ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

EVALUATION OF SOME HEURISTIC LOOK AHEAD RULES FOR MULTIPLE TERMINAL DELIVERY PROBLEMS

by

ROBERT WILLIAM HERING

B.S., Kansas State University, 1968

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

Approved by:

Major Professor

ACKNOWLEDGMENTS

Sincere gratitude goes to Dr. Frank Tillman for the excellent guidance and patience he extended during this research. Sincere thanks also goes to Dr. Said Ashour, Drs. Gene and Doris Grosh, and Professor Jake Smaltz for their help and guidance during my graduate course of study. Gratitude also goes to Mr. Glen Ferleman whose encouragement prompted me to continue my education.

This research was sponsored by a National Science Foundation Grant.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

BACKGROUND AND PURPOSE

One of the major contributors to the United States present level of national economy has been the development of the transportation system. The trucking industry has played a very important role in the development of this vast system. Trucks are used to transport, at least part of the way, approximately three out of every four tons of goods moved commercially in the United States [11]. Within the cities, virtually all the goods moved locally are transported by trucks. They are also used to haul more than 29 billion intercity ton-miles, which is about 38% of the nations intercity freight tonage, and approximately 22% of the total ton-miles transported in the United States. (A ton-mile is a load of one ton transported a distance of one mile).

The trucking industry alone has total expenditures (including wages) of more than $42 billion a year [11]. School bus expenditures for operation and maintenance of the nation's school transportation system exceeds $486 million dollars annually [7]. Add to these figures the expenditures of the railroads, airlines, and water-way shipping and the nations total transportation expenditures would amount to several hundred billion dollars annually.

This tremendous annual expenditure for transportation alone indicates the need to develop methods for reducing the cost of transportation for an industry, school system, or commercial trucking company.

One particular problem which has attracted a great deal of interest is that of finding an optimum solution to a class of problems called the delivery problem. The delivery problem is a combinatorial problem that is easily stated but extremely difficult to solve. The general delivery problem can be stated as one of determining a route or system of routes for a fleet of delivery vehicles from one or more terminals such that all customers demands are satisfied and an objective function (total miles, cost, etc.) is optimized subject to the restrictions (route or vehicle) which may be imposed upon the system.

The general delivery problem can be classified into three distinct sub-problems as shown in Figure 1: the single terminal, multiple terminal, and line haul delivery problems, each with deterministic or probabilistic demands. A discussion of the various methods and formulations for solving the deterministic single and multiple terminal delivery problems will be presented in chapters two and three respectively.

The purpose of this study is to evaluate the various methods proposed for the solution of large practical single and multiple terminal delivery problems. In addition, the selection criteria involving a look ahead feature will be evaluated. This feature will be considered for the following types of carrier routing problems:

(1) Single terminal problem

The selection criteria considered will consist of looking at a three branch decision tree for each of a given number of feasible alternative choices (where an alternative is a pair of demand points being considered for linking) before selecting the "best" alternative for linking at that iteration. The first alternative considered is the pair of demand points which have the maximum savings in

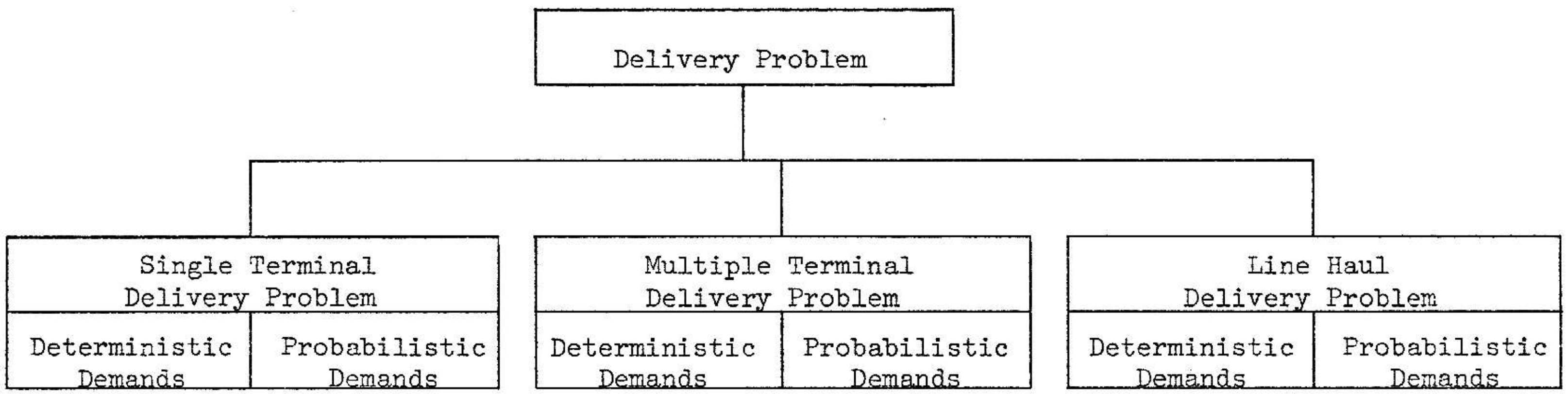

Figure 1: The Delivery Problem.

distance if they are linked. The second alternative is the pair of demand points with the second highest savings in distance. The third alternative is the pair of demand points with the third highest savings etc., until the desired number of alternatives have been selected. Each branch of the decision tree for a given alternative, in effect, considers the consequences of three feasible sequential future decisions.

(2) Multiple terminal problem

The selection criteria considered also consists of looking at a three branch decision tree for each of a given number of alternative choices at each iteration before selecting the "best" alternative for linking at that iteration. Each alternative to be considered is the same as in the single terminal problem.

Several single and multiple terminal problems will be solved so that the various versions of the look ahead feature can be evaluated and a comparison can be made with the solutions by other methods. The problems constructed will consist of twelve problems for each sub-problem. The twelve problems for each case will be divided into five small problems, each with ten demand points, five medium-sized problems, each with twenty-five demand points, and two large problems, each with fifty demand points. For the multiple terminal problems the ten demand point problems will have three terminals, and for the twenty-five and fifty demand point problems there will be five terminals.

The solutions to these problems for the various alternatives will be evaluated in the hopes that some guidelines can be developed for using the look ahead feature, considering the number of alternatives to evaluate for the various sizes of problems.

CHAPTER II

THE SINGLE TERMINAL CARRIER ROUTING PROBLEM

PROBLEM

The problem classified as the single terminal delivery problem, which will be discussed in this chapter, has been titled the "truck dispatching" or "carrier routing" problem. It is basically one of determining routes for a fleet of carriers, delivering a homogeneous commodity from a single terminal to a geographical array of demand points, such that the total miles traveled is minimized. In solving this problem the methods suggested require the following conditions to be satisfied;

(1) The distance matrix is symmetrical.

(2) The demand at each demand point is assumed known and must be fulfilled.

(3) A given demand point must not appear on more than one route.

(4) The carriers may have different carrying capacities which are assumed known.

(5) The routes to be determined must all be either "pick up" or "delivery" routes and not both.

Until recently the method used to solve this type of problem was trial and error. An experienced man would sit down with a map, knowing the demands and the capacities of the carriers, and by trial and error try to find the routes which would give the minimum miles traveled consistent with the available carrier capacities.

More recently, several algorithms have been developed for solving this problem.

SURVEY OF THE LITERATURE

The single terminal carrier routing problem, as stated above, is regarded as a generalization of the classical traveling salesman problem which can be stated as: Find the minimum distance route for a traveling salesman who starts from home, visits each of n specified cities only once, and returns to his home.

If in the carrier routing problem, the carrier had an infinite capacity the problem would reduce to the classical traveling salesman problem. Likewise, if the traveling salesman must return to his home after visiting t $(t<n)$ cities, then the problem would resemble the carrier routing problem.

The principle methods which have been proposed since 1959 for the solution of the single terminal carrier routing problem are branch and bound [16], and [24], simulation [5], and [22], integer programming [1], and heuristic programming [6], [7], [10], [13], [15], [16], [26], and [27].

Discussion and Evaluation of the Proposed Methods

The paper by Pierce [24] gives a good discussion of some of the proposed methods of solution. Pierce proposes a branch and bound solution to the classical traveling salesman problem using a modification of Little's et. al. [19] proposed method. Using this to illustrate the basic ideas of combinatorial programming, he uses this framework to extend the ideas to different variations of the single terminal carrier routing problem which include delivery time constraints, capacity, and other carrier constraints. In the various problem formulations, Pierce discusses the feasibility, dominance and bounding considerations, and other criteria employed during the problem solving process. The problem solution proceeds from a feasible solution to successively better and better solutions such that if the procedure is carried out to completion the optimum solution, if one exists, is found. Pierce does not solve any example problems nor does he indicate the time required to find a solution, or if solutions can be found for large practical problems.

Hayes [16] also gives a discussion of the various proposed methods of solution for the delivery problem and develops a branch and bound algorithm in which he uses a direct extension of the branch and bound algorithm of Little, et al. [19], developed for solving the traveling salesman problem. In his algorithm, Hayes incorporated two of the possible modifications which were suggested by Little, et al. The first was a "go to the right" modification which enabled more nodes to be examined with decreased computation time. Since the size of the tree grew so fast with an increase in the number of customers, the second modification was a "throw away the tree" modification which was essentially a further modification of the "go to the right" method. This modification reduced the number of nodes which had to be stored in memory during the solution process. The author reported that the "throw away the tree" method was the most efficent of the two methods but that neither method is capable of handling larger problems which contain greater than fifteen to twenty customers.

The prospects of developing a branch and bound algorithm with a backtracking feature, which could guarantee an optimal solution, was attractive enough to justify research on such an algorithm at the present time in the department of Industrial Engineering at Kansas State University. At the present, the research has not reached a stage of development such that a statement can be made as to its practicability except that it does show promise.

Knight and Hofer [18] presented a manual method for a more generalized carrier routing problem as a result of consulting work performed for a contract transport firm in London. This method was more concerned with deciding the best possible way to allocate a given work load to a number of vehicles than with finding the minimum distance routes through the set of points. The vehicles in this company were used for collecting and delivering small consignments according to a strict schedule, which varys for the different days of the week but repeats itself from week to week. The method concentrates primarily on allocating the jobs to the vehicles so that idle time was minimized, with the sequencing of jobs on a specific carrier emerging as a by-product of the allocation procedure [18]. This method (as can be seen) is for a little different version of the carrier routing problem than the one being considered herein, therefore, this method was not considered further.

Newton and Thomas [22] used a different approach to the problem in considering the school bus routing problem. Their method consisted first of finding a solution to a classical traveling salesman problem having the same distance matrix using a near-optimum method of solution and then partition this one route into individual routes conforming to the carrier capacity restrictions. Two valid criticisms of this method was pointed out by Hayes [16]. First, there is no reason to suspect beforehand that a system of routes which would minimize the total distance traveled could be partitioned from an optimal traveling salesman route let alone from a near-optimal one. Secondly, Hayes gives an example to show the existence of problems in which their proposed solution would not come anywhere close to the optimum solution. Therefore, in light of these faults, this method of solution was not pursued for possible modifications.

A simulation approach to the carrier routing problem was formulated by Braun [5]. The procedure starts with a random generation of the order of stops and then loads the carriers by dispatching an available carrier with sufficient capacity to the first permuted demand point which has not been assigned to a previous vehicle. A sub-matrix of distances is then formed for each carrier and a traveling salesman algorithm is applied to each sub-matrix. Several problems were solved which had been solved previously by other methods of solutions so that a comparison could be made. In all the problems except one, the solutions obtained by existing heuristic programming methods of solution, discussed below, were "better", where better indicates lower mileage and fewer vehicles. It was also noted that as the problem size increased, poorer approximations to the minimum were obtained using the proposed simulation procedure. This does not rule out simulation as an effective method of solution to the carrier routing problem, but it was felt that further research in this area was not justified in light of the success of the existing heuristic programming algorithms.

Balinski and Quandt [1] developed an integer programming solution to the carrier routing problem which used a 'cutting plane' algorithm developed by Gomory [14]. At the present time, integer programming solutions seem to be limited to small size problems. The method becomes undesirable as the number of customers increase since for relatively small problems the number of variables needed becomes quite large.

The first heuristic programming formulation was proposed in 1959 by Dantzig and Ramser [10] which produced near-optimal solutions. The algorithm first assigns each demand point to a route of its own and then proceeds by synthesizing pairs of routes stage by stage into single routes using the distance matrix to detect likely links based upon distance saved. The first stage synthesis is made according to the constraint that the total quantity required for the pair does not exceed $C/2^{N-1}$, where N is the total number of stages that will be required. The resulting synthesis of the first stage becomes the inputs to the second stage and the resulting syntheses of the second stage become the inputs to the third stage, etc. until at the final stage the resulting syntheses define the completed routes. At each subsequent stage a classical traveling salesman problem must be solved in order to maximize distance saved so that at the final stage the minimum route length is given.

Clarke and Wright [6] felt that Dantzig and Ramser gave too much emphasis to vehicle loading and not enough emphasis to minimizing total distance traveled, therefore, they formulated a modification of the algorithm to shift the emphasis to minimizing total distance traveled. To do this, they removed the $C/2^{N-1}$ constraint applied in the first stage and replaced it with a requirement that simply specified that the capacity C was not to be exceeded at any stage. The algorithm also starts by assigning each demand point to a route of its own. Routes are then combined stage by stage by maximizing the savings (computed from the distance matrix) achieved by linking two of these routes, subject to the capacity constraints. Thus, the final solution is achieved by combining smaller routes and single customers into single larger routes until no further savings can be achieved. This method produced better solutions than Dantzig and Ramser's algorithm. This solution can be improved by solving a classical traveling salesman problem for each route. This method is also feasible for solving large practical carrier routing problems.

Gaskell [13] performed a comparative study of a visual (trial and error) method, a multiple:savings method, which was Clarke and Wright's method, a savings:sequential method, and two other methods he developed which he called λ:multiple method and π:multiple method. In these last two methods, he based the measures of priority on distance measures rather than savings such that both are symmetrical functions. Gaskell concluded that criteria other than the savings were sensible measures of priority for forming routes and that the multiple approach method, such as the Clarke and Wright method, was superior to the sequential method.

In 1967, Cochran [7] formulated a modification of Clarke and Wright's method which added a truck reassignment routine, and a route restriction on the total miles that could be traveled on a given route to show that additional restrictions could easily be added. The truck reallocation modification was designed to utilize 'freed' carriers which had been displaced from the initial allocation by a new combination of demand points, by reassigning the carriers displaced to loads after each pair of demand points were combined [7]. Each new combined demand was then assigned to the carrier of the smallest capacity which was capable of carrying this demand. This modification proved to make better utilization of the available carriers. The modified algorithm also proved effective in solving problems with the restriction limiting the total miles that could be traveled on a given route.

Hayes [16] also developed a heuristic programming algorithm which is quite similar to the simulation algorithm developed by Braun [5]. He describes his algorithm as a cross between a pure random method and a simulation of the method an experienced dispatcher would employ. The "beginning customers" are initially chosen from certain customers at a great distance from the central terminal or warehouse and all other customers are given scores relative to the "beginning customer". Routes are then formed by placing customers, in the same general area as the "beginning customer", starting with the customer with the highest score and continuing until the carrier capacity is met. While constructing the routes, care was taken not to isolate customers causing another route to have a much higher cost because of the necessity of serving that customer [16]. Each of the routes formed are then optimized with regard to miles traveled by solving a classical traveling salesman problem. This process is repeated a large number of times and the solutions obtained at one stage are compared to the previous solutions and the better solution of the two is saved. The algorithm was developed to solve problems in which the single terminal or warehouse was located in the center of the scatter of customers. This approach proved to be disadvantageous when solving problems which did not meet this restriction.

Another heuristic programming method somewhat similar to Hayes' method was proposed by Tyagi [27]. The algorithm starts by first determining N, which is the number of routes needed to make all the deliveries to the given demand points and is computed according to the capacity of the carriers and the total amount of deliveries to be made. The given demand points are then divided into N groups which are formed by selecting the first point and adding other points according to their proximity to the previously selected point. This is continued until the inclusion of one more point would exceed the capacity of the carrier. The other (N-1) groups are constructed in the same manner. This optimum route for each grouping is then found by solving a classical traveling salesman problem. The author reports satisfactory solutions were obtained using the algorithm but only conjectured as to the algorithms ability to handle large practical problems.

The last heuristic programming procedure which can be found in the literature is an algorithm developed by Tillman and Cochran [26] which included a look ahead feature for the selection of points on a route. Extension of this work is the basis for the present work. This algorithm will be discussed in more detail in the next section.

Thus, from the above discussion, it appears that the methods based on heuristic programming are the only algorithmic approaches at the present time that are computationally feasible for solving large practical problems.

For this reason, the following study was undertaken for improving the selection criteria of the heuristic method which was proposed by Tillman and Cochran [26]. Their algorithm will be discussed in detail in the following section, followed by a section suggesting improvements in the algorithm.

TILLMAN AND COCHRAN METHOD

The algorithm by Tillman and Cochran [26] is a modification of the method proposed by Clarke and Wright [6]. The present method incorporates a vehicle reassignment modification and proposes a look ahead feature in an attempt to find a better solution to the single terminal carrier routing problem.

For the purpose of providing the reader with the necessary background, a discussion of the development of the algorithm is presented in the next section. The terms used in the discussion are as follows:

P_i = demand point i, where P_0 denotes the terminal.

$d_{i,j}$ = distance between demand points P_i and P_j.

d_j^0 = distance between terminal P_0 and demand point P_j.

q_i = demand at point P_i.

C_n = carrying capacity of the nth vehicle.

$t_{i,j}$ = index used to indicate whether the demand points P_i and P_j are connected to constitute a link.

Development of the Algorithm

The original development was presented in the paper by Clarke and Wright [6] and was later modified by Tillman and Cochran [26] who felt that several major points were not fully explained.

Initially it is assumed that the demand points P_i, P_j, and P_k are linked only to the terminal P_0, as shown in Figure 2. Three trucks are initially assigned such that each truck travels from the terminal to a demand point and back to the terminal in order to deliver the commodity

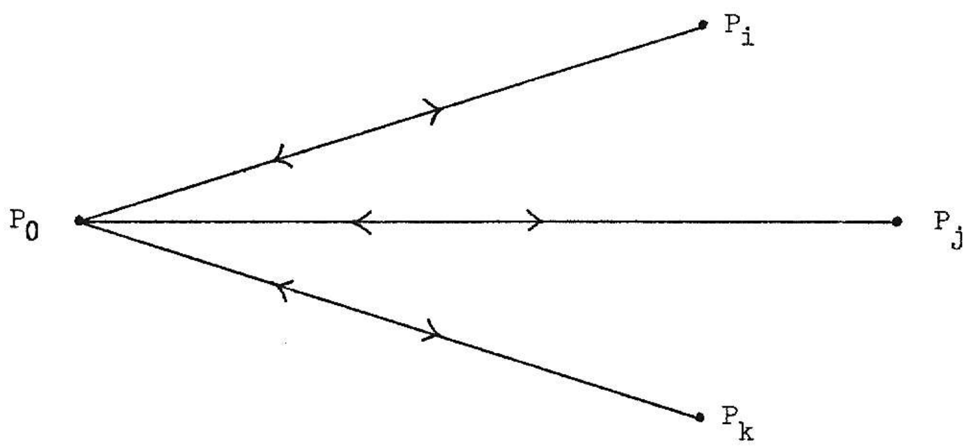

Figure 2: Initial assignment of points on routes.

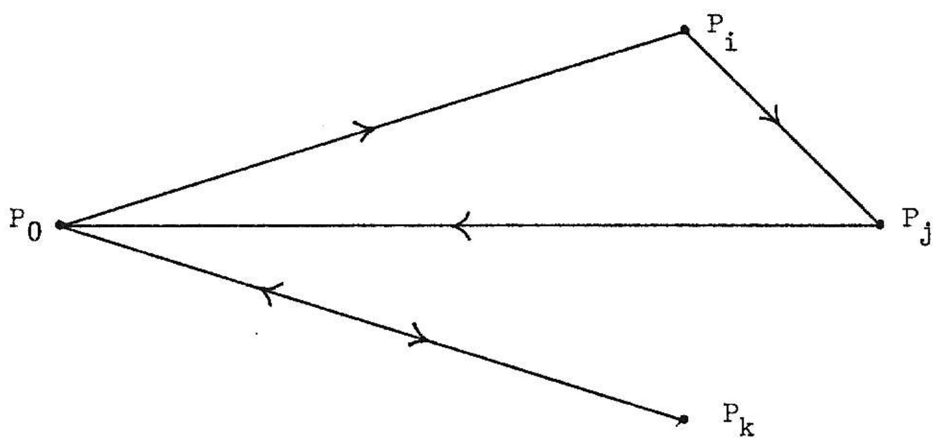

Figure 3: Routes formed as results of linking P_i and P_j.

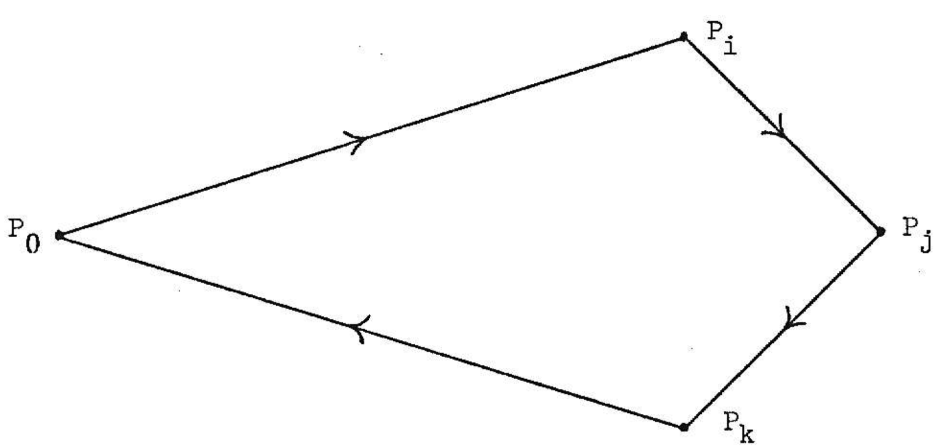

Figure 4: Route formed as result of linking P_j and P_k.

required at that demand point. The direction of travel of these three trucks are indicated by the arrows. The total distance traveled on all routes for this initial assignment is

$$2\ d_i^0 + 2\ d_j^0 + 2\ d_k^0, \tag{1}$$

where the superscript denotes the terminal and the subscript denotes the demand point.

If the demand points P_i and P_j are linked and one link from the terminal to P_i and one link from the terminal to P_j are severed, then the resulting routes would be as shown in Figure 3. The total distance traveled for all routes in this assignment would be

$$d_i^0 + d_{i,j} + d_j^0 + 2\ d_k^0 \tag{2}$$

which is a savings over the initial assignment of

$$d_i^0 + d_j^0 - d_{i,j} \tag{3}$$

The two trucks which were initially assigned to exclusively serve demand points P_i and P_j are removed and a truck of sufficient capacity to carry the combined demand for the two points is assigned to this newly formed route.

The route in Figure 4 is obtained from the routes in Figure 3 by linking demand points P_j and P_k and severing one link from the terminal to P_j and one link from the terminal to P_k. The resulting assignment has a total distance for all routes of

$$d_i^0 + d_{i,j} + d_{j,k} + d_k^0, \tag{4}$$

which is a savings over the previous routes of

$$d_j^0 + d_k^0 - d_{j,k}. \tag{5}$$

In this assignment, the truck previously assigned to serve the route containing the demand points P_i and P_j and the truck exclusively serving demand point P_k are removed, and a truck with sufficient capacity to carry the combined demands of the three points is assigned to this resulting route.

Thus, the savings resulting from linking any two demand points P_i and P_j to a terminal, P_0, can be calculated using the general equation

$$S_{i,j}^0 = d_i^0 + d_j^0 - d_{i,j}. \tag{6}$$

This equation is used to calculate the savings for each pair of points in the problem. These savings are then used to determine the "best" routes consistent with the truck availability and capacity constraints that would optimize the objective function.

In this method, a given demand point can only be linked at most to two other points, one of which may be the terminal. Thus, whenever a given demand point is linked to two other demand points, it is not considered for further linking.

The Algorithm

The step by step computational procedure presented by Tillman and Cochran [26] will now be given using an example problem to illustrate the method.

Step 1.

The first step of the computational procedure is the assigning of identification numbers to the demand points and filling the distances, $d_{i,j}$, in the distance matrix. For an N demand point problem, the demand points P_i $(i=1,2,\ldots,N)$ are numbered such that demand point 1 is closest to the terminal, demand point 2 is next closest and so forth. The distance between two given demand points is located in the lower right-hand corner of the cell. The particular cell containing the distance between demand points P_i and P_j is located by reading down column P_i and across P_j. The first column of the distance matrix contains the distances, d_i^0, from the terminal P_0 to each demand point P_i.

Step 2.

The second step of the computational procedure involves the calculation of the savings matrix. The savings obtained by linking two given demand points is calculated from equation (6) and entered in the lower left-hand corner of the appropriate cell in the distance matrix.

The completed distance matrix for the sample problem containing six demand points is shown in Table 1. This problem was originally presented by Tillman and Cochran [25].

Step 3.

The third step involves the formulation of the initial computational matrix using the same format used to construct the distance matrix. A column vector $Q = (q_1, q_2,\ldots,q_N)$ is added on the left-hand side of this matrix and initially contains the quantity, q_i, which is required at demand point P_i $(i=1,2,\ldots,N)$. The remaining cells contain the values of the index $t_{i,j}$ which indicate whether the demand points are connected and

P_0						
38	P_1					
42	45 35	P_2				
56	72 22	65 33	P_3			
63	47 54	83 22	74 45	P_4		
64	64 38	79 27	100 20	98 29	P_5	
80	56 62	84 38	71 65	121 22	99 45	P_6

Table 1. Distance matrix showing the distances in lower right-hand corner of each cell, and savings in lower left-hand corner of each cell.

Q	P_0						
7	2	P_1					
9	2		P_2				
8	2			P_3			
7	2				P_4		
6	2					P_5	
5	2						P_6

Table 2. Initial basic solution matrix with the initial Q vector.

Capacity	12	15	18
Available	2	1	1
Assumed Available	∞	1	1
Assigned	6	0	0

Table 3. Initial truck availability and assignment table.

constitute a link. The values of the index $t_{i,j}$ will always be 0, 1 or 2 according to the three possibilities such that

(a) the index $t_{i,0} = 2$ if the demand point P_i is served exclusively by a truck from the terminal,

(b) the index $t_{i,j} = 1$ if the demand points P_i and P_j are linked on a route,

(c) the index $t_{i,j} = 0$ if the demand points P_i and P_j are not linked.

It is assumed in the initial solution that the demand points P_i are linked only to the terminal, therefore, all $t_{i,0} = 2$ $(i=1,2,\ldots,N)$ and all the remaining cells have a value $t_{i,j} = 0$. It was noted above that a given demand point can only be linked at most to two other points, one of which may be the terminal P_0, therefore, the following relationship always exists:

$$\sum_{j=0}^{k-1} t_{k,j} + \sum_{i=k+1}^{N} t_{i,k} = 2 \quad (k=1,2,\ldots,N), \tag{7}$$

i.e., the sum of the $t_{k,j}$'s along the kth row plus the sum of the $t_{i,k}$'s down the kth column must always equal 2. During the computational procedure the values of $t_{i,j}$ are adjusted after each pair of points are linked such that equation (7) holds. This also provides a method of recording the routes formed as the algorithm progresses.

The initial computational matrix constructed for the example problem is shown in Table 2. The blank cells in the matrix indicate that the value of $t_{i,j} = 0$.

Step 4.

The fourth step is concerned with the initial assignment of trucks to the demand points which were assumed to be linked only to the terminal. The quantities, q_i, required at each demand point P_i are assumed to be such that an initial assignment of one truck to each demand point is possible. The truck availability and assignment table is constructed such that the truck capacities, C_i, are ordered from the smallest to the largest (i.e., $C_i < C_{i+1}$ (i=1,2,...,n)). In cases where the quantity required at a given demand point is larger than the capacity of the largest available truck, the demand is split into one or more loads equal to the capacity of the largest truck and only the remainder of the requirement, which is less than the capacity of the largest truck, is considered during the solution process. This satisfies the assumption made above that all the demands are such that $q_i \leq C_n$, where C_n is the capacity of the largest truck. Whenever there are not enough trucks available to make the initial assignment of one truck to each demand point, "dummy trucks" with the capacity of the smallest truck are assumed to be available so that an assignment can be made. The algorithm emphasizes combining smaller loads into larger ones, therefore, a reassignment of the trucks previously assigned takes place after each pair of demand points are linked. This reassignment procedure appears in Step 9 of the algorithm below.

There are four trucks available in the example problem, two with 12 units of capacity and one each with 15 and 18 units capacity. The initial assignment of trucks discussed above would require 6 trucks which is more than are available, therefore, an infinite number of trucks with 12 units of capacity are assumed available. These extra trucks constitute the "dummy trucks" mentioned above. The initial truck assignment of six trucks of 12 units capacity and none with capacities of 15 and 18 units for the example problem is shown in Table 3.

Step 5.

An attempt is now made to link the demand points which result in the overall maximum savings by looking at the resulting savings for two successive feasible linkings before a linking is made. Recall that the Clarke and Wright method [6] was to select the cell with the largest savings which is feasible and link these two demand points at each iteration. This procedure may not result in the maximum overall savings. This is the reason for looking at the consequences of two successive linkings before deciding which pair of points should be linked. This method proceeds as follows:

(a) Select the cell with the maximum savings that can be feasibly linked and assume that this pair of points are linked.

(b) From the remaining cells after step a, select the cell with the remaining maximum savings that can be feasibly linked. Add the savings obtained in steps a and b and associate this savings with the first pair of points considered in step a.

(c) Disregard the actions of steps a and b and for the second alternative start over except this time select the cell with the second highest savings that can be feasibly linked. Assume that this pair of demand points are joined.

(d) From the remaining cells after step c, select the cell with the remaining maximum savings that can be feasibly linked. Add the savings obtained in steps c and d and associate this savings with the pair of points considered in step c.

(e) This procedure is continued for the third alternative starting with the third highest savings, until all feasible alternatives have been investigated in the problem.

The total savings associated with each alternative are searched to determine the maximum and the alternative (which is the first pair of demand points assumed linked in each case) associated with this maximum total savings is selected as the pair of demand points to be linked in this iteration.

For the six demand point example problem, the procedure according to Step 5 goes as follows:

(a) The cell containing the maximum feasible savings of 121 is $P_4 - P_6$. If these two points are assumed to be linked, they form the route $P_0 - P_4 - P_6 - P_0$ with a total distance of 165.

(b) The next highest feasible savings selected from the remaining cells is 100 for linking demand points P_3 to P_5. If these two points are assumed linked, the route $P_0 - P_3 - P_5 - P_0$ is formed with a total distance of 140. The total savings obtained for the two links is 221 and is associated with the first pair of points assumed linked in step a.

(c) Disregarding the routes formed above, start over by selecting the second highest feasible savings which is 100 for linking demand points P_3 to P_5. This happens to be the same route formed in step b.

(d) The next highest feasible savings which can be selected from the remaining cells is 121 for linking $P_4 - P_6$. This also happens to be the route formed in step a above. The total savings for steps c and d is 221 and is associated with the pair of points assumed linked in step c.

(e) By repeating the process for every feasible alternative in the problem, the total savings table for the first iteration is obtained as shown in Table 4.

It should be noted that the pair of points selected in steps a through c above, are selected subject to the conditions of Step 6 below.

Step 6.

The points selected to be joined in Step 5 must be tested to see if the restrictions listed below are satisfied before they can be feasibly linked. If the pair of points under consideration are P_i and P_j, then the restrictions which must be satisfied are:

(a) The values of the indexes $t_{i,0}$ and $t_{j,0}$ must be greater than 0 which indicates that the demand points are still linked to the terminal and these links are elgible to be severed.

(b) The demand points P_i and P_j must not already be on the same route. This prevents the forming of a "loop" that does not include the terminal.

(c) The combined quantities, q_i, required by the demand points P_i and P_j and any other demand points which may be on the same route must not exceed the capacity of the available trucks.

(d) Any additional truck and route restrictions placed upon the system must be satisfied before the given demand points are considered a feasible linkage.

If one or more of the above conditions are not satisfied, then this pair of points are excluded from further consideration and the process is repeated from Step 5.

Total Savings	221*	221	220	219	184	183	200	173	193	169	186	185	156	147	166
Link 1	P_4-P_6	P_3-P_5	P_5-P_6	P_4-P_5	P_2-P_6	P_2-P_4	P_2-P_5	P_3-P_4	P_1-P_3	P_3-P_6	P_2-P_3	P_1-P_5	P_1-P_6	P_1-P_4	P_1-P_2
Savings	121	100	99	98	84	83	79	74	72	71	65	64	56	47	45
Link 2	P_3-P_5	P_4-P_6	P_4-P_6	P_4-P_6	P_3-P_5	P_3-P_5	P_4-P_6	P_5-P_6	P_4-P_6	P_4-P_5	P_4-P_6	P_4-P_6	P_3-P_5	P_3-P_5	P_4-P_6
Savings	100	121	121	121	100	100	121	99	121	98	121	121	100	100	121

Table 4. Total Savings table for iteration 1.

For the sample problem, the alternative with the maximum total savings of 221 satisfies all the restrictions listed above, therefore, the pair of points linked in the first iteration are P_4 and P_6. Note also that the points P_3 and P_5 have the same total savings and could also be selected.

Step 7.

If all the conditions listed in Step 6 are satisfied by the pair of points selected in Step 5, then the demand points P_i and P_j are linked and the value of $t_{i,j}$ is set equal to 1 and the values of $t_{i,0}$ and $t_{j,0}$ are decremented by 1 such that equation (7) holds.

Step 8.

The Q vector containing the loads q_i required at the demand points P_i must be amended in two ways to indicate the linking of points P_i and P_j in the iteration. First, each q_i corresponding to the index value $t_{i,0} = 0$ is itself set equal to zero. Secondly, each q_i corresponding to the demand point linked on the newly formed route is set equal to the sum of the demand for all points on the route.

For the example problem, the adjustment of the initial solution matrix to record Steps 7 and 8 is shown in Table 5. Since the demand points to be linked in this iteration are P_4 and P_6, the value of $t_{4,6}$ is set equal to 1 to record the linking and the values of $t_{4,0}$ and $t_{6,0}$ are decremented by one such that $t_{4,0} = 1$ and $t_{6,0} = 1$. The combined load for the route is 12, therefore, q_4 and q_6 are set equal to 12.

Step 9.

This step involves the reassignment of trucks to cover the newly formed routes. The trucks previously assigned to cover the demand points P_i and P_j are removed and a truck of sufficient carrying capacity is

Q	P_0						
7	2	P_1					
9	2		P_2				
8	2			P_3			
12	1				P_4		
6	2					P_5	
12	1				1		P_6

Table 5. Computational matrix after completion of first iteration.

Capacity	12	15	18
Available	2	1	1
Assumed Available	∞	1	1
Assigned	5	0	0

Table 6. Truck assignment table after completion of first iteration.

assigned to cover this newly formed route, which includes the points P_i and P_j and any other points which may be on the route from previous iterations.

For the example problem, the trucks initially assigned to cover P_4 and P_6 are removed and a truck with capacity of 12 units is assigned to cover this new route since the combined load required on the newly formed route is 12 units (i.e., the maximum capacity truck required is still 12). This is illustrated in Table 6. If there are "dummy trucks" assigned when all the routes are formed, then some trucks must be assigned to serve several short routes.

Step 10.

This completes the first iteration. The procedure is repeated from Step 5 if there are more links possible with a positive savings which satisfy all the conditions listed in Step 6. If no more links are possible which satisfies all the conditions, then the final solution has been obtained. The routes formed and the exact order of visitation of the demand points on each route are determined by the values of $t_{i,j}$ from the final solution matrix and the final truck assignment is obtained from the final assignment matrix. The distance traveled on each route and the total distance traveled on all routes is calculated from the original distance matrix.

Two more iterations are required to find the final solution for the example problem. The demand points P_5 and P_6 are linked in the second iteration and the demand points P_1 and P_3 are linked in the last iteration. Tables 7, 8 and 9 illustrate the final solution matrix, the final truck assignment matrix, and the final routes and distances, respectively, for the problem.

Q	P_0						
15	1	P_1					
9	2		P_2				
15	1	1		P_3			
18	1				P_4		
18	1					P_5	
0	0				1	1	P_6

Table 7. Computational matrix after final iteration.

Capacity	12	15	18
Available	2	1	1
Assumed Available	∞	1	1
Assigned	1	1	1

Table 8. Truck assignment table after final iteration.

Route	Distance
P_0-P_1-P_3-P_0	116
P_0-P_2-P_0	84
P_0-P_4-P_6-P_5-P_0	194
Total	394

Table 9. Final route and distance table.

Clarke and Wright's method [6] gave a solution of 420 miles while this method gave a solution of 394 miles which is believed to be the optimum.

The above algorithm was programmed for the IBM 360 model 50 computer so that a comparison could be made with the proposed method which is presented in the next section.

Summary of the Algorithm

A summary of the basic steps in the computational procedure are listed below.

Step 1. Label the demand points P_i $(i=1,2,\ldots,N)$ such that demand point 1 is closest to the terminal, demand point 2 is next closest, etc., and fill in distance matrix (Table 1).

Step 2. Calculate the savings for each pair of demand points using equation (6) and enter them in the savings matrix (Table 1).

Step 3. Set up the initial computational matrix and enter the initial solution (Table 2).

Step 4. Make an initial assignment of one truck to each demand point if a feasible assignment is possible. If the assignment is infeasible split the demands or assume "dummy truck" available, whichever the case, to produce a feasible assignment (Table 3).

Step 5. Select the cell with the maximum feasible savings and assume this pair of points are linked. From the remaining cells, select the cell with the remaining maximum feasible savings. Add the saving for both pairs of points and associate it with the first pair of points assumed linked. Repeat the process for all possible feasible alternatives (Table 4). Select the alternative with the maximum total savings for linking in this iteration.

Step 6. Test the demand points selected to be linked in Step 5 to see if they meet the restrictions a through d stated earlier. If one or more of the conditions are not satisfied, exclude this pair of points from further consideration and return to Step 5.

Step 7. If the pair of points satisfy all the conditions, set $t_{i,j} = 1$ and decrement the values $t_{i,0}$ and $t_{j,0}$ by 1 such that equation (7) holds (Table 5).

Step 8. Amend the Q vector for the newly formed route (Table 5).

Step 9. Reassign the trucks to correspond to the new route (Table 6). This completes the first iteration.

Step 10. If there are more feasible links possible, repeat the procedure from Step 5. If no other feasible links are possible, the final solution has been found. Determine the formed routes and the exact order of visitation, the distances for each route, and the total distance for all routes (Tables 7, 8, and 9 respectively).

AN EXTENDED LOOK AHEAD APPROACH

General Remarks

The previous method of solution developed by Tillman and Cochran [26] was chosen for further study for the following reasons.

(1) As noted above, the methods based on heuristic programming appear to be the only algorithmic methods of solution that are computationally feasible for solving large practical problems.

(2) The procedure is simple and easily programmed on high speed digital computers while at the same time effective in producing a near-optimum solution.

(3) The possibility of formulating a better look ahead feature to obtain optimal or near-optimal solutions was attractive.

(4) One of the major criticisms given by Hayes [16] against the heuristic programming method developed by Clarke and Wright [6] was that once two demand points are linked on a particular route at a given stage it is not changed and it will appear in the final solution which may result in a suboptimal solution. It was felt that the development of an extended look ahead approach which requires considering the consequences of several choices in sequence for a number of alternatives before selecting the "best" alternative for routing would remove this criticism and at the same time produce better solutions. This has been somewhat substantiated by this study which is discussed below and the results are shown in Appendix II.

A computer program was written so that a solution could be obtained for either the single or multiple terminal carrier routing problem. A discussion of the computer program as well as the program itself is presented in Appendix I.

An Extended Look Ahead Selection Criteria

A discussion of the modifications which were made in the Tillman and Cochran method to improve the selection criteria which produces better solutions is presented.

Based on the experience with Tillman and Cochran's algorithm discussed above, it was felt that better solutions could be obtained if the selection criteria was extended to considering three different feasible branches for each alternative. This led to the development of the look ahead feature shown in Figure 5. A decision is first made as to the number of feasible alternatives which will be considered in each iteration for possible linkage. The alternatives are selected from the savings matrix (matrices for the multiple terminal problems discussed in chapter three) such that alternative one (a_{11}) is the pair of demand points with the maximum feasible savings, alternative two (b_{11}) is the pair of demand points with the second highest maximum feasible savings and so forth.

The next step of the extended look ahead selection criteria is to develop the decision tree for each alternative selected. This is done by selecting each alternative one at a time and assuming this pair of demand points are actually routed. The second point for each branch of a given alternative is selected from the savings matrix such that the pair of points in the first branch (a_{12} for the decision tree of

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

Max = Maximum feasible savings
Next Max = Second highest feasible savings
Next Next Max = Third highest feasible savings

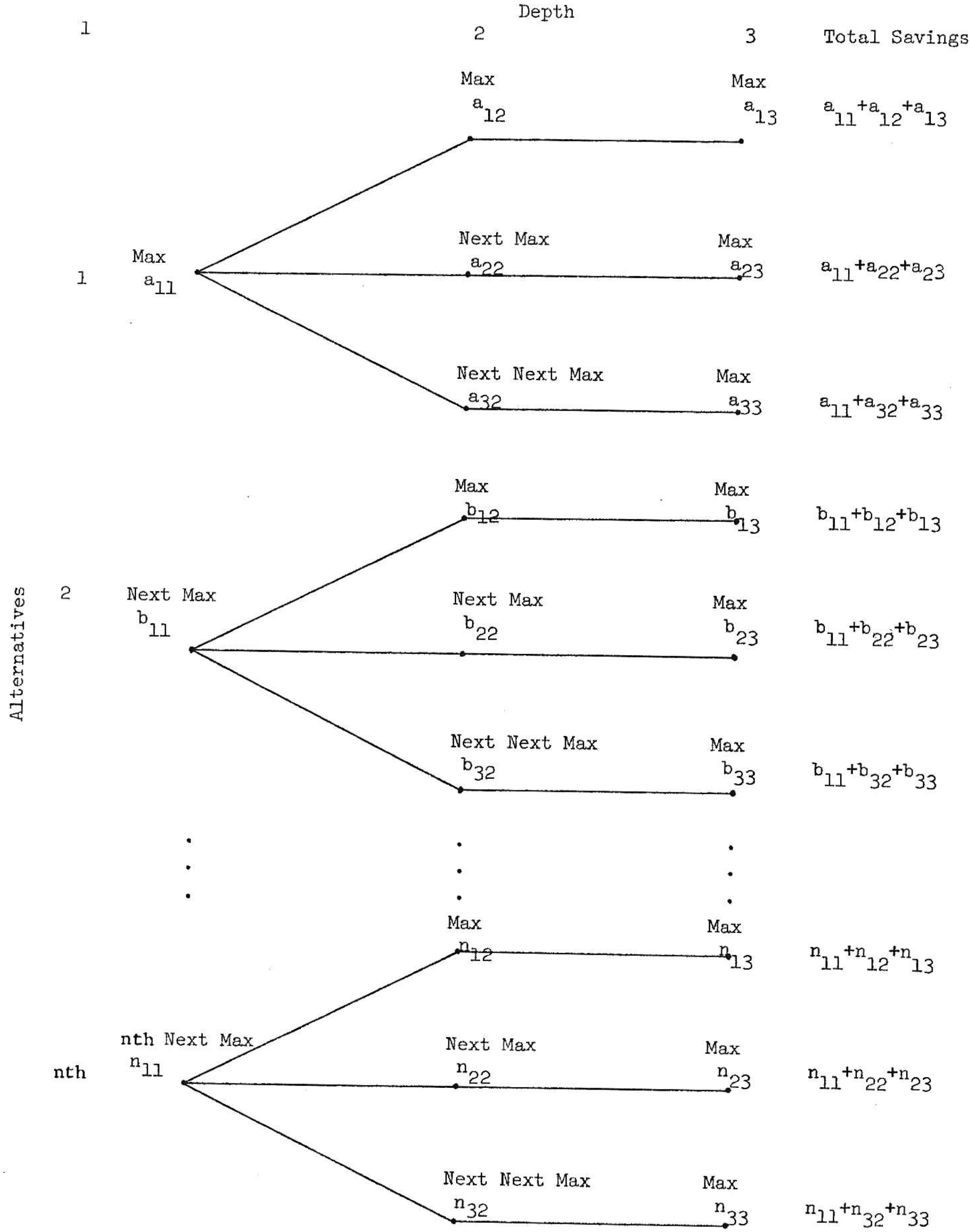

Figure 5: Decision tree for alternatives using the extended look ahead feature.

alternative one) have the maximum feasible savings, the pair of points in the second branch (a_{22}) has the second highest maximum feasible savings, and the pair of points for the third branch (a_{32}) has the third highest maximum feasible savings. Each of these pair of points is then assumed to be routed in sequence with the first pair of points. Each of the third pair of points on each branch is then selected such that this pair of points has the maximum feasible savings remaining in the savings matrices after the previous two assumed linkings in that branch (i.e., for the first branch of the decision tree of alternative one in Figure 5, the third pair of points (a_{13}) is selected such that this pair of points has the maximum feasible savings remaining in the savings matrix after the pair of demand points of a_{11} and a_{12} have been assumed linked in sequence). The total savings is then summed for each branch of the decision tree for a given alternative. In this study, the process was arbitrarily stopped after looking ahead for three decisions. This was due in part to the computer time required for large problems plus the fact it was felt that in most situations this would include the best solution. The maximum of the total savings for the branches is then selected for that alternative. The alternative which has the maximum total savings is then selected and the first pair of points of this branch is the pair of points to be routed in this iteration. The step by step procedure for this extended look ahead feature is given in Step 5 of the proposed algorithm listed below.

The Proposed Algorithm

Step 1.

The first step of the proposed algorithm is the same as the corresponding step in the algorithm of Tillman and Cochran except that it is not necessary to order the demand points according to their distance from the terminal. A decision regarding the number of alternatives which are to be considered in each iteration must be made at this point. When only one alternative is considered in each iteration, the solution procedure is the method of Clarke and Wright's [6]. The number of alternatives to be considered at each iteration is based upon the size of the problem. Hopefully this research will provide some guidelines for this number. In the computer program, provision was made for ten alternatives as the maximum number which can be considered at one time.

Step 2.

Calculate the savings for each pair of points using equation (6) and enter them in the distance matrix. This step is the same as the corresponding step of the previous method.

Step 3.

The third step involves the formulation of the initial computational matrix. This step is the same as the previous methods.

Step 4.

The fourth step of the proposed method consists of making the initial truck assignment assuming "dummy trucks" or splitting demands as necessary to make a feasible assignment. This step is the same as the previous methods.

Step 5.

An attempt is now made to link the demand points which result in the overall maximum savings by looking at the resulting savings of three different branches for each feasible alternative (the number of alternatives to be considered is stated in Step 1; see Figure 5) before a decision is made as to which pair of points is to be linked in this iteration. Each branch, in effect, considers three future linkings for each given alternative.

If the number of alternatives to be considered in each iteration has been set at one in Step 1, then the solution procedure is to select the cell with the maximum savings which is feasible and continue from Step 6.

If the number of alternatives has been set at two or more, then the method proceeds as follows (Reference to Figure 5 will facilitate understanding):

(a) Select the cell with the maximum savings that can be feasibly linked and assume that this pair of points is linked (Point a_{11} of Figure 5).

(b) From the remaining cells after step a, select the cell with the remaining maximum savings that can be feasibly linked and assume that this pair of points is linked (Point a_{12} in Figure 5).

(c) From the remaining cells after steps a and b, select the cell with the remaining maximum savings that can be feasibly linked (Point a_{13} of Figure 5). Add the savings obtained in steps a, b, and c and record it.

(d) Disregard the actions of steps b and c and start over except this time select the cell, from the cells remaining after step a, with the second highest savings that can be feasibly linked and assume this pair of points is linked (Point a_{22}).

(e) From the remaining cells after steps a and d, select the cell with the remaining maximum savings that can be feasibly linked (Point a_{23}). Add the savings obtained in steps a, d, and e and record it.

(f) This procedure is repeated for the third branch associated with the first alternative, selected in step a, by disregarding the actions of steps b, c, d, and e and selecting the cell, from the cells remaining after step a, with the third highest maximum savings that can be feasibly linked, and assume this pair of points is linked (Point a_{32}).

(g) From the remaining cells after steps a and f, select the cell with the remaining maximum savings that can be feasibly linked (Point a_{33} in Figure 5). Add the savings in steps a, f, and g and record it.

(h) The maximum of the three accumulated total savings figures is selected and associated with the first alternative, which is the first pair of points selected in step a.

(i) Disregard the actions taken in steps a through h and start the whole procedure over, only this time, start the procedure (alternative 2) by selecting the cell with the second highest savings that can be feasibly linked and assume this pair of points is linked (Point b_{11}).

(j) From the cells remaining after step i, select the cell with the remaining maximum savings that can be feasibly linked and assume this pair of points is linked (Point b_{12}).

(k) From the cells remaining after steps i and j, select the cell with the remaining maximum savings that can be feasibly linked (Point b_{13}). Add the savings obtained in steps i, j and k and record it.

(l) Disregard the actions of steps j and k and start over except this time select the cell, from the cells remaining after step i, with the second highest savings that can feasibly be linked and assume this pair of points is linked (Point b_{22}).

(m) From the remaining cells after steps i and l, select the cell with the remaining maximum savings that can be feasibly linked (Point b_{23}). Add the savings obtained in steps i, l and m and record it.

(n) This procedure is repeated for the third branch associated with the second alternative, selected in step i, by disregarding the actions of steps j, k, l, and m and selecting the cell from the cells remaining after step i with the third highest maximum savings that can be feasibly linked and assume this pair of points is linked (Point b_{32}).

(o) From the remaining cells after steps i and n, select the cell with the remaining maximum savings that can be feasibly linked (Point b_{33}). Add the savings obtained in steps i, n, and o and record it.

(p) The maximum of the three accumulated total savings figures is selected and associated with the second alternative, which is the pair of points selected in step i.

(q) This procedure is continued for the third highest possible savings, the fourth highest possible savings, etc., until all the feasible alternatives selected in Step 1 have been investigated.

Note that each pair of points being considered for linking in the above steps must satisfy the conditions in Step 6 below before they can be assumed linked.

The maximum is selected from the total savings associated with each alternative and the alternative with this maximum is selected as the pair of demand points to be linked in this iteration.

The above procedure can be best exemplified by solving the six demand point problem used in the previous method. Steps 1, 2, 3 and 4 are again shown in Tables 1, 2, and 3, respectively. Step 5 of the proposed algorithm can be followed by referring to Figure 6. It is assumed that the number of alternatives to be considered in each iteration has been set at two in Step 1. The branches developed for the two alternatives according to the above steps are indicated in Figure 6. The top branch for alternative one was developed from steps a, b, and c with an accumulated total savings of 266. The second branch was derived by ignoring the actions of steps b and c and performing steps d and e. This branch has a total accumulated savings of 292. The last branch for alternative one was developed by ignoring the actions taken in steps b, c, d and e and performing steps f and g. This last branch of alternative one has a total accumulated savings of 272. The maximum total savings associated with the first alternative, according to step h, is the second branch and is 292 which is starred. All the actions taken in steps a through h are disregarded and the process is continued from step i to develop the branches for the second alternative shown in Figure 6. The maximum total savings associated with the second alternative is 266 which is starred.

Alternative one has the maximum total savings of the two alternatives considered, therefore, this pair of demand points (P_4 and P_6) is selected for linking in this iteration.

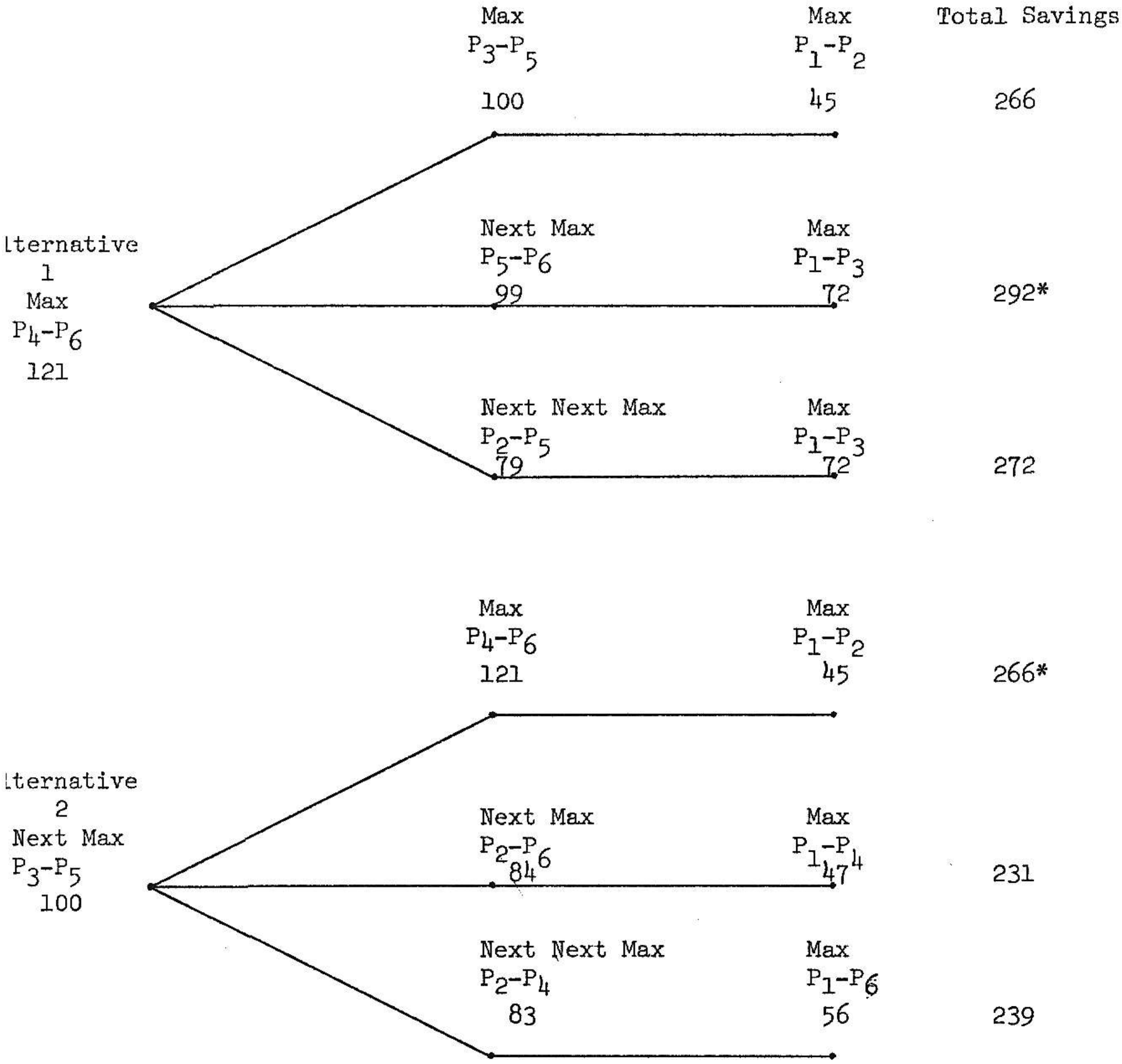

Figure 6: Decision tree for the two alternatives of the sample problem using the extended look ahead feature.

Step 6.

In this step, the demand points selected in Step 5 are checked to determine if they satisfy all the system restrictions. This step is exactly the same as Step 6 of Tillman and Cochran's method.

Step 7.

This step of the proposed algorithm consists of adjusting the $t_{i,j}$ parameters in the computational matrix to record the linking. This step is the same as the corresponding step of the previous method.

For the example problem, the pair of points selected to be linked satisfies all the conditions of Step 6 and the revision of the computational matrix according to Step 7 is the same as before and is shown in Table 5.

Step 8.

This step of the procedure consists of updating the Q vector for the newly formed route. This step is also performed exactly the same as the corresponding step of the previous method.

The adjustment of the Q vector for the sample problem is the same as before and shown in Table 5.

Step 9.

This step of the proposed algorithm involves the reassignment of trucks to cover the newly formed routes. This step is also identical to the same step in the previous method.

The truck assignment for the sample problem with the routing of points P_4 and P_6 is the same as before and is shown in Table 6.

Step 10.

This completes one iteration of the algorithm. Return to Step 5 to check if more feasible links are possible. If no more links are possible, then the final solution has been obtained. The routes formed and the exact order of visitation of the demand points on each route are determined from the final computational matrix. The final truck assignment is obtained from the final truck assignment table. The distances traveled on each route and the total distance traveled on all routes is calculated from the original distance matrix.

As in the previous algorithm, two more iterations are necessary to obtain the final solution using this algorithm to solve the example problem. Demand points P_5 and P_6 are linked in the second iteration and demand points P_1 and P_3 are linked in the final iteration. Table 7 illustrates the final solution matrix, Table 8 gives the final truck assignment table, and Table 9 shows the final routes and distances obtained, since both methods give the same results.

Summary of the Proposed Algorithm

The computational procedure discussed above for the proposed algorithm can now be summarized as follows:

Step 1. Label the demand points P_i $(i=1,2,...,N)$ and fill in the distance matrix. Ordering the demand points according to their relative distance from the terminal is not necessary.

Step 2. Calculate the savings for each pair of demand points and enter them in the savings matrix (Table 1).

Step 3. Set up the initial computational matrix and enter the initial solution (Table 2).

Step 4. Set up the truck assignment table (Table 3). An initial assignment of trucks is made. In the cases where the demand at a given demand point is larger than the largest truck available, the demands are split and only the remainder of the demand is considered. A truck is assigned to haul the full load and is not considered again.

Step 5. Select the alternative based upon the total maximum savings, following the procedure outlined in Step 5 of the proposed algorithm.

Step 6. Test the demand points selected for linking in Step 5 to see that restrictions a through d above have been satisfied. If one or more of the conditions are not satisfied, exclude this pair of points from further consideration and return to Step 5.

Step 7. If the pair of points satisfies all the conditions, set $t_{i,j} = 1$ and decrement the values $t_{i,0}$ and $t_{j,0}$ by 1 such that equation (7) holds (Table 5).

Step 8. Amend the Q vector for the newly formed route (Table 5).

Step 9. Revise the truck assignment table to correspond to the newly formed route (Table 6). This completes one iteration.

Step 10. If there are more feasible links possible, repeat the procedure from Step 5. If no more feasible links are possible, the final solution has been found. Determine the formed routes and exact order of visitation, the distance for each route, and the total distance for all routes (Tables 7, 8, and 9 respectively).

The above procedure has been programmed for the IBM 360/50 computer and several problems of different sizes have been solved. These problems will be discussed in the next section. (The computer program is shown in Appendix I).

DISCUSSION OF PROBLEMS

As noted in chapter I, twelve sample problems were constructed and solved by Clarke and Wright's method, Tillman and Cochran's method, and by the author's proposed method. The sample problems were constructed as follows:

(1) Five single terminal problems with ten demand points each were developed. Problem one was constructed from the multiple terminal problem presented by Tillman [25], by selecting one terminal at random. Problem two, three, four, and five were developed from Rand and McNally's Road Atlas. In each problem a single terminal was selected at random and then ten demand points were selected such that various geographical patterns were obtained. Several trucks ranging from twenty units capacity to fifty units of capacity were assumed available for assignment in each problem. In each of the problems, the quantity required by the demand points were randomly selected from numbers between 5 and 20 such that several linkings would be possible in the solution.

(2) Five single terminal problems with twenty-five demand points each were developed. Problems one, two, and five were developed from Rand and McNally's Road Atlas in the same manner as the ten demand point problems. Problem three was developed from a Kansas map and problem four was developed from an Oklahoma map. Care was also taken in selecting the demand points such that various geographical patterns were obtained. The trucks assumed available in each problem ranged from twenty units of

capacity to one hundred units of capacity. The quantities required by the demand points in each problem were randomly selected from numbers between 15 and 40.

(3) Two single terminal problems with fifty demand points each were also constructed using Rand and McNally's Road Atlas. The demand points in these two problems are dispersed throughout the United States. The trucks assumed available and the quantities required by each demand point were developed in the same manner as the twenty-five demand point problems.

RESULTS

Ten Demand Point Problems

The solutions obtained for the single terminal ten demand point problems are summarized in Table 10. The numbers shown are the total distance traveled on all routes determined by the respective method of solution for each problem. The data for each problem and the best solution obtained is shown in Appendix II.

The histogram showing the number of best solutions obtained using each method to solve the five problems is shown in Figure 7. Observe that Clarke and Wright's method obtained the best solution for only two of the five problems. Tillman and Cochran's method and the author's proposed method obtained the best solution for four of the five problems when two alternatives were considered at each iteration. Tillman and Cochran's method obtained a better solution than Clarke and Wright's method for the fifth problem when considering three alternatives, but was unable to obtain as good of a solution as that obtained by the proposed method using three alternatives. Therefore, the proposed method obtained the best solution for all five problems by considering three alternatives in each iteration. No improvement was obtained using more than three alternatives at each iteration.

Figure 8 shows the average time required to solve the problems with each method using the Watfor compiler. Thus, in order to obtain the best solution for a single terminal problem with ten demand points, the results appear to indicate that the proposed method considering three alternatives at each iteration should be used. This would require approximately 2.04 minutes on the IBM 360/50 computer using the watfor compiler.

Problem Number	Clarke and Wright Method	Tillman and Cochran Method 2-Decision Look Ahead			Proposed Method 3-Decision Look Ahead		
		2 alternatives	3 alternatives	5 alternatives	2 alternatives	3 alternatives	5 alternatives
1	76	76	76	76	76	76	76
2	2846	2470	2470	2470	2470	2470	2470
3	2156	2156	2156	2156	2156	2156	2156
4	1813	1679	1679	1679	1679	1679	1679
5	4146	4146	4121	4121	4146	4109	4109

Table 10: Summary of distances for single terminal ten demand point problems.

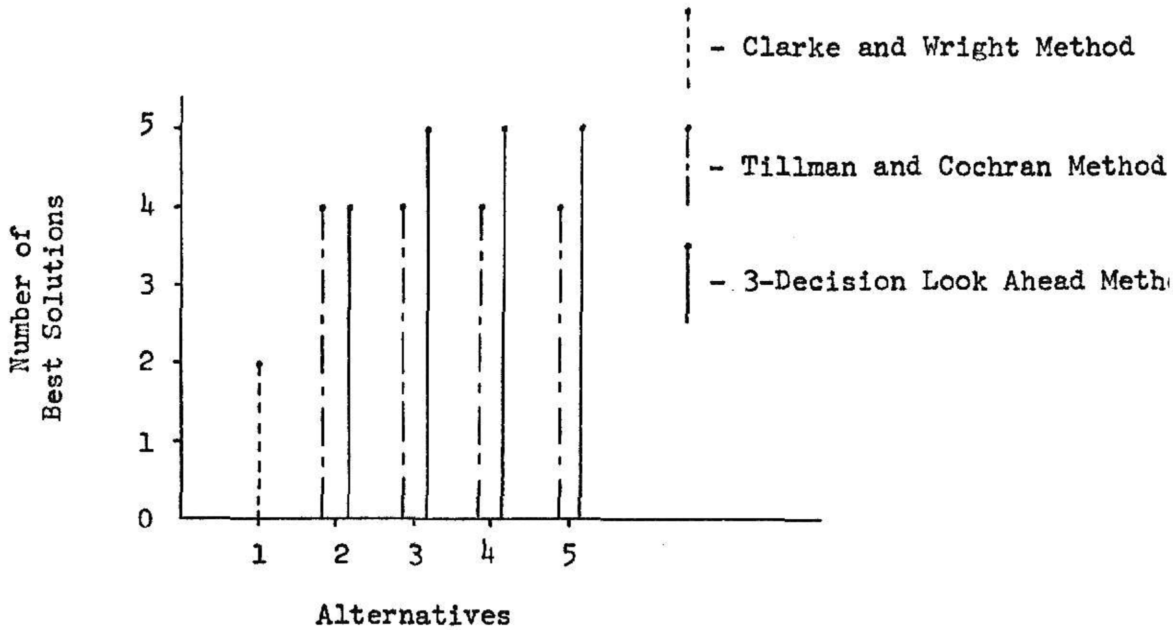

Figure 7: Best solutions for single terminal ten demand point problems.

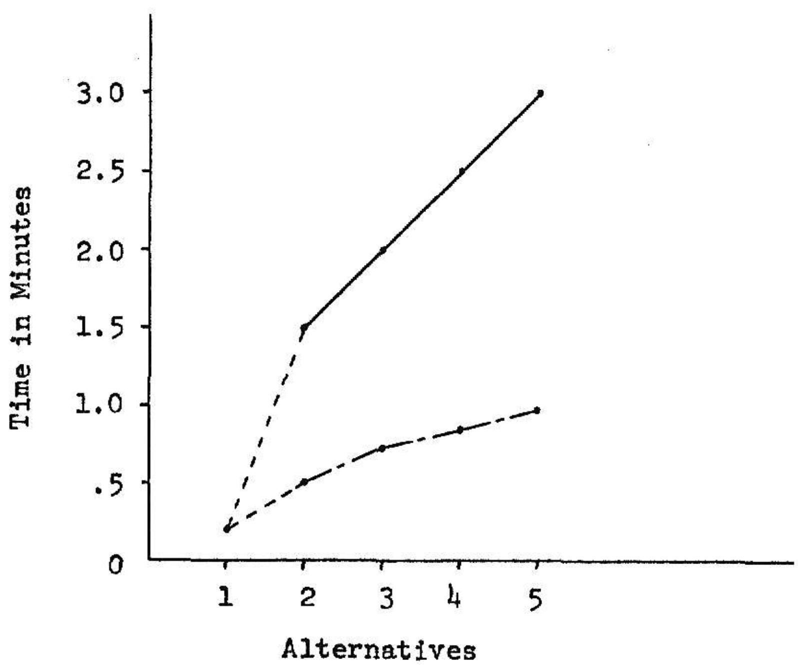

Figure 8: Execution time using Watfor compiler on the IBM 360.

Twenty-five Demand Point Problems

Table 11 contains the summary of solutions obtained with the various methods for the single terminal problems with twenty-five demand points each. The information given is the same as that given for the ten demand point problems. The data and best near-optimal solution obtained for each problem are also shown in Appendix II.

Figure 9 shows the histogram indicating the number of best solutions obtained for the five problems using the three methods of solution. Observe that Clarke and Wright's method obtained the best solution for three of the five problems. When considering two alternatives at each iteration, Tillman and Cochran's method and the author's proposed method also obtained the best solution for three of the five problems. Note that a better solution was found for problem two in this case but a worse solution was obtained for problem one. The same best solutions were obtained for problems three and five as was found using Clarke and Wright's method.

The worse solution obtained for problem one with the two look ahead methods when considering two alternatives in each iteration can be explained in the following way. This is a result of only considering a restricted number of successive linkings (decisions) for each alternative in the look ahead methods before determining the pair of demand points to be linked at that iteration. Remember that Tillman and Cochran's method considers two successive linkings (2-decision look ahead) for

Problem Number	Clarke and Wright Method	Tillman and Cochran Method 2-Decision Look Ahead			Proposed Method 3-Decision Look Ahead		
		2 alternatives	3 alternatives	10 alternatives	2 alternatives	3 alternatives	10 alternatives
1	9604	9990	9848	9848	9709	9689	9689
2	8383	8325	8325	8325	8325	8325	8325
3	2289	2289	2289	2289	2289	2289	2289
4	2788	2788	2788	2788	2657	2638	2638
5	8901	8901	8901	8901	8901	8901	8901

Table 11: Summary of distances for single terminal twenty-five demand point problems.

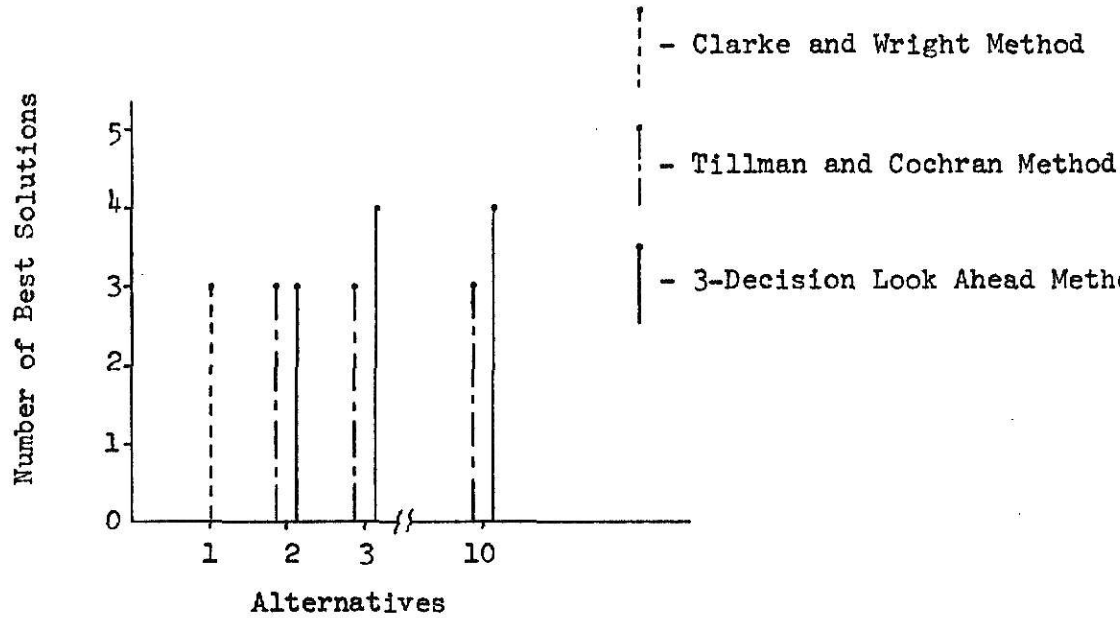

Figure 9: Best solutions for single terminal twenty-five demand point problems.

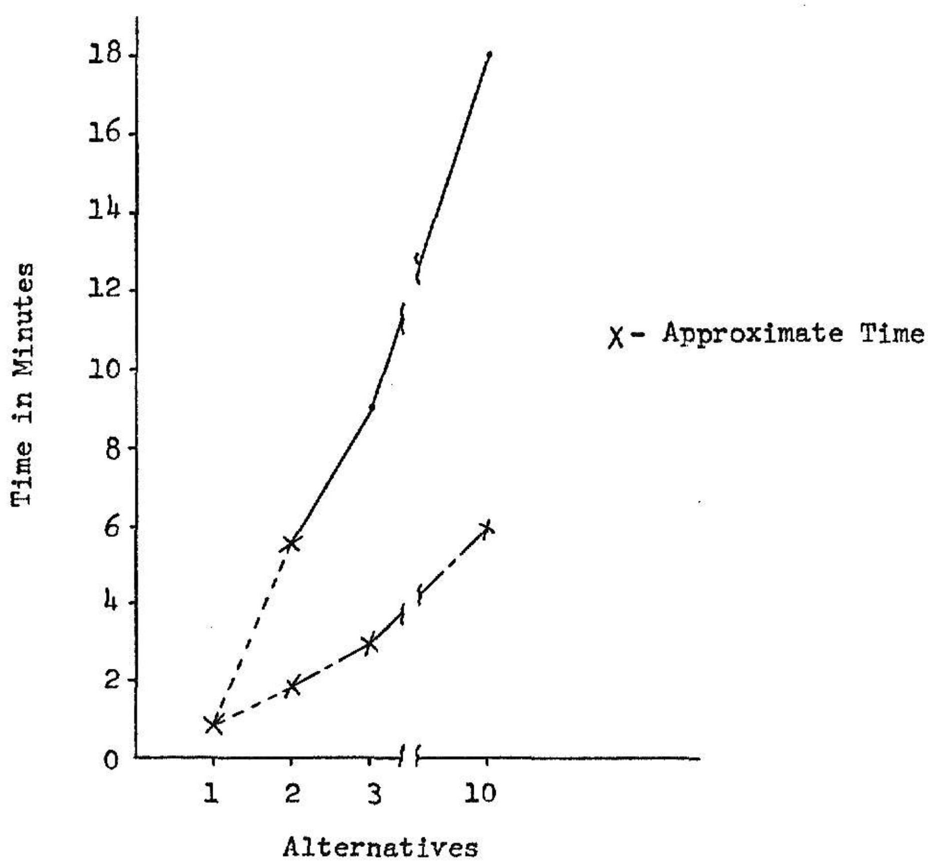

Figure 10: Execution time using G-level Fortran on the IBM 360.

each alternative considered and the author's method considers three successive linkings (3-decision look ahead) for each alternative considered. The solutions obtained by the two look ahead methods for problem one were the best solutions according to the decisions considered for the two alternatives involved, but were not as good as the solution obtained by Clarke and Wright's method which links the pair of demand points with the maximum savings at each iteration.

If four, five, or six successive linkings would have been considered for each alternative at each iteration, the better solution obtained by Clarke and Wright's method could have possibly been obtained or even a better solution might have been possible. This reasoning is supported by the fact that the author's proposed 3-decision look ahead method obtained a better solution than Tillman and Cochran's 2-decision look ahead method when considering two alternatives at each iteration.

The author's proposed method obtained the best solution for problem four when considering three alternatives at each iteration. Therefore, as shown in Figure 9, the proposed method obtained the best solution for four of the five problems solved. Tillman and Cochran's method still only obtained the best solution for three of the five problems. No improvements were obtained by either look ahead method when considering more than three alternatives at each iteration.

Figure 10 shows the average solution time required for solving the problems with each method using the more efficient G-level Fortran compiler. Therefore, the results appear to indicate that the best solution for a single terminal twenty-five demand point problem can be obtained by using the proposed method with three alternatives considered at each iteration. In light of the worse solution obtained in problem one, the author suggests that the problems should first be solved by Clarke and Wright's method to check for this difficulty when using the proposed method. This would involve a total solution time on the IBM 360 computer of approximately ten minutes (One minute for solving the problem with Clarke and Wright's method and nine minutes to solve the problem using the author's proposed method with three alternatives considered at each iteration).

Fifty Demand Point Problems

The solutions obtained for the single terminal problems with fifty demand points are summarized in Table 12. Results for all the intermediate number of alternatives are also not shown unless a different solution was obtained. In this problem only 1,2,3 and 10 alternatives were evaluated. Figure 11 shows the histogram giving the number of best solutions obtained with each method and Figure 12 shows the average solution time required on the IBM 360 computer using the G-level Fortran compiler. The data for each problem and the best solution obtained is shown in Appendix II.

Due to the limited computer time available and the difficulty encountered in developing practical example problems, only two example problems were developed and solved by the three methods. As can be noted from the graphs, Clarke and Wright's method obtained the best solution for one of the two problems. Tillman and Cochran's 2-decision look ahead method was unable to obtain the best solution for either problem, in fact, the solutions obtained were worse than those given

Problem Number	Clarke and Wright Method	Tillman and Cochran Method 2-Decision Look Ahead			Proposed Method 3-Decision Look Ahead	
		2 alternatives	3 alternatives	10 alternatives	2 alternatives	10 alternatives
1	30223	30283	30283	30283	30587	30587
2	33002	33388	33253	33253	32904	32904

Table 12: Summary of distances for single terminal fifty demand point problems.

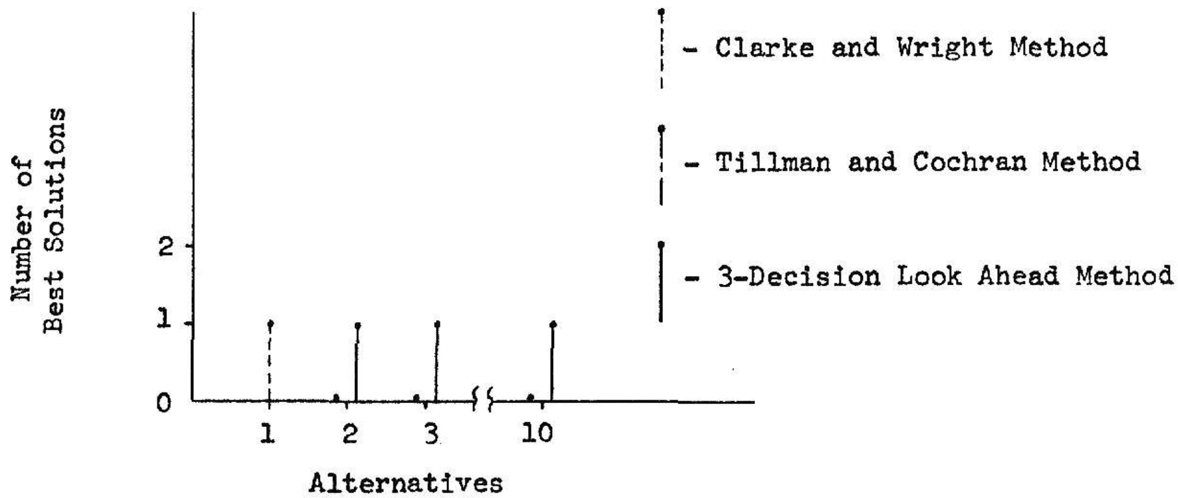

Figure 11: Best solutions for single terminal fifty demand point problem.

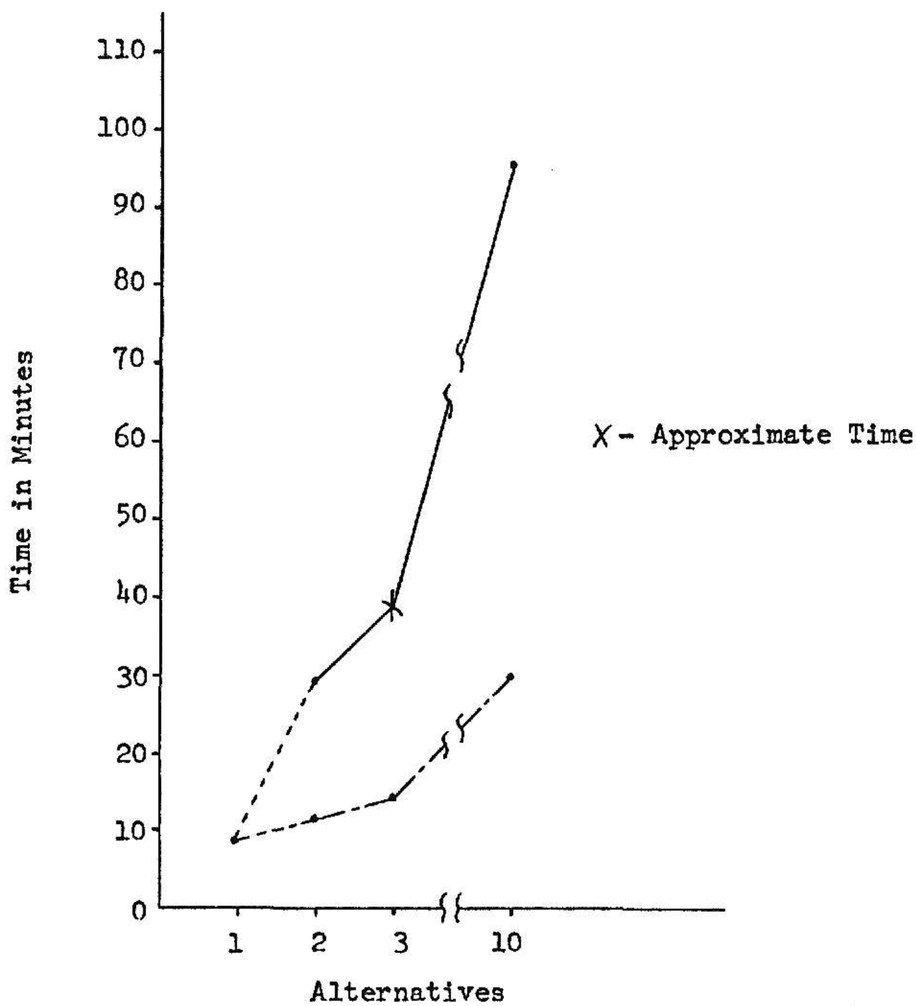

Figure 12: Execution time using G-level Fortran on the IBM 360.

by Clarke and Wright's method. The author's 3-decision look ahead method also obtained a worse solution for problem one but found the best solution for problem two when considering two alternatives at each iteration. The reason for the two look ahead methods obtaining worse solutions in problem one is the same as that given for the same difficulty encountered in the twenty-five demand point problems.

Although more example problems need to be solved by the three methods before a reliable conclusion could be made, the author would recommend that a fifty demand point problem should first be solved by Clarke and Wright's method and then solved by the proposed look ahead method considering at least three alternatives at each iteration. In this manner, the best solution could be obtained and at the same time protect against the problem encountered when using the proposed 3-decision look ahead method. This would entail a total of thirty-eight minutes on the IBM 360 computer (that is eight minutes for Clarke and Wright's method and thirty minutes for the proposed 3-decision look ahead method).

CONCLUSION FOR THE SINGLE TERMINAL PROBLEMS

For the single terminal carrier routing problems, the only algorithmic approaches which are computationally feasible are those based upon heuristic programming. An algorithm proposed by Tillman and Cochran was used as a basis for developing an improved method. An extended look ahead feature was developed for improving the selection criteria and was incorporated into this method. This modified algorithm was then used as a basis for this work.

Several example problems with ten, twenty-five, and fifty demand points each were constructed and solved by Clarke and Wright's method, Tillman and Cochran's method, and the proposed extended look ahead method. Based upon the criteria of finding the minimum total distance traveled on all routes, the author suggests the following guidelines for solving single terminal carrier routing problems.

> Solve the problems first with Clarke and Wright's method to provide a basis for comparison and then solve the problems using the proposed 3-decision look ahead method considering three alternatives at each iteration.

If minimizing computer time is important, the author suggests that Clarke and Wright's method of solution be used since this method provides good answers and requires the minimum amount of computer time.

It is suggested that a possible approach for further research in this area would be to modify the proposed 3-decision look ahead method so that a maximum of three alternatives are considered at each iteration and at least six successive linkings are considered for each alternative (i.e. Develop a 6-decision look ahead method). This would possibly eliminate the difficulty encountered in the 3-decision look ahead method and therefore eliminate the need for first solving the problems with Clarke and Wright's method.

CHAPTER III

THE MULTIPLE TERMINAL CARRIER ROUTING PROBLEM

PROBLEM

The multiple terminal carrier routing problem can be regarded as a generalization of the single terminal problem. The major difference between the two problems is that in the multiple terminal case there are two or more terminals from which the delivery vehicles can be dispatched to carry the commodity to the given demand points. Therefore, the multiple terminal problem is one of determining the "best" delivery routes with respect to some objective function (total miles, cost, etc.) from the appropriate terminals such that the following conditions are satisfied.

(1) The distance matrix must be symmetrical.

(2) All the demands are assumed known and must be fulfilled.

(3) A given demand point may not appear on more than one route (i.e., A given demand point may not be supplied by more than one terminal, and once it is assigned to a terminal, the demand point cannot appear on more than one route from that terminal.

(4) The carriers may have different carrying capacities which are assumed known.

(5) The routes to be determined must all be either "pickup" or "delivery" routes and not both.

SURVEY OF THE LITERATURE

There has been several methods of solution proposed for the solution of the single terminal carrier routing problem, as discussed in chapter two. Although the multiple terminal carrier routing problem is considered a generalization of the single terminal problem, very little research has been conducted on the multiple terminal problem. The only article available in the literature proposes a heuristic programming algorithm for the solution of the multiple terminal problem with probabilistic demands developed by Tillman [25]. This algorithm will be discussed below.

Discussion

Research is presently being conducted in the department of Industrial Engineering at Kansas State University on a branch and bound method of solution for the multiple terminal problem. This is a part of the research noted in progress in chapter two on the single terminal problem. The research has not reached a stage of development such that a more meaningful discussion of the proposed method can be given at this time.

Based upon the conclusion that the methods using heuristic programming approaches were the only algorithmic methods that seemed computationally feasible for solving large practical single terminal problems, Tillman [25] proposed such a method for solving the multiple terminal problem with probabilistic demands. To develop the algorithm, the author utilized the distance and savings matrix concept of Clarke and Wright's method [6] developed for a single terminal problem. The proposed algorithm provides "good" answers to a difficult problem and appears suitable for solving large practical problems.

The algorithm developed by Tillman [25], with some modifications, is equally applicable to multiple terminal problems with deterministic demands which are being discussed in this paper. Therefore, the following study was undertaken for improving the selection criteria of the heuristic algorithm in an effort to obtain "better" solutions. Tillman's [25] algorithm, modified for solution of problems with deterministic demands, will be discussed in detail in the following section followed by suggested improvements.

TILLMAN'S METHOD

The algorithm proposed by Tillman [25] is a heuristic programming method for the solution of the multiple terminal carrier routing problems. As noted, the author utilized the distance and savings matrix concept of Clarke and Wright's method [6] for a single terminal problem, and developed a modified distance matrix concept for the multiple terminal problem.

A discussion of the development of the algorithm is presented in the next section. The definitions of the terms used in the following discussion are as follows:

P_j = demand point j.

$d_{j,k}$ = distance between demand points P_j and P_k.

d_j^i = distance from terminal i to demand point P_j.

$\tilde{d}_j^i$ = modified distance from terminal i to demand point P_j.

$S_{j,k}^i$ = savings associated with linking demand points P_j and P_k to a route from terminal i.

q_j = quantity required at demand point P_j.

C_n = carrying capacity of the nth vehicle.

$t_{j,k}$ = index used to indicate how the demand points P_j and P_k are connected to constitute a link.

The Development

A problem occurs if the savings equation developed by Clarke and Wright [6] for the single terminal problem is directly applied in the multiple terminal problem. The difficulty occurs when computing the savings using equation (6) for two demand points which are close to one terminal and a greater distance to the second terminal. In such cases, the savings computed using this equation would be greatest for the points that are furthest from the terminal. Using the selection criteria of selecting the points to be linked and assigned to a terminal on the basis of the savings computed from equation [6] would indicate that the points should be assigned to the more distant terminal. This is incorrect since the pair of points are actually closer to the other terminal. The solution of this problem led Tillman to develop the following approach.

In the multiple terminal problem, the savings must be computed to reflect the "true" savings relative to each terminal. For the terminal nearest the points, the "true" savings is given by equation (6), but for the terminal furthest away the savings of equation (6) are reduced by the amount that the actual distance exceeds the distance from this point to the nearest terminal [25]. To take this into consideration, a modified distance is computed from each terminal to each point using the equation

$$\tilde{d}_j^i = \min_s d_j^s - (d_j^i - \min_s d_j^s), \tag{8}$$

before computing the savings where the superscript denotes the terminal and the subscript denotes the demand point. The savings are computed for each terminal using the equation

$$S_{j,k}^i = \tilde{d}_j^i + \tilde{d}_k^i - d_{j,k} \tag{9}$$

The algorithm begins with an initial solution such that each demand point is assigned individually to the nearest terminal and a truck is assigned to each demand point [25]. A distance and savings matrix is determined for each terminal using Equations (8) and (9). A pair of demand points is selected for linking at each iteration based on the savings and then assigned to the terminal associated with this improvement. The demand points selected for linking are those with the maximum savings which do not violate the restrictions on the system. The trucks are then reassigned by removing the trucks which were previously assigned to the demand points and assigning a truck with sufficient capacity to the newly formed route. When two demand points are linked and assigned to a terminal, they are eliminated from consideration at the other terminals. The modified distance, $\tilde{d}^i_j$, for the point that is linked to another point at this terminal is set equal to the true distance, d^i_j, and the savings matrix at this terminal is updated as required by this change [25].

This process is repeated until all the demand points are linked which generate a positive savings and do not violate the restrictions on the system. The single points remaining which are not assigned to a route are then assigned to the nearest terminal.

Note, as in the single terminal problem, a given demand point can only be linked at most to two other points, one of which may be the terminal. Therefore, whenever a demand point is linked to two other demand points it is not considered for further linking.

The Algorithm

The step by step computational procedure of the algorithm will now be given using a three terminal and ten demand point problem to illustrate the method. See Figure 13 which shows the example problem.

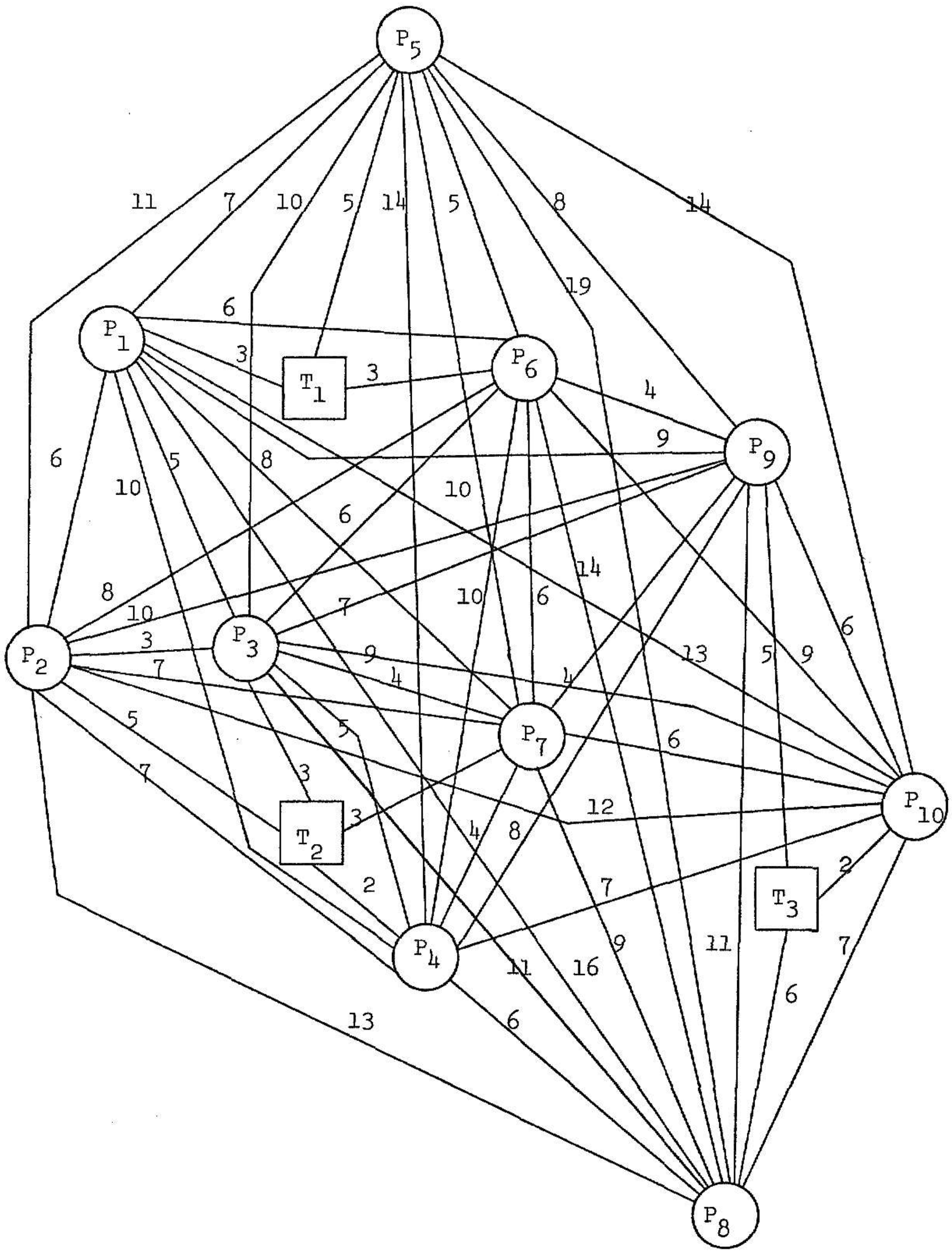

Figure 13: Example problem showing the distances between demand points and the terminals.

Step 1.

The first step of the computational procedure is the assignment of identification numbers to the demand points and constructing a distance matrix for each terminal. Only one half of the matrices are needed since the distances are symmetrical. The demand points are labeled P_j (j=1,2,...,N) for an N demand point problem and the distances, $d_{j,k}$, are inserted in the lower right-hand corner of each cell in each matrix, Tables 13, 14, and 15. Two column vectors are added to the left-hand side of each distance matrix. The first column vector, D^i, of each matrix contains the distances, d^i_j, from the ith terminal to each of the demand points. The modified distances, $\tilde{d}^i_j$, for each terminal are computed using equation (8) and are entered into the second column vector, $\tilde{D}^i$, of the corresponding distance matrix.

Step 2.

The second step of the computational procedure involves the calculation of the savings matrix for each terminal. The savings obtained by linking two specific demand points to a given terminal is calculated from equation (9) and is entered in the lower left-hand corner of the appropriate cell in the corresponding distance matrix.

The completed distance matrices for the three terminals of the sample problem are shown in Tables 13, 14, and 15.

Step 3.

The third step consists of formulating the initial computational matrix using the same format used to construct the distance matrix. Two column vectors are added to the left-hand side of this matrix. The first column vectors are added to the left-hand side of this matrix. The first column vector $Q = (q_1, q_2, \ldots, q_N)$ initially contains the quantities, q_i,

D^1	$\tilde{D}^1$										
3	3	P_1									
6	4	1 6	P_2								
5	1	-1 5	2 3	P_3							
9	-5	-12 10	-8 7	-9 5	P_4						
5	5	1 7	-2 11	-4 10	-14 14	P_5					
3	3	-1 6	-1 8	-2 6	-12 10	3 5	P_6				
6	0	-5 8	-3 7	-3 4	-9 4	-5 10	3 6	P_7			
15	-3	-16 16	-12 13	-13 11	-14 6	-17 19	-14 14	-12 9	P_8		
7	3	-3 9	-3 10	-3 7	-10 8	-1 8	2 4	-1 4	-11 11	P_9	
12	-8	-18 13	-16 12	-16 9	-20 7	-17 14	-14 9	-14 6	-18 7	-11 6	P_{10}

Table 13. Distance matrix for terminal 1 showing the distances in lower right-hand corner of each cell, and savings in lower left-hand corner of each cell.

D^2	$\tilde{D}^2$										
8	-2	P_1									
5	5	-3 6	P_2								
3	3	-4 5	5 3	P_3							
2	2	-10 10	-1 7	-1 5	P_4						
12	-2	-11 7	-8 11	-9 10	-14 14	P_5					
8	-2	-10 6	-5 8	-5 6	-10 10	-9 5	P_6				
3	3	-7 8	1 7	2 4	1 4	-9 10	-5 6	P_7			
8	4	-14 16	-4 13	-4 11	-1 6	-17 19	-12 14	-2 9	P_8		
7	3	-8 9	-2 10	-1 7	-3 8	-7 8	-3 4	2 4	-4 11	P_9	
7	-3	-18 13	-10 12	-9 9	-8 7	-19 14	-14 9	-6 6	-6 7	-6 6	P_{10}

Table 14. Distance matrix for terminal 2 showing the distances in lower right-hand corner of each cell, and savings in lower left-hand corner of each cell.

D^3	$\bar{D}^3$										
12	-6	P_1									
12	-2	-14 6	P_2								
8	-2	-13 5	-7 3	P_3							
6	-2	-18 10	-11 7	-9 5	P_4						
14	-4	-17 11	-17 11	-16 10	-20 14	P_5					
9	-3	-15 6	-13 8	-11 6	-15 10	-12 5	P_6				
4	2	-12 8	-7 7	-4 4	-4 4	-12 10	-7 6	P_7			
6	6	-16 16	-9 13	-7 11	-2 6	-17 19	-11 14	-1 9	P_8		
5	5	-10 9	-7 10	-4 7	-5 8	-7 8	-2 4	3 4	-1 11	P_9	
2	2	-17 13	-12 12	-9 9	-7 7	-16 14	-10 9	-2 6	1 7	1 6	P_{10}

Table 15. Distance matrix for terminal 3 showing the distances in lower right-hand corner of each cell and savings in lower left-hand corner of each cell.

which are required at the demand points P_j $(j=1,2,\ldots,N)$. The second column vector $T = (t_{1,0}, t_{2,0},\ldots,t_{N,0})$ contains the index that indicates how the demand points are linked with the terminals to form a route. The remaining cells contain the values of the index $t_{j,k}$ which indicate how the demand points are connected to constitute a link. The values of the index, $t_{i,j}$, will always be 0, 1, or 2 according to the three possibilities listed in Tillman and Cochran's algorithm in chapter two. The initial solution assumes that the demand points are assigned to the nearest terminal, therefore, all $t_{j,0} = 2$ $(i=1,2,\ldots,N)$ and all the remaining cells have a value $t_{j,k} = 0$. Since a given demand point can only be linked at most to two other points, one of which may be a terminal, the relationship shown in equation (7) must always exist. The values of $t_{j,k}$ are adjusted after each pair of points are linked so that the relationship holds.

The initial computational matrix constructed for the example problem is shown in Table 16. Note that the blank cells in the matrix indicate that the value of $t_{j,k} = 0$. Also note that the index in the upper left-hand corner of the cells in the T vector denotes the terminal to which the route is assigned.

Step 4.

The fourth step of the computational procedure involves the initial assignment of trucks to the demand points which are assumed to be linked to the nearest terminal. If the assignment is infeasible, split the demands where necessary and assume "dummy trucks" as needed such that a feasible assignment can be made. This is discussed in Step 4 of Tillman and Cochran's method in chapter two.

There are three trucks available in the sample problem with carrying capacities of 30 units each. The initial assignment of trucks to the demand points would require 10 trucks which is more than there are trucks available, therefore, an infinite number of trucks with 30 units capacity are assumed available. The extra trucks constitute the "dummy trucks". The initial assignment of trucks for the sample problem is shown in Table 16.

Step 5.

An attempt is made in this step to link the demand points which have the maximum savings and assign the points to the terminal associated with this savings. When searching the savings matrices for the maximum savings, only those savings corresponding to the links that satisfy the conditions of Step 6 should be included in the search.

If there are two or more equal maxima encountered in the search, one of these are selected randomly.

Step 6.

The points selected to be linked in Step 5 must be tested to see if the restrictions listed below are satisfied. For the pair of points under consideration, P_j and P_k, the restrictions to be satisfied are:

(a) The values of the indexes $t_{j,0}$ and $t_{k,0}$ must be greater than zero which indicates that the demand points are still linked to a terminal and these links are eligible to be severed.

(b) The demand points P_j and P_k must not already be on the same route. This prevents the forming of a "loop" that does not include the terminal.

Q	T										
10	[1] 2	P_1									
4	[2] 2		P_2								
8	[2] 2			P_3							
7	[2] 2				P_4						
12	[1] 2					P_5					
6	[1] 2						P_6				
5	[2] 2							P_7			
10	[3] 2								P_8		
8	[3] 2									P_9	
15	[3] 2										P_{10}

Capacity	30
Available	3
Assumed Available	
Assigned	10

Table 16. Initial computational matrix with Q vector and initial truck assignment table. Note the index in the upper left-hand corner of the cells in the vector denotes the terminal to which the route is assigned.

(c) The combined quantities, q_j, required by the demand points P_j and P_k and any other demand points which may be on the same route must not exceed the capacity of the available trucks.

(d) Any other restriction on the system must be satisfied.

If one or more of the above conditions are not satisfied, then this pair of points are excluded from further consideration at this terminal and the process is repeated from Step 5. If the pair of points selected in Step 5 satisfy all the conditions, then they are joined at this terminal and are eliminated from consideration at the other terminals.

The maximum savings of 5 is obtained in the example problem by linking the demand points P_2 and P_3 on a route from terminal 2. This pair of points satisfies all the conditions listed in Step 6, and are therefore linked on a route at terminal 2.

Step 7.

If the demand points, P_j and P_k, selected in Step 5 satisfy all the conditions of Step 6, they are linked and assigned to the terminal associated with this improvement. This is done by setting the value of $t_{j,k} = 1$, and decrementing the values of $t_{j,0}$ and $t_{k,0}$ by 1 such that equation (7) holds. The terminal index in the upper left-hand corner of the cells $t_{j,0}$ and $t_{k,0}$ is set to the terminal which is to serve this route. This pair of points is then eliminated from further consideration at the other terminals by setting the savings associated with each of these points to zero at these terminals. The values of $\tilde{d}_j^i$ and $\tilde{d}_k^i$ are set equal to d_j^i and d_k^i, respectively, at the terminal in which the points

P_j and P_k have been linked. The savings matrix at this terminal is then updated as required by this change.

Step 8.

The Q vector containing the loads q_i are amended to indicate the linking of the demand points P_j and P_k in this iteration. Each q_i corresponding to the index value $t_{i,0} = 0$ is itself set equal to zero and each q_i corresponding to the demand points linked on the newly formed route is set equal to the sum of the demand for all points on the route.

The adjustments to the computational matrix to record Steps 7 and 8 for the example problem are shown in Table 17. The demand points linked in the first iteration are P_2 and P_3, therefore, the value of $t_{2,3}$ is set equal to 1 to record the linking and the values of $t_{2,0}$ and $t_{3,0}$ are decremented by 1 such that $t_{2,0} = 1$ and $t_{3,0} = 1$. The combined load for the route is 12 units, therefore, q_2 and q_3 are set equal to 12.

Step 9.

This step of the computational procedure involves the reassignment of trucks to cover the newly formed routes. The trucks previously assigned to cover the demand points P_j and P_k are removed and a truck of sufficient carrying capacity is assigned to cover this newly formed route, which includes the points P_j and P_k and any other points which may be on the route from previous iterations.

In the sample problem, the trucks initially assigned to cover P_2 and P_3 are removed and a truck is reassigned to cover the new route which has a combined load of 12 units. The truck assignment table is shown in Table 17 after the first iteration.

Q	T										
10	^{1} 2	P_1									
12	^{2} 1		P_2								
12	^{2} 1		1	P_3							
7	^{2} 2				P_4						
12	^{1} 2					P_5					
6	^{1} 2						P_6				
5	^{2} 2							P_7			
10	^{3} 2								P_8		
8	^{3} 2									P_9	
15	^{3} 2										P_{10}

Capacity	30
Available	3
Assumed Available	∞
Assigned	9

Table 17. Computational matrix and truck assignment table after completion of the first iteration.

Step 10.

This completes the first iteration. Return to Step 5 to check for more links with a positive savings which satisfy all the conditions listed in Step 6. If more links are feasible the procedure is continued. If no other links are feasible, the final solution has been obtained. The remaining single points which were not assigned to a route during the computational procedure remained assigned to the nearest terminal. The routes formed, exact order of visitation of the demand points, and the terminals to which the routes are assigned are obtained from the final solution matrix. The final assignment of trucks is obtained from the truck assignment table. The distance traveled on each route and the total distance traveled on all routes is calculated from the original distance matrices.

Four more iterations are required to find the final solution for the sample problem. The demand points P_5 and P_6 are linked and assigned to terminal 1 in the second iteration; the demand points P_7 and P_9 are linked and assigned to terminal 3 in the third iteration; the demand points P_1 and P_5 are linked and assigned to the route at terminal 1; and the demand points P_7 and P_8 are linked and assigned to terminal 3 in the last iteration. The final computational matrix, the final truck assignment table, and the final routes and distances for the problem are given in Tables 18, 19 and 20, respectively. The total distance for all routes is 61 miles.

Summary of the Algorithm

The Steps of the algorithm are summarized below.

Step 1. Label the demand points P_j $(j=1,2,\ldots,N)$ and construct

Q		T										
28	1	1	P_1									
12	2	1		P_2								
12	2	1		1	P_3							
7	2	2				P_4						
0	1	0					P_5					
28	1	1					1	P_6				
0	3	0							P_7			
23	3	1							1	P_8		
23	3	1							1		P_9	
15	3	2										P_{10}

Table 18. Computational matrix after final iteration.

Capacity	30
Available	3
Assumed Available	∞
Assigned	3

Table 19. Truck assignment table after final iteration.

Terminal	Routes	Distance	Load
1	$T_1-P_1-P_5-P_6-T_1$	18	28
2	$T_2-P_2-P_3-T_2$	11	12
	$T_2-P_4-T_2$	4	7
3	$T_3-P_8-P_7-P_9-T_3$	24	23
	$T_3-P_{10}-T_3$	4	15

Table 20. Final route and distance table. One truck is used for both routes at terminals 2 and 3.

a distance matrix for each terminal. Two column vectors are added to the left-hand side of each matrix. The first vector, D^i, contains the distances from the terminal to the demand points and the second vector, $\tilde{D}^i$, contains the modified distances computed with equation (8).

Step 2. Calculate the savings using equation (9) for linking each pair of points to a specific terminal and enter them in the corresponding distance matrix (Tables 13, 14, and 15).

Step 3. Set up the initial computational matrix and enter the initial solution (Table 16).

Step 4. Assign one truck to each demand point, assuming "dummy trucks" are available and split demands if necessary to make a feasible allocation (Table 16).

Step 5. Find the maximum feasible savings possible in the savings matrices. Choose one randomly if there are two or more equal maxima.

Step 6. Test the demand points selected to be linked in Step 5 to see that the restrictions listed above are satisfied. If one or more of the conditions are not satisfied, exclude this pair of points from further consideration at this terminal and return to Step 5.

Step 7. If the pair of points satisfy all the conditions, set $t_{j,k} = 1$ and decrement the values of $t_{j,0}$ and $t_{k,0}$ by 1 such that equation (7) holds. Set the terminal index in cells $t_{j,0}$ and $t_{k,0}$ to the terminal associated with this savings. Eliminate this pair of points from further consideration at the other terminals. Set the values of $\tilde{d}_j^i$ and $\tilde{d}_k^i$ to d_j^i and d_k^i, respectively, at the terminal in which the points P_j and P_k have been linked and update the savings matrix at this terminal as required by the change (Table 17).

Step 8. Amend the Q vector for the newly formed route (Table 17).

Step 9. Reassign the trucks to correspond to the new routes (Table 17). This completes one iteration.

Step 10. Return to Step 5 to check for more feasible links. If no other feasible links are possible, then the final solution has been found. The points not assigned to a route remain assigned to the nearest terminal. Determine the routes formed, the exact order of visitation, and the terminals to which the routes are assigned from the final computational matrix (Table 18). Determine the final truck assignment (Table 19). Determine the distance traveled on each route and the total distance for all routes (Table 20).

THE LOOK AHEAD APPROACH

General Remarks

This section presents a discussion of some modifications to Tillman's algorithm which may improve the selection criteria in an attempt to obtain better solutions to the multiple terminal problem. The modifications in the selection criteria consists of incorporating the look ahead feature discussed in chapter two and illustrated in Figure 5. As noted, the look ahead feature considers the consequences of three future linkings for a given number of alternatives before a pair of points is selected for linking in each iteration. This feature appears to be a significant contribution from the results of solving a number of example problems. (See Appendix III.)

The Proposed Algorithm

The computational procedure of the modified algorithm is given below. To illustrate the method the same problem will be solved as was solved by Tillman's method.

Step 1.

Assign the identification numbers to the demand points and construct the distance matrix for each terminal. This step is the same as the corresponding step in Tillman's method. A decision regarding the number of alternatives which are to be considered in each iteration according to Step 5 below must also be made at this step. If only one alternative is considered in each iteration, the solution procedure is the same as Tillman's method. Otherwise, the number of alternatives to be considered at each iteration is based upon the size of the problem. Again, it is felt that the results from solving several example problems will provide some insight for determining what this number should be for various sizes of problems.

Step 2.

This step of the computational procedure consists of calculating the savings matrix for each terminal using equation (9). This step is also the same as Step 2 of the previous method.

The completed distance matrices for the three terminals of the sample problem are again shown in Tables 13, 14, and 15.

Step 3.

This step involves the formulation of the initial computational matrix, the initial demand vector, and the initial terminal index vector. This step is also the same as Step 3 of the previous method.

The initial computational matrix is again shown in Table 16.

Step 4.

The initial truck assignment is made in this step which is the same as Step 4 in the previous method.

The initial truck assignment for the example problem is also shown in Table 16.

Step 5.

An attempt is made in this step to link the demand points which result in the overall maximum savings by looking at the resulting savings of the three different branches for each of several feasible alternatives. Each branch considers the consequences of a sequence of three future linkings for the given alternative.

The computational procedure will consist of the following steps

(Reference to Figure 5 will facilitate the reader's understanding):

(a) Select the cell with the maximum savings from all the savings matrices which can feasibly be linked and assume that this pair of points is linked and assigned to the terminal corresponding to this improvement (Point a_{11} in Figure 5).

(b) From the remaining cells of all the savings matrices, select the cell with the remaining maximum savings that can be feasibly linked and assume that this pair of points is linked and assigned to the corresponding terminal (Point a_{12} of Figure 5).

(c) From the remaining cells of the savings matrices after steps a and b, select the cell with the remaining maximum savings that can be feasibly linked (Point a_{13} of Figure 5). Add the savings obtained in steps a, b, and c and record it.

(d) Disregard the actions of steps b and c and start over except this time select the cell, in the savings matrices remaining after step a, with the second highest savings that can be feasibly linked and assume that this pair of points is linked and assigned to the corresponding terminal (Point a_{22} in Figure 5).

(e) From the remaining cells in the savings matrices after steps a and d, select the cell with the remaining maximum savings that can feasibly be linked (Point a_{23} in Figure 5). Add the savings obtained in steps a, d, and e and record it.

(f) This procedure is repeated for the third branch associated with the first alternative by disregarding the actions of steps b, c, d, and e and selecting the cell, remaining after step a, with the third highest savings that can feasibly be linked. Assume that this pair of points is linked and assigned to the corresponding terminal (Point a_{32} in Figure 5).

(g) From the remaining cells in the savings matrices after steps a and f, select the cell with the remaining maximum savings which can feasibly be linked (Point a_{33} in Figure 5). Add the savings obtained in steps a, f and g and record it.

(h) The maximum of the three accumulated total savings figures is selected and associated with the first alternative, which is the first pair of points selected in step a.

(i) This procedure is continued as in the single terminal algorithm for the second highest possible savings, the third highest possible savings, etc., until the desired number of alternatives have been investigated.

Note that each pair of points being considered for linking in the above steps must satisfy the conditions in Step 6 below before they can be assumed linked. It should also be noted that when a pair of points is assumed linked, Steps 6 through 9 of the algorithm are assumed to have taken place before the next selection is made.

The total savings figures associated with each alternative are searched for the maximum and the corresponding alternative is selected as the pair of demand points to be linked and assigned to a terminal in this iteration.

The above computational procedure of Step 5 can best be illustrated for the example problem by referring to Figure 14. The number of alternatives by Clarke and Wright's method. The author's 3-decision look ahead method also obtained a worse solution for problem one but found the best solution for problem two when considering two alternatives at each iteration. The reason for the two look ahead methods obtaining worse solutions in problem one is the same as that given for the same difficulty encountered in the twenty-five demand point problems.

Although more example problems need to be solved by the three methods before a reliable conclusion could be made, the author would recommend that a fifty demand point problem should first be solved by Clarke and Wright's method and then solved by the proposed look ahead method considering at least three alternatives at each iteration. In this manner, the best solution could be obtained and at the same time protect against the problem encountered when using the proposed 3-decision look ahead method. This would entail a total of thirty-eight minutes on the IBM 360 computer (that is eight minutes for Clarke and Wright's method and thirty minutes for the proposed 3-decision look ahead method).

CONCLUSION FOR THE SINGLE TERMINAL PROBLEMS

For the single terminal carrier routing problems, the only algorithmic approaches which are computationally feasible are those based upon heuristic programming. An algorithm proposed by Tillman and Cochran was used as a basis for developing an improved method. An extended look ahead feature was developed for improving the selection criteria and was incorporated into this method. This modified algorithm was then used as a basis for this work.

Several example problems with ten, twenty-five, and fifty demand points each were constructed and solved by Clarke and Wright's method, Tillman and Cochran's method, and the proposed extended look ahead method. Based upon the criteria of finding the minimum total distance traveled on all routes, the author suggests the following guidelines for solving single terminal carrier routing problems.

> Solve the problems first with Clarke and Wright's method to provide a basis for comparison and then solve the problems using the proposed 3-decision look ahead method considering three alternatives at each iteration.

If minimizing computer time is important, the author suggests that Clarke and Wright's method of solution be used since this method provides good answers and requires the minimum amount of computer time.

It is suggested that a possible approach for further research in this area would be to modify the proposed 3-decision look ahead method so that a maximum of three alternatives are considered at each iteration and at least six successive linkings are considered for each alternative (i.e. Develop a 6-decision look ahead method). This would possibly eliminate the difficulty encountered in the 3-decision look ahead method and therefore eliminate the need for first solving the problems with Clarke and Wright's method.

CHAPTER III

THE MULTIPLE TERMINAL CARRIER ROUTING PROBLEM

PROBLEM

The multiple terminal carrier routing problem can be regarded as a generalization of the single terminal problem. The major difference between the two problems is that in the multiple terminal case there are two or more terminals from which the delivery vehicles can be dispatched to carry the commodity to the given demand points. Therefore, the multiple terminal problem is one of determining the "best" delivery routes with respect to some objective function (total miles, cost, etc.) from the appropriate terminals such that the following conditions are satisfied.

(1) The distance matrix must be symmetrical.

(2) All the demands are assumed known and must be fulfilled.

(3) A given demand point may not appear on more than one route (i.e., A given demand point may not be supplied by more than one terminal, and once it is assigned to a terminal, the demand point cannot appear on more than one route from that terminal.

(4) The carriers may have different carrying capacities which are assumed known.

(5) The routes to be determined must all be either "pickup" or "delivery" routes and not both.

SURVEY OF THE LITERATURE

There has been several methods of solution proposed for the solution of the single terminal carrier routing problem, as discussed in chapter two. Although the multiple terminal carrier routing problem is considered a generalization of the single terminal problem, very little research has been conducted on the multiple terminal problem. The only article available in the literature proposes a heuristic programming algorithm for the solution of the multiple terminal problem with probabilistic demands developed by Tillman [25]. This algorithm will be discussed below.

Discussion

Research is presently being conducted in the department of Industrial Engineering at Kansas State University on a branch and bound method of solution for the multiple terminal problem. This is a part of the research noted in progress in chapter two on the single terminal problem. The research has not reached a stage of development such that a more meaningful discussion of the proposed method can be given at this time.

Based upon the conclusion that the methods using heuristic programming approaches were the only algorithmic methods that seemed computationally feasible for solving large practical single terminal problems, Tillman [25] proposed such a method for solving the multiple terminal problem with probabilistic demands. To develop the algorithm, the author utilized the distance and savings matrix concept of Clarke and Wright's method [6] developed for a single terminal problem. The proposed algorithm provides "good" answers to a difficult problem and appears suitable for solving large practical problems.

The algorithm developed by Tillman [25], with some modifications, is equally applicable to multiple terminal problems with deterministic demands which are being discussed in this paper. Therefore, the following study was undertaken for improving the selection criteria of the heuristic algorithm in an effort to obtain "better" solutions. Tillman's [25] algorithm, modified for solution of problems with deterministic demands, will be discussed in detail in the following section followed by suggested improvements.

TILLMAN'S METHOD

The algorithm proposed by Tillman [25] is a heuristic programming method for the solution of the multiple terminal carrier routing problems. As noted, the author utilized the distance and savings matrix concept of Clarke and Wright's method [6] for a single terminal problem, and developed a modified distance matrix concept for the multiple terminal problem.

A discussion of the development of the algorithm is presented in the next section. The definitions of the terms used in the following discussion are as follows:

P_j = demand point j.

$d_{j,k}$ = distance between demand points P_j and P_k.

d_j^i = distance from terminal i to demand point P_j.

$\tilde{d}_j^i$ = modified distance from terminal i to demand point P_j.

$S_{j,k}^i$ = savings associated with linking demand points P_j and P_k to a route from terminal i.

q_j = quantity required at demand point P_j.

C_n = carrying capacity of the nth vehicle.

$t_{j,k}$ = index used to indicate how the demand points P_j and P_k are connected to constitute a link.

The Development

A problem occurs if the savings equation developed by Clarke and Wright [6] for the single terminal problem is directly applied in the multiple terminal problem. The difficulty occurs when computing the savings using equation (6) for two demand points which are close to one terminal and a greater distance to the second terminal. In such cases, the savings computed using this equation would be greatest for the points that are furthest from the terminal. Using the selection criteria of selecting the points to be linked and assigned to a terminal on the basis of the savings computed from equation [6] would indicate that the points should be assigned to the more distant terminal. This is incorrect since the pair of points are actually closer to the other terminal. The solution of this problem led Tillman to develop the following approach.

In the multiple terminal problem, the savings must be computed to reflect the "true" savings relative to each terminal. For the terminal nearest the points, the "true" savings is given by equation (6), but for the terminal furthest away the savings of equation (6) are reduced by the amount that the actual distance exceeds the distance from this point to the nearest terminal [25]. To take this into consideration, a modified distance is computed from each terminal to each point using the equation

$$\tilde{d}_j^i = \min_s d_j^s - (d_j^i - \min_s d_j^s), \tag{8}$$

before computing the savings where the superscript denotes the terminal and the subscript denotes the demand point. The savings are computed for each terminal using the equation

$$S_{j,k}^i = \tilde{d}_j^i + \tilde{d}_k^i - d_{j,k} \tag{9}$$

The algorithm begins with an initial solution such that each demand point is assigned individually to the nearest terminal and a truck is assigned to each demand point [25]. A distance and savings matrix is determined for each terminal using Equations (8) and (9). A pair of demand points is selected for linking at each iteration based on the savings and then assigned to the terminal associated with this improvement. The demand points selected for linking are those with the maximum savings which do not violate the restrictions on the system. The trucks are then reassigned by removing the trucks which were previously assigned to the demand points and assigning a truck with sufficient capacity to the newly formed route. When two demand points are linked and assigned to a terminal, they are eliminated from consideration at the other terminals. The modified distance, $\tilde{d}_j^i$, for the point that is linked to another point at this terminal is set equal to the true distance, d_j^i, and the savings matrix at this terminal is updated as required by this change [25].

This process is repeated until all the demand points are linked which generate a positive savings and do not violate the restrictions on the system. The single points remaining which are not assigned to a route are then assigned to the nearest terminal.

Note, as in the single terminal problem, a given demand point can only be linked at most to two other points, one of which may be the terminal. Therefore, whenever a demand point is linked to two other demand points it is not considered for further linking.

The Algorithm

The step by step computational procedure of the algorithm will now be given using a three terminal and ten demand point problem to illustrate the method. See Figure 13 which shows the example problem.

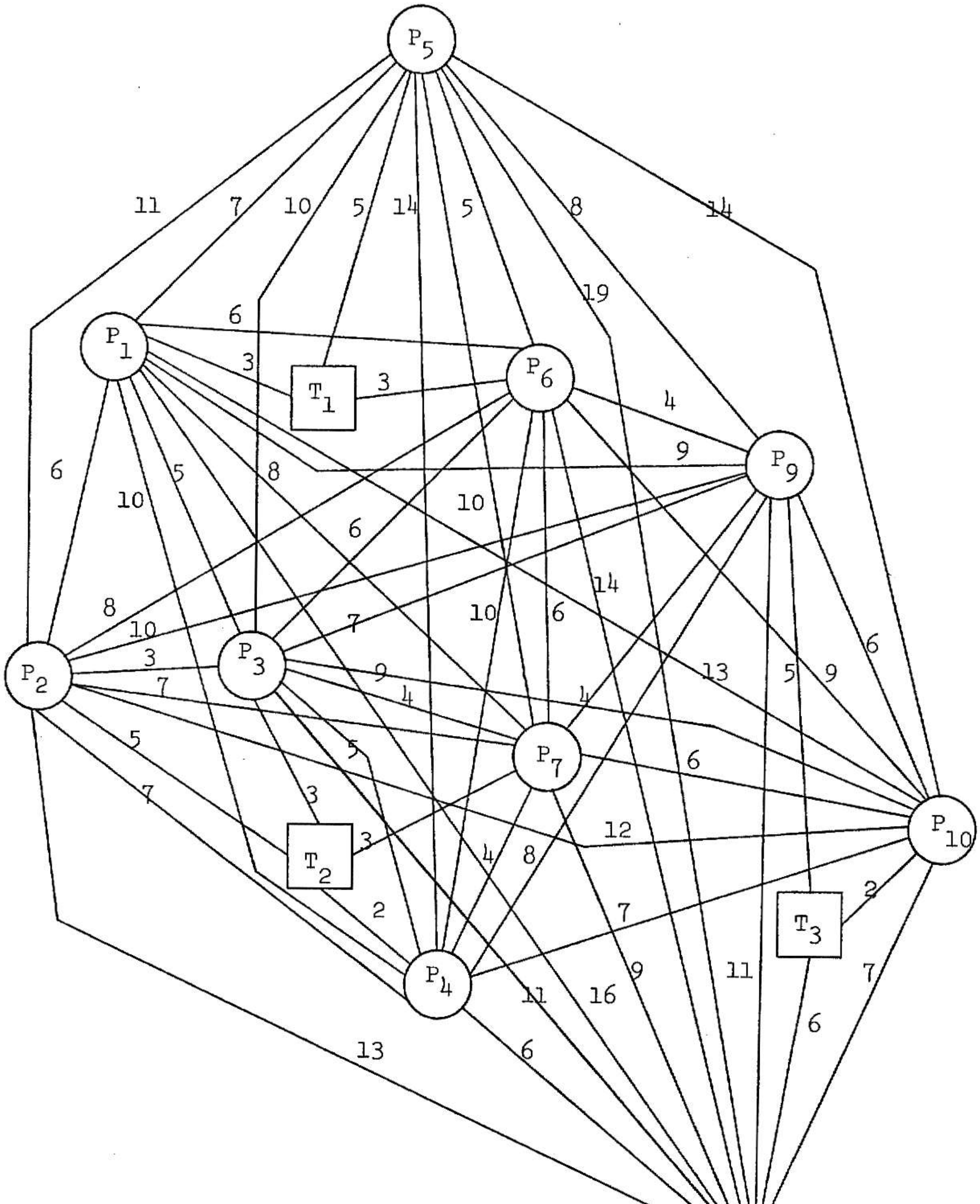

Figure 13: Example problem showing the distances between demand points and the terminals.

Step 1.

The first step of the computational procedure is the assignment of identification numbers to the demand points and constructing a distance matrix for each terminal. Only one half of the matrices are needed since the distances are symmetrical. The demand points are labeled P_j ($j=1,2,\ldots,N$) for an N demand point problem and the distances, $d_{j,k}$, are inserted in the lower right-hand corner of each cell in each matrix, Tables 13, 14, and 15. Two column vectors are added to the left-hand side of each distance matrix. The first column vector, D^i, of each matrix contains the distances, d^i_j, from the ith terminal to each of the demand points. The modified distances, $\tilde{d}^i_j$, for each terminal are computed using equation (8) and are entered into the second column vector, $\tilde{D}^i$, of the corresponding distance matrix.

Step 2.

The second step of the computational procedure involves the calculation of the savings matrix for each terminal. The savings obtained by linking two specific demand points to a given terminal is calculated from equation (9) and is entered in the lower left-hand corner of the appropriate cell in the corresponding distance matrix.

The completed distance matrices for the three terminals of the sample problem are shown in Tables 13, 14, and 15.

Step 3.

The third step consists of formulating the initial computational matrix using the same format used to construct the distance matrix. Two column vectors are added to the left-hand side of this matrix. The first column vectors are added to the left-hand side of this matrix. The first column vector $Q = (q_1, q_2, \ldots, q_N)$ initially contains the quantities, q_i,

D^1	$\bar{D}^1$										
3	3	P_1									
6	4	1 6	P_2								
5	1	-1 5	2 3	P_3							
9	-5	-12 10	-8 7	-9 5	P_4						
5	5	1 7	-2 11	-4 10	-14 14	P_5					
3	3	-1 6	-1 8	-2 6	-12 10	3 5	P_6				
6	0	-5 8	-3 7	-3 4	-9 4	-5 10	3 6	P_7			
15	-3	-16 16	-12 13	-13 11	-14 6	-17 19	-14 14	-12 9	P_8		
7	3	-3 9	-3 10	-3 7	-10 8	-1 8	2 4	-1 4	-11 11	P_9	
12	-8	-18 13	-16 12	-16 9	-20 7	-17 14	-14 9	-14 6	-18 7	-11 6	P_{10}

Table 13. Distance matrix for terminal 1 showing the distances in lower right-hand corner of each cell, and savings in lower left-hand corner of each cell.

D^2	$\tilde{D}^2$										
8	-2	P_1									
5	5	-3 6	P_2								
3	3	-4 5	5 3	P_3							
2	2	-10 10	-1 7	-1 5	P_4						
12	-2	-11 7	-8 11	-9 10	-14 14	P_5					
8	-2	-10 6	-5 8	-5 6	-10 10	-9 5	P_6				
3	3	-7 8	1 7	2 4	1 4	-9 10	-5 6	P_7			
8	4	-14 16	-4 13	-4 11	-1 6	-17 19	-12 14	-2 9	P_8		
7	3	-8 9	-2 10	-1 7	-3 8	-7 8	-3 4	2 4	-4 11	P_9	
7	-3	-18 13	-10 12	-9 9	-8 7	-19 14	-14 9	-6 6	-6 7	-6 6	P_{10}

Table 14. Distance matrix for terminal 2 showing the distances in lower right-hand corner of each cell, and savings in lower left-hand corner of each cell.

D^3	$\tilde{D}^3$										
12	-6	P_1									
12	-2	-14 6	P_2								
8	-2	-13 5	-7 3	P_3							
6	-2	-18 10	-11 7	-9 5	P_4						
14	-4	-17 11	-17 11	-16 10	-20 14	P_5					
9	-3	-15 6	-13 8	-11 6	-15 10	-12 5	P_6				
4	2	-12 8	-7 7	-4 4	-4 4	-12 10	-7 6	P_7			
6	6	-16 16	-9 13	-7 11	-2 6	-17 19	-11 14	-1 9	P_8		
5	5	-10 9	-7 10	-4 7	-5 8	-7 8	-2 4	3 4	-1 11	P_9	
2	2	-17 13	-12 12	-9 9	-7 7	-16 14	-10 9	-2 6	1 7	1 6	P_{10}

Table 15. Distance matrix for terminal 3 showing the distances in lower right-hand corner of each cell and savings in lower left-hand corner of each cell.

which are required at the demand points P_j $(j=1,2,\ldots,N)$. The second column vector $T = (t_{1,0}, t_{2,0},\ldots,t_{N,0})$ contains the index that indicates how the demand points are linked with the terminals to form a route. The remaining cells contain the values of the index $t_{j,k}$ which indicate how the demand points are connected to constitute a link. The values of the index, $t_{i,j}$, will always be 0, 1, or 2 according to the three possibilities listed in Tillman and Cochran's algorithm in chapter two. The initial solution assumes that the demand points are assigned to the nearest terminal, therefore, all $t_{j,0} = 2$ $(i=1,2,\ldots,N)$ and all the remaining cells have a value $t_{j,k} = 0$. Since a given demand point can only be linked at most to two other points, one of which may be a terminal, the relationship shown in equation (7) must always exist. The values of $t_{j,k}$ are adjusted after each pair of points are linked so that the relationship holds.

The initial computational matrix constructed for the example problem is shown in Table 16. Note that the blank cells in the matrix indicate that the value of $t_{j,k} = 0$. Also note that the index in the upper left-hand corner of the cells in the T vector denotes the terminal to which the route is assigned.

Step 4.

The fourth step of the computational procedure involves the initial assignment of trucks to the demand points which are assumed to be linked to the nearest terminal. If the assignment is infeasible, split the demands where necessary and assume "dummy trucks" as needed such that a feasible assignment can be made. This is discussed in Step 4 of Tillman and Cochran's method in chapter two.

There are three trucks available in the sample problem with carrying capacities of 30 units each. The initial assignment of trucks to the demand points would require 10 trucks which is more than there are trucks available, therefore, an infinite number of trucks with 30 units capacity are assumed available. The extra trucks constitute the "dummy trucks". The initial assignment of trucks for the sample problem is shown in Table 16.

Step 5.

An attempt is made in this step to link the demand points which have the maximum savings and assign the points to the terminal associated with this savings. When searching the savings matrices for the maximum savings, only those savings corresponding to the links that satisfy the conditions of Step 6 should be included in the search.

If there are two or more equal maxima encountered in the search, one of these are selected randomly.

Step 6.

The points selected to be linked in Step 5 must be tested to see if the restrictions listed below are satisfied. For the pair of points under consideration, P_j and P_k, the restrictions to be satisfied are:

(a) The values of the indexes $t_{j,0}$ and $t_{k,0}$ must be greater than zero which indicates that the demand points are still linked to a terminal and these links are eligible to be severed.

(b) The demand points P_j and P_k must not already be on the same route. This prevents the forming of a "loop" that does not include the terminal.

Q	T										
10	^{1} 2	P_1									
4	^{2} 2		P_2								
8	^{2} 2			P_3							
7	^{2} 2				P_4						
12	^{1} 2					P_5					
6	^{1} 2						P_6				
5	^{2} 2							P_7			
10	^{3} 2								P_8		
8	^{3} 2									P_9	
15	^{3} 2										P_{10}

Capacity	30
Available	3
Assumed Available	
Assigned	10

Table 16. Initial computational matrix with Q vector and initial truck assignment table. Note the index in the upper left-hand corner of the cells in the vector denotes the terminal to which the route is assigned.

(c) The combined quantities, q_j, required by the demand points P_j and P_k and any other demand points which may be on the same route must not exceed the capacity of the available trucks.

(d) Any other restriction on the system must be satisfied.

If one or more of the above conditions are not satisfied, then this pair of points are excluded from further consideration at this terminal and the process is repeated from Step 5. If the pair of points selected in Step 5 satisfy all the conditions, then they are joined at this terminal and are eliminated from consideration at the other terminals.

The maximum savings of 5 is obtained in the example problem by linking the demand points P_2 and P_3 on a route from terminal 2. This pair of points satisfies all the conditions listed in Step 6, and are therefore linked on a route at terminal 2.

Step 7.

If the demand points, P_j and P_k, selected in Step 5 satisfy all the conditions of Step 6, they are linked and assigned to the terminal associated with this improvement. This is done by setting the value of $t_{j,k} = 1$, and decrementing the values of $t_{j,0}$ and $t_{k,0}$ by 1 such that equation (7) holds. The terminal index in the upper left-hand corner of the cells $t_{j,0}$ and $t_{k,0}$ is set to the terminal which is to serve this route. This pair of points is then eliminated from further consideration at the other terminals by setting the savings associated with each of these points to zero at these terminals. The values of $\tilde{d}^i_j$ and $\tilde{d}^i_k$ are set equal to d^i_j and d^i_k, respectively, at the terminal in which the points

P_j and P_k have been linked. The savings matrix at this terminal is then updated as required by this change.

Step 8.

The Q vector containing the loads q_i are amended to indicate the linking of the demand points P_j and P_k in this iteration. Each q_i corresponding to the index value $t_{i,0} = 0$ is itself set equal to zero and each q_i corresponding to the demand points linked on the newly formed route is set equal to the sum of the demand for all points on the route.

The adjustments to the computational matrix to record Steps 7 and 8 for the example problem are shown in Table 17. The demand points linked in the first iteration are P_2 and P_3, therefore, the value of $t_{2,3}$ is set equal to 1 to record the linking and the values of $t_{2,0}$ and $t_{3,0}$ are decremented by 1 such that $t_{2,0} = 1$ and $t_{3,0} = 1$. The combined load for the route is 12 units, therefore, q_2 and q_3 are set equal to 12.

Step 9.

This step of the computational procedure involves the reassignment of trucks to cover the newly formed routes. The trucks previously assigned to cover the demand points P_j and P_k are removed and a truck of sufficient carrying capacity is assigned to cover this newly formed route, which includes the points P_j and P_k and any other points which may be on the route from previous iterations.

In the sample problem, the trucks initially assigned to cover P_2 and P_3 are removed and a truck is reassigned to cover the new route which has a combined load of 12 units. The truck assignment table is shown in Table 17 after the first iteration.

Q		T										
10	1	2	P_1									
12	2	1		P_2								
12	2	1		1	P_3							
7	2	2				P_4						
12	1	2					P_5					
6	1	2						P_6				
5	2	2							P_7			
10	3	2								P_8		
8	3	2									P_9	
15	3	2										P_{10}

Capacity	30
Available	3
Assumed Available	∞
Assigned	9

Table 17. Computational matrix and truck assignment table after completion of the first iteration.

Step 10.

This completes the first iteration. Return to Step 5 to check for more links with a positive savings which satisfy all the conditions listed in Step 6. If more links are feasible the procedure is continued. If no other links are feasible, the final solution has been obtained. The remaining single points which were not assigned to a route during the computational procedure remained assigned to the nearest terminal. The routes formed, exact order of visitation of the demand points, and the terminals to which the routes are assigned are obtained from the final solution matrix. The final assignment of trucks is obtained from the truck assignment table. The distance traveled on each route and the total distance traveled on all routes is calculated from the original distance matrices.

Four more iterations are required to find the final solution for the sample problem. The demand points P_5 and P_6 are linked and assigned to terminal 1 in the second iteration; the demand points P_7 and P_9 are linked and assigned to terminal 3 in the third iteration; the demand points P_1 and P_5 are linked and assigned to the route at terminal 1; and the demand points P_7 and P_8 are linked and assigned to terminal 3 in the last iteration. The final computational matrix, the final truck assignment table, and the final routes and distances for the problem are given in Tables 18, 19 and 20, respectively. The total distance for all routes is 61 miles.

Summary of the Algorithm

The Steps of the algorithm are summarized below.

Step 1. Label the demand points P_j $(j=1,2,\ldots,N)$ and construct

Q	T										
28	^{1} 1	P_1									
12	^{2} 1		P_2								
12	^{2} 1		1	P_3							
7	^{2} 2				P_4						
0	^{1} 0					P_5					
28	^{1} 1					1	P_6				
0	^{3} 0							P_7			
23	^{3} 1							1	P_8		
23	^{3} 1							1		P_9	
15	^{3} 2										P_{10}

Table 18. Computational matrix after final iteration.

Capacity	30
Available	3
Assumed Available	∞
Assigned	3

Table 19. Truck assignment table after final iteration.

Terminal	Routes	Distance	Load
1	T_1-P_1-P_5-P_6-T_1	18	28
2	T_2-P_2-P_3-T_2	11	12
	T_2-P_4-T_2	4	7
3	T_3-P_8-P_7-P_9-T_3	24	23
	T_3-P_{10}-T_3	4	15

Table 20. Final route and distance table. One truck is used for both routes at terminals 2 and 3.

a distance matrix for each terminal. Two column vectors are added to the left-hand side of each matrix. The first vector, D^i, contains the distances from the terminal to the demand points and the second vector, $\tilde{D}^i$, contains the modified distances computed with equation (8).

Step 2. Calculate the savings using equation (9) for linking each pair of points to a specific terminal and enter them in the corresponding distance matrix (Tables 13, 14, and 15).

Step 3. Set up the initial computational matrix and enter the initial solution (Table 16).

Step 4. Assign one truck to each demand point, assuming "dummy trucks" are available and split demands if necessary to make a feasible allocation (Table 16).

Step 5. Find the maximum feasible savings possible in the savings matrices. Choose one randomly if there are two or more equal maxima.

Step 6. Test the demand points selected to be linked in Step 5 to see that the restrictions listed above are satisfied. If one or more of the conditions are not satisfied, exclude this pair of points from further consideration at this terminal and return to Step 5.

Step 7. If the pair of points satisfy all the conditions, set $t_{j,k} = 1$ and decrement the values of $t_{j,0}$ and $t_{k,0}$ by 1 such that equation (7) holds. Set the terminal index in cells $t_{j,0}$ and $t_{k,0}$ to the terminal associated with this savings. Eliminate this pair of points from further consideration at the other terminals. Set the values of $\tilde{d}_j^i$ and $\tilde{d}_k^i$ to d_j^i and d_k^i, respectively, at the terminal in which the points P_j and P_k have been linked and update the savings matrix at this terminal as required by the change (Table 17).

Step 8. Amend the Q vector for the newly formed route (Table 17).

Step 9. Reassign the trucks to correspond to the new routes (Table 17). This completes one iteration.

Step 10. Return to Step 5 to check for more feasible links. If no other feasible links are possible, then the final solution has been found. The points not assigned to a route remain assigned to the nearest terminal. Determine the routes formed, the exact order of visitation, and the terminals to which the routes are assigned from the final computational matrix (Table 18). Determine the final truck assignment (Table 19). Determine the distance traveled on each route and the total distance for all routes (Table 20).

THE LOOK AHEAD APPROACH

General Remarks

This section presents a discussion of some modifications to Tillman's algorithm which may improve the selection criteria in an attempt to obtain better solutions to the multiple terminal problem. The modifications in the selection criteria consists of incorporating the look ahead feature discussed in chapter two and illustrated in Figure 5. As noted, the look ahead feature considers the consequences of three future linkings for a given number of alternatives before a pair of points is selected for linking in each iteration. This feature appears to be a significant contribution from the results of solving a number of example problems. (See Appendix III.)

The Proposed Algorithm

The computational procedure of the modified algorithm is given below. To illustrate the method the same problem will be solved as was solved by Tillman's method.

Step 1.

Assign the identification numbers to the demand points and construct the distance matrix for each terminal. This step is the same as the corresponding step in Tillman's method. A decision regarding the number of alternatives which are to be considered in each iteration according to Step 5 below must also be made at this step. If only one alternative is considered in each iteration, the solution procedure is the same as Tillman's method. Otherwise, the number of alternatives to be considered at each iteration is based upon the size of the problem. Again, it is felt that the results from solving several example problems will provide some insight for determining what this number should be for various sizes of problems.

Step 2.

This step of the computational procedure consists of calculating the savings matrix for each terminal using equation (9). This step is also the same as Step 2 of the previous method.

The completed distance matrices for the three terminals of the sample problem are again shown in Tables 13, 14, and 15.

Step 3.

This step involves the formulation of the initial computational matrix, the initial demand vector, and the initial terminal index vector. This step is also the same as Step 3 of the previous method.

The initial computational matrix is again shown in Table 16.

Step 4.

The initial truck assignment is made in this step which is the same as Step 4 in the previous method.

The initial truck assignment for the example problem is also shown in Table 16.

Step 5.

An attempt is made in this step to link the demand points which result in the overall maximum savings by looking at the resulting savings of the three different branches for each of several feasible alternatives. Each branch considers the consequences of a sequence of three future linkings for the given alternative.

The computational procedure will consist of the following steps

(Reference to Figure 5 will facilitate the reader's understanding):

(a) Select the cell with the maximum savings from all the savings matrices which can feasibly be linked and assume that this pair of points is linked and assigned to the terminal corresponding to this improvement (Point a_{11} in Figure 5).

(b) From the remaining cells of all the savings matrices, select the cell with the remaining maximum savings that can be feasibly linked and assume that this pair of points is linked and assigned to the corresponding terminal (Point a_{12} of Figure 5).

(c) From the remaining cells of the savings matrices after steps a and b, select the cell with the remaining maximum savings that can be feasibly linked (Point a_{13} of Figure 5). Add the savings obtained in steps a, b, and c and record it.

(d) Disregard the actions of steps b and c and start over except this time select the cell, in the savings matrices remaining after step a, with the second highest savings that can be feasibly linked and assume that this pair of points is linked and assigned to the corresponding terminal (Point a_{22} in Figure 5).

(e) From the remaining cells in the savings matrices after steps a and d, select the cell with the remaining maximum savings that can feasibly be linked (Point a_{23} in Figure 5). Add the savings obtained in steps a, d, and e and record it.

(f) This procedure is repeated for the third branch associated with the first alternative by disregarding the actions of steps b, c, d, and e and selecting the cell, remaining after step a, with the third highest savings that can feasibly be linked. Assume that this pair of points is linked and assigned to the corresponding terminal (Point a_{32} in Figure 5).

(g) From the remaining cells in the savings matrices after steps a and f, select the cell with the remaining maximum savings which can feasibly be linked (Point a_{33} in Figure 5). Add the savings obtained in steps a, f and g and record it.

(h) The maximum of the three accumulated total savings figures is selected and associated with the first alternative, which is the first pair of points selected in step a.

(i) This procedure is continued as in the single terminal algorithm for the second highest possible savings, the third highest possible savings, etc., until the desired number of alternatives have been investigated.

Note that each pair of points being considered for linking in the above steps must satisfy the conditions in Step 6 below before they can be assumed linked. It should also be noted that when a pair of points is assumed linked, Steps 6 through 9 of the algorithm are assumed to have taken place before the next selection is made.

The total savings figures associated with each alternative are searched for the maximum and the corresponding alternative is selected as the pair of demand points to be linked and assigned to a terminal in this iteration.

The above computational procedure of Step 5 can best be illustrated for the example problem by referring to Figure 14. The number of alternatives

ILLEGIBLE

THE FOLLOWING DOCUMENT (S) IS ILLEGIBLE DUE TO THE PRINTING ON THE ORIGINAL BEING CUT OFF

ILLEGIBLE

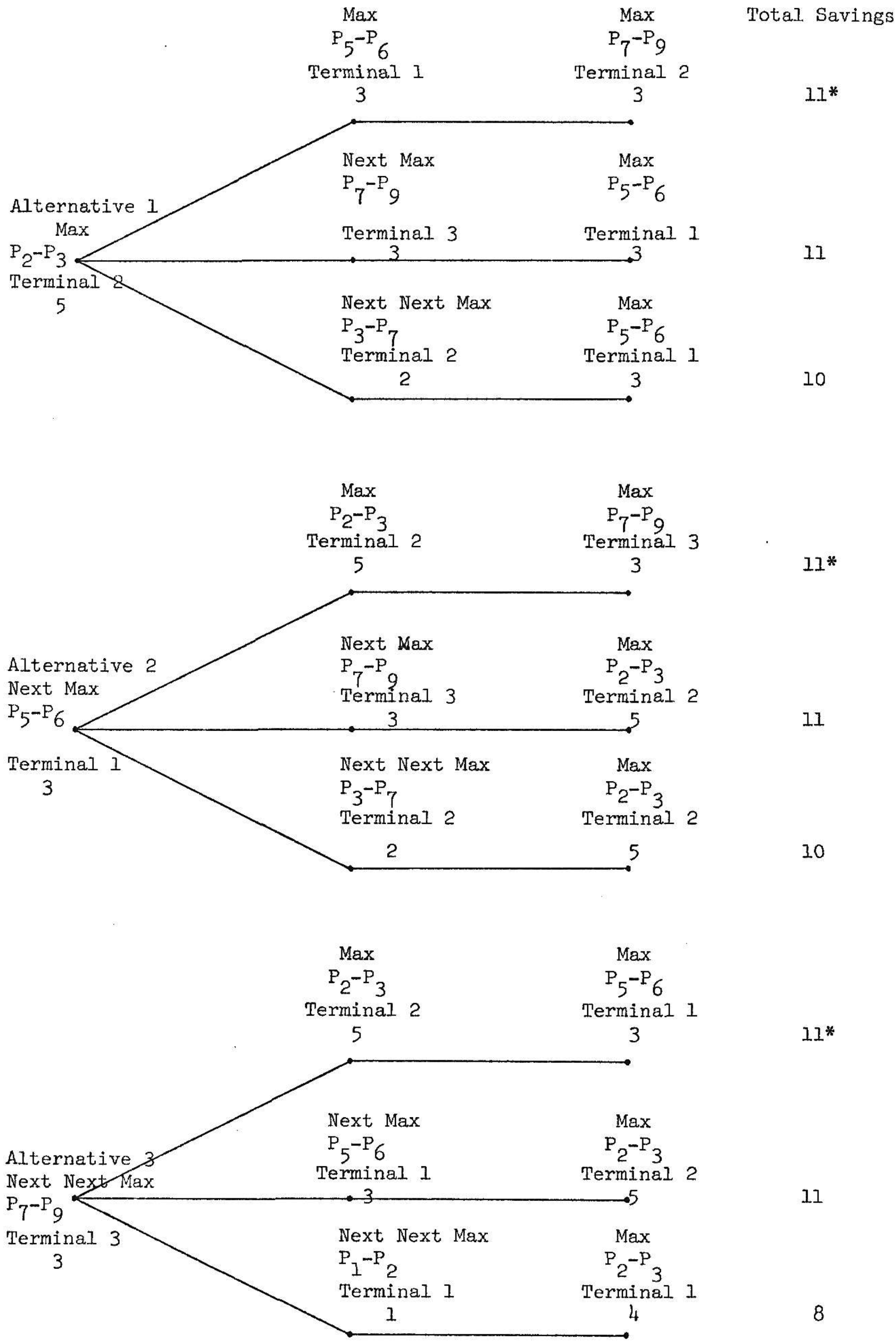

Figure 14: Decision tree for the three alternatives of the sample problem using the look ahead feature.

to be considered in each iteration is arbitrarily assumed to have been set at three in Step 1. The branches developed for the three alternatives of the example problem according to the above steps are shown in Figure 14. The top branch for alternative one was developed by performing steps a, b, and c and has an accumulated total savings of 11. The second branch of alternative one was developed by ignoring the actions taken in steps b and c and repeating the process. This branch also has an accumulated total savings of 11. The last branch for alternative one was developed by ignoring the previous actions and repeating the process. This last branch for alternative one has an accumulated total savings of 10. Therefore, the maximum total savings associated with this first alternative is 11. To develop the decision tree for the second and third alternatives, the entire process is repeated for each alternative.

Since all three alternatives have a total maximum savings of 11, Figure 14, any one of the three alternatives can be selected for linking in this iteration. The assumption is made to arbitrarily select the first alternative with the maximum total savings, therefore, the demand points P_2 and P_3 are to be linked and assigned to the appropriate terminal in this iteration.

Step 6.

In this step, the demand points selected in Step 5 are checked to determine if they satisfy all the system restrictions. This step is the same as the corresponding step in Tillman's algorithm.

The demand points selected in Step 5 for the example problem satisfy all the restrictions, therefore, P_2 and P_3 are linked on a route at terminal 2 in this iteration.

Step 7.

This step of the proposed algorithm consists of adjusting the $t_{i,j}$ parameters in the computational matrix to record the linking. The pair of points selected are eliminated from further consideration at the other terminals and the savings matrix of the terminal associated with the newly formed route is updated. This step is the same as Step 7 of the previous method.

Step 8.

This step of the computational procedure consists of updating the Q vector for the newly formed route. This step is also performed the same as the corresponding step of the previous method.

The adjustment of the computational matrix to record Steps 7 and 8 for the sample problem is also shown in Table 17.

Step 9.

This step of the algorithm involves the reassignment of trucks to cover the newly formed routes. This step is also identical to the same step in the previous algorithm.

The allocation table for the sample problem after the first iteration is also shown in Table 17.

Step 10.

This completes one iteration of the algorithm. Return to Step 5 to check for further feasible savings. If more savings are possible, continue the algorithm from Step 5. If no more feasible savings are possible, then the final solution has been found. The remaining single points which were not assigned to a route during the computational procedure remain assigned to the nearest terminal. The routes formed, the exact order of visitation of the demand points, and the terminals to which the routes are assigned are obtained from the final computational matrix. The final assignment of trucks is obtained from the final truck assignment table. The distances traveled on each route and the total distance traveled on all routes is calculated from the original distance matrices.

Five more iterations are required to find the final solution for the example problem. The demand points P_3 and P_7 are linked and assigned to the route from terminal 2 in the second iteration; the demand points P_9 and P_6 are linked and assigned to terminal 1 in the third iteration; the demand points P_5 and P_9 are linked and assigned to the route at terminal 1 in the fourth iteration; the demand points P_7 and P_4 are linked and assigned to the route at terminal 2 in the fifth iteration; and the demand points P_8 and P_{10} are linked and assigned to terminal 3 in the last iteration. Demand point 1 was not assigned to a route, therefore it remains assigned to terminal 1 which is the nearest terminal. The final computational matrix, the final truck assignment table, and the final routes and distances for the sample problem are given in Tables 21, 22 and 23, respectively. The total distance for all routes is 59 miles which is an improvement of 2 miles and one less route over the final solution obtained for the problem using Tillman's [25] method. The problem used to illustrate the two methods is shown in Appendix III.

Summary of the Proposed Algorithm

A summary of the computational procedure will now be given.

Step 1. Label the demand points P_i ($i=1,2,\ldots,N$) such that identification can be made during the solution process and construct a distance matrix for each terminal. A

Q	T										
10	^{1} 2	P_1									
24	^{2} 1		P_2								
0	^{2} 0		1	P_3							
24	^{2} 1				P_4						
26	^{1} 1					P_5					
26	^{1} 1						P_6				
0	^{2} 0			1	1			P_7			
25	^{3} 1								P_8		
0	^{1} 0					1	1			P_9	
25	^{3} 1								1		P_{10}

Table 21. Computational matrix after final iteration.

Capacity	30
Available	3
Assumed Available	∞
Assigned	3

Table 22. Truck assignment table after final iteration.

Terminal	Routes	Distance	Load
1	T_1-P_5-P_9-P_6-T_1	20	26
	T_1-P_1-T_1	6	10
2	T_2-P_2-P_3-P_7-P_4-T_2	18	24
3	T_3-P_8-P_{10}-T_3	15	25

Table 23. Final route and distance table. One truck is used for both routes at terminal 1.

pair of column vectors are added to the left-hand side of each distance matrix. The first column vector, D^i, contains the distances from the terminal to the demand points and the second column vector, $\tilde{D}^i$, contains the modified distances computed from equation (8).

Step 2. Calculate the savings for linking each pair of demand points to a specific terminal using equation (9) and enter them in the corresponding distance matrix (Tables 13, 14, and 15).

Step 3. Set up the initial computational matrix and enter the initial solution (Table 16).

Step 4. Construct the truck assignment table and make an initial assignment of one truck to each demand point. In order to make an initial assignment of trucks, split the demands where necessary and assume "dummy trucks" as needed to make a feasible allocation (Table 16).

Step 5. Select the alternative to be linked and assign this pair of points to a terminal in this iteration based upon the total maximum savings, following the procedure outlined in Step 5 in the previous discussion.

Step 6. Test the demand points selected to see that the restrictions listed above are satisfied. If one or more of the conditions are not satisfied, exclude this pair of points from further consideration at the terminal and return to Step 5.

Step 7. If the pair of points selected for linking satisfies all the conditions, set $t_{j,k} = 1$ and decrement the values of $t_{j,0}$ and $t_{k,0}$ by 1 such that equation (7) holds. Adjust the terminal index in the cells $t_{j,0}$ and $t_{k,0}$ associated with this improvement. Eliminate this pair of points from further consideration at the other terminals. Adjust the values of $\tilde{d}_j^i$ and $\tilde{d}_k^i$ to d_j^i and d_k^i, respectively, at the terminal in which the route has been assigned and update the savings matrix at this terminal as required by the change. (Table 17).

Step 8. Amend the Q vector for the newly formed route (Table 17).

Step 9. Reassign the trucks to correspond to the new routes (Table 17). This completes one iteration.

Step 10. Return to Step 5 to check for further feasible links. If no further feasible links are possible, then the final solution has been found. The single demand points which were not assigned to a route remain assigned to the nearest terminal. Determine the routes formed, the order of visitation, and the terminals to which the routes are assigned from the final computational matrix (Table 21). Determine the final truck assignment (Table 22). Determine the distances traveled on each route and the total distance traveled for all routes (Table 23).

The above procedure was programmed for the IBM 360/50 computer and a number of problems of different sizes were solved and are discussed in the next section. The computer program is discussed and shown in Appendix I.

DISCUSSION OF PROBLEMS

As in the single terminal case, twelve problems were developed and solved by Tillman's method and the author's proposed 3-decision look ahead method. The sample problems were developed as follows:

(1) Five three-terminal problems with ten demand points each were developed. Problem one is the exact problem presented by Tillman [25]. This is also the problem used in the discussion of Tillman's algorithm and the proposed 3-decision look ahead algorithm above. Problems two through five were developed from the single terminal problems by selecting two more terminals in each problem. Care was taken when selecting the terminals for the problems so that various configurations were developed in regard to the demand points. All other data for the problems is the same as that used in the single terminal problems.

(2) Five problems with five terminals and twenty-five demand points each were developed. These are also the exact problems constructed for the single terminal case except that four more terminals were selected in each problem. Care was also taken when selecting the terminals so that various configurations were developed.

(3) Two five terminal problems with fifty demand points each were developed in the same manner. Four more terminals were selected for each problem developed in the single terminal case, otherwise, all the data for the problems are the same.

RESULTS

Three Terminal Ten Demand Point Problems

A summary of the solutions obtained for the three terminal ten demand point problems is shown in Table 24. The information given for each problem is the same as that given for the single terminal problems. The data and best solution obtained for each problem is shown in Appendix III.

The histogram showing the number of best solutions obtained with the two methods is shown in Figure 15. Note that Tillman's method obtained the best solution for only one of the five problems. The proposed 3-decision look ahead method obtained the best solution for four of the five problems when considering two alternatives at each iteration. An interesting point was noted between the solution given by Tillman's method and the better solution given by the proposed 3-decision look ahead method for problem four (Both solutions are shown in Appendix III). The principle difference was the proposed method indicated that the same demand points are linked in a different order on the third route and that the route is to be assigned to terminal one instead of terminal two.

When three alternatives were considered at each iteration, the proposed 3-decision look ahead method also obtained four best solutions out of five problems. Note that although a better solution was obtained for problem one, a worse solution was obtained for problem three. This is the same difficulty that occurred in the single terminal case. The explanation for this difficulty may be due to the limited number (three) of successive linkings for each alternative considered. It is suggested

Problem Number	Tillman Method	Proposed Method 3-Decision Look Ahead		
		2 alternatives	3 alternatives	5 alternatives
1	61	61	59	59
2	1835	1835	1835	1835
3	2045	2042	2087	2087
4	1715	1706	1706	1706
5	3629	3490	3490	3490

Table 24: Summary of distances for three terminal 10 demand point problems.

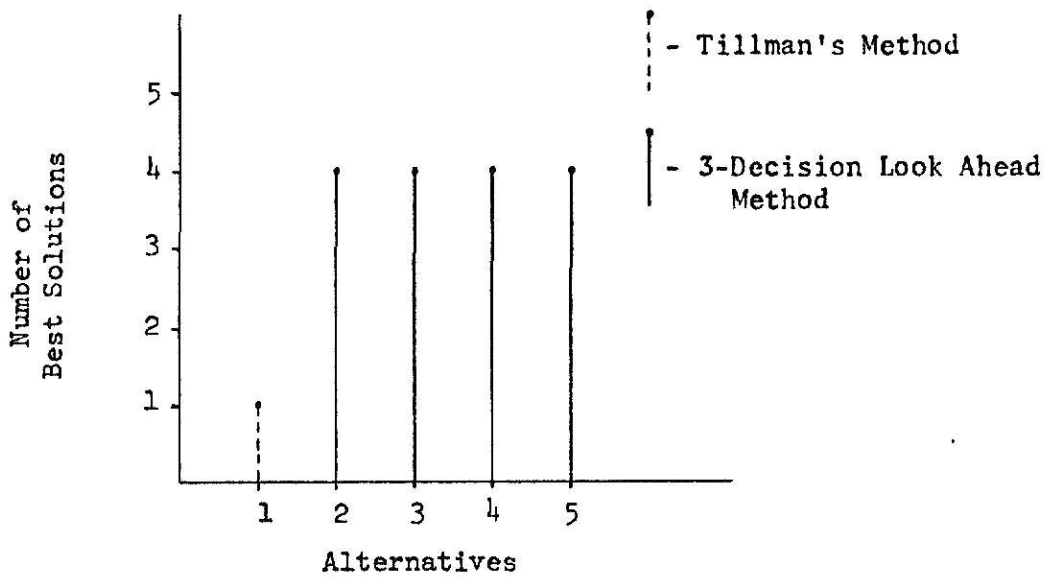

Figure 15: Best solutions for three terminal ten demand point problems.

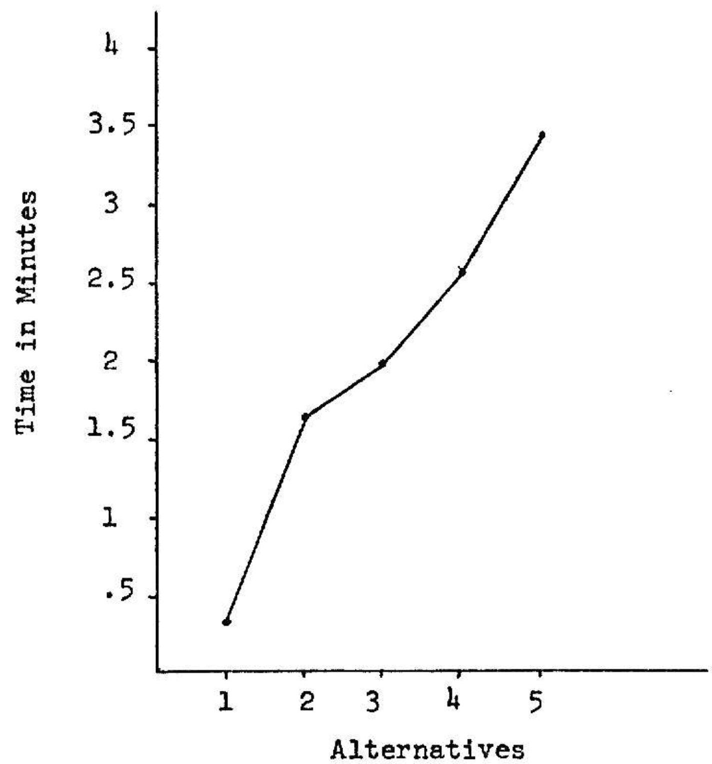

Figure 16: Execution time using Watfor compiler on IBM 360.

again that possibly a modified method should be developed in which at least six successive linkings are considered for each alternative and only a maximum of three alternatives considered at each iteration (i.e. Develop a 6-decision look ahead method of solution).

No improvements in the solution were obtained by considering more than three alternatives at each iteration. Thus, the percent improvement in total mileage obtained by the proposed methods best solutions as compared to the solutions obtained by Tillman's method is 3.2% for problem one, 0.0% for problem two, .15% for problem three, .52% for problem four, and 3.8% for problem five.

Figure 16 shows the average solution time required to solve the problems with the two methods using the Watfor compiler on the IBM 360/50 computer. Thus, the results appear to indicate that the best solution can be obtained for the three terminal ten demand point problems by using the proposed 3-decision look ahead method and considering at least three alternatives at each iteration. Due to the possibility of obtaining a worse solution when using the proposed method, it is suggested that the problems should first be solved using Tillman's method. This would involve a total solution time on the computer of approximately 2.5 minutes (i.e. Thirty seconds for Tillman's method and two minutes for the proposed 3-decision look ahead).

Five Terminal Twenty-five Demand Point Problems

The summary of solutions obtained for the five terminal twenty-five demand point problems is given in Table 25. The information given is the same as before. The data and best solution obtained for each problem is also shown in Appendix III.

Problem Number	Tillman Method	Proposed Method 3-Decision Look Ahead				
		2 alternatives	3 alternatives	5 alternatives	6 alternatives	10 alternatives
1	7005	6832	6832	6832	6832	6832
2	6182	6099	6099	6099	6099	6099
3	1377	1377	1377	1377	1377	1377
4	1824	1722	1824	1828	1828	1828
5	6840	6783	6783	6783	6653	6653

Table 25: Summary of distances for five terminal twenty-five demand point problems.

The histogram showing the number of best solutions obtained with the two methods is shown in Figure 17. As in the ten demand point problems, Tillman's method obtained the best solution for only one of the five problems. The proposed method obtained the best solution for four of the five problems when two alternatives were considered at each iteration. Note that the proposed method obtained the same solution that was originally obtained with Tillman's method in problem four when three alternatives were considered at each iteration. Since the best solution for this problem was obtained with the proposed method when considering two alternatives at each iteration, the solution obtained when considering three alternatives is a worse solution. When five alternatives were considered at each iteration for this problem, an even worse solution was obtained. Thus, the difficulty which seems inherent in the proposed 3-decision look ahead method has occurred again. Therefore, the best solutions were obtained for only three of the five problems when three through five alternatives were considered at each iteration.

When six alternatives were considered at each iteration, the proposed method obtained the best solution for problem five. Therefore, the proposed method obtained the best solution for four of the five problems when considering six alternatives. No improvements were obtained in the solutions by considering more than six alternatives at each iteration. The percent improvement is total mileage obtained by the proposed methods best solutions is 2.5% for problem one, 1.3% for problem two, 0.0% for problem three, 5.6% for problem four, and 2.7% for problem five.

The solution time required to solve the problems with the two methods using the more efficient G-level Fortran compiler on the IBM 360 computer is shown in Figure 18. The results, therefore, appear to indicate that the

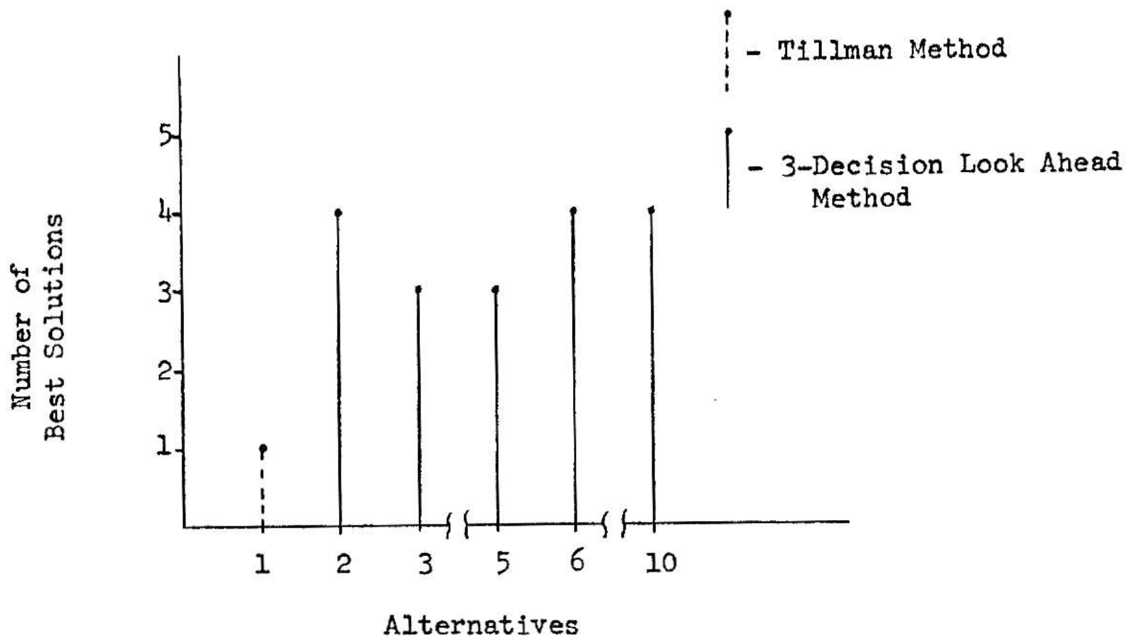

Figure 17: Best solutions for five terminal twenty-five demand point problems.

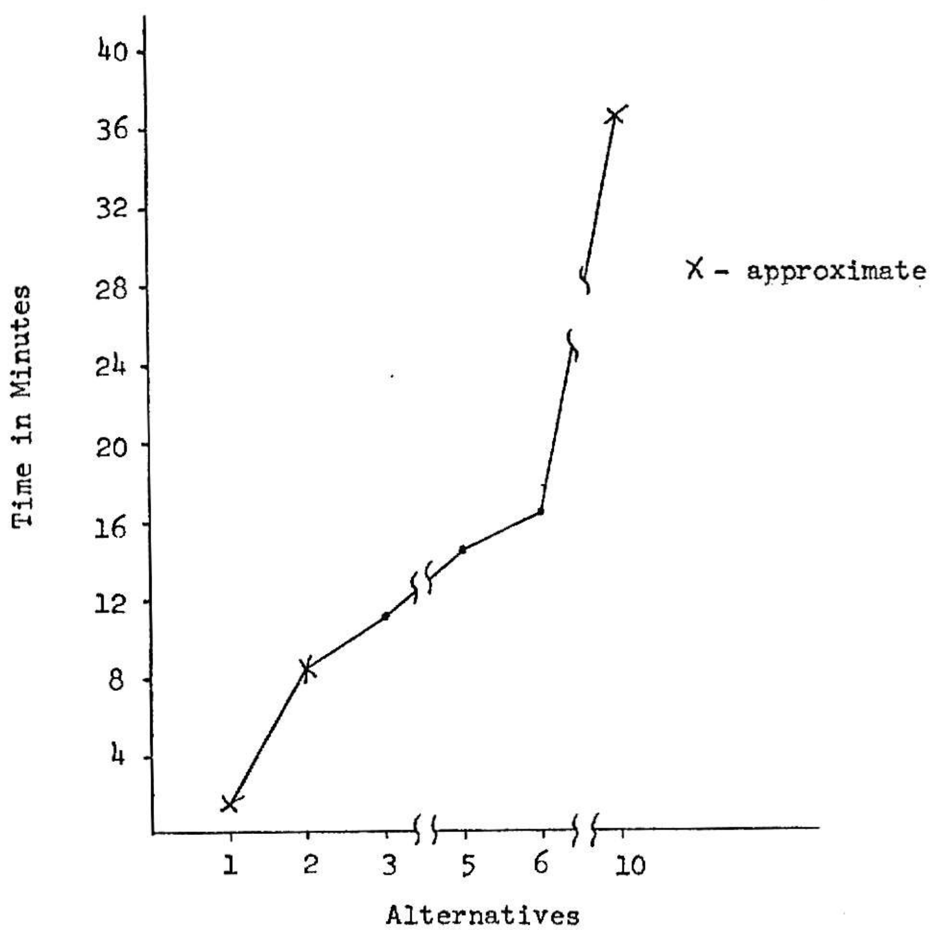

Figure 18: Execution time using G-level Fortran on the IBM 360.

proposed method considering six alternatives at each iteration should be used in order to obtain the best solution for a five terminal twenty-five demand point problem. Once again, it is suggested that the problems should first be solved using Tillman's method in order to check for the fault which appears to be inherent in the proposed 3-decision look ahead method. This would require a total solution time on the 360 computer of approximately eighteen minutes.

Five Terminal Fifty Demand Point Problems

The solutions obtained when solving the two problems with five terminals and fifty demand points each are summarized in Table 26. The data and best solution obtained for each problem is also shown in Appendix III.

The histogram showing the number of best solutions obtained when using the two methods of solution is shown in Figure 19. The average solution time required on the IBM 360 computer using the G-level Fortran compiler is shown in Figure 20.

As can be seen in Figure 19, Tillman's method did not obtain the best solution for either of the two problems. The best solution was obtained for one of the two problems with the proposed method when two alternatives were considered at each iteration. The proposed method obtained the best solution for both problems when three alternatives were considered at each iteration. No improvements were obtained by considering more than three alternatives at each iteration. The percent improvement in total mileage obtained with the proposed method was .06% for problem one and .17% for problem two.

Problem Number	Tillman Method	Proposed Method 3-Decision Look Ahead			
		2 alternatives	3 alternatives	5 alternatives	10 alternatives
1	19067	19054	19054	19054	19054
2	18553	18553	18522	18522	18522

Table 26: Summary of distances for five terminal fifty demand point problems.

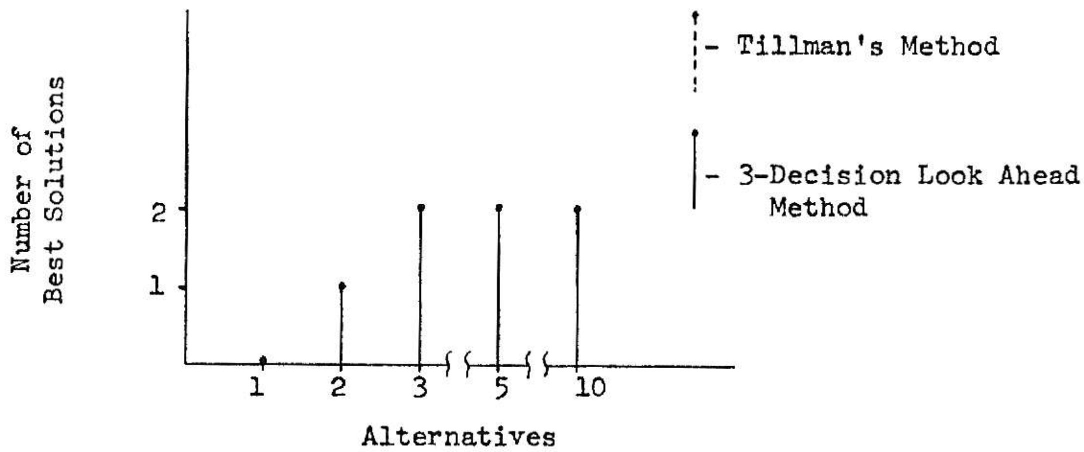

Figure 19: Best solutions for five terminal fifty demand point problems.

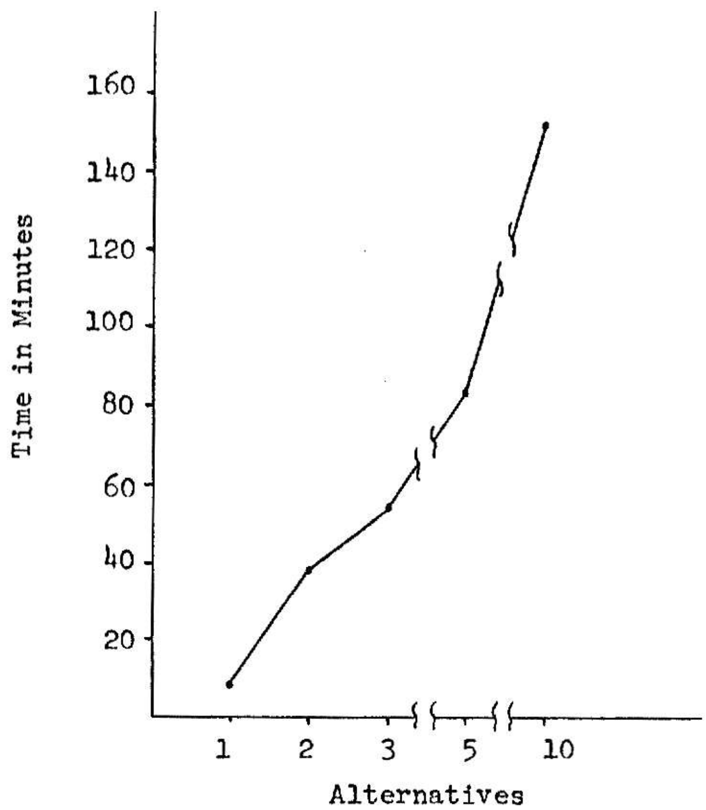

Figure 20: Execution time using G-level Fortran on the IBM 360.

More problems need to be solved by the two methods before a reliable conclusion can be made. However, the results appear to indicate that the best solution for a five terminal fifty demand point problem can be obtained with the proposed look ahead method considering three alternatives at each iteration. This would require a total solution time on the IBM 360 computer of approximately fifty-three minutes using the more efficient G-level Fortran compiler.

Although the difficulty which seems to be inherent in the proposed look ahead method did not appear in this case, it is suggested that precaution should be used when applying this method. Possibly the problems should first be solved using Tillman's method to protect against it occurring. This would add ten more minutes solution time on the IBM 360 computer.

CONCLUSION FOR THE MULTIPLE TERMINAL PROBLEM

Although there have been several methods of solution proposed for solving the single terminal carrier routing problems, only one method of solution had been developed at the time of this research for the solution of multiple terminal carrier routing problems. This method was a heuristic programming algorithm developed by Tillman [25]. Using this method as a basis, a modification was proposed which incorporated a 3-decision look ahead feature.

Several sample multiple terminal problems were developed and solved using Tillman's method and the proposed look ahead algorithm. Based upon the results obtained with the two methods, the following guidelines are suggested in attempting to obtain the best solution for multiple terminal carrier routing problems.

> Solve the multiple terminal problems first with Tillman's method to provide a basis for comparison and then solve the problems with the proposed 3-decision look ahead method considering at least three alternatives at each iteration.

A suggested improvement of the algorithm could be obtained by modifing the proposed method so that at least six successive linkings (6-decision look ahead) are considered for each alternative and consider only a maximum of three alternatives at each iteration.

REFERENCES

1. Balinski, M. L., and Quendt, R. E., "On an Integer Program for a Delivery Problem," Operations Research, Vol. 12, 300-304 (1964).

2. Barachet, L. L., "Graphical Solution of the Traveling-Salesman Problem," Operations Research, Vol. 5, 841-845 (1957).

3. Bellman, R., "On a Routing Problem," Quarterly Journal of Applied Mathematics, Vol. 16, No. 1, 87-90 (1958).

4. Bellmore, M., and Nemhauser, G. L., "The Traveling Salesman Problem: A Survey," Operations Research, Vol. 16, 538-558 (1968).

5. Braun, W., "A Computerized Simulation Approach to the Solution of the Carrier Dispatching Problem," Master's Thesis, Kansas State University.

6. Clarke, G., and Wright, J. W., "Scheduling of Vehicles from a Central Depot to a Number of Delivery Points," Operations Research, Vol. 12, No. 4, 568-581 (1964).

7. Cochran, H., "Optimization of a Carrier Routing Problem," Master's Thesis, Kansas State University (1966).

8. Dantzig, G. B., Fulkerson, D. R., and Johnson, S. M., "On a Linear Programming Combinatorial Approach to the Traveling-Salesman Problem," Operations Research, Vol. 7, 58-66 (1959).

9. Dantzig, G. B., Fulkerson, D. R., and Johnson, S. M., "Solution of a Large-Scale Traveling-Salesman Problem," Operations Research, Vol. 2, 393-410 (1954).

10. Dantzig, G. B., and Ramser, J. H., "The Truck Dispatching Problem," Management Science, Vol. 6, No. 1, 80-91 (1959).

11. Encyclopedia Britannica, "Motor Transportation," Vol. 15 (1966).

12. Flood, M. M., "The Traveling-Salesman Problem," Operations Research, Vol. 4, 61-75 (1956).

13. Gaskell, T. J., "Bases for Vehicle Fleet Scheduling," Operations Research Quarterly, Vol. 18, No. 3, 281-295 (1967).

14. Gomory, R. E., "All-Integer Programming Algorithm" RC-189, IBM Research Center, January 29, 1960.

15. Hausman, W. H., and Gilmour, P., "A Multi-period Truck Delivery Problem," Transportation Research, Vol. 1, 349-357 (1967).

16. Hayes, R. L., "The Delivery Problem," Doctoral Dissertation, Carnegie Institute of Technology (1967).

17. Karg, R. L., and Thompson, G. L., "A Heuristic Approach to Solving Traveling Salesmen Problems," Management Science, Vol. 10, 225-248 (1964).

18. Knight, K. W., and Hofer, J. P., "Vehicle Scheduling with Timed and Connected Calls: A Case Study," Operations Research Quarterly, Vol. 19, No. 3, 299-310 (1968).

19. Little, J. D. C., Murty, K. G., Sweeney, D. W., and Karel, C., "An Algorithm for the Traveling Salesman Problem," Operations Research, Vol. 11, 972-989 (1963).

20. Miller, C. E., Tucker, A. W., and Zemlin, R. A., "Integer Programming Formulation of Traveling Salesman Problems," Association for Computing Machinery, Vol. 7, No. 4, 326-329 (1960).

21. Nace, G. E., "Distributing Goods by VSP/360," Software Age, 8-29 (1969).

22. Newton, R. M., and Thomas, W. H., "Design of School Bus Routes by Digital Computer," Paper presented at Thirtieth National Meeting of ORSA (October, 1966).

23. Nicholson, T. A. J., "A Boundary Method for Planar Traveling Salesman Problems," Operations Research Quarterly, Vol. 19, No. 4, 445-452 (1968).

24. Pierce, J. F., "Direct Search Algorithms for Truck-Dispatching Problems," Transportation Research, Vol. 3, No. 1, 1-42 (1969).

25. Tillman, F. A., "The Multiple Terminal Delivery Problem with Probabilisitc Demands," Transportation Science, Vol. 3, No. 3, 192-204 (1969).

26. Tillman, F. A., and Cochran, H., "A Heuristic Approach for Solving the Delivery Problem," Journal of Industrial Engineering, Vol. 19, No. 7, 354-358 (1968).

27. Tyagi, M. S., "A Practical Method for Truck Dispatching Problems," Journal Operations Research Society of Japan, Vol. 10, Nos. 3 & 4, 76-92 (1968).

APPENDIX I

COMPUTER PROGRAM

DISCUSSION

The computer program is coded in Fortran IV and is written to solve either a single terminal or multiple terminal delivery problem. The single terminal problem is solved by Clarke and Wright's algorithm when the number of alternatives considered at each iteration is set at one (i.e. IDEPTH=1). When IDEPTH > 1, then the single terminal problem is solved with the extended look ahead feature discussed in chapter II.

The multiple terminal problem is solved with Tillman's algorithm when IDEPTH=1 (i.e. when only one alternative is considered at each iteration). When IDEPTH > 1, then the multiple terminal problem is solved with the look ahead algorithm discussed in chapter III.

Input

The input data for solving the carrier routing problem is read in the following order:

(1) The control card

(2) The number and carrying capacities of the trucks

(3) The distance matrix (distances between demand points)

(4) The distances from the terminal(s) to the demand points

(5) The quantity required at each demand point

The control card is for reading in the number of demand points, the number of terminals, the number of different capacity trucks, and the number of alternatives to be considered at each iteration. The data for this first card is punched without a decimal point and is punched in the following format:

Data	Card Columns
Number of demand points	8 - 10
Number of terminals	18 - 20
Number of trucks plus one	28 - 30
Number of alternatives	38 - 40

Note that the data must be right-justified in the data fields.

To facilitate coding the truck reallocation routine, the number of trucks available of a given capacity and the capacities of the trucks are read in from the largest to the smallest, which is just opposite to the discussion of the algorithm. This routine necessitates adding a truck with zero capacity such that the end of the truck assignment table could be located. Therefore it should be noted as shown in the above format that the total number of different capacity trucks read in the control card must include the zero capacity truck. The number of trucks available for each capacity is read in first, followed by their respective capacities. The total number of trucks for each capacity are punched in the data card first followed by the respective capacities from the largest to the smallest truck. A decimal point must be the right-most character in each piece of data and the data are punched in the IBM card in the following format.

Data Field	Card Columns
1	1 - 4
2	7 - 10
3	13 - 16
4	19 - 22
5	25 - 28
6	31 - 34
7	37 - 40

Data Field	Card Columns (continued)
8	43 - 46
9	49 - 52
10	55 - 58
11	61 - 64
12	67 - 70

As many cards as needed are used, with this same format for each additional card required.

The distance matrix is read in by rows. It should be noted that the subscripts for the columns are one greater than shown in the algorithm since a zero subscript is invalid in Fortran IV. The right-most character of each data field for these data cards must also have a decimal point. The data are punched in the IBM cards in the following format

Data Field	Card Columns
1	1 - 5
2	7 - 11
3	13 - 17
4	19 - 23
5	25 - 29
6	31 - 35
7	37 - 41
8	43 - 47
9	49 - 53
10	55 - 59
11	61 - 65
12	67 - 71

Since the distance matrix is symmetrical the first data card only has data punched in the first data field. The second card has two, the third card three, etc. until all the data fields are used. When a row of the distance matrix has more than twelve entries an addition card is used following the above format until all the distances in that row of the matrix have been punched. Each time a new row of the distance matrix is started, a new data card is started with the above format.

The fourth set of data cards read in contain the distances from the terminal(s) to the demand points. The format for the data fields is the same as the format given for punching the distance matrix data. A new card is used each time a new terminal is started and additional cards are used until all the distances for this terminal have been punched.

The last set of data cards contain the quantity of the commodity required at each demand point. The data format for punching this data is also the same as that given above for the distance matrix. Additional cards are used until all of the demand have been punched.

Output

The output has been condensed as much as possible so that a minimum of output is obtained. Intermediate results can be easily obtained by inserting write statements at the end of each iteration to write out the desired information. The output obtained with the program shown below consists of the following:

(1) The distance matrix

(2) The savings matrix (matricies)

(3) The routes determined by the algorithm

(4) The final route matrix

(5) The final truck allocation table and the total distance for all routes.

For single terminal problems, the first column of the distance matrix contains the distance from the terminal to the demand points. For multiple terminal problems, this first column contains the distance from the demand point to the nearest terminal. In both of the cases, the remainder of the matrix contains the distances between the demand points.

The savings matrix (matricies) are not included in the output below so that a minimum of output could be given. The first column of the savings matrix in the single terminal problems again contain the distance to the terminal. In the multiple terminal problems, the first column of the savings matricies contain the modified distances computed using the equation given in chapter III.

Each route determined by the algorithm is recorded seperately in the output and also contains the total distance for the route, the total quantity required, and the capacity of the truck assigned to the route.

It should be noted that an initial assignment of trucks to the demand points was not actually made in the program. Therefore this necessitates refering to the final route matrix to determine the demand points which are to be exclusively served from the terminal and to assign a truck to serve this route. These points will have a two in the terminal index $t_{i,0}$ of the route matrix. The route indicies ($t_{i,j}$) were numbered such that the iteration in which the linking took place could be observed. The first column of the final route matrix contains the total quantity required on the route formed. It should be noted that the intermediate points on a route also contain this total figure rather than setting it equal to zero as discussed in the algorithm.

The final truck assignment table shows the trucks available at the start of the algorithm and the number of each capacity truck assigned to the routes formed. Remember that this does not include an assignment of a truck to the demand points served exclusively from a terminal as noted above. The truck assignment table is followed by the total distance traveled on all routes determined by the algorithm, including the routes with only one demand point which were not listed.

DEFINITION OF VARIABLES IN COMPUTER PROGRAM

IROWS	=	NUMBER OF DEMAND POINTS IN PROBLEM.
ITERMS	=	NUMBER OF TERMINALS IN PROBLEM.
ITK5NO	=	NUMBER OF DIFFERENT CAPACITY TRUCKS.
IDEPTH	=	NUMBER OF ALTERNATIVES CONSIDERED AT EACH ITERATION.
D(I,J)	=	DISTANCE MATRIX WHERE THE FIRST COLUMN CONTAINS THE MINIMUM DISTANCE FROM THE DEMAND POINTS TO THE NEAREST TERMINAL.
SAV(I,J,K,L)	=	SAVINGS MATRICES WHERE THE FIRST COLUMN CONTAINS THE MODIFIED DISTANCES.
TOTAL(I,J,L)	=	WORK MATRICES FOR FEASIBLE SAVINGS WHERE THE FIRST COLUMN CONTAINS THE ROUTING INDEX.
ROUTE(I,J,L)	=	ROUTE MATRICES WHERE THE FIRST COLUMN CONTAINS THE Q VECTOR.
IR(N)	=	STORAGE AREA.
CAP(I,J,N)	=	TRUCK ASSIGNMENT TABLE.
D(I,K)	=	MATRIX CONTAINING DISTANCES FROM TERMINALS TO DEMAND POINTS.
IB(I)	=	STORAGE AREA.
HOLD(I,J)	=	MATRIX USED TO STORE DEMAND POINTS CONSIDERED AS ALTERNATIVES, SAVINGS FOR THE ALTERNATIVES, AND MAXIMUM TOTAL SAVINGS ASSOCIATED WITH THE ALTERNATIVES.
THOLD(I,J)	=	MATRIX USED TO STORE 2ND DEPTH POINTS ASSUMED ROUTED, SAVINGS FOR THESE POINTS, AND TOTAL SAVINGS FOR THE 2ND AND 3RD DEPTH POINTS.

COMPUTER PROGRAM

```
C     PROGRAM TO SOLVE A NEAR OPTIMAL SOLUTION FOR A MULTIPLE
C     DELIVERY PROBLEM.  THIS PROGRAM WILL HANDLE 50 DELIVERY
C     POINTS WITH 5 TERMINALS, WITH AT MOST 20 POSSIBLE DIFFERENT
C     SIZES OF TRUCKS.
C
C     FORMATS FOR READ IN OF DATA.
C
 5000 FORMAT (//1H0,10(3H   *))
 5005 FORMAT (1H0,10(3H   *))
 5010 FORMAT (4I10)
 5011 FORMAT (1H0,12I10)
 5020 FORMAT (12E6.2)
C
C     FORMATS FOR WRITING OUT RESULTS.
C
 5027 FORMAT (1H1,1X,3HROW,2X,8HQUANTITY,4X,5HPT)O*,14(2X,3HPT),I2,1H*))
 5030 FORMAT (1H0,5X,8HTERMINAL,I2,26H  DEMAND POINTS ROUTED ARE,10(3H -
     1-,I2))
 5040 FORMAT (1H0,5X,26HTOTAL DISTANCE OF ROUTE IS,F10.2)
 5045 FORMAT (1H0,5X,29HQUANTITY REQUIRED ON ROUTE IS,F7.2,2X,20HCAPACIT
     1Y OF TRUCK IS,F7.2)
 5050 FORMAT (1H1,20X,10HPROBLEM OF,I3,10H TERMINALS,5X,4HWITH,I3,14H DE
     1MAND POINTS)
 5070 FORMAT (1H-,20X,16HTRUCK ALLOCATION)
 5075 FORMAT (1H0,5X,14HTRUCK CAPACITY,5X,10(4X,F6.0))
 5076 FORMAT (1H0,5X,18HASSUMED ALLOCATION,1X,10(4X,F6.0))
 5077 FORMAT (1H0,5X,16HNUMBER ALLOCATED,3X,10(4X,F6.0))
 5078 FORMAT (1H-,5X,27HTOTAL DISTANCE FOR SYSTEM =,F10.2)
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
C
C     READ IN PARAMETERS IROWS, ITERMS, ITK5NO, AND IDEPTH.
C
      READ (1,5010) IROWS,ITERMS,ITK5NO,IDEPTH
      WRITE (3,5050) ITERMS,IROWS
C
C     READ IN NUMBER AND CAPACITIES OF TRUCKS.
C
      READ (1,5020) ((CAP(I,J,1),J=1,ITK5NO),I=1,2)
C
C     ASSUME AN INFINITE NUMBER OF THE SMALLEST CAPACITY TRUCKS
C     AVAILABLE.
C
      TK5NO=99999.0
      ITK=ITK5NO-1
      CAP(1,ITK,1)=TK5NO
      DO 12 I=1,ITK
   12 CAP(3,I,1)=CAP(1,I,1)
```

```
      CAP(3,ITK5NO,1)=0.0
C
C     READ IN THE DISTANCES BETWEEN THE DEMAND POINTS INTO THE
C     DISTANCE MATRIX DIST(I,J).
C
      DO 25 I=2,IROWS
   25 READ (1,5020) (DIST(I,J),J=2,I)
C
C     INITIALIZE THE SAVINGS AND ROUTE MATRICES TO ZERO.
C
      DO 26 I=2,IROWS
      DO 26 J=2,I
      DO 26 L=1,3
      DO 28 K=1,ITERMS
   28 SAV(I,J,K,L)=0.0
   26 ROUTE(I,J,L)=0.0
C
C     READ IN THE DISTANCES FROM THE TERMINALS TO THE DEMAND POINTS.
C
      DO 27 K=1,ITERMS
   27 READ (1,5020) (SAV(I,1,K,1),I=1,IROWS)
C
C     READ IN THE QUANTITIES OF COMMODITY REQUIRED AT EACH DEMAND
C     POINT.
      READ (1,5020) (ROUTE(I,1,1),I=1,IROWS)
C
C     COMPUTE THE SAVINGS AND ENTER THEM IN THE SAVINGS MATRIX.
C
      CALL SAVING(IROWS,ITERMS)
      IW=1
C
C     WRITE OUT THE DISTANCE MATRIX AND SAVINGS MATRICES.
C
      CALL RIGHT(IW,IROWS,ITERMS)
      RT5NO=0.0
C
C     SET THE INDEX FOR THE INITIAL ASSIGNMENT OF DEMAND POINTS TO
C     THE NEAREST TERMINAL AND SELECT THE TRUCK WITH THE LARGEST
C     CAPACITY WHICH IS AVAILABLE.
C
      DO 220 I=1,IROWS
  220 TOTAL(I,1,1)=2.0
      CATY=CAP(2,1,1)
C
C     INITIALIZE THE ROUTING MATRIX AND THE WORK MATRICES.
C
  300 CALL SET5ZO(IROWS,ITERMS,ITK5NO)
      JOHN=CATY
      RTNUM=RT5NO
      K2=0
      L=1
```

```
C
C     THIS IS THE FIRST STEP OF EACH ITERATION. CHECK FOR FEASIBLE
C     SAVINGS AND ENTER THEM IN THE TOTAL MATRIX.
C
      CALL CHECK(IROWS,CATY,INDEX,I,J,ITERMS,L)
C
C     IF IDEPTH=1, SELECT THE PAIR OF POINTS WITH THE MAXIMUM FEASIBLE
C     SAVINGS AND ROUTE THEM IN THIS ITERATION.
C
      IF (IDEPTH .NE. 1) GO TO 305
      KONT=0
      ITRIAL=3
      CALL MAXIUM(XMAX,IN,JN,IROWS,KONT,ITRIAL,L)
      IF (XMAX .EQ. 0.0) GO TO 1000
      CALL REMOVE(IN,JN,L)
      CALL CHANGE(RT5NO,CATY,IN,JN,L,XMAX,IROWS,ITERMS,L1,L2)
      GO TO 300
  305 DO 360 I=2,IROWS
C
C     INITIALIZE THE WORK MATRICES FOR DEVELOPING THE BRANCHES FOR
C     EACH ALTERNATIVE .
C
      DO 360 J=2,I
      DO 360 L=2,3
  360 TOTAL(I,J,L)=TOTAL(I,J,1)
      DO 365 I=1,10
      DO 365 J=2,3
      HOLD(I,J)=0.0
  365 THOLD(I,J)=0.0
      L=2
      KONT=0
      ITRIAL=1
C
C     SELECT EACH FEASIBLE ALTERNATIVE FROM THE SAVINGS MATRICES.
C
      DO 370 N=1,IDEPTH
      CALL MAXIUM(XMAX,IN,JN,IROWS,KONT,ITRIAL,L)
      IF (N .NE. 1) GO TO 385
  380 IF (XMAX .EQ. 0.0) GO TO 1000
      TOTAL(IN,JN,L)=0.0
      GO TO 370
  385 IF (XMAX .EQ. 0.0) GO TO 395
      TOTAL(IN,JN,L)=0.0
  370 CONTINUE
  395 CALL RESET(IROWS)
C
C     THE NEXT SEQUENCE OF STATEMENTS TO STATEMENT NUMBER 787
C     DEVELOPS THE BRANCHES FOR EACH ALTERNATIVE SELECTED. THE FIRST
C     ALTERNATIVE SELECTED IS ASSUMED ROUTED. THE FEASIBLE SECOND
C     DEPTH POINTS FOR EACH BRANCH ARE THEN SELECTED. EACH OF THESE
C     SECOND DEPTH POINTS ARE ASSUMED LINKED IN SEQUENCE WITH THE
C     ALTERNATIVE AND THE THIRD DEPTH POINTS FOR THE BRANCHES ARE
C     SELECTED. THE TOTAL SAVINGS FOR EACH BRANCH IS ACCUMULATED.
```

```
C      SELECT THE MAXIMUM TOTAL SAVINGS OF THE THREE BRANCHES AND
C      ASSOCIATE IT WITH THE ALTERNATIVE. THIS PROCESS IS REPEATED
C      FOR EACH ALTERNATIVE TO BE CONSIDERED.
C
       DO 787 M=1,IDEPTH
       L=2
       CATY=JOHN
       DO 705 I=1,10
       DO 705 J=2,3
  705  THOLD(I,J)=0.0
C
C      SELECT AN ALTERNATIVE AND ASSUME IT IS ROUTED.
C
       XMAX=HOLD(M,2)
       IF (XMAX .EQ. 0.0) GO TO 790
       IN=HOLD(M,1)/100.
       JN=HOLD(M,1)-(IN*100)
       CALL REMOVE(IN,JN,L)
       CALL CHANGE(RT5NO,CATY,IN,JN,L,XMAX,IROWS,ITERMS,L1,L2)
C
C      SAVE THE MATRICES (ROUTE,TOTAL,SAVINGS,AND TRUCK) SO THEY
C      CAN BE RESET TO DEVELOP THE OTHER BRANCHES.
C
       ANN=CATY
       DO 710 I=1,IROWS
       DO 710 J=1,I
       TOTAL(I,J,3)=TOTAL(I,J,2)
       ROUTE(I,J,3)=ROUTE(I,J,2)
       DO 710 K=1,ITERMS
       SAV(I,J,K,3)=SAV(I,J,K,2)
  710  CONTINUE
       DO 715 I=1,3
       DO 715 J=1,ITK5NO
       CAP(I,J,3)=CAP(I,J,2)
  715  CONTINUE
       CALL ZERO(IROWS)
       L=2
C
C      SELECT THE FEASIBLE SECOND DEPTH POINTS FOR EACH BRANCH
C      FROM THE SAVINGS REMAINING AFTER THE ALTERNATIVE HAS BEEN
C      ASSUMED ROUTED.
C
       CALL CHECK(IROWS,CATY,INDEX,I,J,ITERMS,L)
       DO 718 I=2,IROWS
       DO 718 J=2,I
       TOTAL(I,J,4)=TOTAL(I,J,2)
  718  CONTINUE
       ITRIAL=2
       KONT=0
C
C      SELECT EACH OF THE SECOND DEPTH POINTS ONE AT A TIME AND
C      ASSUME IT IS LINKED IN SEQUENCE WITH THE ALTERNATIVE AND
C      SELECT THE THIRD DEPTH POINTS FOR THE BRANCH. ADD THE
```

```
C     SAVINGS AND STORE IT.
C
      DO 740 N=1,3
      CALL MAXIUM(XMAX,IN,JN,IROWS,KONT,ITRIAL,L)
      GO TO (720,730,730),N
  720 IF (XMAX .EQ. 0.0) GO TO 781
      TOTAL(IN,JN,L)=0.0
      GO TO 740
  730 IF (XMAX .EQ. 0.0) GO TO 750
      TOTAL(IN,JN,L)=0.0
  740 CONTINUE
  750 DO 755 I=2,IROWS
      DO 755 J=2,I
      TOTAL(I,J,2)=TOTAL(I,J,4)
  755 CONTINUE
      DO 780 LAST=1,3
      CATY=ANN
      XMAX=THOLD(LAST,2)
      IF (XMAX .EQ. 0.0) GO TO 781
      IN=THOLD(LAST,1)/100.
      JN=THOLD(LAST,1)-(IN*100)
      CALL REMOVE(IN,JN,L)
      CALL CHANGE(RT5NO,CATY,IN,JN,L,XMAX,IROWS,ITERMS,L1,L2)
      CALL ZERO(IROWS)
      CALL CHECK(IROWS,CATY,INDEX,I,J,ITERMS,L)
      ITRIAL=3
      CALL MAXIUM(XMAX,IN,JN,IROWS,KONT,ITRIAL,L)
      THOLD(LAST,3)=THOLD(LAST,3)+XMAX
      DO 760 I=1,IROWS
      DO 760 J=1,I
      TOTAL(I,J,2)=TOTAL(I,J,3)
      ROUTE(I,J,2)=ROUTE(I,J,3)
      DO 760 K=1,ITERMS
      SAV(I,J,K,2)=SAV(I,J,K,3)
  760 CONTINUE
      DO 770 I=1,3
      DO 770 J=1,ITK5NO
  770 CAP(I,J,2)=CAP(I,J,3)
  780 CONTINUE
C
C     SELECT THE MAXIMUM TOTAL SAVINGS OF THE BRANCHES AND
C     ASSOCIATE IT WITH THE ALTERNATIVE.
C
  781 XTOP=0.0
      DO 782 I=1,3
      IF (THOLD(I,3) .LE. XTOP) GO TO 782
      XTOP=THOLD(I,3)
  782 CONTINUE
      HOLD(M,3)=HOLD(M,3)+XTOP
      DO 785 I=1,IROWS
      DO 785 J=1,I
      DO 785 L=2,3
      TOTAL(I,J,L)=TOTAL(I,J,1)
```

```
      ROUTE(I,J,L)=ROUTE(I,J,1)
      DO 785 K=1,ITERMS
      SAV(I,J,K,L)=SAV(I,J,K,1)
  785 CONTINUE
      DO 786 I=1,3
      DO 786 J=1,ITK5NO
      DO 786 L=2,3
      CAP(I,J,L)=CAP(I,J,1)
  786 CONTINUE
  787 CONTINUE
C
C     SELECT THE ALTERNATIVE WITH THE MAXIMUM TOTAL SAVINGS FOR
C     ACTUAL ROUTING IN THIS ITERATION.
C
  790 XHIGH=0.0
      DO 810 I=1,IDEPTH
      IF (HOLD(I,3) .LE. XHIGH) GO TO 810
      XHIGH=HOLD(I,3)
      MAX=I
  810 CONTINUE
C
C     ROUTE THE ALTERNATIVE SELECTED.
C
      CATY=JOHN
      RT5NO=RTNUM
      L=1
      IN=HOLD(MAX,1)/100.
      JN=HOLD(MAX,1)-(IN*100)
      XMAX=HOLD(MAX,2)
      CALL REMOVE(IN,JN,L)
      CALL CHANGE(RT5NO,CATY,IN,JN,L,XMAX,IROWS,ITERMS,L1,L2)
C
C     THIS COMPLETES ONE ITERATION AND THE PROCESS IS REPEATED
C     FROM STATEMENT 300 TO CHECK FOR MORE FEASIBLE LINKS.
C
      GO TO 300
C
C     IF THERE ARE NO OTHER FEASIBLE LINKS, THEN THE FINAL SOLUTION
C     HAS BEEN FOUND. THE FOLLOWING STATEMENTS ARE FOR WRITING
C     OUT THE ROUTES FORMED, THE DISTANCES FOR EACH ROUTE, THE
C     LOADS, THE FINAL ROUTE MATRIX, THE FINAL TRUCK ASSIGNMENT
C     TABLE, AND THE TOTAL DISTANCE FOR ALL ROUTES.
C
 1000 K1=0
      K2=0
      TOTDST=0.0
      DO 1900 I=1,IROWS
      IF (TOTAL(I,1,1) .EQ. 2.0) TOTDST=TOTDST+2.0*DIST(I,1)
      IF (TOTAL(I,1,1) .NE. 1.0) GO TO 1900
      DISTAN=0.0
      IN=I
      I1=0
      J1=0
```

```
      K3=0
      L=1
 1250 CALL FD5RT(IN,K1,ITERMS,IROWS,I1,J1,I2,J2,IX,K,K2,L)
      CALL FD5K(K,I2,J2,L)
      IF(I1 .EQ. 0) DISTAN=DISTAN+D(IN,K)
      DISTAN=DISTAN+DIST(I2,J2)
      K3=K3+1
      IB(K3)=IN
 1275 CALL CHOOSE(IN,I1,J1,I2,J2,IX,L)
      IF (TOTAL(IN,1,1) .EQ. 0.0) GO TO 1250
 1450 DISTAN=DISTAN+D(IN,K)
      K3=K3+1
      IB(K3)=IN
      CALL LOAD(TRCAP,IN,L)
      IF (IB(1) .GT. IB(K3)) GO TO 1900
      WRITE (3,5000)
      WRITE (3,5030) K,(IB(J),J=1,K3)
      WRITE (3,5040) DISTAN
      WRITE (3,5045) ROUTE(IN,1,1),TRCAP
      WRITE (3,5005)
      TOTDST=TOTDST+DISTAN
 1900 CONTINUE
      IW=2
      CALL RIGHT(IW,IROWS,ITERMS)
      WRITE (3,5070)
      WRITE (3,5075) (CAP(2,I,1),I=1,ITK)
      WRITE (3,5076) (CAP(3,I,1),I=1,ITK)
      DO 1930 I=1,ITK
 1930 CAP(1,I,1)=CAP(3,I,1)-CAP(1,I,1)
      WRITE (3,5077) (CAP(1,I,1),I=1,ITK)
      WRITE (3,5078) TOTDST
      WRITE(3,5005)
      STOP
      END
```

SUBROUTINES

```
      SUBROUTINE SAVING(IROWS,ITERMS)
C
C     THIS ROUTINE COMPUTES THE SAVINGS MATRIX (MATRICES) FOR THE
C     PROBLEM. FOR THE MULTIPLE TERMINAL CASE IT COMPUTES THE
C     MODIFIED DISTANCES AND THEN COMPUTES THE SAVINGS.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      DO 100 I=1,IROWS
      DIST(I,1)=SAV(I,1,1,1)
      DO 50 K=1,ITERMS
      D(I,K)=SAV(I,1,K,1)
      IF (DIST(I,1) .LE. SAV(I,1,K,1)) GO TO 50
      DIST(I,1)=SAV(I,1,K,1)
   50 CONTINUE
      DO 100 K=1,ITERMS
  100 SAV(I,1,K,1)=DIST(I,1)-(SAV(I,1,K,1)-DIST(I,1))
      DO 200 K=1,ITERMS
      DO 200 I=2,IROWS
      DO 200 J=2,I
      SAV(I,J,K,1)=SAV(I,1,K,1)+SAV(J-1,1,K,1)-DIST(I,J)
      IF (SAV(I,J,K,1) .NE. 0.0) GO TO 200
      SAV(I,J,K,1)=-1.0
  200 CONTINUE
      RETURN
      END


      SUBROUTINE RIGHT(IW,IROWS,ITERMS)
C
C     THIS ROUTINE IS USED TO WRITE OUT THE DISTANCE MATRIX AND
C     INITIAL SAVINGS MATRIX (MATRICES).
C
 5025 FORMAT (1H0,1H),I2,1H*,15(2X,F6.0))
 5053 FORMAT (1H-,20X,15HDISTANCE MATRIX)
 5055 FORMAT (1H1,20X,15HDISTANCE MATRIX)
 5060 FORMAT (1H1,20X,14HSAVINGS MATRIX,3X,12HTERMINAL NO.,I3)
 5065 FORMAT (1H1,20X,12HROUTE MATRIX)
 5066 FORMAT (1H0,6X,6HDEMAND/1X,1H),I2,1H*,2(2X,F6.0))
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      IF (IW .EQ. 2) GO TO 1901
      L=0
   30 L=L+1
      IF (L .GT. 1) WRITE (3,5055)
      IF (L .EQ. 1) WRITE (3,5053)
```

THIS BOOK CONTAINS NUMEROUS PAGES WITH THE ORIGINAL PRINTING BEING SKEWED DIFFERENTLY FROM THE TOP OF THE PAGE TO THE BOTTOM.

THIS IS AS RECEIVED FROM THE CUSTOMER.

```
      KA=(L-1)*15+1
      KB=KA+14
      DO 205 I=KA,IROWS
      IF (I .LE. KB) GO TO 204
      WRITE (3,5025) I,(DIST(I,J),J=KA,KB)
      GO TO 205
  204 WRITE (3,5025) I,(DIST(I,J),J=KA,I)
  205 CONTINUE
      IF (KB .LT. IROWS) GO TO 30
      DO 211 K=1,ITERMS
      L=0
  206 L=L+1
      WRITE (3,5060) K
      KA=(L-1)*15+1
      KB=KA+14
      DO 210 I=KA,IROWS
      IF (I .LE. KB) GO TO 207
      WRITE (3,5025) I,(SAV(I,J,K,1),J=KA,KB)
      GO TO 210
  207 WRITE (3,5025) I,(SAV(I,J,K,1),J=KA,I)
  210 CONTINUE
      IF (KB .LT. IROWS) GO TO 206
  211 CONTINUE
      GO TO 1911
 1901 L=0
 1902 L=L+1
      WRITE (3,5065)
      KA=(L-1)*13+1
      KB=KA+12
      IF (L .GT. 1) GO TO 1903
      I=1
      WRITE (3,5066) I,ROUTE(I,1,1),TOTAL(I,1,1)
      IF (L .EQ. 1) KA=2
 1903 DO 1912 I=KA,IROWS
      IF (I .LE. KB) GO TO 1904
      WRITE (3,5025) I,ROUTE(I,1,1),TOTAL(I,1,1),(ROUTE(I,J,1),J=KA,KB)
      GO TO 1912
 1904 WRITE (3,5025) I,ROUTE(I,1,1),TOTAL(I,1,1),(ROUTE(I,J,1),J=KA,I)
 1912 CONTINUE
      IF (KB .LT. IROWS) GO TO 1902
 1911 RETURN
      END



      SUBROUTINE SET5ZO(IROWS,ITERMS,ITK5NO)
C
C     THIS ROUTINE INITIALIZES THE WORK MATRICES USED TO DEVELOP
C     THE BRANCHES FOR EACH ALTERNATIVE.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IP
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
```

```
      DO 310 I=2,IROWS
      DO 310 J=2,I
      DO 310 L=1,3
  310 TOTAL(I,J,L)=0.0
      DO 330 L=2,3
      DO 330 I=1,IROWS
      TOTAL(I,1,L)=TOTAL(I,1,1)
      DO 330 J=1,I
      ROUTE(I,J,L)=ROUTE(I,J,1)
      DO 330 K=1,ITERMS
  330 SAV(I,J,K,L)=SAV(I,J,K,1)
      DO 335 I=1,3
      DO 335 J=1,ITK5NO
      DO 335 L=2,3
      CAP(I,J,L)=CAP(I,J,1)
  335 CONTINUE
      RETURN
      END



      SUBROUTINE RESTR(CATY,INDEX,I,J,L)
C
C     THIS ROUTINE CHECKS EACH SAVINGS TO SEE IF THE RESTRICTIONS
C     ON THE SYSTEM ARE SATISFIED.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      IF (ROUTE(I,J,L) .GT. 0.0) GO TO 320
      IF (TOTAL(J-1,1,L) .EQ. 0.0) GO TO 320
      IF (TOTAL(I,1,L) .EQ. 0.0) GO TO 320
      IF (ROUTE(J-1,1,L)+ROUTE(I,1,L) .GT. CATY) GO TO 320
      INDEX=1
      GO TO 330
  320 INDEX=2
  330 RETURN
      END



      SUBROUTINE CHECK(IROWS,CATY,INDEX,I,J,ITERMS,L)
C
C     THIS ROUTINE SELECTS THE FEASIBLE SAVINGS AND ENTERS THEM
C     IN THE TOTAL MATRIX.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      DO 350 I=2,IROWS
      DO 350 J=2,I
      CALL RESTR(CATY,INDEX,I,J,L)
      IF (INDEX .EQ. 2) GO TO 350
```

```
  340 DO 349 K=1,ITERMS
      IF (SAV(I,J,K,L) .LE. TOTAL(I,J,L)) GO TO 349
      TOTAL(I,J,L)=SAV(I,J,K,L)
  349 CONTINUE
  350 CONTINUE
      RETURN
      END



      SUBROUTINE MAXIUM(XMAX,IN,JN,IROWS,KONT,ITRIAL,L)
C
C     THE ROUTINE IS USED TO SELECT THE MAXIMUM FEASIBLE SAVINGS.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      KONT=KONT+1
      XMAX=0.0
      DO 401 I=2,IROWS
      DO 400 J=2,I
      IF (TOTAL(I,J,L) .LE. XMAX) GO TO 400
      XMAX=TOTAL(I,J,L)
      IN=I
      JN=J
      GO TO (396,397,400),ITRIAL
  396 HOLD(KONT,1)=IN*100+JN
      HOLD(KONT,2)=XMAX
      HOLD(KONT,3)=XMAX
      GO TO 400
  397 THOLD(KONT,1)=IN*100+JN
      THOLD(KONT,2)=XMAX
      THOLD(KONT,3)=XMAX
      GO TO 400
  400 CONTINUE
  401 CONTINUE
      RETURN
      END



      SUBROUTINE RESET(IROWS)
C
C     THIS ROUTINE RESETS THE TOTAL MATRIX WHEN DEVELOPING THE
C     BRANCHES FOR EACH ALTERNATIVE.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      DO 700 I=2,IROWS
      DO 700 J=2,I
  700 TOTAL(I,J,2)=TOTAL(I,J,3)
      RETURN

      END
```

```
      SUBROUTINE ZERO(IROWS)
C
C     THIS ROUTINE INITIALIZES THE TOTAL MATRIX TO ZEROS EXCEPT FOR
C     THE FIRST COLUMN.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      DO 716 I=2,IROWS
      DO 716 J=2,I
      TOTAL(I,J,2)=0.0
  716 CONTINUE
      RETURN
      END



      SUBROUTINE REMOVE(IN,JN,L)
C
C     THE ROUTINE REMOVES THE TRUCKS ASSIGNED IN PREVIOUS ITERATIONS
C     TO THE DEMAND POINTS BEING ROUTED.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      DO 444 I=1,3
      GO TO (431,441,444),I
  431 IF (TOTAL(IN,1,L) .NE. 1.0) GO TO 444
      IA1=IN
  432 K=0
  433 K=K+1
      IF (ROUTE(IA1,1,L)-CAP(2,K,L)) 433,435,434
  434 K=K-1
  435 IF (CAP(1,K,L)-CAP(3,K,L)) 436,434,434
  436 CAP(1,K,L)=CAP(1,K,L)+1.0
      GO TO 444
  441 IF (TOTAL(JN-1,1,L) .NE. 1.0) GO TO 444
      IA1=JN-1
      GO TO 432
  444 CONTINUE
      RETURN
      END



      SUBROUTINE CHANGE(RT5NO,CATY,IN,JN,L,XMAX,IROWS,ITERMS,L1,L2)
C
C     THIS ROUTINE ROUTES THE POINTS UNDER CONSIDERATION. A TRUCK
C     IS ASSIGNED TO THE NEW ROUTE. IN THE MULTIPLE TERMINAL PROBLEM
C     IT REMOVES THE POINTS FROM FURTHER CONSIDERATION AT THE OTHER
C     TERMINALS AND RECOMPUTES THE SAVINGS FOR THE POINTS AT THE
C     TERMINAL TO WHICH THEY WERE ROUTED. THE POSSIBLE LINKS WHICH
C     WOULD CAUSE A LOOP SITUATION ARE ALSO ELIMINATED FROM FURTHER
```

```
C     CONSIDERATION. THE ROUTINE CALLS THE NEXT SEVEN SUBROUTINES TO
C     PERFORM THESE STEPS.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      CALL SET5RT(RT5NO,IN,JN,L)
      CALL CAPCTY(CATY,IN,JN,L)
      K2=0
      IN3=IN
      JN3=JN
      CALL SAV2(IN3,JN3,XMAX,IROWS,L)
      K1=1
      CALL FIND5K(K,IN3,JN3,XMAX,L)
      IF (TOTAL(JN-1,1,L) .EQ. 1.0) GO TO 613
      IF (TOTAL(IN,1,L) .EQ. 1.0) GO TO 615
  448 I1=0
      J1=0
  500 CALL FD5RT(IN,K1,ITERMS,IROWS,I1,J1,I2,J2,IX,K,K2,L)
      IF (K1 .EQ. 1) GO TO 550
      ROUTE(IN,1,L)=ROUTE(IN3,1,L)
      IF (K2 .EQ. 2) GO TO 615
  550 CALL CHOOSE(IN,I1,J1,I2,J2,IX,L)
  611 IF (TOTAL(IN,1,L) .NE. 0.0) GO TO 615
      GO TO 500
  613 IN=JN-1
  615 K2=K2+1
      K1=2
      IR(K2)=IN
      GO TO (448,500,617),K2
  617 CALL LOOP(L1,L2,ITERMS,L)
      RETURN
      END
```

```
      SUBROUTINE SET5RT(RT5NO,IN,JN,L)
C
C     THE ROUTINE SETS THE INDEXES FOR THE NEW ROUTE.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      TOTAL(IN,1,L)=TOTAL(IN,1,L)-1.0
      TOTAL(JN-1,1,L)=TOTAL(JN-1,1,L)-1.0
      RT5NO=RT5NO+1.0
      ROUTE(IN,JN,L)=RT5NO
      ROUTE(IN,1,L)=ROUTE(IN,1,L)+ROUTE(JN-1,1,L)
      ROUTE(JN-1,1,L)=ROUTE(IN,1,L)
      RETURN
      END
```

```
      SUBROUTINE CAPCTY(CATY,IN,JN,L)
C
C     THIS ROUTINE ASSIGNES A TRUCK WITH A CAPACITY JUST LARGE
C     ENOUGH TO TAKE THE LOAD REQUIRED ON THE NEWLY FORMED ROUTE.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      K=0
  410 K=K+1
      IF (ROUTE(IN,1,L)-CAP(2,K,L)) 410,425,420
  420 K=K-1
  425 IF (CAP(1,K,L) .EQ. 0.0) GO TO 420
      CAP(1,K,L)=CAP(1,K,L)-1
      K=0
  440 K=K+1
      IF (CAP(1,K,L) .EQ. 0.0) GO TO 440
      CATY=CAP(2,K,L)
      RETURN
      END




      SUBROUTINE SAV2(IN3,JN3,XMAX,IROWS,L)
C
C     THE ROUTINE RESETS THE MODIFIED DISTANCE TO THE ACTUAL DISTANCE
C     AT THE TERMINAL THE POINTS ARE ROUTED TO AND RECOMPUTES THE
C     SAVINGS REQUIRED BY THIS CHANGE.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      IK=0
      CALL FIND5K(K,IN3,JN3,XMAX,L)
      SAV(IN3,1,K,L)=D(IN3,K)
      SAV(JN3-1,1,K,L)=D(JN3-1,K)
      IN4=IN3
      JN4=IN3+1
  699 IK=IK+1
      IF (TOTAL(IN4,1,L) .NE. 1.0) GO TO 707
      IF (IN4 .LE. 2) GO TO 701
      DO 700 JJ=2,IN4
      IF (SAV(IN4,JJ,K,L) .EQ. 0.0) GO TO 700
      IF (IN4 .NE. IN3) GO TO 689
      IF (JJ .EQ. JN3) GO TO 700
  689 SAV(IN4,JJ,K,L)=SAV(IN4,1,K,L)+SAV(JJ-1,1,K,L)-DIST(IN4,JJ)
  700 CONTINUE
  701 IF (JN4 .GE. IROWS) GO TO 707
      DO 705 IJ=JN4,IROWS
      IF (SAV(IJ,JN4,K,L) .EQ. 0.0) GO TO 705
      IF (JN4 .NE. JN3) GO TO 704
      IF (IJ .EQ. IN3) GO TO 705
  704 SAV(IJ,JN4,K,L)=SAV(IN4,1,K,L)+SAV(IJ,1,K,L)-DIST(IJ,JN4)
  705 CONTINUE
```

```
  707 IF (IK .EQ. 2) GO TO 740
      IN4=JN3-1
      JN4=JN3
      GO TO 699
  740 RETURN
      END



      SUBROUTINE FIND5K(K,IN3,JN3,XMAX,L)
C
C     THIS ROUTINE IS USED TO FIND THE TERMINAL TO WHICH THE
C     NEW ROUTE IS ASSIGNED.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      K=0
  446 K=K+1
      IF (SAV(IN3,JN3,K,L) .NE. XMAX) GO TO 446
      RETURN
      END



      SUBROUTINE FD5RT(IN,K1,ITERMS,IROWS,I1,J1,I2,J2,IX,K,K2,L)
C
C     THIS ROUTINE ADJUSTS THE Q VECTOR TO CORRESPOND TO THE NEW
C     ROUTE AND REMOVES THE POINTS ON THIS NEW ROUTE FROM FURTHER
C     CONSIDERATION AT THE OTHER TERMINALS.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      IF (IN .EQ. 1) GO TO 551
      DO 550 JJ=2,IN
      IF (K2 .EQ. 2) GO TO 540
      IF (IN .NE. I1) GO TO 525
      IF (JJ .EQ. J1) GO TO 540
  525 IF (ROUTE(IN,JJ,L) .EQ. 0.0) GO TO 540
      IX=1
      I2=IN
      J2=JJ
  540 IF (K1 .NE. 2) GO TO 550
      DO 549 I=1,ITERMS
      IF (I .EQ. K) GO TO 549
      SAV(IN,JJ,I,L)=0.0
  549 CONTINUE
  550 CONTINUE
  551 IN1=IN+1
      IF (IN .EQ. IROWS) GO TO 601
      DO 600 IJ=IN1,IROWS
      IF (K2 .EQ. 2) GO TO 570
```

```
      IF (IJ .NE. I1) GO TO 565
      IF (J1 .EQ. IN1) GO TO 570
  565 IF (ROUTE(IJ,IN1,L) .EQ. 0.0) GO TO 570
      IX=2
      I2=IJ
      J2=IN1
  570 IF (K1 .NE. 2) GO TO 600
      DO 599 J=1,ITERMS
      IF (J .EQ. K) GO TO 599
      SAV(IJ,IN+1,J,L)=0.0
  599 CONTINUE
  600 CONTINUE
  601 RETURN
      END
```

```
      SUBROUTINE CHOOSE(IN,I1,J1,I2,J2,IX,L)
C
C     THIS ROUTINE IS USED TO CHOOSE WHICH ROW AND COLUMN TO
C     BE WORKED OR SEARCHED.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      IF (IX .EQ. 1) GO TO 1300
      IN=I2
      GO TO 1350
 1300 IN=J2-1
 1350 I1=I2
      J1=J2
      RETURN
      END
```

```
      SUBROUTINE LOOP(L1,L2,ITERMS,L)
C
C     THIS ROUTINE BLOCKS THE POSSIBLE LINKINGS WHICH WOULD
C     CAUSE A LOOP SITUATION.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      L1=IR(1)
      L2=IR(2)
      DO 620 I=1,ITERMS
      IF (L1-L2) 616,616,618
  616 IF (ROUTE(L2,L1+1,L) .NE. 0.0) GO TO 620
      SAV(L2,L1+1,I,L)=0.0
      GO TO 620
  618 IF (ROUTE(L1,L2+1,L) .NE. 0.0) GO TO 620
      SAV(L1,L2+1,I,L)=0.0
```

```
  620 CONTINUE
      RETURN
      END



      SUBROUTINE FD5K(K,I2,J2,L)
C
C     THIS ROUTINE IS USED IN THE FINAL WRITE ROUTINE TO FIND THE
C     TERMINAL TO WHICH THE ROUTE BEING CONSIDERED IS ASSIGNED.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      K=0
 1410 K=K+1
      IF (SAV(I2,J2,K,L) .EQ. 0.0) GO TO 1410
      RETURN
      END



      SUBROUTINE LOAD(TRCAP,IN,L)
C
C     THIS ROUTINE FINDS THE TRUCK ASSIGNED TO THE ROUTE.
C
      COMMON DIST(50,50),SAV(50,50,5,3),TOTAL(50,50,4),ROUTE(50,50,3),IR
     1(3),CAP(3,20,3),D(50,5),IB(50),HOLD(10,3),THOLD(10,3)
      J=0
 1475 J=J+1
      IF (CAP(2,J,L) .GE. ROUTE(IN,1,L)) GO TO 1475
      TRCAP=CAP(2,J-1,L)
      RETURN
      END
```

APPENDIX II

SINGLE TERMINAL PROBLEMS

SINGLE TERMINAL TEN
DEMAND POINT PROBLEMS

PROBLEM ONE

DEMAND POINT	QUANTITY REQUIRED
1	10
2	4
3	8
4	7
5	12
6	6
7	5
8	10
9	8
10	15

Three trucks with thirty units of capacity each are available. The best solution shown below was obtained with the minimum computation time on the computer using IDEPTH of one (i.e. Clarke and Wright's method).

PROBLEM OF 1 TERMINALS WITH 10 DEMAND POINTS

DISTANCE MATRIX

(1)	8.									
(2)	5.	6.								
(3)	3.	5.	3.							
(4)	2.	10.	7.	5.						
(5)	12.	7.	11.	10.	14.					
(6)	8.	6.	8.	6.	10.	5.				
(7)	3.	8.	7.	4.	4.	10.	6.			
(8)	8.	16.	13.	11.	6.	19.	14.	9.		
(9)	7.	9.	10.	7.	8.	8.	4.	4.	11.	
(10)	7.	13.	12.	9.	7.	14.	9.	6.	7.	6.

```
* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 1 -- 5 -- 6 --
   TOTAL DISTANCE OF ROUTE IS      28.00
   QUANTITY REQUIRED ON ROUTE IS  28.00  CAPACITY OF TRUCK IS  30.00
* * * * * * * * * *


* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 2 -- 3 -- 9 -- 7 --
   TOTAL DISTANCE OF ROUTE IS      22.00
   QUANTITY REQUIRED ON ROUTE IS  25.00  CAPACITY OF TRUCK IS  30.00
* * * * * * * * * *


* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 8 --10 --
   TOTAL DISTANCE OF ROUTE IS      22.00
   QUANTITY REQUIRED ON ROUTE IS  25.00  CAPACITY OF TRUCK IS  30.00
* * * * * * * * * *
```

RCUTE MATRIX

	DEMAND										
(1)	28.	1.									
(2)	25.	1.	0.								
(3)	25.	0.	0.	5.							
(4)	7.	2.	0.	0.	0.						
(5)	28.	0.	2.	0.	0.	0.					
(6)	28.	1.	0.	0.	0.	0.	1.				
(7)	25.	1.	0.	0.	0.	0.	0.	0.			
(8)	25.	1.	0.	0.	0.	0.	0.	0.	0.		
(9)	25.	0.	0.	0.	6.	0.	0.	0.	4.	0.	
(10)	25.	1.	0.	0.	0.	0.	0.	0.	0.	3.	0.

TRUCK ALLOCATION

TRUCK CAPACITY 30.

ASSUMED ALLOCATICN 99999.

NUMBER ALLOCATEC 3.

TCTAL CISTANCE FCR SYSTEM 76.00

* * * * * * * * * *

PROBLEM TWO

DEMAND POINT	QUANTITY REQUIRED
1	12
2	5
3	8
4	15
5	6
6	7
7	14
8	4
9	13
10	8

There are one truck with forty units capacity, three trucks with thirty units capacity, and two trucks with twenty units capacity assumed available.

The best solution shown below was obtained with the minimum computation time using Tillman and Cochran's method with IDEPTH=2.

PROBLEM OF 1 TERMINALS WITH 10 DEMAND POINTS

DISTANCE MATRIX

(1)	315.									
(2)	388.	695.								
(3)	296.	331.	502.							
(4)	158.	152.	478.	284.						
(5)	186.	172.	483.	167.	121.					
(6)	391.	539.	272.	301.	476.	367.				
(7)	301.	217.	569.	125.	216.	114.	394.			
(8)	151.	376.	252.	258.	251.	213.	250.	323.		
(9)	193.	364.	290.	211.	276.	192.	200.	279.	70.	
(10)	239.	132.	572.	388.	110.	221.	608.	317.	368.	408.

```
*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 3 -- 7 -- 5 --
   TOTAL DISTANCE CF ROUTE IS    721.00
   QUANTITY REQUIREC ON ROUTE IS  28.00  CAPACITY OF TRUCK IS  30.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 4 -- 1 --10 --
   TOTAL DISTANCE CF ROUTE IS    681.00
   QUANTITY REQUIREC ON ROUTE IS  35.00  CAPACITY OF TRUCK IS  40.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 8 -- 2 -- 6 -- 9 --
   TOTAL DISTANCE CF ROUTE IS   1068.00
   QUANTITY REQUIREC ON ROUTE IS  29.00  CAPACITY OF TRUCK IS  30.00
*  *  *  *  *  *  *  *  *  *
```

RCUTE MATRIX

	DEMAND										
(1)	35.	0.									
(2)	29.	0.	0.								
(3)	28.	1.	0.	0.							
(4)	35.	1.	6.	0.	0.						
(5)	28.	1.	0.	0.	0.	0.					
(6)	29.	0.	0.	1.	0.	0.	0.				
(7)	28.	0.	0.	0.	2.	0.	5.	0.			
(8)	29.	1.	0.	7.	0.	0.	0.	0.	0.		
(9)	29.	1.	0.	0.	0.	0.	0.	4.	0.	0.	
(10)	35.	1.	3.	0.	0.	0.	0.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	40.	30.	20.
ASSUMED ALLOCATICN	1.	3.	99999.
NUMBER ALLOCATED	1.	2.	0.

TOTAL DISTANCE FCR SYSTEM 2470.00

* * * * * * * * * *

PROBLEM THREE

DEMAND POINT	QUANTITY REQUIRED
1	10
2	6
3	8
4	12
5	7
6	5
7	12
8	9
9	11
10	8

There are two trucks with forty units of capacity, two trucks with thirty units of capacity, and one truck with twenty units of capacity assumed available.

The best solution shown below was obtained with the minimum computation time using IDEPTH=1 (i.e. Clarke and Wright's method).

PROBLEM OF 1 TERMINALS WITH 10 DEMAND POINTS

DISTANCE MATRIX

(1)	151.									
(2)	321.	293.								
(3)	258.	296.	224.							
(4)	251.	158.	154.	284.						
(5)	213.	186.	108.	167.	121.					
(6)	250.	391.	468.	301.	476.	367.				
(7)	323.	301.	113.	125.	216.	114.	394.			
(8)	170.	288.	338.	172.	354.	234.	130.	264.		
(9)	70.	193.	300.	211.	276.	192.	200.	279.	95.	
(10)	390.	511.	558.	391.	574.	457.	144.	484.	220.	321.

```
*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 1 -- 4 --

   TOTAL DISTANCE OF ROUTE IS     560.00

   QUANTITY REQUIRED ON ROUTE IS  22.00  CAPACITY OF TRUCK IS  30.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 3 -- 7 -- 2 -- 5 --

   TOTAL DISTANCE OF ROUTE IS     817.00

   QUANTITY REQUIRED ON ROUTE IS  33.00  CAPACITY OF TRUCK IS  40.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 6 --10 -- 8 -- 9 --

   TOTAL DISTANCE OF ROUTE IS     779.00

   QUANTITY REQUIRED ON ROUTE IS  33.00  CAPACITY OF TRUCK IS  40.00

*  *  *  *  *  *  *  *  *  *
```

RCUTE MATRIX

	DEMAND										
(1)	22.	1.									
(2)	33.	0.	0.								
(3)	33.	1.	0.	0.							
(4)	22.	1.	6.	0.	0.						
(5)	33.	1.	0.	4.	0.	0.					
(6)	33.	1.	0.	0.	0.	0.	0.				
(7)	33.	0.	0.	1.	3.	0.	0.	0.			
(8)	33.	0.	0.	0.	0.	0.	0.	0.	0.		
(9)	33.	1.	0.	0.	0.	0.	0.	0.	0.	7.	
(10)	33.	0.	0.	0.	0.	0.	0.	2.	0.	5.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	40.	30.	20.
ASSUMED ALLOCATICN	2.	2.	99999.
NUMBER ALLOCATED	2.	1.	0.

TOTAL DISTANCE FOR SYSTEM 2156.00

* * * * * * * * * *

PROBLEM FOUR

DEMAND POINT	QUANTITY REQUIRED
1	5
2	12
3	8
4	6
5	15
6	9
7	16
8	10
9	7
10	11

There are one truck with fifty units of capacity, one truck with forty units of capacity, two trucks with thirty units of capacity, and one truck with twenty units of capacity assumed available.

The best solution shown below was obtained with the minimum computation time using Tillman and Cochran's method with IDEPTH=2.

PROBLEM OF 1 TERMINALS WITH 10 DEMAND POINTS

DISTANCE MATRIX

(1)	230.									
(2)	194.	232.								
(3)	244.	33.	265.							
(4)	107.	123.	168.	139.						
(5)	265.	190.	370.	167.	202.					
(6)	154.	233.	325.	212.	152.	160.				
(7)	108.	295.	301.	309.	172.	277.	121.			
(8)	326.	253.	428.	230.	252.	86.	131.	248.		
(9)	113.	340.	262.	354.	217.	375.	216.	114.	347.	
(10)	207.	133.	309.	110.	132.	61.	110.	221.	119.	317.

```
* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 2 -- 1 -- 3 -- 4 --
   TOTAL DISTANCE OF ROUTE IS    705.00
   QUANTITY REQUIRED ON ROUTE IS  31.00  CAPACITY OF TRUCK IS  40.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 6 -- 8 -- 5 --10 --
   TOTAL DISTANCE OF ROUTE IS    639.00
   QUANTITY REQUIRED ON ROUTE IS  45.00  CAPACITY OF TRUCK IS  50.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 7 -- 9 --
   TOTAL DISTANCE OF ROUTE IS    335.00
   QUANTITY REQUIRED ON ROUTE IS  23.00  CAPACITY OF TRUCK IS  30.00
* * * * * * * * * *
```

RCUTE MATRIX

	DEMAND										
(1)	31.	0.									
(2)	31.	1.	6.								
(3)	31.	0.	2.	0.							
(4)	31.	1.	0.	0.	5.						
(5)	45.	0.	0.	0.	0.	0.					
(6)	45.	1.	0.	0.	0.	0.	0.				
(7)	23.	1.	0.	0.	0.	0.	0.	0.			
(8)	45.	0.	0.	0.	0.	0.	1.	4.	0.		
(9)	23.	1.	0.	0.	0.	0.	C.	0.	7.	0.	
(10)	45.	1.	0.	0.	0.	0.	3.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	50.	40.	30.	20.
ASSUMED ALLOCATICN	1.	1.	2.	99999.
NUMBER ALLOCATEC	1.	1.	1.	0.

TCTAL DISTANCE FCR SYSTEM 1679.00

* * * * * * * * * *

PROBLEM FIVE

DEMAND POINT	QUANTITY REQUIRED
1	20
2	15
3	8
4	16
5	7
6	9
7	17
8	10
9	14
10	5

There are two trucks with fifty units of capacity, two trucks with forty units of capacity, two trucks with thirty units of capacity, and one truck with twenty units of capacity assumed available.

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=3.

PROBLEM OF 1 TERMINALS WITH 10 DEMAND POINTS

DISTANCE MATRIX

(1)	558.									
(2)	476.	154.								
(3)	645.	805.	653.							
(4)	514.	400.	248.	403.						
(5)	353.	505.	386.	325.	256.					
(6)	294.	366.	247.	464.	210.	137.				
(7)	302.	252.	187.	686.	375.	346.	209.			
(8)	220.	649.	530.	425.	503.	229.	283.	452.		
(9)	404.	783.	664.	271.	543.	287.	417.	634.	182.	
(10)	450.	895.	776.	384.	733.	473.	529.	698.	246.	186.

```
* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 1 -- 2 --
   TOTAL DISTANCE OF ROUTE IS   1188.00
   QUANTITY REQUIRED ON ROUTE IS  35.00  CAPACITY OF TRUCK IS  40.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 4 -- 3 -- 9 --10 --
   TOTAL DISTANCE OF ROUTE IS   1824.00
   QUANTITY REQUIRED ON ROUTE IS  43.00  CAPACITY OF TRUCK IS  50.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 7 -- 6 -- 5 -- 8 --
   TOTAL DISTANCE OF ROUTE IS   1097.00
   QUANTITY REQUIRED ON ROUTE IS  43.00  CAPACITY OF TRUCK IS  50.00
* * * * * * * * * *
```

RCUTE MATRIX

	DEMAND										
(1)	35.	1.									
(2)	35.	1.	1.								
(3)	43.	0.	0.	0.							
(4)	43.	1.	0.	0.	3.						
(5)	43.	0.	0.	0.	0.	0.					
(6)	43.	0.	0.	0.	0.	0.	5.				
(7)	43.	1.	0.	0.	0.	0.	0.	6.			
(8)	43.	1.	0.	0.	0.	0.	7.	0.	0.		
(9)	43.	0.	0.	0.	2.	0.	0.	0.	0.	0.	
(10)	43.	1.	0.	0.	0.	0.	0.	0.	0.	0.	4.

TRUCK ALLOCATION

TRUCK CAPACITY	50.	40.	30.	20.
ASSUMED ALLOCATICN	2.	2.	2.	99999.
NUMBER ALLOCATED	2.	1.	0.	0.

TCTAL DISTANCE FCR SYSTEM 4109.00

* * * * * * * * * *

SINGLE TERMINAL TWENTY-FIVE
DEMAND POINT PROBLEMS

PROBLEM ONE

DEMAND POINT	QUANTITY REQUIRED	TRUCKS CAPACITY	TRUCKS NUMBER
1	18	100	3
2	26	90	4
3	38	80	2
4	40	70	5
5	27	60	1
6	16	50	6
7	29	40	2
8	30	30	8
9	32	20	2
10	27		
11	18		
12	38		
13	22		
14	16		
15	35		
16	26		
17	18		
18	24		
19	30		
20	28		
21	17		
22	15		
23	20		
24	18		
25	25		

The best solution shown below was obtained with the minimum computation time using Clarke and Wright's method (IDEPTH=1).

PROBLEM OF 1 TERMINALS WITH 25 DEMAND POINTS

DISTANCE MATRIX

(1)	656.													
(2)	468.	574.												
(3)	293.	476.	197.											
(4)	343.	716.	268.	244.										
(5)	785.	367.	398.	517.	655.									
(6)	315.	579.	168.	107.	139.	557.								
(7)	936.	653.	1075.	943.	1187.	1020.	1050.							
(8)	330.	808.	785.	571.	679.	1064.	695.	704.						
(9)	296.	364.	394.	224.	468.	586.	331.	734.	502.					
(10)	158.	582.	307.	154.	212.	671.	152.	999.	478.	284.				
(11)	186.	480.	301.	108.	309.	601.	172.	882.	483.	167.	121.			
(12)	764.	248.	786.	662.	906.	615.	769.	403.	828.	468.	748.	631.		
(13)	391.	567.	663.	468.	715.	870.	539.	565.	272.	301.	476.	367.	556.	
(14)	301.	366.	262.	113.	354.	499.	217.	833.	569.	125.	216.	114.	552.	394.
(15)	544.	247.	611.	502.	723.	581.	586.	464.	608.	273.	553.	436.	210.	336.	389.
(16)	451.	187.	411.	290.	533.	457.	396.	686.	638.	159.	396.	294.	375.	423.	180.
(17)	944.	351.	975.	820.	1063.	697.	926.	498.	989.	642.	926.	805.	181.	730.	710.
(18)	476.	911.	885.	691.	817.	1184.	748.	656.	145.	622.	616.	583.	866.	349.	689.
(19)	151.	611.	513.	321.	475.	812.	376.	815.	252.	258.	251.	213.	669.	250.	323.
(20)	288.	476.	533.	338.	546.	749.	409.	645.	336.	172.	354.	234.	514.	130.	264.
(21)	193.	541.	497.	300.	515.	778.	364.	746.	290.	211.	276.	192.	598.	200.	279.
(22)	511.	530.	753.	558.	766.	864.	629.	425.	344.	391.	574.	457.	503.	144.	484.
(23)	239.	683.	301.	207.	110.	689.	132.	1154.	572.	388.	110.	221.	869.	608.	317.
(24)	693.	664.	935.	740.	948.	998.	811.	271.	471.	573.	756.	641.	543.	324.	668.
(25)	697.	776.	981.	788.	1022.	1100.	852.	384.	403.	621.	783.	682.	733.	344.	714.

DISTANCE MATRIX

(16)	209.									
(17)	397.	530.								
(18)	664.	756.	1026.							
(19)	449.	406.	850.	372.						
(20)	294.	332.	695.	454.	170.					
(21)	383.	355.	779.	410.	70.	95.				
(22)	283.	452.	645.	381.	390.	220.	321.			
(23)	686.	497.	1027.	710.	368.	539.	408.	729.		
(24)	417.	634.	689.	385.	570.	404.	503.	182.	911.	
(25)	529.	698.	833.	303.	548.	450.	507.	246.	915.	186.

```
*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 6 -- 2 -- 3 --11 --
   TOTAL DISTANCE OF ROUTE IS     974.00
   QUANTITY REQUIRED ON ROUTE IS  98.00  CAPACITY OF TRUCK IS 100.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 8 --21 --19 --
   TOTAL DISTANCE OF ROUTE IS     849.00
   QUANTITY REQUIRED ON ROUTE IS  77.00  CAPACITY OF TRUCK IS  80.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 9 --16 --20 --
   TOTAL DISTANCE OF ROUTE IS    1045.00
   QUANTITY REQUIRED ON ROUTE IS  86.00  CAPACITY OF TRUCK IS  90.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --10 -- 4 --23 --
   TOTAL DISTANCE OF ROUTE IS     719.00
   QUANTITY REQUIRED ON ROUTE IS  87.00  CAPACITY OF TRUCK IS  90.00
*  *  *  *  *  *  *  *  *  *
```

```
*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --12 --17 -- 7 --22 --

   TOTAL DISTANCE OF ROUTE IS    2379.00

   QUANTITY REQUIRED ON ROUTE IS 100.00  CAPACITY OF TRUCK IS 100.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --13 --24 --25 --18 --

   TOTAL DISTANCE OF ROUTE IS    1680.00

   QUANTITY REQUIRED ON ROUTE IS  89.00  CAPACITY OF TRUCK IS  90.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --14 -- 5 -- 1 --15 --

   TOTAL DISTANCE OF ROUTE IS    1958.00

   QUANTITY REQUIRED ON ROUTE IS  96.00  CAPACITY OF TRUCK IS 100.00

*  *  *  *  *  *  *  *  *  *
```

RCUTE MATRIX

	DEMAND													
(1)	96.	0.												
(2)	98.	0.	0.											
(3)	98.	0.	0.	12.										
(4)	87.	0.	0.	0.	0.									
(5)	96.	0.	4.	0.	0.	0.								
(6)	96.	1.	0.	9.	0.	0.	0.							
(7)	100.	0.	0.	0.	0.	0.	0.	0.						
(8)	77.	1.	0.	0.	0.	0.	0.	0.	0.					
(9)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	87.	1.	0.	0.	0.	16.	0.	0.	0.	0.	0.			
(11)	98.	1.	0.	0.	15.	0.	0.	0.	0.	0.	0.	0.		
(12)	100.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	89.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	96.	1.	0.	0.	0.	0.	11.	0.	0.	0.	0.	0.	0.	0.
(15)	96.	1.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(16)	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	10.	0.	0.	0.
(17)	100.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.	0.	0.	1.
(18)	89.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(19)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(20)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(21)	77.	0.	0.	0.	0.	0.	0.	0.	0.	18.	0.	0.	0.	0.
(22)	100.	1.	0.	0.	0.	0.	0.	0.	5.	0.	0.	0.	0.	0.
(23)	87.	1.	0.	0.	0.	13.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	89.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	89.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(14)	96.	1.	0.											
(15)	96.	1.	0.	0.										
(16)	86.	0.	0.	0.	0.									
(17)	100.	0.	0.	0.	0.	0.								
(18)	89.	1.	0.	0.	0.	0.	0.							
(19)	77.	1.	0.	0.	0.	0.	0.	0.						
(20)	86.	1.	0.	0.	0.	14.	0.	0.	0.					
(21)	77.	0.	0.	0.	0.	0.	0.	0.	17.	0.				
(22)	100.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(23)	87.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(24)	89.	0.	8.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(25)	89.	0.	0.	0.	0.	0.	0.	7.	0.	0.	0.	0.	0.	3.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATION	3.	4.	2.	5.	1.	6.	2.	8.	99999.
NUMBER ALLOCATED	3.	3.	1.	0.	0.	0.	0.	0.	0.

TOTAL DISTANCE FOR SYSTEM 9604.00

* * * * * * * * * *

PROBLEM TWO

DEMAND POINT	QUANTITY REQUIRED	TRUCKS CAPACITY	TRUCKS NUMBER
1	16	100	4
2	25	90	4
3	36	80	2
4	20	70	2
5	16	60	4
6	24	50	2
7	38	40	2
8	40	30	1
9	18	20	3
10	26		
11	25		
12	30		
13	15		
14	28		
15	19		
16	37		
17	28		
18	18		
19	23		
20	17		
21	22		
22	20		
23	24		
24	15		
25	24		

The best solution shown below was obtained with the minimum computation time using Tillman and Cochran's method with IDEPTH=2.

PROBLEM OF 1 TERMINALS WITH 25 DEMAND POINTS

DISTANCE MATRIX

(1)	476.														
(2)	546.	716.													
(3)	749.	367.	655.												
(4)	409.	579.	139.	557.											
(5)	645.	653.	1187.	1020.	1050.										
(6)	336.	808.	679.	1064.	695.	704.									
(7)	172.	364.	468.	586.	331.	734.	502.								
(8)	354.	582.	212.	671.	152.	999.	478.	284.							
(9)	794.	662.	1284.	1029.	1147.	245.	946.	834.	1114.						
(10)	234.	480.	309.	601.	172.	882.	483.	167.	121.	997.					
(11)	514.	248.	906.	615.	769.	403.	828.	468.	748.	429.	631.				
(12)	130.	567.	715.	870.	539.	565.	272.	301.	476.	780.	367.	556.			
(13)	253.	706.	824.	1001.	656.	499.	201.	423.	585.	741.	484.	661.	146.		
(14)	264.	366.	354.	499.	217.	833.	569.	125.	216.	930.	114.	552.	394.	516.	
(15)	294.	247.	723.	581.	586.	464.	608.	273.	553.	561.	436.	210.	336.	459.	389.
(16)	572.	94.	793.	378.	656.	650.	900.	456.	674.	659.	572.	245.	659.	798.	458.
(17)	302.	187.	533.	457.	396.	686.	638.	159.	396.	783.	294.	375.	423.	554.	180.
(18)	695.	351.	1063.	697.	926.	498.	989.	642.	926.	359.	805.	181.	730.	821.	710.
(19)	454.	911.	817.	1184.	748.	656.	145.	622.	616.	898.	583.	866.	349.	205.	689.
(20)	170.	611.	475.	812.	376.	815.	252.	258.	251.	964.	213.	669.	250.	350.	323.
(21)	591.	742.	134.	568.	191.	1232.	804.	508.	330.	1319.	354.	934.	721.	937.	394.
(22)	95.	541.	515.	778.	364.	746.	290.	211.	276.	895.	192.	598.	200.	309.	279.
(23)	220.	530.	766.	864.	629.	425.	344.	391.	574.	640.	457.	503.	144.	176.	484.
(24)	509.	683.	110.	689.	132.	1154.	572.	388.	110.	1247.	221.	869.	608.	717.	317.
(25)	404.	664.	948.	998.	811.	271.	471.	573.	756.	513.	641.	543.	324.	258.	668.

DISTANCE MATRIX

(16)	339.									
(17)	209.	297.								
(18)	397.	324.	530.							
(19)	664.	1003.	756.	1026.						
(20)	449.	703.	406.	850.	372.					
(21)	758.	819.	559.	1093.	942.	588.				
(22)	383.	633.	355.	779.	410.	70.	628.			
(23)	283.	622.	452.	645.	381.	390.	811.	321.		
(24)	686.	775.	497.	1027.	710.	368.	228.	408.	729.	
(25)	417.	756.	634.	689.	385.	570.	995.	503.	182.	911.

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE -- 1 --16 -- 3 --

TOTAL DISTANCE OF ROUTE IS 1697.00

QUANTITY REQUIRED ON ROUTE IS 89.00 CAPACITY OF TRUCK IS 90.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE -- 4 --21 -- 2 --24 --20 --

TOTAL DISTANCE OF ROUTE IS 1382.00

QUANTITY REQUIRED ON ROUTE IS 99.00 CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE -- 5 -- 9 --18 --11 --15 --

TOTAL DISTANCE OF ROUTE IS 1934.00

QUANTITY REQUIRED ON ROUTE IS 96.00 CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE -- 7 --17 --

TOTAL DISTANCE OF ROUTE IS 633.00

QUANTITY REQUIRED ON ROUTE IS 66.00 CAPACITY OF TRUCK IS 70.00

* * * * * * * * * *

```
* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --10 -- 8 --14 --
   TOTAL DISTANCE OF ROUTE IS    835.00
   QUANTITY REQUIRED ON ROUTE IS  94.00  CAPACITY OF TRUCK IS 100.00
* * * * * * * * * *


* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --12 --25 --23 --
   TOTAL DISTANCE OF ROUTE IS    856.00
   QUANTITY REQUIRED ON ROUTE IS  78.00  CAPACITY OF TRUCK IS  80.00
* * * * * * * * * *


* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --13 --19 -- 6 --22 --
   TOTAL DISTANCE OF ROUTE IS    988.00
   QUANTITY REQUIRED ON ROUTE IS  82.00  CAPACITY OF TRUCK IS  90.00
* * * * * * * * * *
```

ROUTE MATRIX

	DEMAND													
(1)	89.	1.												
(2)	99.	0.	0.											
(3)	89.	1.	0.	0.										
(4)	99.	1.	0.	0.	0.									
(5)	96.	1.	0.	0.	0.	0.								
(6)	82.	0.	0.	0.	0.	0.	0.							
(7)	66.	1.	0.	0.	0.	0.	0.	0.						
(8)	94.	0.	0.	0.	0.	0.	0.	0.	0.					
(9)	96.	0.	0.	0.	0.	0.	1.	0.	0.	0.				
(10)	94.	1.	0.	0.	0.	0.	0.	0.	0.	12.	0.			
(11)	96.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(12)	78.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	82.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	94.	1.	0.	0.	0.	0.	0.	0.	0.	14.	0.	0.	0.	0.
(15)	96.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	10.	0.
(16)	89.	0.	5.	0.	7.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(17)	66.	1.	0.	0.	0.	0.	0.	0.	15.	0.	0.	0.	0.	0.
(18)	96.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	0.	3.	0.
(19)	82.	0.	0.	0.	0.	0.	0.	9.	0.	0.	0.	0.	0.	0.
(20)	99.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(21)	99.	0.	0.	4.	0.	8.	0.	0.	0.	0.	0.	0.	0.	0.
(22)	82.	1.	0.	0.	0.	0.	0.	18.	0.	0.	0.	0.	0.	0.
(23)	78.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	99.	0.	0.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	78.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	17.

ROUTE MATRIX

(14)	94.	1.	0.											
(15)	96.	1.	0.	0.										
(16)	89.	0.	0.	0.	0.									
(17)	66.	1.	0.	0.	0.	0.								
(18)	96.	0.	0.	0.	0.	0.	0.							
(19)	82.	0.	11.	0.	0.	0.	0.	0.						
(20)	99.	1.	0.	0.	0.	0.	0.	0.	0.					
(21)	99.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(22)	82.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(23)	78.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(24)	99.	0.	0.	0.	0.	0.	0.	0.	0.	16.	0.	0.	0.	
(25)	78.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	13.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATICN	4.	4.	2.	2.	4.	2.	2.	1.	99999.
NUMBER ALLOCATED	3.	2.	1.	1.	0.	0.	0.	0.	0.

TOTAL DISTANCE FOR SYSTEM 8325.00

* * * * * * * * * *

PROBLEM THREE

DEMAND POINT	QUANTITY REQUIRED	TRUCKS CAPACITY	TRUCKS NUMBER
1	18	100	2
2	22	90	4
3	35	80	3
4	20	70	2
5	16	60	2
6	38	50	2
7	34	40	4
8	24	30	3
9	26	20	3
10	36		
11	15		
12	27		
13	17		
14	23		
15	36		
16	40		
17	15		
18	16		
19	28		
20	32		
21	22		
22	25		
23	18		
24	30		
25	24		

The best solution shown below was obtained with the minimum computation time using Clarke and Wright's method (IDEPTH=1).

PROBLEM OF 1 TERMINALS WITH 25 DEMAND POINTS

DISTANCE MATRIX

(1)	91.														
(2)	58.	149.													
(3)	222.	140.	258.												
(4)	109.	184.	127.	149.											
(5)	136.	216.	89.	198.	49.										
(6)	33.	94.	64.	194.	90.	122.									
(7)	98.	99.	134.	124.	88.	133.	70.								
(8)	157.	212.	177.	142.	50.	98.	124.	117.							
(9)	115.	101.	173.	239.	218.	250.	128.	146.	252.						
(10)	52.	89.	110.	227.	161.	188.	74.	109.	198.	63.					
(11)	119.	195.	88.	188.	40.	21.	101.	112.	89.	229.	171.				
(12)	113.	24.	154.	118.	167.	212.	90.	79.	192.	123.	111.	191.			
(13)	181.	118.	217.	53.	96.	145.	153.	83.	106.	217.	192.	136.	96.		
(14)	220.	146.	256.	26.	132.	181.	192.	122.	116.	245.	231.	172.	124.	40.	
(15)	132.	43.	170.	100.	162.	207.	106.	76.	186.	142.	130.	186.	19.	81.	109.
(16)	55.	61.	113.	199.	158.	190.	68.	85.	192.	61.	29.	169.	83.	168.	205.
(17)	25.	66.	83.	197.	128.	160.	38.	73.	162.	90.	36.	139.	88.	156.	195.
(18)	188.	150.	224.	58.	100.	149.	160.	90.	84.	236.	199.	140.	128.	31.	32.
(19)	156.	135.	192.	78.	71.	120.	128.	58.	81.	204.	167.	111.	115.	25.	65.
(20)	136.	212.	118.	177.	36.	39.	118.	124.	64.	246.	188.	30.	203.	124.	160.
(21)	161.	237.	156.	172.	60.	74.	143.	147.	30.	271.	213.	65.	222.	136.	146.
(22)	78.	144.	131.	282.	185.	212.	110.	162.	234.	50.	55.	195.	166.	245.	284.
(23)	150.	93.	208.	231.	253.	285.	163.	181.	287.	40.	98.	264.	115.	209.	237.
(24)	32.	123.	35.	254.	136.	117.	65.	130.	186.	146.	84.	111.	145.	213.	252.
(25)	43.	134.	15.	243.	112.	93.	49.	119.	162.	158.	95.	87.	139.	202.	241.

DISTANCE MATRIX

(16)	102.									
(17)	107.	30.								
(18)	114.	175.	163.							
(19)	105.	143.	131.	33.						
(20)	198.	186.	156.	128.	99.					
(21)	216.	211.	181.	114.	111.	35.				
(22)	185.	84.	89.	252.	220.	212.	237.			
(23)	134.	96.	125.	241.	220.	281.	306.	90.		
(24)	164.	87.	57.	220.	188.	141.	176.	96.	182.	
(25)	155.	98.	68.	209.	177.	117.	152.	119.	193.	24.

```
* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 1 --12 --15 --
   TOTAL DISTANCE OF ROUTE IS     266.00
   QUANTITY REQUIRED ON ROUTE IS  81.00  CAPACITY OF TRUCK IS  90.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 4 -- 8 --21 --20 --
   TOTAL DISTANCE OF ROUTE IS     360.00
   QUANTITY REQUIRED ON ROUTE IS  98.00  CAPACITY OF TRUCK IS 100.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --10 --16 --
   TOTAL DISTANCE OF ROUTE IS     136.00
   QUANTITY REQUIRED ON ROUTE IS  76.00  CAPACITY OF TRUCK IS  80.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --11 -- 5 -- 2 --25 --
   TOTAL DISTANCE OF ROUTE IS     287.00
   QUANTITY REQUIRED ON ROUTE IS  77.00  CAPACITY OF TRUCK IS  80.00
* * * * * * * * * *
```

```
*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --13 -- 3 --14 --18 --
   TOTAL DISTANCE OF ROUTE IS    480.00
   QUANTITY REQUIRED ON ROUTE IS  91.00  CAPACITY OF TRUCK IS 100.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --17 -- 7 --19 --
   TOTAL DISTANCE OF ROUTE IS    312.00
   QUANTITY REQUIRED ON ROUTE IS  77.00  CAPACITY OF TRUCK IS  80.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --22 -- 9 --23 --
   TOTAL DISTANCE OF ROUTE IS    318.00
   QUANTITY REQUIRED ON ROUTE IS  69.00  CAPACITY OF TRUCK IS  70.00
*  *  *  *  *  *  *  *  *  *
```

ROUTE MATRIX

	DEMAND													
(1)	81.	1.												
(2)	77.	0.	0.											
(3)	91.	0.	0.	0.										
(4)	98.	1.	0.	0.	0.									
(5)	77.	0.	0.	13.	0.	0.								
(6)	38.	2.	0.	0.	0.	0.	0.							
(7)	77.	0.	0.	0.	0.	0.	0.	0.						
(8)	98.	0.	0.	0.	0.	9.	0.	0.	0.					
(9)	69.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	76.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(11)	77.	1.	0.	0.	0.	0.	6.	0.	0.	0.	0.	0.		
(12)	81.	0.	11.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	91.	1.	0.	0.	3.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	91.	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(15)	81.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.
(16)	76.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	15.	0.	0.
(17)	77.	1.	0.	0.	0.	0.	0.	0.	16.	0.	0.	0.	0.	0.
(18)	91.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(19)	77.	1.	0.	0.	0.	0.	0.	0.	10.	0.	0.	0.	0.	0.
(20)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(21)	98.	0.	0.	0.	0.	0.	0.	0.	0.	4.	0.	0.	0.	0.
(22)	69.	1.	0.	0.	0.	0.	0.	0.	0.	0.	12.	0.	0.	0.
(23)	69.	1.	0.	0.	0.	0.	0.	0.	0.	0.	8.	0.	0.	0.
(24)	30.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	77.	1.	0.	14.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(14)	91.	0.	0.											
(15)	81.	1.	0.	0.										
(16)	76.	1.	0.	0.	0.									
(17)	77.	1.	0.	0.	0.	0.								
(18)	91.	1.	0.	2.	0.	0.	0.							
(19)	77.	1.	0.	0.	0.	0.	0.	0.						
(20)	98.	1.	0.	0.	0.	0.	0.	0.	0.					
(21)	98.	0.	0.	0.	0.	0.	0.	0.	0.	5.				
(22)	69.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(23)	69.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(24)	30.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(25)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATION	2.	4.	3.	2.	2.	2.	4.	3.	99999.
NUMBER ALLOCATED	2.	1.	3.	1.	0.	0.	0.	0.	0.

TOTAL DISTANCE FOR SYSTEM 2289.00

* * * * * * * * * *

PROBLEM FOUR

DEMAND POINT	QUANTITY REQUIRED	TRUCKS CAPACITY	TRUCKS NUMBER
1	20	100	2
2	16	90	3
3	38	80	4
4	24	70	2
5	36	60	1
6	28	50	2
7	18	40	2
8	24	30	1
9	36	20	2
10	22		
11	28		
12	15		
13	30		
14	22		
15	18		
16	25		
17	27		
18	34		
19	23		
20	16		
21	18		
22	26		
23	34		
24	40		
25	17		

The best solution show below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=3.

PROBLEM OF 1 TERMINALS WITH 25 DEMAND POINTS

DISTANCE MATRIX

(1)	125.														
(2)	268.	171.													
(3)	186.	62.	155.												
(4)	49.	174.	310.	235.											
(5)	116.	166.	240.	196.	89.										
(6)	233.	217.	81.	227.	257.	205.									
(7)	163.	81.	107.	96.	210.	149.	136.								
(8)	195.	168.	73.	184.	237.	167.	55.	90.							
(9)	50.	95.	219.	146.	91.	84.	183.	118.	146.						
(10)	203.	91.	88.	68.	249.	188.	170.	40.	124.	158.					
(11)	174.	64.	207.	53.	223.	232.	279.	144.	232.	160.	120.				
(12)	223.	189.	60.	204.	265.	195.	29.	107.	28.	173.	139.	249.			
(13)	140.	111.	132.	126.	185.	121.	114.	35.	59.	93.	75.	173.	86.		
(14)	91.	109.	177.	127.	133.	70.	141.	79.	104.	42.	119.	174.	132.	53.	
(15)	121.	125.	147.	143.	167.	100.	111.	59.	74.	72.	99.	189.	102.	23.	30.
(16)	53.	126.	287.	178.	98.	169.	273.	180.	225.	90.	217.	140.	253.	166.	132.
(17)	132.	64.	143.	84.	178.	117.	161.	36.	106.	88.	76.	128.	134.	47.	49.
(18)	68.	65.	220.	227.	117.	144.	212.	113.	157.	60.	153.	112.	185.	89.	94.
(19)	38.	90.	251.	152.	87.	149.	244.	145.	189.	64.	181.	136.	217.	131.	106.
(20)	152.	33.	137.	44.	198.	152.	188.	52.	140.	110.	63.	92.	160.	82.	83.
(21)	97.	147.	250.	172.	70.	20.	213.	149.	176.	66.	189.	211.	204.	125.	73.
(22)	92.	36.	189.	94.	141.	136.	198.	82.	143.	59.	121.	100.	111.	84.	79.
(23)	69.	105.	212.	149.	104.	59.	176.	110.	138.	26.	150.	170.	166.	85.	34.
(24)	189.	200.	110.	216.	213.	139.	74.	126.	37.	146.	166.	264.	65.	91.	105.
(25)	212.	224.	136.	240.	215.	141.	75.	150.	78.	170.	190.	288.	76.	115.	129.

DISTANCE MATRIX

(16)	164.									
(17)	63.	146.								
(18)	114.	69.	79.							
(19)	136.	42.	110.	32.						
(20)	99.	159.	40.	92.	123.					
(21)	103.	150.	118.	126.	130.	154.				
(22)	99.	101.	48.	34.	66.	58.	118.			
(23)	64.	116.	82.	86.	90.	113.	41.	77.		
(24)	75.	236.	136.	187.	210.	172.	146.	172.	120.	
(25)	99.	261.	160.	211.	235.	196.	149.	196.	144.	41.

```
* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 4 -- 5 --21 --

   TOTAL DISTANCE OF ROUTE IS     255.00

   QUANTITY REQUIRED ON ROUTE IS  78.00  CAPACITY OF TRUCK IS  80.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 6 --12 -- 2 --10 -- 7 --

   TOTAL DISTANCE OF ROUTE IS     613.00

   QUANTITY REQUIRED ON ROUTE IS  99.00  CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 9 --23 --

   TOTAL DISTANCE OF ROUTE IS     145.00

   QUANTITY REQUIRED ON ROUTE IS  70.00  CAPACITY OF TRUCK IS  70.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --11 -- 3 --20 --

   TOTAL DISTANCE OF ROUTE IS     423.00

   QUANTITY REQUIRED ON ROUTE IS  82.00  CAPACITY OF TRUCK IS  90.00

* * * * * * * * * *
```

```
*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --14 --13 --17 --

   TOTAL DISTANCE OF ROUTE IS     323.00

   QUANTITY REQUIRED ON ROUTE IS  79.00  CAPACITY OF TRUCK IS  80.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --15 -- 8 --24 --25 --

   TOTAL DISTANCE OF ROUTE IS     485.00

   QUANTITY REQUIRED ON ROUTE IS  99.00  CAPACITY OF TRUCK IS 100.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --16 --19 --

   TOTAL DISTANCE OF ROUTE IS     133.00

   QUANTITY REQUIRED ON ROUTE IS  48.00  CAPACITY OF TRUCK IS  50.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --18 -- 1 --22 --

   TOTAL DISTANCE OF ROUTE IS     261.00

   QUANTITY REQUIRED ON ROUTE IS  80.00  CAPACITY OF TRUCK IS  80.00

*  *  *  *  *  *  *  *  *  *
```

ROUTE MATRIX

	DEMAND													
(1)	80.	0.												
(2)	99.	0.	0.											
(3)	82.	0.	0.	0.										
(4)	78.	1.	0.	0.	0.									
(5)	78.	0.	0.	0.	0.	16.								
(6)	99.	1.	0.	0.	0.	0.	0.							
(7)	99.	1.	0.	0.	0.	0.	0.	0.						
(8)	99.	0.	0.	0.	0.	0.	0.	0.	0.					
(9)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	99.	0.	0.	3.	0.	0.	0.	0.	6.	0.	0.			
(11)	82.	1.	0.	0.	7.	0.	0.	0.	0.	0.	0.	0.		
(12)	99.	0.	0.	1.	0.	0.	0.	2.	0.	0.	0.	0.	0.	
(13)	79.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	79.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(15)	99.	1.	0.	0.	0.	0.	0.	0.	0.	9.	0.	0.	0.	0.
(16)	48.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(17)	79.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(18)	80.	1.	14.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(19)	48.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(20)	82.	1.	0.	0.	8.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(21)	78.	1.	0.	0.	0.	0.	11.	0.	0.	0.	0.	0.	0.	0.
(22)	80.	1.	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(23)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.	15.	0.	0.	0.
(24)	99.	0.	0.	0.	0.	0.	0.	0.	0.	5.	0.	0.	0.	0.
(25)	99.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(14)	79.	1.	13.											
(15)	99.	1.	0.	0.										
(16)	48.	1.	0.	0.	0.									
(17)	79.	1.	10.	0.	0.	0.								
(18)	80.	1.	0.	0.	0.	0.	0.							
(19)	48.	1.	0.	0.	0.	17.	0.	0.						
(20)	82.	1.	0.	0.	0.	0.	0.	0.	0.					
(21)	78.	1.	0.	0.	0.	0.	0.	0.	0.	0.				
(22)	80.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(23)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(24)	99.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(25)	99.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATION	2.	3.	4.	2.	1.	2.	2.	1.	99999.
NUMBER ALLOCATED	2.	1.	3.	1.	0.	1.	0.	0.	0.

TOTAL DISTANCE FOR SYSTEM 2638.00

* * * * * * * * * *

PROBLEM FIVE

DEMAND POINT	QUANTITY REQUIRED	TRUCKS CAPACITY	TRUCKS NUMBER
1	25	100	4
2	18	90	3
3	36	80	4
4	24	70	2
5	15	60	2
6	17	50	1
7	28	40	2
8	23	30	1
9	16	20	2
10	34		
11	22		
12	18		
13	30		
14	27		
15	16		
16	24		
17	17		
18	28		
19	36		
20	23		
21	22		
22	18		
23	40		
24	25		
25	19		

The best solution shown below was obtained with the minimum computation time using Clarke and Wright's method (IDEPTH=1).

PROBLEM OF 1 TERMINALS WITH 25 DEMAND POINTS

DISTANCE MATRIX

(1)	252.														
(2)	187.	154.													
(3)	451.	730.	656.												
(4)	290.	461.	476.	293.											
(5)	533.	686.	716.	343.	244.										
(6)	457.	215.	367.	785.	517.	655.									
(7)	686.	805.	653.	936.	943.	1187.	1020.								
(8)	638.	894.	808.	338.	571.	679.	1064.	704.							
(9)	159.	415.	364.	296.	224.	468.	586.	734.	502.						
(10)	396.	610.	582.	158.	154.	212.	671.	999.	478.	284.					
(11)	783.	814.	662.	1085.	1040.	1284.	1029.	245.	946.	834.	1114.				
(12)	294.	508.	480.	186.	108.	309.	601.	882.	483.	167.	121.	997.			
(13)	423.	668.	567.	391.	468.	715.	870.	565.	272.	301.	476.	780.	367.		
(14)	554.	810.	706.	499.	590.	824.	1001.	499.	201.	423.	585.	741.	484.	146.	
(15)	346.	505.	386.	644.	618.	862.	720.	325.	573.	409.	679.	445.	562.	354.	405.
(16)	180.	432.	366.	301.	113.	354.	499.	833.	569.	125.	216.	930.	114.	394.	516.
(17)	209.	366.	247.	544.	502.	723.	581.	464.	608.	273.	553.	561.	436.	336.	459.
(18)	297.	173.	94.	748.	568.	793.	378.	650.	900.	456.	674.	659.	572.	659.	798.
(19)	530.	493.	351.	944.	820.	1063.	697.	498.	989.	642.	926.	359.	805.	730.	821.
(20)	756.	1012.	911.	476.	691.	817.	1184.	656.	145.	622.	616.	898.	583.	349.	205.
(21)	302.	558.	476.	288.	338.	546.	749.	645.	336.	172.	354.	794.	234.	130.	253.
(22)	355.	611.	541.	193.	300.	515.	778.	746.	290.	211.	276.	895.	192.	200.	309.
(23)	452.	649.	530.	511.	558.	766.	864.	425.	344.	391.	574.	640.	457.	144.	176.
(24)	497.	668.	683.	239.	207.	110.	689.	1154.	572.	388.	110.	1247.	221.	608.	717.
(25)	698.	895.	776.	697.	788.	1022.	1100.	384.	403.	621.	783.	612.	682.	344.	195.

CISTANCE MATRIX

(16)	508.									
(17)	137.	389.								
(18)	478.	458.	339.							
(19)	416.	710.	397.	324.						
(20)	610.	689.	664.	1003.	1026.					
(21)	353.	264.	294.	572.	695.	454.				
(22)	454.	279.	383.	633.	779.	410.	95.			
(23)	229.	484.	283.	622.	645.	381.	220.	321.		
(24)	783.	317.	686.	775.	1027.	710.	509.	408.	729.	
(25)	473.	714.	529.	868.	833.	303.	450.	507.	246.	915.

```
* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 2 --18 -- 1 -- 6 --

   TOTAL DISTANCE OF ROUTE IS    1126.00

   QUANTITY REQUIRED ON ROUTE IS  88.00  CAPACITY OF TRUCK IS  90.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 4 -- 5 --24 --10 --

   TOTAL DISTANCE OF ROUTE IS    1150.00

   QUANTITY REQUIRED ON ROUTE IS  98.00  CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 7 --11 --19 --

   TOTAL DISTANCE OF ROUTE IS    1820.00

   QUANTITY REQUIRED ON ROUTE IS  86.00  CAPACITY OF TRUCK IS  90.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 8 --20 --25 --14 --

   TOTAL DISTANCE OF ROUTE IS    1835.00

   QUANTITY REQUIRED ON ROUTE IS  92.00  CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *
```

```
*    *    *    *    *    *    *    *    *    *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 9 --15 --17 --
   TOTAL DISTANCE OF ROUTE IS     914.00
   QUANTITY REQUIRED ON ROUTE IS  49.00  CAPACITY OF TRUCK IS  50.00
*    *    *    *    *    *    *    *    *    *

*    *    *    *    *    *    *    *    *    *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --16 --12 -- 3 --22 --
   TOTAL DISTANCE OF ROUTE IS    1028.00
   QUANTITY REQUIRED ON ROUTE IS  96.00  CAPACITY OF TRUCK IS 100.00
*    *    *    *    *    *    *    *    *    *

*    *    *    *    *    *    *    *    *    *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --21 --13 --23 --
   TOTAL DISTANCE OF ROUTE IS    1028.00
   QUANTITY REQUIRED ON ROUTE IS  92.00  CAPACITY OF TRUCK IS 100.00
*    *    *    *    *    *    *    *    *    *
```

ROUTE MATRIX

	DEMAND													
(1)	88.	0.												
(2)	88.	1.	0.											
(3)	96.	0.	0.	0.										
(4)	98.	1.	0.	0.	0.									
(5)	98.	0.	0.	0.	0.	11.								
(6)	88.	1.	13.	0.	0.	0.	0.							
(7)	86.	1.	0.	0.	0.	0.	0.	0.						
(8)	92.	1.	0.	0.	0.	0.	0.	0.	0.					
(9)	49.	1.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(11)	86.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.	0.		
(12)	96.	0.	0.	0.	12.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	92.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(15)	49.	0.	0.	0.	0.	0.	0.	0.	0.	0.	18.	0.	0.	0.
(16)	96.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	17.
(17)	49.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(18)	88.	0.	16.	15.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(19)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	0.
(20)	92.	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.	0.
(21)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(22)	96.	1.	0.	0.	9.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(23)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	98.	0.	0.	0.	0.	0.	6.	0.	0.	0.	0.	7.	0.	0.
(25)	92.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(14)	92.	1.	0.											
(15)	49.	0.	0.	0.										
(16)	96.	1.	0.	0.	0.									
(17)	49.	1.	0.	0.	14.	0.								
(18)	88.	0.	0.	0.	0.	0.	0.							
(19)	86.	1.	0.	0.	0.	0.	0.	0.						
(20)	92.	0.	0.	0.	0.	0.	0.	0.	0.					
(21)	92.	1.	10.	0.	0.	0.	0.	0.	0.	0.				
(22)	96.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(23)	92.	1.	8.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(24)	98.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(25)	92.	0.	0.	4.	0.	0.	0.	0.	0.	3.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATICN	4.	3.	4.	2.	2.	1.	2.	1.	99999.
NUMBER ALLOCATED	4.	2.	0.	0.	0.	1.	0.	0.	0.

TOTAL DISTANCE FCR SYSTEM 8901.00

* * * * * * * * * *

SINGLE TERMINAL FIFTY
DEMAND POINT PROBLEMS

PROBLEM ONE

DEMAND POINT	QUANTITY REQUIRED	DEMAND POINT	QUANTITY REQUIRED
1	25	26	16
2	16	27	35
3	40	28	26
4	36	29	18
5	28	30	24
6	17	31	30
7	19	32	28
8	36	33	17
9	31	34	15
10	24	35	20
11	20	36	18
12	15	37	25
13	18	38	38
14	26	39	40
15	38	40	15
16	40	41	36
17	27	42	18
18	16	43	28
19	29	44	24
20	30	45	35
21	32	46	16
22	27	47	24
23	18	48	26
24	38	49	15
25	22	50	24

TRUCKS

CAPACITY	NUMBER
100	6
90	8
80	3
70	5
60	2
50	6
40	2
30	8
20	3

The best solution shown below was obtained with the minimum computation time using Clarke and Wright's method (IDEPTH=1).

PROBLEM OF 1 TERMINALS WITH 50 DEMAND POINTS

DISTANCE MATRIX

(1)	779.														
(2)	810.	672.													
(3)	1099.	331.	669.												
(4)	706.	702.	154.	787.											
(5)	783.	1214.	1543.	1535.	1504.										
(6)	1456.	653.	1068.	399.	1185.	1823.									
(7)	1015.	207.	877.	345.	902.	1377.	449.								
(8)	648.	1338.	1456.	1656.	1354.	583.	1943.	1496.							
(9)	499.	366.	730.	687.	656.	850.	975.	540.	969.						
(10)	824.	33.	686.	351.	716.	1191.	632.	191.	1310.	343.					
(11)	656.	123.	549.	408.	579.	1207.	769.	323.	1239.	315.	137.				
(12)	499.	1173.	805.	1458.	653.	1175.	1819.	1373.	875.	936.	1187.	1050.			
(13)	201.	707.	984.	1025.	808.	672.	1311.	865.	632.	338.	679.	695.	704.		
(14)	751.	190.	726.	511.	741.	1123.	699.	252.	1238.	271.	167.	202.	1188.	606.	
(15)	423.	454.	415.	718.	364.	1143.	1100.	654.	1069.	296.	468.	331.	734.	502.	444.
(16)	585.	233.	610.	556.	582.	1024.	844.	398.	1105.	158.	212.	152.	999.	478.	160.
(17)	1132.	301.	719.	80.	812.	1504.	398.	294.	1620.	657.	321.	368.	1418.	988.	481.
(18)	1261.	1842.	2053.	2163.	1963.	628.	2451.	2005.	700.	1478.	1819.	1835.	1571.	1162.	1751.
(19)	741.	1270.	814.	1449.	662.	1417.	1916.	1470.	1117.	1085.	1284.	1147.	245.	946.	1337.
(20)	484.	295.	508.	580.	480.	1035.	941.	495.	1074.	186.	309.	172.	882.	483.	277.
(21)	661.	892.	400.	1035.	248.	1479.	1433.	1092.	1282.	764.	906.	769.	403.	828.	927.
(22)	1123.	919.	314.	793.	426.	1857.	1191.	1067.	1770.	1009.	952.	854.	994.	1208.	996.
(23)	146.	662.	668.	931.	567.	930.	1308.	901.	793.	391.	715.	539.	565.	272.	642.
(24)	691.	253.	782.	575.	713.	1063.	785.	338.	1178.	215.	233.	252.	1128.	546.	86.
(25)	405.	848.	505.	1086.	386.	1188.	1494.	1048.	1040.	644.	862.	725.	325.	573.	896.
(26)	1596.	2368.	2197.	2695.	2056.	1649.	3052.	2606.	1169.	2095.	2420.	2245.	1403.	1801.	2347.
(27)	516.	340.	432.	604.	366.	1146.	986.	540.	1162.	301.	354.	217.	833.	569.	375.
(28)	580.	455.	784.	776.	744.	764.	1064.	618.	988.	89.	432.	484.	1015.	361.	364.

(29)	457.	776.	1105.	1097.	1066.	430.	1385.	939.	794.	412.	753.	769.	956.	252.	685.
(30)	554.	519.	252.	725.	187.	1299.	1165.	719.	1200.	451.	533.	396.	686.	638.	555.
(31)	821.	1049.	493.	1138.	351.	1604.	1536.	1253.	1373.	944.	1063.	926.	498.	989.	1085.
(32)	1319.	487.	855.	187.	974.	1691.	216.	445.	1806.	738.	507.	557.	1607.	1173.	667.
(33)	205.	845.	1012.	1163.	911.	581.	1449.	1003.	493.	476.	817.	748.	656.	145.	744.
(34)	350.	448.	662.	818.	611.	857.	1107.	661.	864.	151.	475.	376.	815.	252.	402.
(35)	1238.	406.	766.	97.	884.	1610.	364.	365.	1725.	775.	426.	476.	1526.	1092.	586.
(36)	1226.	2003.	1810.	2325.	1658.	1501.	2682.	2236.	918.	1722.	2050.	1882.	1005.	1430.	1977.
(37)	595.	1130.	1381.	1451.	1295.	207.	1739.	1293.	441.	766.	1107.	1123.	968.	487.	1039.
(38)	937.	105.	697.	230.	742.	1309.	598.	217.	1424.	461.	134.	182.	1232.	804.	285.
(39)	1846.	2476.	2654.	2797.	2552.	1262.	3085.	2639.	1198.	2112.	2453.	2469.	2043.	1819.	2385.
(40)	253.	532.	558.	817.	476.	980.	1178.	802.	898.	288.	546.	409.	645.	336.	543.
(41)	1874.	2541.	2523.	2876.	2393.	1633.	3163.	2716.	1220.	2189.	2530.	2459.	1806.	1852.	2458.
(42)	1872.	2427.	2756.	2748.	2575.	1213.	3036.	2590.	1267.	2063.	2404.	2420.	2112.	1773.	2336.
(43)	1583.	2138.	2467.	2459.	2286.	924.	2747.	2301.	1022.	1774.	2115.	2131.	1891.	1484.	2047.
(44)	309.	487.	611.	854.	541.	912.	1147.	701.	895.	193.	515.	364.	746.	290.	442.
(45)	176.	752.	649.	1037.	530.	959.	1468.	1022.	824.	511.	766.	629.	425.	344.	763.
(46)	1238.	1097.	467.	981.	541.	2010.	1379.	1248.	1886.	1162.	1122.	985.	1077.	1349.	1193.
(47)	717.	133.	668.	454.	683.	1089.	742.	296.	1204.	239.	110.	132.	1154.	572.	61.
(48)	258.	934.	783.	1219.	664.	966.	1650.	1204.	776.	693.	948.	811.	271.	471.	945.
(49)	1048.	331.	630.	39.	748.	1535.	437.	359.	1650.	712.	351.	392.	1372.	1018.	511.
(50)	195.	975.	895.	1297.	776.	791.	1654.	1208.	590.	697.	1022.	852.	384.	403.	949.

DISTANCE MATRIX

(16)	284.														
(17)	697.	526.													
(18)	1772.	1652.	2133.												
(19)	834.	1114.	1474.	1813.											
(20)	167.	121.	540.	1663.	997.										
(21)	468.	748.	1060.	1922.	429.	631.									
(22)	729.	924.	855.	2370.	911.	822.	589.								
(23)	301.	476.	904.	1405.	780.	367.	549.	956.							
(24)	415.	131.	544.	1691.	1245.	248.	879.	1101.	582.						
(25)	409.	679.	1094.	1666.	445.	562.	256.	812.	354.	836.					
(26)	2029.	2181.	2729.	1234.	1553.	2080.	1810.	2397.	1742.	2287.	1701.				
(27)	125.	216.	582.	1777.	930.	114.	552.	708.	394.	347.	508.	2107.			
(28)	374.	265.	746.	1392.	1174.	276.	844.	1098.	469.	304.	723.	2176.	390.		
(29)	706.	586.	1067.	1056.	1198.	597.	1060.	1419.	509.	625.	825.	1940.	711.	326.	
(30)	159.	396.	762.	1800.	783.	294.	375.	570.	423.	527.	346.	2058.	180.	540.	861.
(31)	642.	926.	1163.	2070.	359.	805.	181.	582.	730.	1053.	416.	1901.	710.	1013.	1241.
(32)	888.	712.	186.	2319.	1636.	729.	1222.	980.	1096.	729.	1282.	2915.	769.	932.	1253.
(33)	622.	616.	1127.	1056.	898.	583.	866.	1326.	349.	685.	610.	1662.	689.	500.	358.
(34)	258.	251.	783.	1414.	964.	213.	669.	976.	250.	344.	523.	1946.	323.	226.	423.
(35)	807.	631.	105.	2238.	1546.	648.	1132.	890.	1015.	649.	1201.	2721.	688.	851.	1172.
(36)	1664.	1811.	2358.	1147.	1153.	1710.	1412.	1999.	1372.	1917.	1330.	398.	1757.	1806.	1630.
(37)	989.	940.	1421.	699.	1210.	951.	1256.	1695.	739.	979.	1000.	1558.	1065.	701.	395.
(38)	508.	330.	197.	1937.	1319.	354.	934.	865.	721.	348.	897.	2533.	394.	550.	871.
(39)	2267.	2286.	2767.	657.	2233.	2297.	2450.	2968.	1991.	2325.	2234.	970.	2412.	2026.	1690.
(40)	172.	354.	777.	1498.	794.	234.	514.	872.	130.	483.	353.	1848.	264.	370.	546.
(41)	2297.	2329.	2839.	1134.	1955.	2294.	2212.	2799.	2014.	2399.	2027.	403.	2390.	2213.	1997.
(42)	2357.	2237.	2718.	611.	2302.	2245.	2519.	3070.	2016.	2276.	2277.	1145.	2362.	1977.	1641.
(43)	2068.	1948.	2429.	322.	2138.	1956.	2244.	2781.	1727.	1987.	1988.	1227.	2073.	1688.	1352.
(44)	211.	276.	823.	1452.	895.	192.	598.	925.	200.	382.	454.	1905.	279.	269.	478.

(45)	391.	574.	997.	1437.	640.	457.	503.	956.	144.	703.	229.	1637.	484.	590.	596.
(46)	873.	1077.	1036.	2499.	984.	975.	672.	198.	1108.	1254.	912.	2480.	861.	1251.	1572.
(47)	388.	110.	424.	1717.	1247.	221.	869.	939.	608.	119.	783.	2313.	317.	330.	651.
(48)	573.	756.	1181.	1427.	513.	641.	543.	1090.	324.	883.	287.	1461.	668.	772.	715.
(49)	716.	556.	119.	2163.	1410.	564.	996.	754.	931.	574.	1047.	2644.	596.	776.	1097.
(50)	621.	783.	1330.	1241.	612.	682.	733.	1202.	344.	889.	473.	1402.	714.	778.	655.

CISTANCE MATRIX

(31)	530.														
(32)	949.	1325.													
(33)	756.	1026.	1312.												
(34)	406.	850.	970.	372.											
(35)	868.	1235.	93.	1230.	889.										
(36)	1725.	1503.	2459.	1335.	1576.	2464.									
(37)	1125.	1416.	1607.	390.	739.	1526.	1341.								
(38)	559.	1093.	386.	942.	588.	305.	2163.	1225.							
(39)	2398.	2541.	2953.	1691.	2062.	2872.	1366.	1356.	2571.						
(40)	302.	695.	966.	454.	170.	885.	1478.	823.	591.	2096.					
(41)	2410.	2333.	3025.	1713.	2084.	2944.	800.	1609.	2648.	652.	2126.				
(42)	2512.	2610.	2904.	1667.	2070.	2823.	1541.	1310.	2522.	175.	2109.	827.			
(43)	2223.	2392.	2615.	1378.	1781.	2534.	1369.	1021.	2233.	360.	1820.	915.	289.		
(44)	355.	779.	1010.	410.	70.	929.	1535.	777.	628.	2093.	95.	2115.	2063.	1774.	
(45)	452.	645.	1186.	381.	390.	1105.	1273.	771.	811.	2022.	220.	1958.	2048.	1759.	321.
(46)	714.	653.	1167.	1443.	1120.	1078.	2082.	1833.	1046.	3084.	1016.	2882.	3110.	2821.	1069.
(47)	497.	1027.	610.	710.	368.	529.	1943.	1005.	228.	2351.	509.	2428.	2302.	2013.	408.
(48)	634.	689.	1370.	385.	570.	1289.	1091.	766.	995.	1970.	404.	1776.	2038.	1749.	503.
(49)	686.	1099.	229.	1156.	814.	136.	2274.	1451.	245.	2797.	801.	2869.	2748.	2459.	854.
(50)	698.	833.	1517.	303.	548.	1436.	1032.	584.	1135.	1784.	450.	1721.	1852.	1563.	507.

DISTANCE MATRIX

(46)	1062.				
(47)	729.	1135.			
(48)	182.	1196.	911.		
(49)	1021.	942.	454.	1205.	
(50)	246.	1308.	915.	186.	1246.

```
*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 1 -- 7 --10 --47 --

   TOTAL DISTANCE OF ROUTE IS   2004.00

   QUANTITY REQUIRED ON ROUTE IS  92.00  CAPACITY OF TRUCK IS 100.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 2 --22 --46 --31 --

   TOTAL DISTANCE OF ROUTE IS   2796.00

   QUANTITY REQUIRED ON ROUTE IS  89.00  CAPACITY OF TRUCK IS  90.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 6 --32 --35 --17 --

   TOTAL DISTANCE OF ROUTE IS   3002.00

   QUANTITY REQUIRED ON ROUTE IS  92.00  CAPACITY OF TRUCK IS 100.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 8 -- 5 --37 --

   TOTAL DISTANCE OF ROUTE IS   2033.00

   QUANTITY REQUIRED ON ROUTE IS  89.00  CAPACITY OF TRUCK IS  90.00

*  *  *  *  *  *  *  *  *  *
```

```
*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --11 --14 --24 --

   TOTAL DISTANCE OF ROUTE IS   1635.00

   QUANTITY REQUIRED ON ROUTE IS  84.00  CAPACITY OF TRUCK IS  90.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --13 --33 --

   TOTAL DISTANCE OF ROUTE IS    551.00

   QUANTITY REQUIRED ON ROUTE IS  35.00  CAPACITY OF TRUCK IS  40.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --15 --27 --40 --

   TOTAL DISTANCE OF ROUTE IS   1065.00

   QUANTITY REQUIRED ON ROUTE IS  88.00  CAPACITY OF TRUCK IS  90.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --18 --41 --26 --36 --

   TOTAL DISTANCE OF ROUTE IS   4422.00

   QUANTITY REQUIRED ON ROUTE IS  86.00  CAPACITY OF TRUCK IS  90.00

*  *  *  *  *  *  *  *  *  *
```

```
*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --20 --16 --44 --
   TOTAL DISTANCE OF ROUTE IS    1190.00
   QUANTITY REQUIRED ON ROUTE IS  94.00  CAPACITY OF TRUCK IS 100.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --21 -- 4 --30 --
   TOTAL DISTANCE OF ROUTE IS    1650.00
   QUANTITY REQUIRED ON ROUTE IS  92.00  CAPACITY OF TRUCK IS 100.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --23 --45 --50 --
   TOTAL DISTANCE OF ROUTE IS     731.00
   QUANTITY REQUIRED ON ROUTE IS  77.00  CAPACITY OF TRUCK IS  80.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --25 --19 --12 --48 --
   TOTAL DISTANCE OF ROUTE IS    1624.00
   QUANTITY REQUIRED ON ROUTE IS  92.00  CAPACITY OF TRUCK IS 100.00
*  *  *  *  *  *  *  *  *  *
```

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE --29 --28 -- 9 --34 --

TOTAL DISTANCE OF ROUTE IS 1373.00

QUANTITY REQUIRED ON ROUTE IS 90.00 CAPACITY OF TRUCK IS 90.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE --38 -- 3 --49 --

TOTAL DISTANCE OF ROUTE IS 2254.00

QUANTITY REQUIRED ON ROUTE IS 93.00 CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE --39 --42 --43 --

TOTAL DISTANCE OF ROUTE IS 3893.00

QUANTITY REQUIRED ON ROUTE IS 86.00 CAPACITY OF TRUCK IS 90.00

* * * * * * * * * *

RCUTE MATRIX

	DEMAND													
(1)	92.	1.												
(2)	89.	1.	0.											
(3)	93.	0.	0.	0.										
(4)	92.	0.	0.	0.	0.									
(5)	89.	0.	0.	0.	0.	0.								
(6)	92.	1.	0.	0.	0.	0.	0.							
(7)	92.	0.	14.	0.	0.	0.	0.	0.						
(8)	89.	1.	0.	0.	0.	0.	25.	0.	0.					
(9)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	92.	0.	0.	0.	0.	0.	0.	0.	12.	0.	0.			
(11)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(12)	92.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	35.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	84.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	18.	0.
(15)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(16)	94.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(17)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(18)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(19)	92.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	22.
(20)	94.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(21)	92.	1.	0.	0.	0.	20.	0.	0.	0.	0.	0.	0.	0.	0.
(22)	89.	0.	0.	13.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(23)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(26)	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(27)	88.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(28)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	23.	0.	0.	0.
(29)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(30)	92.	1.	0.	0.	0.	21.	0.	0.	0.	0.	0.	0.	0.	0.
(31)	89.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(32)	92.	0.	0.	0.	0.	0.	0.	4.	0.	0.	0.	0.	0.	0.
(33)	35.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(34)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	29.	0.	0.	0.
(35)	92.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(36)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(37)	89.	1.	0.	0.	0.	0.	19.	0.	0.	0.	0.	0.	0.	0.
(38)	93.	1.	0.	0.	11.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(39)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(42)	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(43)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	94.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(45)	77.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(46)	89.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(47)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	15.	0.	0.
(48)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	32.
(49)	93.	1.	0.	0.	9.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

RCUTE MATRIX

(14)	84.	0.	0.												
(15)	88.	1.	0.	0.											
(16)	94.	0.	0.	0.	0.										
(17)	92.	1.	0.	0.	0.	0.									
(18)	86.	1.	0.	0.	0.	0.	0.								
(19)	92.	0.	0.	0.	0.	0.	0.	0.							
(20)	94.	1.	0.	0.	0.	24.	0.	0.	0.						
(21)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.					
(22)	89.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(23)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(24)	84.	1.	0.	17.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(25)	92.	1.	0.	0.	0.	0.	0.	0.	28.	0.	0.	0.	0.	0.	
(26)	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(27)	88.	0.	0.	0.	26.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(28)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(29)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(30)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(31)	89.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(32)	92.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(33)	35.	1.	33.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(34)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(35)	92.	0.	0.	0.	0.	0.	7.	0.	0.	0.	0.	0.	0.	0.	0.
(36)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(37)	89.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(38)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(39)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	86.	0.	0.	0.	0.	0.	0.	10.	0.	0.	0.	0.	0.	0.	0.
(42)	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(43)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	94.	1.	0.	0.	0.	30.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(45)	77.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	34.	0.	0.
(46)	89.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	8.	0.	0.	0.
(47)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(48)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(49)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(27)	88.	0.	0.												
(28)	90.	0.	0.	0.											
(29)	90.	1.	0.	0.	27.										
(30)	92.	1.	0.	0.	0.	0.									
(31)	89.	1.	0.	0.	0.	0.	0.								
(32)	92.	0.	0.	0.	0.	0.	0.	0.							
(33)	35.	1.	0.	0.	0.	0.	0.	0.	0.						
(34)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.					
(35)	92.	0.	0.	0.	0.	0.	0.	0.	5.	0.	0.				
(36)	86.	1.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(37)	89.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(38)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(39)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	88.	1.	0.	31.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	86.	0.	3.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(42)	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(43)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	94.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(45)	77.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(46)	89.	0.	0.	0.	0.	0.	0.	16.	0.	0.	0.	0.	0.	0.	0.
(47)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(48)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(49)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(40)	88.	1.	0.										
(41)	86.	0.	0.	0.									
(42)	86.	0.	1.	0.	0.								
(43)	86.	1.	0.	0.	0.	2.							
(44)	94.	1.	0.	0.	0.	0.	0.						
(45)	77.	0.	0.	0.	0.	0.	0.	0.					
(46)	89.	0.	0.	0.	0.	0.	0.	0.	0.				
(47)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.			
(48)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(49)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(50)	77.	1.	0.	0.	0.	0.	0.	0.	35.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATICN	6.	8.	3.	5.	2.	6.	2.	8.	99999.
NUMBER ALLOCATED	6.	7.	1.	0.	0.	0.	1.	0.	0.

TCTAL DISTANCE FCR SYSTEM 30223.00

* * * * * * * * * *

PROBLEM TWO

DEMAND POINT	QUANTITY REQUIRED	DEMAND POINT	QUANTITY REQUIRED
1	15	26	18
2	28	27	36
3	16	28	35
4	38	29	24
5	40	30	17
6	25	31	23
7	34	32	21
8	16	33	22
9	24	34	32
10	28	35	34
11	36	36	18
12	18	37	19
13	34	38	37
14	28	39	16
15	18	40	24
16	38	41	20
17	16	42	40
18	18	43	26
19	25	44	15
20	30	45	26
21	24	46	34
22	28	47	18
23	15	48	26
24	36	49	23
25	27	50	17

TRUCKS

CAPACITY	NUMBER
100	5
90	6
80	3
70	4
60	2
50	5
40	3
30	6
20	2

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=2.

PROBLEM OF 1 TERMINALS WITH 50 DEMAND POINTS

DISTANCE MATRIX

(1)	105.														
(2)	230.	331.													
(3)	742.	702.	787.												
(4)	1309.	1214.	1535.	1504.											
(5)	598.	653.	399.	1185.	1823.										
(6)	217.	207.	345.	902.	1377.	449.									
(7)	1424.	1338.	1656.	1354.	583.	1943.	1496.								
(8)	461.	366.	687.	656.	850.	975.	540.	969.							
(9)	284.	230.	494.	476.	1143.	876.	430.	1182.	293.						
(10)	134.	33.	351.	716.	1191.	632.	191.	1310.	343.	244.					
(11)	191.	123.	408.	579.	1207.	769.	323.	1239.	315.	107.	137.				
(12)	1232.	1173.	1458.	653.	1175.	1819.	1373.	875.	936.	943.	1187.	1050.			
(13)	1482.	1385.	1701.	1282.	685.	1989.	1543.	102.	1016.	1169.	1357.	1233.	784.		
(14)	805.	707.	1025.	808.	672.	1311.	865.	632.	338.	571.	679.	695.	704.	679.	
(15)	285.	190.	511.	741.	1123.	699.	252.	1238.	271.	265.	167.	202.	1188.	1284.	606.
(16)	508.	454.	718.	364.	1143.	1100.	654.	1069.	296.	224.	468.	331.	734.	1027.	502.
(17)	330.	233.	556.	582.	1024.	844.	398.	1105.	158.	154.	212.	152.	999.	1156.	478.
(18)	197.	301.	80.	812.	1505.	398.	294.	1620.	657.	472.	321.	368.	1418.	1666.	988.
(19)	1937.	1842.	2163.	1963.	628.	2451.	2005.	700.	1478.	1770.	1819.	1835.	1571.	792.	1162.
(20)	1319.	1270.	1449.	662.	1417.	1916.	1470.	1117.	1085.	1040.	1284.	1147.	245.	1026.	946.
(21)	354.	295.	580.	480.	1035.	941.	495.	1074.	186.	108.	309.	172.	882.	1061.	483.
(22)	934.	892.	1035.	248.	1479.	1433.	1092.	1282.	764.	662.	906.	769.	403.	1191.	828.
(23)	865.	919.	793.	426.	1857.	1191.	1067.	1770.	1009.	775.	952.	854.	994.	1708.	1208.
(24)	721.	662.	931.	567.	930.	1308.	901.	793.	391.	468.	715.	539.	565.	750.	272.
(25)	937.	779.	1099.	706.	783.	1456.	1010.	648.	499.	590.	824.	656.	499.	604.	201.
(26)	348.	253.	575.	713.	1063.	785.	338.	1178.	215.	326.	230.	252.	1128.	1224.	546.
(27)	897.	848.	1086.	386.	1188.	1494.	1048.	1040.	644.	618.	862.	725.	325.	957.	573.
(28)	2533.	2368.	2695.	2056.	1649.	3052.	2606.	1169.	2095.	2186.	2420.	2245.	1403.	1134.	1801.

(29)	394.	340.	604.	366.	1146.	986.	540.	1162.	301.	113.	354.	217.	833.	1120.	569.
(30)	758.	709.	947.	247.	1266.	1355.	909.	1107.	544.	502.	723.	586.	464.	1035.	608.
(31)	550.	455.	776.	745.	764.	1064.	618.	988.	89.	384.	432.	448.	1015.	1040.	361.
(32)	871.	776.	1097.	1066.	430.	1385.	939.	794.	412.	705.	753.	769.	956.	841.	252.
(33)	559.	519.	725.	187.	1299.	1165.	719.	1200.	451.	290.	533.	396.	686.	1158.	638.
(34)	1093.	1049.	1138.	351.	1604.	1536.	1253.	1373.	944.	820.	1063.	926.	498.	1282.	989.
(35)	386.	487.	187.	974.	1691.	216.	445.	1806.	738.	659.	507.	557.	1607.	1851.	1173.
(36)	942.	845.	1163.	911.	581.	1449.	1003.	493.	476.	691.	817.	748.	656.	540.	145.
(37)	588.	448.	818.	611.	857.	1107.	661.	864.	151.	321.	475.	376.	815.	900.	252.
(38)	305.	406.	97.	884.	1610.	304.	365.	1725.	775.	578.	426.	476.	1526.	1770.	1092.
(39)	2163.	2003.	2325.	1658.	1501.	2682.	2236.	918.	1722.	1816.	2050.	1882.	1005.	818.	1430.
(40)	2571.	2476.	2797.	2552.	1262.	3085.	2639.	1198.	2112.	2405.	2453.	2469.	2043.	1278.	1819.
(41)	591.	532.	817.	476.	980.	1178.	802.	898.	288.	338.	546.	409.	645.	856.	336.
(42)	2648.	2541.	2876.	2393.	1633.	3163.	2716.	1220.	2189.	2402.	2530.	2459.	1806.	1270.	1851.
(43)	2522.	2427.	2748.	2575.	1213.	3036.	2590.	1267.	2063.	2356.	2404.	2420.	2112.	1347.	1773.
(44)	2333.	2138.	2459.	2286.	924.	2747.	2301.	1022.	1774.	2067.	2115.	2131.	1891.	1112.	1484.
(45)	628.	487.	854.	541.	912.	1147.	701.	895.	193.	300.	515.	364.	746.	869.	290.
(46)	811.	752.	1037.	530.	959.	1468.	1022.	824.	511.	558.	766.	629.	425.	752.	344.
(47)	1046.	1097.	981.	541.	2010.	1379.	1248.	1886.	1162.	928.	1122.	985.	1077.	1814.	1349.
(48)	228.	133.	454.	683.	1089.	742.	296.	1204.	239.	207.	110.	132.	1154.	1250.	572.
(49)	245.	331.	39.	748.	1535.	437.	359.	1650.	712.	492.	351.	392.	1372.	1696.	1018.
(50)	1135.	975.	1297.	776.	791.	1654.	1208.	590.	697.	788.	1022.	852.	384.	507.	403.

DISTANCE MATRIX

(16)	444.														
(17)	160.	284.													
(18)	481.	697.	526.												
(19)	1751.	1772.	1652.	2133.											
(20)	1337.	834.	1114.	1474.	1813.										
(21)	277.	167.	121.	540.	1663.	997.									
(22)	927.	468.	748.	1060.	1922.	429.	631.								
(23)	996.	729.	924.	855.	2370.	911.	822.	589.							
(24)	642.	301.	476.	904.	1405.	780.	367.	549.	956.						
(25)	751.	423.	585.	1132.	1261.	741.	484.	661.	1123.	146.					
(26)	86.	415.	131.	544.	1691.	1245.	248.	879.	1101.	582.	691.				
(27)	896.	409.	679.	1094.	1666.	445.	562.	256.	812.	354.	405.	836.			
(28)	2347.	2029.	2181.	2729.	1234.	1553.	2080.	1810.	2397.	1742.	1596.	2287.	1701.		
(29)	375.	125.	216.	582.	1777.	930.	114.	552.	708.	394.	516.	347.	508.	2107.	
(30)	713.	273.	553.	953.	1720.	561.	436.	210.	673.	336.	459.	684.	137.	1831.	389.
(31)	364.	374.	265.	746.	1392.	1174.	276.	844.	1098.	469.	580.	304.	723.	2176.	390.
(32)	685.	706.	586.	1067.	1056.	1198.	597.	1060.	1419.	509.	457.	625.	825.	1940.	711.
(33)	555.	159.	396.	762.	1800.	783.	294.	375.	570.	423.	554.	527.	346.	2058.	180.
(34)	1085.	642.	926.	1163.	2070.	359.	805.	181.	582.	730.	821.	1053.	416.	1901.	710.
(35)	667.	888.	712.	186.	2319.	1636.	729.	1222.	980.	1096.	1319.	729.	1282.	2915.	769.
(36)	744.	622.	616.	1127.	1056.	898.	583.	866.	1326.	349.	205.	685.	610.	1662.	689.
(37)	402.	258.	251.	783.	1414.	964.	213.	669.	976.	250.	350.	344.	523.	1946.	323.
(38)	586.	807.	631.	105.	2238.	1546.	648.	1132.	890.	1015.	1238.	649.	1201.	2721.	688.
(39)	1977.	1664.	1811.	2358.	1147.	1153.	1710.	1412.	1999.	1372.	1226.	1917.	1330.	398.	1757.
(40)	2385.	2267.	2286.	2767.	657.	2233.	2297.	2450.	2968.	1991.	1846.	2325.	2234.	970.	2412.
(41)	543.	172.	354.	777.	1498.	794.	234.	514.	872.	130.	253.	483.	353.	1848.	264.
(42)	2458.	2297.	2329.	2839.	1134.	1955.	2294.	2212.	2799.	2014.	1874.	2399.	2027.	403.	2390.
(43)	2336.	2357.	2237.	2718.	611.	2302.	2245.	2519.	3070.	2016.	1872.	2276.	2277.	1145.	2362.
(44)	2047.	2068.	1948.	2429.	322.	2138.	1956.	2244.	2781.	1727.	1583.	1987.	1988.	1227.	2073.

(45)	442.	211.	276.	823.	1452.	895.	192.	598.	925.	200.	309.	382.	454.	1905.	279.
(46)	763.	391.	574.	997.	1437.	640.	457.	503.	956.	144.	176.	703.	229.	1637.	484.
(47)	1193.	873.	1077.	1036.	2499.	984.	975.	672.	198.	1108.	1238.	1254.	912.	2480.	861.
(48)	61.	388.	110.	424.	1717.	1247.	221.	869.	939.	608.	717.	119.	783.	2313.	317.
(49)	511.	716.	556.	119.	2163.	1410.	564.	996.	754.	931.	1048.	574.	1047.	2644.	596.
(50)	949.	621.	783.	1330.	1241.	612.	682.	733.	1202.	344.	195.	889.	473.	1402.	714.

DISTANCE MATRIX

(31)	624.														
(32)	840.	326.													
(33)	209.	540.	861.												
(34)	397.	1013.	1241.	530.											
(35)	1138.	932.	1253.	949.	1325.										
(36)	664.	500.	358.	756.	1026.	1312.									
(37)	449.	226.	423.	406.	850.	970.	372.								
(38)	1057.	851.	1172.	868.	1235.	93.	1230.	889.							
(39)	1466.	1896.	1630.	1725.	1503.	2459.	1335.	1576.	2464.						
(40)	2305.	2026.	1690.	2398.	2541.	2953.	1691.	2062.	2872.	1366.					
(41)	294.	370.	546.	302.	695.	966.	454.	170.	885.	1478.	2096.				
(42)	2157.	2213.	1997.	2410.	2303.	3025.	1713.	2084.	2944.	800.	652.	2126.			
(43)	2331.	1977.	1641.	2512.	2610.	2904.	1667.	2070.	2823.	1541.	175.	2109.	827.		
(44)	2042.	1688.	1352.	2223.	2392.	2615.	1378.	1781.	2534.	1369.	360.	1820.	915.	289.	
(45)	383.	269.	478.	355.	779.	1010.	410.	70.	929.	1535.	2093.	95.	2115.	2063.	1774.
(46)	283.	590.	596.	452.	645.	1186.	381.	390.	1105.	1273.	2022.	220.	1958.	2048.	1759.
(47)	779.	1251.	1572.	714.	653.	1167.	1443.	1120.	1078.	2082.	3084.	1016.	2882.	3110.	2821.
(48)	686.	330.	651.	497.	1027.	610.	710.	368.	529.	1943.	2351.	509.	2428.	2302.	2013.
(49)	908.	776.	1097.	686.	1099.	229.	1156.	814.	136.	2274.	2797.	801.	2869.	2748.	2459.
(50)	529.	778.	655.	698.	833.	1517.	303.	548.	1436.	1032.	1784.	450.	1721.	1852.	1563.

DISTANCE MATRIX

(46)	321.				
(47)	1069.	1062.			
(48)	408.	729.	1135.		
(49)	854.	1021.	942.	454.	
(50)	507.	246.	1308.	915.	1246.

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE -- 1 --11 -- 9 --

TOTAL DISTANCE OF ROUTE IS 619.00

QUANTITY REQUIRED ON ROUTE IS 75.00 CAPACITY OF TRUCK IS 80.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE -- 3 --22 --27 --30 --

TOTAL DISTANCE OF ROUTE IS 2141.00

QUANTITY REQUIRED ON ROUTE IS 97.00 CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE -- 5 --35 --

TOTAL DISTANCE OF ROUTE IS 1200.00

QUANTITY REQUIRED ON ROUTE IS 74.00 CAPACITY OF TRUCK IS 80.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE -- 6 --18 --

TOTAL DISTANCE OF ROUTE IS 708.00

QUANTITY REQUIRED ON ROUTE IS 43.00 CAPACITY OF TRUCK IS 50.00

* * * * * * * * * *

```
* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 7 --13 --36 --

   TOTAL DISTANCE OF ROUTE IS    3008.00

   QUANTITY REQUIRED ON ROUTE IS  86.00  CAPACITY OF TRUCK IS  90.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 8 --31 -- 4 --32 --

   TOTAL DISTANCE OF ROUTE IS    2615.00

   QUANTITY REQUIRED ON ROUTE IS  98.00  CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --10 --15 --26 --48 --

   TOTAL DISTANCE OF ROUTE IS     734.00

   QUANTITY REQUIRED ON ROUTE IS  90.00  CAPACITY OF TRUCK IS  90.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --14 --25 --46 --

   TOTAL DISTANCE OF ROUTE IS    1993.00

   QUANTITY REQUIRED ON ROUTE IS  89.00  CAPACITY OF TRUCK IS  90.00

* * * * * * * * * *
```

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE --16 --24 --41 --

TOTAL DISTANCE OF ROUTE IS 1530.00

QUANTITY REQUIRED ON ROUTE IS 94.00 CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE --17 --37 --45 --21 --

TOTAL DISTANCE OF ROUTE IS 1197.00

QUANTITY REQUIRED ON ROUTE IS 85.00 CAPACITY OF TRUCK IS 90.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE --19 --44 --43 --40 --

TOTAL DISTANCE OF ROUTE IS 5294.00

QUANTITY REQUIRED ON ROUTE IS 90.00 CAPACITY OF TRUCK IS 90.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE --23 --47 --33 --29 --

TOTAL DISTANCE OF ROUTE IS 2351.00

QUANTITY REQUIRED ON ROUTE IS 79.00 CAPACITY OF TRUCK IS 80.00

* * * * * * * * * *

```
* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --34 --20 --12 --50 --

   TOTAL DISTANCE OF ROUTE IS   3216.00

   QUANTITY REQUIRED ON ROUTE IS  97.00  CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --38 -- 2 --49 --

   TOTAL DISTANCE OF ROUTE IS    686.00

   QUANTITY REQUIRED ON ROUTE IS  88.00  CAPACITY OF TRUCK IS  90.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --39 --28 --42 --

   TOTAL DISTANCE OF ROUTE IS   5612.00

   QUANTITY REQUIRED ON ROUTE IS  91.00  CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *
```

ROUTE MATRIX

	DEMAND													
(1)	75.	1.												
(2)	88.	0.	0.											
(3)	97.	1.	0.	0.										
(4)	98.	0.	0.	0.	0.									
(5)	74.	1.	0.	0.	0.	0.								
(6)	43.	1.	0.	0.	0.	0.	0.							
(7)	86.	1.	0.	0.	0.	0.	0.	0.						
(8)	98.	1.	0.	0.	0.	0.	0.	0.	0.					
(9)	75.	1.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(11)	75.	0.	34.	0.	0.	0.	0.	0.	0.	0.	32.	0.		
(12)	97.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	86.	0.	0.	0.	0.	0.	0.	0.	6.	0.	0.	0.	0.	0.
(14)	89.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(15)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	33.	0.	0.
(16)	94.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(17)	85.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(18)	43.	1.	0.	0.	0.	0.	0.	35.	0.	0.	0.	0.	0.	0.
(19)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(20)	97.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.
(21)	85.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(22)	97.	0.	0.	0.	17.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(23)	79.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	94.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	89.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(26)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(27)	97.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(28)	91.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(29)	79.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(30)	97.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(31)	98.	0.	0.	0.	0.	20.	0.	0.	0.	22.	0.	0.	0.	0.
(32)	98.	1.	0.	0.	0.	11.	0.	0.	0.	0.	0.	0.	0.	0.
(33)	79.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(34)	97.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(35)	74.	1.	0.	0.	0.	0.	26.	0.	0.	0.	0.	0.	0.	0.
(36)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(37)	85.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(38)	88.	1.	0.	30.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(39)	91.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	94.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(42)	91.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(43)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(45)	85.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(46)	89.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(47)	79.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(48)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(49)	88.	1.	0.	31.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	97.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.

ROUTE MATRIX

(14)	89.	1.	0.												
(15)	90.	0.	0.	0.											
(16)	94.	1.	0.	0.	0.										
(17)	85.	1.	0.	0.	0.	0.									
(18)	43.	1.	0.	0.	0.	0.	0.								
(19)	90.	1.	0.	0.	0.	0.	0.	0.							
(20)	97.	0.	0.	0.	0.	0.	0.	0.	0.						
(21)	85.	1.	0.	0.	0.	0.	0.	0.	0.	0.					
(22)	97.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(23)	79.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(24)	94.	0.	0.	0.	0.	21.	0.	0.	0.	0.	0.	0.	0.		
(25)	89.	0.	0.	15.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(26)	90.	0.	0.	0.	28.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(27)	97.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	13.	0.	0.	0.
(28)	91.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(29)	79.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(30)	97.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(31)	98.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(32)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(33)	79.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(34)	97.	1.	0.	0.	0.	0.	0.	0.	0.	8.	0.	0.	0.	0.	0.
(35)	74.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(36)	86.	1.	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(37)	85.	0.	0.	0.	0.	0.	27.	0.	0.	0.	0.	0.	0.	0.	0.
(38)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(39)	91.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	94.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	18.	0.
(42)	91.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(43)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	90.	0.	0.	0.	0.	0.	0.	5.	0.	0.	0.	0.	0.	0.	0.
(45)	85.	0.	0.	0.	0.	0.	0.	0.	0.	24.	0.	0.	0.	0.	0.
(46)	89.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	14.
(47)	79.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	12.	0.	0.
(48)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(49)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	97.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(27)	97.	0.	0.												
(28)	91.	0.	0.	0.											
(29)	79.	1.	0.	0.	0.										
(30)	97.	1.	0.	16.	0.	0.									
(31)	98.	0.	0.	0.	0.	0.	0.								
(32)	98.	1.	0.	0.	0.	0.	0.	0.							
(33)	79.	0.	0.	0.	0.	25.	0.	0.	0.						
(34)	97.	1.	0.	0.	0.	0.	0.	0.	0.	0.					
(35)	74.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(36)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(37)	85.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(38)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(39)	91.	1.	0.	0.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	94.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(42)	91.	1.	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(43)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(45)	85.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	19.	0.
(46)	89.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(47)	79.	0.	0.	0.	0.	0.	0.	0.	0.	23.	0.	0.	0.	0.	0.
(48)	90.	1.	29.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(49)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	97.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(40)	90.	1.	0.										
(41)	94.	1.	0.	0.									
(42)	91.	1.	0.	0.	0.								
(43)	90.	0.	0.	1.	0.	0.							
(44)	90.	0.	0.	0.	0.	0.	3.						
(45)	85.	0.	0.	0.	0.	0.	0.	0.					
(46)	89.	1.	0.	0.	0.	0.	0.	0.	0.				
(47)	79.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(48)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(49)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(50)	97.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATION	5.	6.	3.	4.	2.	5.	3.	6.	99999.
NUMBER ALLOCATED	5.	6.	3.	0.	0.	1.	0.	0.	0.

TOTAL DISTANCE FOR SYSTEM 32904.00

* * * * * * * * * *

APPENDIX III

MULTIPLE TERMINAL PROBLEMS

THREE TERMINAL TEN
DEMAND POINT PROBLEMS

PROBLEM ONE

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINALS: TERMINAL 1	TERMINAL 2	TERMINAL 3
1	10	3	8	12
2	4	6	5	12
3	8	5	3	8
4	7	9	2	6
5	12	5	12	14
6	6	3	8	9
7	5	6	3	4
8	10	15	8	6
9	8	7	7	5
10	15	12	7	2

There are three trucks with thirty units capacity available.

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=3.

PROBLEM OF 3 TERMINALS WITH 10 DEMAND POINTS

DISTANCE MATRIX

(1)	3.									
(2)	5.	6.								
(3)	3.	5.	3.							
(4)	2.	10.	7.	5.						
(5)	5.	7.	11.	10.	14.					
(6)	3.	6.	8.	6.	10.	5.				
(7)	3.	8.	7.	4.	4.	10.	6.			
(8)	6.	16.	13.	11.	6.	19.	14.	9.		
(9)	5.	9.	10.	7.	8.	8.	4.	4.	11.	
(10)	2.	13.	12.	9.	7.	14.	9.	6.	7.	6.

```
* * * * * * * * * *
   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 2 -- 3 -- 7 -- 4 --
   TOTAL DISTANCE OF ROUTE IS      18.00
   QUANTITY REQUIRED ON ROUTE IS  24.00  CAPACITY OF TRUCK IS  30.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 5 -- 9 -- 6 --
   TOTAL DISTANCE OF ROUTE IS      20.00
   QUANTITY REQUIRED ON ROUTE IS  26.00  CAPACITY OF TRUCK IS  30.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 3  DEMAND POINTS ROUTED ARE -- 8 --10 --
   TOTAL DISTANCE OF ROUTE IS      15.00
   QUANTITY REQUIRED ON ROUTE IS  25.00  CAPACITY OF TRUCK IS  30.00
* * * * * * * * * *
```

ROUTE MATRIX

	DEMAND										
(1)	10.	2.									
(2)	24.	1.	0.								
(3)	24.	0.	0.	1.							
(4)	24.	1.	0.	0.	0.						
(5)	26.	1.	0.	0.	0.	0.					
(6)	26.	1.	0.	0.	0.	0.	0.				
(7)	24.	0.	0.	0.	2.	5.	0.	0.			
(8)	25.	1.	0.	0.	0.	0.	0.	0.	0.		
(9)	26.	0.	0.	0.	0.	0.	4.	3.	0.	0.	
(10)	25.	1.	0.	0.	0.	0.	0.	0.	0.	6.	0.

TRUCK ALLOCATION

TRUCK CAPACITY 30.

ASSUMED ALLOCATION 99999.

NUMBER ALLOCATED 3.

TOTAL DISTANCE FOR SYSTEM 59.00

* * * * * * * * * *

PROBLEM TWO

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINALS TERMINAL 1	TERMINAL 2	TERMINAL 3
1	12	315	409	107
2	5	388	336	571
3	8	296	172	224
4	15	158	354	154
5	6	186	234	108
6	7	391	130	468
7	14	301	264	113
8	4	151	170	321
9	13	193	95	300
10	8	239	509	207

There are one truck with forty units of capacity, three trucks with thirty units of capacity, and two trucks with twenty units of capacity assumed available.

The best solution shown below was obtained with the minimum computation time using Tillman's method (IDEPTH=1).

PROBLEM OF 3 TERMINALS WITH 10 DEMAND POINTS

DISTANCE MATRIX

(1)	107.									
(2)	336.	695.								
(3)	172.	331.	502.							
(4)	154.	152.	478.	284.						
(5)	108.	172.	483.	167.	121.					
(6)	130.	539.	272.	301.	476.	367.				
(7)	113.	217.	569.	125.	216.	114.	394.			
(8)	151.	376.	252.	258.	251.	213.	250.	323.		
(9)	95.	364.	290.	211.	276.	192.	200.	279.	70.	
(10)	207.	132.	572.	388.	110.	221.	608.	317.	368.	408.

```
*  *  *  *  *  *  *  *  *  *
   TERMINAL 3  DEMAND POINTS ROUTED ARE -- 1 --10 -- 4 --
   TOTAL DISTANCE OF ROUTE IS    503.00
   QUANTITY REQUIRED ON ROUTE IS  35.00  CAPACITY OF TRUCK IS  40.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 3  DEMAND POINTS ROUTED ARE -- 5 -- 3 -- 7 --
   TOTAL DISTANCE OF ROUTE IS    513.00
   QUANTITY REQUIRED ON ROUTE IS  28.00  CAPACITY OF TRUCK IS  30.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 6 -- 2 -- 8 -- 9 --
   TOTAL DISTANCE OF ROUTE IS    819.00
   QUANTITY REQUIRED ON ROUTE IS  29.00  CAPACITY OF TRUCK IS  30.00
*  *  *  *  *  *  *  *  *  *
```

RCUTE MATRIX

	DEMAND										
(1)	35.	1.									
(2)	29.	0.	0.								
(3)	28.	0.	0.	0.							
(4)	35.	1.	0.	C.	0.						
(5)	28.	1.	0.	0.	7.	C.					
(6)	29.	1.	0.	4.	0.	0.	0.				
(7)	28.	1.	0.	0.	6.	C.	C.	0.			
(8)	29.	0.	0.	2.	0.	C.	C.	0.	0.		
(9)	29.	1.	0.	0.	0.	0.	C.	0.	0.	3.	
(10)	35.	0.	5.	0.	0.	1.	0.	0.	0.	C.	0.

TRUCK ALLOCATICN

TRUCK CAPACITY	40.	30.	20.
ASSUMED ALLCCATICN	1.	3.	99999.
NUMBER ALLOCATEC	1.	2.	0.

TCTAL DISTANCE FCR SYSTEM 1835.0C

* * * * * * * * * *

PROBLEM THREE

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINALS TERMINAL 1	TERMINAL 2	TERMINAL 3
1	10	499	151	315
2	6	590	321	107
3	8	423	258	331
4	12	585	251	152
5	7	484	213	172
6	5	146	250	539
7	12	516	323	217
8	9	253	170	409
9	11	309	70	364
10	8	176	390	629

There are two trucks with forty units of capacity, two trucks with thirty units of capacity, and one truck with twenty units of capacity assumed available.

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=2.

PROBLEM OF 3 TERMINALS WITH 10 DEMAND POINTS

DISTANCE MATRIX

(1)	151.									
(2)	107.	293.								
(3)	258.	296.	224.							
(4)	152.	158.	154.	284.						
(5)	172.	186.	108.	167.	121.					
(6)	146.	391.	468.	301.	476.	367.				
(7)	217.	301.	113.	125.	216.	114.	394.			
(8)	170.	288.	338.	172.	354.	234.	130.	264.		
(9)	70.	193.	300.	211.	276.	192.	200.	279.	95.	
(10)	176.	511.	558.	391.	574.	457.	144.	484.	220.	321.

```
* * * * * * * * * *
   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 1 -- 4 --
   TOTAL DISTANCE OF ROUTE IS     560.00
   QUANTITY REQUIRED ON ROUTE IS  22.00  CAPACITY OF TRUCK IS  30.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 3  DEMAND POINTS ROUTED ARE -- 2 -- 7 -- 3 -- 5 --
   TOTAL DISTANCE OF ROUTE IS     684.00
   QUANTITY REQUIRED ON ROUTE IS  33.00  CAPACITY OF TRUCK IS  40.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 6 --10 --
   TOTAL DISTANCE OF ROUTE IS     466.00
   QUANTITY REQUIRED ON ROUTE IS  13.00  CAPACITY OF TRUCK IS  20.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 8 -- 9 --
   TOTAL DISTANCE OF ROUTE IS     335.00
   QUANTITY REQUIRED ON ROUTE IS  20.00  CAPACITY OF TRUCK IS  20.00
* * * * * * * * * *
```

ROUTE MATRIX

	DEMAND										
(1)	22.	1.									
(2)	33.	1.	0.								
(3)	33.	0.	0.	0.							
(4)	22.	1.	6.	0.	0.						
(5)	33.	1.	0.	0.	2.	0.					
(6)	13.	1.	0.	0.	0.	0.	0.				
(7)	33.	0.	0.	3.	1.	0.	0.	0.			
(8)	20.	1.	0.	0.	0.	0.	0.	0.	0.		
(9)	20.	1.	0.	0.	0.	0.	0.	0.	0.	5.	
(10)	13.	1.	0.	0.	0.	0.	0.	4.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	40.	30.	20.
ASSUMED ALLOCATION	2.	2.	99999.
NUMBER ALLOCATED	1.	1.	2.

TOTAL DISTANCE FOR SYSTEM 2045.00

* * * * * * * * * *

PROBLEM FOUR

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINALS TERMINAL 1	TERMINAL 2	TERMINAL 3
1	5	366	230	105
2	12	483	194	219
3	8	343	244	134
4	6	315	107	182
5	15	271	265	285
6	9	158	154	330
7	16	186	108	354
8	10	215	326	348
9	7	301	113	394
10	11	239	207	228

There are one truck with fifty units of capacity, one truck with forty units of capacity, two trucks with thirty units of capacity, and one truck with twenty units of capacity assumed available.

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=2. The first solution shown is the solution obtained with Tillman's method (IDEPTH=1).

FROBLEM CF 3 TERMINALS WITH 10 DEMAND PCINTS

CISTANCE MATRIX

(1)	105.									
(2)	194.	232.								
(3)	134.	33.	265.							
(4)	107.	123.	168.	139.						
(5)	265.	190.	370.	167.	202.					
(6)	154.	233.	325.	212.	152.	160.				
(7)	108.	295.	301.	309.	172.	277.	121.			
(8)	215.	253.	428.	230.	252.	86.	131.	248.		
(9)	113.	340.	262.	354.	217.	375.	216.	114.	347.	
(10)	207.	133.	309.	110.	132.	61.	110.	221.	119.	317.

```
*  *  *  *  *  *  *  *  *  *

   TERMINAL 3  DEMAND POINTS ROUTED ARE -- 1 -- 3 --

   TOTAL DISTANCE OF ROUTE IS    272.00

   QUANTITY REQUIRED ON ROUTE IS  13.00  CAPACITY OF TRUCK IS  20.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 2 -- 4 --

   TOTAL DISTANCE OF ROUTE IS    469.00

   QUANTITY REQUIRED ON ROUTE IS  18.00  CAPACITY OF TRUCK IS  20.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 6 -- 8 -- 5 --10 --

   TOTAL DISTANCE OF ROUTE IS    639.00

   QUANTITY REQUIRED ON ROUTE IS  45.00  CAPACITY OF TRUCK IS  50.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 7 -- 9 --

   TOTAL DISTANCE OF ROUTE IS    335.00

   QUANTITY REQUIRED ON ROUTE IS  23.00  CAPACITY OF TRUCK IS  30.00

*  *  *  *  *  *  *  *  *  *
```

RCUTE MATRIX

	DEMAND										
(1)	13.	1.									
(2)	18.	1.	0.								
(3)	13.	1.	4.	0.							
(4)	18.	1.	0.	5.	0.						
(5)	45.	0.	0.	0.	0.	0.					
(6)	45.	1.	0.	0.	0.	0.	0.				
(7)	23.	1.	0.	0.	0.	0.	0.	0.			
(8)	45.	0.	0.	0.	0.	0.	2.	3.	0.		
(9)	23.	1.	0.	0.	0.	0.	0.	0.	6.	0.	
(10)	45.	1.	0.	0.	0.	0.	1.	0.	0.	0.	0.

TRUCK ALLOCATICN

TRUCK CAPACITY	50.	40.	30.	20.
ASSUMED ALLOCATICN	1.	1.	2.	99999.
NUMBER ALLOCATEC	1.	0.	1.	2.

TCTAL CISTANCE FCR SYSTEM 1715.00

* * * * * * * * * *

```
* * * * * * * * * *

   TERMINAL 3  DEMAND POINTS ROUTED ARE -- 1 -- 3 --

   TOTAL DISTANCE OF ROUTE IS     272.00

   QUANTITY REQUIRED ON ROUTE IS  13.00  CAPACITY OF TRUCK IS  20.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 2 -- 4 --

   TOTAL DISTANCE OF ROUTE IS     469.00

   QUANTITY REQUIRED ON ROUTE IS  18.00  CAPACITY OF TRUCK IS  20.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 6 --10 -- 5 -- 8 --

   TOTAL DISTANCE OF ROUTE IS     630.00

   QUANTITY REQUIRED ON ROUTE IS  45.00  CAPACITY OF TRUCK IS  50.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 7 -- 9 --

   TOTAL DISTANCE OF ROUTE IS     335.00

   QUANTITY REQUIRED ON ROUTE IS  23.00  CAPACITY OF TRUCK IS  30.00

* * * * * * * * * *
```

RCUTE MATRIX

	CEMAND										
(1)	13.	1.									
(2)	18.	1.	0.								
(3)	13.	1.	4.	0.							
(4)	18.	1.	0.	5.	0.						
(5)	45.	0.	0.	0.	0.	0.					
(6)	45.	1.	0.	0.	0.	0.	0.				
(7)	23.	1.	0.	0.	0.	0.	0.	0.			
(8)	45.	1.	0.	0.	0.	0.	1.	0.	0.		
(9)	23.	1.	0.	0.	0.	0.	0.	0.	6.	0.	
(10)	45.	0.	0.	0.	0.	0.	2.	3.	0.	0.	0.

TRUCK ALLOCATION

TRLCK CAPACITY	50.	40.	30.	20.
ASSUMEC ALLOCATICN	1.	1.	2.	99999.
NUMBER ALLOCATEC	1.	0.	1.	2.

TCTAL CISTANCE FCR SYSTEM 1706.00

* * * * * * * * * *

PROBLEM FIVE

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINALS TERMINAL 1	TERMINAL 2	TERMINAL 3
1	20	810	558	432
2	15	706	476	366
3	8	499	645	833
4	16	661	514	552
5	7	405	353	508
6	9	459	294	389
7	17	554	302	180
8	10	176	220	484
9	14	258	404	668
10	5	195	450	714

There are two trucks with fifty units of capacity, two trucks with forty units of capacity, two trucks with thirty units of capacity, and one truck with twenty units of capacity assumed available.

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=2.

PROBLEM OF 3 TERMINALS WITH 10 DEMAND POINTS

CISTANCE MATRIX

(1)	432.									
(2)	366.	154.								
(3)	499.	805.	653.							
(4)	514.	400.	248.	403.						
(5)	353.	505.	386.	325.	256.					
(6)	294.	366.	247.	464.	210.	137.				
(7)	180.	252.	187.	686.	375.	346.	209.			
(8)	176.	649.	530.	425.	503.	229.	283.	452.		
(9)	258.	783.	664.	271.	543.	287.	417.	634.	182.	
(10)	195.	895.	776.	384.	733.	473.	529.	698.	246.	186.

```
*  *  *  *  *  *  *  *  *  *
   TERMINAL 3  DEMAND POINTS ROUTED ARE -- 1 -- 2 --
   TOTAL DISTANCE OF ROUTE IS    952.00
   QUANTITY REQUIRED ON ROUTE IS  35.00  CAPACITY OF TRUCK IS  40.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 5 -- 4 -- 6 -- 7 --
   TOTAL DISTANCE OF ROUTE IS   1330.00
   QUANTITY REQUIRED ON ROUTE IS  49.00  CAPACITY OF TRUCK IS  50.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 8 -- 9 -- 3 --10 --
   TOTAL DISTANCE OF ROUTE IS   1208.00
   QUANTITY REQUIRED ON ROUTE IS  37.00  CAPACITY OF TRUCK IS  40.00
*  *  *  *  *  *  *  *  *  *
```

RCUTE MATRIX

	DEMAND										
(1)	35.	1.									
(2)	35.	1.	1.								
(3)	37.	0.	0.	0.							
(4)	49.	0.	0.	0.	0.						
(5)	49.	1.	0.	0.	0.	2.					
(6)	49.	0.	0.	0.	0.	3.	0.				
(7)	49.	1.	0.	0.	0.	0.	0.	7.			
(8)	37.	1.	0.	0.	0.	0.	0.	0.	0.		
(9)	37.	0.	0.	0.	4.	0.	0.	0.	0.	6.	
(10)	37.	1.	0.	0.	5.	0.	0.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	50.	40.	30.	20.
ASSUMED ALLOCATICN	2.	2.	2.	99999.
NUMBER ALLOCATEC	2.	1.	0.	0.

TCTAL DISTANCE FOR SYSTEM 3490.00

* * * * * * * * * *

FIVE TERMINAL TWENTY-FIVE
DEMAND POINT PROBLEMS

PROBLEM ONE

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINALS TERMINAL 1	TERMINAL 2	TERMINAL 3	TERMINAL 4	TERMINAL 5
1	18	706	656	884	386	154
2	26	785	468	510	750	497
3	38	590	293	578	618	461
4	40	824	343	426	862	686
5	27	1001	785	605	720	215
6	16	656	315	476	725	549
7	29	499	936	1526	325	805
8	30	201	338	1092	573	894
9	32	423	296	807	409	415
10	27	585	158	631	679	610
11	18	484	186	648	562	508
12	38	661	764	1132	256	400
13	22	146	391	1015	354	668
14	16	516	301	688	508	432
15	35	459	544	1057	137	366
16	26	554	451	868	346	252
17	18	821	944	1235	416	493
18	24	205	476	1230	610	1012
19	30	350	151	889	523	662
20	28	253	288	885	353	558
21	17	309	193	929	454	611
22	15	176	511	1105	229	649
23	20	717	239	529	783	668
24	18	258	693	1289	287	783
25	25	195	697	1436	1453	895

TRUCKS CAPACITY	NUMBER
100	3
90	4
80	2
70	5
60	1
50	6
40	2
30	8
20	2

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=2.

PROBLEM OF 5 TERMINALS WITH 25 DEMAND POINTS

DISTANCE MATRIX

(1)	154.														
(2)	468.	574.													
(3)	293.	476.	197.												
(4)	343.	716.	268.	244.											
(5)	215.	367.	388.	517.	655.										
(6)	315.	579.	168.	107.	139.	557.									
(7)	325.	653.	1075.	943.	1187.	1020.	1050.								
(8)	201.	808.	785.	571.	679.	1064.	695.	704.							
(9)	296.	364.	394.	224.	468.	586.	331.	734.	502.						
(10)	158.	582.	307.	154.	212.	671.	152.	999.	478.	284.					
(11)	186.	480.	301.	108.	309.	601.	172.	882.	483.	167.	121.				
(12)	256.	248.	786.	662.	906.	615.	769.	403.	828.	468.	748.	631.			
(13)	146.	567.	663.	468.	715.	870.	539.	565.	272.	301.	476.	367.	556.		
(14)	301.	366.	262.	113.	354.	499.	217.	833.	569.	125.	216.	114.	552.	394.	
(15)	137.	247.	611.	502.	723.	581.	586.	464.	608.	273.	553.	436.	210.	336.	389.
(16)	252.	187.	411.	290.	533.	457.	396.	686.	638.	159.	396.	294.	375.	423.	180.
(17)	416.	351.	925.	820.	1063.	697.	926.	498.	989.	642.	926.	805.	181.	730.	710.
(18)	205.	911.	885.	691.	817.	1184.	748.	656.	145.	622.	616.	583.	866.	349.	689.
(19)	151.	611.	513.	321.	475.	812.	376.	815.	252.	258.	251.	213.	669.	250.	323.
(20)	253.	476.	533.	338.	546.	749.	409.	645.	336.	172.	354.	234.	514.	130.	264.
(21)	193.	541.	497.	300.	515.	778.	364.	746.	290.	211.	276.	192.	598.	200.	279.
(22)	176.	530.	753.	558.	766.	864.	629.	425.	344.	391.	574.	457.	503.	144.	484.
(23)	239.	683.	301.	207.	110.	689.	132.	1154.	572.	388.	110.	221.	869.	608.	317.
(24)	258.	664.	935.	740.	948.	998.	811.	271.	471.	573.	756.	641.	543.	324.	668.
(25)	195.	776.	981.	788.	1022.	1100.	852.	384.	403.	621.	783.	682.	733.	344.	714.

CISTANCE MATRIX

(16)	209.									
(17)	397.	530.								
(18)	664.	756.	1026.							
(19)	449.	406.	850.	372.						
(20)	294.	302.	695.	454.	170.					
(21)	383.	355.	779.	410.	70.	95.				
(22)	283.	452.	645.	381.	390.	220.	321.			
(23)	686.	497.	1027.	710.	368.	509.	408.	729.		
(24)	417.	634.	689.	385.	570.	404.	503.	182.	911.	
(25)	529.	698.	833.	303.	548.	450.	507.	246.	915.	186.

```
*  *  *  *  *  *  *  *  *  *

   TERMINAL 5  DEMAND POINTS ROUTED ARE -- 1 --16 -- 5 --

   TOTAL DISTANCE OF ROUTE IS    1013.00

   QUANTITY REQUIRED ON ROUTE IS  71.00  CAPACITY OF TRUCK IS  80.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 6 -- 2 -- 3 --11 --

   TOTAL DISTANCE OF ROUTE IS     974.00

   QUANTITY REQUIRED ON ROUTE IS  98.00  CAPACITY OF TRUCK IS 100.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 4  DEMAND POINTS ROUTED ARE -- 7 --17 --12 --

   TOTAL DISTANCE OF ROUTE IS    1260.00

   QUANTITY REQUIRED ON ROUTE IS  85.00  CAPACITY OF TRUCK IS  90.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 8 --18 --

   TOTAL DISTANCE OF ROUTE IS     551.00

   QUANTITY REQUIRED ON ROUTE IS  54.00  CAPACITY OF TRUCK IS  60.00

*  *  *  *  *  *  *  *  *  *
```

```
* * * * * * * * * *
   TERMINAL 2  DEMAND POINTS ROUTED ARE --10 -- 4 --23 --
   TOTAL DISTANCE OF ROUTE IS    719.00
   QUANTITY REQUIRED ON ROUTE IS  87.00  CAPACITY OF TRUCK IS  90.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --13 --22 --24 --25 --
   TOTAL DISTANCE OF ROUTE IS    853.00
   QUANTITY REQUIRED ON ROUTE IS  80.00  CAPACITY OF TRUCK IS  80.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 2  DEMAND POINTS ROUTED ARE --14 -- 9 --20 --21 --
   TOTAL DISTANCE OF ROUTE IS    886.00
   QUANTITY REQUIRED ON ROUTE IS  93.00  CAPACITY OF TRUCK IS 100.00
* * * * * * * * * *
```

ROUTE MATRIX

	DEMAND													
(1)	71.	1.												
(2)	98.	0.	0.											
(3)	98.	0.	0.	2.										
(4)	87.	0.	0.	0.	0.									
(5)	71.	1.	0.	0.	0.	0.								
(6)	98.	1.	0.	1.	0.	0.	0.							
(7)	85.	1.	0.	0.	0.	0.	0.	0.						
(8)	54.	1.	0.	0.	0.	0.	0.	0.	0.					
(9)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	87.	1.	0.	0.	0.	9.	0.	0.	0.	0.	0.			
(11)	98.	1.	0.	0.	6.	0.	0.	0.	0.	0.	0.	0.		
(12)	85.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	80.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	4.	0.	0.	0.
(15)	35.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(16)	71.	0.	14.	0.	0.	0.	16.	0.	0.	0.	0.	0.	0.	0.
(17)	85.	0.	0.	0.	0.	0.	0.	0.	13.	0.	0.	0.	0.	3.
(18)	54.	1.	0.	0.	0.	0.	0.	0.	0.	11.	0.	0.	0.	0.
(19)	30.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(20)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.	0.	0.	0.
(21)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(22)	80.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(23)	87.	1.	0.	0.	0.	5.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	80.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	80.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(14)	93.	1.	0.											
(15)	35.	2.	0.	0.										
(16)	71.	0.	0.	0.	0.									
(17)	85.	0.	0.	0.	0.	0.								
(18)	54.	1.	0.	0.	0.	0.	0.							
(19)	30.	2.	0.	0.	0.	0.	0.	0.						
(20)	93.	0.	0.	0.	0.	0.	0.	0.	0.					
(21)	93.	1.	0.	0.	0.	0.	0.	0.	0.	8.				
(22)	80.	0.	15.	0.	0.	0.	0.	0.	0.	0.	0.			
(23)	87.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(24)	80.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	12.	0.	
(25)	80.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	10.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATION	3.	4.	2.	5.	1.	6.	2.	8.	99999.
NUMBER ALLOCATED	2.	2.	2.	1.	0.	0.	0.	0.	0.

TOTAL DISTANCE FOR SYSTEM 6832.00

* * * * * * * * * *

PROBLEM TWO

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINALS TERMINAL 1	TERMINAL 2	TERMINAL 3	TERMINAL 4	TERMINAL 5
1	16	386	476	656	476	154
2	25	862	546	343	244	686
3	36	720	749	785	517	215
4	20	725	409	315	107	549
5	16	325	645	936	943	805
6	24	573	336	338	571	894
7	38	409	172	296	224	415
8	40	679	354	158	154	610
9	18	445	794	1085	1040	814
10	26	562	234	186	108	508
11	25	256	514	764	662	400
12	30	354	130	391	468	668
13	15	405	253	499	590	810
14	28	508	264	301	113	432
15	19	137	294	544	502	366
16	37	478	572	748	568	173
17	28	346	302	451	290	252
18	18	416	695	944	820	493
19	23	610	454	476	691	1012
20	17	523	170	151	321	662
21	22	897	591	461	284	697
22	20	454	95	193	300	611
23	24	229	220	511	558	649
24	15	783	509	239	207	668
25	24	287	404	693	740	783

TRUCKS CAPACITY	NUMBER
100	4
90	4
80	2
70	2
60	4
50	2
40	2
30	1
20	3

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=2.

PROBLEM OF 5 TERMINALS WITH 25 DEMAND POINTS

DISTANCE MATRIX

(1)	154.														
(2)	244.	716.													
(3)	215.	367.	655.												
(4)	107.	579.	139.	557.											
(5)	325.	653.	1187.	1020.	1050.										
(6)	336.	808.	679.	1064.	695.	704.									
(7)	172.	364.	468.	586.	331.	734.	502.								
(8)	154.	582.	212.	671.	152.	999.	478.	284.							
(9)	445.	662.	1284.	1029.	1147.	245.	946.	834.	1114.						
(10)	108.	480.	309.	601.	172.	882.	483.	167.	121.	997.					
(11)	256.	248.	906.	615.	769.	403.	828.	468.	748.	429.	631.				
(12)	130.	567.	715.	870.	539.	565.	272.	301.	476.	780.	367.	556.			
(13)	253.	706.	824.	1001.	656.	499.	201.	423.	585.	741.	484.	661.	146.		
(14)	113.	366.	354.	499.	217.	833.	569.	125.	216.	930.	114.	552.	394.	516.	
(15)	137.	247.	723.	581.	586.	464.	608.	273.	553.	561.	436.	210.	336.	459.	389.
(16)	173.	94.	793.	378.	656.	650.	900.	456.	674.	659.	572.	245.	659.	798.	458.
(17)	252.	187.	533.	457.	396.	686.	638.	159.	396.	783.	294.	375.	423.	554.	180.
(18)	416.	351.	1063.	697.	926.	498.	989.	642.	926.	359.	805.	181.	730.	821.	716.
(19)	454.	911.	817.	1184.	748.	656.	145.	622.	616.	898.	583.	866.	349.	205.	689.
(20)	151.	611.	475.	812.	376.	815.	252.	258.	251.	964.	213.	669.	250.	350.	323.
(21)	284.	742.	134.	568.	191.	1232.	804.	508.	330.	1319.	354.	934.	721.	937.	394.
(22)	95.	541.	515.	778.	364.	746.	290.	211.	276.	895.	192.	598.	200.	309.	279.
(23)	220.	530.	766.	864.	629.	425.	344.	391.	574.	640.	457.	503.	144.	176.	484.
(24)	207.	683.	110.	689.	132.	1154.	572.	388.	110.	1247.	221.	869.	608.	717.	317.
(25)	287.	664.	948.	998.	811.	271.	471.	573.	756.	513.	641.	543.	324.	258.	668.

DISTANCE MATRIX

(16)	339.									
(17)	209.	297.								
(18)	397.	324.	530.							
(19)	664.	1003.	756.	1026.						
(20)	449.	703.	406.	850.	372.					
(21)	758.	819.	559.	1093.	942.	588.				
(22)	383.	633.	355.	779.	410.	70.	628.			
(23)	283.	622.	452.	645.	381.	390.	811.	321.		
(24)	686.	775.	497.	1027.	710.	368.	228.	408.	729.	
(25)	417.	756.	634.	689.	385.	570.	995.	503.	182.	911.

```
* * * * * * * * * *
    TERMINAL 4  DEMAND POINTS ROUTED ARE -- 4 --21 -- 2 --24 --
    TOTAL DISTANCE OF ROUTE IS    749.00
    QUANTITY REQUIRED ON ROUTE IS  82.00  CAPACITY OF TRUCK IS  90.00
* * * * * * * * * *


* * * * * * * * * *
    TERMINAL 1  DEMAND POINTS ROUTED ARE -- 5 -- 9 --18 --11 --15 --
    TOTAL DISTANCE OF ROUTE IS   1457.00
    QUANTITY REQUIRED ON ROUTE IS  96.00  CAPACITY OF TRUCK IS 100.00
* * * * * * * * * *


* * * * * * * * * *
    TERMINAL 2  DEMAND POINTS ROUTED ARE -- 6 --19 --13 --12 --
    TOTAL DISTANCE OF ROUTE IS    962.00
    QUANTITY REQUIRED ON ROUTE IS  92.00  CAPACITY OF TRUCK IS 100.00
* * * * * * * * * *


* * * * * * * * * *
    TERMINAL 2  DEMAND POINTS ROUTED ARE -- 7 --20 --22 --
    TOTAL DISTANCE OF ROUTE IS    595.00
    QUANTITY REQUIRED ON ROUTE IS  75.00  CAPACITY OF TRUCK IS  80.00
* * * * * * * * * *
```

```
* * * * * * * * * *

   TERMINAL 4  DEMAND POINTS ROUTED ARE -- 8 --10 --14 --

   TOTAL DISTANCE OF ROUTE IS    502.00

   QUANTITY REQUIRED ON ROUTE IS  94.00  CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 5  DEMAND POINTS ROUTED ARE --16 -- 1 --17 --

   TOTAL DISTANCE OF ROUTE IS    706.00

   QUANTITY REQUIRED ON ROUTE IS  81.00  CAPACITY OF TRUCK IS  90.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --23 --25 --

   TOTAL DISTANCE OF ROUTE IS    698.00

   QUANTITY REQUIRED ON ROUTE IS  48.00  CAPACITY OF TRUCK IS  50.00

* * * * * * * * * *
```

THIS BOOK CONTAINS NUMEROUS PAGE NUMBERS THAT ARE ILLEGIBLE

THIS IS AS RECEIVED FROM THE CUSTOMER

ROUTE MATRIX

	DEMAND													
(1)	81.	0.												
(2)	82.	0.	0.											
(3)	36.	2.	0.	0.										
(4)	82.	1.	0.	0.	0.									
(5)	96.	1.	0.	0.	0.	0.								
(6)	92.	1.	0.	0.	0.	0.	0.							
(7)	75.	1.	0.	0.	0.	0.	0.	0.						
(8)	94.	1.	0.	0.	0.	0.	0.	0.	0.					
(9)	96.	0.	0.	0.	0.	0.	2.	0.	0.	0.				
(10)	94.	0.	0.	0.	0.	0.	0.	0.	0.	15.	0.			
(11)	96.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(12)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	92.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.
(14)	94.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	0.	0.
(15)	96.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	13.	0.
(16)	81.	1.	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(17)	81.	1.	11.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(18)	96.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.	0.	5.	0.
(19)	92.	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
(20)	75.	0.	0.	0.	0.	0.	0.	0.	17.	0.	0.	0.	0.	0.
(21)	82.	0.	0.	6.	0.	12.	0.	0.	0.	0.	0.	0.	0.	0.
(22)	75.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(23)	48.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	82.	1.	0.	7.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	48.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(14)	94.	1.	0.												
(15)	96.	1.	0.	0.											
(16)	81.	1.	0.	0.	0.										
(17)	81.	1.	0.	0.	0.	0.									
(18)	96.	0.	0.	0.	0.	0.	0.								
(19)	92.	0.	4.	0.	0.	0.	0.	0.							
(20)	75.	0.	0.	0.	0.	0.	0.	0.	0.						
(21)	82.	0.	0.	0.	0.	0.	0.	0.	0.	0.					
(22)	75.	1.	0.	0.	0.	0.	0.	0.	0.	14.	0.				
(23)	48.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(24)	82.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(25)	48.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.	0.	

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATION	4.	4.	2.	2.	4.	2.	2.	1.	99999.
NUMBER ALLOCATED	3.	2.	1.	0.	0.	1.	0.	0.	0.

TOTAL DISTANCE FOR SYSTEM 6099.00

* * * * * * * * * *

PROBLEM THREE

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINALS TERMINAL 1	TERMINAL 2	TERMINAL 3	TERMINAL 4	TERMINAL 5
1	18	175	152	26	88	91
2	22	142	246	248	204	58
3	35	131	51	164	54	222
4	20	18	122	193	110	109
5	16	67	171	225	155	136
6	38	83	182	103	140	33
7	34	76	112	115	70	98
8	24	41	94	227	134	157
9	26	211	251	77	187	115
10	36	157	221	63	175	52
11	15	58	162	204	134	119
12	27	155	130	48	66	113
13	17	78	40	142	32	181
14	23	114	25	170	60	220
15	36	150	115	67	54	132
16	40	151	197	35	147	55
17	15	121	185	65	143	25
18	16	82	22	174	64	188
19	28	53	55	151	53	156
20	32	54	150	221	146	136
21	22	71	124	246	164	161
22	25	193	274	118	230	78
23	18	246	243	71	179	150
24	30	148	242	122	200	32
25	24	127	231	133	168	43

TRUCKS

CAPACITY	NUMBER
100	2
90	4
80	3
70	2
60	2
50	2
40	4
30	3
20	3

The best solution shown below was obtained with the minimum computation time using Tillman's method (IDEPTH=1).

PROBLEM CF 5 TERMINALS WITH 25 DEMAND POINTS

CISTANCE MATRIX

(1)	26.														
(2)	58.	149.													
(3)	51.	140.	258.												
(4)	18.	184.	127.	149.											
(5)	67.	216.	89.	198.	49.										
(6)	33.	94.	64.	194.	90.	122.									
(7)	70.	99.	134.	124.	88.	133.	70.								
(8)	41.	212.	177.	142.	50.	98.	124.	117.							
(9)	77.	101.	173.	239.	218.	250.	128.	146.	252.						
(10)	52.	89.	110.	227.	161.	188.	74.	109.	198.	63.					
(11)	58.	195.	88.	188.	40.	21.	101.	112.	89.	229.	171.				
(12)	48.	24.	154.	118.	167.	212.	90.	79.	192.	123.	111.	191.			
(13)	32.	118.	217.	53.	96.	145.	153.	83.	106.	217.	192.	136.	96.		
(14)	25.	146.	256.	26.	132.	181.	192.	122.	116.	245.	231.	172.	124.	40.	
(15)	54.	43.	170.	100.	162.	207.	106.	76.	186.	142.	130.	186.	19.	81.	109.
(16)	35.	61.	113.	199.	158.	190.	68.	85.	192.	61.	29.	169.	83.	168.	205.
(17)	25.	66.	83.	197.	128.	160.	38.	73.	162.	90.	36.	139.	88.	156.	195.
(18)	22.	150.	224.	58.	100.	149.	160.	90.	84.	236.	199.	140.	128.	31.	32.
(19)	53.	135.	192.	78.	71.	120.	128.	58.	81.	204.	167.	111.	115.	25.	65.
(20)	54.	212.	118.	177.	36.	39.	118.	124.	64.	246.	188.	30.	203.	124.	160.
(21)	71.	237.	156.	172.	60.	74.	143.	147.	30.	271.	213.	65.	222.	136.	146.
(22)	78.	144.	131.	282.	185.	212.	110.	162.	234.	50.	55.	195.	166.	245.	284.
(23)	71.	93.	208.	231.	253.	285.	163.	181.	287.	40.	98.	264.	115.	209.	237.
(24)	32.	123.	35.	254.	136.	117.	65.	130.	186.	146.	84.	111.	145.	213.	252.
(25)	43.	134.	15.	243.	112.	93.	49.	119.	162.	158.	95.	87.	139.	232.	241.

CISTANCE MATRIX

(16)	102.									
(17)	107.	30.								
(18)	114.	175.	163.							
(19)	105.	143.	131.	33.						
(20)	198.	186.	156.	128.	99.					
(21)	216.	211.	181.	114.	111.	35.				
(22)	185.	84.	89.	252.	220.	212.	237.			
(23)	134.	96.	125.	241.	220.	281.	306.	90.		
(24)	164.	87.	57.	220.	188.	141.	176.	96.	182.	
(25)	155.	98.	68.	209.	177.	117.	152.	119.	193.	24.

```
*  *  *  *  *  *  *  *  *  *

   TERMINAL 3  DEMAND POINTS ROUTED ARE -- 1 --12 --15 --

   TOTAL DISTANCE OF ROUTE IS    136.00

   QUANTITY REQUIRED ON ROUTE IS  81.00  CAPACITY OF TRUCK IS  90.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 4 -- 8 --

   TOTAL DISTANCE OF ROUTE IS    109.00

   QUANTITY REQUIRED ON ROUTE IS  44.00  CAPACITY OF TRUCK IS  50.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 4  DEMAND POINTS ROUTED ARE -- 7 --19 --13 --

   TOTAL DISTANCE OF ROUTE IS    185.00

   QUANTITY REQUIRED ON ROUTE IS  79.00  CAPACITY OF TRUCK IS  80.00

*  *  *  *  *  *  *  *  *  *


*  *  *  *  *  *  *  *  *  *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --11 -- 5 --20 --21 --

   TOTAL DISTANCE OF ROUTE IS    224.00

   QUANTITY REQUIRED ON ROUTE IS  85.00  CAPACITY OF TRUCK IS  90.00

*  *  *  *  *  *  *  *  *  *
```

```
* * * * * * * * * *
   TERMINAL 2  DEMAND POINTS ROUTED ARE --14 -- 3 --18 --
   TOTAL DISTANCE CF ROUTE IS    131.00
   QUANTITY REQUIREC ON ROUTE IS  74.00  CAPACITY OF TRUCK IS  80.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 3  DEMAND POINTS ROUTED ARE --16 -- 9 --23 --
   TOTAL DISTANCE CF ROUTE IS    207.00
   QUANTITY REQUIREC ON ROUTE IS  84.00  CAPACITY OF TRUCK IS  90.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE --17 --10 --22 --
   TOTAL DISTANCE CF ROUTE IS    194.00
   QUANTITY REQUIREC ON ROUTE IS  76.00  CAPACITY OF TRUCK IS  80.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE --24 -- 2 --25 --
   TOTAL DISTANCE CF ROUTE IS    125.00
   QUANTITY REQUIREC ON ROUTE IS  76.00  CAPACITY OF TRUCK IS  80.00
* * * * * * * * * *
```

RCUTE MATRIX

	DEMAND													
(1)	81.	1.												
(2)	76.	0.	0.											
(3)	74.	0.	0.	0.										
(4)	44.	1.	0.	0.	0.									
(5)	85.	0.	0.	0.	0.	0.								
(6)	38.	2.	0.	0.	0.	0.	0.							
(7)	79.	1.	0.	0.	0.	0.	0.	0.						
(8)	44.	1.	0.	0.	0.	16.	0.	0.	0.					
(9)	84.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	76.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(11)	85.	1.	0.	0.	0.	0.	2.	0.	0.	0.	0.	0.		
(12)	81.	0.	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	79.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	74.	1.	0.	0.	13.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(15)	81.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.
(16)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.	11.	0.	0.	0.
(17)	76.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	14.	0.	0.
(18)	74.	1.	0.	0.	15.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(19)	79.	0.	0.	0.	0.	0.	0.	0.	8.	0.	0.	0.	0.	0.
(20)	85.	0.	0.	0.	0.	0.	5.	0.	0.	0.	0.	0.	0.	0.
(21)	85.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(22)	76.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.	0.	0.
(23)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.
(24)	76.	1.	0.	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	76.	1.	0.	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

RCUTE MATRIX

(14)	74.	1.	0.											
(15)	81.	1.	0.	0.										
(16)	84.	1.	0.	0.	0.									
(17)	76.	1.	0.	0.	0.	0.								
(18)	74.	1.	0.	0.	0.	0.	0.							
(19)	79.	0.	9.	0.	0.	0.	0.	0.						
(20)	85.	0.	0.	0.	0.	0.	0.	0.	0.					
(21)	85.	1.	0.	0.	0.	0.	0.	0.	0.	3.				
(22)	76.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(23)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(24)	76.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(25)	76.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATICN	2.	4.	3.	2.	2.	2.	4.	3.	99999.
NUMBER ALLOCATEC	0.	4.	3.	0.	0.	1.	0.	0.	0.

TOTAL DISTANCE FCR SYSTEM 1377.00

* * * * * * * * * *

PROBLEM FOUR

DEMAND POINT	QUANTITY REQUIRED	DISTNACES TO TERMINALS: TERMINAL 1	TERMINAL 2	TERMINAL 3	TERMINAL 4	TERMINAL 5
1	20	164	115	62	83	125
2	16	182	56	232	153	268
3	38	182	101	114	98	186
4	24	133	265	153	163	49
5	36	60	201	201	102	116
6	28	147	137	263	143	233
7	18	98	52	143	47	163
8	24	110	93	208	88	195
9	36	91	170	124	71	50
10	22	137	33	153	87	203
11	28	228	153	76	147	174
12	15	137	109	236	116	223
13	30	62	88	149	30	140
14	22	61	131	144	32	91
15	18	39	111	164	44	121
16	25	178	233	64	140	53
17	27	101	89	113	18	132
18	34	151	165	67	72	68
19	23	154	197	74	104	38
20	16	137	81	95	54	152
21	18	66	202	183	103	97
22	26	138	134	65	55	92
23	34	65	162	142	63	69
24	40	81	129	238	118	189
25	17	87	170	262	142	212

TRUCKS

CAPACITY	NUMBER
100	2
90	3
80	4
70	2
60	1
50	2
40	2
30	1
20	2

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=2.

PROBLEM OF 5 TERMINALS WITH 25 DEMAND POINTS

DISTANCE MATRIX

(1)	62.														
(2)	56.	171.													
(3)	98.	62.	155.												
(4)	49.	174.	310.	235.											
(5)	60.	166.	240.	196.	89.										
(6)	137.	217.	81.	227.	257.	205.									
(7)	47.	81.	107.	96.	210.	149.	136.								
(8)	88.	168.	73.	184.	237.	167.	55.	90.							
(9)	50.	95.	219.	146.	91.	84.	183.	118.	146.						
(10)	33.	91.	88.	68.	249.	188.	170.	40.	124.	158.					
(11)	76.	64.	207.	53.	223.	232.	279.	144.	232.	160.	120.				
(12)	109.	189.	60.	204.	265.	195.	29.	107.	28.	173.	139.	249.			
(13)	30.	111.	132.	126.	185.	121.	114.	35.	59.	93.	75.	173.	86.		
(14)	32.	109.	177.	127.	133.	70.	141.	79.	104.	42.	119.	174.	132.	53.	
(15)	39.	125.	147.	143.	167.	100.	111.	59.	74.	72.	99.	189.	102.	23.	30.
(16)	53.	126.	287.	178.	98.	169.	273.	180.	225.	90.	217.	140.	253.	166.	132.
(17)	18.	64.	143.	84.	178.	117.	161.	36.	106.	88.	76.	128.	134.	47.	49.
(18)	67.	65.	220.	227.	117.	144.	212.	113.	157.	60.	153.	112.	185.	89.	94.
(19)	38.	90.	251.	152.	87.	149.	244.	145.	189.	64.	181.	136.	217.	131.	106.
(20)	54.	33.	137.	44.	198.	152.	188.	52.	140.	110.	63.	92.	160.	82.	83.
(21)	66.	147.	250.	172.	70.	20.	213.	149.	176.	66.	189.	211.	204.	125.	73.
(22)	55.	36.	189.	94.	141.	136.	198.	82.	143.	59.	121.	100.	111.	84.	79.
(23)	63.	105.	212.	149.	104.	59.	176.	110.	138.	26.	150.	170.	166.	85.	34.
(24)	81.	200.	110.	216.	213.	139.	74.	126.	37.	146.	166.	264.	65.	91.	105.
(25)	87.	224.	136.	240.	215.	141.	75.	150.	78.	170.	190.	288.	76.	115.	129.

DISTANCE MATRIX

(16)	164.									
(17)	63.	146.								
(18)	114.	69.	79.							
(19)	136.	42.	110.	32.						
(20)	99.	159.	40.	92.	123.					
(21)	103.	150.	118.	126.	130.	154.				
(22)	99.	101.	48.	34.	66.	58.	118.			
(23)	64.	116.	82.	86.	90.	113.	41.	77.		
(24)	75.	236.	136.	187.	210.	172.	146.	172.	120.	
(25)	99.	261.	160.	211.	235.	196.	149.	196.	144.	41.

```
*  *  *  *  *  *  *  *  *  *
   TERMINAL 3  DEMAND POINTS ROUTED ARE -- 1 -- 3 --11 --
   TOTAL DISTANCE OF ROUTE IS     253.00
   QUANTITY REQUIRED ON ROUTE IS  86.00  CAPACITY OF TRUCK IS  90.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 2 -- 6 --12 -- 8 --
   TOTAL DISTANCE OF ROUTE IS     287.00
   QUANTITY REQUIRED ON ROUTE IS  83.00  CAPACITY OF TRUCK IS  90.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 5 --21 --23 --
   TOTAL DISTANCE OF ROUTE IS     186.00
   QUANTITY REQUIRED ON ROUTE IS  88.00  CAPACITY OF TRUCK IS  90.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 4  DEMAND POINTS ROUTED ARE -- 7 --20 --22 --18 --
   TOTAL DISTANCE OF ROUTE IS     263.00
   QUANTITY REQUIRED ON ROUTE IS  94.00  CAPACITY OF TRUCK IS 100.00
*  *  *  *  *  *  *  *  *  *
```

* * * * * * * * * *

TERMINAL 5 DEMAND POINTS ROUTED ARE -- 9 --19 --16 --

TOTAL DISTANCE OF ROUTE IS 209.00

QUANTITY REQUIRED ON ROUTE IS 84.00 CAPACITY OF TRUCK IS 90.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 4 DEMAND POINTS ROUTED ARE --13 --15 --14 --

TOTAL DISTANCE OF ROUTE IS 115.00

QUANTITY REQUIRED ON ROUTE IS 70.00 CAPACITY OF TRUCK IS 70.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE --24 --25 --

TOTAL DISTANCE OF ROUTE IS 209.00

QUANTITY REQUIRED ON ROUTE IS 57.00 CAPACITY OF TRUCK IS 60.00

* * * * * * * * * *

ROUTE MATRIX

	DEMAND													
(1)	86.	1.												
(2)	83.	1.	0.											
(3)	86.	0.	7.	0.										
(4)	24.	2.	0.	0.	0.									
(5)	88.	1.	0.	0.	0.	0.								
(6)	83.	0.	0.	4.	0.	0.	0.							
(7)	54.	1.	0.	0.	0.	0.	0.	0.						
(8)	83.	1.	0.	0.	0.	0.	0.	0.	0.					
(9)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	22.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(11)	86.	1.	0.	0.	6.	0.	0.	0.	0.	0.	0.	0.		
(12)	83.	0.	0.	0.	0.	0.	0.	1.	0.	2.	0.	0.	0.	
(13)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(15)	70.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(16)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(17)	27.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(18)	94.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(19)	84.	0.	0.	0.	0.	0.	0.	0.	0.	0.	15.	0.	0.	0.
(20)	54.	0.	0.	0.	0.	0.	0.	0.	12.	0.	0.	0.	0.	0.
(21)	88.	0.	0.	0.	0.	0.	5.	0.	0.	0.	0.	0.	0.	0.
(22)	54.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(23)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	57.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	57.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

RCUTE MATRIX

(14)	70.	1.	0.											
(15)	70.	0.	13.	14.										
(16)	84.	1.	0.	0.	0.									
(17)	27.	2.	0.	0.	0.	0.								
(18)	94.	1.	0.	0.	0.	0.	0.							
(19)	84.	0.	0.	0.	0.	11.	0.	0.						
(20)	94.	0.	0.	0.	0.	0.	0.	0.	0.					
(21)	88.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(22)	94.	0.	0.	0.	0.	0.	0.	9.	0.	10.	0.			
(23)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	8.	0.		
(24)	57.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(25)	57.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATION	2.	3.	4.	2.	1.	2.	2.	1.	99999.
NUMBER ALLOCATED	2.	3.	0.	2.	0.	0.	0.	0.	0.

TOTAL DISTANCE FOR SYSTEM 1722.00

* * * * * * * * * *

PROBLEM FIVE

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINALS TERMINAL 1	TERMINAL 2	TERMINAL 3	TERMINAL 4	TERMINAL 5
1	25	783	400	252	662	549
2	18	664	248	187	611	579
3	36	693	764	451	151	315
4	24	740	662	290	321	107
5	15	948	906	533	475	137
6	17	998	615	457	812	557
7	28	271	403	686	815	1050
8	23	471	828	638	252	695
9	16	573	468	159	258	331
10	34	756	748	396	251	152
11	22	513	429	783	964	1147
12	18	641	631	294	213	172
13	30	324	556	423	250	539
14	27	258	661	554	350	656
15	16	287	256	346	523	725
16	24	668	552	180	323	217
17	17	417	210	209	449	586
18	28	756	245	297	703	656
19	36	689	181	530	850	926
20	23	385	866	756	372	748
21	22	404	514	302	170	409
22	18	503	598	355	70	364
23	40	182	503	452	390	629
24	25	911	869	497	368	132
25	19	186	733	698	548	852

TRUCKS CAPACITY	NUMBER
100	4
90	3
80	4
70	2
60	2
50	1
40	2
30	1
20	2

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=6.

PROBLEM OF 5 TERMINALS WITH 25 DEMAND POINTS

DISTANCE MATRIX

(1)	252.														
(2)	187.	154.													
(3)	151.	730.	656.												
(4)	107.	461.	476.	293.											
(5)	137.	686.	716.	343.	244.										
(6)	457.	215.	367.	785.	517.	655.									
(7)	271.	805.	653.	936.	943.	1187.	1020.								
(8)	252.	894.	808.	338.	571.	679.	1064.	704.							
(9)	159.	415.	364.	296.	224.	468.	586.	734.	502.						
(10)	152.	610.	582.	158.	154.	212.	671.	999.	478.	284.					
(11)	429.	814.	662.	1085.	1040.	1284.	1029.	245.	946.	834.	1114.				
(12)	172.	508.	485.	186.	108.	309.	601.	882.	483.	167.	121.	997.			
(13)	250.	668.	567.	391.	468.	715.	870.	565.	272.	301.	476.	780.	367.		
(14)	258.	810.	706.	499.	590.	824.	1001.	499.	201.	423.	585.	741.	484.	146.	
(15)	256.	505.	386.	644.	618.	862.	720.	325.	573.	409.	679.	445.	562.	354.	405.
(16)	180.	432.	366.	301.	113.	354.	499.	833.	569.	125.	216.	930.	114.	394.	516.
(17)	209.	366.	247.	544.	502.	723.	581.	464.	608.	273.	553.	561.	436.	336.	459.
(18)	245.	173.	94.	748.	568.	793.	378.	650.	900.	456.	674.	659.	572.	659.	798.
(19)	181.	493.	351.	944.	820.	1063.	697.	498.	989.	642.	926.	359.	805.	730.	821.
(20)	372.	1012.	911.	476.	691.	817.	1184.	656.	145.	622.	616.	898.	583.	349.	205.
(21)	170.	558.	476.	288.	338.	546.	749.	645.	336.	172.	354.	794.	234.	130.	253.
(22)	70.	611.	541.	193.	300.	515.	778.	746.	290.	211.	276.	895.	192.	200.	309.
(23)	182.	649.	530.	511.	558.	766.	864.	425.	344.	391.	574.	640.	457.	144.	176.
(24)	132.	668.	683.	239.	207.	110.	689.	1154.	572.	388.	110.	1247.	221.	608.	717.
(25)	186.	895.	776.	697.	788.	1022.	1100.	384.	403.	621.	783.	612.	682.	344.	195.

DISTANCE MATRIX

(16)	508.									
(17)	137.	389.								
(18)	478.	458.	339.							
(19)	416.	710.	397.	324.						
(20)	610.	689.	664.	1003.	1026.					
(21)	353.	264.	294.	572.	695.	454.				
(22)	454.	279.	383.	633.	779.	410.	95.			
(23)	229.	484.	283.	622.	645.	381.	220.	321.		
(24)	783.	317.	686.	775.	1027.	710.	509.	408.	729.	
(25)	473.	714.	529.	868.	833.	303.	450.	507.	246.	915.

```
* * * * * * * * * *
   TERMINAL 3  DEMAND POINTS ROUTED ARE -- 2 --18 -- 1 -- 6 --
   TOTAL DISTANCE OF ROUTE IS   1126.00
   QUANTITY REQUIRED ON ROUTE IS  88.00  CAPACITY OF TRUCK IS  90.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 4  DEMAND POINTS ROUTED ARE -- 3 -- 9 --21 --22 --
   TOTAL DISTANCE OF ROUTE IS    784.00
   QUANTITY REQUIRED ON ROUTE IS  92.00  CAPACITY OF TRUCK IS 100.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE -- 4 --16 --12 --10 --
   TOTAL DISTANCE OF ROUTE IS    607.00
   QUANTITY REQUIRED ON ROUTE IS 100.00  CAPACITY OF TRUCK IS 100.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE -- 5 --24 --
   TOTAL DISTANCE OF ROUTE IS    379.00
   QUANTITY REQUIRED ON ROUTE IS  40.00  CAPACITY OF TRUCK IS  40.00
* * * * * * * * * *
```

```
* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE -- 7 --11 --25 --
   TOTAL DISTANCE OF ROUTE IS   1314.00
   QUANTITY REQUIRED ON ROUTE IS  69.00  CAPACITY OF TRUCK IS  70.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 4  DEMAND POINTS ROUTED ARE -- 8 --20 --
   TOTAL DISTANCE OF ROUTE IS    769.00
   QUANTITY REQUIRED ON ROUTE IS  46.00  CAPACITY OF TRUCK IS  50.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --14 --13 --23 --
   TOTAL DISTANCE OF ROUTE IS    730.00
   QUANTITY REQUIRED ON ROUTE IS  97.00  CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 2  DEMAND POINTS ROUTED ARE --17 --15 --19 --
   TOTAL DISTANCE OF ROUTE IS    944.00
   QUANTITY REQUIRED ON ROUTE IS  69.00  CAPACITY OF TRUCK IS  70.00

* * * * * * * * * *
```

ROUTE MATRIX

	DEMAND													
(1)	88.	0.												
(2)	88.	1.	0.											
(3)	92.	1.	0.	0.										
(4)	100.	1.	0.	0.	0.									
(5)	40.	1.	0.	0.	0.	0.								
(6)	88.	1.	1.	0.	0.	0.	0.							
(7)	69.	1.	0.	0.	0.	0.	0.	0.						
(8)	46.	1.	0.	0.	0.	0.	0.	0.	0.					
(9)	92.	0.	0.	0.	15.	0.	0.	0.	0.	0.				
(10)	100.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(11)	69.	0.	0.	0.	0.	0.	0.	0.	5.	0.	0.	0.		
(12)	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.	0.	
(13)	97.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	97.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(15)	69.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(16)	100.	0.	0.	0.	0.	11.	0.	0.	0.	0.	0.	0.	0.	10.
(17)	69.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(18)	88.	0.	4.	3.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(19)	69.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(20)	46.	1.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.	0.	0.
(21)	92.	0.	0.	0.	0.	0.	0.	0.	0.	0.	14.	0.	0.	0.
(22)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(23)	97.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	40.	1.	0.	0.	0.	0.	12.	0.	0.	0.	0.	0.	0.	0.
(25)	69.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	0.

RCUTE MATRIX

(14)	97.	1.	7.											
(15)	69.	0.	0.	0.										
(16)	100.	0.	0.	0.	0.									
(17)	69.	1.	0.	0.	6.	0.								
(18)	88.	0.	0.	0.	0.	0.	0.							
(19)	69.	1.	0.	0.	17.	0.	0.	0.						
(20)	46.	1.	0.	0.	0.	0.	0.	0.	0.					
(21)	92.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(22)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	13.			
(23)	97.	1.	8.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(24)	40.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(25)	69.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATICN	4.	3.	4.	2.	2.	1.	2.	1.	99999.
NUMBER ALLOCATEC	3.	1.	1.	2.	1.	0.	0.	0.	0.

TCTAL DISTANCE FCR SYSTEM 6653.CO

* * * * * * * * * *

FIVE TERMINAL FIFTY
DEMAND POINT PROBLEMS

PROBLEM ONE

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINAL TERMINAL 1	TERMINAL 2	TERMINAL 3	TERMINAL 4	TERMINAL 5
1	25	1800	1385	779	709	230
2	16	1900	1401	810	366	461
3	40	2118	1701	1099	947	494
4	36	1781	1282	706	247	476
5	28	960	685	783	1266	1143
6	17	2405	1989	1456	1355	876
7	19	1958	1543	1010	909	430
8	36	462	102	648	1107	1182
9	31	1431	1016	499	544	293
10	24	1772	1357	824	723	244
11	20	1701	1233	656	586	107
12	15	1241	784	499	464	943
13	18	1094	697	201	608	571
14	26	1700	1284	751	713	265
15	38	1539	1027	423	273	224
16	40	1571	1156	585	553	154
17	27	2081	1666	1132	953	472
18	16	500	792	1261	1720	1770
19	29	1431	1026	741	561	1040
20	30	1536	1061	484	436	108
21	32	1648	1191	661	210	662
22	27	2207	1708	1123	673	775
23	18	1255	750	146	336	468
24	38	1640	1224	691	684	326
25	22	1456	957	405	137	618
26	16	716	1134	1596	1831	2186
27	35	1632	1120	516	389	113
28	26	1455	1040	580	624	384
29	18	1239	841	457	840	705
30	24	1670	1158	554	209	290
31	30	1739	1282	821	397	820
32	28	2267	1851	1319	1138	659
33	17	955	540	205	664	691
34	15	1326	900	350	449	321
35	20	2186	1770	1238	1057	578
36	18	653	818	1226	1466	1816
37	25	851	523	595	1054	1059
38	38	1890	1482	937	758	284
39	40	802	1278	1846	2305	2405
40	15	1368	856	253	294	338
41	36	759	1270	1874	2157	2402
42	18	871	1347	1872	2331	2356
43	28	732	1112	1583	2042	2067
44	24	1357	869	309	383	300
45	35	1251	752	176	283	558

PROBLEM ONE
(CONTINUED)

DEMAND POINT	QUANTITY REQUIRED	DISTNACES TO TERMINALS TERMINAL 1	TERMINAL 2	TERMINAL 3	TERMINAL 4	TERMINAL 5
46	16	2313	1814	1238	779	928
47	24	1670	1250	717	686	207
48	26	1191	693	258	417	740
49	15	2111	1696	1048	908	492
50	24	1005	507	195	529	788

TRUCKS

CAPACITY	NUMBER
100	6
90	8
80	3
70	5
60	2
50	6
40	2
30	8
20	3

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=2.

PROBLEM OF 5 TERMINALS WITH 50 DEMAND POINTS

DISTANCE MATRIX

(1)	230.														
(2)	366.	672.													
(3)	494.	331.	669.												
(4)	247.	702.	154.	787.											
(5)	685.	1214.	1543.	1535.	1504.										
(6)	876.	653.	1068.	399.	1185.	1823.									
(7)	430.	207.	877.	345.	902.	1377.	449.								
(8)	102.	1338.	1456.	1656.	1354.	583.	1943.	1496.							
(9)	293.	366.	730.	687.	656.	850.	975.	540.	969.						
(10)	244.	33.	686.	351.	716.	1191.	632.	191.	1310.	343.					
(11)	107.	123.	549.	408.	579.	1207.	769.	323.	1239.	315.	137.				
(12)	464.	1173.	805.	1458.	653.	1175.	1819.	1373.	875.	936.	1187.	1050.			
(13)	201.	707.	984.	1025.	808.	672.	1311.	865.	632.	338.	679.	695.	704.		
(14)	265.	190.	726.	511.	741.	1123.	699.	252.	1238.	271.	167.	202.	1188.	606.	
(15)	224.	454.	415.	718.	364.	1143.	1100.	654.	1069.	296.	468.	331.	734.	502.	444.
(16)	154.	233.	610.	556.	582.	1024.	844.	398.	1105.	158.	212.	152.	999.	478.	160.
(17)	472.	301.	719.	80.	812.	1504.	398.	294.	1620.	657.	321.	368.	1418.	988.	481.
(18)	500.	1842.	2053.	2163.	1963.	628.	2451.	2005.	700.	1478.	1819.	1835.	1571.	1162.	1751.
(19)	561.	1270.	814.	1449.	662.	1417.	1916.	1470.	1117.	1085.	1284.	1147.	245.	946.	1337.
(20)	108.	295.	508.	580.	480.	1035.	941.	495.	1074.	186.	309.	172.	882.	483.	277.
(21)	210.	892.	400.	1035.	248.	1479.	1433.	1092.	1282.	764.	906.	769.	403.	828.	927.
(22)	673.	919.	314.	793.	426.	1857.	1191.	1067.	1770.	1009.	952.	854.	994.	1208.	996.
(23)	146.	662.	668.	931.	567.	930.	1308.	901.	793.	391.	715.	539.	565.	272.	642.
(24)	326.	253.	782.	575.	713.	1063.	785.	338.	1178.	215.	230.	252.	1128.	546.	86.
(25)	137.	848.	505.	1086.	386.	1188.	1494.	1048.	1040.	644.	862.	725.	325.	573.	896.
(26)	716.	2368.	2197.	2695.	2056.	1649.	3052.	2606.	1169.	2095.	2420.	2245.	1403.	1801.	2347.
(27)	113.	340.	432.	604.	366.	1146.	986.	540.	1162.	301.	354.	217.	833.	569.	375.
(28)	384.	455.	784.	776.	744.	764.	1064.	618.	988.	89.	432.	484.	1015.	361.	364.

(29)	457.	776.	1105.	1097.	1066.	430.	1385.	939.	794.	412.	753.	769.	956.	252.	685.
(30)	209.	519.	252.	725.	187.	1299.	1165.	719.	1200.	451.	533.	396.	686.	638.	555.
(31)	397.	1049.	493.	1138.	351.	1604.	1536.	1253.	1373.	944.	1063.	926.	498.	989.	1085.
(32)	659.	487.	855.	187.	974.	1691.	216.	445.	1806.	738.	507.	557.	1607.	1173.	667.
(33)	205.	845.	1012.	1163.	911.	581.	1449.	1003.	493.	476.	817.	748.	656.	145.	744.
(34)	321.	448.	662.	818.	611.	857.	1107.	661.	864.	151.	475.	376.	815.	252.	402.
(35)	578.	406.	766.	97.	884.	1610.	304.	365.	1725.	775.	426.	476.	1526.	1092.	586.
(36)	653.	2003.	1810.	2325.	1658.	1501.	2682.	2236.	918.	1722.	2050.	1882.	1005.	1430.	1977.
(37)	523.	1130.	1381.	1451.	1295.	207.	1739.	1293.	441.	766.	1107.	1123.	968.	487.	1039.
(38)	284.	105.	697.	230.	742.	1309.	598.	217.	1424.	461.	134.	182.	1232.	804.	285.
(39)	802.	2476.	2654.	2797.	2552.	1262.	3085.	2639.	1198.	2112.	2453.	2469.	2043.	1819.	2385.
(40)	253.	532.	558.	817.	476.	980.	1178.	802.	898.	288.	546.	409.	645.	336.	543.
(41)	759.	2541.	2523.	2876.	2393.	1633.	3163.	2716.	1220.	2189.	2530.	2459.	1806.	1852.	2458.
(42)	871.	2427.	2756.	2748.	2575.	1213.	3036.	2590.	1267.	2063.	2404.	2420.	2112.	1773.	2336.
(43)	732.	2138.	2467.	2459.	2286.	924.	2747.	2301.	1022.	1774.	2115.	2131.	1891.	1484.	2047.
(44)	300.	487.	611.	854.	541.	912.	1147.	701.	895.	193.	515.	364.	746.	290.	442.
(45)	176.	752.	649.	1037.	530.	959.	1468.	1022.	824.	511.	766.	629.	425.	344.	763.
(46)	779.	1097.	467.	981.	541.	2010.	1379.	1248.	1886.	1162.	1122.	985.	1077.	1349.	1193.
(47)	207.	133.	668.	454.	683.	1089.	742.	296.	1204.	239.	110.	132.	1154.	572.	61.
(48)	258.	934.	783.	1219.	664.	966.	1650.	1204.	776.	693.	948.	811.	271.	471.	945.
(49)	492.	331.	630.	39.	748.	1535.	437.	359.	1650.	712.	351.	392.	1372.	1018.	511.
(50)	195.	975.	895.	1297.	776.	791.	1654.	1208.	590.	697.	1022.	852.	384.	403.	949.

DISTANCE MATRIX

(16)	284.														
(17)	697.	526.													
(18)	1772.	1652.	2133.												
(19)	834.	1114.	1474.	1813.											
(20)	167.	121.	540.	1663.	997.										
(21)	468.	748.	1060.	1922.	429.	631.									
(22)	729.	924.	855.	2370.	911.	822.	589.								
(23)	301.	476.	904.	1405.	780.	367.	549.	956.							
(24)	415.	131.	544.	1691.	1245.	248.	879.	1101.	582.						
(25)	409.	679.	1094.	1666.	445.	562.	256.	812.	354.	836.					
(26)	2029.	2181.	2729.	1234.	1553.	2080.	1810.	2397.	1742.	2287.	1701.				
(27)	125.	216.	582.	1777.	930.	114.	552.	708.	394.	347.	508.	2107.			
(28)	374.	265.	746.	1392.	1174.	276.	844.	1098.	469.	304.	723.	2176.	390.		
(29)	706.	586.	1067.	1056.	1198.	597.	1060.	1419.	509.	625.	825.	1940.	711.	326.	
(30)	159.	396.	762.	1800.	783.	294.	375.	570.	423.	527.	346.	2058.	180.	540.	861.
(31)	642.	926.	1163.	2070.	359.	805.	181.	582.	730.	1053.	416.	1901.	710.	1013.	1241.
(32)	888.	712.	186.	2319.	1636.	729.	1222.	980.	1096.	729.	1282.	2915.	769.	932.	1253.
(33)	622.	616.	1127.	1056.	898.	583.	866.	1326.	349.	685.	610.	1662.	689.	500.	358.
(34)	258.	251.	783.	1414.	964.	213.	669.	976.	250.	344.	523.	1946.	323.	226.	423.
(35)	807.	631.	105.	2238.	1546.	648.	1132.	890.	1015.	649.	1201.	2721.	688.	851.	1172.
(36)	1664.	1811.	2358.	1147.	1153.	1710.	1412.	1999.	1372.	1917.	1330.	398.	1757.	1806.	1630.
(37)	989.	940.	1421.	699.	1210.	951.	1256.	1695.	739.	979.	1000.	1558.	1065.	701.	395.
(38)	508.	330.	197.	1937.	1319.	354.	934.	865.	721.	348.	897.	2533.	394.	550.	871.
(39)	2267.	2286.	2767.	657.	2233.	2297.	2450.	2968.	1991.	2325.	2234.	970.	2412.	2026.	1690.
(40)	172.	354.	777.	1498.	794.	234.	514.	872.	130.	483.	353.	1848.	264.	370.	546.
(41)	2297.	2329.	2839.	1134.	1955.	2294.	2212.	2799.	2014.	2399.	2027.	403.	2390.	2213.	1997.
(42)	2357.	2237.	2718.	611.	2302.	2245.	2519.	3070.	2016.	2276.	2277.	1145.	2362.	1977.	1641.
(43)	2068.	1948.	2429.	322.	2138.	1956.	2244.	2781.	1727.	1987.	1988.	1227.	2073.	1688.	1352.
(44)	211.	276.	823.	1452.	895.	192.	598.	925.	200.	382.	454.	1905.	279.	269.	478.

(45)	391.	574.	997.	1437.	640.	457.	503.	956.	144.	703.	229.	1637.	484.	590.	596.
(46)	873.	1077.	1036.	2499.	984.	975.	672.	198.	1108.	1254.	912.	2480.	861.	1251.	1572.
(47)	388.	110.	424.	1717.	1247.	221.	869.	939.	608.	119.	783.	2313.	317.	330.	651.
(48)	573.	756.	1181.	1427.	513.	641.	543.	1090.	324.	883.	287.	1461.	668.	772.	715.
(49)	716.	556.	119.	2163.	1410.	564.	996.	754.	931.	574.	1047.	2644.	596.	776.	1097.
(50)	621.	783.	1330.	1241.	612.	682.	733.	1202.	344.	889.	473.	1402.	714.	778.	655.

DISTANCE MATRIX

(31)	530.														
(32)	949.	1325.													
(33)	756.	1026.	1312.												
(34)	406.	850.	970.	372.											
(35)	868.	1235.	93.	1230.	889.										
(36)	1725.	1503.	2459.	1335.	1576.	2464.									
(37)	1125.	1416.	1607.	390.	739.	1526.	1341.								
(38)	559.	1093.	386.	942.	588.	305.	2163.	1225.							
(39)	2398.	2541.	2953.	1691.	2062.	2872.	1366.	1356.	2571.						
(40)	302.	695.	966.	454.	170.	885.	1478.	823.	591.	2096.					
(41)	2410.	2303.	3025.	1713.	2084.	2944.	800.	1609.	2648.	652.	2126.				
(42)	2512.	2610.	2904.	1667.	2070.	2823.	1541.	1310.	2522.	175.	2109.	827.			
(43)	2223.	2392.	2615.	1378.	1781.	2534.	1369.	1021.	2233.	360.	1820.	915.	289.		
(44)	355.	779.	1010.	410.	70.	929.	1535.	777.	628.	2093.	95.	2115.	2063.	1774.	
(45)	452.	645.	1186.	381.	390.	1105.	1273.	771.	811.	2022.	220.	1958.	2048.	1759.	321.
(46)	714.	653.	1167.	1443.	1120.	1078.	2082.	1833.	1046.	3084.	1016.	2882.	3110.	2821.	1069.
(47)	497.	1027.	610.	710.	368.	529.	1943.	1005.	228.	2351.	509.	2428.	2302.	2013.	408.
(48)	634.	689.	1370.	385.	570.	1289.	1091.	766.	995.	1970.	404.	1776.	2038.	1749.	503.
(49)	686.	1099.	229.	1156.	814.	136.	2274.	1451.	245.	2797.	801.	2869.	2748.	2459.	854.
(50)	698.	833.	1517.	303.	548.	1436.	1032.	584.	1135.	1784.	450.	1721.	1852.	1563.	507.

DISTANCE MATRIX

(46)	1062.				
(47)	729.	1135.			
(48)	182.	1196.	911.		
(49)	1021.	942.	454.	1205.	
(50)	246.	1308.	915.	186.	1246.

* * * * * * * * * *

TERMINAL 4 DEMAND POINTS ROUTED ARE -- 2 --22 --46 -- 4 --

TOTAL DISTANCE OF ROUTE IS 1666.00

QUANTITY REQUIRED ON ROUTE IS 95.00 CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 5 DEMAND POINTS ROUTED ARE -- 9 --28 --34 --44 --

TOTAL DISTANCE OF ROUTE IS 978.00

QUANTITY REQUIRED ON ROUTE IS 96.00 CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 5 DEMAND POINTS ROUTED ARE --10 -- 7 -- 3 --49 --

TOTAL DISTANCE OF ROUTE IS 1311.00

QUANTITY REQUIRED ON ROUTE IS 98.00 CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 5 DEMAND POINTS ROUTED ARE --11 -- 1 --38 --

TOTAL DISTANCE OF ROUTE IS 619.00

QUANTITY REQUIRED ON ROUTE IS 83.00 CAPACITY OF TRUCK IS 90.00

* * * * * * * * * *

```
* * * * * * * * * *
   TERMINAL 3  DEMAND POINTS ROUTED ARE --13 --29 --33 --
   TOTAL DISTANCE OF ROUTE IS   1016.00
   QUANTITY REQUIRED ON ROUTE IS  53.00  CAPACITY OF TRUCK IS  60.00
* * * * * * * * * *


* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE --14 --24 --47 --
   TOTAL DISTANCE OF ROUTE IS    677.00
   QUANTITY REQUIRED ON ROUTE IS  88.00  CAPACITY OF TRUCK IS  90.00
* * * * * * * * * *


* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE --16 --20 --
   TOTAL DISTANCE OF ROUTE IS    383.00
   QUANTITY REQUIRED ON ROUTE IS  70.00  CAPACITY OF TRUCK IS  70.00
* * * * * * * * * *


* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE --17 --32 -- 6 --35 --
   TOTAL DISTANCE OF ROUTE IS   1756.00
   QUANTITY REQUIRED ON ROUTE IS  92.00  CAPACITY OF TRUCK IS 100.00
* * * * * * * * * *
```

* * * * * * * * * *

TERMINAL 2 DEMAND POINTS ROUTED ARE --18 -- 5 --37 --

TOTAL DISTANCE OF ROUTE IS   2150.00

QUANTITY REQUIRED ON ROUTE IS 69.00 CAPACITY OF TRUCK IS 70.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 4 DEMAND POINTS ROUTED ARE --21 --25 --

TOTAL DISTANCE OF ROUTE IS   603.00

QUANTITY REQUIRED ON ROUTE IS 54.00 CAPACITY OF TRUCK IS 60.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 3 DEMAND POINTS ROUTED ARE --23 --45 --50 --

TOTAL DISTANCE OF ROUTE IS   731.00

QUANTITY REQUIRED ON ROUTE IS 77.00 CAPACITY OF TRUCK IS 80.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 4 DEMAND POINTS ROUTED ARE --30 --15 --40 --

TOTAL DISTANCE OF ROUTE IS   834.00

QUANTITY REQUIRED ON ROUTE IS 77.00 CAPACITY OF TRUCK IS 80.00

* * * * * * * * * *

```
* * * * * * * * * *

   TERMINAL 4  DEMAND POINTS ROUTED ARE --31 --19 --12 --48 --

   TOTAL DISTANCE OF ROUTE IS   1689.00

   QUANTITY REQUIRED ON ROUTE IS 100.00  CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --36 --26 --41 --

   TOTAL DISTANCE OF ROUTE IS   2213.00

   QUANTITY REQUIRED ON ROUTE IS  70.00  CAPACITY OF TRUCK IS  70.00

* * * * * * * * * *


* * * * * * * * * *

   TERMINAL 1  DEMAND POINTS ROUTED ARE --39 --42 --43 --

   TOTAL DISTANCE OF ROUTE IS   1998.00

   QUANTITY REQUIRED ON ROUTE IS  86.00  CAPACITY OF TRUCK IS  90.00

* * * * * * * * * *
```

ROUTE MATRIX

	DEMAND													
(1)	83.	0.												
(2)	95.	1.	0.											
(3)	98.	0.	0.	0.										
(4)	95.	1.	0.	0.	0.									
(5)	69.	0.	0.	0.	0.	0.								
(6)	92.	0.	0.	0.	0.	0.	0.							
(7)	98.	0.	0.	0.	15.	0.	0.	0.						
(8)	36.	2.	0.	0.	0.	0.	0.	0.	0.					
(9)	96.	1.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	98.	1.	0.	0.	0.	0.	0.	0.	19.	0.	0.			
(11)	83.	1.	29.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(12)	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	53.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(14)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(15)	77.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(16)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(17)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(18)	69.	1.	0.	0.	0.	0.	26.	0.	0.	0.	0.	0.	0.	0.
(19)	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	11.
(20)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(21)	54.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(22)	95.	0.	0.	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(23)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	88.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	54.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(26)	70.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(27)	35.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(28)	96.	0.	0.	0.	0.	0.	0.	0.	0.	0.	14.	0.	0.	0.
(29)	53.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(30)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(31)	100.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(32)	92.	0.	0.	0.	0.	0.	0.	2.	0.	0.	0.	0.	0.	0.
(33)	53.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(34)	96.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(35)	92.	1.	0.	0.	0.	0.	0.	5.	0.	0.	0.	0.	0.	0.
(36)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(37)	69.	1.	0.	0.	0.	0.	7.	0.	0.	0.	0.	0.	0.	0.
(38)	83.	1.	22.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(39)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(42)	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(43)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	96.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(45)	77.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(46)	95.	0.	0.	0.	0.	18.	0.	0.	0.	0.	0.	0.	0.	0.
(47)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(48)	100.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	25.
(49)	98.	1.	0.	0.	9.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(14)	88.	1.	0.												
(15)	77.	0.	0.	0.											
(16)	70.	1.	0.	0.	0.										
(17)	92.	1.	0.	0.	0.	0.									
(18)	69.	1.	0.	0.	0.	0.	0.								
(19)	100.	0.	0.	0.	0.	0.	0.	0.							
(20)	70.	1.	0.	0.	0.	31.	0.	0.	0.						
(21)	54.	1.	0.	0.	0.	0.	0.	0.	0.	0.					
(22)	95.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(23)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(24)	88.	0.	0.	17.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(25)	54.	1.	0.	0.	0.	0.	0.	0.	0.	0.	33.	0.	0.	0.	
(26)	70.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(27)	35.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(28)	96.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(29)	53.	0.	23.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(30)	77.	1.	0.	0.	27.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(31)	100.	1.	0.	0.	0.	0.	0.	0.	13.	0.	0.	0.	0.	0.	0.
(32)	92.	0.	0.	0.	0.	0.	10.	0.	0.	0.	0.	0.	0.	0.	0.
(33)	53.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(34)	96.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(35)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(36)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(37)	69.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(38)	83.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(39)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	77.	1.	0.	0.	28.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	70.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(42)	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(43)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	96.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(45)	77.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	30.	0.	0.
(46)	95.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	0.	0.	0.
(47)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	21.	0.
(48)	100.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(49)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(27)	35.	2.	0.												
(28)	96.	0.	0.	0.											
(29)	53.	0.	0.	0.	0.										
(30)	77.	1.	0.	0.	0.	0.									
(31)	100.	1.	0.	0.	0.	0.	0.								
(32)	92.	0.	0.	0.	0.	0.	0.	0.							
(33)	53.	1.	0.	0.	0.	24.	0.	0.	0.						
(34)	96.	0.	0.	0.	20.	0.	0.	0.	0.	0.					
(35)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(36)	70.	1.	8.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(37)	69.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(38)	83.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(39)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	70.	1.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(42)	86.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(43)	86.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	96.	1.	0.	0.	0.	0.	0.	0.	0.	0.	16.	0.	0.	0.	0.
(45)	77.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(46)	95.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(47)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(48)	100.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(49)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	77.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(40)	77.	1.	0.										
(41)	70.	1.	0.	0.									
(42)	86.	0.	1.	0.	0.								
(43)	86.	1.	0.	0.	0.	3.							
(44)	96.	1.	0.	0.	0.	0.	0.						
(45)	77.	0.	0.	0.	0.	0.	0.	0.					
(46)	95.	0.	0.	0.	0.	0.	0.	0.	0.				
(47)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.			
(48)	100.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(49)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(50)	77.	1.	0.	0.	0.	0.	0.	0.	32.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATION	6.	8.	3.	5.	2.	6.	2.	8.	99999.
NUMBER ALLOCATED	5.	3.	2.	4.	1.	0.	0.	0.	0.

TOTAL DISTANCE FOR SYSTEM 19054.00

* * * * * * * * * *

PROBLEM TWO

DEMAND POINT	QUANTITY REQUIRED	DISTANCES TO TERMINALS TERMINAL 1	TERMINAL 2	TERMINAL 3	TERMINAL 4	TERMINAL 5
1	15	1800	1130	934	672	105
2	28	2118	1451	1219	699	230
3	16	1781	1295	664	154	742
4	38	960	207	966	1543	1309
5	40	2405	1739	1650	1068	598
6	25	1958	1293	1204	877	217
7	34	462	441	776	1456	1424
8	16	1431	776	693	730	461
9	24	1644	1059	740	461	284
10	28	1772	1107	948	686	134
11	36	1701	1123	811	549	191
12	18	1241	968	271	805	1232
13	34	512	523	693	1401	1482
14	28	1094	487	471	894	805
15	18	1700	1039	945	726	285
16	38	1539	989	573	415	508
17	16	1571	940	756	610	330
18	18	2081	1421	1181	719	197
19	25	500	699	1427	2053	1937
20	30	1431	1210	513	814	1319
21	24	1536	951	641	508	354
22	28	1648	1256	543	400	934
23	15	2207	1695	1090	314	865
24	36	1255	739	324	668	721
25	27	1116	595	258	810	937
26	18	1640	979	883	782	348
27	36	1456	1000	287	505	897
28	35	716	1558	1461	2197	2533
29	24	1632	1065	668	432	394
30	17	1534	1054	417	366	758
31	23	1455	701	772	784	550
32	21	1239	395	715	1105	871
33	22	1670	1125	634	252	559
34	32	1739	1416	689	493	1093
35	34	2267	1607	1370	855	386
36	18	955	390	385	1012	942
37	19	1326	739	570	662	588
38	37	2186	1526	1289	766	305
39	16	653	1341	1091	1810	2163
40	24	802	1356	1970	2654	2571
41	20	1368	823	404	558	591
42	40	759	1609	1776	2523	2648
43	26	871	1310	2038	2756	2522
44	15	732	1021	1749	2467	2333
45	26	1357	777	503	611	628

PROBLEM TWO
(CONTINUED)

		DISTANCES TO TERMINALS				
DEMAND POINT	QUANTITY REQUIRED	TERMINAL 1	TERMINAL 2	TERMINAL 3	TERMINAL 4	TERMINAL 5
46	34	1251	771	182	649	811
47	18	2313	1833	1196	467	1046
48	26	1670	1005	911	668	228
49	23	2111	1451	1205	630	245
50	17	1005	584	186	895	1135

TRUCKS

CAPACITY	NUMBER
100	5
90	6
80	3
70	4
60	2
50	5
40	3
30	6
20	2

The best solution shown below was obtained with the minimum computation time using the proposed 3-decision look ahead method with IDEPTH=3.

PROBLEM OF 5 TERMINALS WITH 50 DEMAND POINTS

DISTANCE MATRIX

(1)	105.														
(2)	230.	331.													
(3)	154.	702.	787.												
(4)	207.	1214.	1535.	1504.											
(5)	598.	653.	399.	1185.	1823.										
(6)	217.	207.	345.	902.	1377.	449.									
(7)	441.	1338.	1656.	1354.	583.	1943.	1496.								
(8)	461.	366.	687.	656.	850.	975.	540.	969.							
(9)	284.	230.	494.	476.	1143.	876.	430.	1182.	293.						
(10)	134.	33.	351.	716.	1191.	632.	191.	1310.	343.	244.					
(11)	191.	123.	408.	579.	1207.	769.	323.	1239.	315.	107.	137.				
(12)	271.	1173.	1458.	653.	1175.	1819.	1373.	875.	936.	943.	1187.	1050.			
(13)	512.	1385.	1701.	1282.	685.	1989.	1543.	102.	1016.	1169.	1357.	1233.	784.		
(14)	471.	707.	1025.	808.	672.	1311.	865.	632.	338.	571.	679.	695.	704.	679.	
(15)	285.	190.	511.	741.	1123.	699.	252.	1238.	271.	265.	167.	202.	1188.	1284.	606.
(16)	415.	454.	718.	364.	1143.	1100.	654.	1069.	296.	224.	468.	331.	734.	1027.	502.
(17)	330.	233.	556.	582.	1024.	844.	398.	1105.	158.	154.	212.	152.	999.	1156.	478.
(18)	197.	301.	80.	812.	1505.	398.	294.	1620.	657.	472.	321.	368.	1418.	1666.	988.
(19)	500.	1842.	2163.	1963.	628.	2451.	2005.	700.	1478.	1770.	1819.	1835.	1571.	792.	1162.
(20)	513.	1270.	1449.	662.	1417.	1916.	1470.	1117.	1085.	1040.	1284.	1147.	245.	1026.	946.
(21)	354.	295.	580.	480.	1035.	941.	495.	1074.	186.	108.	309.	172.	882.	1061.	483.
(22)	400.	892.	1035.	248.	1479.	1433.	1092.	1282.	764.	662.	906.	769.	403.	1191.	828.
(23)	314.	919.	793.	426.	1857.	1191.	1067.	1770.	1009.	775.	952.	854.	994.	1708.	1208.
(24)	324.	662.	931.	567.	930.	1308.	901.	793.	391.	468.	715.	539.	565.	750.	272.
(25)	258.	779.	1099.	706.	783.	1456.	1010.	648.	499.	590.	824.	656.	499.	604.	231.
(26)	348.	253.	575.	713.	1063.	785.	338.	1178.	215.	326.	230.	252.	1128.	1224.	546.
(27)	287.	848.	1086.	386.	1188.	1494.	1048.	1040.	644.	618.	862.	725.	325.	957.	573.
(28)	716.	2368.	2695.	2056.	1649.	3052.	2606.	1169.	2095.	2186.	2420.	2245.	1403.	1134.	1801.

(29)	394.	340.	604.	366.	1146.	986.	540.	1162.	301.	113.	354.	217.	833.	1120.	569.
(30)	366.	709.	947.	247.	1266.	1355.	909.	1107.	544.	502.	723.	586.	464.	1035.	608.
(31)	550.	455.	776.	745.	764.	1064.	618.	988.	89.	384.	432.	448.	1015.	1040.	361.
(32)	395.	776.	1097.	1066.	430.	1385.	939.	794.	412.	705.	753.	769.	956.	841.	252.
(33)	252.	519.	725.	187.	1299.	1165.	719.	1200.	451.	290.	533.	396.	686.	1158.	638.
(34)	493.	1049.	1138.	351.	1604.	1536.	1253.	1373.	944.	820.	1063.	926.	498.	1282.	989.
(35)	386.	487.	187.	974.	1691.	216.	445.	1806.	738.	659.	507.	557.	1607.	1851.	1173.
(36)	385.	845.	1163.	911.	581.	1449.	1003.	493.	476.	691.	817.	748.	656.	540.	145.
(37)	570.	448.	818.	611.	857.	1107.	661.	864.	151.	321.	475.	376.	815.	930.	252.
(38)	305.	406.	97.	884.	1610.	304.	365.	1725.	775.	578.	426.	476.	1526.	1770.	1092.
(39)	653.	2003.	2325.	1658.	1501.	2682.	2236.	918.	1722.	1816.	2050.	1882.	1005.	818.	1430.
(40)	802.	2476.	2797.	2552.	1262.	3085.	2639.	1198.	2112.	2405.	2453.	2469.	2043.	1278.	1819.
(41)	404.	532.	817.	476.	980.	1178.	802.	898.	288.	338.	546.	409.	645.	856.	336.
(42)	759.	2541.	2876.	2393.	1633.	3163.	2716.	1220.	2189.	2402.	2530.	2459.	1806.	1270.	1851.
(43)	871.	2427.	2748.	2575.	1213.	3036.	2590.	1267.	2063.	2356.	2404.	2420.	2112.	1347.	1773.
(44)	732.	2138.	2459.	2286.	924.	2747.	2301.	1022.	1774.	2067.	2115.	2131.	1891.	1112.	1484.
(45)	503.	487.	854.	541.	912.	1147.	701.	895.	193.	300.	515.	364.	746.	869.	290.
(46)	182.	752.	1037.	530.	959.	1468.	1022.	824.	511.	558.	766.	629.	425.	752.	344.
(47)	467.	1097.	981.	541.	2010.	1379.	1248.	1886.	1162.	928.	1122.	985.	1077.	1814.	1349.
(48)	228.	133.	454.	683.	1089.	742.	296.	1204.	239.	207.	110.	132.	1154.	1250.	572.
(49)	245.	331.	39.	748.	1535.	437.	359.	1650.	712.	492.	351.	392.	1372.	1696.	1018.
(50)	186.	975.	1297.	776.	791.	1654.	1208.	590.	697.	788.	1022.	852.	384.	507.	403.

DISTANCE MATRIX

(16)	444.														
(17)	160.	284.													
(18)	481.	697.	526.												
(19)	1751.	1772.	1652.	2133.											
(20)	1337.	834.	1114.	1474.	1813.										
(21)	277.	167.	121.	540.	1663.	997.									
(22)	927.	468.	748.	1060.	1922.	429.	631.								
(23)	996.	729.	924.	855.	2370.	911.	822.	589.							
(24)	642.	301.	476.	904.	1405.	780.	367.	549.	956.						
(25)	751.	423.	585.	1132.	1261.	741.	484.	661.	1123.	146.					
(26)	86.	415.	131.	544.	1691.	1245.	248.	879.	1101.	582.	691.				
(27)	896.	409.	679.	1094.	1666.	445.	562.	256.	812.	354.	405.	836.			
(28)	2347.	2029.	2181.	2729.	1234.	1553.	2080.	1810.	2397.	1742.	1596.	2287.	1701.		
(29)	375.	125.	216.	582.	1777.	930.	114.	552.	708.	394.	516.	347.	508.	2107.	
(30)	713.	273.	553.	953.	1720.	561.	436.	210.	673.	336.	459.	684.	137.	1831.	389.
(31)	364.	374.	265.	746.	1392.	1174.	276.	844.	1098.	469.	580.	304.	723.	2176.	390.
(32)	685.	706.	586.	1067.	1056.	1198.	597.	1060.	1419.	509.	457.	625.	825.	1940.	711.
(33)	555.	159.	396.	762.	1800.	783.	294.	375.	570.	423.	554.	527.	346.	2058.	180.
(34)	1085.	642.	926.	1163.	2070.	359.	805.	181.	582.	730.	821.	1053.	416.	1901.	710.
(35)	667.	888.	712.	186.	2319.	1636.	729.	1222.	980.	1096.	1319.	729.	1282.	2915.	769.
(36)	744.	622.	616.	1127.	1056.	898.	583.	866.	1326.	349.	205.	685.	610.	1662.	689.
(37)	402.	258.	251.	783.	1414.	964.	213.	669.	976.	250.	350.	344.	523.	1946.	323.
(38)	586.	807.	631.	105.	2238.	1546.	648.	1132.	890.	1015.	1238.	649.	1201.	2721.	688.
(39)	1977.	1664.	1811.	2358.	1147.	1153.	1710.	1412.	1999.	1372.	1226.	1917.	1330.	398.	1757.
(40)	2385.	2267.	2286.	2767.	657.	2233.	2297.	2450.	2968.	1991.	1846.	2325.	2234.	970.	2412.
(41)	543.	172.	354.	777.	1498.	794.	234.	514.	872.	130.	253.	483.	353.	1848.	264.
(42)	2458.	2297.	2329.	2839.	1134.	1955.	2294.	2212.	2799.	2014.	1874.	2399.	2027.	403.	2390.
(43)	2336.	2357.	2237.	2718.	611.	2302.	2245.	2519.	3070.	2016.	1872.	2276.	2277.	1145.	2362.
(44)	2047.	2068.	1948.	2429.	322.	2138.	1956.	2244.	2781.	1727.	1583.	1987.	1988.	1227.	2073.

(45)	442.	211.	276.	823.	1452.	895.	192.	598.	925.	200.	309.	382.	454.	1905.	279.
(46)	763.	391.	574.	997.	1437.	640.	457.	503.	956.	144.	176.	703.	229.	1637.	484.
(47)	1193.	873.	1077.	1036.	2499.	984.	975.	672.	198.	1108.	1238.	1254.	912.	2480.	861.
(48)	61.	388.	110.	424.	1717.	1247.	221.	869.	939.	608.	717.	119.	783.	2313.	317.
(49)	511.	716.	556.	119.	2163.	1410.	564.	996.	754.	931.	1048.	574.	1047.	2644.	596.
(50)	949.	621.	783.	1330.	1241.	612.	682.	733.	1202.	344.	195.	889.	473.	1402.	714.

DISTANCE MATRIX

(31)	624.														
(32)	840.	326.													
(33)	209.	540.	861.												
(34)	397.	1013.	1241.	530.											
(35)	1138.	932.	1253.	949.	1325.										
(36)	664.	500.	358.	756.	1026.	1312.									
(37)	449.	226.	423.	406.	850.	970.	372.								
(38)	1057.	851.	1172.	868.	1235.	93.	1230.	889.							
(39)	1466.	1806.	1630.	1725.	1503.	2459.	1335.	1576.	2464.						
(40)	2305.	2026.	1690.	2398.	2541.	2953.	1691.	2062.	2872.	1366.					
(41)	294.	370.	546.	302.	695.	966.	454.	170.	885.	1478.	2096.				
(42)	2157.	2213.	1997.	2410.	2303.	3025.	1713.	2084.	2944.	800.	652.	2126.			
(43)	2331.	1977.	1641.	2512.	2610.	2904.	1667.	2070.	2823.	1541.	175.	2109.	827.		
(44)	2042.	1688.	1352.	2223.	2392.	2615.	1378.	1781.	2534.	1369.	360.	1820.	915.	289.	
(45)	383.	269.	478.	355.	779.	1010.	410.	70.	929.	1535.	2093.	95.	2115.	2063.	1774.
(46)	283.	590.	596.	452.	645.	1186.	381.	390.	1105.	1273.	2022.	220.	1958.	2048.	1759.
(47)	779.	1251.	1572.	714.	653.	1167.	1443.	1120.	1078.	2082.	3084.	1016.	2882.	3110.	2821.
(48)	686.	330.	651.	497.	1027.	610.	710.	368.	529.	1943.	2351.	509.	2428.	2302.	2013.
(49)	908.	776.	1097.	686.	1099.	229.	1156.	814.	136.	2274.	2797.	801.	2869.	2748.	2459.
(50)	529.	778.	655.	698.	833.	1517.	303.	548.	1436.	1032.	1784.	450.	1721.	1852.	1563.

DISTANCE MATRIX

(46)	321.				
(47)	1069.	1062.			
(48)	408.	729.	1135.		
(49)	854.	1021.	942.	454.	
(50)	507.	246.	1308.	915.	1246.

```
* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE -- 1 --10 --
   TOTAL DISTANCE OF ROUTE IS    272.00
   QUANTITY REQUIRED ON ROUTE IS  43.00  CAPACITY OF TRUCK IS  50.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 4  DEMAND POINTS ROUTED ARE -- 3 --34 --22 --30 --
   TOTAL DISTANCE OF ROUTE IS   1262.00
   QUANTITY REQUIRED ON ROUTE IS  93.00  CAPACITY OF TRUCK IS 100.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 4 --32 --
   TOTAL DISTANCE OF ROUTE IS   1032.00
   QUANTITY REQUIRED ON ROUTE IS  59.00  CAPACITY OF TRUCK IS  60.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE -- 6 --15 --26 --48 --
   TOTAL DISTANCE OF ROUTE IS    902.00
   QUANTITY REQUIRED ON ROUTE IS  87.00  CAPACITY OF TRUCK IS  90.00
* * * * * * * * * *
```

```
*  *  *  *  *  *  *  *  *  *
   TERMINAL 2  DEMAND POINTS ROUTED ARE -- 7 --13 --
   TOTAL DISTANCE OF ROUTE IS   1066.00
   QUANTITY REQUIRED ON ROUTE IS  68.00  CAPACITY OF TRUCK IS  70.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 5  DEMAND POINTS ROUTED ARE -- 9 --11 --
   TOTAL DISTANCE OF ROUTE IS    582.00
   QUANTITY REQUIRED ON ROUTE IS  60.00  CAPACITY OF TRUCK IS  60.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 3  DEMAND POINTS ROUTED ARE --12 --20 --27 --
   TOTAL DISTANCE OF ROUTE IS   1248.00
   QUANTITY REQUIRED ON ROUTE IS  84.00  CAPACITY OF TRUCK IS  90.00
*  *  *  *  *  *  *  *  *  *

*  *  *  *  *  *  *  *  *  *
   TERMINAL 3  DEMAND POINTS ROUTED ARE --14 --37 --45 --41 --
   TOTAL DISTANCE OF ROUTE IS   1292.00
   QUANTITY REQUIRED ON ROUTE IS  93.00  CAPACITY OF TRUCK IS 100.00
*  *  *  *  *  *  *  *  *  *
```

```
* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE --17 -- 8 --31 --21 --
   TOTAL DISTANCE OF ROUTE IS   1207.00
   QUANTITY REQUIRED ON ROUTE IS  79.00  CAPACITY OF TRUCK IS  80.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 5  DEMAND POINTS ROUTED ARE --18 -- 5 --35 --
   TOTAL DISTANCE OF ROUTE IS   1197.00
   QUANTITY REQUIRED ON ROUTE IS  92.00  CAPACITY OF TRUCK IS 100.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 1  DEMAND POINTS ROUTED ARE --19 --44 --43 --40 --
   TOTAL DISTANCE OF ROUTE IS   2088.00
   QUANTITY REQUIRED ON ROUTE IS  90.00  CAPACITY OF TRUCK IS  90.00
* * * * * * * * * *

* * * * * * * * * *
   TERMINAL 4  DEMAND POINTS ROUTED ARE --23 --47 --
   TOTAL DISTANCE OF ROUTE IS    979.00
   QUANTITY REQUIRED ON ROUTE IS  33.00  CAPACITY OF TRUCK IS  40.00
* * * * * * * * * *
```

* * * * * * * * * *

TERMINAL 3 DEMAND POINTS ROUTED ARE --24 --25 --36 --50 --

TOTAL DISTANCE OF ROUTE IS 1164.00

QUANTITY REQUIRED ON ROUTE IS 98.00 CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 4 DEMAND POINTS ROUTED ARE --29 --16 --33 --

TOTAL DISTANCE OF ROUTE IS 968.00

QUANTITY REQUIRED ON ROUTE IS 84.00 CAPACITY OF TRUCK IS 90.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 5 DEMAND POINTS ROUTED ARE --38 -- 2 --49 --

TOTAL DISTANCE OF ROUTE IS 686.00

QUANTITY REQUIRED ON ROUTE IS 88.00 CAPACITY OF TRUCK IS 90.00

* * * * * * * * * *

* * * * * * * * * *

TERMINAL 1 DEMAND POINTS ROUTED ARE --39 --28 --42 --

TOTAL DISTANCE OF ROUTE IS 2213.00

QUANTITY REQUIRED ON ROUTE IS 91.00 CAPACITY OF TRUCK IS 100.00

* * * * * * * * * *

RCUTE MATRIX

	DEMAND													
(1)	43.	1.												
(2)	88.	0.	0.											
(3)	93.	1.	0.	0.										
(4)	59.	1.	0.	0.	0.									
(5)	92.	0.	0.	0.	0.	0.								
(6)	87.	1.	0.	0.	0.	0.	0.							
(7)	68.	1.	0.	0.	0.	0.	0.	0.						
(8)	79.	0.	0.	0.	0.	0.	0.	0.	0.					
(9)	60.	1.	0.	0.	0.	0.	0.	0.	0.	0.				
(10)	43.	1.	32.	0.	0.	0.	0.	0.	0.	0.	0.			
(11)	60.	1.	0.	0.	0.	0.	0.	0.	0.	0.	27.	0.		
(12)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(13)	68.	1.	0.	0.	0.	0.	0.	0.	8.	0.	0.	0.	0.	0.
(14)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(15)	87.	0.	0.	0.	0.	0.	0.	31.	0.	0.	0.	0.	0.	0.
(16)	84.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(17)	79.	1.	0.	0.	0.	0.	0.	0.	0.	14.	0.	0.	0.	0.
(18)	92.	1.	0.	0.	0.	0.	26.	0.	0.	0.	0.	0.	0.	0.
(19)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(20)	84.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	19.
(21)	79.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(22)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(23)	33.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(24)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(25)	98.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(26)	87.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(27)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(28)	91.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(29)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(30)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(31)	79.	0.	0.	0.	0.	0.	0.	0.	0.	6.	0.	0.	0.	0.
(32)	59.	1.	0.	0.	0.	33.	0.	0.	0.	0.	0.	0.	0.	0.
(33)	84.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(34)	93.	0.	0.	0.	29.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(35)	92.	1.	0.	0.	0.	0.	11.	0.	0.	0.	0.	0.	0.	0.
(36)	98.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(37)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(38)	88.	1.	0.	23.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(39)	91.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(42)	91.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(43)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(45)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(46)	34.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(47)	33.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(48)	87.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(49)	88.	1.	0.	25.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(14)	93.	1.	0.												
(15)	87.	0.	0.	0.											
(16)	84.	0.	0.	0.	0.										
(17)	79.	1.	0.	0.	0.	0.									
(18)	92.	1.	0.	0.	0.	0.	0.								
(19)	90.	1.	0.	0.	0.	0.	0.	0.							
(20)	84.	0.	0.	0.	0.	0.	0.	0.	0.						
(21)	79.	1.	0.	0.	0.	0.	0.	0.	0.	0.					
(22)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(23)	33.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(24)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(25)	98.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	24.	
(26)	87.	0.	0.	0.	18.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(27)	84.	1.	0.	0.	0.	0.	0.	0.	0.	28.	0.	0.	0.	0.	0.
(28)	91.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(29)	84.	1.	0.	0.	0.	13.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(30)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	17.	0.	0.	0.
(31)	79.	0.	0.	0.	0.	0.	0.	0.	0.	0.	15.	0.	0.	0.	0.
(32)	59.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(33)	84.	1.	0.	0.	0.	20.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(34)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	12.	0.	0.	0.
(35)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(36)	98.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	22.
(37)	93.	0.	0.	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(38)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(39)	91.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(42)	91.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(43)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	90.	0.	0.	0.	0.	0.	0.	0.	7.	0.	0.	0.	0.	0.	0.
(45)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(46)	34.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(47)	33.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16.	0.	0.
(48)	87.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(49)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ROUTE MATRIX

(27)	84.	1.	0.												
(28)	91.	0.	0.	0.											
(29)	84.	1.	0.	0.	0.										
(30)	93.	1.	0.	0.	0.	0.									
(31)	79.	0.	0.	0.	0.	0.	0.								
(32)	59.	1.	0.	0.	0.	0.	0.	0.							
(33)	84.	1.	0.	0.	0.	0.	0.	0.	0.						
(34)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.					
(35)	92.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.				
(36)	98.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
(37)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(38)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(39)	91.	1.	0.	0.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(40)	90.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(41)	93.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(42)	91.	1.	0.	0.	3.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(43)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(44)	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(45)	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	0.
(46)	34.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(47)	33.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(48)	87.	1.	21.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(49)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(50)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	30.	0.	0.

ROUTE MATRIX

(40)	90.	1.	0.										
(41)	93.	1.	0.	0.									
(42)	91.	1.	0.	0.	0.								
(43)	90.	0.	0.	1.	0.	0.							
(44)	90.	0.	0.	0.	0.	0.	2.						
(45)	93.	0.	0.	0.	9.	0.	0.	0.					
(46)	34.	2.	0.	0.	0.	0.	0.	0.	0.				
(47)	33.	1.	0.	0.	0.	0.	0.	0.	0.	0.			
(48)	87.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.		
(49)	88.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	
(50)	98.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TRUCK ALLOCATION

TRUCK CAPACITY	100.	90.	80.	70.	60.	50.	40.	30.	20.
ASSUMED ALLOCATION	5.	6.	3.	4.	2.	5.	3.	6.	99999.
NUMBER ALLOCATED	5.	5.	1.	1.	2.	1.	1.	0.	0.

TOTAL DISTANCE FOR SYSTEM 18522.00

* * * * * * * * * *

EVALUATION OF SOME HEURISTIC LOOK AHEAD RULES FOR MULTIPLE TERMINAL DELIVERY PROBLEMS

by

ROBERT WILLIAM HERING

B.S., Kansas State University, 1968

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

This work is concerned with the development of an improved selection criteria in the form of an extended look ahead feature which can be used to obtain an optimal or near optimal solution to large single and multiple terminal carrier routing problems. The carrier routing problems which were considered in this research are those which have deterministic demands, symmetrical distance matricies, and the same or different capacity delivery vehicles.

At the present time, the only solution methods that are computationally feasible for solving large carrier routing problems are those that are based upon heuristic programming. One of the major criticisms of the existing heuristic programming methods is that once two demand points are linked on a particular route at a given stage, they are not reassigned and will appear connected in the final solution. Thus, this procedure may lead to a suboptimal solution. It was felt that an extended look ahead selection criteria which requires considering the consequences of several decisions in sequence would provide a way around this problem.

The procedure was developed for the single terminal carrier routing problem and then extended to solve the more general multiple terminal carrier routing problem. A computer program was written for solving the single or multiple terminal terminal carrier routing problem with this method.

Several example problems were developed for both the single and multiple terminal cases in order to evaluate the effectiveness of this look ahead method of solution. Relatively good success was obtained using this procedure.