerized Coil	155	247	546	820	1723	5015	2419	3426	4135	937	510	19933
7	Sized Label	61505	190286	33074	163443	211144	382717	110506	122058	59984	0	0	1334717
8	Hanger	4887	13788	40240	15156	113833	9008	18879	15980	0	0	0	231771
9	Washing Instruction	62510	231647	101998	146601	277252	582148	193439	118028	74523	390	0	1788536
10	Packaging Box	1018	13935	1797	5552	10350	7323	6120	8770	6342	0	0	61207
11	Sized Washing Instruction	27104	113495	70426	112077	197152	171929	212276	136784	278488	7323	0	1327054
12	Packaging Box Label	91969	99298	190713	229640	181239	195492	273587	196622	90657	0	0	1549217
13	Weaving Ribbon (in meters)	6408	52059	1561	74348	160285	198129	143841	35436	124353	7781	0	804201
14	Press Button	0	0	20240	64742	163074	60720	366648	186961	69784	0	0	932169
15	Elastic Band	0	0	7024	1043	9008	62204	2518	19247	11938	0	0	112982
16	Separator	547	12402	2428	10578	13619	16840	8754	13922	8490	252	0	87832
17	Plastic String	167263	290686	75998	329823	756521	776620	312733	369060	377619	0	0	3456323
18	Button	0	0	78505	131680	44765	13180	0	4400	0	0	0	272530
19	Tape	39	136	20	209	500	33	152	102	465	0	0	1656
20	Packaging Tape	0	194	172	479	574	112	66	107	126	0	0	1830
21	Sticker	0	2431	114	868	4602	21640	7019	4473	0	0	0	41147
22	UPC Label	0	0	2942	0	0	0	0	59041	0	0	0	61983
23	Packaging Paper	0	1843	0	0	49	0	2687	2090	0	0	0	6669

APPENDIX B6

PURCHASING COSTS OF MATERIALS ON MONTHLY BASIS

	Material (in 000's TL)	Supplier	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11	2001-12	2002-01	2002-02	2002-03	2002-04
P1	Polyester Coil	Muteks	1500	1523	1540	1500	1765	1822	1800	1781	1813	1850	1850
		Coats	1500	1500	1485	1500	1691	1822	1450	1850	1813	1850	1850
P2	Label	Borneman	40	8	79	13	14	18	18	11	19	14	0
		Wah Sing	11	17	28	28	31	32	15	29	26	14	0
		Desan	23	16	79	20	19	19	19	20	700	14	0
		Akın Etiketçilik	3	4	3	5	4	3	4	6	5	14	0
		Öztek Etiket	40	5	5	5	31	7	29	29	6	14	0
		Teslo	40	17	79	14	15	16	15	17	13	14	0
		Dizayn	40	17	79	28	20	20	29	29	22	14	0
		Eticart	40	17	79	28	31	32	29	29	24	14	0
		New Yuen	40	17	79	28	31	32	29	29	700	14	0
		Wing Tak	40	17	79	28	31	11	10	29	700	14	0
P3	Zip	YKK	1044	1153	812	1103	734	872	778	803	888	0	0
		Muteks	196	1153	593	594	725	872	803	798	960	0	0
		Opti Fermuar	1044	1057	812	1103	552	872	803	803	960	0	0
P4	Print	Heat Seal	1048	149	442	210	46	65	809	90	19	0	0
		Printec	1048	149	442	210	108	110	427	90	159	0	0
		Chris Kay	727	105	442	210	1379	1102	809	90	159	0	0
		Rapid Transfer	1048	149	442	210	1379	1102	809	90	159	0	0
P5	Nylon Bag	Emek Plastik	35	22	22	23	24	33	27	29	42	39	0
		Ada Plastik	27	21	22	39	36	28	27	22	29	39	0
		Gürdemir Plastik	35	35	24	39	39	33	27	25	25	39	0
		Selda Plastik	35	35	24	39	39	21	27	29	42	39	0
		Muteks	35	35	3	4	4	4	4	29	42	39	0
		Altın	24	24	24	39	39	33	27	29	42	39	0
		Bora Tekstil	35	35	24	39	39	33	27	29	42	39	0
P6	Mercerized Coil	Muteks	3785	4308	4197	5642	5612	5221	5218	5171	5170	5088	5260
		Coats	3785	4308	4197	5642	5612	5404	5422	5349	4964	4544	4869

	Material (in 000's)	Supplier	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11	2001-12	2002-01	2002-02	2002-03	2002-04
P7	Sized Label	Teslo	132	38	29	36	111	43	76	100	105	0	0
		Dizayn	132	38	29	36	10	10	76	100	12	0	0
		Borneman	132	38	29	36	65	25	39	36	23	0	0
		Paxar Italy	29	32	29	156	4	43	4	34	38	0	0
		Wah Sing	132	38	29	36	46	43	76	100	105	0	0
		Öztek Etiket	132	38	29	36	111	24	35	100	105	0	0
P8	Hanger	Tam Plastik	158	60	95	237	240	142	59	65	500	0	0
		Randy Hangers	158	60	278	237	240	142	221	65	500	0	0
P9	Washing Instruction	Intermat	14	14	15	15	15	17	17	58	52	56	0
		Öztek Etiket	14	13	40	56	15	32	31	58	52	56	0
		Akın Etiketçilik	7	8	8	8	8	5	6	8	10	56	0
		Teslo	14	38	40	56	62	93	61	58	52	56	0
		Wah Sing	14	38	40	56	31	32	29	29	52	56	0
P10	Packaging Box	Onurcan Ambalaj	527	561	523	523	671	733	685	703	722	0	0
		Orsan Ambalaj	527	571	523	560	638	733	685	703	722	0	0
P11	Sized Washing Instruction	Akın Etiketçilik	6	5	6	7	7	8	7	8	8	56	0
		Wah Sing	6	49	54	42	46	56	55	58	52	56	0
		Ayrıntı	6	49	54	56	12	15	17	13	18	56	0
		Borneman	6	49	54	56	29	56	59	58	52	56	0
		Öztek Etiket	6	27	54	56	46	29	29	29	52	56	0
		Kuloğlu	6	49	54	56	20	56	59	58	20	56	0
		Paxar	6	49	54	56	46	56	59	58	52	56	0
P12	Packaging Box Label	Borneman	11	16	15	17	22	15	20	77	60	0	0
		Hobby Etiket	9	63	13	28	77	14	14	77	60	0	0
		İstanbul Etiket	11	63	22	22	14	17	16	16	17	0	0
		Grafficart	5	5	64	7	7	79	20	77	60	0	0
		RVL	11	63	64	28	77	79	20	77	60	0	0
		Profit	11	25	64	28	77	32	20	77	60	0	0
		Kwan Tat	11	63	64	28	66	79	20	77	60	0	0
P13	Weaving Ribbon	Muteks	125	7	7	8	39	8	15	78	10	111	0
		Suner	125	7	7	8	57	111	111	52	111	111	0
P14	Press Button	Scovill	0	0	13	14	15	55	15	14	13	0	0
		Ching Fung	0	0	13	14	93	55	15	231	13	0	0
		YKK	0	0	13	14	93	55	15	231	13	0	0

	Material (in 000's)	Supplier	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11	2001-12	2002-01	2002-02	2002-03	2002-04
P15	Elastic Band	Bam Tekstil	0	0	80	59	110	66	63	61	100	0	0
		Muteks	0	0	80	59	110	45	44	61	100	0	0
		Armoni	0	0	80	59	110	66	63	61	84	0	0
P16	Separator	Onurcan Ambalaj	43	43	44	43	51	243	52	59	63	65	0
		Özgün	43	43	44	43	51	30	52	59	30	65	0
P17	Plastic String	Şık Düğme	1	1	1	1	4	1	1	1	1	0	0
		Muteks	1	1	9	9	9	9	9	11	4	0	0
P18	Button	Primoda	0	0	15	163	15	5	0	4	0	0	0
		Muteks	0	0	15	4	4	5	0	4	0	0	0
		Lauragel	0	0	15	163	201	5	0	4	0	0	0
		Banner	0	0	15	14	201	5	0	4	0	0	0
P19	Tape	Özgül	900	900	880	1000	1000	1000	1000	1000	1690	0	0
		Baran Kırtasiye	900	1690	1690	1690	1690	1690	1690	1690	1690	0	0
P20	Packaging Tape	Megabant	0	758	750	750	779	850	0	850	849	0	0
		Atılım Ambalaj	0	758	750	2000	2550	850	0	850	849	0	0
P21	Sticker	Merve	0	125	100	125	125	150	150	200	0	0	0
		Vipeks	0	125	100	125	14	10	150	200	0	0	0
		Primoda	0	125	100	125	125	150	23	28	0	0	0
P22	UPC Label	Softek	0	0	8	0	0	0	0	18	0	0	0
		Santra	0	0	8	0	0	0	0	18	0	0	0
P23	Packaging Paper	Bayramoğlu	0	10	0	0	10	0	150	240	0	0	0
		Merve	0	10	0	0	10	0	150	150	0	0	0
		Softek	0	10	0	0	10	0	150	240	0	0	0

APENDIX B7

DEMAND DATA OF ITEMS OUTSOURCED ON MONTHLY BASIS

Item (in units)	Feb.-02	Mar.-02	Apr.-02	May.-02	Jun.-02	Jul-02	Total
Coral Garden	39800	17914	0	2400	0	0	60114
Dilliards	0	2130	69703	0	0	0	71833
Panel Block	0	0	5400	3210	31668	23447	63725
Anna	0	0	6693	750	0	0	7443
Embossed	1321	7399	18445	0	0	0	27165
Emily	40030	50020	1200	2486	0	0	93736
Face-off	0	0	4119	2030	3036	0	9185
Leather Crew	0	0	0	0	14174	2323	16497
Liberty	0	1340	3927	37	0	0	5304
Service Collar	0	0	0	31689	3097	1358	36144
Side Flag	0	0	850	4495	0	0	5345
Sparkle Flag	0	1640	12583	6776	38497	27684	87180
Stamp Front	0	0	0	3150	6113	0	9263
Traditional	0	0	0	0	28810	8069	36879

APPENDIX B8

COEFFICIENTS OF GOAL CONSTRAINTS FOR MATERIALS SUPPLIER SELECTION

		COEFFICIENTS			
Material	Supplier	K	T	Y	R
Polyester Coil	Muteks	-0,030	0,008	0,001	0,000
	Coats	0,008	-0,033	-0,005	0,000
Label	Borneman	-0,017	-0,254	-0,083	-0,149
	Wah Sing	0,000	-0,538	-0,027	-0,124
	Desan	0,000	-0,091	-0,139	-0,222
	Akın Etiketçilik	-0,050	-0,150	-0,036	-0,200
	Öztek Etiket	0,000	-0,500	-0,005	0,031
	Teslo	0,000	-0,244	-0,013	-0,074
	Dizayn	0,000	0,000	-0,002	-0,165
	Eticart	0,000	0,000	-0,023	-0,201
	New Yuen	0,000	-1,000	-0,003	-0,207
	Wing Tak	0,000	-0,600	0,000	-0,189
Zip	YKK	-0,002	-0,358	0,005	0,010
	Muteks	0,001	-0,157	-0,021	0,000
	Opti Fermuar	-0,028	0,039	-0,024	-0,039
Print	Heat Seal	0,000	0,000	-0,028	-0,016
	Printec	-0,071	-0,179	0,000	-0,001
	Chris Kay	-0,050	-0,409	-0,001	0,000
	Rapid Transfer	0,000	0,000	-0,192	-0,016
Nylon Bag	Emek Plastik	0,000	-0,046	-0,031	-0,077
	Ada Plastik	-0,032	-0,210	-0,037	-0,079
	Gürdemir Plastik	-0,062	-0,312	-0,110	-0,086
	Selda Plastik	0,000	0,000	-0,158	-0,057
	Muteks	0,000	0,000	0,008	0,000
	Altın	0,000	-0,333	-0,068	0,007
	Bora Tekstil	0,000	0,000	-0,070	-0,029
Mercerized Coil	Muteks	0,007	-0,095	0,006	0,000
	Coats	-0,028	0,024	-0,025	0,000
Sized Label	Teslo	0,000	-0,138	-0,070	-0,095
	Dizayn	0,000	0,012	-0,130	-0,137
	Borneman	-0,025	-0,334	-0,159	-0,110
	Paxar	-0,059	-0,047	-0,180	-0,140
	Wah Sing	0,000	-0,488	-0,015	-0,149
	Öztek Etiket	0,000	-0,131	0,004	0,024
Hanger	Tam Plastik	-0,076	0,024	-0,014	0,002
	Randy Hangers	0,019	-0,095	0,004	-0,009
Washing Instruction	Intermat	-0,081	-0,164	0,001	-0,111
	Öztek Etiket	-0,034	-0,158	-0,005	-0,047
	Akın Etiketçilik	0,001	0,011	-0,050	-0,259
	Teslo	-0,004	-0,045	-0,003	-0,263
	Wah Sing	-0,006	-0,158	-0,109	0,012
Packaging Box	Onurcan Ambalaj	-0,018	-0,186	-0,008	-0,021
	Orsan Ambalaj	0,004	0,047	0,002	0,005

			COEFFICIENTS			
	Material	Supplier	K	T	Y	R
	Sized Washing Instruction	Akın Etiketçilik	-0,048	-0,256	-0,064	-0,169
		Wah Sing	0,000	-0,538	0,000	-0,215
		Ayrıntı	-0,077	-0,385	-0,302	-0,222
		Borneman	0,000	-0,333	-0,021	-0,226
		Öztek Etiket	0,000	-0,250	-0,037	-0,025
		Kuloğlu	0,000	0,000	0,000	0,006
		Paxar	0,000	0,000	0,000	-0,178
	Packaging Box Label	Borneman	-0,028	-0,194	-0,020	-0,328
		Hobby Etiket	0,000	-0,400	-0,014	-0,350
		İstanbul Etiket	0,000	-0,171	-0,037	-0,334
		Grafficart	0,000	0,000	-0,052	-0,345
		RVL	0,000	0,000	0,003	-0,347
		Profit	0,000	-0,200	-0,401	0,082
		Kwan Tat	0,000	0,000	-0,248	-0,338
3	Weaving Ribbon	Muteks	-0,034	0,031	0,000	0,000
		Suner	0,008	-0,122	0,000	0,000
4	Press Button	Scovill	0,000	-0,098	-0,004	0,036
		Ching Fung	0,000	0,024	0,000	-0,155
		YKK	0,000	-0,476	0,000	-0,144
5	Elastic Band	Bam Tekstil	0,000	0,000	0,000	0,003
		Muteks	0,000	0,000	-0,001	0,000
		Armoni	-0,500	-0,500	0,000	-0,010
6	Seperator	Onurcan Ambalaj	-0,041	-0,274	-0,054	-0,076
		Özgün Ambalaj	0,010	0,069	0,013	0,019
7	Plastic String	Şık Düğme	-0,026	0,020	0,004	0,000
		Muteks	0,007	-0,080	-0,018	0,000
18	Button	Primoda	0,000	-0,250	-0,226	-0,003
		Muteks	-0,050	-0,450	0,001	0,000
		Lauragel	0,000	0,000	-0,053	0,011
		Banner	0,000	0,000	-0,130	-0,009
19	Tape	Özgül Kırtasiye	-0,080	0,005	-0,070	0,000
		Baran Kırtasiye	0,020	-0,020	0,018	*
20	Packaging Tape	Megabant	-0,057	0,112	-0,122	-0,195
		Atılım Ambalaj	0,008	-0,759	-0,270	0,049
21	Sticker	Merve	-0,067	0,000	0,017	-0,049
		Vipeks	0,000	0,000	-0,070	-0,077
		Primoda	0,000	-0,500	-0,177	0,012
22	UPC Label	Softek	-0,034	0,200	0,016	0,000
		Santra	0,000	-0,800	-0,065	-0,001
23	Packaging Paper	Bayramoğlu	-0,045	-0,455	-0,435	-0,010
		Merve	0,000	0,000	-0,014	0,003
		Softek	0,000	0,000	0,003	-0,030

** : Since the suppliers of tape are both traders, it is not considered in capacity utlization goal.*

APPENDIX B9

COEFFICIENTS OF GOAL CONSTRAINTS FOR OUTSOURCING

			COEFFICIENTS								
No	Item	Outsourcer	K1	K2	K3	K4	T	Y	P	R1	R2
1	Coral Garden	FB	-0,420	0,000	0,000	-0,017	-0,554	0,000	0,101	0,030	-0,002
		User	-0,320	0,000	0,000	-0,018	-0,499	0,000	-0,406	-0,119	-0,011
		Zitex	0,080	0,000	0,000	0,004	0,125	0,000	-0,489	-0,227	0,001
2	Dilliards	User	0,050	-0,417	-0,260	-0,030	0,000	-0,012	0,051	0,022	-0,009
		Zitex	-0,200	0,104	0,065	0,008	0,000	0,003	-0,206	-0,086	0,002
3	Panel Block	Aysan	0,000	0,000	0,000	0,000	-0,759	0,000	0,024	-0,135	-0,045
		Çağ	-0,400	0,000	0,000	-0,020	-0,394	0,000	-0,098	-0,096	0,007
		Sesil	0,000	0,000	0,000	0,000	-0,759	0,000	-0,222	0,024	-0,035
		Zitex	0,000	0,000	0,000	-0,038	0,099	0,000	-0,467	-0,110	-0,029
4	Anna	Canbaz	0,200	0,000	0,000	-0,053	-0,115	0,000	0,005	-0,089	-0,024
		User	-0,800	0,000	0,000	0,013	0,029	0,000	-0,020	0,022	0,006
5	Embossed	Aysan	0,000	0,000	0,000	-0,034	0,045	0,000	-0,117	-0,132	-0,015
		Canbaz	0,000	0,000	0,000	-0,013	-0,955	0,000	0,024	-0,110	-0,040
		Sesil	0,000	0,000	0,000	0,002	-0,179	0,000	-0,096	0,027	-0,005
		Zitex	0,000	0,000	0,000	-0,006	-0,796	0,000	-0,156	-0,107	0,001
6	Emily	Çağ	0,070	0,000	0,000	-0,042	0,073	0,000	-0,175	-0,096	0,007
		Sesil	-0,430	0,000	0,000	0,004	-0,823	0,000	-0,335	0,024	-0,035
		Zitex	-0,280	0,000	0,000	-0,018	-0,294	0,000	0,044	-0,110	-0,029
7	Face-off	Çağ	0,000	0,000	0,000	-0,022	0,057	0,000	0,060	-0,096	0,007
		Sesil	-0,250	0,000	0,000	0,006	-0,227	0,000	-0,227	0,024	-0,035
		Zitex	0,000	0,000	0,000	-0,063	-0,296	0,000	-0,238	-0,110	-0,029
8	Leather crew	Aysan	-0,200	0,000	0,000	-0,010	0,189	0,000	-0,048	-0,226	-0,011
		FB	0,050	0,000	0,000	0,003	-0,755	0,000	0,012	0,056	0,003
9	Liberty	FB	0,060	0,000	0,000	-0,040	0,129	0,000	0,106	0,030	0,002
		User	-0,240	0,000	0,000	0,010	-0,517	0,000	-0,423	-0,119	-0,007
10	Service collar	Aysan	-1,000	0,000	0,000	0,002	-0,870	0,000	-0,253	-0,257	-0,057
		FB	-0,500	0,000	0,000	-0,008	-0,870	0,000	0,005	0,025	-0,043
		Kinex	0,000	0,000	0,000	-0,036	0,130	0,000	-0,020	-0,293	0,011
		Sesil	0,000	0,000	0,000	-0,032	-0,518	0,000	-0,336	-0,098	-0,047

No	Item	Outsourcer	COEFFICIENTS								
			K1	K2	K3	K4	T	Y	P	R1	R2
11	Side Flag	Canbaz	-0,240	0,000	0,000	0,016	-0,070	0,000	0,005	0,012	-0,074
		Kinex	0,060	0,000	0,000	-0,063	0,018	0,000	-0,021	-0,046	0,018
12	Sparkle Flag	Aysan	-0,500	0,000	0,000	-0,040	-0,375	0,000	0,012	-0,154	-0,044
		Çağ	-0,250	-0,249	-0,727	-0,011	0,036	-0,066	-0,048	-0,115	0,009
		Sesil	0,000	-0,062	-0,083	-0,027	-0,143	-0,007	-0,313	0,005	-0,034
		User	0,000	0,000	0,000	0,003	-0,375	0,000	-0,372	-0,021	-0,039
13	Stamp Front	Canbaz	0,050	0,000	0,000	-0,074	0,175	0,000	-0,172	-0,092	-0,068
		Çağ	-0,450	0,000	0,000	0,002	-0,825	0,000	0,043	-0,075	0,010
		User	-0,200	0,000	0,000	-0,010	-0,698	0,000	-0,332	0,019	-0,038
14	Traditional	Aysan	0,000	0,000	0,000	-0,005	0,000	0,000	-0,005	-0,127	-0,056
		Kinex	0,000	0,000	0,000	0,001	0,000	0,000	0,001	-0,163	0,012
		Sesil	0,000	0,000	0,000	-0,041	0,000	0,000	-0,543	0,032	-0,046

APPENDIX C1

LINGO FORMULATION OF MODEL 1 IN MATERIALS SUPPLIER SELECTION

```
SETS:
MATERIALS/1..23/; (There are 23 types of materials)
NODES/1..4/;

(TY# is the total quantity ordered from a supplier of material #.
K# is the quality performance measure of a supplier of material #.
L#  is the lead-time performance measure of a supplier of material #.)

SUPPLIERS1/1..2/:TY1,K1,L1;
SUPPLIERS2/1..10/:TY2,CAP2,K2,L2;
SUPPLIERS3/1..3/:TY3,K3,L3;
SUPPLIERS4/1..4/:TY4,K4,L4;
SUPPLIERS5/1..7/:TY5,K5,L5;
SUPPLIERS6/1..2/:TY6,K6,L6;
SUPPLIERS7/1..6/:TY7,K7,L7;
SUPPLIERS8/1..2/:TY8,K8,L8;
SUPPLIERS9/1..5/:TY9,K9,L9;
SUPPLIERS10/1..2/:TY10,K10,L10;
SUPPLIERS11/1..7/:TY11,K11,L11;
SUPPLIERS12/1..7/:TY12,K12,L12;
SUPPLIERS13/1..2/:TY13,K13,L13;
SUPPLIERS14/1..3/:TY14,K14,L14;
SUPPLIERS15/1..3/:TY15,K15,L15;
SUPPLIERS16/1..2/:TY16,K16,L16;
SUPPLIERS17/1..2/:TY17,K17,L17;
SUPPLIERS18/1..4/:TY18,K18,L18;
SUPPLIERS19/1..2/:TY19,K19,L19;
SUPPLIERS20/1..2/:TY20,K20,L20;
SUPPLIERS21/1..3/:TY21,K21,L21;
SUPPLIERS22/1..2/:TY22,K22,L22;
SUPPLIERS23/1..3/:TY23,K23,L23;

(QD# is the demand belonging to material #)

MONTHS/1..11/:QD1,QD2,QD3,QD4,QD5,QD6,QD7,QD8,QD9,QD10,QD11,QD12,QD13,QD14,QD15,QD16,QD17,Q
D18,QD19,QD20,QD21,QD22,QD23;

(Y# is the quantity ordered of material# .
P# is the purchasing cost matrix of material#.
X# is 1 for selected suppliers, 0 for non-selected suppliers. X is only used in models 3& 4.)

ARC1(SUPPLIERS1,MONTHS):Y1,P1,X1;
ARC2(SUPPLIERS2,MONTHS):Y2,P2,X3;
ARC3(SUPPLIERS3,MONTHS):Y3,P3,X3;
ARC4(SUPPLIERS4,MONTHS):Y4,P4,X4;
ARC5(SUPPLIERS5,MONTHS):Y5,P5,X5;
ARC6(SUPPLIERS6,MONTHS):Y6,P6,X6;
ARC7(SUPPLIERS7,MONTHS):Y7,P7,X7;
ARC8(SUPPLIERS8,MONTHS):Y8,P8,X8;
ARC9(SUPPLIERS9,MONTHS):Y9,P9,X9;
ARC10(SUPPLIERS10,MONTHS):Y10,P10,X10;
ARC11(SUPPLIERS11,MONTHS):Y11,P11,X11;
ARC12(SUPPLIERS12,MONTHS):Y12,P12,X12;
ARC13(SUPPLIERS13,MONTHS):Y13,P13,X13;
```

```
ARC14(SUPPLIERS14,MONTHS):Y14,P14,X14;
ARC15(SUPPLIERS15,MONTHS):Y15,P15,X15;
ARC16(SUPPLIERS16,MONTHS):Y16,P16,X16;
ARC17(SUPPLIERS17,MONTHS):Y17,P17,X17;
ARC18(SUPPLIERS18,MONTHS):Y18,P18,X18;
ARC19(SUPPLIERS19,MONTHS):Y19,P19,X19;
ARC20(SUPPLIERS20,MONTHS):Y20,P20,X20;
ARC21(SUPPLIERS21,MONTHS):Y21,P21,X21;
ARC22(SUPPLIERS22,MONTHS):Y22,P22,X22;
ARC23(SUPPLIERS23,MONTHS):Y23,P23,X23;
```

(SA is the positive deviation, SE is the negative deviation belonging to goals.)

```
ARC24(NODES,MATERIALS,MONTHS):SA,SE;

ENDSETS

DATA:

QD1=302 258 2403 714 2336 2760 4806 1306 3059 104 20;
```

(The rest of the demand vectors can be found in appendix A5)

```
P1=1500 1523 1540 1500 1765 1822 1800 1781 1813 1850 1850
   1500 1500 1485 1500 1691 1822 1450 1850 1813 1850 1850;
```

(The rest of the purchasing costs can be found in appendix A6)

```
K1=0.962        1.000;
```

(The rest of the quality performance values can be found in appendix A3)

```
L1=0.697        0.656 ;
```

(The rest of the lead-time performance values can be found in appendix A3)

```
ENDDATA

MIN = @SUM(MONTHS(K):@SUM(MATERIALS(J): 0.443*SA(1,J,K)+
                                        0.316*SA(2,J,K)+
                                        0.168*SA(3,J,K)+
                                        0.072*SA(4,J,K)));
```

[***Objective function of model 2 and model 4:***

```
MIN = @SUM(MONTHS(K):@SUM(MATERIALS(J): 0.3*SA(1,J,K)+
                                        0.3*SA(2,J,K)+
                                        0.2*SA(3,J,K)+
                                        0.2*SA(4,J,K)));
```

]

(The coefficients in all goal constraints can be seen in Appendix A7)

(Quality Goal Constraints)

```
@FOR(MONTHS(K): (-0.03*Y1(1,K)+0.008*Y1(2,K)+SA(1,1,K)-SE(1,1,K))=0);
@FOR(MONTHS(K): (-0.017*Y2(1,K)-0.05*Y2(4,K)+SA(1,2,K)-SE(1,2,K))=0);
@FOR(MONTHS(K): (-0.002*Y3(1,K)+0.001*Y3(2,K)-0.028*Y3(3,K)+SA(1,3,K)-SE(1,3,K))=0);
@FOR(MONTHS(K): (-0.071*Y4(2,K)-0.05*Y4(3,K)+SA(1,4,K)-SE(1,4,K))=0);
@FOR(MONTHS(K): (-0.032*Y5(2,K)-0.062*Y5(3,K)+SA(1,5,K)-SE(1,5,K))=0);
@FOR(MONTHS(K): (0.007*Y6(1,K)-0.028*Y6(2,K)+SA(1,6,K)-SE(1,6,K))=0);
```

```
@FOR(MONTHS(K): (-0.025*Y7(3,K)-0.059*Y7(4,K)+SA(1,7,K)-SE(1,7,K))=0);
@FOR(MONTHS(K): (-0.076*Y8(1,K)+0.019*Y8(2,K)+SA(1,8,K)-SE(1,8,K))=0);
@FOR(MONTHS(K):(-0.081*Y9(1,K)-0.034*Y9(2,K)+0.001*Y9(3,K)-0.004*Y9(4,K)-0.006*Y9(5,K)+SA(1,9,K)-
                SE(1,9,K))=0);
@FOR(MONTHS(K): (-0.018*Y10(1,K)+0.004*Y10(2,K)+SA(1,10,K)-SE(1,10,K))=0);
@FOR(MONTHS(K): (-0.048*Y11(1,K)-0.077*Y11(3,K)+SA(1,11,K)-SE(1,11,K))=0);
@FOR(MONTHS(K): (-0.028*Y12(1,K)+SA(1,12,K)-SE(1,12,K))=0);
@FOR(MONTHS(K): (-0.034*Y13(1,K)+0.008*Y13(2,K)+SA(1,13,K)-SE(1,13,K))=0);
@FOR(MONTHS(K): (-0.5*Y15(3,K)+SA(1,15,K)-SE(1,15,K))=0);
@FOR(MONTHS(K): (-0.041*Y16(1,K)+0.01*Y16(2,K)+SA(1,16,K)-SE(1,16,K))=0);
@FOR(MONTHS(K): (-0.026*Y17(1,K)+0.007*Y17(2,K)+SA(1,17,K)-SE(1,17,K))=0);
@FOR(MONTHS(K): (-0.05*Y18(2,K)+SA(1,18,K)-SE(1,18,K))=0);
@FOR(MONTHS(K): (-0.08*Y19(1,K)+0.02*Y19(2,K)+SA(1,19,K)-SE(1,19,K))=0);
@FOR(MONTHS(K): (-0.057*Y20(1,K)+0.008*Y20(2,K)+SA(1,20,K)-SE(1,20,K))=0);
@FOR(MONTHS(K): (-0.067*Y21(1,K)+SA(1,21,K)-SE(1,21,K))=0);
@FOR(MONTHS(K): (-0.034*Y22(1,K)+SA(1,22,K)-SE(1,22,K))=0);
@FOR(MONTHS(K): (-0.045*Y23(1,K)+SA(1,23,K)-SE(1,23,K))=0);
```

(Lead-Time Goal Constraints)

```
@FOR(MONTHS(K): (0.008*Y1(1,K)-0.033*Y1(2,K)+SA(2,1,K)-SE(2,1,K))=0);
@FOR(MONTHS(K):(-0.254*Y2(1,K)-0.538*Y2(2,K)-0.091*Y2(3,K)-0.15*Y2(4,K)-0.5*Y2(5,K)-0.244*Y2(6,K)-
                Y2(9,K)- 0.6*Y2(10,K)+SA(2,2,K)-SE(2,2,K))=0);
@FOR(MONTHS(K): (-0.358*Y3(1,K)-0.157*Y3(2,K)+0.039*Y3(3,K)+SA(2,3,K)-SE(2,3,K))=0);
@FOR(MONTHS(K): (-0.179*Y4(2,K)-0.409*Y4(3,K)+SA(2,4,K)-SE(2,4,K))=0);
@FOR(MONTHS(K):(-0.046*Y5(1,K)-0.210*Y5(2,K)-0.312*Y5(3,K)-0.333*Y5(6,K)+SA(2,5,K)-SE(2,5,K))=0);
@FOR(MONTHS(K): (-0.095*Y6(1,K)+0.024*Y6(2,K)+SA(2,6,K)-SE(2,6,K))=0);
@FOR(MONTHS(K):(-0.138*Y7(1,K)+0.012*Y7(2,K)-0.334*Y7(3,K)-0.047*Y7(4,K)-0.488*Y7(5,K)-
                0.131*Y7(6,K)+SA(2,7,K)-SE(2,7,K))=0);
@FOR(MONTHS(K): (0.024*Y8(1,K)-0.095*Y8(2,K)+SA(2,8,K)-SE(2,8,K))=0);
@FOR(MONTHS(K):(-0.154*Y9(1,K)-0.158*Y9(2,K)+0.011*Y9(3,K)-0.045*Y9(4,K)-0.158*Y9(5,K)+SA(2,9,K)-
                SE(2,9,K))=0);
@FOR(MONTHS(K): (-0.186*Y10(1,K)+0.047*Y10(2,K)+SA(2,10,K)-SE(2,10,K))=0);
@FOR(MONTHS(K):(-0.256*Y11(1,K)-0.538*Y11(2,K)-0.385*Y11(3,K)-0.333*Y11(4,K)-0.25*Y11(5,K)+SA(2,11,K)-
                SE(2,11,K))=0);
@FOR(MONTHS(K):(-0.194*Y12(1,K)-0.4*Y12(2,K)-0.171*Y12(3,K)-0.2*Y12(6,K)+SA(2,12,K)-SE(2,12,K))=0);
@FOR(MONTHS(K): (0.031*Y13(1,K)-0.122*Y13(2,K)+SA(2,13,K)-SE(2,13,K))=0);
@FOR(MONTHS(K): (-0.098*Y14(1,K)+0.024*Y14(2,K)-0.476*Y14(3,K)+SA(2,14,K)-SE(2,14,K))=0);
@FOR(MONTHS(K): (-0.5*Y15(3,K)+SA(2,15,K)-SE(2,15,K))=0);
@FOR(MONTHS(K): (-0.274*Y16(1,K)+0.069*Y16(2,K)+SA(2,16,K)-SE(2,16,K))=0);
@FOR(MONTHS(K): (0.02*Y17(1,K)-0.08*Y17(2,K)+SA(2,17,K)-SE(2,17,K))=0);
@FOR(MONTHS(K): (-0.25*Y18(1,K)-0.45*Y18(2,K)+SA(2,18,K)-SE(2,18,K))=0);
@FOR(MONTHS(K): (0.005*Y19(1,K)-0.02*Y19(2,K)+SA(2,19,K)-SE(2,19,K))=0);
@FOR(MONTHS(K): (0.112*Y20(1,K)-0.759*Y20(2,K)+SA(2,20,K)-SE(2,20,K))=0);
@FOR(MONTHS(K): (-0.5*Y21(3,K)+SA(2,21,K)-SE(2,21,K))=0);
@FOR(MONTHS(K): (0.2*Y22(1,K)-0.8*Y22(2,K)+SA(2,22,K)-SE(2,22,K))=0);
@FOR(MONTHS(K): (-0.455*Y23(1,K)+SA(2,23,K)-SE(2,23,K))=0);
```

(Delivery Performance Goal Constraints)

```
@FOR(MONTHS(K): (0.001*Y1(1,K)-0.005*Y1(2,K)+SA(3,1,K)-SE(3,1,K))=0);
@FOR(MONTHS(K):(-0.083*Y2(1,K)-0.027*Y2(2,K)-0.139*Y2(3,K)-0.036*Y2(4,K)-0.005*Y2(5,K)-0.013*Y2(6,K)-
                0.002*Y2(7,K)-0.023*Y2(8,K)-0.003*Y2(9,K)+SA(3,2,K)-SE(3,2,K))=0);
@FOR(MONTHS(K): (0.005*Y3(1,K)-0.021*Y3(2,K)-0.024*Y3(3,K)+SA(3,3,K)-SE(3,3,K))=0);
@FOR(MONTHS(K): (-0.028*Y4(1,K)-0.001*Y4(3,K)-0.192*Y4(4,K)+SA(3,4,K)-SE(3,4,K))=0);
@FOR(MONTHS(K):(-0.031*Y5(1,K)-0.037*Y5(2,K)-0.11*Y5(3,K)-0.158*Y5(4,K)+0.008*Y5(5,K)-0.068*Y5(6,K)-
                0.07*Y5(7,K)+SA(3,5,K)-SE(3,5,K))=0);
@FOR(MONTHS(K): (0.006*Y6(1,K)-0.025*Y6(2,K)+SA(3,6,K)-SE(3,6,K))=0);
@FOR(MONTHS(K):(-0.07*Y7(1,K)-0.13*Y7(2,K)-0.159*Y7(3,K)-0.18*Y7(4,K)-0.015*Y7(5,K)+0.004*Y7(6,K)+
                SA(3,7,K)-SE(3,7,K))=0);
```

```
@FOR(MONTHS(K): (-0.014*Y8(1,K)+0.004*Y8(2,K)+SA(3,8,K)-SE(3,8,K))=0);
@FOR(MONTHS(K):(0.001*Y9(1,K)-0.005*Y9(2,K)-0.05*Y9(3,K)-0.003*Y9(4,K)-0.11*Y9(5,K)+SA(3,9,K)-
                SE(3,9,K))=0);
@FOR(MONTHS(K): (-0.008*Y10(1,K)+0.002*Y10(2,K)+SA(3,10,K)-SE(3,10,K))=0);
@FOR(MONTHS(K):(-0.064*Y11(1,K)-0.302*Y11(3,K)-0.021*Y11(4,K)-0.037*Y11(5,K)+SA(3,11,K)-SE(3,11,K))=0);
@FOR(MONTHS(K):(-0.02*Y12(1,K)-0.01*Y12(2,K)-0.04*Y12(3,K)-0.05*Y12(4,K)+0.003*Y12(5,K)-
                0.401*Y12(6,K)-0.248*Y12(7,K)+SA(3,12,K)-SE(3,12,K))=0);
@FOR(MONTHS(K): (-0.004*Y14(1,K)+SA(3,14,K)-SE(3,14,K))=0);
@FOR(MONTHS(K): (-0.001*Y15(2,K)+SA(3,15,K)-SE(3,15,K))=0);
@FOR(MONTHS(K): (-0.054*Y16(1,K)+0.013*Y16(2,K)+SA(3,16,K)-SE(3,16,K))=0);
@FOR(MONTHS(K): (0.004*Y17(1,K)-0.018*Y17(2,K)+SA(3,17,K)-SE(3,17,K))=0);
@FOR(MONTHS(K):(-0.226*Y18(1,K)+0.001*Y18(2,K)-0.053*Y18(3,K)-0.13*Y18(4,K)+SA(3,18,K)-SE(3,18,K))=0);
@FOR(MONTHS(K): (-0.07*Y19(1,K)+0.018*Y19(2,K)+SA(3,19,K)-SE(3,19,K))=0);
@FOR(MONTHS(K): (-0.122*Y20(1,K)-0.27*Y20(2,K)+SA(3,20,K)-SE(3,20,K))=0);
@FOR(MONTHS(K): (0.017*Y21(1,K)-0.07*Y21(2,K)-0.177*Y21(3,K)+SA(3,21,K)-SE(3,21,K))=0);
@FOR(MONTHS(K): (0.016*Y22(1,K)-0.065*Y22(2,K)+SA(3,22,K)-SE(3,22,K))=0);
@FOR(MONTHS(K): (-0.435*Y23(1,K)-0.014*Y23(2,K)+0.003*Y23(3,K)+SA(3,23,K)-SE(3,23,K))=0);
```

(Capacity Utilization Goal Constraints)

```
@FOR(MONTHS(K):(-0.145*Y2(1,K)-0.123*Y2(2,K)-0.136*Y2(3,K)-0.192*Y2(4,K)+0.019*Y2(5,K)-0.077*Y2(6,K)-
                0.172*Y2(7,K)-0.193*Y2(8,K)-0.199*Y2(9,K)-0.182*Y2(10,K)+SA(4,2,K)-SE(4,2,K))=0);
@FOR(MONTHS(K): (0.01*Y3(1,K)-0.04*Y3(3,K)+SA(4,3,K)-SE(4,3,K))=0);
@FOR(MONTHS(K): (-0.016*Y4(1,K)-0.001*Y4(2,K)-0.016*Y4(4,K)+SA(4,4,K)-SE(4,4,K))=0);
@FOR(MONTHS(K):(-0.077*Y5(1,K)-0.079*Y5(2,K)-0.086*Y5(3,K)-0.057*Y5(4,K)+0.007*Y5(6,K)-
                0.029*Y5(7,K)+SA(4,5,K)-SE(4,5,K))=0);
@FOR(MONTHS(K):(-0.095*Y7(1,K)-0.137*Y7(2,K)-0.11*Y7(3,K)-0.14*Y7(4,K)-0.149*Y7(5,K)+ 0.024*Y7(6,K)+
                SA(4,7,K)-SE(4,7,K))=0);
@FOR(MONTHS(K): (0.002*Y8(1,K)-0.009*Y8(2,K)+SA(4,8,K)-SE(4,8,K))=0);
@FOR(MONTHS(K):(-0.11*Y9(1,K)-0.047*Y9(2,K)-0.259*Y9(3,K)-0.263*Y9(4,K)+0.012*Y9(5,K)+SA(4,9,K)-
                SE(4,9,K))=0);
@FOR(MONTHS(K): (-0.021*Y10(1,K)+0.002*Y10(2,K)+SA(4,10,K)-SE(4,10,K))=0);
@FOR(MONTHS(K):(-0.169*Y11(1,K)-0.215*Y11(2,K)-0.222*Y11(3,K)-0.226*Y11(4,K)-0.025*Y11(5,K)+
                0.006*Y11(6,K)-0.178*Y11(7,K)+SA(4,11,K)-SE(4,11,K))=0);
@FOR(MONTHS(K):(-0.328*Y12(1,K)-0.35*Y12(2,K)-0.334*Y12(3,K)-0.345*Y12(4,K)-0.347*Y12(5,K)+
                0.082*Y12(6,K)-0.338*Y12(7,K)+SA(4,12,K)-SE(4,12,K))=0);
@FOR(MONTHS(K): (0.036*Y14(1,K)-0.155*Y14(2,K)-0.144*Y14(3,K)+SA(4,14,K)-SE(4,14,K))=0);
@FOR(MONTHS(K): (0.003*Y15(1,K)-0.01*Y15(3,K)+SA(4,15,K)-SE(4,15,K))=0);
@FOR(MONTHS(K): (-0.076*Y16(1,K)+0.019*Y16(2,K)+SA(4,16,K)-SE(4,16,K))=0);
@FOR(MONTHS(K): (-0.003*Y18(1,K)+0.011*Y18(3,K)-0.009*Y18(3,K)+SA(4,18,K)-SE(4,18,K))=0);
@FOR(MONTHS(K): (-0.195*Y20(1,K)+0.049*Y20(2,K)+SA(4,20,K)-SE(4,20,K))=0);
@FOR(MONTHS(K): (-0.049*Y21(1,K)-0.077*Y21(2,K)+0.012*Y21(3,K)+SA(4,21,K)-SE(4,21,K))=0);
@FOR(MONTHS(K): (-0.01*Y22(2,K)+SA(4,22,K)-SE(4,22,K))=0);
@FOR(MONTHS(K): (-0.01*Y23(1,K)+0.003*Y23(2,K)-0.03*Y23(3,K)+SA(4,23,K)-SE(4,23,K))=0);
```

(Demand Constraints)

```
@FOR(MONTHS(K):(@SUM(SUPPLIERS1(I):Y1(I,K)))-QD1(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS2(I):Y2(I,K)))-QD2(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS3(I):Y3(I,K)))-QD3(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS4(I):Y4(I,K)))-QD4(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS5(I):Y5(I,K)))-QD5(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS6(I):Y6(I,K)))-QD6(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS7(I):Y7(I,K)))-QD7(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS8(I):Y8(I,K)))-QD8(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS9(I):Y9(I,K)))-QD9(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS10(I):Y10(I,K)))-QD10(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS11(I):Y11(I,K)))-QD11(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS12(I):Y12(I,K)))-QD12(K)=0);
```

```
@FOR(MONTHS(K):(@SUM(SUPPLIERS13(I):Y13(I,K)))-QD13(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS14(I):Y14(I,K)))-QD14(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS15(I):Y15(I,K)))-QD15(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS16(I):Y16(I,K)))-QD16(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS17(I):Y17(I,K)))-QD17(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS18(I):Y18(I,K)))-QD18(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS19(I):Y19(I,K)))-QD19(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS20(I):Y20(I,K)))-QD20(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS21(I):Y21(I,K)))-QD21(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS22(I):Y22(I,K)))-QD22(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS23(I):Y23(I,K)))-QD23(K)=0);
```

(Capacity Constraints)

```
@FOR(MONTHS(K):(Y2(1,K)+Y7(3,K)+Y11(4,K))<=833333);
@FOR(MONTHS(K):(Y2(2,K)+Y7(5,K)+Y9(5,K)+Y11(2,K))<=208333);
@FOR(MONTHS(K):(Y7(4,K)+Y11(7,K))<=1000000);
@FOR(MONTHS(K):(Y2(4,K)+Y9(3,K)+Y11(1,K))<=833333);
@FOR(MONTHS(K):(Y2(5,K)+Y7(6,K)+Y9(2,K)+Y11(5,K))<=125000);
@FOR(MONTHS(K):(Y2(6,K)+Y7(1,K)+Y9(4,K))<=166666);
@FOR(MONTHS(K):(Y2(7,K)+Y7(2,K))<=83333);
```

(Total Quantities Ordered)

```
@FOR(SUPPLIERS1(I): TY1(I)=@SUM(MONTHS(K):Y1(I,K)));
@FOR(SUPPLIERS2(I): TY2(I)=@SUM(MONTHS(K):Y2(I,K)));
@FOR(SUPPLIERS3(I): TY3(I)=@SUM(MONTHS(K):Y3(I,K)));
@FOR(SUPPLIERS4(I): TY4(I)=@SUM(MONTHS(K):Y4(I,K)));
@FOR(SUPPLIERS5(I): TY5(I)=@SUM(MONTHS(K):Y5(I,K)));
@FOR(SUPPLIERS6(I): TY6(I)=@SUM(MONTHS(K):Y6(I,K)));
@FOR(SUPPLIERS7(I): TY7(I)=@SUM(MONTHS(K):Y7(I,K)));
@FOR(SUPPLIERS8(I): TY8(I)=@SUM(MONTHS(K):Y8(I,K)));
@FOR(SUPPLIERS9(I): TY9(I)=@SUM(MONTHS(K):Y9(I,K)));
@FOR(SUPPLIERS10(I): TY10(I)=@SUM(MONTHS(K):Y10(I,K)));
@FOR(SUPPLIERS11(I): TY11(I)=@SUM(MONTHS(K):Y11(I,K)));
@FOR(SUPPLIERS12(I): TY12(I)=@SUM(MONTHS(K):Y12(I,K)));
@FOR(SUPPLIERS13(I): TY13(I)=@SUM(MONTHS(K):Y13(I,K)));
@FOR(SUPPLIERS14(I): TY14(I)=@SUM(MONTHS(K):Y14(I,K)));
@FOR(SUPPLIERS15(I): TY15(I)=@SUM(MONTHS(K):Y15(I,K)));
@FOR(SUPPLIERS16(I): TY16(I)=@SUM(MONTHS(K):Y16(I,K)));
@FOR(SUPPLIERS17(I): TY17(I)=@SUM(MONTHS(K):Y17(I,K)));
@FOR(SUPPLIERS18(I): TY18(I)=@SUM(MONTHS(K):Y18(I,K)));
@FOR(SUPPLIERS19(I): TY19(I)=@SUM(MONTHS(K):Y19(I,K)));
@FOR(SUPPLIERS20(I): TY20(I)=@SUM(MONTHS(K):Y20(I,K)));
@FOR(SUPPLIERS21(I): TY21(I)=@SUM(MONTHS(K):Y21(I,K)));
@FOR(SUPPLIERS22(I): TY22(I)=@SUM(MONTHS(K):Y22(I,K)));
@FOR(SUPPLIERS23(I): TY23(I)=@SUM(MONTHS(K):Y23(I,K)));
```

(Computation of Costs)

```
COST1=@SUM(ARC1:P1*Y1);
COST2=@SUM(ARC2:P2*Y2);
COST3=@SUM(ARC3:P3*Y3);
COST4=@SUM(ARC4:P4*Y4);
COST5=@SUM(ARC5:P5*Y5);
COST6=@SUM(ARC6:P6*Y6);
COST7=@SUM(ARC7:P7*Y7);
COST8=@SUM(ARC8:P8*Y8);
COST9=@SUM(ARC9:P9*Y9);
COST10=@SUM(ARC10:P10*Y10);
```

```
COST11=@SUM(ARC11:P11*Y11);
COST12=@SUM(ARC12:P12*Y12);
COST13=@SUM(ARC13:P13*Y13);
COST14=@SUM(ARC14:P14*Y14);
COST15=@SUM(ARC15:P15*Y15);
COST16=@SUM(ARC16:P16*Y16);
COST17=@SUM(ARC17:P17*Y17);
COST18=@SUM(ARC18:P18*Y18);
COST19=@SUM(ARC19:P19*Y19);
COST20=@SUM(ARC20:P20*Y20);
COST21=@SUM(ARC21:P21*Y21);
COST22=@SUM(ARC22:P22*Y22);
COST23=@SUM(ARC23:P23*Y23);
```

(Computation of Units Accepted)

```
TQ1=@SUM(SUPPLIERS1(I):K1*TY1);
TQ2=@SUM(SUPPLIERS2(I):K2*TY2);
TQ3=@SUM(SUPPLIERS3(I):K3*TY3);
TQ4=@SUM(SUPPLIERS4(I):K4*TY4);
TQ5=@SUM(SUPPLIERS5(I):K5*TY5);
TQ6=@SUM(SUPPLIERS6(I):K6*TY6);
TQ7=@SUM(SUPPLIERS7(I):K7*TY7);
TQ8=@SUM(SUPPLIERS8(I):K8*TY8);
TQ9=@SUM(SUPPLIERS9(I):K9*TY9);
TQ10=@SUM(SUPPLIERS10(I):K10*TY10);
TQ11=@SUM(SUPPLIERS11(I):K11*TY11);
TQ12=@SUM(SUPPLIERS12(I):K12*TY12);
TQ13=@SUM(SUPPLIERS13(I):K13*TY13);
TQ14=@SUM(SUPPLIERS14(I):K14*TY14);
TQ15=@SUM(SUPPLIERS15(I):K15*TY15);
TQ16=@SUM(SUPPLIERS16(I):K16*TY16);
TQ17=@SUM(SUPPLIERS17(I):K17*TY17);
TQ18=@SUM(SUPPLIERS18(I):K18*TY18);
TQ19=@SUM(SUPPLIERS19(I):K19*TY19);
TQ20=@SUM(SUPPLIERS20(I):K20*TY20);
TQ21=@SUM(SUPPLIERS21(I):K21*TY21);
TQ22=@SUM(SUPPLIERS22(I):K22*TY22);
TQ23=@SUM(SUPPLIERS23(I):K23*TY23);
```

(Computation of Units On-Time)

```
TL1=@SUM(SUPPLIERS1(I):L1*TY1);
TL2=@SUM(SUPPLIERS2(I):L2*TY2);
TL3=@SUM(SUPPLIERS3(I):L3*TY3);
TL4=@SUM(SUPPLIERS4(I):L4*TY4);
TL5=@SUM(SUPPLIERS5(I):L5*TY5);
TL6=@SUM(SUPPLIERS6(I):L6*TY6);
TL7=@SUM(SUPPLIERS7(I):L7*TY7);
TL8=@SUM(SUPPLIERS8(I):L8*TY8);
TL9=@SUM(SUPPLIERS9(I):L9*TY9);
TL10=@SUM(SUPPLIERS10(I):L10*TY10);
TL11=@SUM(SUPPLIERS11(I):L11*TY11);
TL12=@SUM(SUPPLIERS12(I):L12*TY12);
TL13=@SUM(SUPPLIERS13(I):L13*TY13);
TL14=@SUM(SUPPLIERS14(I):L14*TY14);
TL15=@SUM(SUPPLIERS15(I):L15*TY15);
TL16=@SUM(SUPPLIERS16(I):L16*TY16);
TL17=@SUM(SUPPLIERS17(I):L17*TY17);
TL18=@SUM(SUPPLIERS18(I):L18*TY18);
```

```
TL19=@SUM(SUPPLIERS19(I):L19*TY19);
TL20=@SUM(SUPPLIERS20(I):L20*TY20);
TL21=@SUM(SUPPLIERS21(I):L21*TY21);
TL22=@SUM(SUPPLIERS22(I):L22*TY22);
TL23=@SUM(SUPPLIERS23(I):L23*TY23);
```

(Integer Variables)

```
@FOR(ARC1(I,K):@GIN(Y1(I,K)));
@FOR(ARC2(I,K):@GIN(Y2(I,K)));
@FOR(ARC3(I,K):@GIN(Y3(I,K)));
@FOR(ARC4(I,K):@GIN(Y4(I,K)));
@FOR(ARC5(I,K):@GIN(Y5(I,K)));
@FOR(ARC6(I,K):@GIN(Y6(I,K)));
@FOR(ARC7(I,K):@GIN(Y7(I,K)));
@FOR(ARC8(I,K):@GIN(Y8(I,K)));
@FOR(ARC9(I,K):@GIN(Y9(I,K)));
@FOR(ARC10(I,K):@GIN(Y10(I,K)));
@FOR(ARC11(I,K):@GIN(Y11(I,K)));
@FOR(ARC12(I,K):@GIN(Y12(I,K)));
@FOR(ARC13(I,K):@GIN(Y13(I,K)));
@FOR(ARC14(I,K):@GIN(Y14(I,K)));
@FOR(ARC15(I,K):@GIN(Y15(I,K)));
@FOR(ARC16(I,K):@GIN(Y16(I,K)));
@FOR(ARC17(I,K):@GIN(Y17(I,K)));
@FOR(ARC18(I,K):@GIN(Y18(I,K)));
@FOR(ARC19(I,K):@GIN(Y19(I,K)));
@FOR(ARC20(I,K):@GIN(Y20(I,K)));
@FOR(ARC21(I,K):@GIN(Y21(I,K)));
@FOR(ARC22(I,K):@GIN(Y22(I,K)));
@FOR(ARC23(I,K):@GIN(Y23(I,K)));

END
```

ADDITIONAL LINES TO MODEL 1 FORMULATION FOR MODELS 3 & 4

(Number of suppliers is 2.)

```
@FOR(MONTHS(K):(@SUM(SUPPLIERS1(I):X1(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS2(I):X2(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS3(I):X3(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS4(I):X4(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS5(I):X5(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS6(I):X6(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS7(I):X7(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS8(I):X8(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS9(I):X9(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS10(I):X10(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS11(I):X11(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS12(I):X12(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS13(I):X13(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS14(I):X14(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS15(I):X15(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS16(I):X16(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS17(I):X17(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS18(I):X18(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS21(I):X21(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS22(I):X22(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS23(I):X23(I,K)))=2);
```

(Minimum number of units to be ordered from a selected supplier)

```
@FOR(ARC1(I,K)|QD1(K)#GT#0 :2*X1(I,K)-Y1(I,K)<=0);
@FOR(ARC2(I,K)|QD2(K)#GT#0 :86*X2(I,K)-Y2(I,K)<=0);
@FOR(ARC3(I,K)|QD3(K)#GT#0 :350*X3(I,K)-Y3(I,K)<=0);
@FOR(ARC4(I,K)|QD4(K)#GT#0 :1000*X4(I,K)-Y4(I,K)<=0);
@FOR(ARC5(I,K)|QD5(K)#GT#0 :30*X5(I,K)-Y5(I,K)<=0);
@FOR(ARC6(I,K)|QD6(K)#GT#0 :15*X6(I,K)-Y6(I,K)<=0);
@FOR(ARC7(I,K)|QD7(K)#GT#0 :3300*X7(I,K)-Y7(I,K)<=0);
@FOR(ARC8(I,K)|QD8(K)#GT#0 :480*X8(I,K)-Y8(I,K)<=0);
@FOR(ARC9(I,K)|QD9(K)#GT#0 :39*X9(I,K)-Y9(I,K)<=0);
@FOR(ARC10(I,K)|QD10(K)#GT#0 :100*X10(I,K)-Y10(I,K)<=0);
@FOR(ARC11(I,K)|QD11(K)#GT#0 :730*X11(I,K)-Y11(I,K)<=0);
@FOR(ARC12(I,K)|QD12(K)#GT#0 :9000*X12(I,K)-Y12(I,K)<=0);
@FOR(ARC13(I,K)|QD13(K)#GT#0 :150*X13(I,K)-Y13(I,K)<=0);
@FOR(ARC14(I,K)|QD14(K)#GT#0 :2000*X14(I,K)-Y14(I,K)<=0);
@FOR(ARC15(I,K)|QD15(K)#GT#0 :100*X15(I,K)-Y15(I,K)<=0);
@FOR(ARC16(I,K)|QD16(K)#GT#0 :25*X16(I,K)-Y16(I,K)<=0);
@FOR(ARC17(I,K)|QD17(K)#GT#0 :7500*X17(I,K)-Y17(I,K)<=0);
@FOR(ARC18(I,K)|QD18(K)#GT#0 :440*X18(I,K)-Y18(I,K)<=0);
@FOR(ARC19(I,K)|QD19(K)#GT#0 :2*X19(I,K)-Y19(I,K)<=0);
@FOR(ARC20(I,K)|QD20(K)#GT#0 :6*X20(I,K)-Y20(I,K)<=0);
@FOR(ARC21(I,K)|QD21(K)#GT#0 :10*X21(I,K)-Y21(I,K)<=0);
@FOR(ARC22(I,K)|QD22(K)#GT#0 :290*X22(I,K)-Y22(I,K)<=0);
@FOR(ARC23(I,K)|QD23(K)#GT#0 :4*X23(I,K)-Y23(I,K)<=0);
```

(No units should be assigned to a supplier that is not selected)

```
@FOR(ARC1(I,K): (500000*X1(I,K)-Y1(I,K))>=0);
@FOR(ARC2(I,K): (500000*X2(I,K)-Y2(I,K))>=0);
@FOR(ARC3(I,K): (500000*X3(I,K)-Y3(I,K))>=0);
@FOR(ARC4(I,K): (500000*X4(I,K)-Y4(I,K))>=0);
@FOR(ARC5(I,K): (500000*X5(I,K)-Y5(I,K))>=0);
@FOR(ARC6(I,K): (500000*X6(I,K)-Y6(I,K))>=0);
@FOR(ARC7(I,K): (500000*X7(I,K)-Y7(I,K))>=0);
@FOR(ARC8(I,K): (500000*X8(I,K)-Y8(I,K))>=0);
@FOR(ARC9(I,K): (500000*X9(I,K)-Y9(I,K))>=0);
@FOR(ARC10(I,K): (500000*X10(I,K)-Y10(I,K))>=0);
@FOR(ARC11(I,K): (500000*X11(I,K)-Y11(I,K))>=0);
@FOR(ARC12(I,K): (500000*X12(I,K)-Y12(I,K))>=0);
@FOR(ARC13(I,K): (500000*X13(I,K)-Y13(I,K))>=0);
@FOR(ARC14(I,K): (500000*X14(I,K)-Y14(I,K))>=0);
@FOR(ARC15(I,K): (500000*X15(I,K)-Y15(I,K))>=0);
@FOR(ARC16(I,K): (500000*X16(I,K)-Y16(I,K))>=0);
@FOR(ARC17(I,K): (500000*X17(I,K)-Y17(I,K))>=0);
@FOR(ARC18(I,K): (500000*X18(I,K)-Y18(I,K))>=0);
@FOR(ARC19(I,K): (500000*X19(I,K)-Y19(I,K))>=0);
@FOR(ARC20(I,K): (500000*X20(I,K)-Y20(I,K))>=0);
@FOR(ARC21(I,K): (500000*X21(I,K)-Y21(I,K))>=0);
@FOR(ARC22(I,K): (500000*X221I,K)-Y22(I,K))>=0);
@FOR(ARC23(I,K): (500000*X23(I,K)-Y23(I,K))>=0);
```

(Binary Variables)

```
@FOR(ARC1(I,K):@BIN(X1(I,K)));
@FOR(ARC2(I,K):@BIN(X2(I,K)));
@FOR(ARC3(I,K):@BIN(X3(I,K)));
```

```
@FOR(ARC4(I,K):@BIN(X4(I,K)));
@FOR(ARC5(I,K):@BIN(X5(I,K)));
@FOR(ARC6(I,K):@BIN(X6(I,K)));
@FOR(ARC7(I,K):@BIN(X7(I,K)));
@FOR(ARC8(I,K):@BIN(X8(I,K)));
@FOR(ARC9(I,K):@BIN(X9(I,K)));
@FOR(ARC10(I,K):@BIN(X10(I,K)));
@FOR(ARC11(I,K):@BIN(X11(I,K)));
@FOR(ARC12(I,K):@BIN(X12(I,K)));
@FOR(ARC13(I,K):@BIN(X13(I,K)));
@FOR(ARC14(I,K):@BIN(X14(I,K)));
@FOR(ARC15(I,K):@BIN(X15(I,K)));
@FOR(ARC16(I,K):@BIN(X16(I,K)));
@FOR(ARC17(I,K):@BIN(X17(I,K)));
@FOR(ARC18(I,K):@BIN(X18(I,K)));
@FOR(ARC19(I,K):@BIN(X19(I,K)));
@FOR(ARC20(I,K):@BIN(X20(I,K)));
@FOR(ARC21(I,K):@BIN(X21(I,K)));
@FOR(ARC22(I,K):@BIN(X22(I,K)));
@FOR(ARC23(I,K):@BIN(X23(I,K)));
```

APPENDIX C2

LINGO FORMULATION OF MODEL 1 IN OUTSOURCER'S SELECTION PROBLEM

```
SETS:
MODELS/1..14/;          (There are 14 items outsourced)
NODES/1..9/;

( K2# is the quality performance measure of an outsourcer of item #.
 L#   is the lead-time performance measure of an outsourcer of item #.
TY# is the total quantity ordered from an outsoucer of item #.)

SUPPLIERS1/1..3/:K21, L1,TY1;
SUPPLIERS2/1..2/:K22, L2,TY2;
SUPPLIERS3/1..4/:K23, L3, TY3;
SUPPLIERS4/1..2/:K24, L4, TY4;
SUPPLIERS5/1..4/:K25, L5, TY5;
SUPPLIERS6/1..3/:K26, L6, TY6;
SUPPLIERS7/1..3/:K27, L7, TY7;
SUPPLIERS8/1..2/:K28, L8, TY8;
SUPPLIERS9/1..2/:K29, L9, TY9;
SUPPLIERS10/1..4/:K210, L10, TY10;
SUPPLIERS11/1..2/:K211, L11, TY11;
SUPPLIERS12/1..4/:K212, L12, TY12;
SUPPLIERS13/1..3/:K213, L13, TY13;
SUPPLIERS14/1..3/:K214, L14, TY14;

(QD# is the demand belonging to item #)

MONTHS/1..6/:QD1,QD2,QD3,QD4,QD5,QD6,QD7,QD8,QD9,QD10,QD11,QD12,QD13,QD14;

(Y# is the quantity ordered of item # .
 X# is 1 for selected outsourcers, 0 for non-selected outsourcers. X is only used in models
3& 4.)

ARC1(SUPPLIERS1,MONTHS):X1,Y1;
ARC2(SUPPLIERS2,MONTHS):X2,Y2;
ARC3(SUPPLIERS3,MONTHS):X3,Y3;
ARC4(SUPPLIERS4,MONTHS):X4,Y4;
ARC5(SUPPLIERS5,MONTHS):X5,Y5;
ARC6(SUPPLIERS6,MONTHS):X6,Y6;
ARC7(SUPPLIERS7,MONTHS):X7,Y7;
ARC8(SUPPLIERS8,MONTHS):X8,Y8;
ARC9(SUPPLIERS9,MONTHS):X9,Y9;
ARC10(SUPPLIERS10,MONTHS):X10,Y10;
ARC11(SUPPLIERS11,MONTHS):X11,Y11;
ARC12(SUPPLIERS12,MONTHS):X12,Y12;
ARC13(SUPPLIERS13,MONTHS):X13,Y13;
ARC14(SUPPLIERS14,MONTHS):X14,Y14;

(SA is the positive deviation, SE is the negative deviation belonging to goals.)

ARC15(NODES,MODELS,MONTHS):SA,SE;

ENDSETS
```

DATA:

QD1=39800 17914 0 2400 0 0 ;

(The rest of the demand vectors can be found in appendix B5)

K21=1.000 1.000 1.000;

(The rest of the quality performance values can be found in appendix B3)

L1=0.000 0.055 0.679;

(The rest of the lead-time performance values can be found in appendix B3)

ENDDATA

```
MIN=@SUM(MONTHS(K):@SUM(MODELS(J): 0.06*SA(1,J,K)+
                                   0.12*SA(2,J,K)+
                                   0.06*SA(3,J,K)+
                                   0.13*SA(4,J,K)+
                                   0.3 *SA(5,J,K)+
                                   0.13*SA(6,J,K)+
                                   0.1 *SA(7,J,K)+
                                   0.05*SA(8,J,K)+
                                   0.05*SA(9,J,K)));
```

[***Objective function of model 2 and model 4:***

```
MIN=@SUM(MONTHS(K):@SUM(MODELS(J): 0.117*SA(1,J,K)+
                                   0.162*SA(2,J,K)+
                                   0.117*SA(3,J,K)+
                                   0.162*SA(4,J,K)+
                                   0.153*SA(5,J,K)+
                                   0.132*SA(6,J,K)+
                                   0.08 *SA(7,J,K)+
                                   0.049*SA(8,J,K)+
                                   0.028*SA(9,J,K))); ]
```

(The coefficients in all goal constraints can be seen in Appendix B6)

(Quality K1 Goal Constraints)

```
@FOR(MONTHS(K): (-0.42*Y1(1,K)-0.32*Y1(2,K)+0.08*Y1(3,K)+SA(1,1,K)-SE(1,1,K))=0);
@FOR(MONTHS(K): (0.05*Y2(1,K)-0.2*Y2(2,K)+SA(1,2,K)-SE(1,2,K))=0);
@FOR(MONTHS(K): (-0.4*Y3(2,K)+SA(1,3,K)-SE(1,3,K))=0);
@FOR(MONTHS(K): (0.2*Y4(1,K)-0.8*Y4(2,K)+SA(1,4,K)-SE(1,4,K))=0);
@FOR(MONTHS(K): (0.07*Y6(1,K)-0.43*Y6(2,K)-0.28*Y6(3,K)+SA(1,6,K)-SE(1,6,K))=0);
@FOR(MONTHS(K): (-0.25*Y7(2,K)+SA(1,7,K)-SE(1,7,K))=0);
@FOR(MONTHS(K): (-0.2*Y8(1,K)+0.05*Y8(2,K)+SA(1,8,K)-SE(1,8,K))=0);
@FOR(MONTHS(K): (0.06*Y9(1,K)-0.24*Y9(2,K)+SA(1,9,K)-SE(1,9,K))=0);
@FOR(MONTHS(K): (-Y10(1,K)-0.5*Y10(2,K)+SA(1,10,K)-SE(1,10,K))=0);
@FOR(MONTHS(K): (-0.24*Y11(1,K)+0.06*Y11(2,K)+SA(1,11,K)-SE(1,11,K))=0);
@FOR(MONTHS(K): (-0.5*Y12(1,K)-0.25*Y12(2,K)+SA(1,12,K)-SE(1,12,K))=0);
@FOR(MONTHS(K): (0.05*Y13(1,K)-0.45*Y13(2,K)-0.2*Y13(3,K)+SA(1,13,K)-SE(1,13,K))=0);
```

(Quality K2 Goal Constraints)

@FOR(MONTHS(K): (-0.417*Y2(1,K)+0.104*Y2(2,K)+SA(2,2,K)-SE(2,2,K))=0);
@FOR(MONTHS(K): (-0.249*Y12(2,K)-0.062*Y12(3,K)+SA(2,13,K)-SE(2,13,K))=0);

(Quality K3 Goal Constraints)

@FOR(MONTHS(K): (-0.26*Y2(1,K)+0.065*Y2(2,K)+SA(3,2,K)-SE(3,2,K))=0);
@FOR(MONTHS(K): (-0.727*Y12(2,K)-0.083*Y12(3,K)+SA(3,13,K)-SE(3,13,K))=0);

(Quality K4 Goal Constraints)

@FOR(MONTHS(K): (-0.017*Y1(1,K)-0.018*Y1(2,K)+0.04*Y1(3,K)+SA(4,1,K)-SE(4,1,K))=0);
@FOR(MONTHS(K): (-0.03*Y2(1,K)+0.008*Y2(2,K)+SA(4,2,K)-SE(4,2,K))=0);
@FOR(MONTHS(K): (-0.02*Y3(2,K)-0.038*Y3(4,K)+SA(4,3,K)-SE(4,3,K))=0);
@FOR(MONTHS(K): (-0.053*Y4(1,K)+0.013*Y4(2,K)+SA(4,4,K)-SE(4,4,K))=0);
@FOR(MONTHS(K): (-0.034*Y5(1,K)-0.013*Y5(2,K)+0.002*Y5(3,K)-0.006*Y5(4,K)+SA(4,5,K)-
SE(4,5,K))=0);
@FOR(MONTHS(K): (-0.042*Y6(1,K)+0.004*Y6(2,K)-0.018*Y6(3,K)+SA(4,6,K)-SE(4,6,K))=0);
@FOR(MONTHS(K): (-0.022*Y7(1,K)+0.006*Y7(2,K)-0.063*Y7(3,K)+SA(4,7,K)-SE(4,7,K))=0);
@FOR(MONTHS(K): (-0.01*Y8(1,K)+0.003*Y8(2,K)+SA(4,8,K)-SE(4,8,K))=0);
@FOR(MONTHS(K): (-0.04*Y9(1,K)+0.01*Y9(2,K)+SA(4,9,K)-SE(4,9,K))=0);
@FOR(MONTHS(K): (0.002*Y10(1,K)-0.008*Y10(2,K)-0.036*Y10(3,K)-0.032*Y10(4,K)+SA(4,10,K)-
SE(4,10,K))=0);
@FOR(MONTHS(K): (0.016*Y11(1,K)-0.063*Y11(2,K)+SA(4,11,K)-SE(4,11,K))=0);
@FOR(MONTHS(K): (-0.04*Y12(1,K)-0.011*Y12(2,K)-0.027*Y12(3,K)+0.003*Y12(4,K)+SA(4,12,K)-
SE(4,12,K))=0);
@FOR(MONTHS(K): (-0.074*Y13(1,K)+0.002*Y13(2,K)-0.001*Y13(3,K)+SA(4,13,K)-SE(4,13,K))=0);
@FOR(MONTHS(K): (-0.005*Y14(1,K)+0.001*Y14(2,K)-0.041*Y14(3,K)+SA(4,14,K)-SE(4,14,K))=0);

(Lead-Time Goal Constraints)

@FOR(MONTHS(K): (-0.554*Y1(1,K)-0.499*Y1(2,K)+0.125*Y1(3,K)+SA(5,1,K)-SE(5,1,K))=0);
@FOR(MONTHS(K): (-0.759*Y3(1,K)-0.394*Y3(2,K)-0.759*Y3(3,K)+0.099*Y3(4,K)+SA(5,3,K)-
SE(5,3,K))=0);
@FOR(MONTHS(K): (-0.115*Y4(1,K)+0.029*Y4(2,K)+SA(5,4,K)-SE(5,5,K))=0);
@FOR(MONTHS(K): (0.45*Y5(1,K)-0.955*Y5(2,K)-0.179*Y5(3,K)-0.796*Y5(4,K)+SA(5,5,K)-
SE(5,5,K))=0);
@FOR(MONTHS(K): (0.073*Y6(1,K)-0.823*Y6(2,K)-0.294*Y6(3,K)+SA(5,6,K)-SE(5,6,K))=0);
@FOR(MONTHS(K): (-0.057*Y7(1,K)-0.227*Y7(2,K)-0.296*Y7(3,K)+SA(5,7,K)-SE(5,7,K))=0);
@FOR(MONTHS(K): (0.189*Y8(1,K)-0.755*Y8(2,K)+SA(5,8,K)-SE(5,8,K))=0);
@FOR(MONTHS(K): (0.129*Y9(1,K)-0.517*Y9(2,K)+SA(5,9,K)-SE(5,9,K))=0);
@FOR(MONTHS(K): (-0.87*Y10(1,K)-0.87*Y10(2,K)+0.13*Y10(3,K)-0.518*Y10(4,K)+SA(5,10,K)-
SE(5,10,K))=0);
@FOR(MONTHS(K): (-0.07*Y11(1,K)+0.018*Y11(2,K)+SA(5,11,K)-SE(5,11,K))=0);
@FOR(MONTHS(K): (-0.375*Y12(1,K)+0.036*Y12(2,K)-0.143*Y12(3,K)-0.375*Y12(4,K)+SA(5,12,K)-
SE(5,12,K))=0);
@FOR(MONTHS(K): (0.175*Y13(1,K)-0.825*Y13(2,K)-0.698*Y13(3,K)+SA(5,13,K)-SE(5,13,K))=0);

(Delivery Performance Goal Constraints)

@FOR(MONTHS(K): (-0.012*Y2(1,K)+0.003*Y2(2,K)+SA(6,2,K)-SE(6,2,K))=0);
@FOR(MONTHS(K): (-0.066*Y12(2,K)-0.007*Y12(3,K)+SA(6,2,K)-SE(6,2,K))=0);

(Productivity Goal Constraints)

@FOR(MONTHS(K): (0.101*Y1(1,K)-0.406*Y1(2,K)-0.489*Y1(3,K)+SA(7,1,K)-SE(7,1,K))=0);
@FOR(MONTHS(K): (0.051*Y2(1,K)-0.206*Y2(2,K)+SA(7,2,K)-SE(7,2,K))=0);
@FOR(MONTHS(K): (0.024*Y3(1,K)-0.098*Y3(2,K)-0.222*Y3(2,K)-0.467*Y3(4,K)+SA(7,3,K)-SE(7,3,K))=0);
@FOR(MONTHS(K): (0.005*Y4(1,K)-0.02*Y4(2,K)+SA(7,4,K)-SE(7,4,K))=0);
@FOR(MONTHS(K): (-0.117*Y5(1,K)+0.024*Y5(2,K)-0.096*Y5(3,K)-0.156*Y5(4,K)+SA(7,5,K)-SE(7,5,K))=0);
@FOR(MONTHS(K): (-0.175*Y6(1,K)-0.335*Y6(2,K)+0.0448*Y6(3,K)+SA(7,6,K)-SE(7,6,K))=0);
@FOR(MONTHS(K): (0.06*Y7(1,K)-0.227*Y7(2,K)-0.238*Y7(3,K)+SA(7,7,K)-SE(7,7,K))=0);
@FOR(MONTHS(K): (-0.048*Y8(1,K)+0.012*Y8(2,K)+SA(7,8,K)-SE(7,8,K))=0);
@FOR(MONTHS(K): (0.106*Y9(1,K)-0.423*Y9(2,K)+SA(7,9,K)-SE(7,9,K))=0);
@FOR(MONTHS(K): (-0.253*Y10(1,K)+0.005*Y10(2,K)-0.02*Y10(3,K)-0.336*Y10(4,K)+SA(7,10,K)-SE(7,10,K))=0);
@FOR(MONTHS(K): (0.005*Y11(1,K)-0.021*Y11(2,K)+SA(7,11,K)-SE(7,11,K))=0);
@FOR(MONTHS(K): (0.012*Y12(1,K)-0.048*Y12(2,K)-0.313*Y12(3,K)-0.372*Y12(4,K)+SA(7,12,K)-SE(7,12,K))=0);
@FOR(MONTHS(K): (-0.172*Y13(1,K)+0.043*Y13(2,K)-0.332*Y13(3,K)+SA(7,13,K)-SE(7,13,K))=0);
@FOR(MONTHS(K): (-0.005*Y14(1,K)+0.001*Y14(2,K)-0.543*Y14(3,K)+SA(7,14,K)-SE(7,14,K))=0);

(Capacity Utilization Goal Constraints)

@FOR(MONTHS(K): (0.03*Y1(1,K)-0.119*Y1(2,K)-0.227*Y1(3,K)+SA(8,1,K)-SE(8,1,K))=0);
@FOR(MONTHS(K): (0.022*Y2(1,K)-0.086*Y2(2,K)+SA(8,2,K)-SE(8,2,K))=0);
@FOR(MONTHS(K): (-0.135*Y3(1,K)-0.096*Y3(2,K)+0.024*Y3(3,K)-0.11*Y3(4,K)+SA(8,3,K)-SE(8,3,K))=0);
@FOR(MONTHS(K): (-0.089*Y4(1,K)+0.022*Y4(2,K)+SA(8,4,K)-SE(8,4,K))=0);
@FOR(MONTHS(K): (-0.132*Y5(1,K)-0.11*Y5(2,K)+0.027*Y5(3,K)-0.107*Y5(4,K)+SA(8,5,K)-SE(8,5,K))=0);
@FOR(MONTHS(K): (-0.096*Y6(1,K)+0.024*Y6(2,K)-0.11*Y6(3,K)+SA(8,6,K)-SE(8,6,K))=0);
@FOR(MONTHS(K): (-0.096*Y7(1,K)+0.024*Y7(2,K)-0.11*Y7(3,K)+SA(8,7,K)-SE(8,7,K))=0);
@FOR(MONTHS(K): (-0.226*Y8(1,K)+0.056*Y8(2,K)+SA(8,8,K)-SE(8,8,K))=0);
@FOR(MONTHS(K): (0.03*Y9(1,K)-0.119*Y9(2,K)+SA(8,9,K)-SE(8,9,K))=0);
@FOR(MONTHS(K): (-0.257*Y10(1,K)+0.025*Y10(2,K)-0.293*Y10(3,K)-0.098*Y10(4,K)+SA(8,10,K)-SE(8,10,K))=0);
@FOR(MONTHS(K): (0.012*Y11(1,K)-0.046*Y11(2,K)+SA(8,11,K)-SE(8,11,K))=0);
@FOR(MONTHS(K): (-0.154*Y12(1,K)-0.115*Y12(2,K)+0.005*Y12(3,K)-0.021*Y12(4,K)+SA(8,12,K)-SE(8,12,K))=0);
@FOR(MONTHS(K): (-0.092*Y13(1,K)-0.075*Y13(2,K)+0.019*Y13(3,K)+SA(8,13,K)-SE(8,13,K))=0);
@FOR(MONTHS(K): (-0.127*Y14(1,K)-0.163*Y14(2,K)+0.032*Y14(3,K)+SA(8,14,K)-SE(8,14,K))=0);

(University Graduates Goal Constraints)

@FOR(MONTHS(K): (-0.002*Y1(1,K)-0.011*Y1(2,K)+0.001*Y1(3,K)+SA(9,1,K)-SE(9,1,K))=0);
@FOR(MONTHS(K): (-0.009*Y2(1,K)+0.002*Y2(2,K)+SA(9,2,K)-SE(9,2,K))=0);
@FOR(MONTHS(K): (-0.045*Y3(1,K)+0.007*Y3(2,K)-0.035*Y3(3,K)-0.029*Y3(4,K)+SA(9,3,K)-SE(9,3,K))=0);
@FOR(MONTHS(K): (-0.024*Y4(1,K)+0.006*Y4(2,K)+SA(9,4,K)-SE(9,4,K))=0);
@FOR(MONTHS(K): (-0.015*Y5(1,K)-0.04*Y5(2,K)-0.005*Y5(3,K)+0.001*Y5(4,K)+SA(9,5,K)-SE(9,5,K))=0);
@FOR(MONTHS(K): (0.007*Y6(1,K)-0.035*Y6(2,K)-0.029*Y6(3,K)+SA(9,6,K)-SE(9,6,K))=0);
@FOR(MONTHS(K): (0.007*Y7(1,K)-0.035*Y7(2,K)-0.029*Y7(3,K)+SA(9,7,K)-SE(9,7,K))=0);
@FOR(MONTHS(K): (-0.011*Y8(1,K)+0.003*Y8(2,K)+SA(9,8,K)-SE(9,8,K))=0);
@FOR(MONTHS(K): (0.002*Y9(1,K)-0.007*Y9(2,K)+SA(9,9,K)-SE(9,9,K))=0);
@FOR(MONTHS(K): (-0.057*Y10(1,K)-0.043*Y10(2,K)+0.011*Y10(3,K)-0.047*Y10(4,K)+SA(9,10,K)-SE(9,10,K))=0);
@FOR(MONTHS(K): (-0.074*Y11(1,K)+0.018*Y11(2,K)+SA(9,11,K)-SE(9,11,K))=0);

```
@FOR(MONTHS(K): (-0.044*Y12(1,K)+0.009*Y12(2,K)-0.034*Y12(3,K)-0.039*Y12(4,K)+SA(9,12,K)-
                SE(9,12,K))=0);
@FOR(MONTHS(K): (-0.068*Y13(1,K)+0.01*Y13(2,K)-0.038*Y13(3,K)+SA(9,13,K)-SE(9,13,K))=0);
@FOR(MONTHS(K): (-0.056*Y14(1,K)+0.012*Y14(2,K)-0.046*Y14(3,K)+SA(9,14,K)-SE(9,14,K))=0);
```

(Demand Constraints)

```
@FOR(MONTHS(K):(@SUM(SUPPLIERS1(I):Y1(I,K)))-QD1(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS2(I):Y2(I,K)))-QD2(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS3(I):Y3(I,K)))-QD3(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS4(I):Y4(I,K)))-QD4(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS5(I):Y5(I,K)))-QD5(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS6(I):Y6(I,K)))-QD6(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS7(I):Y7(I,K)))-QD7(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS8(I):Y8(I,K)))-QD8(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS9(I):Y9(I,K)))-QD9(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS10(I):Y10(I,K)))-QD10(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS11(I):Y11(I,K)))-QD11(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS12(I):Y12(I,K)))-QD12(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS13(I):Y13(I,K)))-QD13(K)=0);
@FOR(MONTHS(K):(@SUM(SUPPLIERS14(I):Y14(I,K)))-QD14(K)=0);
```

(Capacity Constraints)

```
@FOR(MONTHS(K):(Y3(1,K)+Y5(1,K)+Y8(1,K)+Y10(1,K)+Y12(1,K)+Y14(1,K))<=50000);
@FOR(MONTHS(K):(Y4(1,K)+Y5(2,K)+Y11(1,K)+Y13(1,K))<=20833);
@FOR(MONTHS(K):(Y3(2,K)+Y6(1,K)+Y7(1,K)+Y12(2,K)+Y13(2,K))<=10000);
@FOR(MONTHS(K):(Y1(1,K)+Y8(2,K)+Y9(1,K)+Y10(2,K))<=8333);
@FOR(MONTHS(K):(Y10(3,K)+Y11(2,K)+Y14(2,K))<=12500);
@FOR(MONTHS(K):(Y3(3,K)+Y5(3,K)+Y6(2,K)+Y7(2,K)+Y10(4,K)+Y12(3,K)+Y14(3,K))<=83333);
@FOR(MONTHS(K):(Y1(2,K)+Y2(1,K)+Y4(2,K)+Y9(2,K)+Y12(4,K)+Y13(3,K))<=70833);
@FOR(MONTHS(K):(Y1(3,K)+Y2(2,K)+Y3(4,K)+Y5(4,K)+Y6(3,K)+Y7(3,K))<=100000);
```

(Total Quantities Ordered)

```
@FOR(SUPPLIERS1(I): TY1(I)=@SUM(MONTHS(K):Y1(I,K)));
@FOR(SUPPLIERS2(I): TY2(I)=@SUM(MONTHS(K):Y2(I,K)));
@FOR(SUPPLIERS3(I): TY3(I)=@SUM(MONTHS(K):Y3(I,K)));
@FOR(SUPPLIERS4(I): TY4(I)=@SUM(MONTHS(K):Y4(I,K)));
@FOR(SUPPLIERS5(I): TY5(I)=@SUM(MONTHS(K):Y5(I,K)));
@FOR(SUPPLIERS6(I): TY6(I)=@SUM(MONTHS(K):Y6(I,K)));
@FOR(SUPPLIERS7(I): TY7(I)=@SUM(MONTHS(K):Y7(I,K)));
@FOR(SUPPLIERS8(I): TY8(I)=@SUM(MONTHS(K):Y8(I,K)));
@FOR(SUPPLIERS9(I): TY9(I)=@SUM(MONTHS(K):Y9(I,K)));
@FOR(SUPPLIERS10(I): TY10(I)=@SUM(MONTHS(K):Y10(I,K)));
@FOR(SUPPLIERS11(I): TY11(I)=@SUM(MONTHS(K):Y11(I,K)));
@FOR(SUPPLIERS12(I): TY12(I)=@SUM(MONTHS(K):Y12(I,K)));
@FOR(SUPPLIERS13(I): TY13(I)=@SUM(MONTHS(K):Y13(I,K)));
@FOR(SUPPLIERS14(I): TY14(I)=@SUM(MONTHS(K):Y14(I,K)));
```

(Computation of Units Accepted)

```
TQ1=@SUM(SUPPLIERS1(I):TK21*TY1);
TQ2=@SUM(SUPPLIERS2(I):TK22*TY2);
TQ3=@SUM(SUPPLIERS3(I):TK23*TY3);
```

```
TQ4=@SUM(SUPPLIERS4(I):TK24*TY4);
TQ5=@SUM(SUPPLIERS5(I):TK25*TY5);
TQ6=@SUM(SUPPLIERS6(I):TK26*TY6);
TQ7=@SUM(SUPPLIERS7(I):TK27*TY7);
TQ8=@SUM(SUPPLIERS8(I):TK28*TY8);
TQ9=@SUM(SUPPLIERS9(I):TK29*TY9);
TQ10=@SUM(SUPPLIERS10(I):TK210*TY10);
TQ11=@SUM(SUPPLIERS11(I):TK211*TY11);
TQ12=@SUM(SUPPLIERS12(I):TK212*TY12);
TQ13=@SUM(SUPPLIERS13(I):TK213*TY13);
TQ14=@SUM(SUPPLIERS14(I):TK214*TY14);
```

(Computation of Units On-Time)

```
TL1=@SUM(SUPPLIERS1(I):TT1*TY1);
TL2=@SUM(SUPPLIERS2(I):TT2*TY2);
TL3=@SUM(SUPPLIERS3(I):TT3*TY3);
TL4=@SUM(SUPPLIERS4(I):TT4*TY4);
TL5=@SUM(SUPPLIERS5(I):TT5*TY5);
TL6=@SUM(SUPPLIERS6(I):TT6*TY6);
TL7=@SUM(SUPPLIERS7(I):TT7*TY7);
TL8=@SUM(SUPPLIERS8(I):TT8*TY8);
TL9=@SUM(SUPPLIERS9(I):TT9*TY9);
TL10=@SUM(SUPPLIERS10(I):TT10*TY10);
TL11=@SUM(SUPPLIERS11(I):TT11*TY11);
TL12=@SUM(SUPPLIERS12(I):TT12*TY12);
TL13=@SUM(SUPPLIERS13(I):TT13*TY13);
TL14=@SUM(SUPPLIERS14(I):TT14*TY14);
```

(Integer Variables)

```
@FOR(ARC1(I,K):@GIN(Y1(I,K)));
@FOR(ARC2(I,K):@GIN(Y2(I,K)));
@FOR(ARC3(I,K):@GIN(Y3(I,K)));
@FOR(ARC4(I,K):@GIN(Y4(I,K)));
@FOR(ARC5(I,K):@GIN(Y5(I,K)));
@FOR(ARC6(I,K):@GIN(Y6(I,K)));
@FOR(ARC7(I,K):@GIN(Y7(I,K)));
@FOR(ARC8(I,K):@GIN(Y8(I,K)));
@FOR(ARC9(I,K):@GIN(Y9(I,K)));
@FOR(ARC10(I,K):@GIN(Y10(I,K)));
@FOR(ARC11(I,K):@GIN(Y11(I,K)));
@FOR(ARC12(I,K):@GIN(Y12(I,K)));
@FOR(ARC13(I,K):@GIN(Y13(I,K)));
@FOR(ARC14(I,K):@GIN(Y14(I,K)));

END
```

ADDITIONAL LINES TO MODEL 1 FORMULATION FOR MODELS 3 & 4

(Number of suppliers is 2.)

```
@FOR(MONTHS(K):(@SUM(SUPPLIERS1(I):X1(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS2(I):X2(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS3(I):X3(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS4(I):X4(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS5(I):X5(I,K)))=2);
```

```
@FOR(MONTHS(K):(@SUM(SUPPLIERS6(I):X6(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS7(I):X7(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS8(I):X8(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS9(I):X9(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS10(I):X10(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS11(I):X11(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS12(I):X12(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS13(I):X13(I,K)))=2);
@FOR(MONTHS(K):(@SUM(SUPPLIERS14(I):X14(I,K)))=2);
```

(Minimum number of units to be ordered from a selected supplier)

```
@FOR(ARC1(I,K)|QD1(K)#GT#0 :(240*X1(I,K)-Y1(I,K))<=0);
@FOR(ARC2(I,K)|QD2(K)#GT#0 :(210*X2(I,K)-Y2(I,K))<=0);
@FOR(ARC3(I,K)|QD3(K)#GT#0 :(540*X3(I,K)-Y3(I,K))<=0);
@FOR(ARC4(I,K)|QD4(K)#GT#0 :(75*X4(I,K)-Y4(I,K))<=0);
@FOR(ARC5(I,K)|QD5(K)#GT#0 :(130*X5(I,K)-Y5(I,K))<=0);
@FOR(ARC6(I,K)|QD6(K)#GT#0 :(120*X6(I,K)-Y6(I,K))<=0);
@FOR(ARC7(I,K)|QD7(K)#GT#0 :(200*X7(I,K)-Y7(I,K))<=0);
@FOR(ARC8(I,K)|QD8(K)#GT#0 :(230*X8(I,K)-Y8(I,K))<=0);
@FOR(ARC10(I,K)|QD10(K)#GT#0 :(130*X10(I,K)-Y10(I,K))<=0);
@FOR(ARC11(I,K)|QD11(K)#GT#0 :(85*X11(I,K)-Y11(I,K))<=0);
@FOR(ARC12(I,K)|QD12(K)#GT#0 :(160*X12(I,K)-Y12(I,K))<=0);
@FOR(ARC13(I,K)|QD13(K)#GT#0 :(310*X13(I,K)-Y13(I,K))<=0);
@FOR(ARC14(I,K)|QD14(K)#GT#0 :(800*X14(I,K)-Y14(I,K))<=0);
```

(No units should be assigned to a supplier that is not selected)

```
@FOR(ARC1(I,K): (500000*X1(I,K)-Y1(I,K))>=0);
@FOR(ARC2(I,K): (500000*X2(I,K)-Y2(I,K))>=0);
@FOR(ARC3(I,K): (500000*X3(I,K)-Y3(I,K))>=0);
@FOR(ARC4(I,K): (500000*X4(I,K)-Y4(I,K))>=0);
@FOR(ARC5(I,K): (500000*X5(I,K)-Y5(I,K))>=0);
@FOR(ARC6(I,K): (500000*X6(I,K)-Y6(I,K))>=0);
@FOR(ARC7(I,K): (500000*X7(I,K)-Y7(I,K))>=0);
@FOR(ARC8(I,K): (500000*X8(I,K)-Y8(I,K))>=0);
@FOR(ARC9(I,K): (500000*X9(I,K)-Y9(I,K))>=0);
@FOR(ARC10(I,K): (500000*X10(I,K)-Y10(I,K))>=0);
@FOR(ARC11(I,K): (500000*X11(I,K)-Y11(I,K))>=0);
@FOR(ARC12(I,K): (500000*X12(I,K)-Y12(I,K))>=0);
@FOR(ARC13(I,K): (500000*X13(I,K)-Y13(I,K))>=0);
@FOR(ARC14(I,K): (500000*X14(I,K)-Y14(I,K))>=0);
```

(Binary Variables)

```
@FOR(ARC1(I,K):@BIN(X1(I,K)));
@FOR(ARC2(I,K):@BIN(X2(I,K)));
@FOR(ARC3(I,K):@BIN(X3(I,K)));
@FOR(ARC4(I,K):@BIN(X4(I,K)));
@FOR(ARC5(I,K):@BIN(X5(I,K)));
@FOR(ARC6(I,K):@BIN(X6(I,K)));
@FOR(ARC7(I,K):@BIN(X7(I,K)));
@FOR(ARC8(I,K):@BIN(X8(I,K)));
@FOR(ARC9(I,K):@BIN(X9(I,K)));
@FOR(ARC10(I,K):@BIN(X10(I,K)));
@FOR(ARC11(I,K):@BIN(X11(I,K)));
@FOR(ARC12(I,K):@BIN(X12(I,K)));
@FOR(ARC13(I,K):@BIN(X13(I,K)));
@FOR(ARC14(I,K):@BIN(X14(I,K)));
```

SOLUTIONS OF FOUR ALTERNATIVE MODELS IN MATERIALS SUPPLIER SELECTION

Table D1.1: Quantities Ordered By Model 1

No	Material	No	Supplier	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11	2001-12	2002-01	2002-02	2002-03	2002-04
1	Polyester Coil	1	Muteks	64	55	5069	151	492	581	1012	275	644	22	5
		2	Coats	238	203	1897	563	1844	2179	3794	1031	2415	82	15
2	Label	1	Borneman											
		2	Wah Sing											
		3	Desan											
		4	Akın Etiketçilik											
		5	Öztek Etiket											
		6	Teslo											
		7	Dizayn	26990		53035						28383	860	
		8	Eticart	6670	119782	83702	205171	313197	600038	434081	165325	280189		
		9	New Yuen											
		10	Wing Tak											
3	Zip	1	YKK	1		3	1		2		1			
		2	Muteks	3077	6840	2367	4661	17541	5759	3033	5863	703		
		3	Opti Fermuar	12397	27536	9559	18776	70615	23203	12211	23613	2833		
4	Print	1	Heat Seal	17280	10833	77809	18002	84992	338648	41923	99150	324110		
		2	Printec											
		3	Chris Kay											
		4	Rapid Transfer											
5	Nylon Bag	1	Emek Plastik											
		2	Ada Plastik											
		3	Gürdemir Plastik											
		4	Selda Plastik											
		5	Muteks	118351	442892	254664	301160	771232	849403	418180	338347	211330	313	
		6	Altın											
		7	Bora Tekstil											
6	Mercerized Coil	1	Muteks	31	50	110	166	348	1011	488	691	834	189	103
		2	Coats	124	197	436	654	1375	4004	1931	2735	3301	748	407
7	Sized Label	1	Teslo					2811	166666					
		2	Dizayn	56343	83333	30298	83333	83333	83333	83333	83333	54950		
		3	Borneman											
		4	Paxar						7718					
		5	Wah Sing											
		6	Öztek Etiket	5162	106953	2776	80110	125000	125000	27173	38725	5034		

8	Hanger	1	Tam Plastik	978	2758	8048	3031	22767	1802	[illegible]	[illegible]			
		2	Randy Hangers	3909	11030	32192	12125	91066	7206	15103	12784			
9	Washing Instruction	1	Intermat					12	4216					
		2	Öztek Etiket	2	5	4	12					2		
		3	Akın Etiketçilik	50235	186155	81970	117828	222816	544158	155443	94843	59888	313	
		4	Teslo	12273	45487	20024	28761	54424	37996	23185	14633	77		
		5	Wah Sing						33774					
10	Packaging Box	1	Onurcan Ambalaj	89	1211	157	482	901	637	533	763	552		
		2	Orsan Ambalaj	929	12724	1640	5070	9449	6686	5587	8007	5790		
11	Sized Washing Instruction	1	Akın Etiketçilik											
		2	Wah Sing											
		3	Ayrıntı											
		4	Borneman											
		5	Öztek Etiket											
		6	Kuloğlu	26220	113495	70426	112077	197152	171929	212276	136784	278488	7084	
		7	Paxar	884									239	
12	Packaging Box Label	1	Borneman											
		2	Hobby Etiket											
		3	İstanbul Etiket											
		4	Grafficart	5206	5621	10781	12999	10259	11066	15416	11125	5127		
		5	RVL	86763	93677	179929	216641	170980	184426	258156	185496	85529		
		6	Profit											
		7	Kwan Tat			3				15	1	1		
13	Weaving Ribbon	1	Muteks	5110	41511	1245	59284	127810	157986	114697	28256	99157	6204	
		2	Suner	1298	10548	316	15064	32475	40143	29144	7180	25196	1577	
14	Çıt çıt	1	Scovill			3982	12736	32080	11945	72127	36779	13728		
		2	Ching Fung			16258	52006	130994	48775	294521	150182	56056		
		3	YKK											
15	Rubber	1	Bam Tekstil			7024	1043	9008	62204	2518	19247	11938		
		2	Muteks											
		3	Armoni											
16	Seperator	1	Onurcan Ambalaj	106	2406	471	2052	2642	3267	1698	2701	1648	49	
		2	Özgün	441	9996	1957	8526	10977	13573	7056	11221	6842	203	
17	Kılçık	1	Şık Düğme	133810	232549	60799	263859	605218	621296	250187	295248	302096		
		2	Muteks	33453	58137	15199	65964	151303	155324	62546	73812	75523		
18	Button	1	Primoda											
		2	Muteks											
		3	Lauragel			78505	131680	44765	13180		4400			
		4	Banner											

19	Tape	1	Özgül	8	27	4	41	100						
		2	Baran Kırtasiye	31	109	16	168	400	27	122	82	372		
20	Packaging Tape	1	Megabant		169	150	418	501	98	58	94	110		
		2	Atılım Ambalaj		25	22	61	73	14	8	13	16		
21	Sticker	1	Merve											
		2	Vipeks		2431	114	868	4602	21640	7019	4473			
		3	Primoda											
22	UPC Label	1	Softek			2354					47233			
		2	Santra			588					11808			
23	Packaging Paper	1	Bayramoğlu											
		2	Merve		326			9		475	368			
		3	Softek		1517			40		2212	1722			

Table D1.2: Quantities Ordered By Model 2

No	Material	No	Supplier	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11	2001-12	2002-01	2002-02	2002-03	2002-04
1	Polyester Coil	1	Muteks	243	208	1935	574	1880	2221	3869	1051	2462	83	16
		2	Coats	59	50	468	140	456	539	937	255	597	21	4
2	Label	1	Borneman											
		2	Wah Sing											
		3	Desan											
		4	Akın Etiketçilik											
		5	Öztek Etiket											
		6	Teslo											
		7	Dizayn	33660	18047	78403	44890			66860	65139	74391	860	
		8	Eticart		101735	58334	160281	313197	600038	367221	100186	234181		
		9	New Yuen											
		10	Wing Tak											
3	Zip	1	YKK	7		7	10	3	3		5			
		2	Muteks	3065	6840	2359	4643	17535	5757	3033	5855	703		
		3	Opti Fermuar	12403	27536	9563	18785	70618	23204	12211	23617	2833		
4	Print	1	Heat Seal	17280	10833	77809	18002	84992	338648	41923	99150	324110		
		2	Printec											
		3	Chris Kay											
		4	Rapid Transfer											
5	Nylon Bag	1	Emek Plastik											
		2	Ada Plastik											
		3	Gürdemir Plastik											
		4	Selda Plastik											
		5	Muteks	118351	442892	254664	301160	771232	849403	418180	338347	211330	313	
		6	Altın											
		7	Bora Tekstil											
6	Mercerized Coil	1	Muteks	32	50	110	166	348	1011	487	691	834	189	103
		2	Coats	123	197	436	654	1375	4004	1932	2735	3301	748	407
7	Sized Label	1	Teslo					2811	166666					
		2	Dizayn	9169	65286	4930	38443	83333	83333	16473	18194	8942		
		3	Borneman											
		4	Paxar						7718					
		5	Wah Sing											
		6	Öztek Etiket	52336	125000	28144	125000	125000	125000	94033	103864	51042		
8	Hanger	1	Tam Plastik	3901	11007	32124	12100	90875	7192	15071	12757			
		2	Randy Hangers	986	2781	8116	3056	22958	1816	3808	3223			

No	Material	No	Supplier	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11	2001-12	2002-01	2002-02	2002-03	2002-04
9	Washing Instruction	1	Intermat											
		2	Öztek Etiket	4069		6639				12591	7683	4849	26	
		3	Akın Etiketçilik	58441	216569	95359	137058	259205	544257	180848	110345	69672	364	
		4	Teslo					1						
		5	Wah Sing		15078		9543	18046	37891			2		
10	Packaging Box	1	Onurcan Ambalaj	89	1211	156	482	900	637	533	763	551		
		2	Orsan Ambalaj	929	12724	1641	5070	9450	6686	5587	8007	5791		
11	Sized Washing Instruction	1	Akın Etiketçilik											
		2	Wah Sing											
		3	Ayrıntı											
		4	Borneman											
		5	Öztek Etiket											
		6	Kuloğlu	26221	113495	70426	112077	197152	171929	212276	136784	278488	7085	
		7	Paxar	883									238	
12	Packaging Box Label	1	Borneman											
		2	Hobby Etiket											
		3	İstanbul Etiket											
		4	Grafficart		3	1	2				1	2		
		5	RVL	91286	98558	189296	227933	179893	194040	271555	195161	89982		
		6	Profit	683	737	1416	1705	1346	1452	2032	1460	673		
		7	Kwan Tat											
13	Weaving Ribbon	1	Muteks	5110	41511	1245	59284	127810	157986	114696	28256	99157	6205	
		2	Suner	1298	10548	316	15064	32475	40143	29145	7180	25196	1576	
14	Çıt çıt	1	Scovill			16425	52539	132337	49275	297541	151722	56632		
		2	Ching Fung			3815	12203	30737	11445	69107	35239	13152		
		3	YKK											
15	Rubber	1	Bam Tekstil			7024	1043	9008	62204	2518	19247	11938		
		2	Muteks											
		3	Armoni											
16	Seperator	1	Onurcan Ambalaj	107	2407	472	2053	2642	3268	1698	2701	1648	49	
		2	Özgün	440	9995	1956	8525	10977	13572	7056	11221	6842	203	
17	Kılçık	1	Şık Düğme	133810	232549	60799	263859	605218	621296	250187	295248	302096		
		2	Muteks	33453	58137	15199	65964	151303	155324	62546	73812	75523		
18	Button	1	Primoda											
		2	Muteks											
		3	Lauragel			78505	131680	44765	13180		4400			
		4	Banner											

No	Material	No	Supplier	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11	2001-12	2002-01	2002-02	2002-03	2002-04
19	Tape	1	Özgül	8	27	4	41	100	6	30	20	93		
		2	Baran Kırtasiye	31	109	16	168	400	27	122	82	372		
20	Packaging Tape	1	Megabant		169	150	418	500	98	58	94	110		
		2	Atılım Ambalaj		25	22	61	74	14	8	13	16		
21	Sticker	1	Merve		1956	91	699	3703	17411	5647	3599			
		2	Vipeks		475	23	169	899	4229	1372	874			
		3	Primoda											
22	UPC Label	1	Softek			2360					47378			
		2	Santra			582					11663			
23	Packaging Paper	1	Bayramoğlu											
		2	Merve		1675			44		2442	1901			
		3	Softek		168			5		245	189			

Table D1.3: Quantities Ordered By Model 3

No	Material		Supplier	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11	2001-12	2002-01	2002-02	2002-03	2002-04
1	Polyester Coil	1	Muteks	64	55	5069	151	492	581	1012	275	644	22	5
		2	Coats	238	203	1897	563	1844	2179	3794	1031	2415	82	15
2	Label	1	Borneman											
		2	Wah Sing											
		3	Desan						100038					
		4	Akın Etiketçilik											
		5	Öztek Etiket											
		6	Teslo											
		7	Dizayn	26990	86	53559	86	86		86	86	28383	774	
		8	Eticart	6670	119696	83178	205085	313111	500000	433995	165239	280189	86	
		9	New Yuen											
		10	Wing Tak											
3	Zip	1	YKK					8660						
		2	Muteks	3079	6840	2373	4663		5763	3033	5865	703		
		3	Opti Fermuar	12396	27536	9556	18775	79496	23201	12211	23612	2833		
4	Print	1	Heat Seal	16280	9833	76809	17002	83992	337648	40923	98150	323110		
		2	Printec											
		3	Chris Kay											
		4	Rapid Transfer	1000	1000	1000	1000	1000	1000	1000	1000	1000		
5	Nylon Bag	1	Emek Plastik											
		2	Ada Plastik											
		3	Gürdemir Plastik											
		4	Selda Plastik											
		5	Muteks	118321	442862	254634	301130	500000	500000	418150	338317	211300	283	
		6	Altın											
		7	Bora Tekstil	30	30	30	30	271232	349403	30	30	30	30	
6	Mercerized Coil	1	Muteks	32	50	110	166	348	1011	487	690	834	189	103
		2	Coats	123	197	436	654	1375	4004	1932	2736	3301	748	407
7	Sized Label	1	Teslo				80196	127897						
		2	Dizayn	56343	83247	29774	83247	83247		83247	83247	54950		
		3	Borneman											
		4	Paxar						257717					
		5	Wah Sing											
		6	Öztek Etiket	5162	107039	3300			125000	27259	38811	5034		
8	Hanger	1	Tam Plastik	978	2758	8048	3031	22767	1802	3776	3196			
		2	Randy Hangers	3909	11030	32192	12125	91066	7206	15103	12784			

No	Material		Supplier	2001-06	2001-07	2001-08	2001-09							
9	Washing Instruction	1	Intermat						82148					
		2	Öztek Etiket	4069			117805	18046				4851		
		3	Akın Etiketçilik	58441	186146	81962		259206	500000	155443	94843	69672	314	
		4	Teslo		45501	20036	28796			37996	23185		76	
		5	Wah Sing											
10	Packaging Box	1	Onurcan Ambalaj	100	100	100	100	901	100	533	100	100		
		2	Orsan Ambalaj	918	13835	1697	5453	9449	7223	5587	8670	6242		
11	Sized Washing Instruction	1	Akın Etiketçilik											
		2	Wah Sing											
		3	Ayrıntı											
		4	Borneman											
		5	Öztek Etiket											
		6	Kuloğlu	26374	112765	69696	108423	190723	166322	205355	132324	269406	6593	
		7	Paxar	730	730	730	3654	6429	5607	6921	4460	9082	730	
12	Packaging Box Label	1	Borneman											
		2	Hobby Etiket											
		3	İstanbul Etiket											
		4	Grafficart	9000	9000	10796	12999	10259	11065	15481	11129	9000		
		5	RVL	82969	90298	179917	216641	170980	184427		185493	81657		
		6	Profit											
		7	Kwan Tat							258106				
13	Weaving Ribbon	1	Muteks	5110	41511	1245	59284	127810	157986	114697	28256	88157	6204	
		2	Suner	1298	10548	316	15064	32475	40143	29144	7180	25196	1577	
14	Çıt çıt	1	Scovill			3982	12736	32080	11945	72128	36779	13728		
		2	Ching Fung			16258	52006	130994	48775	294520	150182	56056		
		3	YKK											
15	Rubber	1	Bam Tekstil			6924	943	8908	62104	2418	19147	11838		
		2	Muteks			100	100	100	100	100	100	100		
		3	Armoni											
16	Seperator	1	Onurcan Ambalaj	25	25	471	25	25	25	25	2702	25	25	
		2	Özgün	522	12377	1957	10553	13594	16815	8729	11220	8465	227	
17	Kılçık	1	Şık Düğme	13381	232549	60798	263859	500000	500000	250187	295248	302096		
		2	Muteks	33452	58137	15200	65964	256521	276620	62546	73812	75523		
18	Button	1	Primoda											
		2	Muteks											
		3	Lauragel			78065	131240	44325	12740	3960				
		4	Banner			440	440	440	440	440				

No	Material		Supplier	2001-06	2001-07	2001-08	2001-09							
19	Tape	1	Özgül	8	27	4	41	100	6	30	20	93		
		2	Baran Kırtasiye	31	109	16	168	400	27	122	82	372		
20	Packaging Tape	1	Megabant		169	150	418	501	98	58	94	110		
		2	Atılım Ambalaj		25	22	61	73	14	8	13	16		
21	Sticker	1	Merve		10	10	10	10	10	10	10			
		2	Vipeks		2421	104	858	4592	21630	7009	4463			
		3	Primoda											
22	UPC Label	1	Softek			2354					47233			
		2	Santra			588					11808			
23	Packaging Paper	1	Bayramoğlu											
		2	Merve		326			9		475	368			
		3	Softek		1517			40		2212	1722			

Table D1.4: Quantities Ordered By Model 4

No	Material		Supplier	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11	2001-12	2002-01	2002-02	2002-03	2002-04
1	Polyester Coil	1	Muteks	243	208	1935	574	1880	2221	3869	1051	2462	83	16
		2	Coats	59	50	468	140	456	539	937	255	597	21	4
2	Label	1	Borneman											
		2	Wah Sing											
		3	Desan						100038					
		4	Akın Etiketçilik											
		5	Öztek Etiket											
		6	Teslo											
		7	Dizayn	33574	18047	78403	44890	83333		66860	65138	74391	774	
		8	Eticart	86	101735	58334	160281	229864	500000	367221	100187	234181	86	
		9	New Yuen											
		10	Wing Tak											
3	Zip	1	YKK		3376			8660	2845					
		2	Muteks	3079		2373	4663			3033	5865	703		
		3	Opti Fermuar	12396	31000	9556	18775	79496	26119	12211	23612	2833		
4	Print	1	Heat Seal	16280	9833	76809	17002	83992	337648	40923	98150	323110		
		2	Printec											
		3	Chris Kay											
		4	Rapid Transfer	1000	1000	1000	1000	1000	1000	1000	1000	1000		
5	Nylon Bag	1	Emek Plastik											
		2	Ada Plastik											
		3	Gürdemir Plastik											
		4	Selda Plastik											
		5	Muteks	118321	442862	254634	301130	500000	500000	418150	338317	211300	283	
		6	Altın											
		7	Bora Tekstil	30	30	30	30	271232	349403	30	30	30	30	
6	Mercerized Coil	1	Muteks	31	50	111	166	348	1011	487	691	834	189	103
		2	Coats	124	197	435	654	1375	4004	1932	2735	3301	748	407
7	Sized Label	1	Teslo					86144						
		2	Dizayn	9169	65286	4930	38443			16473	18195	8942		
		3	Borneman											
		4	Paxar						257717					
		5	Wah Sing											
		6	Öztek Etiket	52336	125000	28144	125000	125000	125000	94033	103863	51042		
8	Hanger	1	Tam Plastik	3901	11007	32124	12100	90875	7191	15071	12757			
		2	Randy Hangers	986	2781	8116	3056	22958	1817	3808	3223			

No	Material		Supplier	2001-06	2001-07	2001-08	2001-09							
9	Washing Instruction	1	Intermat				137059		415482					
		2	Öztek Etiket	4069		6639				12591	7683	4851	39	
		3	Akın Etiketçilik	58441	216569	95359		259206		180848	110345	69672	351	
		4	Teslo						166666					
		5	Wah Sing		15078		9542	18046						
10	Packaging Box	1	Onurcan Ambalaj	100	100	100	100	901	100	533	100	100		
		2	Orsan Ambalaj	918	13835	1697	5452	9449	7223	5587	8670	6242		
11	Sized Washing Instruction	1	Akın Etiketçilik											
		2	Wah Sing											
		3	Ayrıntı											
		4	Borneman											
		5	Öztek Etiket											
		6	Kuloğlu	26374	112765	69696	108423	190723	166323	205355	132324	269407	6593	
		7	Paxar	730	730	730	3654	6429	5606	6921	4460	9081	730	
12	Packaging Box Label	1	Borneman					36248						
		2	Hobby Etiket											
		3	İstanbul Etiket											
		4	Grafficart	9000	9000	10796	12999		11065	15486	11129	9000		
		5	RVL	82969	90298	179917	216641		184427	258101	185493	81657		
		6	Profit					144991						
		7	Kwan Tat											
13	Weaving Ribbon	1	Muteks	5110	41511	1244	59284	127810	157986	114696	28256	99157	6204	
		2	Suner	1298	10548	317	15064	32475	40143	29145	7180	25196	1577	
14	Çıt çıt	1	Scovill			16425	52539	132337	49275	297542	151722	56632		
		2	Ching Fung			3815	12203	30737	11445	69106	35239	13152		
		3	YKK											
15	Rubber	1	Bam Tekstil			6924	943	8908	62104	2418	19147	11838		
		2	Muteks			100	100	100	100	100	100	100		
		3	Armoni											
16	Seperator	1	Onurcan Ambalaj	25	25	472	25	25	25	25	2702	25	25	
		2	Özgün	522	12377	1956	10553	13594	16815	8729	11211	8465	227	
17	Kılçık	1	Şık Düğme	133810	232549	60799	263859	500000	500000	250187	295248	302096		
		2	Muteks	33453	58137	15199	65964	256521	276620	62546	73812	75523		
18	Button	1	Primoda											
		2	Muteks											
		3	Lauragel			78065	131240	44325	12740		3960			
		4	Banner			440	440	440	440		440			

No	Material		Supplier	2001-06	2001-07	2001-08	2001-09	2001-10	2001-11					
19	Tape	1	Özgül	8	27	4	41	100	6	30	20	93		
		2	Baran Kırtasiye	31	109	16	168	400	27	122	82	372		
20	Packaging Tape	1	Megabant		169	150	418	501	98	58	94	110		
		2	Atılım Ambalaj		25	22	61	73	14	8	13	16		
21	Sticker	1	Merve		1956	91	698	3703	17412	5648	3599			
		2	Vipeks		475	23	170	899	4228	1371	874			
		3	Primoda											
22	UPC Label	1	Softek			2360					47378			
		2	Santra			582					11663			
23	Packaging Paper	1	Bayramoğlu											
		2	Merve		1675			44		2442	1901			
		3	Softek		168			5		245	189			

APPENDIX D2

COMPARISON OF MODEL RESULTS AND THE CURRENT SYSTEM OF MATERIALS SUPPLIER SELECTION

Table D2.1: Comparison of the Number of Units Accepted of the Proposed Models and the Current System

Units Accepted		Model 1	Model 2	Model 3	Model 4	Actual
Material 1	Polyester Coil	17.923	17.515	17.923	17.515	17.437
Material 2	Label	2.317.423	2.317.423	2.317.423	2.317.423	2.184.451
Material 3	Zip	234.750	234.749	234.738	234.657	240.781
Material 4	Print	1.012.747	1.012.747	1.012.747	1.012.747	849.417
Material 5	Nylon Bag	3.705.872	3.705.872	3.705.872	3.705.872	3.632.093
Material 6	Mercerized Coil	18.439	18.439	18.439	18.439	18.328
Material 7	Sized Label	1.334.262	1.334.262	1.330.360	1.319.512	1.332.994
Material 8	Hanger	227.367	214.193	227.367	214.193	215.791
Material 9	Washing Instruction	1.747.420	1.747.369	1.747.418	1.735.823	1.702.559
Material 10	Packaging Box	61.090	61.090	61.164	61.187	60.638
Material 11	Sized Washing Instruction	1.327.054	1.327.054	1.327.054	1.327.054	1.316.533
Material 12	Packaging Box Label	1.549.217	1.549.217	1.549.217	1.549.217	1.517.298
Material 13	Weaving Ribbon	777.268	777.268	777.268	777.268	740.554
Material 14	Press Button	932.169	932.169	932.169	932.169	932.169
Material 15	Elastic Band	112.982	112.982	112.982	112.982	104.341
Material 16	Separator	86.963	86.963	87.693	87.597	77.304
Material 17	Plastic String	3.365.076	3.365.076	3.372.551	3.372.551	3.315.666
Material 18	Button	272.530	272.530	272.530	272.530	269.459
Material 19	Tape	1.623	1.623	1.623	1.623	1.644
Material 20	Packaging Tape	1.726	1.726	1.726	1.726	1.811
Material 21	Sticker	41.147	38.929	41.142	38.929	31.317
Material 22	UPC Label	60.297	60.292	60.297	60.292	60.411
Material 23	Packaging Paper	6.669	6.669	6.669	6.669	6.425
Sum		19.212.015	19.196.158	19.216.374	19.177.976	18.629.421

Table D2.2: Comparison of the Number of Units On-Time of the Proposed Models and the Current System

Units On-Time		Model 1	Model 2	Model 3	Model 4	Actual
Material 1	Polyester Coil	12.009	12.449	12.009	12.449	12.537
Material 2	Label	2.317.423	2.317.423	2.308.320	2.308.320	1.597.547
Material 3	Zip	223.531	223.531	223.531	223.532	157.858
Material 4	Print	1.012.747	1.012.747	1.012.747	1.012.747	806.575
Material 5	Nylon Bag	3.705.872	3.705.872	3.705.872	3.705.872	2.838.325
Material 6	Mercerized Coil	14.531	14.531	14.531	14.531	14.269
Material 7	Sized Label	1.235.062	1.190.233	1.238.578	1.187.983	1.088.019
Material 8	Hanger	198.582	215.084	198.582	215.084	222.479
Material 9	Washing Instruction	1.355.710	1.355.710	1.355.710	1.333.093	1.138.889
Material 10	Packaging Box	54.580	54.581	55.368	55.611	41.562
Material 11	Sized Washing Instruction	1.327.054	1.327.054	1.327.054	1.327.054	1.024.616
Material 12	Packaging Box Label	1.549.217	1.546.916	1.549.217	1.549.217	1.248.086
Material 13	Weaving Ribbon	580.633	580.633	580.633	580.633	613.483
Material 14	Press Button	909.797	839.880	909.797	839.880	866.895
Material 15	Elastic Band	112.982	112.982	112.982	112.982	106.689
Material 16	Separator	81.987	81.986	86.898	86.254	56.654
Material 17	Plastic String	3.041.565	3.041.565	3.018.913	3.018.913	3.136.169
Material 18	Button	272.530	272.530	272.530	272.530	103.764
Material 19	Tape	1.457	1.457	1.457	1.457	1.656
Material 20	Packaging Tape	1.392	1.391	1.392	1.392	1.126
Material 21	Sticker	41.147	41.147	41.147	41.147	24.939
Material 22	UPC Label	49.587	49.738	49.587	49.738	59.041
Material 23	Packaging Paper	6.669	6.669	6.669	6.669	6.118
Sum		18.106.064	18.006.108	18.083.523	17.957.087	15.167.296

Table D2.3: Cost Comparison of the Proposed Models and the Current System

Cost (in 000's)		Model 1	Model 2	Model 3	Model 4	Actual
Material 1	**Polyester Coil**	30.019.250 TL	31.150.480 TL	30.019.320 TL	31.150.480 TL	32.027.602 TL
Material 2	**Label**	73.488.070 TL	73.379.360 TL	72.187.050 TL	71.160.880 TL	96.655.027 TL
Material 3	**Zip**	199.415.800 TL	199.436.500 TL	199.352.700 TL	199.411.800 TL	210.644.000 TL
Material 4	**Print**	132.992.400 TL	132.992.400 TL	135.501.700 TL	135.501.700 TL	201.848.028 TL
Material 5	**Nylon Bag**	48.529.140 TL	48.529.140 TL	67.901.240 TL	67.901.240 TL	106.100.201 TL
Material 6	**Mercerized Coil**	103.953.300 TL	103.953.500 TL	103.953.300 TL	103.953.500 TL	103.608.286 TL
Material 7	**Sized Label**	69.255.030 TL	70.788.320 TL	69.457.630 TL	82.042.440 TL	55.066.463 TL
Material 8	**Hanger**	48.100.340 TL	41.868.970 TL	48.100.340 TL	41.868.970 TL	50.516.154 TL
Material 9	**Washing Instruction**	23.318.370 TL	15.561.940 TL	28.588.500 TL	25.637.180 TL	50.361.290 TL
Material 10	**Packaging Box**	39.445.870 TL	39.445.840 TL	39.429.980 TL	39.444.150 TL	39.491.791 TL
Material 11	**Sized Washing Instruction**	55.709.870 TL	55.709.870 TL	56.023.050 TL	55.752.810 TL	38.507.137 TL
Material 12	**Packaging Box Label**	79.973.270 TL	81.231.950 TL	79.757.180 TL	79.757.180 TL	35.706.230 TL
Material 13	**Weaving Ribbon**	26.458.870 TL	26.458.970 TL	26.458.980 TL	26.458.970 TL	26.806.089 TL
Material 14	**Press Button**	58.824.960 TL	26.100.350 TL	58.824.960 TL	26.100.350 TL	20.401.459 TL
Material 15	**Elastic Band**	8.236.353 TL	8.236.353 TL	8.232.347 TL	8.232.347 TL	8.850.082 TL
Material 16	**Separator**	4.620.276 TL	4.620.488 TL	3.877.264 TL	3.877.264 TL	8.398.054 TL
Material 17	**Plastic String**	8.768.373 TL	8.768.373 TL	10.221.120 TL	10.221.120 TL	7.295.639 TL
Material 18	**Button**	31.664.610 TL	31.664.610 TL	31.599.260 TL	31.599.260 TL	4.069.729 TL
Material 19	**Tape**	2.607.330 TL	2.607.330 TL	2.607.330 TL	2.607.330 TL	2.385.970 TL
Material 20	**Packaging Tape**	1.581.098 TL	1.582.869 TL	1.581.098 TL	1.581.098 TL	2.087.445 TL
Material 21	**Sticker**	2.652.573 TL	5.500.728 TL	2.654.831 TL	5.500.728 TL	1.751.136 TL
Material 22	**UPC Label**	1.077.541 TL	1.077.541 TL	1.077.541 TL	1.077.541 TL	1.077.566 TL
Material 23	**Packaging Paper**	890.450 TL	752.480 TL	890.450 TL	752.480 TL	747.710 TL
Sum		1.051.583.144 TL	1.011.418.362 TL	1.078.297.171 TL	1.051.590.818 TL	1.104.403.086 TL

APPENDIX D3

PERCENT CHANGES IN MODEL RESULTS OF MATERIALS SUPPLIER SELECTION

Table D3.1: Percent Changes In Units Accepted Compared To The Current System

Units Accepted %		Model 1	Model 2	Model 3	Model 4
Material 1	Polyester Coil	2,79	0,45	2,79	0,45
Material 2	Label	6,09	6,09	6,09	6,09
Material 3	Zip	-2,5	-2,51	-2,62	-2,71
Material 4	Print	19,23	19,23	19,23	19,23
Material 5	Nylon Bag	2,03	2,03	2,03	2,03
Material 6	Mercerized Coil	0,61	0,61	0,61	0,61
Material 7	Sized Label	0,1	0,1	-1,01	-1,01
Material 8	Hanger	5,36	-0,74	5,36	-0,74
Material 9	Washing Instruction	2,63	2,63	2	-0,06
Material 10	Packaging Box	0,75	0,75	0,86	0,86
Material 11	Sized Washing Instruction	0,8	0,8	0,8	0,8
Material 12	Packaging Box Label	2,1	2,1	2,1	2,04
Material 13	Weaving Ribbon	4,96	4,96	4,96	4,96
Material 14	Press Button	0	0	0	0
Material 15	Elastic Band	8,28	8,28	8,28	8,28
Material 16	Separator	12,49	12,49	13,4	13,4
Material 17	Plastic String	1,49	1,49	1,72	1,72
Material 18	Button	1,14	1,14	1,14	1,14
Material 19	Tape	-1,27	-1,27	-1,27	-1,27
Material 20	Packaging Tape	-4,69	-4,68	-4,69	-4,69
Material 21	Sticker	31,39	24,31	31,38	24,31
Material 22	UPC Label	-0,19	-0,2	-0,19	-0,2
Material 23	Packaging Paper	3,8	3,8	3,8	3,8
Sum		3,13	3,04	3,03	2,75

Table D3.2: Percent Changes In Units On-Time Compared To The Current System

Units On-Time %		Model 1	Model 2	Model 3	Model 4
Material 1	Polyester Coil	-4,21	-0,7	-4,21	-0,7
Material 2	Label	45,06	45,06	44,49	44,49
Material 3	Zip	41,6	41,6	41,6	41,6
Material 4	Print	25,56	25,56	25,56	25,56
Material 5	Nylon Bag	30,57	30,57	30,57	30,57
Material 6	Mercerized Coil	1,84	1,84	1,84	1,84
Material 7	Sized Label	13,51	9,39	14,31	9,19
Material 8	Hanger	-10,74	-3,32	-10,74	-3,32
Material 9	Washing Instruction	19,04	19,04	16,66	10,78
Material 10	Packaging Box	31,32	31,32	33,11	33,11
Material 11	Sized Washing Instruction	29,52	29,52	29,52	29,52
Material 12	Packaging Box Label	24,13	23,94	24,13	21,24
Material 13	Weaving Ribbon	-5,35	-5,35	-5,35	-5,35
Material 14	Press Button	4,95	-3,12	4,95	-3,12
Material 15	Elastic Band	5,9	5,9	5,9	5,9
Material 16	Separator	44,72	44,71	52,99	52,99
Material 17	Plastic String	-3,02	-3,02	-3,74	-3,74
Material 18	Button	162,64	162,64	162,64	162,64
Material 19	Tape	-12	-12	-12	-12
Material 20	Packaging Tape	23,61	23,53	23,61	23,61
Material 21	Sticker	64,99	64,99	64,99	64,99
Material 22	UPC Label	-16,01	-15,76	-16,01	-15,76
Material 23	Packaging Paper	9,01	9,01	9,01	9,01
Sum		19,38	18,72	19,08	17,69

Table D3.3: Percent Changes In Costs Compared To The Current System

Cost Change %		Model 1	Model 2	Model 3	Model 4
Material 1	Polyester Coil	-6,27	-2,74	-6,27	-2,74
Material 2	Label	-23,97	-24,08	-25,28	-26,38
Material 3	Zip	-5,33	-5,32	-6,02	-6,18
Material 4	Print	-34,11	-34,11	-32,87	-32,87
Material 5	Nylon Bag	-54,26	-54,26	-36	-36
Material 6	Mercerized Coil	0,33	0,33	0,33	0,33
Material 7	Sized Label	25,77	28,55	30,9	48,99
Material 8	Hanger	-4,78	-17,12	-4,78	-17,12
Material 9	Washing Instruction	-53,7	-69,1	-48,87	-30,02
Material 10	Packaging Box	-0,12	-0,12	-0,05	-0,05
Material 11	Sized Washing Instruction	44,67	44,67	45,88	45,88
Material 12	Packaging Box Label	123,98	127,5	123,37	119,74
Material 13	Weaving Ribbon	-1,3	-1,29	-1,3	-1,29
Material 14	Press Button	188,34	27,93	188,34	27,93
Material 15	Elastic Band	-6,93	-6,93	-6,98	-6,98
Material 16	Separator	-44,98	-44,98	-53,83	-53,83
Material 17	Plastic String	20,19	20,19	40,1	40,1
Material 18	Button	678,05	678,05	676,45	676,45
Material 19	Tape	9,28	9,28	9,28	9,28
Material 20	Packaging Tape	-24,26	-24,17	-24,26	-24,26
Material 21	Sticker	51,48	214,12	51,61	214,12
Material 22	UPC Label	0	0	0	0
Material 23	Packaging Paper	19,09	0,64	19,09	0,64
Sum		-4,78	-8,42	-2,49	-4,15

APPENDIX D4

SOLUTIONS OF ALL ALTERNATIVE MODELS IN OUTSOURCERS SELECTION

Table D4.1: Selected Outsourcers And Quantites Ordered By Model 1

		Quantity Ordered (in units)					
		Feb.-02	Mar.-02	Apr.-02	May.-02	Jun.-02	Jul.-02
1-Coral Garden							
Outsourcer	FB	7326	3297		441		
	User						
	Zitex	32474	14617		1959		
2-Dilliards							
Outsourcer	User		426	13492			
	Zitex		1704	55761			
3-Panel Block							
Outsourcer	Aysan						
	Çağ						
	Sesil			623	370	3654	2705
	Zitex			4777	2840	28014	20742
4-Anna							
Outsourcer	Canbaz			5355	600		
	User			1338	150		
5-Embossed							
Outsourcer	Aysan	376	2107	5249			
	Canbaz		1				
	Sesil	945	5291	13196			
	Zitex						
6-Emily							
Outsourcer	Çağ	10000	10000	961	1992		
	Sesil						
	Zitex	30030	40020	239	494		
7-Face off							
Outsourcer	Çağ			4119	2030	3036	
	Sesil						
	Zitex						
8-Leather Crew							
Outsourcer	Aysan					11336	1858
	FB					2838	465
9-Liberty							
Outsourcer	FB		1073	3143	30		
	User		267	784	7		
10-Service Collar							
Outsourcer	Aysan						
	FB						
	Kinex				12500	3097	1358
	Sesil				19189		
11-Side Flag							
Outsourcer	Canbaz			170	4495		
	Kinex			680			

		Quantity Ordered (in units)					
		Feb.-02	Mar.-02	Apr.-02	May.-02	Jun.-02	Jul.-02
12-Sparkle Flag							
Outsourcer	Aysan						
	Çağ						
	Sesil			3			
	User		1640	12580	6776	38497	27684
13-Stamp Front							
Outsourcer	Canbaz				2835	5502	
	Çağ				315	611	
	User						
14-Traditional							
Outsourcer	Aysan					19407	1424
	Kinex					9403	6645
	Sesil						

Table D4.2: Selected Outsourcers And Quantites Ordered By Model 2

		Quantity Ordered (in units)					
		Feb.-02	Mar.-02	Apr.-02	May.-02	Jun.-02	Jul.-02
1-Coral Garden							
Outsourcer	FB	7327	3298		442		
	User						
	Zitex	32473	14616		1958		
2-Dilliards							
Outsourcer	User		1191	19832			
	Zitex		939	49871			
3-Panel Block							
Outsourcer	Aysan						
	Çağ						
	Sesil			623	370	3654	2705
	Zitex			4777	2840	28014	20742
4-Anna							
Outsourcer	Canbaz			5354	600		
	User			1339	150		
5-Embossed							
Outsourcer	Aysan	376	2129	5249			
	Canbaz						
	Sesil	945	5246	13196	24		
	Zitex						
6-Emily							
Outsourcer	Çağ	10000	9997	962	1992		
	Sesil						
	Zitex	30030	40023	238	494		
7-Face off							
Outsourcer	Çağ			4119	2030	3036	
	Sesil						
	Zitex						
8-Leather Crew							
Outsourcer	Aysan					11337	1858
	FB					2837	465
9-Liberty							
Outsourcer	FB		1073	3143	30		
	User		267	784	7		
10-Service Collar							
Outsourcer	Aysan						
	FB						
	Kinex				12500	3097	1358
	Sesil				19189		
11-Side Flag							
Outsourcer	Canbaz			170	4495		
	Kinex			680			
12-Sparkle Flag							
Outsourcer	Aysan		26	26	473	2686	1932
	Çağ		3	8			
	Sesil		1611	12549			
	User				6303	35811	25752

		Quantity Ordered (in units)					
		Feb.-02	Mar.-02	Apr.-02	May.-02	Jun.-02	Jul.-02
13-Stamp Front							
Outsourcer	Canbaz				2599	5044	
	Çağ				551	1069	
	User						
14-Traditional							
Outsourcer	Aysan					19407	1424
	Kinex					9403	6645
	Sesil						

Table D4.3: Selected Outsourcers And Quantites Ordered By Model 3

		Quantity Ordered (in units)					
		Feb.-02	Mar.-02	Apr.-02	May.-02	Jun.-02	Jul.-02
1-Coral Garden							
Outsourcer	FB	7326	3297		441		
	User						
	Zitex	32474	14617		1959		
2-Dilliards							
Outsourcer	User		503	14019			
	Zitex		1627	55684			
3-Panel Block							
Outsourcer	Aysan						
	Çağ						
	Sesil			623	540	3654	2705
	Zitex			4777	2670	28014	20742
4-Anna							
Outsourcer	Canbaz			5355	600		
	User			1338	150		
5-Embossed							
Outsourcer	Aysan	376	2106	5249			
	Canbaz						
	Sesil	945	5293	13196			
	Zitex						
6-Emily							
Outsourcer	Çağ	10000	10000	961	1992		
	Sesil						
	Zitex	30030	40020	239	494		
7-Face off							
Outsourcer	Çağ			3919	1830	2836	
	Sesil						
	Zitex			200	200	200	
8-Leather Crew							
Outsourcer	Aysan					11336	1858
	FB					2838	465
9-Liberty							
Outsourcer	FB		1073	3143	30		
	User		267	784	7		
10-Service Collar							
Outsourcer	Aysan						
	FB						
	Kinex				12415	2967	1228
	Sesil				19274	130	130
11-Side Flag							
Outsourcer	Canbaz			170	4410		
	Kinex			680	85		
12-Sparkle Flag							
Outsourcer	Aysan				160	160	160
	Çağ						
	Sesil		165	168			
	User		1475	12415	6616	38337	27524

		Quantity Ordered (in units)					
		Feb.-02	Mar.-02	Apr.-02	May.-02	Jun.-02	Jul.-02
13-Stamp Front							
Outsourcer	Canbaz				2835	5502	
	Çağ				315	611	
	User						
14-Traditional							
Outsourcer	Aysan					19277	1424
	Kinex					9533	6645
	Sesil						

Table D4.4: Selected Outsourcers And Quantites Ordered By Model 4

		Quantity Ordered (in units)					
		Feb.-02	Mar.-02	Apr.-02	May.-02	Jun.-02	Jul.-02
1-Coral Garden							
Outsourcer	FB	7327	3298		442		
	User						
	Zitex	32473	14616		1958		
2-Dilliards							
Outsourcer	User		1112	19738			
	Zitex		1018	49965			
3-Panel Block							
Outsourcer	Aysan						
	Çağ				540		
	Sesil			623		3654	2705
	Zitex			4777	2670	28014	20742
4-Anna							
Outsourcer	Canbaz			5354	600		
	User			1339	150		
5-Embossed							
Outsourcer	Aysan	376	2106	5249			
	Canbaz						
	Sesil	945	5293	13196			
	Zitex						
6-Emily							
Outsourcer	Çağ	10000	10000	962	1992		
	Sesil						
	Zitex	30030	40020	238	494		
7-Face off							
Outsourcer	Çağ			3919	1830	2836	
	Sesil			200	200	200	
	Zitex						
8-Leather Crew							
Outsourcer	Aysan					11337	1858
	FB					2837	465
9-Liberty							
Outsourcer	FB		1073	3143	30		
	User		267	784	7		
10-Service Collar							
Outsourcer	Aysan						
	FB					130	130
	Kinex				12415	2967	1228
	Sesil				19274		
11-Side Flag							
Outsourcer	Canbaz			170	4410		
	Kinex			680	85		
12-Sparkle Flag							
Outsourcer	Aysan			160	472	2686	1931
	Çağ						
	Sesil		1470	12423			
	User		170		6304	35811	25753

		Quantity Ordered (in units)					
		Feb.-02	Mar.-02	Apr.-02	May.-02	Jun.-02	Jul.-02
3-Stamp Front							
Outsourcer	Canbaz				2599	5044	
	Çağ				551	1069	
	User						
4-Traditional							
Outsourcer	Aysan					19277	1423
	Kinex					9533	6646
	Sesil						

APPENDIX D5

COMPARISON OF THE RESULTS OF ALTERNATIVE MODELS IN OUTSOURCERS SELECTION

Table D5.1: Number of units accepted item by item.

Units Accepted	Model 1	Model 2	Model 3	Model 4	Actual
1-Coral Garden	60.114	60.114	60.114	60.114	58.000
2-Dilliards	64.347	60.880	64.267	60.970	34.970
3-Panel Block	63.725	63.725	63.725	63.725	59.910
4-Anna	7.443	7.443	7.443	7.443	7.350
5-Embossed	27.165	27.165	27.165	27.165	25.240
6-Emily	93.736	93.736	93.736	93.736	83.100
7-Face off	9.185	9.185	9.185	9.185	10.500
8-Leather Crew	16.497	16.497	16.497	16.497	15.900
9-Liberty	5.304	5.304	5.304	5.304	4.990
10-Service Collar	36.144	36.144	36.144	36.144	35.050
11-Side Flag	5.345	5.345	5.345	5.345	5.050
12-Sparkle Flag	87.180	86.299	87.159	86.319	81.792
13-Stamp Front	9.263	9.263	9.263	9.263	8.750
14-Traditional	36.879	36.879	36.879	36.879	34.150
Total	522.327	517.979	522.226	518.089	464.752

Table D5.2: Number of units on-time item by item.

Units On-Time	Model 1	Model 2	Model 3	Model 4	Actual
1-Coral Garden	33.305	33.303	33.305	33.303	16.724
2-Dilliards	71.833	71.833	71.833	71.833	70.690
3-Panel Block	48.368	48.368	48.222	48.419	5.805
4-Anna	6.585	6.586	6.585	6.586	7.242
5-Embossed	22.811	22.802	22.812	22.812	6.863
6-Emily	58.010	58.009	58.010	58.010	40.539
7-Face off	9.185	9.185	8.973	9.015	10.500
8-Leather Crew	12.455	12.456	12.455	12.456	1.746
9-Liberty	2.791	2.791	2.791	2.791	911
10-Service Collar	23.710	23.710	23.486	23.394	8.858
11-Side Flag	2.396	2.396	2.403	2.403	2.282
12-Sparkle Flag	1	3.290	77	3.223	2.020
13-Stamp Front	8.337	7.643	8.337	7.643	1.448
14-Traditional	0	0	0	0	0
Total	299.786	302.371	299.290	301.888	175.628

Table D5.3: Purchasing costs item by item.

Total Cost (in 000's)	Model 1	Model 2	Model 3	Model 4	Actual
1-Coral Garden	60.106.797 TL	60.107.062 TL	60.106.797 TL	60.107.062 TL	60.019.604 TL
2-Dilliards	58.787.993 TL	59.227.688 TL	59.166.648 TL	59.096.228 TL	57.150.140 TL
3-Panel Block	97.323.603 TL	97.323.603 TL	97.361.003 TL	97.361.003 TL	96.150.038 TL
4-Anna	6.762.593 TL	6.762.738 TL	6.762.593 TL	6.762.738 TL	6.568.583 TL
5-Embossed	22.819.773 TL	21.202.243 TL	22.819.343 TL	22.819.343 TL	27.091.319 TL
6-Emily	70.678.036 TL	70.977.946 TL	70.678.036 TL	70.678.036 TL	80.361.106 TL
7-Face off	11.395.655 TL	11.395.655 TL	11.511.655 TL	11.511.655 TL	11.751.927 TL
8-Leather Crew	14.064.212 TL	14.064.117 TL	14.064.212 TL	14.064.117 TL	17.196.769 TL
9-Liberty	7.332.314 TL	7.332.314 TL	7.332.314 TL	7.332.314 TL	5.715.167 TL
10-Service Collar	42.798.659 TL	42.798.659 TL	42.845.459 TL	42.845.459 TL	49.603.814 TL
11-Side Flag	22.156.019 TL	22.156.019 TL	22.174.719 TL	22.174.719 TL	22.247.293 TL
12-Sparkle Flag	97.261.025 TL	98.002.925 TL	97.482.500 TL	97.989.295 TL	91.525.656 TL
13-Stamp Front	14.284.328 TL	14.317.118 TL	14.284.328 TL	14.317.118 TL	14.920.216 TL
14-Traditional	48.868.799 TL	48.868.799 TL	48.872.699 TL	48.872.554 TL	41.378.730 TL
Total	574.639.805 TL	574.536.885 TL	575.462.305 TL	575.931.640 TL	581.680.360 TL

APPENDIX D6

PERCENT CHANGES ACHIEVED BY ALTERNATIVE MODELS OF OUTSOURCERS SELECTION

Table D6.1: Percent changes in the number of units accepted item by item.

Units Accepted (%)	Model 1	Model 2	Model 3	Model 4
1-Coral Garden	3,64	3,64	3,64	3,64
2-Dilliards	84,01	74,09	83,78	74,35
3-Panel Block	6,37	6,37	6,37	6,37
4-Anna	1,27	1,27	1,27	1,27
5-Embossed	7,63	7,63	7,63	7,63
6-Emily	12,8	12,8	12,8	12,8
7-Face off	-12,52	-12,52	-12,52	-12,52
8-Leather Crew	3,75	3,75	3,75	3,75
9-Liberty	6,29	6,29	6,29	6,29
10-Service Collar	3,12	3,12	3,12	3,12
11-Side Flag	5,84	5,84	5,84	5,84
12-Sparkle Flag	6,59	5,51	6,56	5,53
13-Stamp Front	5,86	5,86	5,86	5,86
14-Traditional	7,99	7,99	7,99	7,99
Overall	12,39	11,45	12,37	11,48

Table D6.2: Percent changes in the number of units on-time item by item.

Units On-time (%)	Model 1	Model 2	Model 3	Model 4
1-Coral Garden	99,14	99,13	99,14	99,13
2-Dilliards	1,62	1,62	1,62	1,62
3-Panel Block	733,21	733,21	730,7	734,1
4-Anna	-9,07	-9,06	-9,07	-9,06
5-Embossed	232,38	232,25	232,39	232,39
6-Emily	43,1	43,1	43,1	43,1
7-Face off	-12,52	-12,52	-14,54	-14,15
8-Leather Crew	613,35	613,41	613,35	613,41
9-Liberty	206,33	206,33	206,33	206,33
10-Service Collar	167,66	167,66	165,14	164,11
11-Side Flag	4,98	4,98	5,31	5,31
12-Sparkle Flag	-99,97	62,85	-96,18	59,56
13-Stamp Front	475,76	427,83	475,76	427,83
14-Traditional	0	0	0	0
Overall	70,69	72,17	70,41	71,89

Table D6.3: Percent changes in the purchasing costs item by item.

Cost (%)	Model 1	Model 2	Model 3	Model 4
1-Coral Garden	0,15	0,15	0,15	0,15
2-Dilliards	2,87	3,64	3,53	3,41
3-Panel Block	1,22	1,22	1,26	1,26
4-Anna	2,95	2,96	2,95	2,96
5-Embossed	-15,77	-21,74	-15,77	-15,77
6-Emily	-12,05	-11,68	-12,05	-12,05
7-Face off	-3,03	-3,03	-2,04	-2,04
8-Leather Crew	-18,22	-18,22	-18,22	-18,22
9-Liberty	28,3	28,3	28,3	28,3
10-Service Collar	-13,72	-13,72	-13,62	-13,62
11-Side Flag	-0,41	-0,41	-0,33	-0,33
12-Sparkle Flag	6,27	7,08	6,51	7,06
13-Stamp Front	-4,26	-4,04	-4,26	-4,04
14-Traditional	18,1	18,1	18,11	18,11
Overall	-1,21	-1,23	-1,07	-0,99