# OPTIMIZATION OF WAREHOUSE SETTING

# AND

# COTTON TEXTILE SUPPLYING POLICY OF

# SÜMERBANK

# IN MARMARA REGION

by

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We hereby recommend that the thesis entitled "Optimization of Warehouse Setting and Cotton Textile Supplying Policy of Sümerbank in Marmara Region" submitted by İsmail Yanık be accepted in partial fulfillment of the requirements for the Degree of Master of Science in Industrial Engineering, School of Engineering, Boğaziçi University.

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# *ABSTRACT*

*İsmail Yanık, M.Sc.*
*Boğaziçi University, 1982*

*This thesis presents a mixed integer programming model designed for the analysis of various planning problems associated with the optimal setting of warehouse capacities and transportation of the cotton textile products among the Sümerbank system composed of factories, district warehouses and retail shops.*

*The model has been numerically tested by the relevant data taken from Sümerbank Purchasing and Marketing Organization (Alım Satım Müessesesi, ASM) concerning ten cotton textile factories and five district warehouses with three or four capacity alternatives placed in Marmara Region. The effects caused by the variations in the demand and stock-turnover rates are observed and reported in a comparative basis.*

# ÖZ

*İsmail Yanık, M.Sc.*
*Boğaziçi Üniversitesi, 1982*

*Bu çalışmada fabrika bölge deposu ve mağazalardan oluşan Sümerbank dağıtım sistemi ele alınarak, Sümerbank Alım ve Satım Müessesesi (ASM) yetkililerinin kısa ve uzun vadeli kararlarına yardımcı olması amacıyla bölge depolarının kapasite seçimi ile pamuklu mamullerin dağıtımını eniyileyen bir 0-1 karmaşık tamsayı programlama modeli kurulmuştur.*

*Sümerbank dağıtım sistemi içinde, Türkiyedeki on pamuklu fabrikası ile bu fabrikalardan mal alan Marmara Bölgesine ait beş bölge deposu için, ASM'den alınan gerçek istatistiklere dayanılarak elde edilen, modelin sayısal çözümleri ve sonuçları verilmektedir. Bu çözümler sistemde meydana gelebilecek talep artışı, stok-devir hızının azalması gibi değişikliklerin, depolama ve dağıtım olaylarına etkisini karşılaştırmalı olarak incelemektedir.*

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# CHAPTER I

# INTRODUCTION

In distribution systems, warehouses serve as centers to and from which commodities are transported and temporarily stored. The warehouse's capital, operating, personnel and distribution expenses are the tangible costs, whereas unsatisfied demand, late delivery and dead stock are the intangible costs. The intangible costs can be reduced by properly planned warehousing system and by the improved customer relations. However, the main research area is the warehouse's tangible costs. In the long run, to be profitable, the warehouse location and the warehouse capacity which it is proper to the overall system must be discussed carefully in detail.

Beside this, transportation of commodities is another problem which must be considered. In the last three years (1979-1981) petroleum prices were tripled, and they are expected to rise in the future too. This increase will affect the transportation costs directly. So the improvement in warehousing system will cause important savings in the transportation costs in turn.

Sümerbank faces both of these problems as well as the other firms in Turkey and is looking for a solution to optimize warehousing and distribution costs.

The overall purpose of this thesis is to develop a model which may be used as a quantitative framework for the analysis of short and long-term planning problems associated with the optimal district warehouse location, capacity setting and commodity supplying policy of Sümerbank.

The model developed in the thesis (developed model) has been numerically worked out and analysed on the basis of ten factories, five district warehouses with three or four alternative capacities, the relevant official data and expert estimates are as of the year 1980.

The contents of the following subsequent chapters are as follows: In Chapter II, general definition of the problem and current distribution system of Sümerbank is presented. Methodological choices in warehouse location, the solution techniques and important examples of multicommodity distribution systems found in the literature are presented in Chapter III. Mathematical modelling of the system is presented in Chapter IV as two subsequent parts, the model and the developed model. In Chapter V input data, solutions and discussions are presented, and Chapter VI is the conclusion and the suggestions for future work.

# CHAPTER II

# DEFINITION OF THE SYSTEM

## II.1 GENERAL PROBLEM

The system which will be studied in this thesis is a warehouse location and commodities distribution system composed of factories, district warehouses and retail shops. A number of factories supply the given retail shops with specified demand quantities.

Every factory produces its own specific commodity with known production capacity. There is a known demand for each commodity at each of a number of retail shops. This demand is satisfied by shipping via district warehouses with each retail shop being assigned exclusively to a single district. A warehouse assumed to each district and the district warehouses can trans-ship the commodities to each other.

It is required to select the optimum set of district warehouses from a given (specified) set by determining the warehouse capacities and quantities shipped so that the total capital and operating costs of the warehouses and distribution costs are minimized.

The schematic representation of the system is shown in Figure 1.

## II.2 CURRENT DISTRIBUTION AND WAREHOUSING SYSTEM OF SÜMERBANK

Before studying the existing problem, it will be helpful to look at the operational aspects of Sümerbank in some detail.

Main production areas of Sümerbank are the consumption goods which

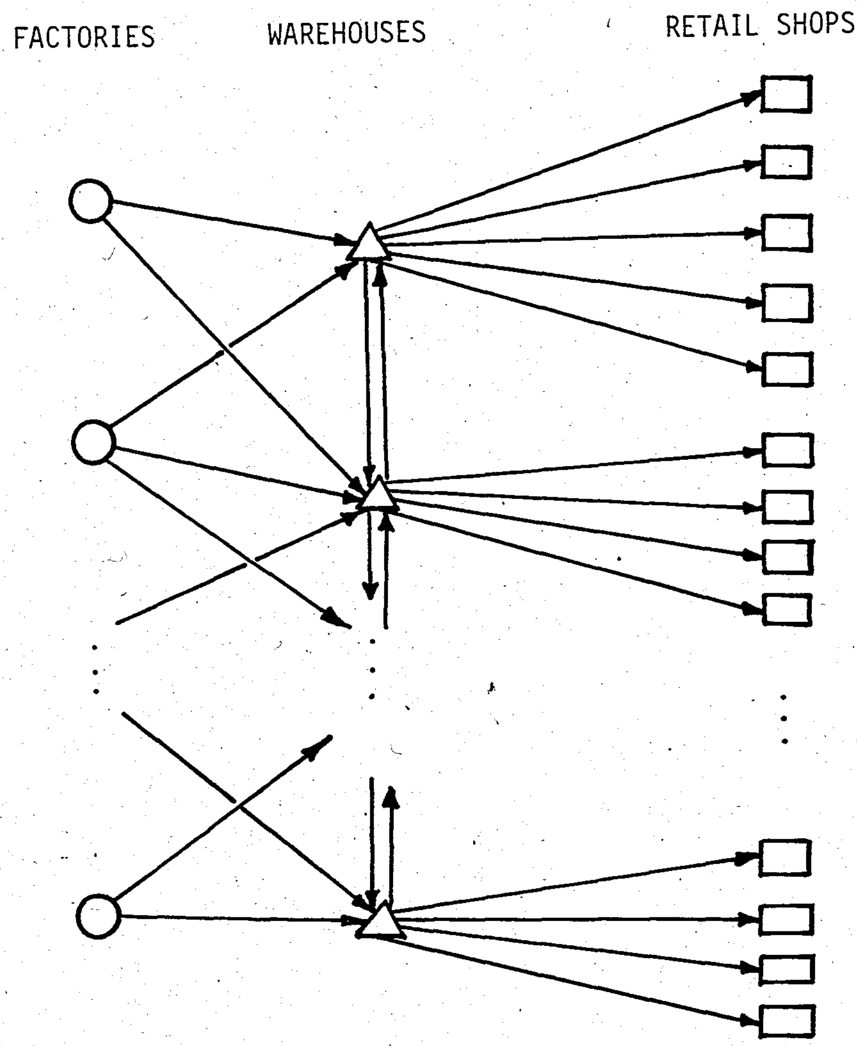


Figure 1 : Schematic representation of the system

are cotton and woolen textile, clothing, porcelain and footware.

There are 17 factories, 23 district warehouses and more than 450 retail shops. Figure 2 illustrates the main flow of information, goods and cash, between the General Directorate of Sümerbank, the factories, the Purchasing and Marketing Organization of Sümerbank (ASM), the district directorates and four groups of buyers. As shown in the Figure 2, production and consignment orders are given by the ASM to the factories which forward the goods to the district warehouses and then to the retailshops.

In general, this system works in the following manner:

i- Yearly protocols are prepared by the ASM and the factories. Included in these protocols are yearly production programs, based on types, and approved by the General Directorate: In ASM's own forecast of future sales, estimates prepared by the salesmen of the shops and the managers of the districts are also taken into consideration. In making protocols the following points are taken into consideration:
- the sales forecast for each product type,
- the production capacities of the factories,
- the profitability of products,
- the constraints in material purchase or availability.

ii- In a year, usually in every 3 or 4 months, the ASM gives the plants the production volumes in color and design.

iii- The retail shops send monthly order lists to the district warehouses to which they are affiliated. These in turn, compile and revise them, and then send them on to the factories. In cases of emergency, it is also possible to order more frequently and the shop personnel may go to the district warehouses or factories to make their own selections and place orders. However, the second procedure is not widely used and is generally limited to woolen goods. Usually the shop and district orders do not cover such

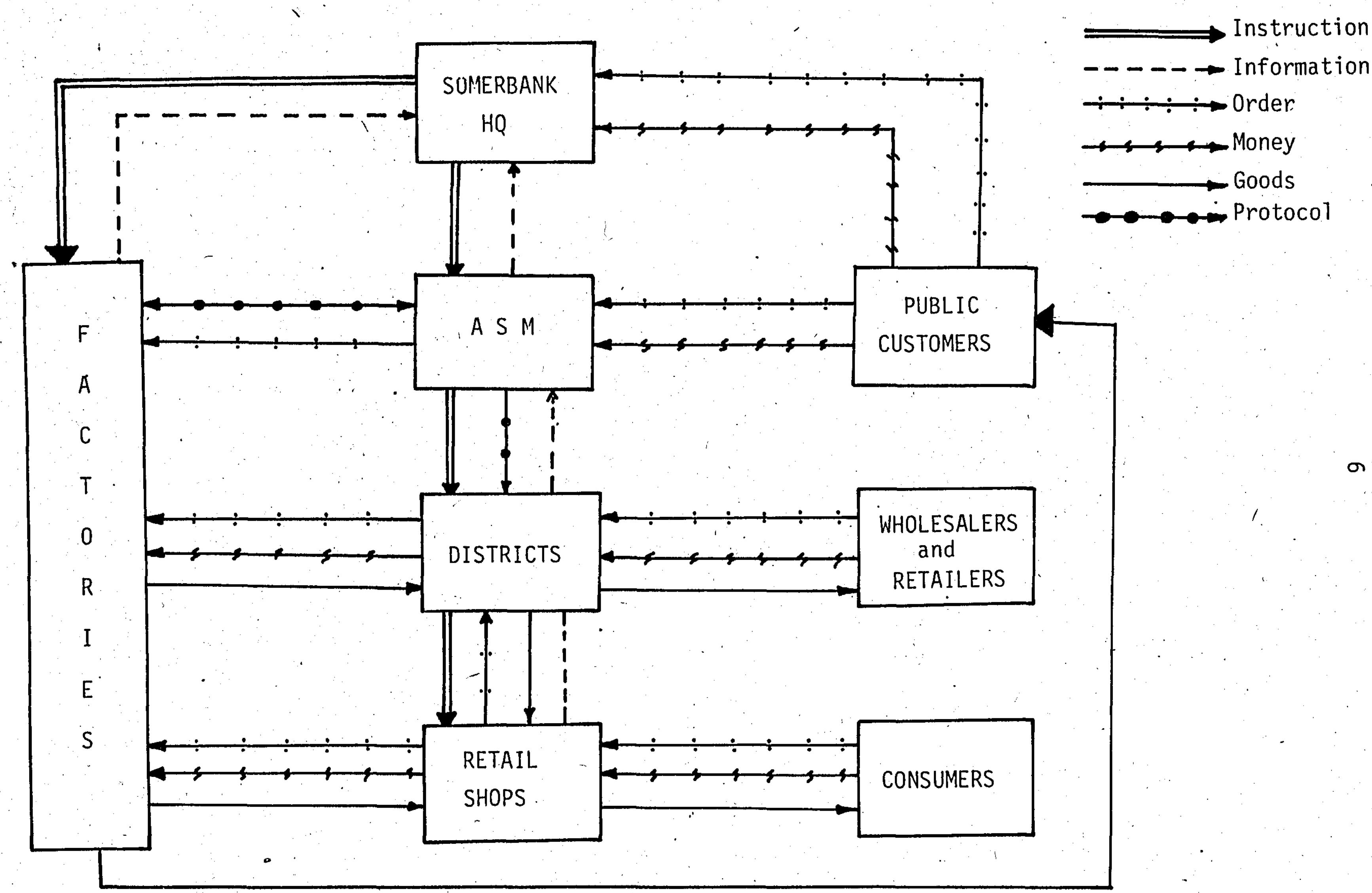


Figure 2 : Information, Orders, Goods, Money Flow Chart for Sümerbank

details as color and design.

iv- The factories send the goods to the district warehouses. The direct shipments to the retail shops are required for the very special cases. For the transportation, trucking and transportation companies with private agreements are employed.

If factories can not use their total production capacities by producing ASM's orders, they look for orders from private sector for the unused capacity.

In the diagnosis report ( 7), it is pointed out that Sümerbank works for both orders and stock. In private sector, the risk is not taken by the factories to such an extend. ASM takes all risk and they can not make good forecasts. Sümerbank also gets orders from army and some public organizations. Producing for stock has some advantages besides some disadvantages. It makes possible the reduction of the set up costs for the sake of factories but, at the same time increases stocks, production delays and furthermore causes product run-outs.

Retail shops are assigned to the district warehouses based on their geographical settings. A factory can send goods to every district warehouse, and warehouses can also transfer goods to each other. A retail shop can be served from only one warehouse to which it is affiliated. The orders are first directed to the warehouses by the retail shops and those orders are complied and transferred to the factories, then bulk shipments are expected from factories to the warehouses.

Transportation between factories and warehouses are given to contractors, and unit transportation cost is re-examined and bid every year accordingly. For the secondary transportation, small trucks or vans are used between warehouses and retail shops.

It is also stated in the diagnosis report that important malfunctions occur in the transportation between the factories and the districts, and the shops. Lack of pick-up vans belonging to the districts necessitates the use of the State Railways and contracted trucks in dispatching the goods to retail shops. The necessity of loading the truck fully, in order to decrease unit transportation cost, eliminates flexibility in shipment from the district to the retail shop and long times elapse between any two shipments. The orders, which are less than five tons are delayed until they are summed up to five tons or more. Also using the railway system and contracted trucks makes it necessary to have the goods very well packed. Since re-packing facilities are lacking in the districts, the goods must be sent out in the same bale as they arrive in from the factories. This eliminates the possibility of making re-assortment (distribution of color and design combinations) in district warehouses. Having pick-up vans in the districts would make it possible to do shipment more frequently and repack the goods; because packing regulations for district warehouse owned vans are not as strict as for railway system and contracted trucks.

# CHAPTER III

# LITERATURE SURVEY

## III.1 METHODOLOGICAL CHOICES IN DEPOT LOCATION

The literature on depot (or warehouse) location is extensive. In this seciton, methodological choices in depot location will be discussed.

In general, when choosing the objective the choice is between minimization of the costs (which may be warehouse construction and operation costs, distribution costs, stock-holding and run-out costs) or maximization of the gross profit from the operations (which is revenue-costs).

In order to determine the procedures to be adopted in a warehouse location study seven choices are proposed by Rand (17).

i- Objective : cost minimization or return on assets criteria.

ii- Potential locations : anywhere (infinite set) or particular sites (feasible set).

iii- Search procedure : optimizing or heuristic.

iv- Planning horizon : this season, this year, next year, sometime, etc..

v- Present sites : to be included or not.

vi- Capacities : to be included or not.

vii- Local delivery cost : determined by statistical analysis or vehicle scheduling package.

A total cost approach to distribution requires that individual cost elements are considered in relation to total costs. The more number of warehouses are increased, the more the cost of the warehousing system (construction and operating costs) increases, but the distribution (transportation) costs decrease. All these costs need to be balanced with the inventory levels required to support different number of warehouses. Also run-out costs can be added to the system in order to consider the opportunity cost of unsatisfied demand.

Distribution costs and warehousing which are mentioned above can be summarized as in Figure 3. Similar numeric diagrams are given by Beattie (2).

The purpose behind the cost minimization philosophy is maximization of profits (as in this study). Then, if the revenue is assumed to be fixed, the positive difference between revenue and costs will be profit. However, this is not necessarily the case. Mercer (15) has demonstrated that sales can vary with the distribution policy and suggested that "a company could be ruined because it minimized its distribution costs". He has also demonstrated that market share declines as the distance from a depot increases.

Kuehn and Hamburger (12) incorporate the run-out costs (cost of lost sales) in their objective function before minimizing total distribution costs. They also propose that warehouses will decrease delivery time relative to direct factory shipment and improve the relations between retailshops and warehouses by permitting retail shops to reduce their inventories.

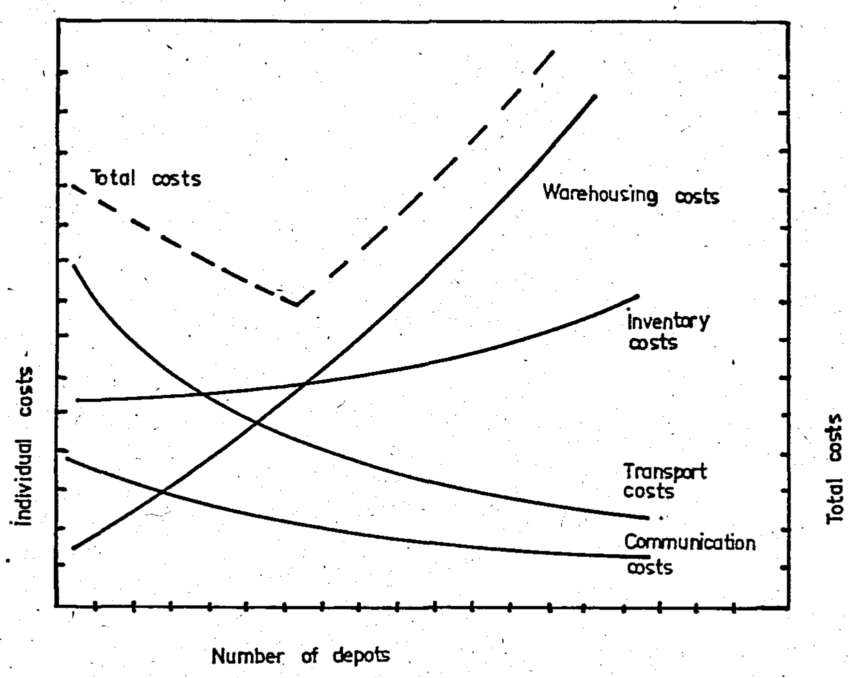


Figure 3 : Distribution costs and warehousing

Another discussion can be given between the infinite set approach to depot location (that is allowing no restrictions as to where depots should be located) and the feasible set approach (that is specifying a list of possible depot locations).

The main features of these approaches listed by Eilon et al (5) are :

The infinite set approach :

i- It does not require the locations which are selected to be apriori attractive.

ii- Alternative solutions are available in multisite selection problems.

iii- It is possible that the solution will involve a non-feasible location for instance, a site on a mountain range.

iv- Transport costs must be a monotonic function of distance.

The feasible set approch :

i- It incorporates costs which are related to specific geographical conditions.

ii- It does not require transport cost to be any function of distance.

iii- It requires a set of sites which are known to be feasible and for which all cost data are available.

iv- The number of locations must be finite and sufficiently small for computational efficiency.

v- The set of feasible sites may not include the optimum solution of infinite set problem.

Eilon et al (5) favour the infinite set approach. However, three criticisms of this approach for multisite selection can be made.

First, no method will guarantee finding an optimal (or near optimal) solution. A common algorithm can be described briefly as:

i- Choose the number of depots-n,

ii- Allocate these to sites (at random or otherwise),

iii- Allocate customers to the sites,

iv- Consider each of the n-regions in turn and find the best site serving these customers in that region by, for instance minimization distance in kms,

v- Stop if no improvement has been made,

iv- Otherwise return to step 3.

It is usually necessary to generate many solutions with different starting points and then choose the best that has been found.

Secondly, it is possible to obtain a solution giving non-feasible sites. For instance in the case that is studied, a depot can be located on the middle of Marmara Sea by studying an infinite set approach.

Thirdly, there is no procedure, apart from enumeration, for determining the number of depots. Thus the approximate algorithm described above would need to be used for a number different n to determine the optimal n.

The usual criticism that seems to be made of the feasible set approach is that a large number of possible locations need to be specified in order to ensure a realistic solution.

By using the feasible set approach for the multi-site depot location problem it is possible to arrive at a solution within the model formulation that will answer four questions that are asked in any depot location study.

i- How many depots are required?

ii- Where should they be located?

iii- Which retail shops should be assigned to them?

iv- What would be their storage and service (handling) capacities?

Search procedure closely linked with the choice between the infinite set and feasible set approaches is the choice of the mathematical algorithm that will be used to achieve the objective.

Eilon et al (5) discuss the numeric-analytic technique, dynamic programming, electrical and mechanical analogues and heuristic methods for the infinite set approach. For the feasible set approach they suggest that the choice lies between mixed integer programming, the transportation method, simulation methods, heuristic methods and networks. The short summaries of these techniques will be given in section III.2.

In depot (warehouse) location study there is a trade-off between the complexity of the search procedure and the sophistication of the cost functions. This can be seen in Figure 4.

A thorough and exhaustive search procedure required in studying infinite set approach with very simple cost functions. The feasible set approach allows the use of more complex cost functions but the very fact that a feasible set of locations used reduces the thoroughness of the search. Heuristic and simulation methods allow an increase in the complexity of the cost functions at the expense of reducing the complexity of search procedure.

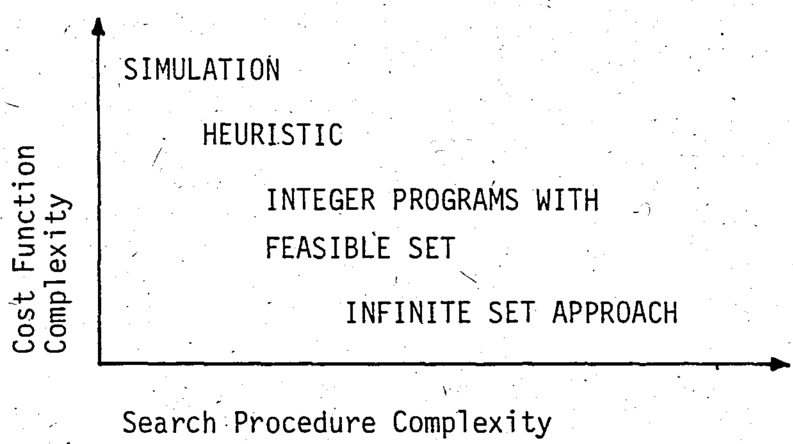


Figure 4 : The relationship between complexity in search procedures and cost functions. G.K.Rand (17).

In the literature, most depot location studies have been concerned with a static situation. One demand pattern has been used and little or no attempt made to consider possible future changes in demand. In recent paper, however, Meyer (16) has described the development of a mixed integer mathematical programming model designed to provide strategic decisions for the selection of a set of proposed facilities and their projected timing within a five year implementation horizon. The objective was to maximize the ratio of net return to total assets over the entire economic life of the facilities considered.

Management scientist presented with the initial depot location problem (the so-called "green fields" situation) is not common. Usually the company or firm will already have a number of depots located previously as in the Sümerbank case. The analyst is, therefore, faced with another choice. One possibility is to include the present sites in the model as a fixed base from which to move (even if the possibility of dropping old sites, in addition to including new locations, is allowed). The other is to find the "green fields" solution (that is, ignore the present site configuration) and then to consider the question of implementation of the green fields solution in consideration of the present locations.

When starting a depot location study the above mentioned choices are faced. Decisions in most of these issues will depend on the particular situation that is being investigated.

## III.2 SOLUTION TECHNIQUES

The solution techniques developed and implemented for plant and warehouse locations can be classified as follows :

i- Simulation

ii- Heuristics

iii- Exact algorithms used in integer programming

a- cutting methods - cutting plane algorithm

b- search methods - branch and bound technique

c- dynamic programming

Short summaries of these techniques are given below.

### III.2.1 Simulation

In contrast to optimization models, the simulation technique in itself is not an optimizing procedure. Situations arise where it becomes rather complex to model a problem mathematically ; or even if (reasonably accurate) mathematical models can be constructed, available techniques may not be suitable to solve the resulting models. In such cases, it would be necessary to resort to other means for analyzing the system. Here simulation proves useful (19). In the general sense, simulation deals with the study of (dynamic) systems over time. Simulation models are designed to sample the characteristics of the system they represent by "observing" the system over time and subsequently gathering pertinent information. The execution of a simulation "run" may be regarded as an observation or a sample in a statistical experiment. This naturally gives rise to the problems of designing the (simulation) experiment, gathering observations in a manner compatible with proper statistical analysis, and implementing the proper test to examine the significance of simulation results.

### III.2.2 Heuristics

A heuristic is a rule of thumb or principle which reduces the amount of search in problem solving. The most important feature is; the model under consideration may be quite suitable for intuitive and reasonable "rules of thumb". This approach, as compared with an exact algorithm, does not guarantee an optimal solution. Nevertheles, in some cases it may be preferable to a random or instructed search. The central idea is to progress toward an acceptable, as opposed to an optimum, solution. This methodology has been found especially useful in problems where either no exact algorithm has been developed or an exact algorithm exists but the magnitude of the problem is too large for present digital computer systems with respect to size or time.

The main reasons for using a heuristic solution technique may be as follows :

i- The structure of the model could be of such a nature that an exact solution procedure is not known.

ii- The exact solution procedure may be known but it may be impossible or prohibitive to handle its data requirements.

iii- A heuristic method could be used for learning purposes, for instance, to have an intuitive feeling as to what variables are important.

iv- A heuristic could be used as a part of an iterative procedure that guarantees the finding of an optimal solution.

v- A good starting solution could be found by using heuristics for implicit enumeration methods.

Heuristics can be categorized according to the basic reasonings used to develop them.

i- Decomposition Methods :
The problem is broken into smaller parts and every sub-problem is solved separately while taking into account possible interactions among the other sub-problems.

ii- Inductive Methods :
The procedure is to generalize from smaller (or somewhat simpler/basic) versions of the same problem. Properties and systematic steps of the solution for the smaller problems can be used to develop a heuristic method to solve larger problems.

iii- Reduction Methods :
The general approach here is to obtain the optimal solutions to several numerical cases under consideration.

Common features of these solutions are extracted and are assumed to hold in general.

iv- Approximation Methods :
The procedure is to change the nature of the problem in some way and use the solution of the revised problem (e.g. linearization of a non-linear function).

v- Constructive Methods :
The basic idea of a constructive method is to literally build up to a single feasible solution, often in a deterministic, sequential fashion.

vi- Local Improvement Methods :
In contrast with the constructive method, these start with a feasible solution and improve upon it iteratively.

Kuehn and Hamburger (12) have developed a subject model which includes multiple products, the capability of handling non-linear transportation costs, warehousing costs, and delivery time to customer.

The model's solution rests on two key heuristics :

i- Locations with the greatest promise are those at or near concentrations of demand.

ii- Near-optimum warehousing systems can be developed by locating warehouses one at a time and adding at each stage of the analysis that specific warehouse which produces the greatest cost saving for the entire system.

Procedurally, m possible warehouse sites are selected from n possible locations. Each of these m sites is evaluated, and a warehouse is located at that site yielding the largest reduction in distribution costs. The remaining (m-1) sites then reassessed, and a warehouse is again located if there is an indicated reduction in costs. Non-economical warehouses are discarded after this sequential procedure is completed. Feldman, Lehrer and Ray (8) have extended this work to handle concave warehousing cost functions.

### III.2.3 Exact Algorithms Used in Integer Programming

The formulations derived for facilities location problems can be solved by the several derived algorithms of "operations research" techniques. Among these, most of the algorithms derived for the zero-one and mixed integer programs in the computer libraries. For the big size models, some decomposition algorithms were developed. The Bender's Decomposition was efficiently applied to the model developed by Geoffrion and Graves (10).

#### III.2.3.1 Cutting Methods - Cutting Plane Algorithm

Cutting methods, which are developed primarily for integer linear problems, start with the continuous optimum. By systematically adding special "secondary" constraints, which essentially represent necessary conditions for integrality, the continuous solution space is gradually modified until its continuous optimum extreme point satisfies the integer conditions. The idea of the cutting plane algorithm is to change the convex set of the solution space so that the appropriate extreme point becomes all-integer.

#### III.2.3.2 Search Methods - Branch and Bound Method

Search methods originate from the straight forward idea of enumerating all feasible integer points. The basic idea is to develop "clever" tests that consider only a (small) portion of the feasible integer explicitly but automatically account for the remaining points implicitly.

Branch and bound method is the most prominent method of tree-search type algorithms among the other such as additive algorithm (pure binary problem) and zero-one (polynomial) programming. The fundamental idea of branch and bound technique is to partition the set of all feasible solutions into several subsets, and assuming the function is to be maximized (or minimized) an upper (or lower) bound is determined for each of the subsets. Then subsets which have upper bounds greater (or less) than the current upper (or lower) bound for the objective function are eliminated from further consideration.

III.2.3.3 Dynamic Programming

Dynamic programming is the name given to a particular kind of sequential decision process in which it is desired to optimize (maximize or minimize) a criterion function subject to constraints. The dynamic problem is defined in terms of five entities : the state ("S"), the stage, the decision space, the transformation function, and the criterion function. The state is specified by the parameter or set of parameters which contain all the information necessary to make the current and all future decisions, hopefully in an optimal fashion. The stage or epoch n is defined in terms of the process of decision making : a stage exists whenever a decision is called for. The decision space D is the space of all possible decision variables, which may vary from stage to stage and also may be a function of the state of the system of any stage ; that is, $D=D(n,S_n)$. The transformation function Z relates the new state of the system to the old state, naturally as a function of the decision made, $S_{n+1}=Z(S_n,d_n)$, where $d_n \in D(n.S_n)$. Finally, the criterion function ("C") is the measure of performance of the system and is a function of all the decisions made and the initial state of the system. $C=C(S_0,\{d_n\})$. Of course, we are always interested in the optimum of C, which we shall denote by $f^*$; $f^*$ is the minimum (or maximum) value of $C(S_0,\{d_n\})$, and to emphasize the fact that the initial state is $S_0$ and the optimization is over a finite planning horizon of this technique is given by Robert F. Love (13), and presented in section III.3.1.

## III.3 SOME EXAMPLES OF MODEL APPLICATIONS IN FACILITIES LOCATION

### III.3.1 One-Dimensional Facility Location-Allocation

A dynamic programming algorithm is presented by R.F.Love (13) to locate m variable facilities in relation to n existing facilities situated on one route. Each of the n existing facilities has a requirement flow which must be supplied by the variable facilities. The algorithm does the allocation simultaneously with the location. R.F.Love considered a one-dimensional location-allocation problem that arises when a set of new facilities is to be added in relation to a set of existing facilities. The structure of the problem is given as :

i- a set of n points $a_j$, $j=1,\ldots,n$ on the Euclidean line called existing facilities,

ii- known non-negative weights $r_j$ $=1,\ldots,n$ representing requirements at each existing facility point, and

iii- a set of m unlocated or variable facilities.

The problem is to determine :

i- the optimal location for each of the m variable facilities and, ii- the optimal allocation of existing facility requirements to the variable facilities so that all requirements are satisfied.

Let the m unknown facility locations be given by $x_i$, i=1,...,m. When the criteria to be satisfied is the minimization of total weighted distances, the problem may be stated as

$$\text{Minimize } R(x,w) = \sum_{ij} w_{ij} \, |x_i - a_j|$$

$$\text{s.t.} \quad \sum_i w_{ij} = r_j \qquad \text{for all } j$$

$$w_{ij} \geq 0$$

where $x=(x_1,\ldots,x_m)$ and $w=(w_{11},\ldots,w_{1m},w_{21},\ldots,w_{mn})$

## III.3.2 A Simple Warehouse Location Problem

The warehouse (plant) location problem in its simplest form has been formulated by Effroymson and Ray (3) as a mixed integer program as follows : with m potential warehouses (with unlimited capacity) and n customers,

$$\text{Minimize } Z = \sum_{ij} C_{ij}\, x_{ij} + \sum_i F_i\, y_i$$

s.t.

$$\sum_i x_{ij} = 1 \qquad j = 1,2,\ldots,n$$

$$0 \leq \sum_j x_{ij} \leq n_i\, y_i \qquad i = 1,2,\ldots,m$$

$$y_i = 0 \text{ or } 1 \quad \text{(integer)} \quad \text{where } i \in N_j \quad j \in P_i$$

$t_{ij}$ : the per unit cost which includes the FOB cost at the warehouse "i", the warehouse handling cost and the transportation cost from the warehouse to the customer "j"

$D_j$ : the demand at customer j

$x_{ij}$ : the portion of $D_j$ supplied from warehouse i

$F_i$ : the fixed cost associated with warehouse i

$N_j$ : set of warehouses which can supply customer j

$P_i$ : set of those customers that can be supplied by warehouse i

$n_i$ : number of elements in $P_i$

The objective of the model is minimization of costs which are fixed set up and distribution costs, potential locations are limited to particular sites in the feasible set. Solution procedure is branch and bound. Problem is not time-scaled and concerns for only one period of time. There is no present sites and economies of scale is not applied to warehouse storage capacities. The unit distribution and handling costs are assumed to be linear.

Three kinds of efficiencies have been developed and added to the branch and bound algorithm by Effroymson and Ray. Briefly these are:

i- at each successive stage, the branch and bound algorithm requires the selection of a warehouse, from the set of free warehouses at that stage, to be constrained open or closed. Formal rules for selecting the free warehouse have been developed, ii- at each step of the branch and bound algorithm, a linear program, without the integer restrictions on the y's, is to be solved,

iii- several improvements related to the computer programming of the branch and bound algorithm are proposed.

### III.3.3 A Two-Level Plant and Warehouse Location Problem

A model is proposed by Kaufman (10) for the simultaneous location of plants and warehouses among a given set of possible locations in order to satisfy a given demand at minimum cost. The demand of each customer may be satisfied directly from a plant or through a warehouse. The model also applies to the design of a distribution network with two levels of warehouses. A branch and bound algorithm which generalizes previous work by Effroymson and Ray (3) (which is given in section III.3.2) is presented.

In this work the simple plant location problem is generalized to cope with a two-level distribution system. The model applies to the problem of simultaneously locating plants and warehouses or large and small warehouses, and it is formulated as follows : given a set of locations where plants may be built, a set of locations where plants may be built, a known demand from a given set of customers which must be satisfied and assuming a warehouse is located with each plant, determine the numbers and locations of plants and warehouses to be established in order to minimize total production and distribution costs.

The model implicitly assumes consideration of a single product or a homogenous product mix.

This problem may be expressed mathematically in the following way:

$$\text{Minimize } Z \quad \sum_i f_i \, y_i + \sum_j g_j \, z_j + \sum_{ijk} c_{ijk} \, x_{ijk}$$

$$\sum_{ij} x_{ijk} = 1 \qquad (1)$$

$$\sum_j x_{ijk} \leq y_i \qquad (2)$$

$$\sum_i x_{ijk} \leq z_j \qquad (3)$$

$$y_i \leq z_i \qquad (4)$$

$$y_i, z_j = 0,1 \qquad x_{ijk} \geq 0 \qquad (5)$$

where $f_j$ denotes the fixed cost for establishing a plant at location i, $g_j$ denotes the fixed cost for establishing a warehouse at location j, $c_{ijk}$ denotes the cost of satisfying the demand of customer k from plant located at i through a warehouse located at j ; $y_i$ is a binary variable equal to 1 if a plant is located at i and equal to zero otherwise ; $z_j$ is a binary variable equal to 1 if a warehouse is located at j and equal to zero otherwise ; $x_{ijk}$ is a continuous variable equal to the fraction of the demand of customer k satisfied by plant i through warehouse j.

The constraints (2) express that the demand of each customer must be satisfied, the constraints (2) and (3) express that the demand of customer k can only be satisfied from i through j if a plant is located at i and a warehouse at j. The constraints (4) ensure that a warehouse is located with each plant and the constraints (5) is the non-negativity and binary configurations.

### III.3.4 Multilocation Plant Sizing and Timing

A dynamic multilocation problem is solved by Rao and Rutenberg (18). In the model constructed time is continuous, and demands can grow at varying rates in different markets and at different times. There are economies of scale in building plant capacity. With plant sizes held constant, transportation cost is optimized through continuous time so as to set plant timings. The study deals with the dynamic trade-off between plant economies of scale and the cost of manufacturing and transportation to supply geographically dispersed customers. Customer demands grow through time (usually at different rates), so plants early in the construction sequence should be sized for use throughout the planning period. More formally, for a given construction squence the model can time and size plants to satisfy growing market demands while minimizing the present value of plant fixed costs, plus the present value of operating and transportation costs.

The objective of the study is to minimize total cost over time, which is composed of warehouse construction, product distribution, handling and storage costs. These costs could vary through time, but they are assumed to be constant. Potential locations for warehouses are pre-determined, and their capacities are sized and timed optimaly over a continuous time horizon.

Initial statement of the problem is given as :

The problem is to minimize the present value of costs of construction, production and transportation incurred over the time horizon {0,T}. At time T total plant capacity will be $\sum_m b_m(T)$, where $b_m$ is the demand at market m.

$$\text{Minimize } Z \; \sum_n f_n (a_n) e^{-r\tau_n} + \int_0^T \sum_{mn} c_{nm} x_{nm}(t) e^{-rt} dt$$

where r is the discount rate.

s.t.

$$\sum_m x_{nm}(t) \leq a_n(t) \qquad \text{for all } n,t \in \{0,T\}$$

Shipments can not exceed capacity where

$$a_n(t) = 0 \qquad t \in \{0,\tau_n\},$$

$$= a_n \qquad t \in \{\tau_n,T\}$$

$$\sum_n x_{nm}(t) \geq b_m(t) \qquad \text{for all } m,t \in \{0,T\}$$

Each demand must be satisfied continuously through time.

$$x_{nm}(t) \geq 0 \qquad \text{for all } n,m.$$

### III.3.5 Multicommodity Distribution System Design by Mixed Integer Programming

A multicommodity capacitated single-period problem is formulated as a mixed integer linear program by Geoffrion and Graves (9).

There are several commodities produced at several plants with known production capacities. There is a known demand for each commodity at each of a number of customer zones. This demand is satisfied by shipping via regional distribution centers (DC), with each customer zone being assigned exclusively to a single DC. There are lower as well as upper bounds on the allowable total annual throughput of each DC. The possible locations for the DC's are given, but the particular sites to be used are to be selected so as to result in the least total distribution cost. The DC costs are expressed as fixed charges (imposed for the sites actually used) plus a linear variable charge. Transportation cost are taken to be linear.

Thus the problem is to determine which DC sites to use, what size DC to have at each selected site, what customer zones should be served by each DC, and what the pattern of transportation flows should be for all commodities. This is to be done so as to meet the given demands at minimum total distribution cost subject to the plant capacity and DC throughput constraints.

The mathematical formulation of the problem uses the following notations.

$i$ : index for commodities,

$j$ : index for plants,

$k$ : index for possible distribution center (DC) sites,

$l$ : index for customer demand zones.

$S_{ij}$ : supply (production capacity) for commodity i at plant j,

$D_{il}$ : demand for commodity i in customer zone l,

$\overline{V}_k, \underline{V}_k$ : minimum, maximum allowed total annual throughput for a DC at site k,

$f_k$ : fixed portion of the annual possession and operating costs for a DC at site k,

$v_k$ : variable unit cost of throughput for a DC at site k,

$C_{ijkl}$ : average unit cost of producing and shipping commodity i from plant j through DC k to customer zone l,

$x_{ijkl}$ : a variable denoting the amount of commodity i shipped from plant j through DC k to customer zone l,

$y_{kl}$ : a 0-1 variable that will be 1 if DC k serves customer zone l, and 0 otherwise,

$z_k$ : a 0-1 variable that will be 1 if a DC is acquired at site k, and 0 otherwise.

The problem can be written as the following mixed integer linear program.

$$\text{Min} \quad \sum_{ijkl} C_{ijkl}\, x_{ijkl} + \sum_{k} \{ f_k\, z_k + v_k \sum_{il} D_{il}\, y_{kl} \} \qquad (1)$$

$x \geq 0; y, z = 0, 1$

$$\sum_{kl} x_{ijkl} \leq S_{ij} \qquad \text{for all } i,j \qquad (2)$$

$$\sum_{j} x_{ijkl} = D_{il}\, y_{kl} \qquad \text{for all } i,k,l \qquad (3)$$

$$\sum_{k} y_{kl} = 1 \qquad (4)$$

$$\underline{V}_k\, z_k \leq \sum_{il} D_{il}\, y_{kl} \leq \overline{V}_k\, z_k \qquad \text{for all } k \qquad (5)$$

Linear configuration constraints on y and/or z. (6)

The notation $y,z = 0,1$ means that every component $y_{kl}$ and $z_k$ must be 0 or 1.

The correspondence between this model and the verbal problem statement should be apparent. The quantity $\sum_{il} D_{il}\, y_{kl}$ is interpreted as the total annual throughput of the kth DC. Constraints (2) are are the supply constraints, (3) stipulate both that legitimate demand must be met (when $y_{kl} = 1$) and that $x_{ijkl}$ must be 0 for all ij when $y_{kl} = 0$. Constraints (4) specify that each customer zone must be served by a single DC. Besides keeping the total annual throughput between $\underline{V}_k$ and $\overline{V}_k$ or at 0 according to whether or not a DC is open, (5) also enforces the correct logical relationship between y and z (i.e., $z_k = 1 \leftrightarrow y_{kl} = 1$ for some l ). Constraints (6) are deliberately not spelled out in detail for the sake notational simplicity.

In this model the transportation variables are quadruply subscripted, whereas previous intermediate location models (Bartakke et al (1), Elwein and Gray (6), Elson (5), Marks, Liebman and Bellmore (14)), employ separate transportation variables for plant-to-DC and DC-to-customer shipments. That is, in this model it might have been used two sets of triply subscripted variables ($x_{ijk}$ and $x_{ikl}$, say) linked by a flow conservation constraint for each commodity-DC combination.

This alternative suffers from a lack of flexibility for some applications, because it "forgets" the origin of a commodity once it arrives at a DC.

The quadruply subscripted tranportation variables also make it easy to accommodate direct plant-customer zone shipments so long as a customer zone does not try to receive a given commodity both from a DC and a plant. For instance, suppose that a certain subset of customer zones is to obtain all commodities directly from the plants instead of via DC's. Then one simply adds a fictitious DC site k, say, with the associated $z_{k_0}$ and $y_{k_0 l}$'s fixed at unity and specifies the rates $C_{ijk_0 l}$ appropriately for each associated ijl (there is no need for (5) to include a constraint for $k_0$). One may also accommodate the situation in which a customer zone obtains some commodities directly from the plants and the others through its DC. Just make the $C_{ijkl}$'s corresponding to the direct commodities independent of the possible DC's for such a customer zone, and omit the il combinations corresponding to the directly shipped commodities from both $\sum_{il} D_{il}\, y_{kl}$ terms in the model.

Another unique feature of the model is that no customer zone is allowed to deal with more than one DC, since the $y_{kl}$'s must be 0 or 1 and not fractional. Thus each customer's demand must be satisfied by a single DC or directly from a producing plant. This assumption is required by the decomposition technique developed by the authors. Their first-hand experience with three firms, each in a different industry, is that the accounting systems and the marketing structures are geared to serving each customer zone from a single DC. Any change in this convention would be expensive both in terms of added administrative costs and in terms of less convenient service as perceived by customers. There would also be economic disadvantages due to reduced economies of scale in DC-to-customer shipments.

The arbitrary configuration constraints (6) give the model quite a lot of flexibility to incorporate many of the complexities and idiosyncrasies found in most real applications. For instance (6) permits :

i- upper and/or lower bounds on the total number of open DC's allowed ;

ii- specification of subsets of DC's among which at most one, at least one, exactly two, etc., are required to be open ;

iii- precedence relations pertaining to the open DC's (not A unless B, etc.) ;

iv- mandatory service area constraints (if DC A is open, it must serve customer zone B) ;

v- more detailed capacity constraints on the size of a DC than (5) permits, as by weighting the capacity consumption characteristics of each commodity differently or by writing separate constraints for individual or subsets of commodities ;

vi- constraints on the joint capacity of several DC's if they share common resources or facilities ;

vii- customer service constraints like,

$$\left( \sum_{kl} t_{ikl}\, d_{il}\, y_{kl} \right) / \sum_{l} D_{il} \leq T_i ,$$

where $t_{ikl}$ is the average time to make a delivery of commodity i to customer zone after receiving an order at DC k, and $T_i$ is a desired bound on the average delivery delay for commodity i.

# CHAPTER IV

## MATHEMATICAL MODELLING OF THE SYSTEM

This chapter presents two consecutive mixed integer programming (MIP) models. The first one introduces the simplest version of the system which is described in Chapter II. The first model is modified to satisfy the specifications of the Sümerbank distribution system. Some approximations are made for the sake of simplicity and solution of the problem. A few constraints and variables are added in order to satisfy the specific requirements of Sümerbank distribution system.

Previously mentioned seven choices (Section III.1) are applied to the Sümerbank distribution system and the following points are taken into consideration for modelling.

The overall objective is minimization of costs which are composed of warehouses' personnel, rent and operating expenses plus distribution expenses.

Because of physical and geographical conditions possible locations for district warehouses are predetermined and each retail shop is assigned to a warehouse exclusively. Because of these two conditions, location allocation problem is eliminated. So that the questions which may arise in potential locations choice, such as "how many depots, where should they be located and which retail shops should be assigned to them" are predetermined.

The search procedure which may be applied to this problem can be mixed integer programming which will optimize the proper district warehouse capacity and the quantities shipped from factories to warehouses and transshipments among different district warehouses if profitable for the overall distribution system. The maximum integer (binary) variable is the $j \times m$, where $j=1,2,\ldots,5$ is the number of predetermined district warehouses and $m=1,2,3,(4)$ is the warehouse storage capacity alternatives. In the Sümerbank distribution system maximum number of binary variables is 16 for Marmara Region and this size is feasible for the solution technique which is available in Univac 1106 Computer as Functional Mathematical Programming System.

This study will be concerned with the static situation for one year (as of 1980) and future changes in demand pattern and stock-turnover rates for the warehouses will be considered.

The present sites for the district warehouses of the already existing distribution system are predetermined same as the real system, the only difference is three or four storage capacity alternatives for these predetermined districts are proposed. Warehouse operating costs are non-linear with economies of scale applies as warehouse capacity increases to reflect this situation 3 or 4 warehouse capacities being considered as unit cost decreases with increasing capacities.

The transportation costs are inputed to the system as the prices for transporting a unit of product between all possible departure and destination points such as factory to warehouse and warehouse to warehouse. In fact transportation costs are non-linear, for the amounts under consideration it is assumed to be linear.

By taking into consideration of these choices a quantitative framework will be set for the analysis of various planning problems associated with optimum capacity setting and commodity supplying policy of Sümerbank distribution system.

## IV.1 THE MODEL

Schematic representation of this system was given in Figure 1. In this distribution system, the commodities are sent from factories to possible district warehouses and from district warehouses to retail shops. The direct shipments from factories to the retail shops are not allowed. A 0-1 mixed integer programming model has been constructed to decide the optimum capacities of the district warehouses and distribution scheme of the problem.

### IV.1.1 Notation and Definition of Indeces and Variables

i- indeces

i: index indicating the factory (also the product group since each type of product is produced in only one factory)

j: index indicating the warehouses (depots)

k: index indicating the retail shops

ii- variables

$x_{ij}$: amount of units transported from $i^{th}$ factory to $j^{th}$ warehouse

$y_{ijk}$: amount of units produced at $i^{th}$ factory and transported from $j^{th}$ warehouse to $k^{th}$ retail shop

$z_j$: binary variable, 1 if the $j^{th}$ warehouse is open
0 otherwise

### IV.1.2 Predetermined Coefficients, Costs and Bounds

$F_j$: operating cost of $j^{th}$ warehouse for one year

$C^1_{ij}$: cost of transporting one unit from $i^{th}$ factory to $j^{th}$ warehouse

$C^2_{jk}$: cost of transporting one unit from $j^{th}$ warehouse to $k^{th}$ retail shop

$D_{ik}$: demand of $i^{th}$ product group in retail shop k

$STR_j$: stock turn-over rate of $j^{th}$ warehouse

$K_j$: maximum allowable storage capacity of $j^{th}$ warehouse at a time

$P_i$: yearly production capacity of $i^{th}$ factory (or maximum supply of $i^{th}$ product

### IV.1.3 Formulation of the Model

Objective Function

Min Total Cost $\sum_j F_j z_j + \sum_{ij} C^1_{ij} x_{ij} + \sum_{jk} C^2_{jk} y_{ijk}$ (IV-1)

Demand Constraints

$$\sum_j y_{ijk} \geq D_{ik} \qquad \text{for all } i,k \qquad \text{(IV-2)}$$

Material Balance Constraints

$$x_{ij} = \sum_k y_{ijk} \qquad \text{for all } i,j \qquad \text{(IV-3)}$$

Warehouse Capacity Constraints

$$\sum_j x_{ij} \leq STR_j \; K_j \; z_j \qquad \text{for all } j \qquad (IV\text{-}4)$$

Production Capacity Constraints

$$\sum_j x_{ij} \leq P_i \qquad \text{for all } i \qquad (IV\text{-}5)$$

$z=0,1$ and non-negativity constraints

Objective of the model is to minimize the costs which are composed of operating expenses of warehouses and distribution (transportation) expenses. Cost coefficients $C^1$ and $C^2$ are different since the transport media between factory-warehouse and warehouse-retail shop are different. Constraints (IV-2) are the demand constraints. Constraints (IV-3) are the material balance constraints and stipulate that the amount of products ($x_{ij}$) transported from factories to a specific warehouse must be equal to the amount ($y_{ijk}$) which are sent to the retail shops from this warehouse. Constraints (IV-4) limits the throughput of the $j^{th}$ warehouse according to its given storage capacity. It also prevents the shipments to the non-existing (closed) warehouses. When the warehouse is closed, $z = 0$ value makes right-hand-side (which is storage capacity) 0. Constraints (IV-5) limits the demand by the production capacity of $i^{th}$ factory. Normally this constraint is redundant, otherwise, this solution will be infeasible. In this model all transportation costs are assumed to be linear.

## IV.2 THE DEVELOPED MODEL

Previously mentioned model is applied to the Sümerbank system and besides some additions also some approximations are made. For the sake of simplicity, retail shops are discarded from the system and their demand is mounted over the related warehouse. This is because of the assignment of retail shops to the district warehouses in the physical system. In the Sümerbank system possible locations for the warehouses are pre-determined according to its physical and geographical conditions, also each retail shop is pre-assigned to a district warehouse according to its geographical condition, in order to prevent the duplicate booking and to decrease the complexity of the system. Because of these two conditions the location allocation problem is eliminated.

The schematic representation of the new system will be as shown in Figure 5.

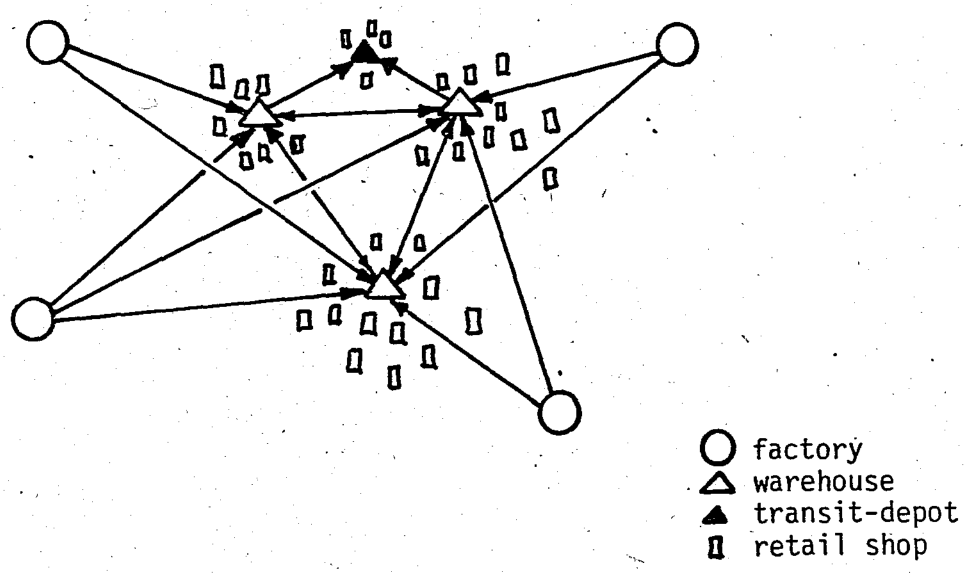


Figure 5 : Schematic representation of the developed system

In this new system there would be two kinds of warehouses: first kind of warehouses will work as a transit-depot, and normal warehouse facilities will not exist. They will be used for transferring the commodities from other warehouses to the demand centers (retail shops). In fact the demand of the transit depot will be served from the nearest potential (normal) warehouse. Conversely, normal warehouse will serve for their own demand plus other transit-depots' demands. By the use of transit-depots, warehouse usage will increase the efficiency appreciably.

The intershipment of commodities between warehouses and transit-depots allowed by this developed model exists in the present Sümerbank distribution system as shipments from warehouse to warehouse. Existance of alternative warehouse capacities decreases the total cost of the distribution system, by choosing the appropriate capacity according to the conditions of the district.

### IV.2.1 Notation and Definition of Indeces and Variables

i- indeces

i : index indicating the factory (and the product group since each product is produced in only one factory
$i = 1,2,...,10$

j,d : indeces indicating the warehouse from the feasible set
$j = 1,2,..,5$
$d = 1,2,..,5$

m : index indicating the alternative capacities of warehouses
$m = 1,2,3,(4)$

ii- variables

$x_{ij}$ : amount of units transported from $i^{th}$ factory to $j^{th}$ warehouse

$g_{ijd}$ : amount of units (produced in $i^{th}$ factory ) transported from $j^{th}$ warehouse to the warehouse d, $(j \neq d)$

$g_{idj}$ : amount of units (produced in $i^{th}$ factory) transported to $j^{th}$ warehouse from the warehouse d, $(j \neq d)$

$z_{jm}$ : binary variable, 1 if the $j^{th}$ warehouse with capacity m is open,
0 otherwise

IV.2.2 Predetermined Coefficients, Costs and Bounds

$F_{jm}$ : operating cost of $j^{th}$ warehouse with capacity m for one year including rent, personnel and other expenses

$C^1_{ij}$ : average cost of transporting one unit (of $i^{th}$ product) from $i^{th}$ factory to $j^{th}$ warehouse

$C^2_{jd}$ : average cost of transporting one unit of product from $j^{th}$ warehouse to other warehouses

$D_{ij}$ : demand of $i^{th}$ product group in retail shop j

$STR_j$ : stock turn-over rate of $j^{th}$ warehouse

$SK_{jm}$ : maximum allowable storage capacity of $j^{th}$ warehouse with capacity alternative m (at a time)

$P_i$ : yearly production capacity of $i^{th}$ factory (or maximum supply of $i^{th}$ product group)

$A_{ij}$ : coefficients of direct shipments from $i^{th}$ factory to $j^{th}$ warehouse

$B_{ij}$ : coefficients of intershipments between warehouses

## IV.2.3 Formulation of the Developed Model

Objective Function

Min Total Cost
$$\sum_{jm} F_{jm} z_{jm} + \sum_{ij} C^1_{ij} x_{ij} + \sum_{ijd} C^2_{jd} g_{ijd} \qquad \text{(IV-11)}$$

Material Balance and Demand Constraints

$$x_{ij} - \sum_{d} g_{ijd} + \sum_{\substack{d \\ d \neq j}} g_{idj} = D_{ij} \qquad \text{for all } i,j \qquad \text{(IV.12)}$$

Warehouse Storage Capacity Constraints

$$\sum_{i} A_{ij} x_{ij} + \sum_{id} B_{ij} g_{idj} \leq \sum_{m} STR_j SK_{jm} z_{jm} \qquad \text{for all } j \qquad \text{(IV-13)}$$

Production Capacity (Maximum Supply) Constraints

$$\sum_{j} x_{ij} \leq P_i \qquad \text{for all } i \qquad \text{(IV-14)}$$

Only One Warehouse Capacity is Chosen

$$\sum_{m} z_{jm} \leq 1 \qquad \text{for all } j \qquad \text{(IV-15)}$$

Plus non-negativity constraints and fixed variables

The objective of the model is to minimize the total cost which is composed of operating costs of the warehouses with alternative capacities, factory-to-warehouse and warehouse-to-warehouse transportation costs. In fact the hidden objective is the maximization of the profit since profit is the positive difference between revenue and costs. The demand in the retail shops is satisfied by getting the commodities directly from its district warehouse or via other regions' warehouses through its transit-depot. The material balances in the warehouses are satisfied by the constraints (IV-12). The demand of for the warehouse is obtained by summing up the demands of the retail shops which are affiliated to the warehouse in concern and inputed to the model. The annual throughputs of the warehouses restricted by the constraints (IV-13), if the $j^{th}$ warehouse is open, will permit a yearly throughput which is decided as multiplying the storage capacity of the $j^{th}$ warehouse ($SK_{jm}$) by its stock turn-over rate ($STR_j$) and the throughput will be zero if the warehouse set to be closed. An efficient storage policy will be achieved by the use of coefficients $A_{ij}$ and $B_{ij}$. They are used to differentiate the storage burden of a unit of good i arriving at warehouse j as a direct shipment verses transshipment. Most often a unit of good i causes less strain on the storage facilities at j since it is packed and ordered for immediate delivery to retail shops. Constraints (IV-14) keep the control of maximum supply, if an amount more than supply is demanded an infeasible solution is obtained, otherwise, this constraint will be redundant. These constraints will also help to put the district allowances for some product groups when it is required. Constraints (IV-15) will guarantee that only one warehouse capacity is chosen for an open warehouse over the alternatives which is best suited for the optimal status of the solution. Also, some bounds and pre-determined variables may be added for sensitivity analysis.

# CHAPTER V

# NUMERICAL RESULTS

The developed model has been solved by FMPS (Functional Mathematical Programming System) of Univac 1106 Data Processing System used at Computer Center of Boğaziçi University. Mixed integer programming mode in FMPS is constructed for solving this type of problems where the integer variables are required to be binary (i.e., 0 or 1). The solution algorithm is branch and bound and the features of FMPS can be seen in reference (20).

## V.1 INPUT DATA

The data used in this problem were taken from Planning, Accounting, Transportation and Personnel Departments of Sümerbank.

### V.1.1 Demands of District Warehouses ($D_{ij}$)

The sales of the year 1980 are taken as the demands of the district warehouses and shown in Table 1. The district warehouses are considered to be located in Balıkesir, Bursa, İstanbul, İzmit and Tekirdağ. However, the cotton textile factories in the system are Nazilli, İzmir, Eskişehir, Antalya, Ereğli, Kayseri, Adana, Bakırköy, Malatya and Maraş factories.

TABLE 1 : SALES OF DISTRICT WAREHOUSES IN YEAR 1980 (as km of cloth)

| Warehouse / Factory | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Nazilli | 810 | 671 | 2858 | 959 | 437 |
| İzmir | 650 | 886 | 2165 | 798 | 387 |
| Eskişehir | 758 | 711 | 2175 | 750 | 295 |
| Antalya | 73 | 63 | 537 | 125 | 39 |
| Ereğli | 162 | 148 | 397 | 96 | 8 |
| Kayseri | 220 | 288 | 1684 | 467 | 419 |
| Adana | 30 | 14 | 68 | 1 | 15 |
| Bakırköy | 251 | 176 | 779 | 123 | 77 |
| Malatya | 270 | 262 | 981 | 357 | 160 |
| Maraş | 69 | 121 | 335 | 114 | 94 |

V.1.2 Production Capacities of Factories ($P_i$)

Yearly programmed productions are inputed to the system as $P_i$'s in a way, they are the restrictions in order to prevent the over-supply of the product group "i". These figures are given in Table 2. The product types in the product groups are given in Appendix E.

V.1.3 Transportation Costs ($C^1_{ij}$ and $C^2_{jk}$)

Transportation costs are taken from Buntaş Transportation Co., which is a private sector transportation agent and serves for only Sümerbank. The data is given in Table A.1 in Appendix A as the price of transporting one ton of product between given two points, and this data is converted from ton to km of the cloth by using products' average weights which are given in Table A.2. The resulting transportation costs of the product groups are listed in Table 3. Similar calculations are done for the costs of transportations among district warehouses. The rough data in TL/ton/ specified distance is given in Table A.3 and the resulting transportation costs in TL/km of product for given specified distances are listed in Table 4.

TABLE 2 : PROGRAMMED PRODUCTION OF FACTORIES IN 1980 (km of cloth)

| Factory | Programmed Production |
|---|---|
| Nazilli | 35,300 |
| İzmir | 34,500 |
| Eskişehir | 22,150 |
| Antalya | 8,250 |
| Ereğli | 11,694 |
| Kayseri | 35,850 |
| Adana | 15,000 |
| Bakırköy | 20,180 |
| Malatya | 14,460 |
| Maraş | 5,555 |

TABLE 3 : BUNTAŞ TRANSPORTATION COSTS in 1980 FACTORY TO WAREHOUSE (km of cloth/TL)

| Warehouse / Factory | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Nazilli | 329 | 398 | 595 | 554 | 654 |
| İzmir | 284 | 328 | 475 | 446 | 522 |
| Eskişehir | 338 | 302 | 366 | 254 | 427 |
| Antalya | 824 | 636 | 808 | 753 | 900 |
| Ereğli | 1212 | 1134 | 1217 | 1161 | 1349 |
| Kayseri | 372 | 312 | 342 | 312 | 402 |
| Adana | 590 | 455 | 579 | 539 | 645 |
| Bakırköy | 723 | 611 | 431 | 500 | 487 |
| Malatya | 2168 | 1949 | 2076 | 1983 | 2376 |
| Maraş | 2119 | 1777 | 2052 | 1937 | 2319 |

TABLE 4 : BUNTAŞ TRANSPORTATION COSTS in 1980 WAREHOUSE TO WAREHOUSE (km of cloth/TL)

| Warehouse / Warehouse | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Balıkesir | - | 422 | 430 | 476 | 496 |
| Bursa | 422 | - | 363 | 331 | 469 |
| İstanbul | 430 | 363 | - | 297 | 289 |
| İzmit | 476 | 331 | 297 | - | 382 |
| Tekirdağ | 496 | 469 | 289 | 382 | - |

### V.1.4 Operating Expenses of Warehouses ($F_{jm}$)

Total operating expenses are composed of personnel, rent and other expenses such as water, electricity, etc., calculated for every district warehouse storage capacity alternative according to its region, size and personnel requirements. Total operating cost figures are given in Table 5. The cost figures of rent, personnel and other expenses are given in Appendix B.

TABLE 5 : TOTAL OPERATING EXPENSES OF THE WAREHOUSES ( yearly 1000 TL )

| Capacity Alternative | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| A | 365 | 449 | 485 | 449 | 415 |
| B | 1426 | 1846 | 3422 | 1385 | 1191 |
| C | 2222 | 3062 | 6153 | 3062 | 1846 |
| D | - | - | 8814 | - | - |

V.1.5 Storage Capacity of Warehouse ($SK_{jm}$)

There are 3 possible alternatives for storage capacities of district warehouses at Balıkesir, Bursa, İzmit and Tekirdağ and 4 alternatives at İstanbul. These alternatives are listed in Table 6.

TABLE 6 : SIZE OF THE DISTRICT WAREHOUSE ($m^2$)

| Capacity Alternative | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| A | 200 | 200 | 200 | 200 | 200 |
| B | 1000 | 1000 | 2000 | 700 | 500 |
| C | 2000 | 2000 | 4000 | 2000 | 1000 |
| D | - | - | 6000 | - | - |

Generally 60% of the capacities of these warehouses are reserved for cotton products and 70% of the reserved place is used effectively. The net storage areas in $m^2$ for cotton products are given in Table C.1 in Appendix C.

In the average one bale occupies $0.75m^2$ storage area and at most 5 bales can be stacked vertically. Since one bale of cotton product is approximately 720m in length and the maximum amount of cotton products which can be stored in the warehouses are calculated and given in Table C.2.

V.1.6 Stock Turn-Over Rate ($STR_j$)

The average weighted stock turn-over rates calculated are calculated by using percentage sales of products in the warehouses, which are given in Table D.1, in Appendix D. The following formula (V.1) and the data in Table D.2 were used.

$$STR_j = \frac{\sum_i (STR_i \ \% \text{ sales of product } i)}{\sum_i (\ \% \text{ sales of product } i\ )} \qquad (V.1)$$

$$i = 1,2,\ldots,10$$

The resulting average weighted stock turn-over rates are listed in Table 7.

TABLE 7 : AVERAGE WEIGHTED STOCK TURN-OVER RATES ($STR_j$)

| Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|
| 4.55 | 4.56 | 4.49 | 4.49 | 4.68 |

V.2 SOLUTIONS OF THE MODEL (DEVELOPED)

Previously mentioned numerical data which is gathered from ASM used in five different solutions. In Solution 1, 1980 sales of retail shops are inputed to the system. In Solution 2 present warehouse sizes are fixed. In Solution 3, only demands of the system are increased 100%. In Solution 4 present warehouse sizes are fixed and to the same time demand is increased 100%. In Solution 5, stock turn-over rates of the warehouses decreased 50%, and the systems response is examined according to these variations.

### V.2.1 Solution 1

The input data for this solution corresponds to the actual conditions faced by ASM in 1980 and alternative warehouse setting policy is optimized. The main results that emerge from this solution are given in Tables 8,9 and 10.

Total cost which consists of the operating expenses of open warehouses plus transportation costs is minimized as 23,325,188.- TL.

In Table 8, optimum capacities of five district warehouses and their corresponding capacity usage percentages are tabulated. As seen in the table, Balıkesir, Bursa and Tekirdağ warehouses have smallest capacity alternative, whereas İstanbul and İzmit warehouses have the second smallest capacity alternative. In all warehouses except İstanbul warehouse, storage capacity is used 100% efficiently. However, in İstanbul, warehouse is used at 76% of its capacity.

TABLE 8 : OPTIMAL SOLUTION 1, LIST OF OPEN WAREHOUSES AND THEIR STORAGE EFFICIENCIES

| Warehouse | Capacity Alternative | Capacity $m^2$ | Capacity Usage % |
|---|---|---|---|
| Balıkesir | A | 200 | 100 |
| Bursa | A | 200 | 100 |
| İstanbul | B | 2000 | 76 |
| İzmit | B | 700 | 100 |
| Tekirdağ | A | 180 | 100 |

The amounts of cotton textile products which are sent to district warehouses from factories are given in Table 9. Some of the demands of districts Balıkesir, Bursa and Tekirdağ are not directly shipped from factories but via other district warehouses namely from İstanbul and İzmit warehouses are shown in Table 10 and 11, respectively.

TABLE 9 : SOLUTION 1 - FACTORY TO WAREHOUSE SHIPMENTS (km of cloth)

| Warehouse<br>Factory | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Nazilli | 810 | 671 | 2858 | 959 | 437 |
| İzmir | 538 | 546 | 2384 | 1030 | 387 |
| Eskişehir | - | - | 2175 | 2219 | 295 |
| Antalya | - | - | 645 | 188 | 4 |
| Ereğli | - | - | 567 | 244 | - |
| Kayseri | - | - | 1904 | 755 | 419 |
| Adana | - | - | 98 | 15 | 15 |
| Bakırköy | - | - | 1206 | 123 | 77 |
| Malatya | - | - | 1411 | 619 | - |
| Maraş | - | 121 | 429 | 183 | - |

TABLE 10 : SOLUTION 1 - SHIPMENTS FROM ISTANBUL TO OTHER WAREHOUSES (km of cloth)

| Warehouse<br>Product of | Balıkesir | Bursa | Tekirdağ |
|---|---|---|---|
| İzmir | 112 | 107 | - |
| Antalya | 73 | - | 35 |
| Ereğli | 162 | - | 8 |
| Kayseri | 220 | - | - |
| Adana | 30 | - | - |
| Bakırköy | 251 | 176 | - |
| Malatya | 270 | - | 160 |
| Maraş | - | - | 94 |

One of the interesting example of Solution 1 is that the demand of Tekirdağ warehouse of Antalya factory's products is supplied partly from İstanbul warehouse as seen in Table 10.

TABLE 11 : SOLUTION 1 - SHIPMENTS FROM İZMİT TO OTHER WAREHOUSES (km of cloth)

| Warehouse / Product of | Balıkesir | Bursa |
|---|---|---|
| İzmir | - | 232 |
| Eskişehir | 758 | 711 |
| Antalya | - | 63 |
| Ereğli | - | 148 |
| Kayseri | - | 288 |
| Adana | - | 14 |
| Malatya | - | 262 |
| Maraş | 69 | - |

### V.2.2 Solution 2

In this solution, the alternative warehouse capacities are set to the present storage capacities of the warehouses and only transportation policy is optimized. The value of objective function in this solution is 30,071,908.- TL. Since the storage capacities are larger than those in Solution 1, the usage percentages are dropped sharply (Table 12). Only Tekirdağ warehouse is used at its maximum capacity.

TABLE 12 : SOLUTION 2 - LIST OF OPEN WAREHOUSES AND THEIR STORAGE EFFICIENCIES

| Warehouse | Capacity Alternative | Capacity $m^2$ | Capacity Usage % |
|---|---|---|---|
| Balıkesir | B | 1000 | 36 |
| Bursa | B | 1000 | 37 |
| İstanbul | D | 6000 | 22 |
| İzmit | B | 700 | 60 |
| Tekirdağ | A | 180 | 100 |

TABLE 13 : SOLUTION 2 - FACTORY TO WAREHOUSE SHIPMENTS (km of cloth)

| Warehouse / Factory | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Nazilli | 845 | 671 | 2858 | 959 | 402 |
| İzmir | 650 | 886 | 2165 | 798 | 387 |
| Eskişehir | 758 | 711 | 2175 | 750 | 295 |
| Antalya | 73 | 63 | 537 | 125 | 39 |
| Ereğli | 162 | 148 | 405 | 96 | - |
| Kayseri | 220 | 288 | 1684 | 467 | 419 |
| Adana | 30 | 14 | 68 | 1 | 15 |
| Bakırköy | 251 | 176 | 779 | 123 | 77 |
| Malatya | 270 | 262 | 1141 | 357 | - |
| Maraş | 69 | 215 | 335 | 114 | - |

The transportation schemes are shown in Table 13 and 14. Only Tekirdağ warehouse receives products via other warehouses, since others have enough storage capacities, the goods are shipped directly from the factories.

TABLE 14 : SOLUTION 2 - SHIPMENTS TO TEKİRDAĞ FROM OTHER WAREHOUSES (km of cloth)

| Warehouse / Product of | Balıkesir | Bursa | Tekirdağ |
|---|---|---|---|
| Nazilli | 35 | - | - |
| Ereğli | - | - | 8 |
| Malatya | - | - | 160 |
| Maraş | - | 94 | - |

V.2.3 Solution 3

In this solution, the demand of the system is increased 100% and other input data remained the same as in Solution 1. The optimum cost value is 43,470,364.- TL and other results are given in Tables 15,16,17 and 18.

TABLE 15 : OPTIMAL SOLUTION 3, LIST OF OPEN WAREHOUSES AND THEIR STORAGE EFFICIENCIES

| Warehouse | Capacity Alternative | Capacity $m^2$ | Capacity Usage % |
|---|---|---|---|
| Balıkesir | C | 2000 | 75 |
| Bursa | B | 1000 | 100 |
| İstanbul | B | 2000 | 100 |
| İzmit | B | 700 | 100 |
| Tekirdağ | B | 500 | 79 |

TABLE 16 : SOLUTION 3 - FACTORY TO WAREHOUSE SHIPMENTS (km of cloth)

| Warehouse / Factory | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Nazilli | 7336 | 2773 | - | 487 | 874 |
| İzmir | 2720 | 1772 | 2910 | 1596 | 774 |
| Eskişehir | 1516 | 1422 | 4350 | 1500 | 590 |
| Antalya | 146 | 126 | 1074 | 250 | 78 |
| Ereğli | 324 | 290 | 794 | 192 | 16 |
| Kayseri | 440 | 570 | 3368 | 934 | 838 |
| Adana | 60 | 20 | 136 | 2 | 30 |
| Bakırköy | 502 | 352 | 1558 | 246 | 154 |
| Malatya | 540 | 524 | 1962 | 714 | 320 |
| Maraş | 138 | 1323 | - | - | 5 |

Since the demand is increased, second alternatives are used in all of the warehouses except in Balıkesir. Some of the products of Nazilli and Maraş factories, are first sent to Balıkesir and Bursa and later to İstanbul, İzmit and Tekirdağ warehouses.

TABLE 17 : SOLUTION 3 - SHIPMENTS FROM BALIKESIR TO İSTANBUL (km of cloth)

| Warehouse / Product of | İstanbul |
|---|---|
| Nazilli | 5716 |
| İzmir | 1420 |

TABLE 18 : SOLUTION 3 - SHIPMENTS FROM BURSA TO OTHER WAREHOUSES (km of cloth)

| Warehouse / Product of | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|
| Nazilli | - | 1431 | - |
| Maraş | 670 | 228 | 183 |

### V.2.4 Solution 4

In this solution, the present warehouse storage capacities are tested by the increase in demand (100%).

TABLE 19 : OPTIMAL SOLUTION 4, LIST OF OPEN WAREHOUSES AND THEIR STORAGE EFFICIENCIES

| Warehouse | Capacity Alternative | Capacity $m^2$ | Capacity Usage % |
|---|---|---|---|
| Balıkesir | B | 1000 | 81 |
| Bursa | B | 1000 | 93 |
| İstanbul | D | 6000 | 47 |
| İzmit | B | 700 | 100 |
| Tekirdağ | A | 180 | 100 |

Solution 4 is the combination of Solution 2 and Solution 3, so that only transportation policy is optimized. The optimum cost value is 46,727,991.- TL and other results are given in Tables 19,20,21 and 22.

TABLE 20 : SOLUTION 4 - FACTORY TO WAREHOUSE SHIPMENTS (km of cloth)

| Warehouse / Factory | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Nazilli | 2494 | 2773 | 5716 | 487 | - |
| İzmir | 1300 | 1772 | 4330 | 1596 | 774 |
| Eskişehir | 1516 | 1422 | 4940 | 1500 | - |
| Antalya | 146 | 126 | 1152 | 250 | - |
| Ereğli | 324 | 296 | 810 | 192 | - |
| Kayseri | 440 | 576 | 4144 | 934 | 62 |
| Adana | 60 | 28 | 166 | 2 | - |
| Bakırköy | 502 | 352 | 1558 | 246 | 154 |
| Malatya | 540 | 524 | 2282 | 714 | - |
| Maraş | 138 | 658 | 670 | - | - |

Since the storage efficiencies are 100%, some of the demands of İzmit and Tekirdağ warehouses are sent via other warehouses namely Balıkesir, Bursa and İstanbul as seen in Tables 21 and 22.

TABLE 21 : SOLUTION 4 - SHIPMENTS TO IZMIT FROM BURSA WAREHOUSE (km of cloth)

| Warehouse / Product of | İzmit |
|---|---|
| Nazilli | 1431 |
| Maraş | 228 |

TABLE 22 : SOLUTION 4 - SHIPMENTS TO TEKİRDAĞ FROM OTHER WAREHOUSES (km of cloth)

| Warehouse / Product of | Balıkesir | Bursa | İstanbul |
|---|---|---|---|
| Nazilli | 874 | - | - |
| Eskişehir | - | - | 590 |
| Antalya | - | - | 78 |
| Ereğli | - | - | 16 |
| Kayseri | - | - | 776 |
| Adana | - | - | 30 |
| Malatya | - | - | 320 |
| Maraş | - | 188 | - |

V.2.5 Solution 5

Any variation in the stock turn-over rate can affect the results as well as the demand variations.

TABLE 23 : OPTIMAL SOLUTION 5, LIST OF OPEN WAREHOUSES AND THEIR STORAGE EFFICIENCIES

| Warehouse | Capacity Alternative | Capacity $m^2$ | Capacity Usage % |
|---|---|---|---|
| Balıkesir | C | 2000 | 89 |
| Bursa | B | 1000 | 100 |
| İstanbul | B | 2000 | 100 |
| İzmit | B | 700 | 100 |
| Tekirdağ | A | 180 | 100 |

In order to observe the response of the system against this kind of variation the stock turn-over rates are decreased 50%, and the optimum cost value is 26,616,021.-TL., other results are given in Tables 23,24,25 and 26.

TABLE 24 : SOLUTION 5 - FACTORY TO WAREHOUSE SHIPMENTS (km of cloth)

| Warehouse / Factory | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Nazilli | 4330 | 1162 | - | 243 | - |
| İzmir | 1747 | 886 | 1455 | 798 | - |
| Eskişehir | 1053 | 711 | 2175 | 750 | - |
| Antalya | 73 | 102 | 537 | 125 | - |
| Ereğli | 162 | 156 | 397 | 96 | - |
| Kayseri | 220 | 289 | 1684 | 467 | 418 |
| Adana | 30 | 29 | 68 | 1 | - |
| Bakırköy | 251 | 176 | 779 | 123 | 77 |
| Malatya | 270 | 422 | 981 | 357 | - |
| Maraş | 69 | 664 | - | - | - |

TABLE 25 : SOLUTION 5 - SHIPMENTS FROM BURSA TO OTHER WAREHOUSES (km of cloth)

| Warehouse / Product of | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|
| Nazilli | - | 491 | - |
| Antalya | - | - | 39 |
| Ereğli | - | - | 8 |
| Kayseri | - | - | 1 |
| Adana | - | - | 15 |
| Malatya | - | - | 160 |
| Maraş | 335 | 114 | 94 |

In four of the warehouses the storage capacity is used at the highest efficiency (100%). Since Balıkesir and Bursa warehouses have excess storage capacity they also serve for İstanbul, İzmit and Tekirdağ warehouses, as seen in Tables 25 and 26.

TABLE 26 : SOLUTION 5 - SHIPMENTS FROM BALIKESİR TO OTHER WAREHOUSES (km of cloth)

| Warehouse / Product of | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|
| Nazilli | 2858 | 225 | 437 |
| İzmir | 710 | - | 387 |
| Eskişehir | - | - | 295 |

### V.2.6 The Shadow Prices of Warehouse Storage Capacities

The shadow prices of warehouse storage capacities are given in Table 27, the non-relevant data is shown by a dash (-).
In Solution 1 Balıkesir warehouse's storage capacity shadow price is 207 for alternative capacity A, which means a unit increase in the storage capacity will cause a 207 units reduction in the cost value. In this case the shadow prices are the reduced costs which are also used in the literature. Zero shadow price means the warehouse has excess capacity and any increase in the capacity will not reduce the cost.

TABLE 27 : THE SHADOW PRICES OF WAREHOUSE CAPACITIES OBTAINED FROM OPTIMAL SOLUTIONS

| Warehouse | Capacity Alternative | SOLUTIONS 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Balıkesir | A | 207 | - | - | - | - |
| | B | - | 0 | - | 0 | - |
| | C | - | - | 0 | - | 0 |
| Bursa | A | 170 | - | - | - | - |
| | B | - | 0 | 18 | 0 | 19 |
| | C | - | - | - | - | - |
| İstanbul | A | - | - | - | - | - |
| | B | 0 | - | 80 | - | 80 |
| | C | - | - | - | - | - |
| | D | - | 0 | - | 0 | - |
| İzmit | A | - | - | - | - | - |
| | B | 15 | 0 | 83 | 58 | 84 |
| | C | - | - | - | - | - |
| Tekirdağ | A | 66 | 57 | - | 76 | 152 |
| | B | - | - | 0 | - | - |
| | C | - | - | - | - | - |

## V.3 DISCUSSION OF THE SOLUTIONS

Eventhough the input data of the first two solutions is the same, a 21% reduction of total cost is observed in Solution 1. The difference among the two solutions is that the Solution 2 brings no alternatives to the warehouse capacities but takes them as the present warehouses.

Another important result obtained from Solution 2 is that : storage efficiencies of the present warehouses are quite low except for the Tekirdağ warehouse, especially İstanbul, Balıkesir and Bursa warehouses.

In Solution 1, which is the proposed (o reference) solution ; İstanbul warehouse mainly works as a distribution center, which is proper to the strategic and economical position of İstanbul. İzmit warehouse runs at a higher capacity since it is placed near the important junction of the highway that connects Marmara Region to other regions.

In Solution 2, the transfers between the warehouses are quite rare since most of the warehouses have low storage efficiencies. The excess capacities for storage allow direct shipments from the factories.

In Solution 3, the demand of the system increased 100% in order to observe the system's response to this input modification. In the real case expected 1981 sales would be lower than 1980 sales, because Sümerbank commodity prices were nearly 20% cheaper than the current market where more than 100% inflation and the polytical effects were seen in the year 1980. So the above mentioned 100% modification of the 1980 sales and its results will be helpful for the future decisions. However, current and short-term decisions which will be made, must be based on Solution 1.

The 100% increase in demand causes 86% increase in the total cost and all of the small transit depots leave the system and second alternatives of the warehouses except Balıkesir warehouse run at the highest storage efficiency.

In Solution 4 the above mentioned increase is applied to the present warehouse system. Most of the warehouses run at high storage efficiency, except İstanbul warehouse.

Comparison of the first three solutions' total costs with Solution 4's total cost given as :

| Solutions | Difference |
|---|---|
| 1 - 4 | 99% increase |
| 2 - 4 | 55% increase |
| 3 - 4 | 7% increase |

The bottle-neck occurs at Tekirdağ warehouse since it was fixed to set the capacity alternative A, which is the smallest capacity alternative (the transit-depot).

In Solution 5, the stock turn-over rates are decreased 50% in order to observe the slow-market effects. Increase in the total cost compared with Solution 1 is 13%.

Nearly all of the warehouses run at the highest efficiencies. Balıkesir and Bursa warehouses fed other warehouses in order to maintain optimality.

The Solution 5 reveals that, Sümerbank system is not much sensitive to the variation in the stock turn-over rates, in contrast to the variations in the demand.

Further implementations, required by the specific conditions of the distribution system can be obtained by small variations in the input data.

# CHAPTER VI

# CONCLUSIONS
# AND
# SUGGESTIONS FOR FUTURE WORK

The objective of this thesis was to develop a model which is capable of setting optimal warehouse capacity alternatives and distribution of commodities. So a model has been designed and numerically tested with the overall aim, providing ASM management with a quantitative framework for the analysis of various short and long-term planning problems associated with three stage warehousing system, which consists of factories, district warehouses and retail shops.

The ASM management can easily overview the system make optimum decisions on "where to locate the central warehouses, which capacity size is required, from where the commodities must be supplied, wheather the trans-shipment would be profitable or not, what would be the cost of a preference on warehouse settings and transport amounts, what would be the storage requirements if the demand increased or decreased for some amount?".

Another important criteria is that for the five solutions, average central processing unit times and total running times on Univac 1106 Computer are 63 and 170 seconds respectively for 16 integers.

So, big size model can also be tested numerically.

The developed model presented in section IV.2 can be modified for more detailed and long range problems. It can also be associated with different transportation media such as rail transportations, and handling restrictions which may appear in the district warehouses.

Once the experience is gained with these given models, and attempt may be made to develop a global model for the special conditions to be encountered all over Turkey, in the district warehouse location, storage capacity setting and transportation problem of Sümerbank.

# BIBLIOGRAPHY

1- Bartakke,M.N., Bloomquist,J.V., Korah,J.K., Popino,J.P., "Optimizaton of a Multi-National Physical System" 40th ORSA Meeting Anaheim, California, 1971.

2- Beattie,R.W., "Improving the Structure of a Distribution System", Int. J.Phys.Distr. 1, 1973.

3- Efroymson,M.A., and Ray,T.L., "A Branch and Bound Algorithm for Plant Location" Opl. Res. Quartl. 14, 1966.

4- Eilon,C.D.T., Watson-Gandy, and Christofides,N., "Distribution Management: Mathematical Modelling and Practical Analysis" Griffin, London, 19870.

5- Elson,D.G., "Site Location via Mixed Integer Programming" Opl. Res. Quartl., 23, 1972.

6- Elwein,L.B. and Gray,P., "Solving Fixed Charge Location Allocation Problems with Capacity and Configuration Constraints, AIIE Transactions, III, 1971.

7- Evranos,Ç., Önerdem,L., Aydın,Ş., and Süer,Y., "Rationalization and Modernization Program for the Cotton Textile Division of Sümerbank - Diagnosis and Recommendation Report" TÜBİTAK M.A.E., 1979.

8- Feldman,E., Lehrer,F.A. and Ray,T.L., "Warehouse Location under Continuous Economies of Scale" Mangmt. Sci. 9, 1966.

9- Geoffrion,A.M. and Grawes, G.W., "Multicommodity Distribution System Design by Benders Decomposition." Mangmt. Sci. 20 No.5, 1974

10- Kaufman,L., Eede,M.V. and Hansen,P., "A Plant and Warehouse Location Problem" Opl. Res. Quartl. 28, 1977.

11- Knester,J.L., and Mize,J.H., "Optimization Techniques with Fortran", 1973

12- Kuehn,A.A., and Hamburger,M.J., "A Heuristic Program for Locating Warehouses" Mangmt. Sci. 9, 1963.

13- Love,R.F., "One Dimensional Facility Location - Allocation Using Dynamic Programming" Mangmt. Sci., 22, 1976.

14- Marks,D.H., Liebman,J.C., and Bellmore,M., "Optimal Location of Intermediate Facilities in a Trans-shipment Network", 37th National ORSA Meeting, Washington, 1970.

15- Mercer,A., "Strategic Planning of Physical Distribution Systems." Int. J. Phys. Distr., 1970.

16- Meyer,C.F., "A Long Range Selection and Timing Analysis System for Facility Location Theory" Opl. Res. Quartl., 25, 1974.

17- Rand,G.K., "Methodolojical Choices in Depot Location Studies" Opl. Res. Quartl., 27, 1976.

18- Rao,R.C., and Rutenberg,D.P., "Multilocation Plant Sizing and Timing" Mangmt. Sci., 23, 1977.

19- Taha,H.A., "Operations Research an Introduction" Department of I.E., University of Arkansas, 1976.

20- Topaç,E., "Functional Mathematical Programming System" Dept. of I.E., Boğaziçi University, 1978.

# APPENDICES.

# APPENDIX A

## BUNTAŞ CO. CONTRACTED TRANSPORT COSTS

## AVERAGE WEIGHTS OF PRODUCT GROUPS

TABLE A.1 : BUNTAŞ CO. TRANSPORTATION COSTS (in 1980 TL/ton)
FACTORY TO WAREHOUSE

| Warehouse / Factory | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Nazilli | 2632 | 3180 | 4760 | 4428 | 5234 |
| İzmir | 2274 | 2622 | 3802 | 3570 | 4176 |
| Eskişehir | 2502 | 2234 | 2712 | 1878 | 3160 |
| Antalya | 4849 | 3740 | 4754 | 4427 | 5296 |
| Ereğli | 5050 | 4726 | 5070 | 4838 | 5620 |
| Kayseri | 3100 | 2600 | 2850 | 2600 | 3350 |
| Adana | 4918 | 3794 | 4822 | 4490 | 5372 |
| Bakırköy | 1928 | 1630 | 1150 | 1332 | 1298 |
| Malatya | 5420 | 4872 | 5190 | 4958 | 5940 |
| Maraş | 5169 | 4333 | 5006 | 4724 | 5656 |

TABLE A.2 : AVERAGE WEIGHTS OF THE PRODUCT GROUPS

(gm / m)

| Product of | Average Weight |
|---|---|
| Nazilli | 125 |
| İzmir | 125 |
| Eskişehir | 135 |
| Antalya | 170 |
| Ereğli | 240 |
| Kayseri | 120 |
| Adana | 150 |
| Bakırköy | 375 |
| Malatya | 400 |
| Maraş | 410 |

TABLE A.3 : BUNTAŞ CO. TRANSPORTATİON COSTS (in 1980 TL/ton)

WAREHOUSE TO WAREHOUSE

| Warehouse / Warehouse | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Balıkesir | - | 1894 | 1928 | 2135 | 2225 |
| Bursa | 1894 | - | 1630 | 1486 | 2105 |
| İstanbul | 1928 | 1630 | - | 1332 | 1298 |
| İzmit | 2135 | 1486 | 1332 | - | 1712 |
| Tekirdağ | 2225 | 2105 | 1298 | 1712 | - |

# APPENDIX B

## WAREHOUSE EXPENSES

TABLE B.1 : RENT EXPENSES OF DISTRICT WAREHOUSES (yearly 1000 TL)

| Capacity Alternative | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| A | 60 | 144 | 180 | 144 | 120 |
| B | 300 | 720 | 1800 | 504 | 360 |
| C | 600 | 1440 | 3600 | 1440 | 720 |
| D | - | - | 5400 | - | - |

TABLE B.2 : PERSONNEL EXPENSES OF DISTRICT WAREHOUSES (yearly 1000 TL)

| Capacity Alternative | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| A | 145 | 145 | 145 | 145 | 145 |
| B | 726 | 726 | 872 | 581 | 581 |
| C | 872 | 872 | 1453 | 872 | 726 |
| D | - | - | 2179 | - | - |

TABLE B.3 : OTHER EXPENSES OF DISTRICT WAREHOUSES (yearly 1000 TL)

| Capacity Alternative | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| A | 160 | 160 | 160 | 160 | 150 |
| B | 400 | 400 | 750 | 300 | 250 |
| C | 750 | 750 | 1100 | 750 | 400 |
| D | - | - | 1235 | - | - |

# APPENDIX C

## WAREHOUSE STORAGE AREA

## MAXIMUM STORABLE AMOUNT
## OF COTTON TEXTILE

TABLE C.1 : WAREHOUSE STORAGE AREA ($m^2$)

| Capacity Alternative | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| A | 84 | 84 | 84 | 84 | 76 |
| B | 420 | 420 | 840 | 294 | 210 |
| C | 840 | 840 | 1680 | 840 | 420 |
| D | - | - | 2520 | - | - |

TABLE C.2 : MAXIMUM STORABLE AMOUNT OF CLOTH IN THE WAREHOUSES (1000m )

| Capacity Alternative | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| A | 403.2 | 403.2 | 403.2 | 403.2 | 365. |
| B | 2016. | 2016. | 4032. | 1411. | 1008. |
| C | 4032. | 4032. | 8064. | 4032. | 2016 |
| D | - | - | 12096. | - | - |

# APPENDIX D

PERCENTAGE DEMANDS OF DISTRICTS

STOCK TURN-OVER RATES OF PRODUCT GROUPS

TABLE D.1 : PERCENTAGE DEMANDS OF DISTRICT WAREHOUSES ALL OVER TURKEY (in year 1980 )

| Warehouse / Product of | Balıkesir | Bursa | İstanbul | İzmit | Tekirdağ |
|---|---|---|---|---|---|
| Nazilli | 3.78 | 2.77 | 25.97 | 4.27 | 2.63 |
| İzmir | 3.22 | 2.64 | 20.81 | 3.42 | 2.11 |
| Eskişehir | 3.85 | 3.32 | 19.37 | 3.19 | 1.96 |
| Antalya | 4.62 | 2.29 | 19.73 | 3.25 | 2.00 |
| Ereğli | 3.02 | 2.31 | 18.30 | 3.01 | 1.85 |
| Kayseri | 3.15 | 3.59 | 19.39 | 3.19 | 1.96 |
| Adana | 2.44 | 2.53 | 20.60 | 3.39 | 2.09 |
| Bakırköy | 1.85 | 2.07 | 18.81 | 3.10 | 1.90 |
| Malatya | 3.67 | 2.53 | 21.71 | 3.57 | 2.20 |
| Maraş | 4.28 | 2.07 | 20.56 | 3.38 | 2.08 |

TABLE D.2 : STOCK TURN-OVER RATES OF PRODUCT GROUPS ( $STR_i$ )

| Product of | Stock Turn-Over Rate |
|---|---|
| Nazilli | 4 |
| İzmir | 4 |
| Eskişehir | 4 |
| Antalya | 6 |
| Ereğli | 4 |
| Kayseri | 6 |
| Adana | 6 |
| Bakırköy | 3 |
| Malatya | 4 |
| Maraş | 4 |

# APPENDIX E

PRODUCT TYPES OF FACTORIES

Product Types Produced in Factory : Nazilli

203 Basma
204 Pijamalık Basma
206 " Pazen
207 Çamaşırl. Pazen
223 Fan. Pazen Ropluk
227 İnce Çamaşırlık
257 Çamaşirlık Pazen
261 Mer.Bahar Emprime
279 Pijamalık Pazen
280 Çamaşırlık Pazen

Product Types Produced in Factory : İzmir

201 Film Saten Emprime
202 Basma
238 Boğaziçi Emprime
239/215 Pike Emprime
249 Otoman Emprime
265 Merserize Çiçekli Emprime
269 Mini Emprime
270/216 Merserize Döşemelik
286 Ropluk Pazen
297/273 Flanel Emprime
380 Hasse

Product Types Produced in Factory : Antalya

2063 İpekli Boy Pijama

Product Types Produced in Factory : Eskişehir

205 Basma
232 Merserize Basma
283 Kreton Emprime
284 Kreton Emprime
290 Jet Poplin Emprime
293 Divitin
722 Jet Saten Döşemelik

Product Types Produced in Factory : Ereğli

370 Geniş Hasse
372 Dar Hasse
378 Mermerşahi

Product Types Produced in Factory : Kayseri

101 Kaput Bezi
110 Kaput Bezi
119 Kaput Bezi
351 Renkli Patiska
383 Düz Pazen
416 Diyagonal
603 Kozalina
604 Lüks Dril

Product Types Produced in Factory : Adana

134 Ham Bez
151 Ham Bez

Product Types Produced in Factory : Malatya

135 Ham Bez
627 Jakardrel
628 Yollu Kutil
629 Yollu Çiçekli Kutil
973 Goblen

Product Types Produced in Factory : Maraş

318 Lüks Hasse