A DECISION - SUPPORT SYSTEM FOR DISTRIBUTION SYSTEM DESIGN

by

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A DECISION-SUPPORT SYSTEM FOR DISTRIBUTION SYSTEM DESIGN

The developed model can have two or three effectiveness criteria, according to the manager's choice :

(a) the total distribution cost and ;

(b) the realised sales level ;

or ;

(a) the total distribution cost ;

(b) the realised sales level and ;

(c) the delivery times .

The model provides six devices to the manager who wants to improve the current distribution system :

(a) to improve without changing the current system - i.e the present warehouse and vehicle numbers and capacities remain unchanged-

(b) to change the current warehouse capacities, rearranging them;

(c) to decide on additional warehouses as well as rearranging the current ones ;

(d) to buy or hire new vehicles ;

(e) to use the vehicle policy together with the rearrangement of the current warehouse capacities ;

(f) to choose additional warehouses and decide on vehicle policy

The manager who chooses one of those alternatives must give the data about the current situation and the alternative he mentioned. Besides he must determine an investigation period (week/month/year).

After the data step, first, the manager will be given a report according to averages, in order to make him able to take appropriate decisions. In this report are mentioned the total distribution cost of the current system - warehouse investment and operating cost, transportation investment and operating cost, inventory holding and shortage cost-, the distribution cost per sale and, if the manager is interested the delivery times composed of loading, unloading, waiting times and time spent in road. The manager may analyse the components of the total distribution costs separately.

The next step of the model is the analysis of chosen alternative. This analysis is composed of three parts. First, with the Vogel approach, the appropriate transportation cost from factory and warehouses to consumers is fulfilled. Next, the simulation may be executed. The simulation illustrates the influences of the demand and production fluctuation on shortage , inventory level and lost sales, by building a dynamic relationship between the periods. In the third and last part, a report similar to that of the current situation is prepared and the manager is asked if his last trial is the best analysed till then. In this step, the manager must decide not only paying attention to the reported costs but also to the results of the simulation and besides, to the delivery times, if chosen as an effectiveness criteria. When the manager gives an affirmative answer, this trial is kept as " best ".

Continuing by this way, the manager may improve the current system, in the direction he wants, by trying the same alternative with different data or applying different alternatives.

DAĞITIM PROBLEMİ İÇİN BİR KARAR-DESTEK SİSTEMİ

Geliştirilen model karar vericinin isteğine göre iki ya da üç etkinlik ölçütüne sahip olabilir. Bunlar;

(a) toplam dağıtım maliyeti ve ;

(b) gerçekleşen satış miktarları

veya ;

(a) toplam dağıtım maliyeti ;

(b) gerçekleşen satış miktarları ve ;

(c) iletim zamanları

şeklinde sıralanabilir.

Model, yürürlükte olan dağıtım sistemini iyileştirmeyi arzu eden karar vericiye, iyileştirmeyi hangi yönde yapmak istediğini belirlemesi amacı ile altı alternatif sunmaktadır. Bu seçenekler :

(a) yürürlükteki sistemi-yani mevcut depo ve taşıt sayıları ile kapasitelerini-değiştirmeden iyileştirmek ;

(b) eski depoların kapasitelerini yeniden düzenlemek ;

(c) ek depo yer ve kapasiteleri ve istenirse aynı anda eski depo kapasitelerini yeniden düzenlemek,

(d) yeni taşıtlar satın almak veya kiralamak ;

(e) taşıt politikasını mevcut depo kapasite, yer ve sayılarını iyileştirme politikası ile birlikte yürütmek ;

(f) ek depo yer ve kapasitelerini belirlemek + (e) ;

Bu seçeneklerden birini seçen karar verici , yürürlükteki durum ve gerçekleştirmeyi tasarladığı değişiklikler ile ilgili verileri bilgisayara vermeli, ayrıca bir inceleme dönemi (hafta/ay/yıl) saptamalıdır.

Veri girişinden sonra , öncelikle yöneticiye yürürlükteki durumu inceleyip daha iyi kararlar alabilmesi için ortalama talep ve üretim değerlerine göre bir rapor sunulur. Bu raporda, yürürlükteki sistemin toplam dağıtım maliyeti-depo yatırım, işletme maliyetleri, ulaşım yatırım ve işletme maliyetleri, elde tutma ve yok satma maliyetlerinin toplamı-, birim satış başına düşen miktar ve eğer yöneticinin ilgi alanı ise, fabrikadan depolara, fabrika ve depodan kendi tüketim merkezlerine ve diğer tüketim merkezlerine toplam iletim zamanları-yükleme, boşaltma, bekleme ve yolda geçen zaman-ortaya konmaktadır. Yönetici isterse, toplam dağıtım maliyetinin bölümlerini, yukarda belirtildiği gibi, ayrı ayrı inceleyebilir.

Modelin bundan sonraki aşaması, seçenek deneme aşamasıdır. Karar vericinin gerçekleştirmeyi tasarladığı değişikliğin incelenmesi, üç aşamada olmaktadır. Önce, Vogel yaklaşımı ile fabrika ve depolardan müşterilere, mümkün en ucuz taşıma maliyeti ile taşıma sağlanmakta, sonra eğer yönetici isterse, simulasyona girilmektedir. Simulasyon talep ve-söz konusu ise-üretimdeki dalgalanmaların yok satma, elde tutma ve satış kaybı üzerine etkilerini, simulasyon dönemleri arasında dinamik bir ilişki kurarak ortaya koymakta ve yöneticinin bu sorunu çözmesine yardımcı olmaktadır. Üçüncü ve son aşamada ise, yürürlükteki durum raporuna benzer bir rapor hazırlanır ve yöneticiden, son denemesinin şu ana kadar incelediklerinin en iyisi olup olmadığı sorulur. Bu aşamada karar verici yalnız rapor yoluyla saptadığı maliyet değerlerine değil ama aynı zamanda simulasyonda incelediği yok satma, elde tutma ve satış kayıplarına, ayrıca, eğer etkinlik ölçütü olarak seçmişse, iletim zamanlarına da önem vererek bir sonuca varmalıdır. Yöneticinin olumlu cevap vermesi halinde, bu denemesi " en iyi " olarak saklanır.

Yönetici, bu şekilde, aynı seçeneği değişik verilerle veya başka seçenekler denemek sureti ile, etkinlik ölçütü olarak belirlediği alanlarda iyileştirme yapabilecek ve böylece yürürlükteki sistemi, kendi istediği yönde geliştirebilecektir.

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I. THE DISTRIBUTION PROBLEM

1.1 Definition

The distribution problem of a manufacturing firm can be handled in two aspects ;

(a) Selection of the distribution channel ;

(b) Design of physical distribution.

The channel selection is the selection and organization of institutions through which the product-service flow is made available to the market. The concept of marketing channels is decision-oriented since the channel's function cannot be achieved without some strategy.

The transfer of goods between institutions is necessary to keep the interaction of the channel members at a logical level. This movement of goods is called "physical distribution " and realises a key relation between production and marketing.

In this thesis, it is assumed that a classical distribution channel-i.e factory-wholesaler-retailer-consumer or factory-warehouse-wholesaler-retailer-is already selected by the firm under consideration and the aim is to help the manager of that firm in the improvement of the physical distribution system.

A physical distribution system consists of three basic components:

(a) Facility location structure;

(b) Transportation ;

(c) Inventory.

With respect to total performance in a physical distribution system, almost any level of service can be obtained if an enterprise is willing to pay the price ; for example, a full-line inventory could be situated in close geographical proximity to all major customers. A fleet of trucks could be held in a constant state of delivery readiness. Under these situations, a customer's order could be delivered within a few minutes but such extreme performance is neither practical nor necessary to support most marketing and manufacturing systems. A typical enterprise will find that the physical distribution system, balancing reasonable performance level and realistic cost expenditure must be preferred. Very seldom will either the lowest total cost or the highest service performance system constitutes the best logistical goal.

1.2 Basic Functions of the Distribution System

1.2.1. Facility Location Structure

In this study, only the warehouse location problem is analysed. The purpose of the warehouse is to consolidate purchases from distant procurement points and replenish inventory to retail outlets. The warehouses represent one part of a firm's effort to gain time and place utility . A warehouse exists if it can provide service or cost advantages in a given market. The nature of this problem is influenced by several important variables including customer's buying patterns and delivery expectations, freight rate structure, warehouse operating cost, location and production capacities of factories and cost of building or renting suitable warehouses in different cities. The decision to lease or buy warehousing facilities involves basically a financial problem. Leasing can greatly reduce the cost of capital for a firm but it is not always easy to find facilities when and where the firms want them. In fact, leasing warehouses may place a greater burden on transportation if effective location cannot be obtained and much of the advantages of leasing the warehouse may be offset by increased transportation and handling cost.

1.2.2. Transportation

Transportation links geographically dispersed manufacturing, warehousing and market locations into an integrated system.

The five basic transportation modes are rail, highway, water, pipeline and air.

At the beginning of this study , the highway is compared with rail in order to make a selection between them. The conclusion is that motor carriers have relatively small investment in terminal facilities and owned right-of-way. The variable cost per ton-km of motor carrier is high because of the requirement that a separate power unit be operated for each trailer and because of the relatively much more limited capacity of trailer. The net result is a structure of low fixed cost coupled with high variable cost. On the other hand, with respect to railroads, motor carriers are more economically adapted to handling smaller shipments moving shorter distances. Because of the flexibility of store-door delivery, motor carriers have captured almost all freight moving in the distributive industries from wholesalers or warehouses to retailstores. Therefore in this study, only the highway mode, composed of trailers and trucks, is taken into consideration and it is expected that a manager can have three alternatives in establishing transportation capability. First, a private fleet of equipment may be purchased. Second, the manager may engage the services of any legally authorized transport company that offers point-to-point transfer at specified charges or third he can combine the first and the second alternatives.

Leasing has the general advantage that the charge is known in advance and the cost does not vary in the short run. It has the further advantage of shifting many headaches of operation such as maintenance, scheduling. A large proportion of small orders can be handled more economically by leasing vehicles.

1.2.3. Inventory

One of the main functions of inventory is to provide safety stock protection against uncertainty. In this study uncertainty concerns the fluctuations in rate of sales which are assumed to be normally distributed.

It is important to realize that the size of safety stocks increases as higher and higher levels of stockout protection are desired. At lower levels of desired protection a substantial degree of protection is enjoyed with relatively low investment in safety stocks. As the desired level of protection increases, the size of investment necessary to gain each increment of added protection increases.

In the developed program, as will be explained in detail in chapter IV, the necessary safety stock that must be maintained in warehouses and/or plant can be found by the manager with respect to the results of a dynamic simulation.

1.3. Relationships Between Basic Functions

1.3.1. Transportation Versus Warehouse Costs

The total transportation cost will decrease warehouses are added to the logistical network. The reduction in transport cost results from consolidated volume shipments to warehouses coupled with short-haul small shipments from warehouse locations to customers. If facilities are added beyond the optimum number of warehouses, total cost will increase. The main reason for the cost increase is that the quantity of consolidated volume shipments to each warehouse decreases, which results in a higher rate per hundred-weight. In other words , the frequency of small shipments inbound to warehouses increases finally as more and more warehoses are added to the network, the benefit of consolidated shipments is diminished and total transportation cost increases at an increasing rate.

1.3.2. Inventory Versus Warehouse Costs

The addition of locations to the logistical system impacts safety stock requirements in two ways. First, reducing the duration of the perfor mance cycle relieves the need for safety stocks. The second and more serious influence is that the addition of each new warehouse creates the need for an additional safety stock.This increase results from an inability to aggregate sales across the larger market area. As a consequence, separate safety stocks must be established for each market which takes into consid tion the total impact of local variation in demand.

1.4 Service Level-Cost Level Relationships

The performance measurement of service level suggested in this study is based upon capability and lost sales. Lost sales, as will be explained in chapter IV, are taken into consideration by means of a dynamic simulation. The capability is taken as a measure of total elapsed time from transmittal to all customers.

With respect to the importance the manager attaches to the service level and cost level, different results may be obtained. For example, if the manager thinks that his firm's most important burden is high cost level and tries to achieve lowest total cost, then the service capability will be a function of that least-cost system design. On the other hand if he is indifferent on a cost basis as to which warehouse services the customers, then, from the customer's viewpoint, a reduction can result in terms of delivery time. However, as this maximum service level strategy is rarely found in reality , in this study it is not analysed without cost reduction strategy.

While the incremental service resulting from additional locations is a diminishing function, the incremental cost associated with each location is an increasing function. Besides, additional service may or may not result from increasing the number of warehouses. If the manager tries to elevate the quality of transportation in order to increase the performance level, the transportation cost curve will be shifted up to reflect higher per shipment expenditure. Another direct way to vary service level is to increase or decrease the amount of safety stock held at one or more warehouse facilities. The impact of increasing the safety stock levels provides a substantial degree of performance ; as the desired performance is increased, the safety stocks required to achieve each equal increment of performance increase at an increasing rate.

Establishment of service standards constitutes a critical managerial policy. Management often falls into the trap of being overly optimistic in their service policies. The result may be excessively high costs followed by erratic performance. Alternative shipment size, type of shipment, inventory level and range of facility locations must be systematically taken into consideration to decide on an acceptable service level and its associated cost.[(1)x]

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[x]Numbers enclosed in brackets refer to the references in the bibliography.

II. REVIEW OF THE LITERATURE

2.1 Background of the Problem

The general approach to the physical distribution problem has been to treat the problem as a multistage decision process in which the parameters are optimized in sequence, each time assuming that the other parameters remain constant. Because of the complexities arising from the interrelations of the problems, it has often been found necessary to make some simplifying assumptions in the structure of the model that sometimes simplifies out the reality.

In this study, some of the model applications based on analytic, heuristic and simulation techniques are reviewed and analysed in order to underline the weaknesses mentioned above.

2.1.1. Baumol and Wolfe's Transportation Algorithm

Baumol and Wolfe(2) describe a case study in some detail. The cost function they use is the sum of the transportation costs from the factory to depots and from depots to customers. Also included are depot operating costs composed of fixed costs, which do not apply if the depot is not used and of the variable costs depending on the throughput of the depot. Their procedure is to build a matrix of transportation costs from the factory to each customer through that depot that gives the cheapest costs and then solve the resulting transportation problem. In the first calculation this matrix includes only the pure transportation costs. In subsequent iterations, the matrix of costs is built up of transport cost plus the marginal depot operating costs. These transportation problems are constructed and solved until the throughput of the depots does not change from one iteration to the next.

The developed model is a static, single product model. Only the transportation and warehouse costs are handled and the delivery times are not incorporated. It is decided that half of the throughput of the depot will be held for inventory control. In other words, the demands are taken deterministic and the accurate inventory level is not found by means of the algorithm but is dictated. Because of the constant nature of the demands , a stockout probability is not even mentioned, therefore the customer service level is assumed optimal which is most probably unrealistic.

2.1.2. Efroymson and Ray's Mixed-Integer Algorithm

The objective of the model developed as a simple warehouse location, single product model, is minimisation of costs which are fixed set up and distribution costs[3]. Potential locations are limited to particular sites in the feasible set. The unit distribution and handling costs are assumed to be linear.

Efroymson and Ray assert that at any node in the branch-and-bound tree, three sets can be identified;

K_o-includes all the sites at which no depots are located ;

K_1- includes all the sites at which depots are located ;

K_2- includes the "free" sites for which a decision to locate depots has not been made.

Their method is to consider customer j and scan every depot in set K_1 and K_2 and assign the customer to that depot with

$$\min_{i \in K_1 \cup K_2} [C_{ij} + g_i / n_i] \qquad (1)$$

Where C_{ij} is the cost of supplying a unit to customer j ($j = 1$ --n) from depot i ($i = 1$ -- m). This term may also include the unit operating cost of depot i. N_i is the number customers supplied from depot i

$$g_i = \begin{cases} \text{fixed cost of depot } i & \text{for } i \in K_2 \\ 0 & \text{for } i \in K_1 \end{cases}$$

The depot selected in this way is used to supply the total demand of customer j.

The developed model is not time scaled and ignores the origin of the commodity ; in other words, the cost of supplying a unit from plant to depot as well as the direct transportation from plant to customer are not considered. Besides, it takes the capacity of warehouses as unlimited and the demands as deterministic, therefore the inventory level problem is not analysed.

Experience with the algorithm shows that for practical problems, the computation times and storage requirements are high although it does not permit the handling of delivery times and the accurate type, size and number of vehicles are not analysed.

2.1.3. Geoffrion and Graves Multicommodity Distribution System Design

The benefit of decomposition is that it permits multiple commodities to be incorporated into system design. Most firms have a variety of products which are purchased in varied assortments and quantities by customers. While such products may be shipped and stored together, they are not interchangeable from the viewpoint of servicing customer requirements.

To handle this realistic requirement, the decomposition technique provides a procedure for dividing the multicommodity situation into a series of single commodity problems. The procedure for arriving at commodity assignment follows an iterative process wherein costs associated with each commodity are tested for convergence until a minimum cost or optimum solution is identified.

Geoffrion and Graves'[4] procedure, for arriving at a system design, follows a two-stage iterative process. First, given the location structure, individual commodities are optimally assigned to minimize cost. This aspect of the design procedure is similar to the basic transportation solution, however, it is formatted on a multiproduct basis using the decomposition technique. Second, a mixed integer algorithm is utilized to enumerate the facility structure in terms of individual commodity customer assignments. The combined solution is tested for optimality and the two step procedure is repeated until convergence is within accepted tolerance.

The aim is to meet the given demands at minimum total distribution cost subject to the plant capacity and distribution center throughput constraints. Another feature of the model is that each customer's demand must be satisfied by a single distribution center or directly from the plant. A customer service constraint can be added to satisfy the desired bound on the average delivery delay for commodity i.

The problem is of static nature. As in all of the above mentioned algorithms, it assumes that there is no need to examine the entire distribution system, but only transportation and warehousing factors. Thus the problem is a capacitated depot location problem for deterministic demand and tries to determine which distribution center to have at each selected site, what customer zone should be served by each distribution center and what the pattern of transportation flow should be for all commodities. The inventory level, the accurate type, size and number of vehicles are again beyond the scope of the model. Therefore, similar to the others, the optimality feature of the technique is relative, being only as valid as the design problem formatting.

2.1.4. Klein and Klimpel's Non Linear, Dynamic Model

Klein and Klimpel[5] are concerned with developing an algorithm to solve the problem of determining the location and size of a depot over a planning horizon. They incorporate economies of scale inherent in depot size. They suggest polynomial expressions for fixed capital requirements, annual working capital, fixed and variable annual costs. Given forecasts of demands and of the costs of known site, the objective function is the sum of the net present values for all depot locations and this is the function to be maximized, subject to the constraint of satisfying demand and to non negativity constraints for depot sizes and for shipment sizes.

Despite of its superiority to all the above mentioned models, this model is again able to solve only the site selection problem without trying to integrate the basic functions of the distribution problem. On the other hand, the method can converge to a solution which may be a local optimum, because of the non-linearity of the objective function, so that several runs may be necessary with different initial feasible solutions which will require high computation time.

2.1.5. Kuehn and Hamburger's Heuristic Algorithm.

The heuristic program proposed by Kuehn and Hamburger[6] consists of two parts :

(a) The main program : It locates warehouses producing the greatest cost of saving for the entire system one at a time, until no additional warehouses can be added to the network without increasing total cost.

(b) The bump and shift routine : when the list of potential sites is exhausted, the program enters the second stage, called the bump and shift routine. This routine eliminates any depots which are now uneconomical because of the proximity of other depots ("bump"), it also attempts to make further saving by relocating each depot at other sites in its neighbourhood ("shift").

The add approach , as remarked by Feldman, Lehrer and Ray[7] has an initial rapid drive to achieve feasibility but may not be the best route to the optimum. Besides, rarely is the distributor interested in designing a network from the ground up, but most probably wants to improve his current distribution system.

The warehousing costs handled are composed of a fixed and variable cost which increases linearly with the throughput of the warehouse. This representation of warehousing cost has the computational advantage but is not satisfactory for those problems where the economies of scale affect warehousing cost over the ranges of warehouse sizes. On the other hand, the unlimited capacity assumption is unrealistic.

The procedure is not able to handle the functional relationship between size of safety stock and the number and size of warehouses and it does not analyse a variety of vehicle size. The effect of shipping delays is only mentioned by opportunity costs.

2.1.6. Shycon and Maffei's Simulation Model

Shycon and Maffei (8) do not outline a computational method for determining the sets of warehouse sites to be evaluated. Their approach requires that management specify the warehouse systems (number and locations) to be evaluated. Given the design objective the simulation deletes warehouse locations one at a time from the maximum to a managerially specified minimum or until only one facility remains in the system. To save computer storage space they locate factories, warehouses and customers in terms of longitude and latitude and subsequently approximate shipping costs between all of the points in terms of the computed air miles. The use of air mile distances as approximations for shipping costs is an interesting approach to the problem and should be studied in more detail to determine the magnitude of error likely to result in cost data generated in this manner. If the error is within acceptable limits, it affords a means of reducing the time required in collecting and analysing the cost data.

In its most detailed application, a simulation approach to the problem would permit the processing of actual customer orders through the alternative warehouse distribution system being analysed and imputing costs to the various phases of the operation. This approach would permit incorporation of the dynamic elements of warehousing and inventory cost, but the Sycon and Maffei approach does not simulate the distribution system in that degree of detail but rather estimates warehousing and inventory costs as functions of the total volume of each product routed through any given warehouse. Because of its static nature, the model seeks to incorporate time relationships critical to logistical planning situation. Its primary purpose is to quantify the total cost and threshold customer service according to actual deterministic customer order. The threshold customer service is the customer service which results from the least-total-cost system and is opposite to the mentality of system design studies.

While relatively easy and inexpensive to use, the delete location algorithm used to select location configuration does not offer exact analysis of all available facility locations , because once deleted, a warehouse cannot reenter the system at a further iteration.

2.1.7. Eilon, Watson and Cristofides' Vehicle Fleet Size Algorithm

The objective of the algorithm developed by Eilon, Watson and Cristofides[9] is to determine the size of the company owned vehicle fleet (N) such that the total of fixed and variable costs corresponding to hired and owned vehicle, over the cycle, is minimized.

They consider a period i in which V_{i1} is the smallest number of vehicles with which customer demands can be met, corresponding to a total mileage D_{i1} and V_{i2} is the number of vehicles required to achieve the shortest total corresponding distance, denoted by D_{i2}. Having calculated the minimum number of vehicles for each period, another algorithm is applied to determine the shortest routes and the corresponding vehicle number. The next stage of solution is to find the optimal fleet size N. This value must range between an upper limit of $\max_i V_{i2}$ (i.e. the largest possible number of vehicles that may have to be used in any one period) and a lower bound of $\min_i V_{i1}$ (i.e. the smallest possible number of vehicles that can supply at least one period.) The procedure to find the optimal value of N is to start with the upper bound (namely put $N = \max_i V_{i2}$) calculate the corresponding cost C, and repeat for new values of N, reducing it by one vehicle at a time, until the minimum cost is found or alternatively until the lower bound is reached (namely $N = \min_i V_{i1}$) If $N < V_{i1}$ for any i then the company fleet is not sufficient to supply the customers, and vehicles must be hired. The smallest possible number is $V_{i1} - N$ and the largest possible number that must be investigated is $V_{i2} - N$ therefore, calculating and comparing the costs for alternative number of hired vehicles, between the limits mentioned above, the accurate number of hired vehicle leading to minimum cost can be found.

The developed algorithm is again static of nature, because even if several periods are analysed , they are independent of each other. The customers demands are assumed to be known for each period in the cycles and remain unchanged from cycle to cycle. On the other hand the number, capacity and location of warehouses as well as the type and size of the vehicle are given as input data at the beginning and stock out and inventory level problems are not analysed.

2.2 Current State of the Art

As the examination of the literature indicates, in general one or two approaches have been taken so far. Authors have either adopted a simple cost formulation and developed a complex optimization procedure or tried to solve a more complex cost model with an heuristic or simulation approach but all have taken into consideration only a specified part of the problem and a system approach is not realized and the basic focus of these approches have been warehouse operation and transportation costs. However, the most important cost on which improvement must be made is the total cost of performing the physical distribution activity and not the separate cost of the individual segments and the aim must be to find a reasonable cost level to procure a desired level of service and not to find the least-cost design leading to a threshold service level. Continued attention to individual parts of the problem develops increased efficiency in isolated segment but such increased efficiency may decrease the effectiveness of the overall operation.

On the other hand , one of the fundamental assumptions made in most of the developed algorithms is that the demands are static. Clearly such an assumption does not always apply in practice. An increase or decrease in customer demand generally will influence the inventory level. The greater the vagaries in demand, then naturally the higher will be the safety stock requirement. Directly linked with this is, of course, the service policy of the firm. The higher the service level demanded then the greater will be the safety stocks needed to meet the policy. Therefore the static demand assumption can lead to lost sales and can affect the dominating position of a firm.

Another critical aspect of the above mentioned models is that they all try to impose a solution to the manager without permitting him to collaborate and to choose the solution which is most appropriate to his firm.

III. A DECISION SUPPORT SYSTEM FOR DISTRIBUTION

3.1 Logic of the System

In order to develop an interactive computer program destinated to solve the general physical distribution problem of the firms, in collaboration with the manager, first it has been tried to determine the most crucial issues of the physical distribution systems, making contacts with five firms. Those firms are a distribution firm, a hygienic items firm, a vegetable oil factory, a beverage firm and an electrical instruments manufacturing company. The managers of all these firms have indicated that since top management is ordinarily concerned with major functions such as sales, production and finance, minor subfunctions such as inventory control, warehousing, shipping are left to specialists. Specialists tend to establish their own standards and managerial controls are exercised around the self-imposed standards. There is little try for the integration of interrelated minor functions.

Until all distribution activities are interrelated and until all distribution costs are considered, the potential for improved efficiency and cost reduction cannot be realized. Besides, it is considered that all of the managers don't understand the mathematics involved in the optimizing models developed by the specialists and this makes them distrust the model. The real-life situations are too complex to be easily handled by the techniques and they normally have to be simplified in the models. On the other hand , without the cooperation of the management, the quantitative specialist finds it difficult to correctly analyse the situation and without gaining manager's understanding and acceptance, the model cannot be used. Another reason for the lack of acceptance is that the type of model which is most desirable by the manager is not necessarily an optimisation model.

The developed system tries to take into consideration the problems mentioned above. In contrast to many others that can be found in the literature, it does not dictate an optimal physical distribution system but leads the manager to analyse his own decisions for realising better solutions. Using his experience as well as getting hints from the program, the manager will be able to improve the current system.

The basic philosophy of the program is that the physical distribution problem is not a single problem, but a combination of interrelated problems which concerns the determination of:

(a) the number of warehouses ;
(b) the location of the sites for these warehouses ;
(c) the allocation of customers to these warehouses ;
(d) the size of the warehouses ;
(e) the necessary number of vehicles ;
(f) the appropriate vehicle sizes ;
(g) the adequate inventory levels ;
(h) the adequate delivery times and service levels.

The main idea is that there exists no ideal logistical system suitable to the needs of all enterprises ; therefore the manager must have a clear understanding of the strengths and weaknesses of his logistical network. In particular, the review must be directed at an evaluation of the existing system's capabilities and deficiencies and at the identification of areas where a substantial opportunity for improvement exists. The developed program tries to realize it by giving the manager a report of this current physical distribution situation. Once the manager has accomplished the review of the current system , using again the interactive program, he can pretest alternative distribution policies and get related results for each of them. During his analysis, he may carry out calculations to evaluate a line of ideas and then discarding it, try another. Based on these analysis he may conceive of another thought, leading to a solution which was not amongst his initial alternatives. The analysis must be a step-by-step process. As the studies proceed, they will indicate potentially useful modification in the distribution system. For example, if the market is dispersed and demand fluctuates then certain functions will be brought into existence. Inventory should be held to act as a buffer for the fluctuations in demand so that the predetermined service level can be met. Because of the dispersion, stock will be held in warehouses to facilitate distribution to the individual markets. Both the location of the warehouses and the level of inventory will be affected by the time factor which in its turn depends on the efficiency of the transport operation. Therefore the manager will test the effect of alternative number of warehouses, changed locations, different number of vehicles and different response time, as a whole and not as subproblems. Testing and eliminating alternatives, the manager can reach a distribution system, most probably not optimal but more suitable than the current system.

3.2 Comparison with other Approaches

In order to underline the special feature of the developed program, it is tried to compare the basic characteristics of that program with those of the other approaches mentioned in chapter II.

The comparison is made about the effectiveness criteria, starting point, period of analysis, time structure, demand structure, production structure, warehouse capacity, warehousing cost, inventory level, shortages, lost sales, transportation cost, accurate vehicle type, size and number, delivery times, number of product and solution approach. The results are given in table 3.1.

Compared approaches are Baumol and Wolfe transportation algorithm, Efroymson and Ray's mixed - integer algorithm, Geoffrion and Graves' multicommodity distribution system design, Klein and Klimpel's non-linear, dynamic model Kuehn and Hamburger's heuristic algorithm, Shycon and Maffei's Simulation Mode Eilon, Watson and Cristofides' vehicle fleet size algorithm and the developed program.

In table 3.1, the abbreviations used are : min. : minimum, max. : maximum, distri : distribution, var. : variable, opt. : optimum, sol: solution, algo. : algorithm, serv. : service, constr. : constraint, aver. : average.

Table 3.1 Comparison with other Approaches

	Baumol and Wolfe	Effraymson and Ray	Geoffrion and Graves	Klein and Klimpel	Kuehn and Hamburger	Shycon and Maffei	Eilon Et. al.	Developed Approach
Efficiency Criteria	Min. warehousing and transportation costs	Min. warehousing and transportation costs	Min. warehousing and transportation costs	Max. sum of net present values for all depot locations	Min. warehouse and transportation costs	Min. warehousing and transportation (+) treshold customer service level	Optimal fleet size to minimize fixed and var. costs of hired and owned vehicles.	Reasonable total distri. costs (+) reasonable sales level (+) reasonable delivery times (if desired)
Starting point	From the ground up	From the ground up	with initial sol. or from the ground up	From the ground up	From the ground up	From the ground up	From the ground up	with initial sol. or from the ground up
period of analysis	chosen by the manager	chosen by the manager	year	year	year	year	chosen by the manager	chosen by the manager
Time structure	static	static	static	dynamic	static	static	static	static (+) dynamic
Demand structure	deterministic	deterministic	deterministic	deterministic	deterministic	deterministic	deterministic	deter. probabilistic
product. struct.	deterministic	deterministic	deterministic	deterministic	deterministic	deterministic	deterministic	deter. (+) probab.
warehou. capacity	limited	un limited	limited	limited	un limited	un limited	limited	limited
warehousing cost	fixed (+) concave cost	fixed (+) linear cost with respect to thro through-put or concave with no fixed cost	fixed (+) linear cost with respect to through put (a piecewise lin. rep. can be realized)	polynomial exp. for fixed capital requirement and var. annual cost	fixed and semi variable cost depending on the throughput	Not specified	Not considered	piecewise linear representation can be realized

Table 3.1 (Continue)

	Baumol and Wolfe	Effraymson and Ray	Geoffrion and Graves	Klein and Klimpel	Kuehn and Hamburger	Shycon and Maffei	Eilon Et al.	Developed Approach
Inventory level	given as a funct. of warehouse throughput	Not considered	Not considered	Not considered	given as a funct. of warehouse throughput	given as a funct. of warehouse throughput	Not considered	specified by the manager analysing simulation
shortage	Not considered	Not considered	Not considered	Not considered	Not considered	Not considered	Not considered	analysed by means of simu.
lost sales	Not considered	Not considered	Not considered	Not considered	Not considered	Not considered	Not considered	given by manager
transportation cost	linear var. depending on the amount shipped	linear var. depending on the amount shipped	linear var. depending on the amount shipped	polynomial expression for fixed and var.annual cost	proportional to the railroad distance between shipping points	Air-mile distances used as approximations	fixed cost and distance (mile)dependent var.cost	fixed cost and ton-km dependent var. cost
Appropriate vehicle type	Not analysed	Not analysed	Not analysed	Not analysed	Not analysed	Not analysed	given as input	can be analysed
Appro. vehicle size	"	"	"	"	"	"	"	"
Appro. veh. number	"	"	"	"	"	"	Analysed	"
Delivery times	"	"	can be taken as a customer serv. constr. with a bound on the aver. delivery delay for commodity i	"	taken into consideration, by putting opportunity cost associated with shipping delays	"	desired to be within the period chosen	can be analysed and specified by the manager
Number of product	single product	single product	Multi product	Single product	Single product	Multi product	Single product	Single product
Solution approach	an opt. sol. is dictated by the algorithm	an opt. sol. is dictated by the algo.	an opt. sol. is dictated by the algo.	an opt. sol. is dictated by the algo.	a near opt. sol is dictated	a near opt. sol is dictated	a near opt. sol is dictated	the manager choses an appro riate sol.

IV. USING THE SYSTEM

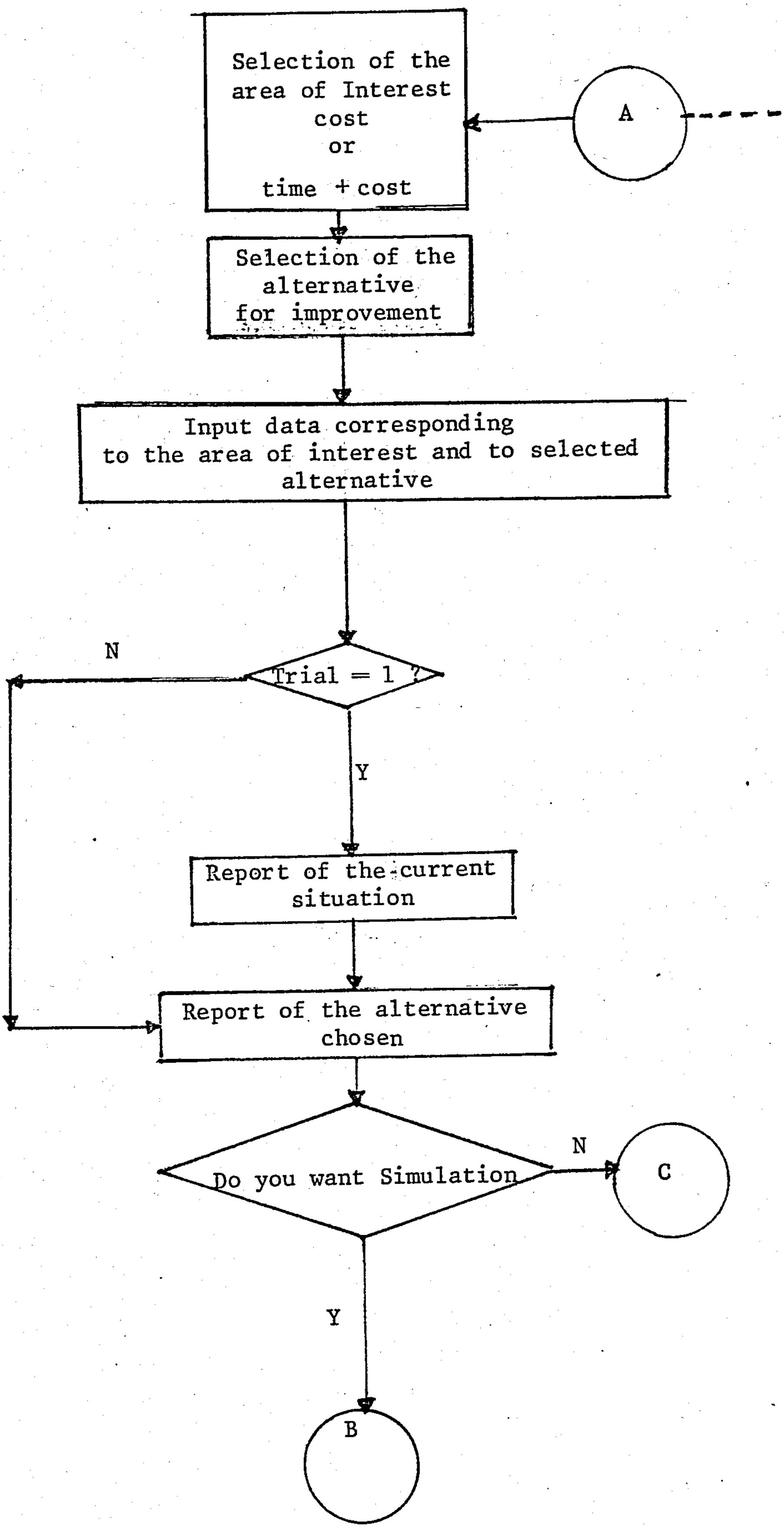
4.1 Flow Chart of the Program

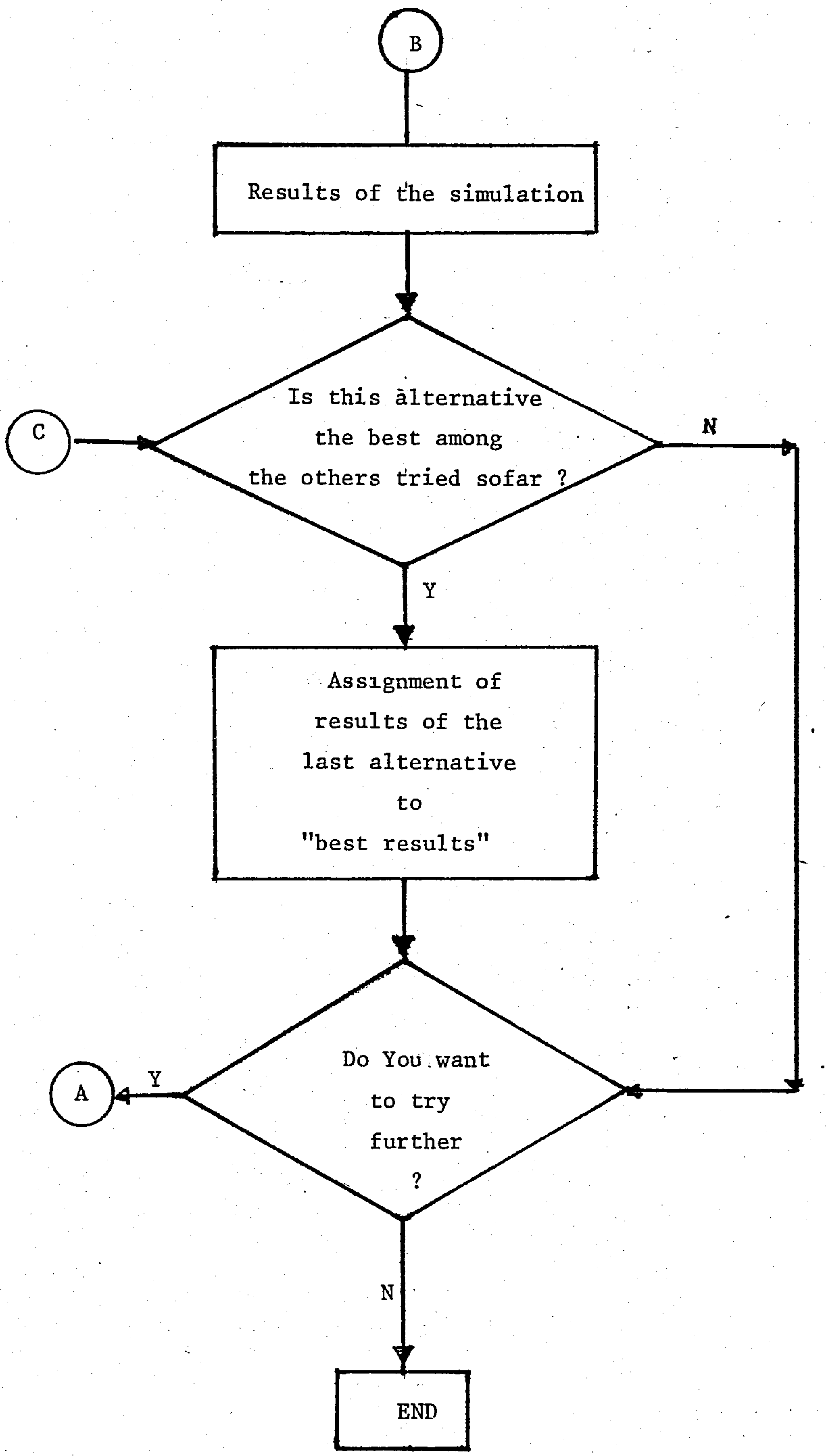
The program includes three parts. In the first part, the manager is asked about the area-cost or time + cost - where he wishes to make improvement and his selection among the alternatives offered to him in order to realize this improvement. Based on this selected alternative, he will be interrogated on the corresponding data about the current situation of his firm and about his chosen alternative.

On the second step of the program, a report of the current distribution system is prepared, according to the average production and demands, in order to let the manager step back and reevaluate its traditional organizational arrangement.

On the third step, the chosen alternative is analysed and if it is required by the manager the effect of the deviation from the average demand and-if it is probabilistic-from the average production, on inventory levels shortages and lost sales is mentioned by means of a simulation routine. Further, as in the current situation, a report is again prepared with the corresponding average values. If the results are the best obtained so far, they are kept in a " best results " file.

The summary flow-chart of the program can be illustrated as follows:


Selection of the area of Interest cost or time + cost
A
Selection of the alternative for improvement
Input data corresponding to the area of interest and to selected alternative
N
Trial = 1 ?
Y
Report of the current situation
Report of the alternative chosen
Do you want Simulation
N
C
Y
B


B
Results of the simulation
Is this alternative
the best among
the others tried sofar ?
C
N
Y
Assignment of
results of the
last alternative
to
"best results"
Do You want
to try
further
?
A
Y
N
END

A detailed flow-chart of the program is given in appendice A.

4.2 User's Manual

4.2.1. Analysis of the Data

To analyse his decisions, the manager can choose three types of time interval-year, month, week-but he has to give the data accordingly.

The alternatives proposed to the manager in order to improve the distribution system can be stated as follows :

1. To Improve the Current Situation Pattern
   With this alternative, taking the problem as a location-allocation problem and without changing the present warehouse capacities and/or number of vehicles etc, possibility of a better distribution pattern is analysed.

2. To Try New Decisions

   a. New Decisions about Warehouses ;

      (1) The rearrangement of the present warehouse capacities and improvement on the distribution pattern .

      (2) The selection of additional warehouse locations, rearrangement of the additional and current warehouse capacities and improvement on the distribution pattern at the same time.

   b. New Decisions about Vehicles ;

      With this alternative, the manager can decide to buy and/or hire new trailers or trucks in addition to the existing ones. In order to satisfy customers demand , three categories of transportation is assumed possible :

      - from plant to warehouses
      - from plant and warehouses to distant consumers
      - from plant and warehouses to local consumers.

      Therefore decisions about buying or hiring vehicles can be given either in one of these categories or in both.

c. New Decisions about Warehouses and Vehicles;

(1) The manager can rearrange the current warehouse capacities and take decisions about buying and/or hiring new vehicles at the same time

(2) The manager can select additional warehouse location(s) and capacity(ies), rearrange the already existing ones and buy and/or hire new vehicles at the same time

In order to prepare the reports of the current situation, as well as of the chosen alternatives, the following data are needed :

1. Consumer sites and their demands

The manager must consider the consumer sites as the wholesaler sites and give the data accurately. The demands are assumed to be normally distributed, therefore the manager is asked about the average demands and their greatest deviations in the chosen period of time. However, deterministic demands may also be analysed, in case the deviations are specified as zero.

If no change is desired, the mentioned data are given only once at the beginning of the program

2. Production Data

The manager may consider the production either as deterministic or as probabilistic.

If the production is probabilistic, he must mention whether the probability of the positive and negative deviation from the average production is the same or not ; i.e if the production is normally distributed or not. In the former case, the average production relative to the given period and its greatest deviation are demanded. In the latter case, for at most five intervals, the expected amount of production and its relative cumulative probability must be given.

If the production is deterministic, the manager has only to mention the average production for the chosen period of time.

The production data should be given only once, as long as it is not changed.

3. Capacities Data

The location of the current and additional warehouses -if they exists-, as well as their corresponding capacities are asked to the manager.

The total number of warehouses including the current and additional ones cannot be more than six. Besides, warehouses can only be located in the given consumer sites but not in one where the plant itself exists.

The amount of product sent from the plant to warehouses is expected not to be more than the production capacity of the plant. Therefore, in case the warehouse capacities exceed production capacity, the manager is informed about the exceeding amount in the current and/or alternative situation and is asked the reason. Exceeding the plant production is thought to be possible for three reasons :

a. In reality, there may be no lack of production but although the whole warehouse capacities are not efficiently used, 100 per cent usage values are indicated by the manager. In this case, the manager must give the effective usage percentages of the capacities.

b. In reality, there may be no lack of production but initial inventories may be held in the plant and/or warehouses. In this case, the manager is asked about the amount of inventories held.

c. Production may be really exceeded because some of the warehouse capacities may be wrongly mentioned by the manager. In this case, the manager is asked to correct the corresponding data.

Even if the capacity is not exceeded, thinking that the firm may hold inventories and/or not use the whole capacity of warehouses, the manager will be interrogated on the effectiveness of the capacities and on the amount of inventory held.

The mentioned data should be given each time new decisions about warehouses are going to be analysed.

4. Distance Data

The manager will fill a distance matrix(km) prepared as a triangular matrix , giving the distances of one consumer site to others coming alphabetically after it.
The corresponding data should be given only once, as long as it is not changed.

5. Cost Data

The cost data are divided in three parts :

a. Warehouse Operating and Investment Costs

The manager must give the operating and-if an investment is under consideration the investment costs corresponding to the chosen period of time (TL/(week/month/year)).

b. Transportation Costs

The data about the transportation costs are divided in three categories as mentioned before.

For each category, the manager is asked about :

(1) Currently used vehicle type (trailer or truck) ;
(2) Current vehicle number
(3) Current vehicle capacity (ton);
(4) Additional vehicle type (trailer or truck) ;
(5) Additional vehicle number ;
(6) Additional vehicle capacity(ton).

In case the manager wants to reduce the current vehicle number, he must give the additional vehicle number with minus sign. If the alternative chosen by the manager is not about hiring or buying new vehicles then the last three inputs are omitted. In addition to the above information, the manager is interrogated on :

(1) Fixed transportation costs (TL/(week/month/year)) ;
(2) Variable transportation costs (TL/ton-km);
(3) Investment cost of the vehicles-if an investment is under consideration (TL/(week/month/year) .

The corresponding inputs must be given again for each of the three categories of transportation.

c. Inventory Holding and Shortage Costs

These cost will be given, according to the chosen period of time and per unit of good held or out of stock.

Once given at the beginning of the program, at further tries, the warehouse costs and transportation costs data will be skipped out or asked to the manager, according to the alternative chosen but the inventory holding and shortages costs will be asked at each new try in order to enable the manager to change the corresponding costs.

6. Delivery Time Data

If the delivery time is one of the manager's area of interest, he must give the delivery time data of his current as well as additional vehicles. The necessary data which will be given again for each of the three categories are :

(1) Average loading, unloading and waiting time per vehicle (hour/vehicle-travel) ;

(2) Average speed per vehicle (km/h) .

If the manager has not chosen the delivery time as one of the area of interest, the mentioned data will be skipped out; otherwise, the current delivery time data will be given only once, but the delivery time of additional vehicles-if they exist-will be given at the beginning of each new try.

7. Expected Changes in Current Events

The manager is asked whether the period he is analysing is the current period or not ;if the analysis is extended to a future period, the expected increase in demand till this period is needed. Besides, for the case where the demand of a definite consumer site will not be supplied, the percentage of shortage considered as lost sales is demanded. This information will be necassary for establishing a relation between the periods, during the dynamic simulation that is going to be handled.

The corresponding inputs will be given only once unless the manager desires to change it.

4.2.2. Report of the Current Situation

Once all the data mentioned above are given, the further step is tha preparation of the current situation report ; but before, the manager is asked about the current consumer sites served directly from the plant and the amount of delivered goods as well as the sites served by means of warehouses and the corresponding amount delivered.

The prepared report corresponds to the chosen period (month /year / week) and is based on average demands and production values. The aim of this report is to make the manager be aware of the current situation of his distribution system before doing any improvement. It mentions the total cost of the current physical distribution system, the unit cost per sale and-if it is the area of interest-the delivery times.

Delivery times (in hour and day) are analysed in three categories as mentioned earlier and in each of them they are handled as the time spent for the preparation to travel (loading, unloading and waiting times) and the time spent during the travel. The formulation can be stated for each category as follows.

$$2 \times \frac{\sum \left(\begin{array}{c}\text{amount to be delivered} \\ \text{to definitesite, in category i}\end{array} \right) \times (\text{distance to that site})}{\left(\begin{array}{c}\text{current number of} \\ \text{vehicle in i}\end{array} \right) \times \left(\begin{array}{c}\text{current vehicle} \\ \text{capacity in i}\end{array} \right) \times \left(\begin{array}{c}\text{current average} \\ \text{speed per vehicle in i}\end{array} \right)}$$

$$+ \qquad (2)$$

$$\begin{array}{c}\text{current} \\ \text{vehicle} \\ \text{in i}\end{array} \times \left(\begin{array}{c}\text{cur.aver.load.} \\ \text{in i}\end{array} + \begin{array}{c}\text{unload.} \\ \text{in i}\end{array} + \begin{array}{c}\text{wait. time} \\ \text{in i}\end{array} \right) \times \frac{\begin{array}{c}\text{total amount} \\ \text{to be delivered} \\ \text{in i}\end{array}}{\begin{array}{c}\text{total capacities} \\ \text{of the cur. vehicles}\end{array}}$$

i = 1,2,3 where;
1 denotes the transportation from plant to warehouse
2 denotes the transportation from plant and warehouse to distant consumer
3 denotes the transportation from plant and warehouses to local consumer

The first term will give the total time spent during the travels. The multiplication by two is necessary to take into consideration the going and returning of the vehicles. The second term will give the total elapsed time for the preparation to travels.

In case the manager desires detailed information about costs, the warehouse operating, warehouse investment, transportation operating, transportation investment, holding and shortage costs which are the components of total cost are illustrated separately.

At the end of this step in the program, a "summary file" is opened to keep the basic results of this current distribution system and of all the alternatives that will be analysed later. The basic results are taken as warehouse capacities, locations, total cost and the delivery times of each of the three categories.

4.2.3. Report of the Alternative Situation

In this section of the program, the results of the alternative chosen by the manager are analysed and a report similar to that of the current situation is mentioned.

This section consists of three parts :

(a) Vogel approximation application ;

(b) Simulation ;

(c) Reporting .

4.2.3.1. Vogel Approximation Application. Whatever the alternative chosen by the manager , the Vogel Approximation method is applied in order to find accurate transportation costs. The method is based on the minimum variable cost of transportation from factory to consumers, when warehousing costs are ignored.

Solving the Vogel matrix, the transportation cost (TL/ton) of delivering goods from the plant directly to consumer j is taken as :

$$C = C_j \times doj \qquad (3)$$

Where:

C_j = Variable trunking cost from the plant to consumer j (TL/ton-km).

In the developed program C_j may be taken different for local and distant consumer groups but not for each of the consumers separately. Besides, it is assumed to be equal to the variable trunking cost from depot to consumer j .

doj = distance between plant and consumer j.

The transportation cost (TL/ton) of delivering goods from a warehouse to consumer j is taken as,

$$C = B_i \, d_{oi} + C_j \, d_{ij} \tag{4}$$

The first term in the equation represents the transportation cost from the plant to warehouse i and the second term the transportation cost from warehouse to consumer j where :

B_i = trunking cost from the plant to depot i (TL/ton-km). It is assumed to be same for each depot

C_j = variable trunking cost from depot to consumer j

d_{oi} = distance between plant and depot i

d_{ij} = distance between depot i and consumer j

The first assumption is that if a facility is stocked out, to prohibit a prolonged backorder or to avoid order cancellation, a policy exists to fill the short items on the order from other shipping points. Thus the customer will be serviced but at an increased cost and if none of the facilities are able to fill the order, then, there will be shortages. The second assumption is that all customers' orders are given totally at the beginning of the period.

If an increase in demand is expected by the manager at the end of the investigation period, then the average demands are handled as :

$$\frac{\text{Current demands given by the manager} + \text{Expected increased demands at the end of the period}}{2} \tag{5}$$

Otherwise, the average demands given by the manager are taken without any changes. Thus, for a customer j, the cost of supplying one unit through each of the m depots and directly through the plant is computed and the customer is tried to be allocated to the plant or warehouse involving the lowest transportation cost.

4.2.3.2. Simulation. By this step of the program, the effect of the deviations from the average demands and average production-if probabilistic-on sales, shortages and inventory levels becomes visible. But, in case it is undesired by the manager, this step may be omitted and the reporting step may be directly executed.

In the simulation, the performance of the system during any time period is expected to have influence on the nature of future operations. Therefore, it is assumed that the lost sale of a previous period will reduce the average demand of future periods by an amonnt equal to that loss. As a result if the firm is in a dominating position in the market and the lost sale percentages mentioned by the manager is low, the corresponding reduction in demand will also be insignificant and vice-versa.

If the manager expects an increase in demand , in each simulation period, being considered as an exponential function of the corresponding period, the average demand (D) is increased with a calculated rate (r) and at the end of last simulation period, it is expected to reach $D(1+r)$ level which is the expected increased level mentioned by the manager.

As the demands are assumed normally distributed around the average, in each simulation period, random numbers, corresponding to the unchanged or increased averages-according to manager's expectation-, are created by normal random number generation. The average production is taken without any change in the deterministic case, is normal randomly generated in probabilistic and normally distributed case and only randomly generated in probabilistic but not normally distributed case.

At the first simulation period, if there is initial inventory in the plant, it is added to the current production and the total amount constitutes the upperbound the supply can reach during any simulation period. At the beginning of the period, first, the efficient capacity of each warehouse are delivered but if there is initial inventory in a warehouse, it is substracted from the good that must be delivered to that warehouse. Once those arrangements are finished, using vogel approximation method, the generated demands are tried to be satisfied accurately. If none of the facilities are able to fulfill a customer site's order in the previous period , at the next simulation period, first the percentage of the shortage indicated by the manager as lost sale will be cancelled from the average demand before randomly generating the demand of the period and the remaining part will be cancelled from the generated production of the period in order to be satisfied previously but this will cause a reduction in the plant supply for the current period.

In case stocks remain in the plant from the previous period, it will be added to the generated production of the next period but if this amount exceeds the limit mentioned above, this will result with a reduction in production. On the other hand, if stocks remain in a warehouse then the necessary amount to be delivered to that warehouse at the next period will be reduced by that stock level and if the current supply of the plant is unsufficient to send the necessary amount of goods to warehouses, the deliveries to each warehouse will be equally reduced. After all these changes made at the beginning of the next period , the distribution from the plant and warehouses is again realized by vogel approximation and all the mentioned operations are handled similarly till the end of the last simulation period. Once the simulation is executed, the distribution of the total demand and supply around the averages are mentioned. Besides, five intervals are created and the probability of shortage level corresponding to each interval is calculated for all of the consumer sites and for each simulation period and the same procedure is applied to the stock levels of plant and warehouses. With a third screen, the demand levels reached at the end of the simulation and the average sales realized during the simulation are indicated . In case an increase in demand was expected , the manager may consider by means of this screen that although exponentially increased, the expected demand level may not be reached because of lost sales and the resulting reduction in demands. Even if an increase is not expected, this screen will still be useful to mention the effect of lost sales - if they happen-on the initial average demands.

If the consumptions of cities where lost sales happen are not important for the firm, the manager may not need to take precautions but in the alternative case, the screens mentioned above will help him during further trials in finding methods to afford the effect of the fluctuations.

4.2.3.3. Reporting. Similar to the current situation report, the alternative situation report is based on average demand and supply and mentions the total cost, unit cost per sale investment cost and delivery times of the analysed alternative. If desired, the components of the total cost may be again given separately. Delivery times calculations are as stated previously but, if the chosen alternative concerns buying or hiring vehicles, then the loading, unloading and waiting times, as well as the capacity and the average speed of the vehicles will be handled as the weighted averages of the current and additional vehicle values.

In the further step, the basic information about the analysed alternative is kept in the "summary file" mentioned before; besides if the manager indicates that the last results are the bests obtained so far , the transportation, investment, warehousing, holding and shortage costs of the corresponding alternative are kept in the "best solution " file. At this stage, if the simulation of the analysed alternative is executed, then the manager must take into consideration the simulation values as well as the report values before deciding on the availability of the alternative but if the simulation is not executed, he will be obliged to decide, only analysing the costs and delivery times values illustrated in the report. Therefore in case he considers those results as the most appropriate ones it will be advisable to analyse the same alternative in a next try, but executing also simulation.

Business managers are used to thinking in terms of averages and average rates, However, the answers to many important questions affecting the distribution system design depend on the characteristics of sales and demand variations around the average. The statistical characteristics of the variations determine in a very significant way how a distribution system will work and how it should be designed to operate economically. If the firm has a dominating position and a highly desirable brand image, then its consumers may be prepared to wait until the stockout situation is remedied but if the firm is in competition then the occurance of a stockout will mean that the consumer will simply go elsewhere to have his demand met. The risk of lost sales can be reduced by maintaining a high inventory level or contrarily costs are decreased by keeping low inventory level but an indiscriminate reduction in inventory levels may seriously damage the reliability of delivery service to customers. Without analysing the simulation values, the manager can not take into consideration the lost sales and reduction in demands due to fluctuations and most probably thinks that holding inventories only increases costs. Therefore decisions with respect to averages can lead the system to decreased sales and consequently to inefficiency.

The developed program will try to increase the manager's ability of integrating the activities of the system adequately.For example, during his analysis the manager will understand that concentration on reducing the cost of only one factor can have the effect of increasing the cost of another factor by an amount greater than the amount saved. Additionally by means of a simulation, the results of the deviations from the averages will give him an idea about lost sales, shortages and stock levels. Trying to offer a maximum service level, he will consider that complete inventories will be immediately available to all customers but entailing unreasonable costs or conversely minimising the service level, he will realize that delivery times will increase and probably the sales will decrease. Therefore, trying different data on the same alternative or analysing different alternatives, he will try to find a reasonable level of service without incurring unreasonably excessive costs.

4.3 Sample Problem

The solving of a sample problem is thought to be necassary to reveal the main reasoning of the developed program.

In this example, the consumer sites, the average monthly demands, warhouse operating and investment costs, the location and production capacity of the plant are those of a beverage firm and the information about transportation costs is obtained from a distribution company. Shortage cost is taken equ to the price of one ton of the beverage firm product and holding cost is assumed to be the price of holding one ton of the product as safety stock, inste of putting the related money in a bank with fifty per cent interest.

The related data are as follows :

Consumer Sites	Demand/month (ton)	Greatest Deviation (ton)
Ağrı	113	50
Artvin	38	10
Erzurum	263	100
Giresun	106	45
Gümüşhane	45	20
Kastamonu	38	14
Kars	155	75
Rize	81	33
Sivas	263	110
Trabzon	156	80

Plant : A plant with 1258 t (deterministic) capacity exists in Erzurum.

Warehouse : A warehouse of 333 t is bought in Trabzon, in the current situation

Distance Matrix
(km)

	Ağ.	Art.	Erz.	Gi.	Gü.	Ka.	Kar.	Ri.	Si.	Trab.
Ağ.	20	476	181	641	390	1077	226	580	624	505
Art.		20	295	370	349	887	272	159	729	234
Erz.			20	460	209	896	211	399	443	324
Gi.				20	251	519	632	211	391	136
Gü.					20	770	420	190	380	115
Ka.						20	1107	730	490	656
Kar.							20	421	654	496
Ri.								20	570	75
Si.									20	495
Trab.										20

Warehousing Costs

	Buying		Hiring
	Investment Cost (TL/month)	Operating Cost (TL/month)	Operating Cost (TL/month)
- 200t	199800	800000	950 000
200 - 400t	325800	1.5 E06	1.7 E06
400 - 800t	451725	2.1 E06	2.5 E06
800 - 1250 t	574725	2.5 E06	3.2 E06

Transportation Costs

	Buying		Hiring	
	Fixed Cost (TL/month)	Variable Cost (TL/ton-km)	Investment (TL/month)	Variable Cost (TL/ton - km)
1 TIR (20t)	620 000	16	260 000	67
1 truck (10t)	481 250	25	90 625	80
1 truck (2.5t)	393 750	54	468 75	85

In the current situation , 3 TIRs are hired for the transportation from plant to warehouses, 2 trucks of 10t are hired for the transportation from plant and warehouses to distant consumers and 3 trucks of 2.5t are hired for the transportation from plant and warehouses to local consumers .

Inventory Holding Cost (TL/ton-month)	Shortage Cost (TL/ton-month)
10 000	240 000

Expected Changes in the Current Events

Expected increase in demand, at the end of the investigation period : 5 %

Expected percentage of shortage considered as lost sales : 25 %

table 4.1 Summary Results of the trials

	Warehouses	Initial Inventory	Total cost	Total sales	unit cost	trans Operation	Wareh. Operation	Trans. Investment	Wareh. Investment	Shortage Cost	Holding cost	P → W delivery	Pand W → DC delivery	Pand W → LC delivery
0	t/month Trabzon 333	-	3.78552 x 10^7	1258	30091.6	2.8807 x 10^7	1.5 x 10^6	-	-	7.54799 x 10^6	-	5 days 3 TIR of 20 t (hired)	37 days 2 trucks of 10 t (hired)	26 days 3 trucks of 2.5 t (hired)
1	Alt : 1 Trabzon 333	-	3.53154 x 10^7	1258	28072.7	2.6267 x 10^7	1.5 x 10^6	-	-	7.54799 x 10^6	-	"	34days 2 trucks of 10 t (hired)	25 days 3 trucks of 2.5 t (hired)
2	Alt : 2 Trabzon 361	-	3.63105 x 10^7	1258	28863.7	2.6312 x 10^7	2.45 x 10^6	-	-	7.54799 x 10^6	-	6 days 3 TIR of 20 t (hired)	32 days 2 trucks of 10 t (hired)	27 days 3 trucks of 2.5t (hired)
3	Alt : 5 Trabzon 389	-	3.24578 x 10^7	1258	25801.1	2.1679 x 10^7	2.45 x 10^6	780000	-	7.54799 x 10^6	-	6 days 3 TIR of 20 t (bought)	34 days 2 trucks of 10t (hired)	"
4	Alt : 5 Trabzon 361	-	3.13113 x 10^7	1258	24889.8	2.05333 x 10^7	2.45 x 10^6	780000	-	7.54799 x 10^6	-	"	32 days 2 trucks of 10t (hired)	"
5	Alt : 6 Trabzon 350 Sivas 309 (bought)	-	2.69296 x 10^7	1258	21406.7	1.43258 x 10^7	3.95 x 10^6	780000	325800	7.54799 x 10^6	-	12 days 3 TIR of 20t (bought)	17 days 2trucks of 10 t (hired)	44days 3trucks of 2.5t (hired)

table 4.1 (continue)

	Warehouses	Initial Inventory	Total cost	Total sales	unit cost	trans. Operation	Wareh. Operation	Trans. Investment	Wareh. Investment	Shortage Cost	Holding cost	P→ W delivery	Pand W → DC delivery	Pand W → LC delivery
6	Alt : 6 Trabzon 350 Sivas 309 (hired)	-	2.68038 x 10^7	1258	21306.7	1.43258 x 10^7	4.15 x 10^6	780000	-	7.54799 x 10^6	-	"	"	"
7	Alt : 6 Trabzon 350 Sivas 309 (hired)	Plant → 31t	2.00474 x 10^7	1289	15552.7	1.48544 x 10^7	4.15 x 10^6	780000	-	107988	155000	"	18days 2 trucks of 10t (hired)	"
8	Alt : 6 Trabzon 350 Sivas 309 (hired)	Plant → 32 t	1.99524 x 10^7	1289.45	15473.6	1.48596 x 10^7	4.15 x 10^6	780000	-	-	162750	12 days 3 TIR of 20t (bought)	18days 2trucks of 10t (hired)	44days 3trucks of 2.5t (hired)
9	Alt : 6 Trabzon 350 Sivas 309 (hired)	Plant → 32 t	1.99524 x 10^7	1289.45	15473.6	1.48596 x 10^7	4.15 x 10^6	780000	-	-	162750	"	14days 3trucks of 10t (hired)	42days 5trucks of 2.5t (hired)
10	Alt : 6 Trabzon 351 Sivas 309 (hired)	Plant → 32 t	1.99054 x 10^7	1289.45	15437.1	1.48126 x 10^7	4.15 x 10^6	780000	-	-	162750	"	"	17days 3trucks of 2.5t + 2trucks of 10t (hired)
11	Alt : 6 Trabzon 351 Sivas 309 (hired)	Plant 47 → 20t → 17t	2.02012 x 10^7	"	15666.5	1.4588 x 10^7	4.15 x 10^6	780000	-	-	682750	11days 3 TIR of 20t (bought)	"	"

Delivery Time Data

	Loading Time (H/vehicle-travel)	Unloading Time (h/vehicle-travel)	Waiting Time (h/vehicle-travel)	Average Speed (km/h)
1 TIR (20 t)	.75	.75	1	60
1 truck (10 t)	.4	.4	1	50
1 truck (2.5 t)	.3	.3	2	50

In order to get a solution thought to be more suitable than the current physical distribution system, first the current situation has been investigated; then, eleven trials have been made. The summary results of the trials are shown in table 4.1. In this table, the plant is represented by P, the warehouse is represented by W, local consumers by LC and distant consumers by DC. The investigations were firstly made according to average demand and production values, then, considering the tenth trial as the best trial realized so far, a simulation was made in order to find out the effect of demand fluctuations on this alternative. Therefore the eleventh trial was realized with the aim of reducing this effect. Although this trial was needing a greater total and unit distribution cost that the tenth it has been preferred because of its reduction in lost sales happened during the simulation.

The reasoning chain of all the trials can be stated as follows :

Trial No :

0) initial state : From the average report of the current situation, the excessive level of shortage and of the transportation costs as well as the inaccurate delivery times from the plant and warehouses to local and distant consumers were inspected.

1) Alternative No : 1 : The excessive level of transportation cost of trial No : 0 has been tried to be reduced only by applying Vogel Approximation, without changing the present warehouse capacities, the number of trailers etc. As a result, a reduction of 2539800 TL in transportation operating

costs was realized. Besides, the delivery times to the distant consumers were reduced by three days and to local consumers, by one day.

2) Alternative No : 2 According to the results of Vogel Approximation in trial No 1, a fraction of demand of Trabzon was supplied by Erzurum because of the lack of warehouse capacity. Therefore, in order to overcome this insufficiency and reduce the transportation cost, the warehouse capacity of Trabzon was increased from 333 t to 361 t. Nevertheless, this created in the transportation operating cost, an increase of 45100 TL; besides, the warehouse operating cost was also increased by 950 000 TL.

3) Alternative No 5 : Thinking that the increase of transportation cost in trial No : 2 might be caused by the high price of hiring TIRs and in order to take advantage of consolidated volume shipments, it was decided to buy the previously hired three TIRs. At the same time, the capacity of Trabzon was increased to 389 t with the aim of sending goods to Kastamonu from Trabzon. As a result, a gain of 4632700 TL in transportaion cost was reached.

4) Alternative No 5 : The supply of demand of Kastamonu from Trabzon has caused Erzurum to send 29 unit less to Gümüşhane. However the cost of satisfying the demand of Gümüşhane was cheaper than that of Kastamonu therefore,the capacity of Trabzon was again decreased to 361 t. This has realized a decrease of 1146500 TL in the transportation costs.

5) Alternative No 6 : In order to use the consolidated volume shipment more efficiently, a warehouse of 309 t. was bought in Sivas, in addition to the warehouse of Trabzon. In the meanwhile, noticing that still 9.4 t was sent from Trabzon to Kastamonu because of 361 t of capacity, this capacity was reduced to 350 t. This trial was profitable because, while increasing the warehouse operating cost by 1.5 E 06 TL and resulting with an investment cost of 325800 TL, it was decreasing the transportation operating cost by 6207500TL.

6) Alternative No 6 : Instead of buying a warehouse in Sivas, the hiring alternative was thought to be more profitable. As

a result, while warehouse operating cost of trial No 5 was increased by 200000 TL, the warehouse investment cost disappeared (325800 TL) therefore the sixth trial was preferred to the fifth.

7) Alternative No 6 : At this trial, the high shortage cost level was considered. The reason for this problem was the manager's expectation of a five per cent demand increase. In the reports, although the increased average demand ((demand of the current period + increased demand at the end of the investigation period)/2) was used, the production remained tha same and was insufficient to satisfy the total demands. From the report of trial No 6 , it was understood that Gümüşhane was the city with the lack of supply of 31.45 t and the demand of this consumer site was directly satisfied by Erzurum, it was decided that Erzurum should keep an inventory of 31 t. While this trial made the holding cost equal to 155000 TL, it realized a decrease of 7440002 TL in shortage cost and it was a profitable trial.

8) Alternative No 6 : In order to annul the shortage entirely, 32 t of stock was kept in Erzurum. This trial increased the holding cost by 7750 TL while the shortage cost became zero. So, it was a profitable trial.

9) Alternative No 6 : In this trial, the aim was to make quicker deliveries from the plant and warehouses to distant and local consumers. For this reason one truck of 10t for the delivery to distant consumers and two trucks of 2.5t for the delivery to local consumers were hired, in addition to the existing ones. This policy, with respect to the eight trial, provided a saving of 4 days for the first group of consumers and a saving of 2 days for the second group of consumers.

10) Alternative No 6 : One of the differences of that trial from the previous one was that 2 trucks of 10 t instead of 3 trucks of 2.5 t were hired for the purpose of quicker delivery to local consumers. This trial changed the variable transportation cost from 85 TL/ton-km to 83 TL/ton-km because of the weighted average of the variable cost of 3 trucks of 2.5 t and 2 trucks of 10 t. In the meantime, from the results of trial No 9,

it was revealed that Erzurum has satisfied 1 t of the demand of Trabzon because of the warehouse insufficiency and the warehouse capacity was increased to 351 t. This trial procured a saving of 47 000 TL in the transportation cost. At the same time, the delivery times from plant and warehouses to local consumers changed from 42 days to 17.

11) Alternative No 6 : In this trial, a simulation is executed, accepting that the results of the tenth trial were the most suitable but instead of the expected increase of five per cent in the initial period demands which was 1258 t ; at the end of the last simulation period this amount was decreased to 1229t. In order to reduce the effect of the fluctuations in the consumer sites where the decrease in demand was important for the firm (Artvin, Giresun, Gümüşhane, Kastamonu, Sivas, Trabzon), stocks of 47t in the plant of 20t in Trabzon and of 17 t in Sivas were decided to be kept, according to the distribution pattern. This trial reduced the transportation cost by 224090 TL and increased the holding cost by 520000TL. The last trial was considered to be the best because of the increase in selling capacity (1249t) with respect to that of the previous trial (1229t) at the end of the last simulation period, in spite of the increase in the total and unit distribution cost. Although at the end of the simulation, the initial selling capacity (1258 t) was decreased, another trial was not considered because of the increase of demand in the consumer sites with a demand capacity greater than or equal to 100 t and a decrease in the cities were the demand capacities were less but another policy might be to increase the safety stock level in plant and/or warehouses .

Demands of the consumer sites at the beginning and at the end of the simulation for trial No 1, trial No 10 and trial No 11 are given in table 4.2.

Table 4.2 Demand levels at the begining and at the end of the simulation

	At the beginnig of the simulation (ton)	At the end of the simulation		
		Trial No 1 (ton)	Trial No 10 (ton)	Trial No 11 (ton)
Ağrı	113	118.65	118.65	118.65
Artvin	38	18.27	34.32	28.75
Erzurum	263	276.15	276.15	276.15
Giresun	106	111.3	105.12	111.3
Gümüşhane	45	25.01	31.96	35.17
Kastamonu	38	12.10	26.39	25.48
Kars	155	162.75	162.49	162.75
Rize	81	85.05	85.05	85.05
Sivas	263	268.83	262.90	266.7
Trabzon	156	124.605	142.01	142.99
Average Sales During the Simulation :	1258	1198	1229	1249

V. CONCLUSION

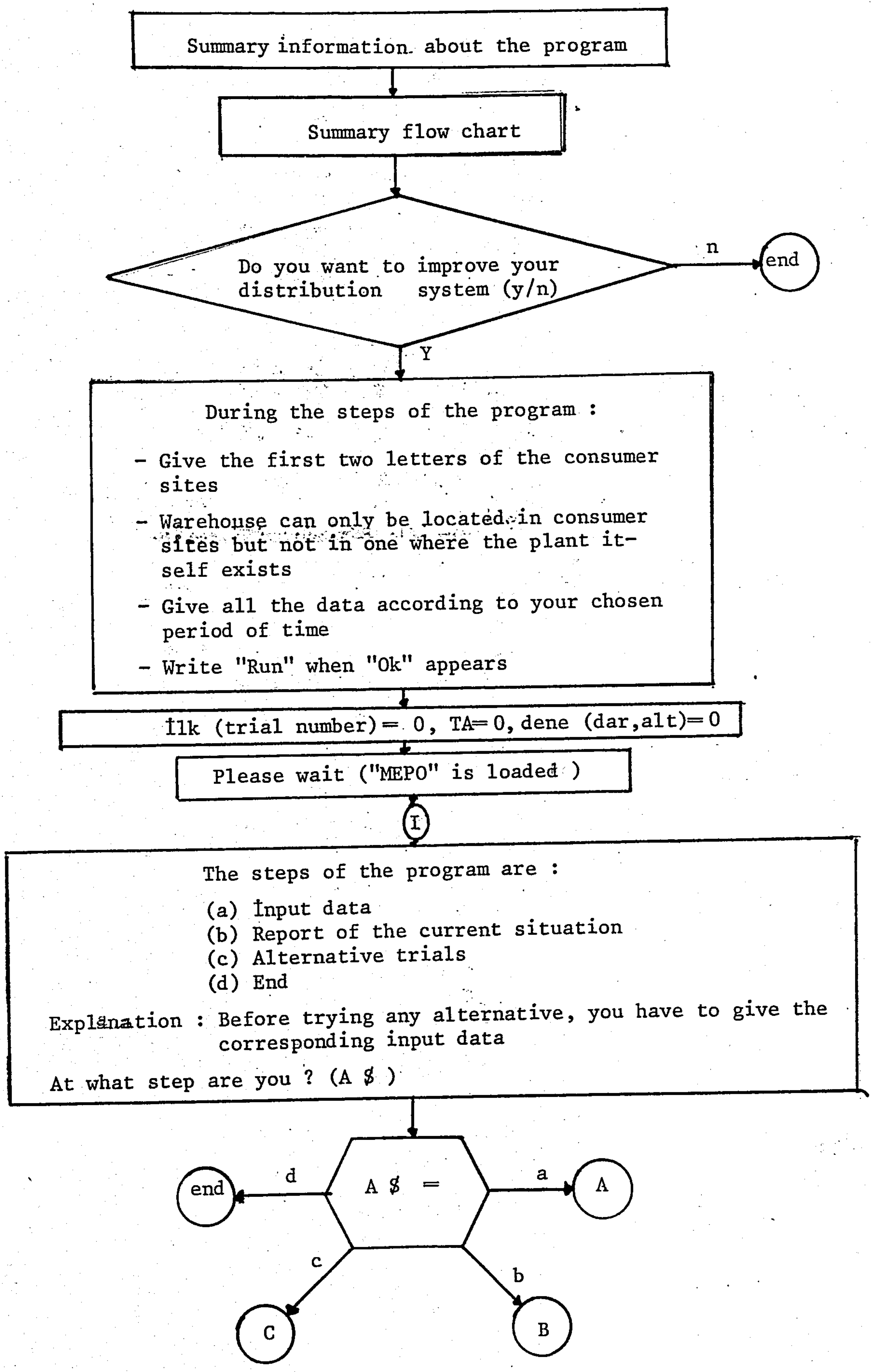
The tendency of most specialists has been to overlook the potentials for reducing the cost of some stratejic factors in the distribution sytem. The result was a condition of apparent efficiency in the various parts but not in the operation of the integrated whole. When decisions are made about transportation warehousing or inventory levels separately, they are based on an analysis of alternatives within that specific function, without taking into consideration the possible effect upon closely related ones. Being static, in most of the developed models, the interrelationships between the previous and future periods have not been analysed and besides as the objective of the models was cost minimisation , the reductions in delivery times or the increase in sales have not been taken as area of interest. On the other hand, specialists have rejected the cooperation with the manager of the firm and as a result, have had great difficulties in adapting the algorithms to the problems at hand.

The developed program of this study aims to avoid all the weaknesses mentioned above and with the computer-manager cooperation, tries to gain an insight into the nature of the current physical distribution of the firm and to restructure it, considering the system as a whole. The prevailing practice is to evaluate the alternatives given in the program and try to reach decisions which will result with the reasonable efficieny and least cost in the total performance.

A P P E N D I C E S

A P P E N D I C E S   A

D E T A I L E D   F L O W - C H A R T


Summary information about the program
Summary flow chart
Do you want to improve your distribution system (y/n)
n
end
Y
During the steps of the program :
- Give the first two letters of the consumer sites
- Warehouse can only be located in consumer sites but not in one where the plant itself exists
- Give all the data according to your chosen period of time
- Write "Run" when "Ok" appears
İlk (trial number) = 0, TA = 0, dene (dar,alt) = 0
Please wait ("MEPO" is loaded)
I
The steps of the program are :
(a) İnput data
(b) Report of the current situation
(c) Alternative trials
(d) End
Explanation : Before trying any alternative, you have to give the corresponding input data
At what step are you ? (A $)
A $ =
d
end
a
A
c
C
b
B

(A)

Which criterion do you prefer (Dar)

(1) cost
(2) time + cost

Explanations about the alternatives

TO IMPROVE CURRENT SITUATION

1- Explanation : To get a better distribution pattern with the current situation data

NEW ALTERNATIVES

About warehouses

2- To rearrange the present warehouse capacities and get a better distribution pattern.

3- To rearrange the present and new warehouse capacities and get a better distribution pattern.

About Vehicles

4- To buy and/or hire new vehicles (trailer/ truck)

About Vehicles + warehouses

5- (2) + (4)

6- (3) + (4)

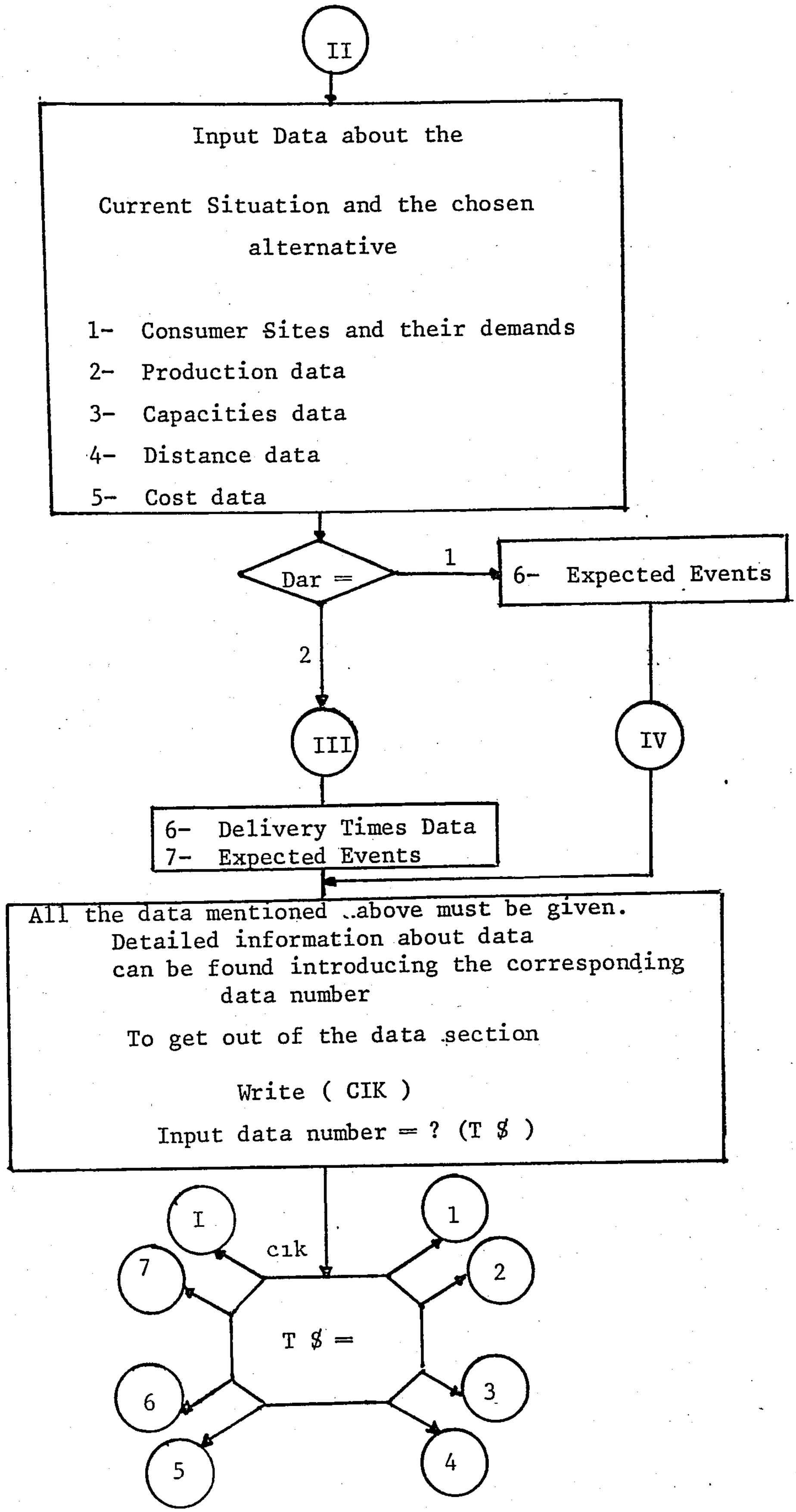
Recommendation : It is recommended to try to improve the current situation first .

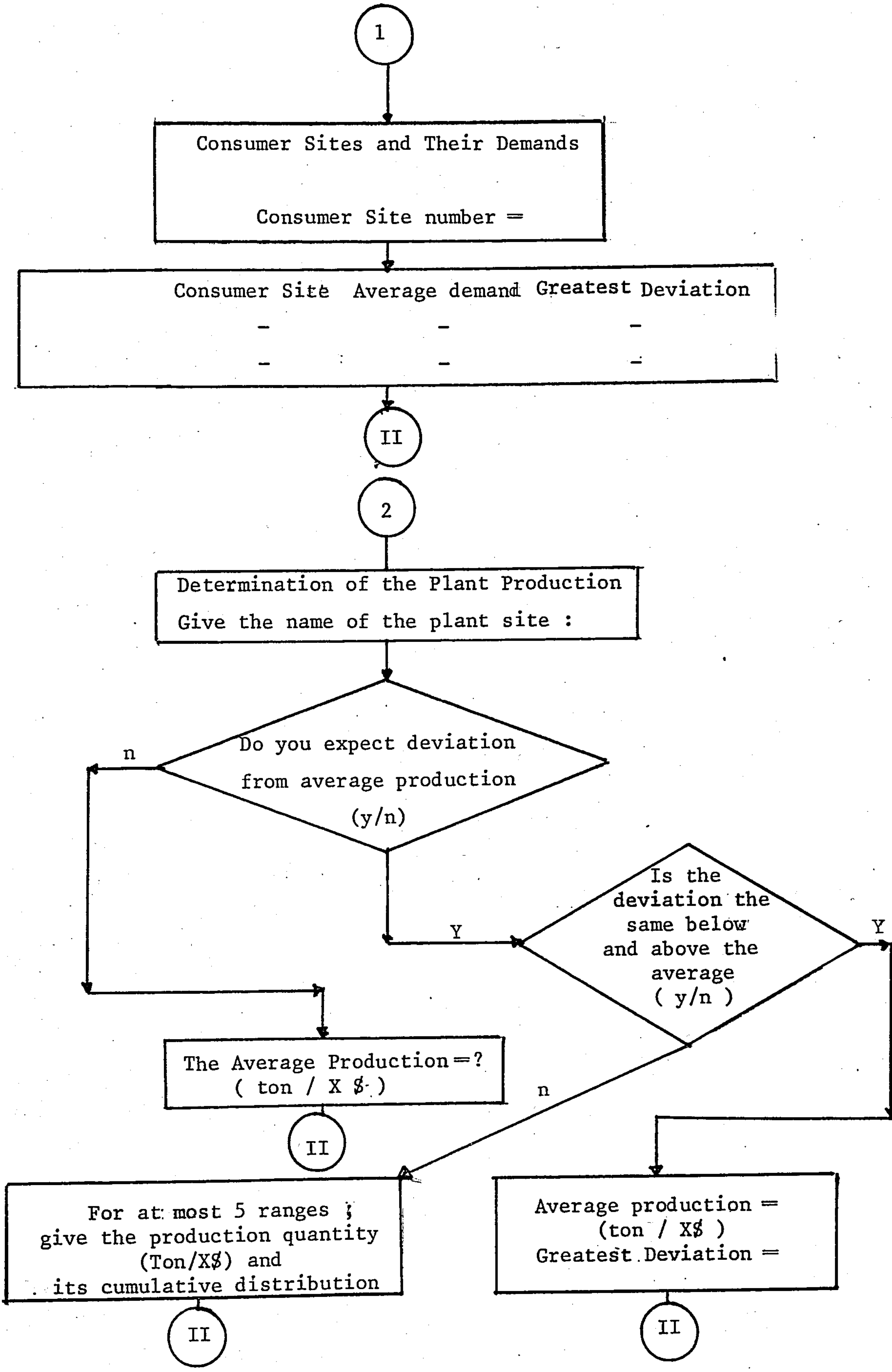
Warning : Total number of warehouses cannot exceed 6

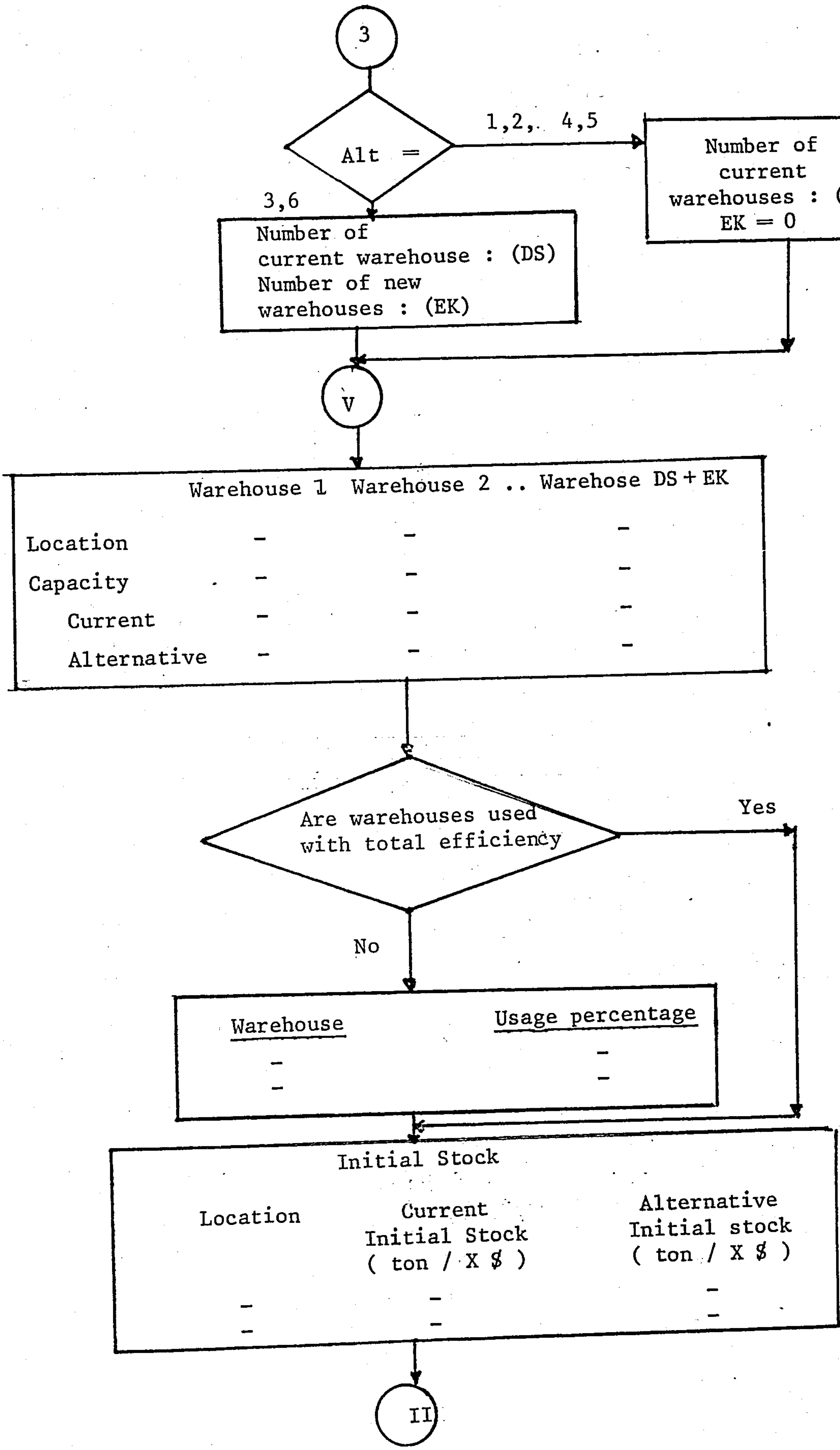
Alternative number = ? (Alt)

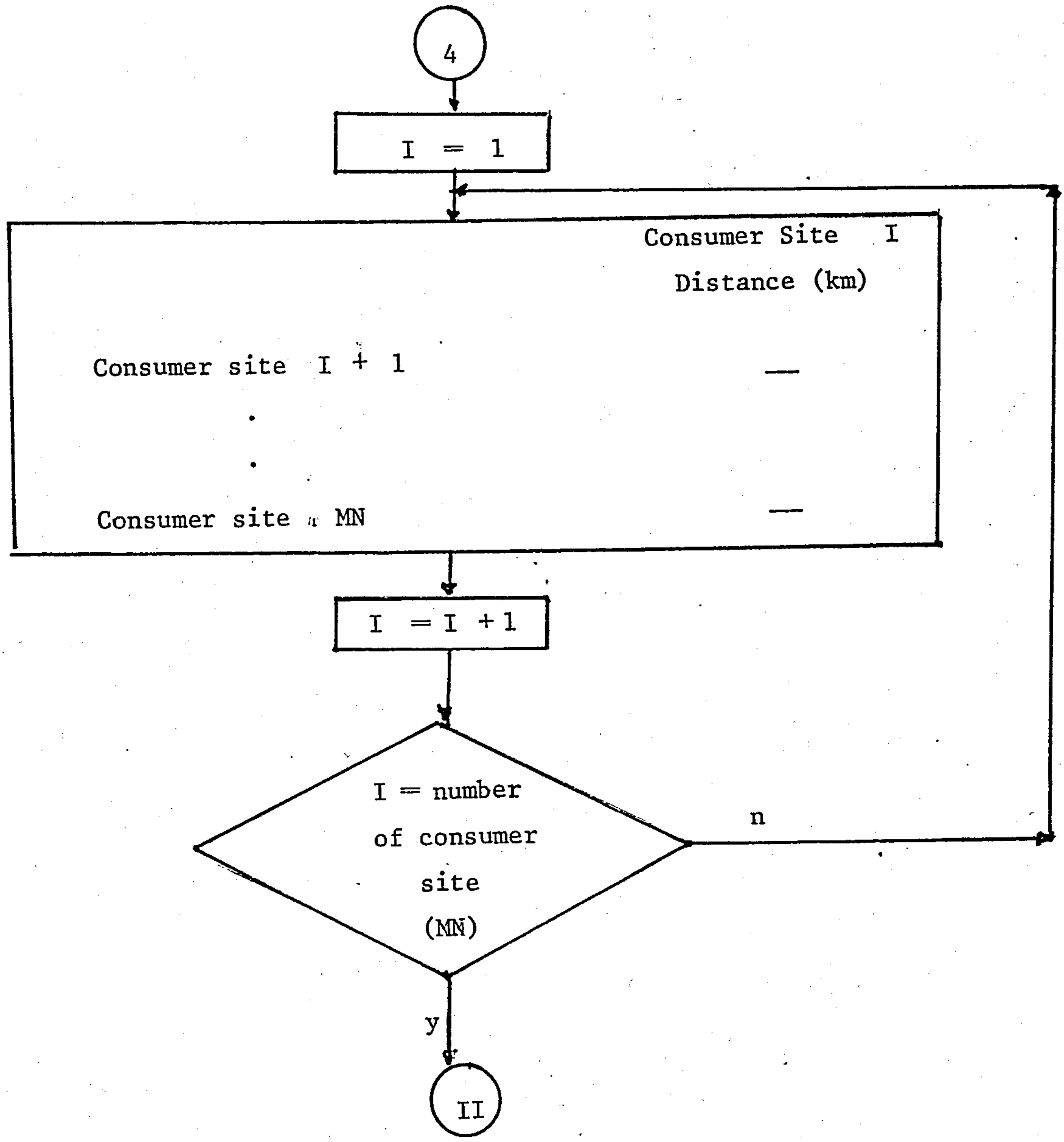
Choose your period of time for analysis (week/month/year) (X $)

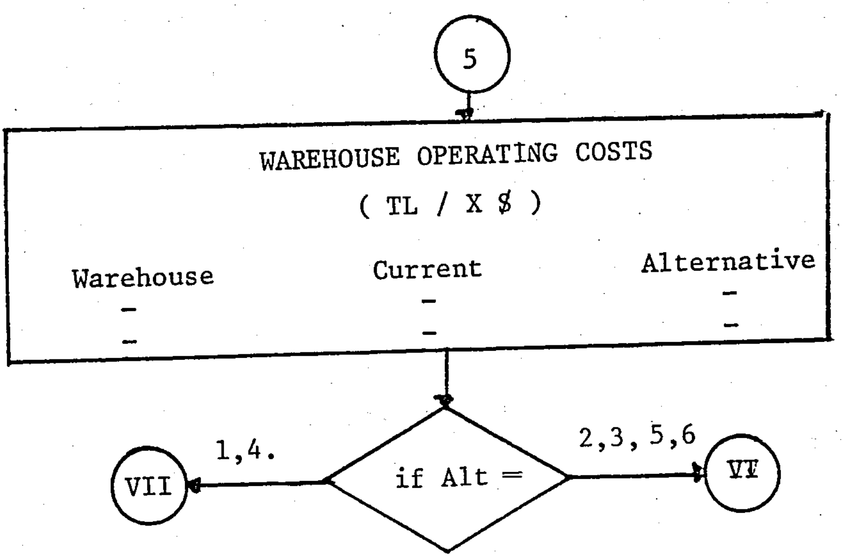
(II)

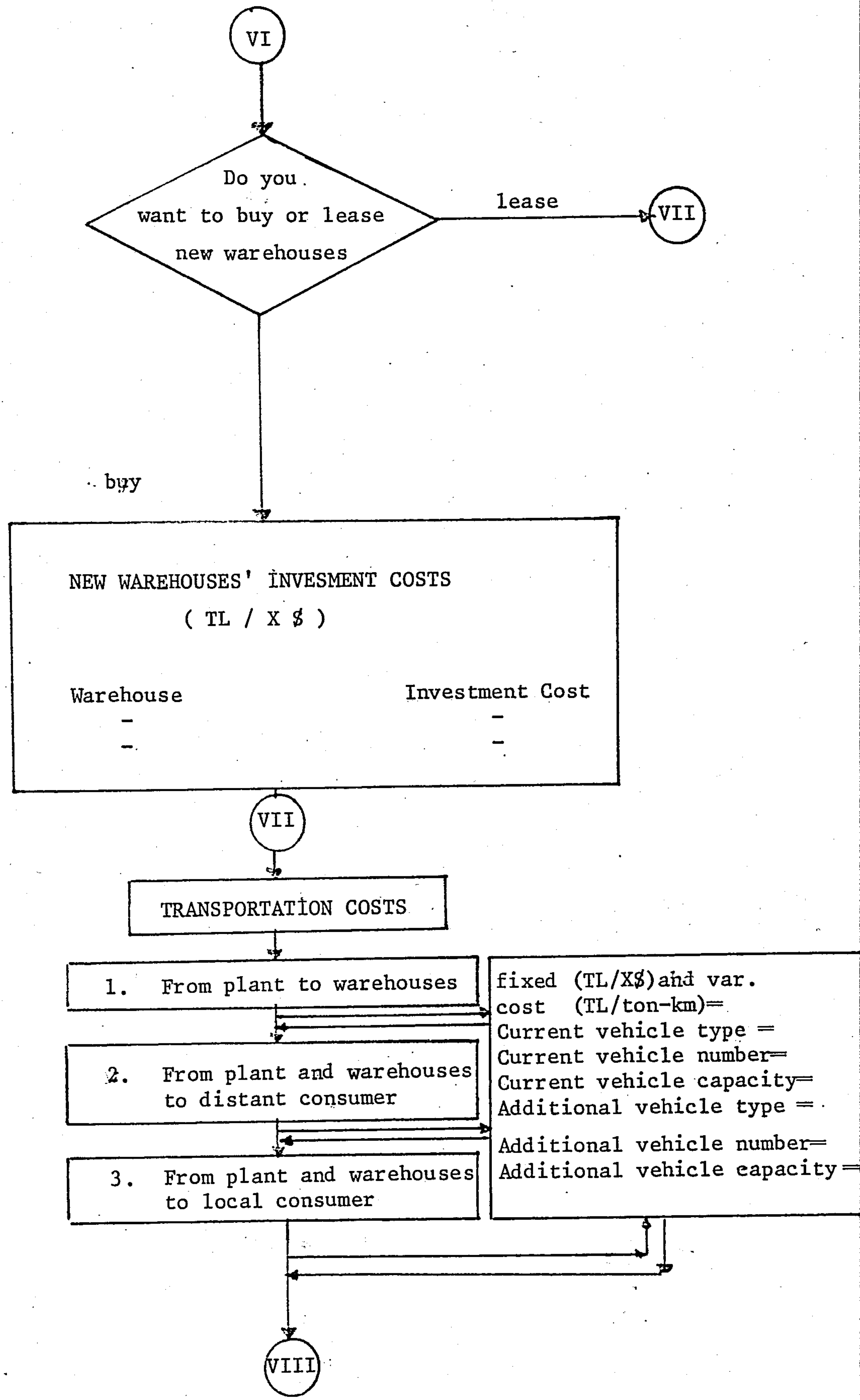

II
Input Data about the
Current Situation and the chosen
alternative
1- Consumer Sites and their demands
2- Production data
3- Capacities data
4- Distance data
5- Cost data
Dar =
1
6- Expected Events
2
III
IV
6- Delivery Times Data
7- Expected Events
All the data mentioned above must be given.
Detailed information about data
can be found introducing the corresponding
data number
To get out of the data section
Write (CIK)
Input data number = ? (T $)
I
cik
1
7
2
T $ =
6
3
5
4

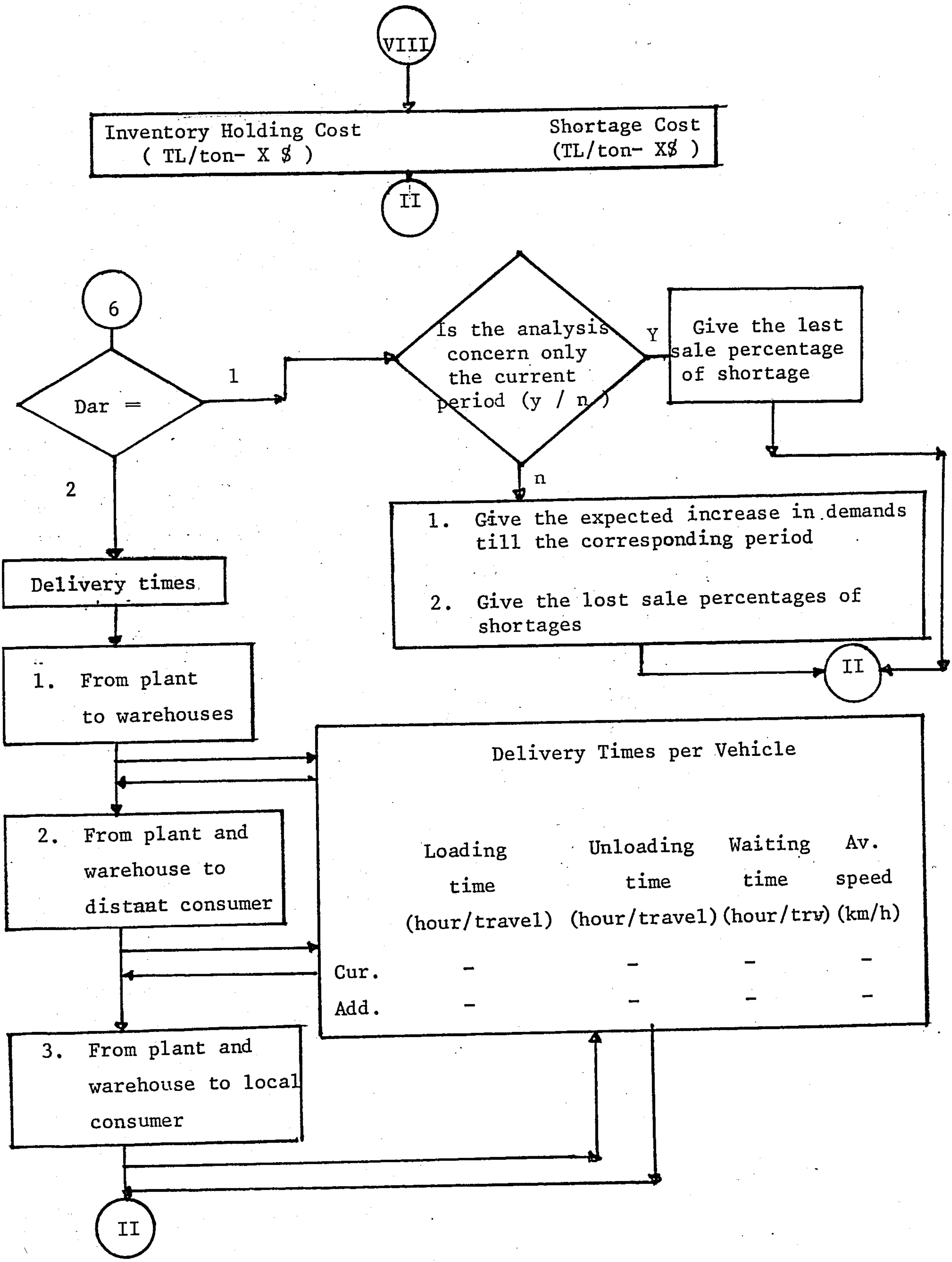

1
Consumer Sites and Their Demands
Consumer Site number =
Consumer Site Average demand Greatest Deviation
II
2
Determination of the Plant Production
Give the name of the plant site :
Do you expect deviation from average production (y/n)
n
Y
Is the deviation the same below and above the average (y/n)
Y
n
The Average Production =? (ton / X $)
II
For at most 5 ranges ; give the production quantity (Ton/X$) and its cumulative distribution
II
Average production = (ton / X$)
Greatest Deviation =
II

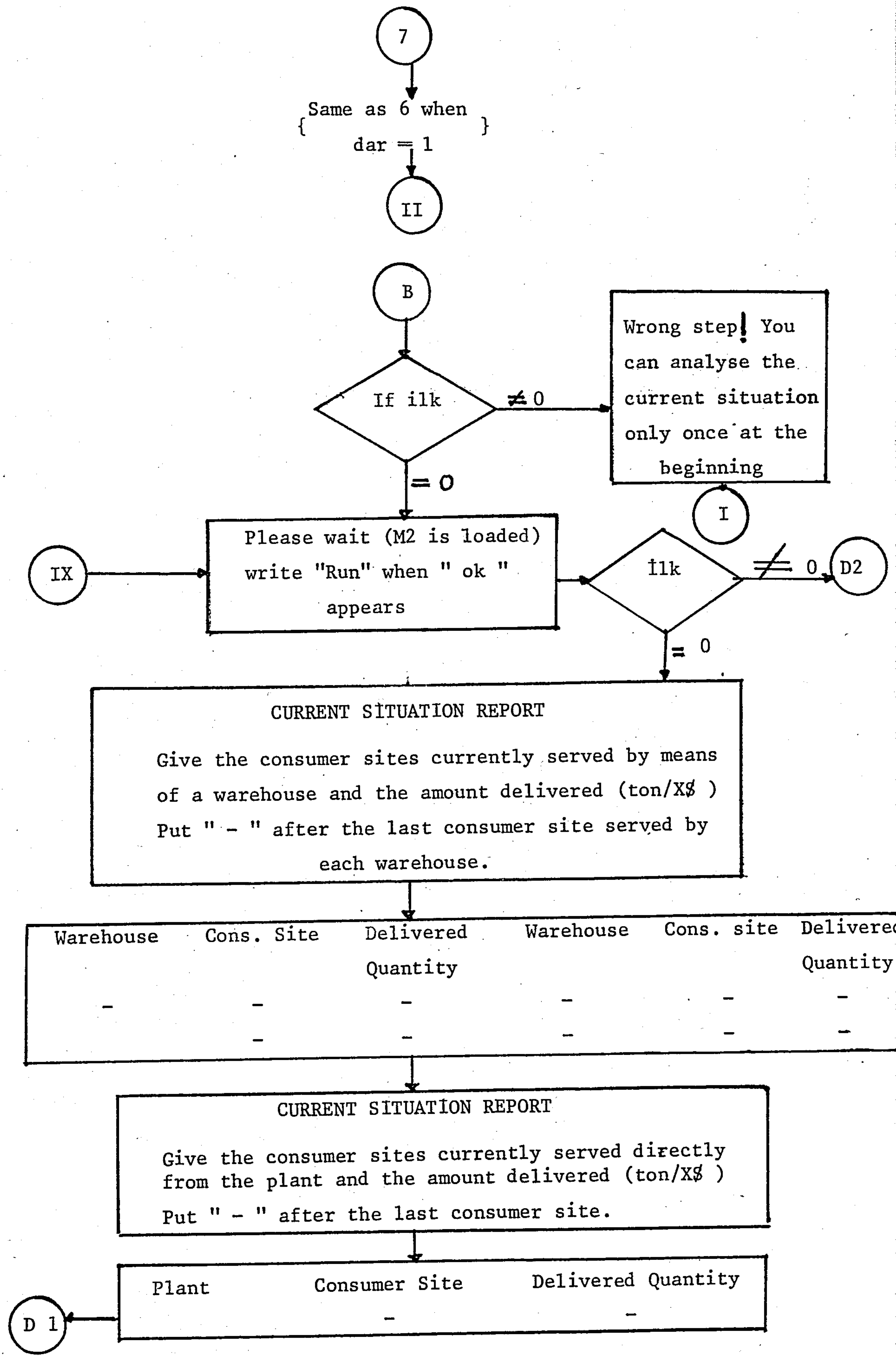

3
Alt =
1,2, 4,5
Number of current warehouses : (DS) EK = 0
3,6
Number of current warehouse : (DS) Number of new warehouses : (EK)
V
Warehouse 1 Warehouse 2 .. Warehose DS + EK
Location
Capacity
Current
Alternative
Are warehouses used with total efficiency
Yes
No
Warehouse
Usage percentage
Initial Stock
Location
Current Initial Stock (ton / X $)
Alternative Initial stock (ton / X $)
II

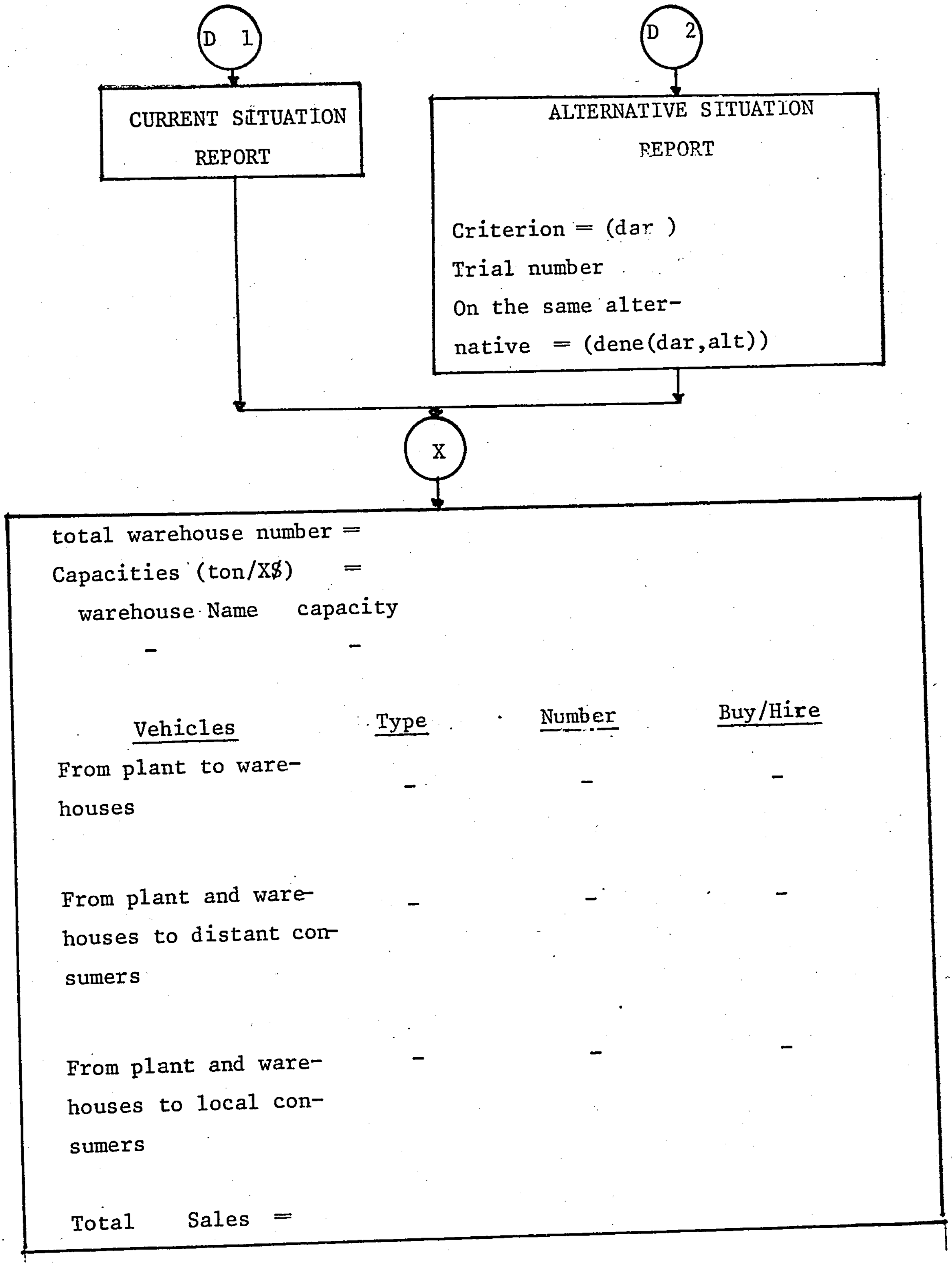

4
I = 1
Consumer Site I
Distance (km)
Consumer site I + 1
Consumer site MN
I = I + 1
I = number of consumer site (MN)
n
y
II

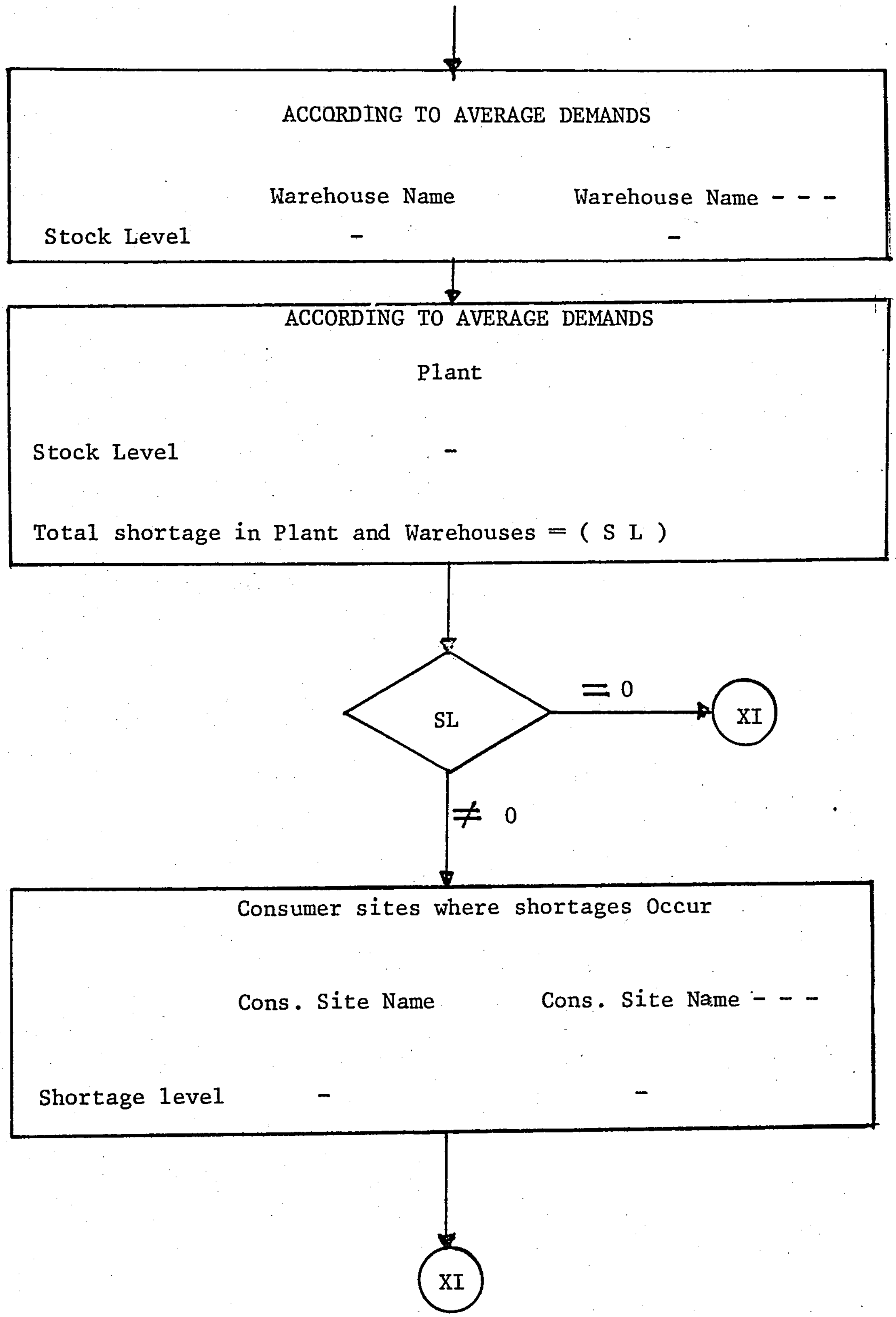

5
WAREHOUSE OPERATING COSTS
(TL / X $)
Warehouse
Current
Alternative
if Alt =
1,4.
VII
2,3, 5,6
VI

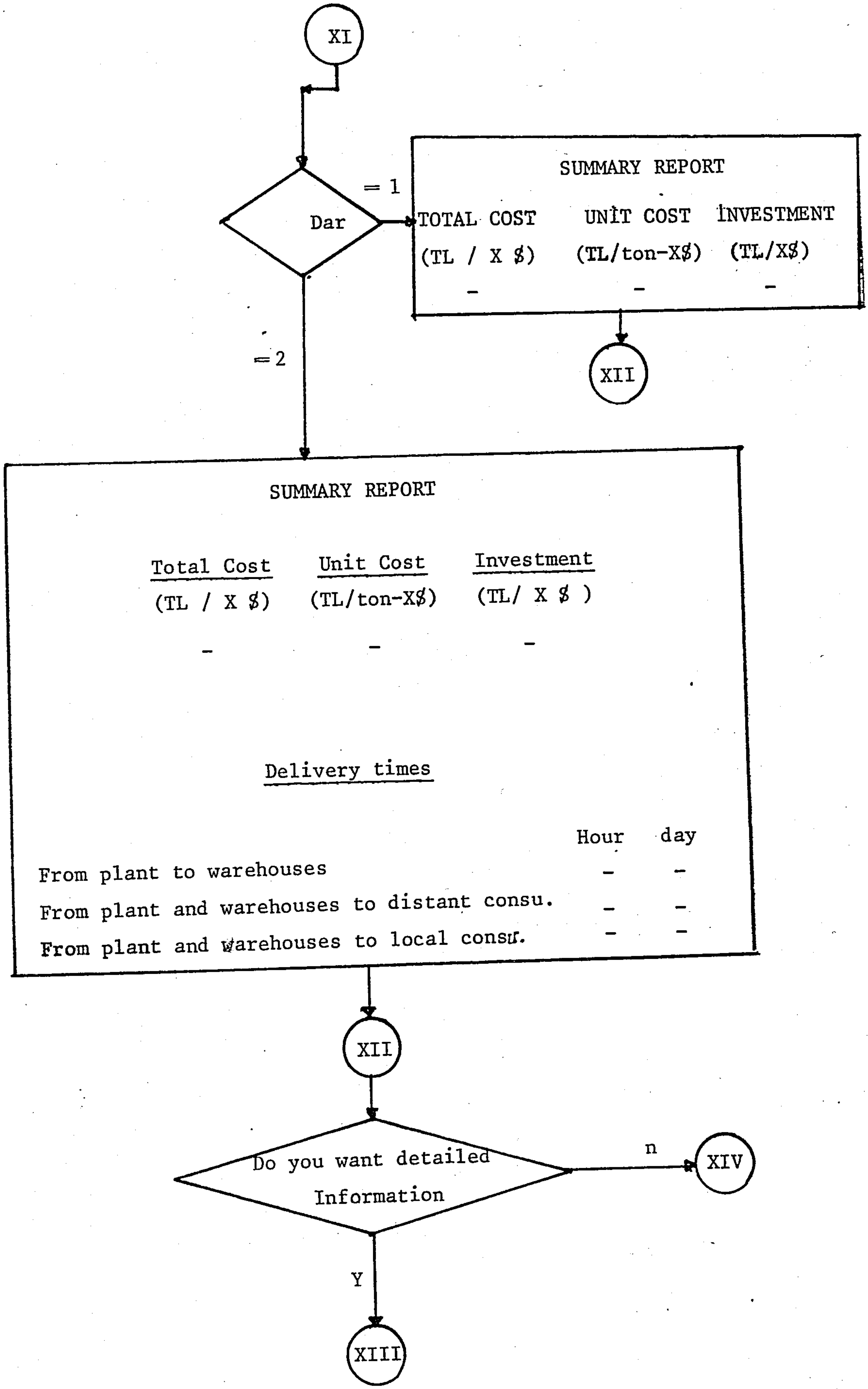

VI
Do you want to buy or lease new warehouses
lease
VII
buy
NEW WAREHOUSES' INVESMENT COSTS
(TL / X $)
Warehouse
Investment Cost
VII
TRANSPORTATION COSTS
1. From plant to warehouses
2. From plant and warehouses to distant consumer
3. From plant and warehouses to local consumer
fixed (TL/X$) and var. cost (TL/ton-km)=
Current vehicle type =
Current vehicle number=
Current vehicle capacity=
Additional vehicle type =
Additional vehicle number=
Additional vehicle capacity=
VIII

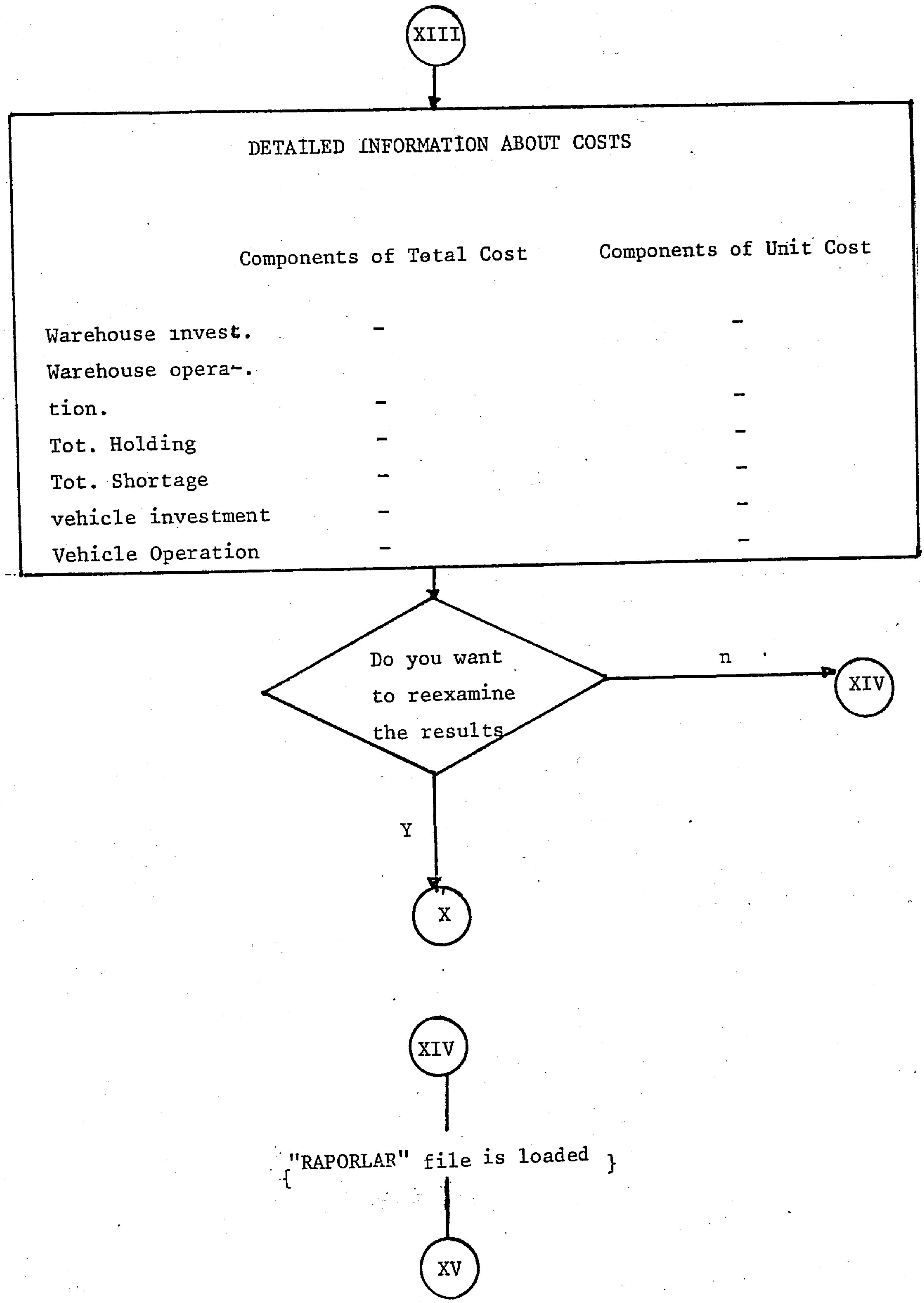

VIII
Inventory Holding Cost
(TL/ton- X $)
Shortage Cost
(TL/ton- X$)
II
6
Dar =
1
2
Is the analysis concern only the current period (y / n)
Y
Give the last sale percentage of shortage
n
1. Give the expected increase in demands till the corresponding period
2. Give the lost sale percentages of shortages
II
Delivery times
1. From plant to warehouses
2. From plant and warehouse to distant consumer
3. From plant and warehouse to local consumer
Delivery Times per Vehicle
Loading time (hour/travel)
Unloading time (hour/travel)
Waiting time (hour/trv)
Av. speed (km/h)
Cur.
Add.
II


7
Same as 6 when dar = 1
II
B
If ilk
≠ 0
Wrong step! You can analyse the current situation only once at the beginning
= 0
I
IX
Please wait (M2 is loaded) write "Run" when " ok " appears
ilk
≠ 0
D2
= 0
CURRENT SITUATION REPORT
Give the consumer sites currently served by means of a warehouse and the amount delivered (ton/X$)
Put " - " after the last consumer site served by each warehouse.
Warehouse
Cons. Site
Delivered Quantity
Warehouse
Cons. site
Delivered Quantity
CURRENT SITUATION REPORT
Give the consumer sites currently served directly from the plant and the amount delivered (ton/X$)
Put " - " after the last consumer site.
Plant
Consumer Site
Delivered Quantity
D 1


D 1
CURRENT SITUATION REPORT
D 2
ALTERNATIVE SITUATION REPORT
Criterion = (dar)
Trial number
On the same alter-
native = (dene(dar,alt))
X
total warehouse number =
Capacities (ton/X$) =
warehouse Name
capacity
Vehicles
Type
Number
Buy/Hire
From plant to ware-
houses
From plant and ware-
houses to distant con-
sumers
From plant and ware-
houses to local con-
sumers
Total Sales =


ACCORDING TO AVERAGE DEMANDS
Warehouse Name
Warehouse Name - - -
Stock Level
-
-
ACCORDING TO AVERAGE DEMANDS
Plant
Stock Level
-
Total shortage in Plant and Warehouses = (S L)
SL
= 0
XI
≠ 0
Consumer sites where shortages Occur
Cons. Site Name
Cons. Site Name - - -
Shortage level
-
-
XI


XI
Dar
= 1
SUMMARY REPORT
TOTAL COST
(TL / X $)
-
UNIT COST
(TL/ton-X$)
-
INVESTMENT
(TL/X$)
-
XII
= 2
SUMMARY REPORT
Total Cost
(TL / X $)
-
Unit Cost
(TL/ton-X$)
-
Investment
(TL/ X $)
-
Delivery times
Hour
day
From plant to warehouses - -
From plant and warehouses to distant consu. - -
From plant and warehouses to local consu. - -
XII
Do you want detailed
Information
n
XIV
Y
XIII

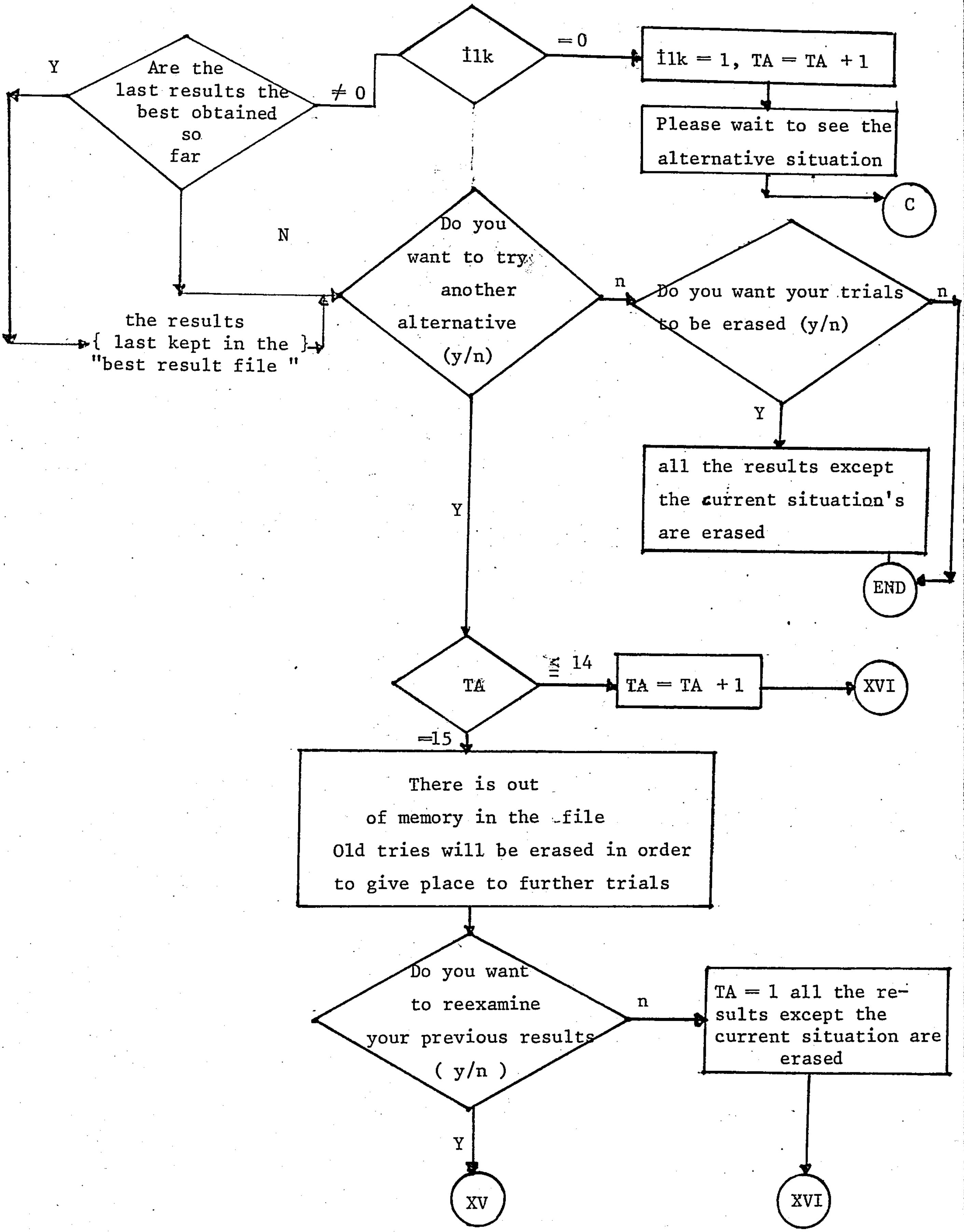

XIII
DETAILED INFORMATION ABOUT COSTS
Components of Total Cost
Components of Unit Cost
Warehouse invest.
Warehouse operation.
Tot. Holding
Tot. Shortage
vehicle investment
Vehicle Operation
Do you want to reexamine the results
n
XIV
Y
X
XIV
"RAPORLAR" file is loaded
XV

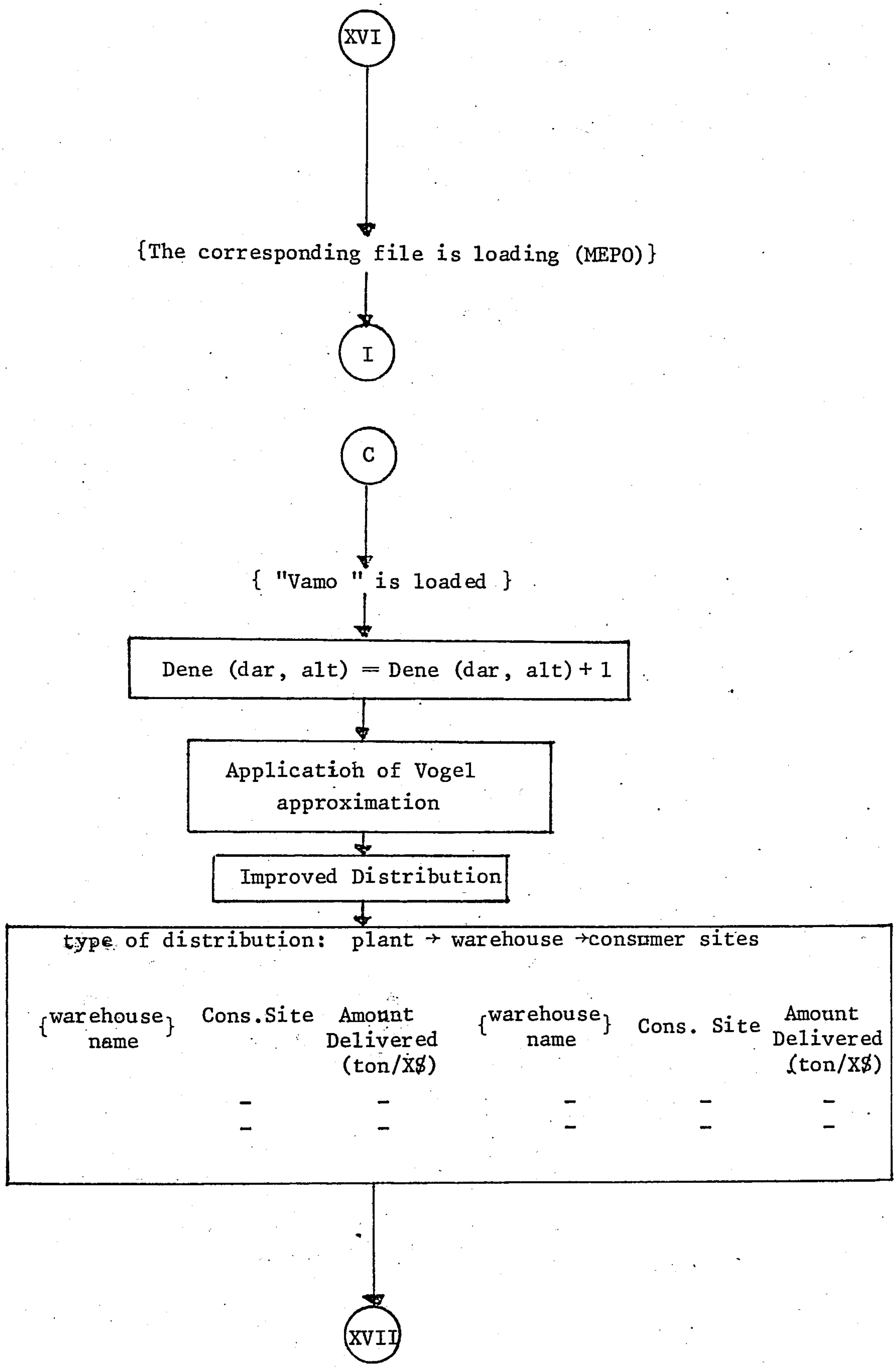
XV

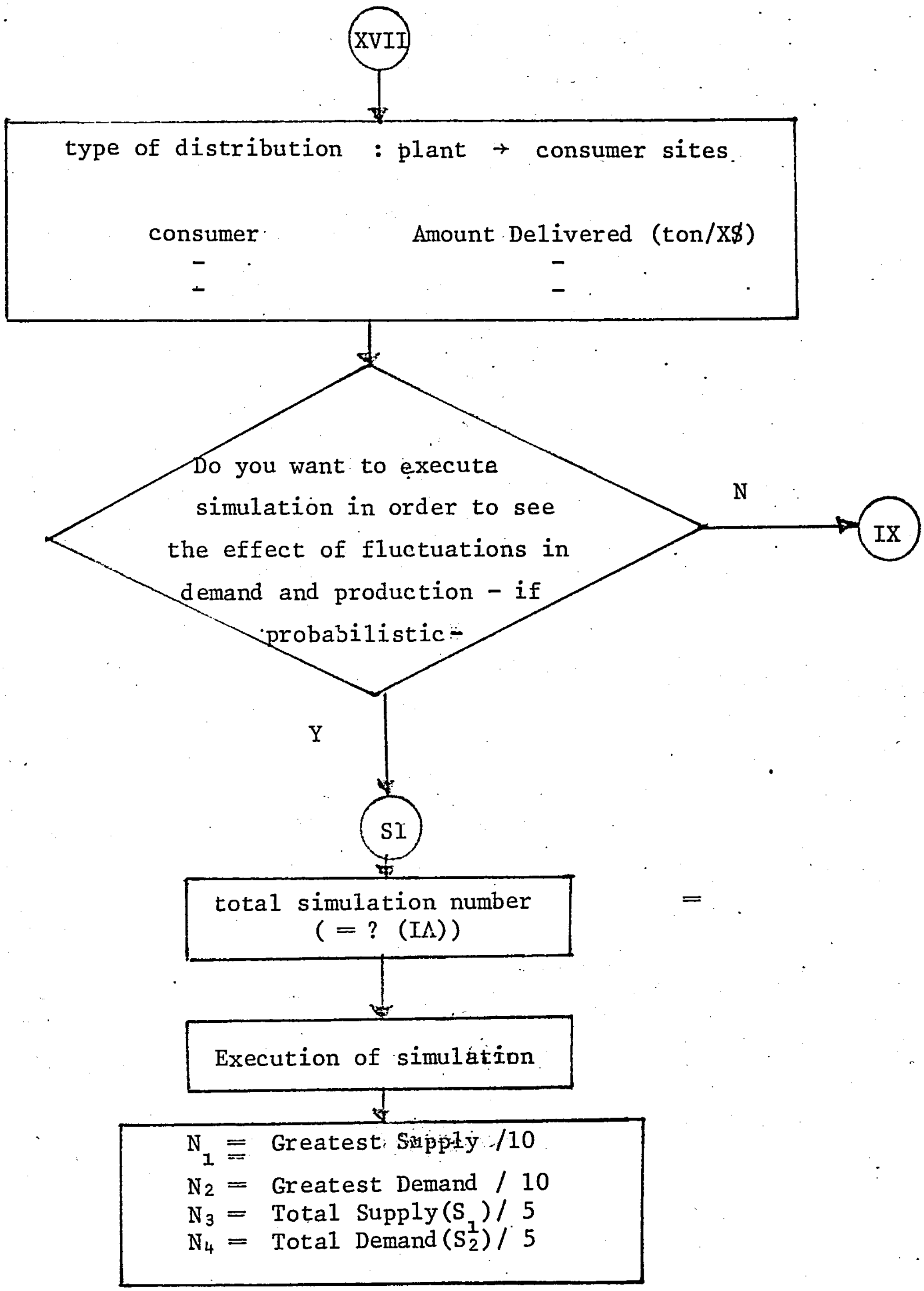
PRESERVED SUMMARY RESULTS

Explication : P : plant, W : warehouse, OCS : distant consumers, ICS: local consumers

Trial No : (TA)		Warehouse Capacities 0 1 2 3 4 5 6	Tot. Cost.	Delivery Times(day) P→W Pand W→OCS Pand W→ICS
0	{name}	—	—	—
	{capacity}	—	—	—
1	{name}	—	—	—
	{capacity}	—	—	—
—		—	—	—
—		—	—	—
—		—	—	—


Y
Are the last results the best obtained so far
≠ 0
Ilk
= 0
Ilk = 1, TA = TA + 1
Please wait to see the alternative situation
C
N
Do you want to try another alternative (y/n)
n
Do you want your trials to be erased (y/n)
n
the results last kept in the "best result file "
Y
all the results except the current situation's are erased
Y
END
TA
≦ 14
TA = TA + 1
XVI
=15
There is out of memory in the file
Old tries will be erased in order to give place to further trials
Do you want to reexamine your previous results (y/n)
n
TA = 1 all the results except the current situation are erased
Y
XV
XVI


XVI
{The corresponding file is loading (MEPO)}
I
C
{ "Vamo " is loaded }
Dene (dar, alt) = Dene (dar, alt) + 1
Application of Vogel approximation
Improved Distribution
type of distribution: plant → warehouse →consumer sites
{warehouse name}
Cons.Site
Amount Delivered (ton/X$)
{warehouse name}
Cons. Site
Amount Delivered (ton/X$)
XVII


XVII
type of distribution : plant → consumer sites
consumer
Amount Delivered (ton/X$)
Do you want to execute simulation in order to see the effect of fluctuations in demand and production - if probabilistic -
N
IX
Y
S1
total simulation number (= ? (IA))
Execution of simulation
N1 = Greatest Supply /10
N2 = Greatest Demand / 10
N3 = Total Supply(S1)/ 5
N4 = Total Demand(S2)/ 5

The Ratios of inventory in plant and warehouses

	$(N_1 - 2N_1)$	$(2N_1 - 3N_1)$	$(3N_1 - 4N_1)$	$(4N_1 - 5N_1)$
{Plant name}	-	-	-	-
{Depot name}	-	-	-	-

The ratios of shortage level in consumer sites

	$(N_2 - 2N_2)$	$(2N_2 - 3N_2)$	$(3N_2 - 4N_2)$	$(4N_2 - 5N_2)$
Cons. Site's	-	-	-	-
{ name }	-	-	-	-

THE PROBABILITY DISTRIBUTION OF SUPPLY DURING THE SIMULATION

Average Total Supply Defore Simulation : (SI)

	Probability
$(S_1 - 3N_3) \leq$ Supply $(S_1) < S_1 - 2N_3$	-
$(S_1 - 2N_3) \leq$ Supply $< S_1 - N_3$	-
$(S_1 - N_3) \leq$ Supply $< S_1$	-
$(S_1) \leq$ Supply $< S_1 + N_3$	-
$(S_1 + N_3) \leq$ Supply $< S_1 + 2N_3$	-

THE PROBABILITY DISTRIBUTION
OF DEMANDS DURING SIMULATION

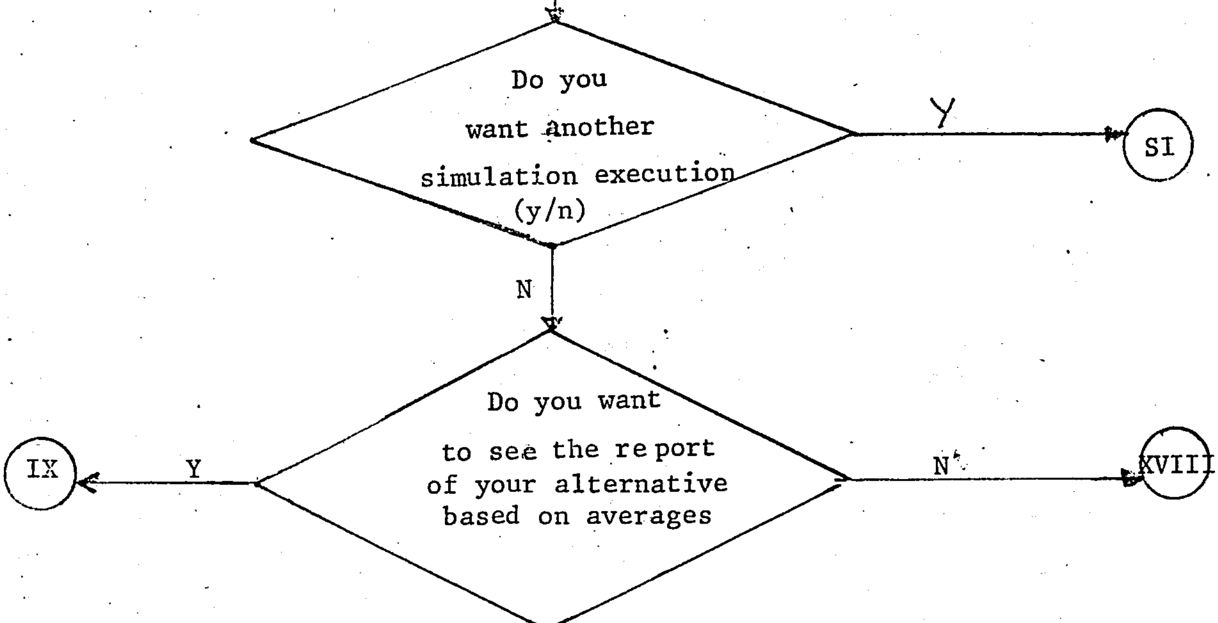
Average Total Demand Before Simulation : (S_2)

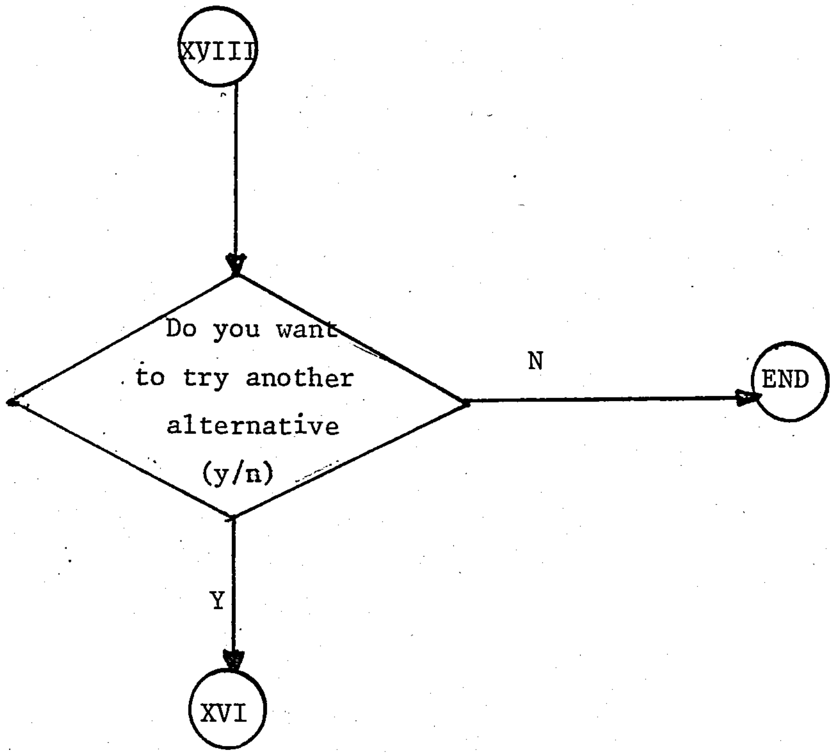
	Probability
$(S_1 - 3N_4) \leqq (S_2) < (S_2 - 2N_4)$	–
$(S_2 - 2N_4) \leqq (S_2) < (S_2 - N_4)$	–
$(S_2 - N_4) \leqq (S_2) < (S_2 \quad)$	–
$(S_2 - \quad) \leqq (S_2) < (S_2 + N_4)$	–
$(S_2 + N_4) \leqq (S_2) < (S_2 + 2N_4)$	–

DEMANDS AT THE END
OF THE
SIMULATION

	At the beginning of sim.	At the end of sim.
{Consumer Site's}	–	–
name	–	–

Average Sales :




XVIII
Do you want to try another alternative (y/n)
N
END
Y
XVI

A P P E N D İ X B

D I S K E T T E


FLEXIBLE DISK
uteplus
uteplus
FD34-4001-31345
DS/DD, 77 tracks, soft
One Year Warranty
Purchase Date:

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