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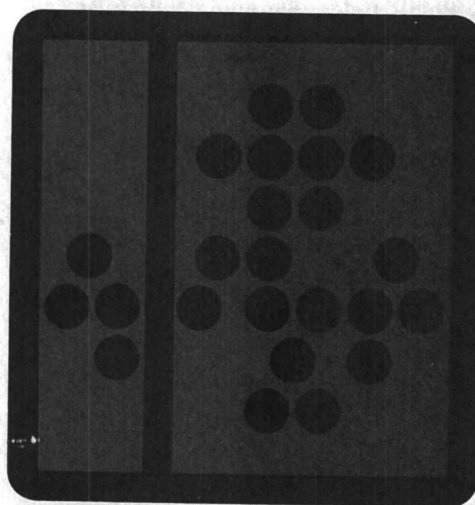
SOUTHERN METHODIST UNIV

*Optimization Models for use in
a Delivery Truck Environment*

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IN A DELIVERY TRUCK
ENVIRONMENT**

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EXECUTIVE SUMMARY

There are many optimization procedures and algorithms that can be implemented for delivery operations. The thrust of this paper concerns the following topics and their relevance to delivery vehicles: equipment replacement, truck utilization and optimization, and efficient routing practices.

An important decision facing all businesses is when to replace equipment. Equipment can be industrial machinery, office machines, or vehicles. In our consideration here, we look at the gains in recent years in the area of equipment replacement because of the availability of interactive financial planning languages such as IFPS. The development of an IFPS model for an optimal equipment replacement strategy for a relatively small delivery fleet is presented and examined here. Questions such as the lease versus buy decision are investigated.

Next, a linear programming model is developed which determines an organization's optimal number of vehicles to maintain in order to meet current demands while staying within specified constraints. Questions are answered concerning which routes should be run on which days in order to meet organizational constraints and not violate current organizational structure. The resulting model that was developed was solved using LINDO. A sensitivity analysis was performed by the authors to present management with two different operation strategies.

Finally, the routing of the trucks was investigated. We investigated the problem of the m routes n stops routing problem. The model was developed as a 'traveling salesman problem' because the trucks started

and ended at a central location. The algorithm we present can be applied to any travelling salesman problem with n stops on a route with a relatively small n . The unique structure of our problem allowed us to develop a general policy to follow in the routing of the trucks. The number of stops in each route of our problem was small and we were able to develop a 'try-all-possibilities' algorithm rather than utilize heuristics. The code for our algorithm as well as the output is presented.

The results of our study can be applicable not only to small delivery fleet operations but any type of organization that maintains fleet vehicles.

BACKGROUND AND DESCRIPTION OF ORGANIZATION

D'Ann Sales, Inc. is a privately owned Tupperware Home Parties distributor in the Dallas area. D'Ann Sales is located on Gamma Rd. in Farmers Branch. Their headquarters serve as a warehouse, a meeting room, and also houses their administrative offices. Tupperware Home Parties, Inc. , a multi-level marketing organization, is based upon the "home party" principle. The Tupperware representatives, dealers, go into the hostesses' homes and conduct parties at which time customers see the products and place their orders. The dealers submit their orders on a weekly basis to the distributor who fills the orders out of inventory on hand. The dealers can either pick up their Tupperware at the warehouse or have it delivered to their home.

D'Ann Sales supports approximately 50 managers who each have an average of 15-20 dealers working below them. Both the dealers and the managers hold parties and deliver Tupperware. Because of the added responsibility placed upon the managers in training and assisting the dealers, they receive additional benefits. They receive commissions of their dealers' sales, receive a company car, and have their tupperware delivered to their homes for free. The D'Ann Sales' representatives have weekly meetings at the distribution center on Mondays to discuss sales strategy, view new product releases, and place their orders for the week. The orders are filled with inventory on hand and deliveries begin as early as that night. The deliveries continue until all have been completed by Wednesday evening. The quick turn-around allows the managers to get the Tupperware back to their customers on a timely basis.

As the warehouse workers begin filling the orders, the administrative staff begins processing the paperwork associated with each order. D'Ann's computerized

accounting/inventory system bills the dealers for the Tupperware as well as keeps track of inventory records for re-ordering purposes. The consistency of their sales over a three week time period allows them to use a Just-in-Time inventory procedure. If this week is week 2, they order Tupperware for use in week 4 based upon the sales from this week. The inventory of Tupperware on hand this week is based upon sales from week 1. The Just-in-Time procedure allows them to keep a week's inventory on-the-shelf for next week's orders. This procedure is aided by the computer's accurate records as well as the short lead time in receiving their merchandise. D'Ann is able to order Tupperware and receive it within 3 to 4 working days. These factors have led to a structural week with which they have had great success.

To restate, the orders are placed at the warehouse by the dealers on Monday. The warehouse fills and delivers the orders on Monday, Tuesday, and Wednesday. Thursday is spent unloading the shipments of new Tupperware and restocking the shelves for the next week's orders. D'Ann is closed on Friday except for administrative purposes.

D'Ann Sales makes deliveries by means of Ford Econoline Trucks. Currently, they own five of these vehicles which range in age from 7 to 9 years old. At the current level of operation, only three of these trucks are utilized and are only used three days a week. The other two are left idle until a major breakdown occurs on one of the operating trucks or when increased sales demand extra deliveries.

The current deliveries are divided up into 7 routes. On each route, are managers who have their Tupperware delivered weekly. When a *dealer* decides to have *her* order delivered, the shipping clerk determines which route she should be placed on based upon her location relative to the managers in the area.

After looking into the background of this organization, we decided to focus our

study upon the utilization of their trucks. Three areas were researched. First, we investigated the problem of *when* D'ann Sales should replace their trucks. We believed that the trucks they are operating are beyond their economic life. We constructed an optimum equipment replacement strategy for D'Ann Sales' truck fleet based upon their current maintenance and repair costs. We also looked into the question of leasing versus owning trucks. Would it be cheaper for them to lease as opposed to owning their trucks? Would it be cheaper to lease a back up rather than own an additional truck for emergencies?

Next, we investigated the *number* of trucks D'Ann should keep on hand. We looked into such areas as which trucks they should run on which route. Included in this research was an investigation as to the minimum and maximum number of trucks they could have if they changed the current structure of their deliveries. (e.g. the number of hours an individual truck runs per day.) We developed a model that determines the minimum number of trucks as well which days of the week would be 'delivery days' for which routes based upon current company policies and structure which they wished to maintain.

The final area we investigated was D'Ann's routing of the trucks. A shortest path program was developed that minimizes total distance travelled during deliveries. We were able to base our model upon the classic "travelling salesman problem" since the trucks leave from and return to the warehouse. The stops on the routes were assumed to be the managers' homes who receive orders every week, and it was desired to give a general route to follow which would allow for the addition of stops for any dealers who wish to have their orders delivered in a particular week.

EQUIPMENT REPLACEMENT ANALYSIS

History and Background

Equipment replacement is a managerial tool that has been overlooked as being significant in many operations. Equipment replacement decisions, however, are the most frequently made business decisions. Deciding not to replace today, is a decision to maintain a machine. (Shore, p. 58). The philosophy behind equipment replacement is there exists an optimum time to replace a machine. "Optimum life of motor vehicles employed in business and industry is that service life which minimizes costs of ownership and operation. Annual maintenance and operating costs tend to rise as the vehicle ages, while fixed annual charges decrease as the average useful life increases." (Brennan, p. 297) Deterioration increases with the age of the truck, and with this, increased maintenance and repair costs are observed. As the truck ages, the resale value decreases, and depreciation eventually ceases. As these costs and benefits oppose each other, an optimum time is obtained. The difference between the benefits and costs must be evaluated in terms of its present value.

A significant step in the advancement of equipment replacement models began in 1949 by George Terbourgh. Terbourgh was the "first to make quite explicit the role that the future plays in making the replacement decision." (Shore, p. 84) The future's role in deciding how much tomorrow's money is valued today has hindered decision makers' utilization of good equipment replacement strategies. The formulas used in the 1950's to solve replacement problems were extremely lengthy and technical and obtaining the solution to these problems was extremely tedious. (See Appendix A for an example of formulas used.)

Recently, equipment replacement has been able to become an important

managerial tool because of the availability of spread sheet languages and programming packages such as IFPS (Interactive Financial Planning System). With the use of these packages, the calculation of the time value of money becomes a simple one-function operation rather than a tedious one.

IFPS is a package which allows the user to input column-like data and manipulate these columns by summing, adding, etc. either across the rows or down the columns. The user is able to obtain immediate feedback and thus, is able to communicate efficiently with the machine. IFPS has several built-in functions including a **Net Present Value Calculation(NPVC)** function which finds the present value of a future sum of money. IFPS is a useful tool because of its "What-If" function allowing the user to examine different alternatives to find the optimal solution.

D'Ann Sales currently owns five trucks which range in age from 7 to 9 years and have been fully depreciated. We wanted to construct a model which would find an optimal replacement strategy for these trucks. Are these trucks beyond their economic life? Would D'Ann Sales benefit from replacing their trucks periodically? At what time should a truck be replaced? Because of the useful functions of IFPS, we were able to solve D'Ann Sales' truck replacement problem by developing a suitable IFPS model.

Technical Analysis

A complete listing of the IFPS model is in Appendix B and should be referred to in the following sections.

Definition of Variables:

Columns1-12: Defines 12 years as our investigation period.

Investment: The cost of a new truck today. This cost is \$12,700.

Inflation: We assumed an inflation rate of 5% after consulting with the tax staff at Arthur Andersen & Co.

Depreciation: D'Ann Sales uses a 5 year straight-line depreciation schedule. The formula for straight line depreciation is:

$$(\text{Investment}-\text{Salvage Value})/\text{number of years}$$

In the case of D'Ann Sales this figure is:

$$(\$12700-\$500)/5 = \$2440 \text{ per year for five years.}$$

Maintenance: Total annual costs of maintenance are \$110 per truck.

The cost breakdown is as follows:

Tune-up \$60.00

Oil Changes \$30.00
(3 per year)

Miscellaneous \$20.00 (wiper blades, fluids,
 radiator flushes, etc.)

Tires: Tires are replaced on each truck every 2 years at a cost of \$80 per tire. Each truck has 6 tires, thus, the total cost for tires

per truck is \$480 every other year.

Breakdown: D'Ann Sales currently experiences a major breakdown each year ranging from \$800 to \$1200. Assuming that the cost of a breakdown will increase with the age of the vehicle, we assumed an average annual breakdown cost of \$1200 for the oldest vehicle. In the case of D'Ann Sales, the oldest vehicle is 9 years. We also assumed that this average annual breakdown cost would increase linearly. Therefore, dividing \$1200 over 8 years (we assumed that there would be no breakdown expense during first year of ownership due to maintenance contracts) we obtained \$150 as the increase in breakdown expense on a yearly basis. This implies that the breakdown expense for a vehicle would be \$150 for year 2, \$300 for year 3, etc. While this figure is probabilistic, our results will show that this expense will not alter the solution drastically.

Expenses: Expenses are the total of Maintenance, Tire, and Breakdown costs as defined above. The summation of these variables is then multiplied by Inflation to account for rising costs of operation .

Salvage and Salvage Value: The figures for the Salvage Value were derived based upon current dealer resale values for Econoline trucks of varying age. We obtained these resale values from a

Ford dealership. For a truck sold during the first year of ownership, this value is \$8000. The values then decrease by different percentages (defined by Salfac). The dealership did not have resale values for vehicles older than 10 years (\$2,000 was the resale value for a 10 year old vehicle.) In our model, when the salvage value falls below \$2000, a resale value of \$500 was estimated. (Note: This amount (\$500) is the Salvage Value at the end of the economic life which was used in computing the depreciation above.) The Salfac factors are merely percentages of the new car cost in relation to the book values of the resale values. The percentages were used instead of the actual resale values to allow for different vehicle investment costs to be examined for future decision making. The future figures would be estimates, however, and not exact figures. The IFPS column for Salvage is the same as the resale values from the Ford Dealership.

Discount Rate: Discount Rate is D'Ann Sales' opportunity cost of capital used for computing the present worth of their costs and investments. We initially assumed this rate to be 12%. However, Arthur Andersen & Co. advised us that a 7% Discount Rate would be more realistic.

IFPS CALCULATION

The goal of our IFPS analysis is to obtain the present worth of a truck ranging from 1 to 12 years old. Because the present worths of the vehicles are negative (no income is generated from the trucks), replacement should occur in the year that present worth begins to rise. To compute the present worth, the net present value is computed for Salvage Value and then Net Present Value is computed for Depreciation minus Expenses. (Both of these calculations incorporate the Discount Rate). The Net Present Value column represents the present worth assuming that the vehicle is not replaced. Lines 210-230 of the model compute the present worth assuming the vehicle is replaced at the end of its useful life. An annual annuity payment is computed that has the same present value as the truck and is received for the life of the vehicle. (Gray, 356). This Annuity function, line 220, computes a discount factor which is defined as $1 + \text{Discount Rate}$, and increases at this rate each year. The Net Present Value With Replacement (Column 5 of Results) is then computed by multiplying Net Present Value Without Replacement by the discount factor divided by the discount factor minus 1.

A further explanation of the IFPS functions used in our model can be obtained by consulting Gray.

Interpretation of Results

Consult Appendix B for the model and the output to be discussed here. The Input Data section as well as the Calculation of Salvage PV section of the output merely reiterates the variable values outlined above. We will focus our attention on the first and fifth column of the Results section in analyzing the equipment replacement model for D'Ann Sales. The first column (NPV Without Replacement) shows the net present

value of a vehicle one year from now through 12 years from now. Respectively, these costs are: -\$10620, -\$8767, -\$7116, -\$5646, -\$4338, -\$4409, -\$4476, -\$4538, -\$4597, -\$4652, -\$4703, and -\$4751. The figures rise until year 6 when the NPV decreases to -\$4409. The costs for the fifth column (NPV With Replacement) for years 1 through 12 are -\$32450, -\$16811, -\$10252, -\$6623, -\$4957, -\$5959, -\$6717, -\$6022, -\$5997, -\$5957, -\$6399, and -\$6219. Again, the NPV decreases in year 6. This shows that equipment replacement should occur at the end of year 5, the year with the greatest present value. Both columns (NPV With Replacement and NPV Without Replacement) indicate replacement at the end of year 5. The NPV With Replacement is much less sensitive to differences in variables which is indicated by the difference between the NPV of year 4 and 6 compared to the NPV of year 5. This lessened sensitivity is desired because of the assumptions made in our variables. Since D'Ann Sales will replace their trucks at the end of their life, the NPV With Replacement column is the basis for our solution. The result for the NPV With Replacement column shows the net present value in year 5 to be -\$4957. The net present value in year 6 is -\$5959 which allows a \$1000 flexibility before this solution will not be optimal. Therefore, we can be assured that this 5 year replacement plan is reasonable and reliable for D'Ann Sales.

We tried several "What If" options to allow for change in our variables. In the first case, we tested the option of leasing a vehicle as opposed to buying it new. Leasing agents at Ryder Truck Rentals were consulted, and they estimated the cost of leasing a Ford Econoline Truck to be \$600 per month plus \$.08 per mile. This leasing contract would include full maintenance provided by the rental company. In resolving the model, we zeroed the variables associated with Expenses and Maintenance, as well as the Salvage variables. Using the leasing costs provided by Ryder, our Investment

became \$8409 for leasing a truck for a year. This figure was computed by:

$$\begin{aligned} \$600 \times 12 \text{ months} &= \$7200 \text{ per year} + \$0.08 \times 15,116.4 \text{ miles} = \$8409. \\ & \text{(15,116.4 is D'Ann's average yearly mileage)} \end{aligned}$$

The results of this "What-If" option are printed on page 003 of Appendix B. In this case, we use the first column of the Results section, (NPV Without Replacement), since equipment replacement is not an option with leasing. We would simply renew the lease. The per year values are the summation of this renewal with inflation taken into account.

A comparison of the first column of the "What-If" option to the first column of the original solution follows.

	<u>Leasing</u>	<u>Purchase</u>
1	-\$ 8409	-\$10620
2	-\$16292	-\$ 8767
3	-\$23683	-\$ 7116
4	-\$30612	-\$ 5646
5	-\$37108	-\$ 4338
6	- 43197	-\$ 4409
.	.	.
.	.	.
.	.	.

As can be seen, if a truck is used for one year only, leasing the truck is less expensive than buying it. However, as early as year 2, leasing the vehicle becomes more

expensive than to own it. This trend continues on through year 12. Interestingly enough, if D'Ann Sales experienced certain periods requiring an additional truck because of increased growth or breakdown of an operating truck, they would be able to lease a truck for this period, for up to one year, for less than the cost of buying a new truck.

For the second "What-If" option, we looked at the possibility of arranging a leasing option where D'Ann Sales would be responsible for all maintenance on the vehicle. Again, from column 1 of the Results section on page 004 of Appendix B, the figures show that owning a new truck would be less expensive, unless the truck is kept on hand for fewer than two years. We assumed a yearly leasing cost of \$5000 for illustration purposes only.

The third "What-If" case adjusted the discount rate from 12% to 7% as recommended. A comparison of the results obtained from the fifth columns follow.

	<u>Solution at 12%</u>	<u>Solution at 7%</u>
1	- \$32450	-\$46557
2	- \$16811	- \$20722
3	- \$10252	- \$ 9945
4	- \$ 6623	- \$ 4026
5	- \$ 4957	- \$1514
6	-\$ 5959	- \$ 4053

As can be seen, the optimal replacement time still occurs at the end of year 5.

These results at 7% also indicate a decreased sensitivity compared to the figures at 12%. Since 7% is the more realistic figure for today's economy, the figures obtained are more reliable. The conclusion is that vehicles should be replaced after 5 years of use and this solution is very insensitive to minor changes in the variable values.

LINDO-TRUCK UTILIZATION AND OPTIMIZATION

Analysis of the Situation

Currently, D'Ann Sales operates 3 of their 5 Econoline vans 3 days a week, and warehouse workers double as drivers for the delivery trucks. The extra two trucks are kept on hand in case of increased sales or unexpected breakdowns of operating trucks. The routes' delivery times, besides being limited by the 3 day restriction, are also restricted by the number of orders that can be filled (represented by number of truckloads that can be filled in a day) and by the number of hours warehouse workers can be spared to drive delivery trucks. For our model, these hours were set to be the same as the current structure. Management is interested in not greatly altering the number of hours spent delivering per day or the number of truckloads that could be delivered in one day.

Our goal was to determine the number of trucks needed to service the delivery routes. We used as a variable constraint the number of hours each individual truck could spend driving. That is, if the delivery hour constraint was 6 hours on Monday, they could send four trucks out and have 24 hours worth of delivering, provided that the constraint of the number of truckloads that could be packed would be met. However, if one truck ran 24 hours straight, the same amount of work could be accomplished. While infeasible, this helps illustrate the point of our objective: To stay within the constraints set by management and determine how many trucks should be run on which days for how many hours.

Management's goal is to minimize the number of trucks needed. (This is supported as being a reasonable goal since our IFPS concluded that there is a cost associated with owning a truck.) These constraints set by management are as follows:

1. 7 routes must be delivered between Monday and Wednesday night.
2. Routes represent an approximate 'truck load' and cannot be altered. (i.e. we did not consider restructuring the routes or determining the capacity of the truck. We assumed that one route consisted of, at most, one truckload.)
3. Routes have certain delivery times associated with them.

<u>Route</u>	<u>Assigned Number</u>	<u>Time to Deliver</u>
Plano/Richardson	1	3 Hours
Dls/Mesquite/Balch Spgs	2	4 Hours
Dallas	3	2 Hours
Lancaster/Cedar Hill/ Grand Prairie/ Desoto	4	6 Hours
Dallas/Oak Cliff	5	3 Hours
F. Branch/Carrolton/Colony	6	3 Hours
Garland	7	4 Hours

4. The number of truckloads which can be packed and ready for delivery each day is:
2 on Monday, 1 on Tuesday, and 4 on Wednesday.
5. The maximum number of total delivery hours on Monday is 6 - that is, 1 truck can spend 6 hours delivering, 2 trucks can spend 3 hours each delivering, etc. The total number of delivery hours on Tuesday and Wednesday are 4 and 15 respectively.

6. A variable constraint can be placed on the number of hours one truck can spend driving; these constraints were variable by adjusting the right-hand side coefficients. We placed high right hand side coefficients on these less than or equal to constraints to effectively "turn them off". By doing this, we allow a truck to run as many hours as the other constraints will allow it . We restricted this constraint by varying the number of hours to be run by one truck on Monday night to 3 since the deliveries do not start until late in the afternoon. We would not want a truck to deliver past 9 pm since all the deliveries are made to residential homes. We restricted the Wednesday hours first to 10 then to 6 to avoid excessive driving. It was not necessary to restrict the Tuesday hours since only 1 route is run on Tuesday. These alterations gave us some support for suggestions to management about possibly changing the number of hours they allow one truck to be on the road per day.

Technical Analysis

We determined that the constraints set up by management could be optimized by using a Linear Programming Model. Linear Programming is "a mathematical procedure for determining optimal allocation of scarce resources." (Schrage, 2)

We used the constraints given to us by management to formulate our linear programming model.

Our basic model was:

Minimize: The Number of Delivery Trucks for D'Ann Sales

Subject To:

Monday Delivery Hours ≤ 6

Tuesday Delivery Hours ≤ 4

Wednesday Delivery Hours ≤ 15

Number of Routes on Monday ≤ 2

Number of Routes on Tuesday ≤ 1

Number of Routes on Wednesday ≤ 4

Every Route Must Be Run Once Each Week

Routes are Run Only Monday through Wednesday

Max Hours for One Truck to Run in a Day (variable)

We utilized 3 dimensional variables to represent the truck number, the day of the week, and the route number. All of our variables are of the form $x(i,j,k)$ where i is the truck number: 1 through 5; j is the day of the week to run : 1-3 (Monday through Wednesday) and k is the route number : 1-7. All variables are integer variables which are forced to be either 0 or 1 because of the constraints.

The model then, in terms of these $x(i,j,k)$ variables is as follows:

Objective Function:

$$\text{Min: } \sum x(1,j,k) + \sum 2x(2,j,k) + \sum 3x(3,j,k) + \sum 4x(4,j,k) + \sum 5x(5,j,k)$$

Subject to:

$$\sum 3x(i,1,1) + \sum 4x(i,1,2) + \sum 2x(i,1,3) + \sum 6x(i,1,4) + \sum 3x(i,1,5) + \sum 3x(i,1,6) + \\ \sum 4x(i,1,5) \leq 6$$

$$\sum 3x(i,2,1) + \sum 4x(i,2,2) + \sum 2x(i,2,3) + \sum 6x(i,2,4) + \sum 3x(i,2,5) + \sum 3x(i,2,6) + \\ \sum 4x(i,2,5) \leq 4$$

$$\sum 3x(i,3,1) + \sum 4x(i,3,2) + \sum 2x(i,3,3) + \sum 6x(i,3,4) + \sum 3x(i,3,5) + \sum 3x(i,3,6) + \\ \sum 4x(i,3,5) \leq 15$$

$$\sum x(i,1,k) \leq 2$$

$$\sum x(i,2,k) \leq 1$$

$$\sum x(i,3,k) \leq 4$$

$$\sum x(i,j,1) = 1$$

$$\sum x(i,j,2..7)$$

$$3x(1,1,1) + 4x(1,1,2) + 2x(1,1,3) + 6x(1,1,4) + 3x(1,1,5) + 3x(1,1,6) + 4x(1,1,7) \leq \{15\text{-case1, 3-case 2, 3-case 3}\}$$

$$3x(2,1,1) + 4x(2,1,2) + 2x(2,1,3) + 6x(2,1,4) + 3x(2,1,5) + 3x(2,1,6) + 4x(2,1,7) \leq \{15, 3, 3\}$$

$$3x(3,1,1) + 4x(3,1,2) + 2x(3,1,3) + 6x(3,1,4) + 3x(3,1,5) + 3x(3,1,6) + 4x(3,1,7) \leq \{15,3,3\}$$

$$3x(4,1,1) + 4x(4,1,2) + 2x(4,1,3) + 6x(4,1,4) + 3x(4,1,5) + 3x(4,1,6) + 4x(4,1,7) \leq \{15,3,3\}$$

$$3x(5,1,1) + 4x(5,1,2) + 2x(5,1,3) + 6x(5,1,4) + 3x(5,1,5) + 3x(5,1,6) + 4x(5,1,7) \leq \{15,3,3\}$$

$$3x(1,3,1) + 4x(1,3,2) + 2x(1,3,3) + 6x(1,3,4) + 3x(1,3,5) + 3x(1,3,6) + 4x(1,3,7) \leq \{15\text{-case1, 10-case 2, 6-case 3}\}$$

$$3x(2,3,1) + 4x(2,3,2) + 2x(2,3,3) + 6x(2,3,4) + 3x(2,3,5) + 3x(2,3,6) + 4x(2,3,7) \leq \{15, 10, 6\}$$

$$3x(3,3,1) + 4x(3,3,2) + 2x(3,3,3) + 6x(3,3,4) + 3x(3,3,5) + 3x(3,3,6) + 4x(3,3,7) \leq \{15,3,3\}$$

$$3x(4,3,1) + 4x(4,3,2) + 2x(4,3,3) + 6x(4,3,4) + 3x(4,3,5) + 3x(4,3,6) + 4x(4,3,7) \leq \{15,3,3\}$$

$$3x(5,3,1) + 4x(5,3,2) + 2x(5,3,3) + 6x(5,3,4) + 3x(5,3,5) + 3x(5,3,6) + 4x(5,3,7) \leq \{15,3,3\}$$

A brief description of our objective function and constraints now follows.

Objective Function:

$$\text{Min: } \sum x(1,j,k) + \sum 2x(2,j,k) + \sum 3x(3,j,k) + \sum 4x(4,j,k) + \sum 5x(5,j,k)$$

This effectively minimizes the number of trucks needed per route per day. From this solution, we are able to determine the minimum number of trucks needed. The weights of 2,3,4, and 5 are arbitrary and merely push the solution in the direction of using 1 truck, and only uses an additional truck if needed due to other restricting constraints.

Subject to:

$$\sum 3x(i,1,1) + \sum 4x(i,1,2) + \sum 2x(i,1,3) + \sum 6x(i,1,4) + \sum 3x(i,1,5) + \sum 3x(i,1,6) + \sum 4x(i,1,7) \leq 6$$

This constraint limits the total number of delivery hours on Monday to 6. The coefficients are the delivery times of routes 1 - 7 as given in above section. (i.e. delivery time for route 1 is 3 hours)

$$\sum 3x(i,2,1) + \sum 4x(i,2,2) + \sum 2x(i,2,3) + \sum 6x(i,2,4) + \sum 3x(i,2,5) + \sum 3x(i,2,6) + \sum 4x(i,2,5) \leq 4$$

This constraint is similar to the one above with the exception of this being the total Tuesday delivery hours available (Tuesday indicated by $j = 2$).

$$\sum 3x(i,3,1) + \sum 4x(i,3,2) + \sum 2x(i,3,3) + \sum 6x(i,3,4) + \sum 3x(i,3,5) + \sum 3x(i,3,6) + \sum 4x(i,3,5) \leq 15$$

This is the total Wednesday delivery hours available.

$$\sum x(i,1,k) \leq 2$$

This limits the number of routes run on Monday to 2.

$$\sum x(i,2,k) \leq 1$$

This limits the number of routes run on Tuesday to 1.

$$\sum x(i,3,k) \leq 4$$

This limits the number of routes run on Wednesday to 4.

$$\sum x(i,j,1) = 1$$

This forces route 1 to be run once and only once each week.

$$\sum x(i,j,2 \dots 7) = 1$$

This also forces all other routes to be run once and only once.

$$3x(1,1,1) + 4x(1,1,2) + 2x(1,1,3) + 6x(1,1,4) + 3x(1,1,5) + 3x(1,1,6) + 4x(1,1,7) \leq \{15\text{-case1, 3-case 2, 3-case 3}\}$$

This constraint is the variable constraint. It restricts the number of hours truck 1 can run on Monday to 15, 3, 3 for case 1, 2, 3 respectively.

$$3x(2,1,1) + 4x(2,1,2) + 2x(2,1,3) + 6x(2,1,4) + 3x(2,1,5) + 3x(2,1,6) + 4x(2,1,7) \leq \{15, 3, 3\}$$

Restricting the number of hours truck 2 can run on Monday to 15, 3, 3 for the three cases.

$$3x(3,1,1) + 4x(3,1,2) + 2x(3,1,3) + 6x(3,1,4) + 3x(3,1,5) + 3x(3,1,6) + 4x(3,1,7) \leq \{15,3,3\}$$

Restricting the number of hours truck 3 can run on Monday to 15, 3, 3 for the three cases.

$$3x(4,1,1) + 4x(4,1,2) + 2x(4,1,3) + 6x(4,1,4) + 3x(4,1,5) + 3x(4,1,6) + 4x(4,1,7) \leq \{15,3,3\}$$

Restricting the number of hours truck 4 can run on Monday to 15, 3, 3 for the three cases.

$$3x(5,1,1) + 4x(5,1,2) + 2x(5,1,3) + 6x(5,1,4) + 3x(5,1,5) + 3x(5,1,6) + 4x(5,1,7) \leq \{15,3,3\}$$

Restricting the number of hours truck 5 can run on Monday to 15,3,3 for the three cases.

$$3x(1,3,1) + 4x(1,3,2) + 2x(1,3,3) + 6x(1,3,4) + 3x(1,3,5) + 3x(1,3,6) + 4x(1,3,7) \leq \{15\text{-case 1, 10-case 2, 6-case 3}\}$$

This constraint is the variable constraint for Wednesday. It restricts the number of hours truck 1 can run on Wednesday to 15, 10, 6 for case 1, 2, 3 respectively.

$$3x(2,3,1) + 4x(2,3,2) + 2x(2,3,3) + 6x(2,3,4) + 3x(2,3,5) + 3x(2,3,6) + 4x(2,3,7) \leq \{15, 10, 6\}$$

Restricting the number of hours truck 2 can run on Wednesday to 15, 10, 6 for the three cases.

$$3x(3,3,1) + 4x(3,3,2) + 2x(3,3,3) + 6x(3,3,4) + 3x(3,3,5) + 3x(3,3,6) + 4x(3,3,7) \leq \{15, 10, 6\}$$

Restricting the number of hours truck 3 can run on Wednesday to 15, 10, 6 for the three cases.

$$3x(4,3,1) + 4x(4,3,2) + 2x(4,3,3) + 6x(4,3,4) + 3x(4,3,5) + 3x(4,3,6) + 4x(4,3,7) \leq \{15, 10, 6\}$$

Restricting the number of hours truck 4 can run on Wednesday to 15, 10, 6 for the three cases.

$$3x(5,3,1) + 4x(5,3,2) + 2x(5,3,3) + 6x(5,3,4) + 3x(5,3,5) + 3x(5,3,6) + 4x(5,3,7) \leq \{15, 10, 6\}$$

Restricting the number of hours truck 5 can run on Wednesday to 15, 10, 6 for the three cases.

Again, all variables are either 0 or 1 variables. Any coefficients on the variables represent the delivery times in hours of routes as indicated previously. To see the complete listing of the L.P. models generated, see Appendix C1-3. The models differ only in the last 10 constraints which vary the number of hours an individual truck can run on Monday and Wednesday.

To solve this problem, we utilized a software package called LINDO. The procedures carried out by LINDO are beyond the scope of this report; for more detailed information concerning LINDO please consult Schrage. LINDO is a linear programming software package which solves complex systems of linear equations. Our model consisted on one objective function, 23 constraints, and 105 integer variables and was quickly and easily solved by LINDO. The results follow.

Case 1: (Appendix C1) No restrictions are placed on the maximum number of delivery hours for one truck.

All the variables were 0 except for: X111,x116,x127,x132,x133,x134,and x135. This means that one truck can run all 7 routes without violating any of the constraints. The infeasibility of this solution lies in the fact that on Monday the 1 truck runs a total of 6 hours and on Wednesday the truck runs for 15 hours. Since orders for merchandise are not received at the warehouse until Monday morning, and Monday deliveries do not begin until late in the afternoon the Monday night route would run late into the evening, which is an undesirable condition. Wednesday's driving time is also excessive, not to mention the extra hours that the warehouse would have to remain open to reload the truck between routes.

Case 2: (Appendix C2)-Restricting Individual truck hours on Monday to 3 and individual truck hours on Wednesday to 10.

The 'on' variables in this case are $x_{116}, x_{127}, x_{132}, x_{133}, x_{135}, x_{211}$, and x_{234} . This case suggests that D'Ann operate 2 trucks instead of 1. Once again, we may not have the most ideal situation most ideal conditions, but the difference in the cost of an extra truck may offset the inconveniences caused by having to keep the warehouse open additional hours to reload trucks for Wednesday's 9 hours of driving time.

Case 3: (Appendix C3)-Restricting Individual truck hours on Monday to 3 and individual truck hours on Wednesday to 6.

The 'on' variables in this case are $x_{115}, x_{122}, x_{133}, x_{136}, x_{211}, x_{237}$, and x_{334} . This case supports operating three trucks, and the maximum number of driving hours for any one truck in one day is 6. This solution tells us that Truck 1 should run route 5 on Monday and route 2 on Tuesday and route 3 on Wednesday. Truck 2 should run route 1 on Monday and route 7 on Wednesday, and Truck 3 should run route 4 on Wednesday. While this solution suggests Truck 3 only run one route one day a week, D'Ann is given the security of having an extra truck on hand in case of emergencies.

The value of the Objective Function in each solution is of virtually no merit. The least value it can be is 7 since each route must be run once. The Objective Function values greater than 7 are because more than one truck is in operation and the weight value is increasing the function value. The slack and sensitivity values were of little use to us because we performed our own sensitivity analysis by varying the right-hand sides of the last 10 constraints based upon different needs at D'Ann Sales.

THE TRAVELING SALESMAN PROBLEM

Analysis of the Situation

The traveling salesman problem is one of the oldest "un-solved" computer science problems. There are many heuristics that give close optimal solutions, but as of yet, no algorithm exists that solves the problem without trying every possibility. (Aho, p.323).

The application of the traveling salesman problem to D'Ann Sales is in the routing of the different deliveries. Each truck must leave the warehouse, make between 5 and 10 stops on the route, and then return to the warehouse. Every week, the number of stops on a route may increase or decrease by 5 or 6 depending on how many dealers pay to have their order delivered. Because of the variability of this situation, our goal was to construct a *general* path that should be followed. The individual drivers can use human judgement to decide where the extra stops should be and how to deviate from the general path.

Because the managers get their Tupperware delivered free, there is a natural arrangement of people who would be included in the stops on the general path every week. Therefore, our purpose was to devise a shortest path from the warehouse, to each manager's home on the route, and then back to the warehouse. Again, because of the structure of the organization, no attempt was made to redesign the routes. Each route is designed to hold a "truck load" of merchandise; thus, there was no need to consider the capacity of the trucks. Each route is set up within a specific area of the metroplex, and a dealer who adds her stop to the list on any given week will be placed on the route closest to her home. Thus, our model was ready to be solved.

Technical Analysis

Because the number of stops on each route is relatively small in every case (less than or equal to 10), our program implemented an algorithm rather than a heuristic. The program takes as input the number of the route, the number of stops on each route, the names of the managers on the route, and the distance (cost) between each stop.

The stops on every route were plotted on a standard Rand McNally Dallas Map. The distances were computed by taking the measurements between the stops. These measurements were computed by using straight line distances. Straight line distances were used for several reasons. First, they were used for simplicity reasons. Next, the shortest path generated was only a general path, and exact street by street distances would be ambiguous as the actual path may vary with extra stops every week. Another reason for using straight line distances is the difference between measuring distances in terms of miles as opposed to hours. Because of the constraints of our LINDO model being in terms of hours, it would be more logical to measure distances in terms of minutes rather than miles. However, the potential drawbacks in trying to compute the distances in terms of hours are numerous.

The experienced truck driver knows that it may be faster to take road x over road y even though road y is shorter. This may be because of the traffic, stoplights, construction, etc. on road y. Not only are these factors important, but the "shorter" road may depend on other factors such as the time of the day or weather conditions. Deliveries at 5 pm might take 2 hours longer on rush hour traffic roads than on residential roads. So, instead of trying to determine the variables of time of day, traffic, weather, stop lights, etc., we simplified the model by using these straight line distances.

The program uses a data structure called Counter. Counter is the control device

that makes sure every combination of stops on a route is considered. It assigns an ordering of 1 . . n with n being the number of stops on the route. For example, for n=5 the algorithm tries the combination 1-2-3-4-5-1. This implies starting at the warehouse, going to stop 2, stop 3, stop 4, stop 5 and then returning once again to the warehouse. The program reads the distances associated from making each of these stops and calculates the total distance of this route, and then puts this initial trial into the value for minimum distance. The counter is then updated, and a new combination is tried, 1-2-3-5-4-1. The distance of this new combination is computed and then compared to the current value of minimum distance. If this new distance is less than minimum distance, then the variable Mincost is now this new distance and the variable Minpath is the new minimum path. This process is repeated until every path combination has been tried. After every combination is tried, the shortest path is the value stored in Minpath and the minimum distance is the value stored in Mincost. Please see Appendix D for a complete listing of the program and output, and Appendix F for additional program comments and descriptions.

Interpretation of Results

The output for routes 1 through 7 as can be observed in Appendix D is as follows:

<u>Route</u>	<u>Shortest Path to Follow</u>
1	Warehouse, Ritner, Sweat, Coffee, Lokke, Marshall, Davies, Cook, Warehouse
2	Warehouse, Folk, Macias, Swindell, Poston, Lane, Feuerbacher, Brown, Warehouse
3	Warehouse, Gonzales, Alamanza, Alvarez, Orozco, Branch, Warehouse
4	Warehouse, Barder, Gardiner, Easley, Bevill, Hard, Coward, Cooper, Warehouse
5	Warehouse, Bush, Cleveland, Wall, Neely, Richards, Steward, Jones, Warehouse
6	Warehouse, Foster, Fairchild, Cruise, Linden, Ward, Neal, Warehouse
7	Warehouse, Scott, Caston, Baker, Wood, Hooks, Thompson, Phillips, Warehouse

A note is in order about the computation times of the procedure. Because the program finds combinations of n stops, the number of arithmetic operations the program must make is at least $n!$. This becomes a major drawback for n greater than 8. See the table below for a list of estimated program computation times.

<u>n =</u>	<u>Response Time</u>
3 Stops	Instantaneous
6 Stops	10 Seconds
7 Stops	1.4 Minutes
8 Stops	40 Minutes
9 Stops	90 Minutes
10 Stops	14 Hours

Because of the length of time to compute stops greater than 8, we limited the number of stops on two routes to 8. [They originally had 10-12 stops]. This was a minor assumption, since the solution is merely a general path. We eliminated 2-4 stops in each case by eliminating stops that were within a mile of another stop on the route and their deletion would not alter the solution greatly.

The minimum distances are in inches, and to convert the inches to miles, one can use the conversion factor from the map: 1 inch= 0.70 miles.

RECOMMENDATIONS AND CONCLUSIONS

To summarize the results of the three models, D'Ann Sales should replace their trucks at the end of the fifth year of ownership. They can run all of their routes with 2 trucks if they allow 1 truck to run 10 hours on Wednesday, and they can operate 3 trucks if they limit the Wednesday delivery hours to 6.

We suggest that D'Ann Sales immediately sell two of their trucks. They are not beneficial to the organization by sitting on the lot, and D'Ann is losing money by keeping them as a part of their delivery fleet. We recommend that D'Ann implement our recommended equipment replacement strategy as soon as it is economically feasible. If possible, they should sell all of their current trucks and buy two or three new trucks. A more feasible solution would be, perhaps, to gradually adopt this equipment replacement strategy. The gradual adoption would prevent a major (\$30,000+) capital outlay every five years. Instead, the investments would be staggered by buying one new truck now, one next year, and one the following year, and then begin the five year replacement strategy.

The strategy would follow the schedule:

<u>1986</u>	Buy new Truck 1
<u>1987</u>	Buy new Truck 2
<u>1988</u>	Buy new Truck 3
<u>1989</u>	
<u>1991</u>	
<u>1992</u>	Replace Truck 1
<u>1993</u>	Replace Truck 2
<u>1994</u>	Replace Truck 3
	etc.

Management also needs to decide whether they want to limit the hours of individual truck driving on Wednesday. They need to consider the trade-off between the cost of owning an additional truck as opposed to the long hours on Wednesday. They may decide to own the third truck to have on hand for emergencies. They need to consider, however, that it is less expensive for them to rent a truck for these periods of breakdown if the periods are less than a year. If the periods extend past the one year period, owning a new truck becomes more economically feasible for the organization. Depending on whether they decide to operate with 2 or 3 trucks, they should run the routes on the days shown by the LINDO output below.

	<u>2 Trucks</u> <u>(Delivery Day)</u>	<u>3 Trucks</u> <u>(Delivery Day)</u>
Route 1	Monday	Monday
Route 2	Wednesday	Tuesday
Route 3	Wednesday	Wednesday
Route 4	Wednesday	Wednesday
Route 5	Wednesday	Monday
Route 6	Monday	Wednesday
Route 7	Tuesday	Wednesday

Next, D'Ann should follow the general paths as indicated by the output from our basic program:

<u>Route</u>	<u>Shortest Path to Follow</u>
1	Warehouse, Ritner, Sweat, Coffee, Lokke, Marshall, Davies, Cook, Warehouse
2	Warehouse, Folk, Macias, Swindell, Poston, Lane, Feuerbacher, Brown, Warehouse
3	Warehouse, Gonzales, Alamanza, Alvarez, Orozco, Branch, Warehouse
4	Warehouse, Barder, Gardiner, Easley, Bevill, Hard, Coward, Cooper, Warehouse
5	Warehouse, Bush, Cleveland, Wall, Neely, Richards, Steward, Jones, Warehouse
6	Warehouse, Foster, Fairchild, Cruise, Linden, Ward, Neal, Warehouse
7	Warehouse, Scott, Caston, Baker, Wood, Hooks, Thompson, Phillips, Warehouse

In conclusion, we should note that all of the above recommendations are cost saving for D'Ann Sales, and that they do not violate any of the managerial constraints nor do they alter the current structure of the firm.

CRITIQUE

Overall, we believe that our project was successful. The problems we found at D'Ann were not limited to D'Ann in particular, but can apply to any delivery service operation. We feel that the models we developed were applicable to D'Ann's problems and that the results that we obtained will be cost saving to them. We believe that our recommendations to D'Ann Sales will be largely accepted and implemented. From talking with current management, they have already made decisions to sell part of their fleet. However, the organization is very conservative, and even though we have the figures to support that they could successfully operate with only 2 trucks, we do not believe that they will allow their fleet level to fall below 3 trucks for fear of emergency situations.

Implementation of the shortest path program will difficult to win over on the part of the drivers. They have been running basically the same routes for years, and they travel the route they 'know' is shortest from experience and human judgement.

Ideas for further investigation would include more sensitivity studies on the LINDO model to suggest further ideas to management about their current structure and operation. A further investigation into the shortest path problem would lead to perhaps the restructuring of the current routes and varying the capacity of their vehicles and possibly devising a heuristic that could be used at the warehouse every week to get the exact path to travel.

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APPENDIX A

Below is an example of the tedious equations used in the 1950's to solve equipment replacement problems. This example was taken from Brennan's article.

Alpha and Beta in the formula are statistical, hyperbolic determinants that relate salvage value to the age of the vehicle by the formula: $s = \text{Alpha} + \text{Beta}/x$ where s =net salvage, a ratio to investment cost and x = age of the vehicle at retirement, in years.

t is the effective tax rate upon income tax and i is the interest rate.

The complexity of this formula demonstrates the advantages of using IFPS.

OPTIMUM LIFE

As the optimum value of n , we take that which minimizes $C(n)$ in Equation 21. Evidently if one sets $dC(n)/dn = 0$, he can see from the terms of Equation 21 that a solution for n would be quite involved. To avoid this, we go back to Equation 2 and note that for

$$\frac{dC(n)}{dn} = 0, \quad P \frac{df(n)}{dn} = - \frac{d\bar{m}(n)}{dn} \quad \text{Eq. 22.}$$

Hence, if these functions are plotted on a graph with abscissas n , their intersection will give the value of n satisfying Equation 2.

By differentiation of Equation 21 one obtains:

$$P \frac{df(n)}{dn} = P \left[\frac{1}{(1-t)} \left\{ \frac{\beta}{n^2} \left[\frac{i}{(1+i)^n - 1} \right] + \left[1 - \alpha - \frac{\beta}{n} \right] \left[\frac{-i(1+i)^n \log_e (1+i)}{[(1+i)^n - 1]^2} \right] \right\} \right. \\ \left. + \frac{t}{1-t} \left[\frac{1-\alpha}{n^2} - \frac{2\beta}{n^3} \right] \right]$$

Differentiation of Equation 20 gives:

$$\frac{d\bar{m}(n)}{dn} = - \gamma k \left\{ \frac{[(1+i)^n - 1] - n(1+i)^n \log_e (1+i)}{[(1+i)^n - 1]^2} \right\}$$

APPENDIX B

INPUT: MODEL TRUCKS
 READY FOR EDIT, LAST LINE IS 230
 INPUT: LIST

1
 MODEL TRUCKS VERSION OF 04/25/86 15:43
 10 COLUMNS 1-12
 20 * EQUIPMENT REPLACEMENT
 30 *
 40 *INPUT DATA
 50 *
 60 INVESTMENT=12700,0
 65 INFLATION=.05
 70 DEPRECIATION=((12700-500)/5) FOR 5,0
 80 MAINTENANCE=110
 81 TIRES=0,480,0,480,0,480,0,480,0,480,0,480
 82 BREAKDOWN=0,150,PREVIOUS + 150
 83 EXPENSES=MAINTENANCE+TIRES+BREAKDOWN,PREVIOUS+(PREVIOUS*INFLATION)
 84 SALFAC=.63,.84,.87,.87,.76,.75,.90
 90 SALVAGE=8000,IF PREVIOUS .LT. 2000 THEN 500 ELSE PREVIOUS * SALFAC
 100 DISCOUNT RATE=.12
 110 *
 120 *CALCULATION OF SALVAGE pv
 130 *
 140 CUMULATIVE PV=NPVC(SALVAGE,DISCOUNT RATE,0)
 150 SALVAGE PV=CUMULATIVE PV-PREVIOUS CUMULATIVE PV
 160 *
 170 *RESULTS
 180 *
 190 NPV WITHOUT SALVAGE=NPVC(DEPRECIATION-EXPENSES,DISCOUNT RATE,'
 191 INVESTMENT)
 200 NET PRESENT VALUE=NPV WITHOUT SALVAGE + SALVAGE PV
 210 DISCOUNT FACTOR=1 + DISCOUNT RATE, PREVIOUS * (1 + DISCOUNT RATE)
 220 ANNUITY FACTOR=DISCOUNT FACTOR/(DISCOUNT FACTOR-1)
 230 NPV WITH REPLACEMENT=NET PRESENT VALUE * ANNUITY FACTOR
 END OF MODEL
 INPUT: SOLVE
 MODEL TRUCKS VERSION OF 04/25/86 15:43 -- 12 COLUMNS 17 VARIABLES
 ENTER SOLVE OPTIONS
 INPUT: INVERT
 INPUT: ALL

EQUIPMENT REPLACEMENT

INPUT DATA

	INVESTME	INFLATIO	DEPRECIA	MAINTENA	TIRES	BREAKDOW
1	12700	.0500	2440	110	0	0
2	0	.0500	2440	110	480	150
3	0	.0500	2440	110	0	300
4	0	.0500	2440	110	480	450
5	0	.0500	2440	110	0	600
6	0	.0500	0	110	480	750
7	0	.0500	0	110	0	900
8	0	.0500	0	110	480	1050
9	0	.0500	0	110	0	1200

10	0	.0500	0	110	480	1350
11	0	.0500	0	110	0	1500
12	0	.0500	0	110	480	1650

CALCULATION OF SALVAGE pv

	EXPENSES	SALFAC	SALVAGE	DISCOUNT	CUMULATI	SALVAGE
1	110	.6300	8000	.1200	7143	7143
2	115.5	.8400	6720	.1200	12500	5357
3	121.3	.8700	5846	.1200	16661	4161
4	127.3	.8700	5086	.1200	19894	3232
5	133.7	.7600	3866	.1200	22087	2193
6	140.4	.7500	2899	.1200	23556	1469
7	147.4	.9000	2609	.1200	24736	1180
8	154.8	.9000	2348	.1200	25685	948.5
9	162.5	.9000	2114	.1200	26447	762.2
10	170.6	.9000	1902	.1200	27060	612.5
11	179.2	.9000	500	.1200	27203	143.7
12	188.1	.9000	500	.1200	27332	128.3

RESULTS

	NPV WITH	NET PRES	DISCOUNT	ANNUITY	NPV WITH
1	-10620	-3477	1.120	9.333	-32450
2	-8767	-3409	1.254	4.931	-16811
3	-7116	-2955	1.405	3.470	-10252
4	-5646	-2414	1.574	2.744	-6623
5	-4338	-2144	1.762	2.312	-4957
6	-4409	-2940	1.974	2.027	-5959
7	-4476	-3295	2.211	1.826	-6017
8	-4538	-3590	2.476	1.678	-6022
9	-4597	-3835	2.773	1.564	-5997
10	-4652	-4039	3.106	1.475	-5957
11	-4703	-4559	3.479	1.403	-6399
12	-4751	-4623	3.896	1.345	-6219

ENTER SOLVE OPTIONS.

INPUT: WHAT IF

WHAT IF CASE 1

ENTER STATEMENTS

INPUT: INVESTMENT=8409, PREVIOUS+(PREVIOUS*INFLATION)

INPUT: DEPRECIATION=0

INPUT: EXPENSES=0

INPUT: TIRES=0

INPUT: BREAKDOWN=0

INPUT: MAINTENANCE=0

INPUT: SALFAC=0

INPUT: SALVAGE=0

INPUT: SOLVE

ENTER SOLVE OPTIONS

INPUT: INVERT

INPUT: ALL

***** WHAT IF CASE 1 *****

8 WHAT IF STATEMENTS PROCESSED

EQUIPMENT REPLACEMENT

INPUT DATA

	INVESTME	INFLATIO	DEPRECIA	MAINTENA	TIRES	BREAKDOW
1	8409	.0500	0	0	0	0
2	8829	.0500	0	0	0	0
3	9271	.0500	0	0	0	0
4	9734	.0500	0	0	0	0
5	10221	.0500	0	0	0	0
6	10732	.0500	0	0	0	0
7	11269	.0500	0	0	0	0
8	11832	.0500	0	0	0	0
9	12424	.0500	0	0	0	0
10	13045	.0500	0	0	0	0
11	13697	.0500	0	0	0	0
12	14382	.0500	0	0	0	0

CALCULATION OF SALVAGE pv

	EXPENSES	SALFAC	SALVAGE	DISCOUNT	CUMULATI	SALVAGE
1	0	0	0	.1200	0	0
2	0	0	0	.1200	0	0
3	0	0	0	.1200	0	0
4	0	0	0	.1200	0	0
5	0	0	0	.1200	0	0
6	0	0	0	.1200	0	0
7	0	0	0	.1200	0	0
8	0	0	0	.1200	0	0
9	0	0	0	.1200	0	0
10	0	0	0	.1200	0	0
11	0	0	0	.1200	0	0
12	0	0	0	.1200	0	0

RESULTS

	NPV WITH	NET PRES	DISCOUNT	ANNUITY	NPV WITH
1	-8409	-8409	1.120	9.333	-78484
2	-16292	-16292	1.254	4.931	-80335
3	-23683	-23683	1.405	3.470	-82170
4	-30612	-30612	1.574	2.744	-83988
5	-37108	-37108	1.762	2.312	-85784
6	-43197	-43197	1.974	2.027	-87556
7	-48907	-48907	2.211	1.826	-89303
8	-54259	-54259	2.476	1.678	-91021
9	-59277	-59277	2.773	1.564	-92708
10	-63981	-63981	3.106	1.475	-94364
11	-68391	-68391	3.479	1.403	-95984
12	-72526	-72526	3.896	1.345	-97569

ENTER SOLVE OPTIONS

INPUT: WHAT IF

WHAT IF CASE 2

ENTER STATEMENTS
 INPUT: INVESTMENT=5000
 INPUT: SALFAC=0
 INPUT: SALVAGE=0
 INPUT: SOLVE
 ENTER SOLVE OPTIONS
 INPUT: INVERT
 INPUT: ALL

***** WHAT IF CASE 2 *****
 3 WHAT IF STATEMENTS PROCESSED

EQUIPMENT REPLACEMENT

INPUT DATA

	INVESTME	INFLATIO	DEPRECIA	MAINTENA	TIRES	BREAKDOW
1	5000	.0500	2440	110	0	0
2	5000	.0500	2440	110	480	150
3	5000	.0500	2440	110	0	300
4	5000	.0500	2440	110	480	450
5	5000	.0500	2440	110	0	600
6	5000	.0500	0	110	480	750
7	5000	.0500	0	110	0	900
8	5000	.0500	0	110	480	1050
9	5000	.0500	0	110	0	1200
10	5000	.0500	0	110	480	1350
11	5000	.0500	0	110	0	1500
12	5000	.0500	0	110	480	1650

CALCULATION OF SALVAGE pv

	EXPENSES	SALFAC	SALVAGE	DISCOUNT	CUMULATI	SALVAGE
1	110	0	0	.1200	0	0
2	115.5	0	0	.1200	0	0
3	121.3	0	0	.1200	0	0
4	127.3	0	0	.1200	0	0
5	133.7	0	0	.1200	0	0
6	140.4	0	0	.1200	0	0
7	147.4	0	0	.1200	0	0
8	154.8	0	0	.1200	0	0
9	162.5	0	0	.1200	0	0
10	170.6	0	0	.1200	0	0
11	179.2	0	0	.1200	0	0
12	188.1	0	0	.1200	0	0

RESULTS

	NPV WITH	NET PRES	DISCOUNT	ANNUITY	NPV WITH
1	-2920	-2920	1.120	9.333	-27250
2	-5531	-5531	1.254	4.931	-27272
3	-7866	-7866	1.405	3.470	-27293
4	-9956	-9956	1.574	2.744	-27314
5	-11824	-11824	1.762	2.312	-27335

6	-14733	-14733	1.974	2.027	-29862
7	-17333	-17333	2.211	1.826	-31649
8	-19657	-19657	2.476	1.678	-32975
9	-21735	-21735	2.773	1.564	-33993
10	-23593	-23593	3.106	1.475	-34796
11	-25254	-25254	3.479	1.403	-35443
12	-26740	-26740	3.896	1.345	-35973

ENTER SOLVE OPTIONS

INPUT: WHAT IF

WHAT IF CASE 3

ENTER STATEMENTS

INPUT: DISCOUNT RATE = .07

INPUT: SOLVE

ENTER SOLVE OPTIONS

INPUT: ALL

***** WHAT IF CASE 3 *****

1 WHAT IF STATEMENT PROCESSED

EQUIPMENT REPLACEMENT

INPUT DATA

	INVESTME	INFLATIO	DEPRECIA	MAINTENA	TIRES	BREAKDOW
1	12700	.0500	2440	110	0	0
2	0	.0500	2440	110	480	150
3	0	.0500	2440	110	0	300
4	0	.0500	2440	110	480	450
5	0	.0500	2440	110	0	600
6	0	.0500	0	110	480	750
7	0	.0500	0	110	0	900
8	0	.0500	0	110	480	1050
9	0	.0500	0	110	0	1200
10	0	.0500	0	110	480	1350
11	0	.0500	0	110	0	1500
12	0	.0500	0	110	480	1650

CALCULATION OF SALVAGE pv

	EXPENSES	SALFAC	SALVAGE	DISCOUNT	CUMULATI	SALVAGE
1	110	.6300	8000	.0700	7477	7477
2	115.5	.8400	6720	.0700	13346	5870
3	121.3	.8700	5846	.0700	18119	4772
4	127.3	.8700	5086	.0700	21999	3880
5	133.7	.7600	3866	.0700	24755	2756
6	140.4	.7500	2899	.0700	26687	1932
7	147.4	.9000	2609	.0700	28312	1625
8	154.8	.9000	2348	.0700	29679	1367
9	162.5	.9000	2114	.0700	30828	1150
10	170.6	.9000	1902	.0700	31795	967.0
11	179.2	.9000	500	.0700	32033	237.5
12	188.1	.9000	500	.0700	32255	222.0

RESULTS

	NPV WITH	NET	PRES	DISCOUNT	ANNUITY	NPV WITH
1	-10522	-3046		1.070	15.29	-46557
2	-8492	-2623		1.145	7.901	-20722
3	-6599	-1827		1.225	5.444	-9945
4	-4835	-954.7		1.311	4.218	-4026
5	-3191	-434.5		1.403	3.484	-1514
6	-3284	-1352		1.501	2.997	-4053
7	-3376	-1751		1.606	2.651	-4642
8	-3466	-2099		1.718	2.392	-5022
9	-3555	-2405		1.838	2.193	-5273
10	-3641	-2674		1.967	2.034	-5439
11	-3726	-3489		2.105	1.905	-6647
12	-3810	-3588		2.252	1.799	-6453

ENTER SOLVE OPTIONS
INPUT: QUIT

APPENDIX C1

MIN X111 + X112 + X113 + X114 + X115 + X116 + X117 + X121
+ X122 + X123 + X124 + X125 + X126 + X127 + X131 + X132
+ X133 + X134 + X135 + X136 + X137 + 2 X211 + 2 X212
+ 2 X213 + 2 X214 + 2 X215 + 2 X216 + 2 X217 + 2 X221
+ 2 X222 + 2 X223 + 2 X224 + 2 X225 + 2 X226 + 2 X227
+ 2 X231 + 2 X232 + 2 X233 + 2 X234 + 2 X235 + 2 X236
+ 2 X237 + 3 X311 + 3 X312 + 3 X313 + 3 X314 + 3 X315
+ 3 X316 + 3 X317 + 3 X321 + 3 X322 + 3 X323 + 3 X324
+ 3 X325 + 3 X326 + 3 X327 + 3 X331 + 3 X332 + 3 X333
+ 3 X334 + 3 X335 + 3 X336 + 3 X337 + 4 X411 + 4 X412
+ 4 X413 + 4 X414 + 4 X415 + 4 X416 + 4 X417 + 4 X421
+ 4 X422 + 4 X423 + 4 X424 + 4 X425 + 4 X426 + 4 X427
+ 4 X431 + 4 X432 + 4 X433 + 4 X434 + 4 X435 + 4 X436
+ 4 X437 + 5 X511 + 5 X512 + 5 X513 + 5 X514 + 5 X515
+ 5 X516 + 5 X517 + 5 X521 + 5 X522 + 5 X523 + 5 X524
+ 5 X525 + 5 X526 + 5 X527 + 5 X531 + 5 X532 + 5 X533
+ 5 X534 + 5 X535 + 5 X536 + 5 X537

SUBJECT TO
MONHOURS) 3 X111 + 4 X112 + 2 X113 + 6 X114 + 3 X115 + 3 X116
+ 4 X117 + 3 X211 + 4 X212 + 2 X213 + 6 X214 + 3 X215
+ 3 X216 + 4 X217 + 3 X311 + 4 X312 + 2 X313 + 6 X314
+ 3 X315 + 3 X316 + 4 X317 + 3 X411 + 4 X412 + 2 X413
+ 6 X414 + 3 X415 + 3 X416 + 4 X417 + 3 X511 + 4 X512
+ 2 X513 + 6 X514 + 3 X515 + 3 X516 + 4 X517 <= 6

TUEHOURS) 3 X121 + 4 X122 + 2 X123 + 6 X124 + 3 X125 + 3 X126
+ 4 X127 + 3 X221 + 4 X222 + 2 X223 + 6 X224 + 3 X225
+ 3 X226 + 4 X227 + 3 X321 + 4 X322 + 2 X323 + 6 X324
+ 3 X325 + 3 X326 + 4 X327 + 3 X421 + 4 X422 + 2 X423
+ 6 X424 + 3 X425 + 3 X426 + 4 X427 + 3 X521 + 4 X522
+ 2 X523 + 6 X524 + 3 X525 + 3 X526 + 4 X527 <= 4

WEDHOURS) 3 X131 + 4 X132 + 2 X133 + 6 X134 + 3 X135 + 3 X136
+ 4 X137 + 3 X231 + 4 X232 + 2 X233 + 6 X234 + 3 X235
+ 3 X236 + 4 X237 + 3 X331 + 4 X332 + 2 X333 + 6 X334
+ 3 X335 + 3 X336 + 4 X337 + 3 X431 + 4 X432 + 2 X433
+ 6 X434 + 3 X435 + 3 X436 + 4 X437 + 3 X531 + 4 X532
+ 2 X533 + 6 X534 + 3 X535 + 3 X536 + 4 X537 <= 15

TRKMON) X111 + X112 + X113 + X114 + X115 + X116 + X117 + X211
+ X212 + X213 + X214 + X215 + X216 + X217 + X311 + X312
+ X313 + X314 + X315 + X316 + X317 + X411 + X412 + X413
+ X414 + X415 + X416 + X417 + X511 + X512 + X513 + X514
+ X515 + X516 + X517 <= 2

TRKTUE) X121 + X122 + X123 + X124 + X125 + X126 + X127 + X221
+ X222 + X223 + X224 + X225 + X226 + X227 + X321 + X322
+ X323 + X324 + X325 + X326 + X327 + X421 + X422 + X423
+ X424 + X425 + X426 + X427 + X521 + X522 + X523 + X524
+ X525 + X526 + X527 <= 1

TRKWED) X131 + X132 + X133 + X134 + X135 + X136 + X137 + X231
+ X232 + X233 + X234 + X235 + X236 + X237 + X331 + X332
+ X333 + X334 + X335 + X336 + X337 + X431 + X432 + X433
+ X434 + X435 + X436 + X437 + X531 + X532 + X533 + X534
+ X535 + X536 + X537 <= 4

RTE1) X111 + X121 + X131 + X211 + X221 + X231 + X311 + X321
+ X331 + X411 + X421 + X431 + X511 + X521 + X531 = 1

RTE2) X112 + X122 + X132 + X212 + X222 + X232 + X312 + X322

```

+ X332 + X412 + X422 + X432 + X512 + X522 + X532 = 1
RTE3) X113 + X123 + X133 + X213 + X223 + X233 + X313 + X323
+ X333 + X413 + X423 + X433 + X513 + X523 + X533 = 1
RTE4) X114 + X124 + X134 + X214 + X224 + X234 + X314 + X324
+ X334 + X414 + X424 + X434 + X514 + X524 + X534 = 1
RTE5) X115 + X125 + X135 + X215 + X225 + X235 + X315 + X325
+ X335 + X415 + X425 + X435 + X515 + X525 + X535 = 1
RTE6) X116 + X126 + X136 + X216 + X226 + X236 + X316 + X326
+ X336 + X416 + X426 + X436 + X516 + X526 + X536 = 1
RTE7) X117 + X127 + X137 + X217 + X227 + X237 + X317 + X327
+ X337 + X417 + X427 + X437 + X517 + X527 + X537 = 1
MAXTRK11) 3 X111 + 4 X112 + 2 X113 + 6 X114 + 3 X115 + 3 X116
+ 4 X117 <= 15
MAXTRK21) 3 X211 + 4 X212 + 2 X213 + 6 X214 + 3 X215 + 3 X216
+ 4 X217 <= 15
MAXTRK31) 3 X311 + 4 X312 + 2 X313 + 6 X314 + 3 X315 + 3 X316
+ 4 X317 <= 15
MAXTRK41) 3 X411 + 4 X412 + 2 X413 + 6 X414 + 3 X415 + 3 X416
+ 4 X417 <= 15
MAXTRK51) 3 X511 + 4 X512 + 2 X513 + 6 X514 + 3 X515 + 3 X516
+ 4 X517 <= 15
MAXTRK13) 3 X131 + 4 X132 + 2 X133 + 6 X134 + 3 X135 + 3 X136
+ 4 X137 <= 15
MAXTRK23) 3 X231 + 4 X232 + 2 X233 + 6 X234 + 3 X235 + 3 X236
+ 4 X237 <= 15
MAXTRK33) 3 X331 + 4 X332 + 2 X333 + 6 X334 + 3 X335 + 3 X336
+ 4 X337 <= 15
MAXTRK43) 3 X431 + 4 X432 + 2 X433 + 6 X434 + 3 X435 + 3 X436
+ 4 X437 <= 15
MAXTRK53) 3 X531 + 4 X532 + 2 X533 + 6 X534 + 3 X535 + 3 X536
+ 4 X537 <= 15
END
INTEGER-VARIABLES= 105

```

OBJECTIVE FUNCTION VALUE

1) 7.00000000

VARIABLE	VALUE	REDUCED COST
X111	1.000000	1.000000
X112	0.000000	1.000000
X113	0.000000	1.000000
X114	0.000000	1.000000
X115	0.000000	1.000000
X116	1.000000	1.000000
X117	0.000000	1.000000
X121	0.000000	1.000000
X122	0.000000	1.000000
X123	0.000000	1.000000
X124	0.000000	1.000000
X125	0.000000	1.000000
X126	0.000000	1.000000
X127	1.000000	1.000000

X131	0.000000	1.000000
X132	1.000000	1.000000
X133	1.000000	1.000000
X134	1.000000	1.000000
X135	1.000000	1.000000
X136	0.000000	1.000000
X137	0.000000	1.000000
X211	0.000000	2.000000
X212	0.000000	2.000000
X213	0.000000	2.000000
X214	0.000000	2.000000
X215	0.000000	2.000000
X216	0.000000	2.000000
X217	0.000000	2.000000
X221	0.000000	2.000000
X222	0.000000	2.000000
X223	0.000000	2.000000
X224	0.000000	2.000000
X225	0.000000	2.000000
X226	0.000000	2.000000
X227	0.000000	2.000000
X231	0.000000	2.000000
X232	0.000000	2.000000
X233	0.000000	2.000000
X234	0.000000	2.000000
X235	0.000000	2.000000
X236	0.000000	2.000000
X237	0.000000	2.000000
X311	0.000000	3.000000
X312	0.000000	3.000000
X313	0.000000	3.000000
X314	0.000000	3.000000
X315	0.000000	3.000000
X316	0.000000	3.000000
X317	0.000000	3.000000
X321	0.000000	3.000000
X322	0.000000	3.000000
X323	0.000000	3.000000
X324	0.000000	3.000000
X325	0.000000	3.000000
X326	0.000000	3.000000
X327	0.000000	3.000000
X331	0.000000	3.000000
X332	0.000000	3.000000
X333	0.000000	3.000000
X334	0.000000	3.000000
X335	0.000000	3.000000
X336	0.000000	3.000000
X337	0.000000	3.000000
X411	0.000000	4.000000
X412	0.000000	4.000000
X413	0.000000	4.000000
X414	0.000000	4.000000
X415	0.000000	4.000000
X416	0.000000	4.000000

X417	0.000000	4.000000
X421	0.000000	4.000000
X422	0.000000	4.000000
X423	0.000000	4.000000
X424	0.000000	4.000000
X425	0.000000	4.000000
X426	0.000000	4.000000
X427	0.000000	4.000000
X431	0.000000	4.000000
X432	0.000000	4.000000
X433	0.000000	4.000000
X434	0.000000	4.000000
X435	0.000000	4.000000
X436	0.000000	4.000000
X437	0.000000	4.000000
X511	0.000000	5.000000
X512	0.000000	5.000000
X513	0.000000	5.000000
X514	0.000000	5.000000
X515	0.000000	5.000000
X516	0.000000	5.000000
X517	0.000000	5.000000
X521	0.000000	5.000000
X522	0.000000	5.000000
X523	0.000000	5.000000
X524	0.000000	5.000000
X525	0.000000	5.000000
X526	0.000000	5.000000
X527	0.000000	5.000000
X531	0.000000	5.000000
X532	0.000000	5.000000
X533	0.000000	5.000000
X534	0.000000	5.000000
X535	0.000000	5.000000
X536	0.000000	5.000000
X537	0.000000	5.000000

ROW	SLACK	OR SURPLUS	DUAL PRICES
MONHOURS)	0.000000		0.000000
TUEHOURS)	0.000000		0.000000
WEDHOURS)	0.000000		0.000000
TRKMON)	0.000000		0.000000
TRKTUE)	0.000000		0.000000
TRKWED)	0.000000		0.000000
RTE1)	0.000000		0.000000
RTE2)	0.000000		0.000000
RTE3)	0.000000		0.000000
RTE4)	0.000000		0.000000
RTE5)	0.000000		0.000000
RTE6)	0.000000		0.000000
RTE7)	0.000000		0.000000
MAXTRK11)	9.000000		0.000000
MAXTRK21)	15.000000		0.000000
MAXTRK31)	15.000000		0.000000

MAXTRK41)	15.000000	0.000000
MAXTRK51)	15.000000	0.000000
MAXTRK13)	0.000000	0.000000
MAXTRK23)	15.000000	0.000000
MAXTRK33)	15.000000	0.000000
MAXTRK43)	15.000000	0.000000
MAXTRK53)	15.000000	0.000000

NO. ITERATIONS= 0
 BRANCHES= 0 DETERM.= 1.000E 0

RANGES IN WHICH THE BASIS IS UNCHANGED

VARIABLE	CURRENT COEF	OBJ COEFFICIENT RANGES	
		ALLOWABLE INCREASE	ALLOWABLE DECREASE
X111	1.000000	-1.000000	INFINITY
X112	1.000000	INFINITY	1.000000
X113	1.000000	INFINITY	1.000000
X114	1.000000	INFINITY	1.000000
X115	1.000000	INFINITY	1.000000
X116	1.000000	-1.000000	INFINITY
X117	1.000000	INFINITY	1.000000
X121	1.000000	INFINITY	1.000000
X122	1.000000	INFINITY	1.000000
X123	1.000000	INFINITY	1.000000
X124	1.000000	INFINITY	1.000000
X125	1.000000	INFINITY	1.000000
X126	1.000000	INFINITY	1.000000
X127	1.000000	-1.000000	INFINITY
X131	1.000000	INFINITY	1.000000
X132	1.000000	-1.000000	INFINITY
X133	1.000000	-1.000000	INFINITY
X134	1.000000	-1.000000	INFINITY
X135	1.000000	-1.000000	INFINITY
X136	1.000000	INFINITY	1.000000
X137	1.000000	INFINITY	1.000000
X211	2.000000	INFINITY	2.000000
X212	2.000000	INFINITY	2.000000
X213	2.000000	INFINITY	2.000000
X214	2.000000	INFINITY	2.000000
X215	2.000000	INFINITY	2.000000
X216	2.000000	INFINITY	2.000000
X217	2.000000	INFINITY	2.000000
X221	2.000000	INFINITY	2.000000
X222	2.000000	INFINITY	2.000000
X223	2.000000	INFINITY	2.000000
X224	2.000000	INFINITY	2.000000
X225	2.000000	INFINITY	2.000000
X226	2.000000	INFINITY	2.000000
X227	2.000000	INFINITY	2.000000
X231	2.000000	INFINITY	2.000000
X232	2.000000	INFINITY	2.000000
X233	2.000000	INFINITY	2.000000

X234	2.000000	INFINITY	2.000000
X235	2.000000	INFINITY	2.000000
X236	2.000000	INFINITY	2.000000
X237	2.000000	INFINITY	2.000000
X311	3.000000	INFINITY	3.000000
X312	3.000000	INFINITY	3.000000
X313	3.000000	INFINITY	3.000000
X314	3.000000	INFINITY	3.000000
X315	3.000000	INFINITY	3.000000
X316	3.000000	INFINITY	3.000000
X317	3.000000	INFINITY	3.000000
X321	3.000000	INFINITY	3.000000
X322	3.000000	INFINITY	3.000000
X323	3.000000	INFINITY	3.000000
X324	3.000000	INFINITY	3.000000
X325	3.000000	INFINITY	3.000000
X326	3.000000	INFINITY	3.000000
X327	3.000000	INFINITY	3.000000
X331	3.000000	INFINITY	3.000000
X332	3.000000	INFINITY	3.000000
X333	3.000000	INFINITY	3.000000
X334	3.000000	INFINITY	3.000000
X335	3.000000	INFINITY	3.000000
X336	3.000000	INFINITY	3.000000
X337	3.000000	INFINITY	3.000000
X411	4.000000	INFINITY	4.000000
X412	4.000000	INFINITY	4.000000
X413	4.000000	INFINITY	4.000000
X414	4.000000	INFINITY	4.000000
X415	4.000000	INFINITY	4.000000
X416	4.000000	INFINITY	4.000000
X417	4.000000	INFINITY	4.000000
X421	4.000000	INFINITY	4.000000
X422	4.000000	INFINITY	4.000000
X423	4.000000	INFINITY	4.000000
X424	4.000000	INFINITY	4.000000
X425	4.000000	INFINITY	4.000000
X426	4.000000	INFINITY	4.000000
X427	4.000000	INFINITY	4.000000
X431	4.000000	INFINITY	4.000000
X432	4.000000	INFINITY	4.000000
X433	4.000000	INFINITY	4.000000
X434	4.000000	INFINITY	4.000000
X435	4.000000	INFINITY	4.000000
X436	4.000000	INFINITY	4.000000
X437	4.000000	INFINITY	4.000000
X511	5.000000	INFINITY	5.000000
X512	5.000000	INFINITY	5.000000
X513	5.000000	INFINITY	5.000000
X514	5.000000	INFINITY	5.000000
X515	5.000000	INFINITY	5.000000
X516	5.000000	INFINITY	5.000000
X517	5.000000	INFINITY	5.000000
X521	5.000000	INFINITY	5.000000
X522	5.000000	INFINITY	5.000000

X523	5.000000	INFINITY	5.000000
X524	5.000000	INFINITY	5.000000
X525	5.000000	INFINITY	5.000000
X526	5.000000	INFINITY	5.000000
X527	5.000000	INFINITY	5.000000
X531	5.000000	INFINITY	5.000000
X532	5.000000	INFINITY	5.000000
X533	5.000000	INFINITY	5.000000
X534	5.000000	INFINITY	5.000000
X535	5.000000	INFINITY	5.000000
X536	5.000000	INFINITY	5.000000
X537	5.000000	INFINITY	5.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
MONHOURS	6.000000	INFINITY	0.000000
TUEHOURS	4.000000	INFINITY	0.000000
WEDHOURS	15.000000	INFINITY	0.000000
TRKMON	2.000000	INFINITY	0.000000
TRKTUE	1.000000	INFINITY	0.000000
TRKWED	4.000000	INFINITY	0.000000
RTE1	1.000000	INFINITY	0.000000
RTE2	1.000000	INFINITY	0.000000
RTE3	1.000000	INFINITY	0.000000
RTE4	1.000000	INFINITY	0.000000
RTE5	1.000000	INFINITY	0.000000
RTE6	1.000000	INFINITY	0.000000
RTE7	1.000000	INFINITY	0.000000
MAXTRK11	15.000000	INFINITY	9.000000
MAXTRK21	15.000000	INFINITY	15.000000
MAXTRK31	15.000000	INFINITY	15.000000
MAXTRK41	15.000000	INFINITY	15.000000
MAXTRK51	15.000000	INFINITY	15.000000
MAXTRK13	15.000000	INFINITY	0.000000
MAXTRK23	15.000000	INFINITY	15.000000
MAXTRK33	15.000000	INFINITY	15.000000
MAXTRK43	15.000000	INFINITY	15.000000
MAXTRK53	15.000000	INFINITY	15.000000

APPENDIX C2

MIN X111 + X112 + X113 + X114 + X115 + X116 + X117 + X121
+ X122 + X123 + X124 + X125 + X126 + X127 + X131 + X132
+ X133 + X134 + X135 + X136 + X137 + 2 X211 + 2 X212
+ 2 X213 + 2 X214 + 2 X215 + 2 X216 + 2 X217 + 2 X221
+ 2 X222 + 2 X223 + 2 X224 + 2 X225 + 2 X226 + 2 X227
+ 2 X231 + 2 X232 + 2 X233 + 2 X234 + 2 X235 + 2 X236
+ 2 X237 + 3 X311 + 3 X312 + 3 X313 + 3 X314 + 3 X315
+ 3 X316 + 3 X317 + 3 X321 + 3 X322 + 3 X323 + 3 X324
+ 3 X325 + 3 X326 + 3 X327 + 3 X331 + 3 X332 + 3 X333
+ 3 X334 + 3 X335 + 3 X336 + 3 X337 + 4 X411 + 4 X412
+ 4 X413 + 4 X414 + 4 X415 + 4 X416 + 4 X417 + 4 X421
+ 4 X422 + 4 X423 + 4 X424 + 4 X425 + 4 X426 + 4 X427
+ 4 X431 + 4 X432 + 4 X433 + 4 X434 + 4 X435 + 4 X436
+ 4 X437 + 5 X511 + 5 X512 + 5 X513 + 5 X514 + 5 X515
+ 5 X516 + 5 X517 + 5 X521 + 5 X522 + 5 X523 + 5 X524
+ 5 X525 + 5 X526 + 5 X527 + 5 X531 + 5 X532 + 5 X533
+ 5 X534 + 5 X535 + 5 X536 + 5 X537

SUBJECT TO
MONHOURS) 3 X111 + 4 X112 + 2 X113 + 6 X114 + 3 X115 + 3 X116
+ 4 X117 + 3 X211 + 4 X212 + 2 X213 + 6 X214 + 3 X215
+ 3 X216 + 4 X217 + 3 X311 + 4 X312 + 2 X313 + 6 X314
+ 3 X315 + 3 X316 + 4 X317 + 3 X411 + 4 X412 + 2 X413
+ 6 X414 + 3 X415 + 3 X416 + 4 X417 + 3 X511 + 4 X512
+ 2 X513 + 6 X514 + 3 X515 + 3 X516 + 4 X517 <= 6

TUEHOURS) 3 X121 + 4 X122 + 2 X123 + 6 X124 + 3 X125 + 3 X126
+ 4 X127 + 3 X221 + 4 X222 + 2 X223 + 6 X224 + 3 X225
+ 3 X226 + 4 X227 + 3 X321 + 4 X322 + 2 X323 + 6 X324
+ 3 X325 + 3 X326 + 4 X327 + 3 X421 + 4 X422 + 2 X423
+ 6 X424 + 3 X425 + 3 X426 + 4 X427 + 3 X521 + 4 X522
+ 2 X523 + 6 X524 + 3 X525 + 3 X526 + 4 X527 <= 4

WEDHOURS) 3 X131 + 4 X132 + 2 X133 + 6 X134 + 3 X135 + 3 X136
+ 4 X137 + 3 X231 + 4 X232 + 2 X233 + 6 X234 + 3 X235
+ 3 X236 + 4 X237 + 3 X331 + 4 X332 + 2 X333 + 6 X334
+ 3 X335 + 3 X336 + 4 X337 + 3 X431 + 4 X432 + 2 X433
+ 6 X434 + 3 X435 + 3 X436 + 4 X437 + 3 X531 + 4 X532
+ 2 X533 + 6 X534 + 3 X535 + 3 X536 + 4 X537 <= 15

TRKMON) X111 + X112 + X113 + X114 + X115 + X116 + X117 + X211
+ X212 + X213 + X214 + X215 + X216 + X217 + X311 + X312
+ X313 + X314 + X315 + X316 + X317 + X411 + X412 + X413
+ X414 + X415 + X416 + X417 + X511 + X512 + X513 + X514
+ X515 + X516 + X517 <= 2

TRKTUE) X121 + X122 + X123 + X124 + X125 + X126 + X127 + X221
+ X222 + X223 + X224 + X225 + X226 + X227 + X321 + X322
+ X323 + X324 + X325 + X326 + X327 + X421 + X422 + X423
+ X424 + X425 + X426 + X427 + X521 + X522 + X523 + X524
+ X525 + X526 + X527 <= 1

TRKWED) X131 + X132 + X133 + X134 + X135 + X136 + X137 + X231
+ X232 + X233 + X234 + X235 + X236 + X237 + X331 + X332
+ X333 + X334 + X335 + X336 + X337 + X431 + X432 + X433
+ X434 + X435 + X436 + X437 + X531 + X532 + X533 + X534
+ X535 + X536 + X537 <= 4

RTE1) X111 + X121 + X131 + X211 + X221 + X231 + X311 + X321
+ X331 + X411 + X421 + X431 + X511 + X521 + X531 = 1

RTE2) X112 + X122 + X132 + X212 + X222 + X232 + X312 + X322

```

+ X332 + X412 + X422 + X432 + X512 + X522 + X532 = 1
RTE3) X113 + X123 + X133 + X213 + X223 + X233 + X313 + X323
+ X333 + X413 + X423 + X433 + X513 + X523 + X533 = 1
RTE4) X114 + X124 + X134 + X214 + X224 + X234 + X314 + X324
+ X334 + X414 + X424 + X434 + X514 + X524 + X534 = 1
RTE5) X115 + X125 + X135 + X215 + X225 + X235 + X315 + X325
+ X335 + X415 + X425 + X435 + X515 + X525 + X535 = 1
RTE6) X116 + X126 + X136 + X216 + X226 + X236 + X316 + X326
+ X336 + X416 + X426 + X436 + X516 + X526 + X536 = 1
RTE7) X117 + X127 + X137 + X217 + X227 + X237 + X317 + X327
+ X337 + X417 + X427 + X437 + X517 + X527 + X537 = 1
MAXTRK11) 3 X111 + 4 X112 + 2 X113 + 6 X114 + 3 X115 + 3 X116
+ 4 X117 <= 3
MAXTRK21) 3 X211 + 4 X212 + 2 X213 + 6 X214 + 3 X215 + 3 X216
+ 4 X217 <= 3
MAXTRK31) 3 X311 + 4 X312 + 2 X313 + 6 X314 + 3 X315 + 3 X316
+ 4 X317 <= 3
MAXTRK41) 3 X411 + 4 X412 + 2 X413 + 6 X414 + 3 X415 + 3 X416
+ 4 X417 <= 3
MAXTRK51) 3 X511 + 4 X512 + 2 X513 + 6 X514 + 3 X515 + 3 X516
+ 4 X517 <= 3
MAXTRK13) 3 X131 + 4 X132 + 2 X133 + 6 X134 + 3 X135 + 3 X136
+ 4 X137 <= 10
MAXTRK23) 3 X231 + 4 X232 + 2 X233 + 6 X234 + 3 X235 + 3 X236
+ 4 X237 <= 10
MAXTRK33) 3 X331 + 4 X332 + 2 X333 + 6 X334 + 3 X335 + 3 X336
+ 4 X337 <= 10
MAXTRK43) 3 X431 + 4 X432 + 2 X433 + 6 X434 + 3 X435 + 3 X436
+ 4 X437 <= 10
MAXTRK53) 3 X531 + 4 X532 + 2 X533 + 6 X534 + 3 X535 + 3 X536
+ 4 X537 <= 10
END
INTEGER-VARIABLES= 105

```

OBJECTIVE FUNCTION VALUE

1) 9.00000000

VARIABLE	VALUE	REDUCED COST
X111	0.000000	1.000000
X112	0.000000	1.000000
X113	0.000000	1.000000
X114	0.000000	1.000000
X115	0.000000	1.000000
X116	1.000000	1.000000
X117	0.000000	1.000000
X121	0.000000	1.000000
X122	0.000000	1.000000
X123	0.000000	1.000000
X124	0.000000	1.000000
X125	0.000000	1.000000
X126	0.000000	1.000000
X127	1.000000	1.000000

X131	0.000000	1.000000
X132	1.000000	1.000000
X133	1.000000	1.000000
X134	0.000000	1.000000
X135	1.000000	1.000000
X136	0.000000	1.000000
X137	0.000000	1.000000
X211	1.000000	2.000000
X212	0.000000	2.000000
X213	0.000000	2.000000
X214	0.000000	2.000000
X215	0.000000	2.000000
X216	0.000000	2.000000
X217	0.000000	2.000000
X221	0.000000	2.000000
X222	0.000000	2.000000
X223	0.000000	2.000000
X224	0.000000	2.000000
X225	0.000000	2.000000
X226	0.000000	2.000000
X227	0.000000	2.000000
X231	0.000000	2.000000
X232	0.000000	2.000000
X233	0.000000	2.000000
X234	1.000000	2.000000
X235	0.000000	2.000000
X236	0.000000	2.000000
X237	0.000000	2.000000
X311	0.000000	3.000000
X312	0.000000	3.000000
X313	0.000000	3.000000
X314	0.000000	3.000000
X315	0.000000	3.000000
X316	0.000000	3.000000
X317	0.000000	3.000000
X321	0.000000	3.000000
X322	0.000000	3.000000
X323	0.000000	3.000000
X324	0.000000	3.000000
X325	0.000000	3.000000
X326	0.000000	3.000000
X327	0.000000	3.000000
X331	0.000000	3.000000
X332	0.000000	3.000000
X333	0.000000	3.000000
X334	0.000000	3.000000
X335	0.000000	3.000000
X336	0.000000	3.000000
X337	0.000000	3.000000
X411	0.000000	4.000000
X412	0.000000	4.000000
X413	0.000000	4.000000
X414	0.000000	4.000000
X415	0.000000	4.000000
X416	0.000000	4.000000

X417	0.000000	4.000000
X421	0.000000	4.000000
X422	0.000000	4.000000
X423	0.000000	4.000000
X424	0.000000	4.000000
X425	0.000000	4.000000
X426	0.000000	4.000000
X427	0.000000	4.000000
X431	0.000000	4.000000
X432	0.000000	4.000000
X433	0.000000	4.000000
X434	0.000000	4.000000
X435	0.000000	4.000000
X436	0.000000	4.000000
X437	0.000000	4.000000
X511	0.000000	5.000000
X512	0.000000	5.000000
X513	0.000000	5.000000
X514	0.000000	5.000000
X515	0.000000	5.000000
X516	0.000000	5.000000
X517	0.000000	5.000000
X521	0.000000	5.000000
X522	0.000000	5.000000
X523	0.000000	5.000000
X524	0.000000	5.000000
X525	0.000000	5.000000
X526	0.000000	5.000000
X527	0.000000	5.000000
X531	0.000000	5.000000
X532	0.000000	5.000000
X533	0.000000	5.000000
X534	0.000000	5.000000
X535	0.000000	5.000000
X536	0.000000	5.000000
X537	0.000000	5.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
MONHOURS)	0.000000	0.000000
TUEHOURS)	0.000000	0.000000
WEDHOURS)	0.000000	0.000000
TRKMON)	0.000000	0.000000
TRKTUE)	0.000000	0.000000
TRKWED)	0.000000	0.000000
RTE1)	0.000000	0.000000
RTE2)	0.000000	0.000000
RTE3)	0.000000	0.000000
RTE4)	0.000000	0.000000
RTE5)	0.000000	0.000000
RTE6)	0.000000	0.000000
RTE7)	0.000000	0.000000
MAXTRK11)	0.000000	0.000000
MAXTRK21)	0.000000	0.000000
MAXTRK31)	3.000000	0.000000

MAXTRK41)	3.000000	0.000000
MAXTRK51)	3.000000	0.000000
MAXTRK13)	1.000000	0.000000
MAXTRK23)	4.000000	0.000000
MAXTRK33)	10.000000	0.000000
MAXTRK43)	10.000000	0.000000
MAXTRK53)	10.000000	0.000000

NO. ITERATIONS= 0
 BRANCHES= 15 DETERM.= 1.000E 0

RANGES IN WHICH THE BASIS IS UNCHANGED

VARIABLE	CURRENT COEF	OBJ COEFFICIENT RANGES	
		ALLOWABLE INCREASE	ALLOWABLE DECREASE
X111	1.000000	INFINITY	1.000000
X112	1.000000	INFINITY	1.000000
X113	1.000000	INFINITY	1.000000
X114	1.000000	INFINITY	1.000000
X115	1.000000	INFINITY	1.000000
X116	1.000000	-1.000000	INFINITY
X117	1.000000	INFINITY	1.000000
X121	1.000000	INFINITY	1.000000
X122	1.000000	INFINITY	1.000000
X123	1.000000	INFINITY	1.000000
X124	1.000000	INFINITY	1.000000
X125	1.000000	INFINITY	1.000000
X126	1.000000	INFINITY	1.000000
X127	1.000000	-1.000000	INFINITY
X131	1.000000	INFINITY	1.000000
X132	1.000000	-1.000000	INFINITY
X133	1.000000	-1.000000	INFINITY
X134	1.000000	INFINITY	1.000000
X135	1.000000	-1.000000	INFINITY
X136	1.000000	INFINITY	1.000000
X137	1.000000	INFINITY	1.000000
X211	2.000000	-2.000000	INFINITY
X212	2.000000	INFINITY	2.000000
X213	2.000000	INFINITY	2.000000
X214	2.000000	INFINITY	2.000000
X215	2.000000	INFINITY	2.000000
X216	2.000000	INFINITY	2.000000
X217	2.000000	INFINITY	2.000000
X221	2.000000	INFINITY	2.000000
X222	2.000000	INFINITY	2.000000
X223	2.000000	INFINITY	2.000000
X224	2.000000	INFINITY	2.000000
X225	2.000000	INFINITY	2.000000
X226	2.000000	INFINITY	2.000000
X227	2.000000	INFINITY	2.000000
X231	2.000000	INFINITY	2.000000
X232	2.000000	INFINITY	2.000000
X233	2.000000	INFINITY	2.000000

X234	2.000000	-2.000000	INFINITY
X235	2.000000	INFINITY	2.000000
X236	2.000000	INFINITY	2.000000
X237	2.000000	INFINITY	2.000000
X311	3.000000	INFINITY	3.000000
X312	3.000000	INFINITY	3.000000
X313	3.000000	INFINITY	3.000000
X314	3.000000	INFINITY	3.000000
X315	3.000000	INFINITY	3.000000
X316	3.000000	INFINITY	3.000000
X317	3.000000	INFINITY	3.000000
X321	3.000000	INFINITY	3.000000
X322	3.000000	INFINITY	3.000000
X323	3.000000	INFINITY	3.000000
X324	3.000000	INFINITY	3.000000
X325	3.000000	INFINITY	3.000000
X326	3.000000	INFINITY	3.000000
X327	3.000000	INFINITY	3.000000
X331	3.000000	INFINITY	3.000000
X332	3.000000	INFINITY	3.000000
X333	3.000000	INFINITY	3.000000
X334	3.000000	INFINITY	3.000000
X335	3.000000	INFINITY	3.000000
X336	3.000000	INFINITY	3.000000
X337	3.000000	INFINITY	3.000000
X411	4.000000	INFINITY	4.000000
X412	4.000000	INFINITY	4.000000
X413	4.000000	INFINITY	4.000000
X414	4.000000	INFINITY	4.000000
X415	4.000000	INFINITY	4.000000
X416	4.000000	INFINITY	4.000000
X417	4.000000	INFINITY	4.000000
X421	4.000000	INFINITY	4.000000
X422	4.000000	INFINITY	4.000000
X423	4.000000	INFINITY	4.000000
X424	4.000000	INFINITY	4.000000
X425	4.000000	INFINITY	4.000000
X426	4.000000	INFINITY	4.000000
X427	4.000000	INFINITY	4.000000
X431	4.000000	INFINITY	4.000000
X432	4.000000	INFINITY	4.000000
X433	4.000000	INFINITY	4.000000
X434	4.000000	INFINITY	4.000000
X435	4.000000	INFINITY	4.000000
X436	4.000000	INFINITY	4.000000
X437	4.000000	INFINITY	4.000000
X511	5.000000	INFINITY	5.000000
X512	5.000000	INFINITY	5.000000
X513	5.000000	INFINITY	5.000000
X514	5.000000	INFINITY	5.000000
X515	5.000000	INFINITY	5.000000
X516	5.000000	INFINITY	5.000000
X517	5.000000	INFINITY	5.000000
X521	5.000000	INFINITY	5.000000
X522	5.000000	INFINITY	5.000000

X523	5.000000	INFINITY	5.000000
X524	5.000000	INFINITY	5.000000
X525	5.000000	INFINITY	5.000000
X526	5.000000	INFINITY	5.000000
X527	5.000000	INFINITY	5.000000
X531	5.000000	INFINITY	5.000000
X532	5.000000	INFINITY	5.000000
X533	5.000000	INFINITY	5.000000
X534	5.000000	INFINITY	5.000000
X535	5.000000	INFINITY	5.000000
X536	5.000000	INFINITY	5.000000
X537	5.000000	INFINITY	5.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
MONHOURS	6.000000	INFINITY	0.000000
TUEHOURS	4.000000	INFINITY	0.000000
WEDHOURS	15.000000	INFINITY	0.000000
TRKMON	2.000000	INFINITY	0.000000
TRKTUE	1.000000	INFINITY	0.000000
TRKWED	4.000000	INFINITY	0.000000
RTE1	1.000000	INFINITY	0.000000
RTE2	1.000000	INFINITY	0.000000
RTE3	1.000000	INFINITY	0.000000
RTE4	1.000000	INFINITY	0.000000
RTE5	1.000000	INFINITY	0.000000
RTE6	1.000000	INFINITY	0.000000
RTE7	1.000000	INFINITY	0.000000
MAXTRK11	3.000000	INFINITY	0.000000
MAXTRK21	3.000000	INFINITY	0.000000
MAXTRK31	3.000000	INFINITY	3.000000
MAXTRK41	3.000000	INFINITY	3.000000
MAXTRK51	3.000000	INFINITY	3.000000
MAXTRK13	10.000000	INFINITY	1.000000
MAXTRK23	10.000000	INFINITY	4.000000
MAXTRK33	10.000000	INFINITY	10.000000
MAXTRK43	10.000000	INFINITY	10.000000
MAXTRK53	10.000000	INFINITY	10.000000

APPENDIX C3

MIN X111 + X112 + X113 + X114 + X115 + X116 + X117 + X121
+ X122 + X123 + X124 + X125 + X126 + X127 + X131 + X132
+ X133 + X134 + X135 + X136 + X137 + 2 X211 + 2 X212
+ 2 X213 + 2 X214 + 2 X215 + 2 X216 + 2 X217 + 2 X221
+ 2 X222 + 2 X223 + 2 X224 + 2 X225 + 2 X226 + 2 X227
+ 2 X231 + 2 X232 + 2 X233 + 2 X234 + 2 X235 + 2 X236
+ 2 X237 + 3 X311 + 3 X312 + 3 X313 + 3 X314 + 3 X315
+ 3 X316 + 3 X317 + 3 X321 + 3 X322 + 3 X323 + 3 X324
+ 3 X325 + 3 X326 + 3 X327 + 3 X331 + 3 X332 + 3 X333
+ 3 X334 + 3 X335 + 3 X336 + 3 X337 + 4 X411 + 4 X412
+ 4 X413 + 4 X414 + 4 X415 + 4 X416 + 4 X417 + 4 X421
+ 4 X422 + 4 X423 + 4 X424 + 4 X425 + 4 X426 + 4 X427
+ 4 X431 + 4 X432 + 4 X433 + 4 X434 + 4 X435 + 4 X436
+ 4 X437 + 5 X511 + 5 X512 + 5 X513 + 5 X514 + 5 X515
+ 5 X516 + 5 X517 + 5 X521 + 5 X522 + 5 X523 + 5 X524
+ 5 X525 + 5 X526 + 5 X527 + 5 X531 + 5 X532 + 5 X533
+ 5 X534 + 5 X535 + 5 X536 + 5 X537

SUBJECT TO
MONHOURS) 3 X111 + 4 X112 + 2 X113 + 6 X114 + 3 X115 + 3 X116
+ 4 X117 + 3 X211 + 4 X212 + 2 X213 + 6 X214 + 3 X215
+ 3 X216 + 4 X217 + 3 X311 + 4 X312 + 2 X313 + 6 X314
+ 3 X315 + 3 X316 + 4 X317 + 3 X411 + 4 X412 + 2 X413
+ 6 X414 + 3 X415 + 3 X416 + 4 X417 + 3 X511 + 4 X512
+ 2 X513 + 6 X514 + 3 X515 + 3 X516 + 4 X517 <= 6

TUEHOURS) 3 X121 + 4 X122 + 2 X123 + 6 X124 + 3 X125 + 3 X126
+ 4 X127 + 3 X221 + 4 X222 + 2 X223 + 6 X224 + 3 X225
+ 3 X226 + 4 X227 + 3 X321 + 4 X322 + 2 X323 + 6 X324
+ 3 X325 + 3 X326 + 4 X327 + 3 X421 + 4 X422 + 2 X423
+ 6 X424 + 3 X425 + 3 X426 + 4 X427 + 3 X521 + 4 X522
+ 2 X523 + 6 X524 + 3 X525 + 3 X526 + 4 X527 <= 4

WEDHOURS) 3 X131 + 4 X132 + 2 X133 + 6 X134 + 3 X135 + 3 X136
+ 4 X137 + 3 X231 + 4 X232 + 2 X233 + 6 X234 + 3 X235
+ 3 X236 + 4 X237 + 3 X331 + 4 X332 + 2 X333 + 6 X334
+ 3 X335 + 3 X336 + 4 X337 + 3 X431 + 4 X432 + 2 X433
+ 6 X434 + 3 X435 + 3 X436 + 4 X437 + 3 X531 + 4 X532
+ 2 X533 + 6 X534 + 3 X535 + 3 X536 + 4 X537 <= 15

TRKMON) X111 + X112 + X113 + X114 + X115 + X116 + X117 + X211
+ X212 + X213 + X214 + X215 + X216 + X217 + X311 + X312
+ X313 + X314 + X315 + X316 + X317 + X411 + X412 + X413
+ X414 + X415 + X416 + X417 + X511 + X512 + X513 + X514
+ X515 + X516 + X517 <= 2

TRKTUE) X121 + X122 + X123 + X124 + X125 + X126 + X127 + X221
+ X222 + X223 + X224 + X225 + X226 + X227 + X321 + X322
+ X323 + X324 + X325 + X326 + X327 + X421 + X422 + X423
+ X424 + X425 + X426 + X427 + X521 + X522 + X523 + X524
+ X525 + X526 + X527 <= 1

TRKWED) X131 + X132 + X133 + X134 + X135 + X136 + X137 + X231
+ X232 + X233 + X234 + X235 + X236 + X237 + X331 + X332
+ X333 + X334 + X335 + X336 + X337 + X431 + X432 + X433
+ X434 + X435 + X436 + X437 + X531 + X532 + X533 + X534
+ X535 + X536 + X537 <= 4

RTE1) X111 + X121 + X131 + X211 + X221 + X231 + X311 + X321
+ X331 + X411 + X421 + X431 + X511 + X521 + X531 = 1

RTE2) X112 + X122 + X132 + X212 + X222 + X232 + X312 + X322

```

+ X332 + X412 + X422 + X432 + X512 + X522 + X532 = 1
RTE3) X113 + X123 + X133 + X213 + X223 + X233 + X313 + X323
+ X333 + X413 + X423 + X433 + X513 + X523 + X533 = 1
RTE4) X114 + X124 + X134 + X214 + X224 + X234 + X314 + X324
+ X334 + X414 + X424 + X434 + X514 + X524 + X534 = 1
RTE5) X115 + X125 + X135 + X215 + X225 + X235 + X315 + X325
+ X335 + X415 + X425 + X435 + X515 + X525 + X535 = 1
RTE6) X116 + X126 + X136 + X216 + X226 + X236 + X316 + X326
+ X336 + X416 + X426 + X436 + X516 + X526 + X536 = 1
RTE7) X117 + X127 + X137 + X217 + X227 + X237 + X317 + X327
+ X337 + X417 + X427 + X437 + X517 + X527 + X537 = 1
MAXTRK11) 3 X111 + 4 X112 + 2 X113 + 6 X114 + 3 X115 + 3 X116
+ 4 X117 <= 3
MAXTRK21) 3 X211 + 4 X212 + 2 X213 + 6 X214 + 3 X215 + 3 X216
+ 4 X217 <= 3
MAXTRK31) 3 X311 + 4 X312 + 2 X313 + 6 X314 + 3 X315 + 3 X316
+ 4 X317 <= 3
MAXTRK41) 3 X411 + 4 X412 + 2 X413 + 6 X414 + 3 X415 + 3 X416
+ 4 X417 <= 3
MAXTRK51) 3 X511 + 4 X512 + 2 X513 + 6 X514 + 3 X515 + 3 X516
+ 4 X517 <= 3
MAXTRK13) 3 X131 + 4 X132 + 2 X133 + 6 X134 + 3 X135 + 3 X136
+ 4 X137 <= 6
MAXTRK23) 3 X231 + 4 X232 + 2 X233 + 6 X234 + 3 X235 + 3 X236
+ 4 X237 <= 6
MAXTRK33) 3 X331 + 4 X332 + 2 X333 + 6 X334 + 3 X335 + 3 X336
+ 4 X337 <= 6
MAXTRK43) 3 X431 + 4 X432 + 2 X433 + 6 X434 + 3 X435 + 3 X436
+ 4 X437 <= 6
MAXTRK53) 3 X531 + 4 X532 + 2 X533 + 6 X534 + 3 X535 + 3 X536
+ 4 X537 <= 6
END
INTEGER-VARIABLES= 105

```

OBJECTIVE FUNCTION VALUE

1) 11.0000000

VARIABLE	VALUE	REDUCED COST
X111	0.000000	1.000000
X112	0.000000	1.000000
X113	0.000000	1.000000
X114	0.000000	1.000000
X115	1.000000	1.000000
X116	0.000000	1.000000
X117	0.000000	1.000000
X121	0.000000	1.000000
X122	1.000000	1.000000
X123	0.000000	1.000000
X124	0.000000	1.000000
X125	0.000000	1.000000
X126	0.000000	1.000000
X127	0.000000	1.000000

X131	0.000000	1.000000
X132	0.000000	1.000000
X133	1.000000	1.000000
X134	0.000000	1.000000
X135	0.000000	1.000000
X136	1.000000	1.000000
X137	0.000000	1.000000
X211	1.000000	2.000000
X212	0.000000	2.000000
X213	0.000000	2.000000
X214	0.000000	2.000000
X215	0.000000	2.000000
X216	0.000000	2.000000
X217	0.000000	2.000000
X221	0.000000	2.000000
X222	0.000000	2.000000
X223	0.000000	2.000000
X224	0.000000	2.000000
X225	0.000000	2.000000
X226	0.000000	2.000000
X227	0.000000	2.000000
X231	0.000000	2.000000
X232	0.000000	2.000000
X233	0.000000	2.000000
X234	0.000000	2.000000
X235	0.000000	2.000000
X236	0.000000	2.000000
X237	1.000000	2.000000
X311	0.000000	3.000000
X312	0.000000	3.000000
X313	0.000000	3.000000
X314	0.000000	3.000000
X315	0.000000	3.000000
X316	0.000000	3.000000
X317	0.000000	3.000000
X321	0.000000	3.000000
X322	0.000000	3.000000
X323	0.000000	3.000000
X324	0.000000	3.000000
X325	0.000000	3.000000
X326	0.000000	3.000000
X327	0.000000	3.000000
X331	0.000000	3.000000
X332	0.000000	3.000000
X333	0.000000	3.000000
X334	1.000000	3.000000
X335	0.000000	3.000000
X336	0.000000	3.000000
X337	0.000000	3.000000
X411	0.000000	4.000000
X412	0.000000	4.000000
X413	0.000000	4.000000
X414	0.000000	4.000000
X415	0.000000	4.000000
X416	0.000000	4.000000

X417	0.000000	4.000000
X421	0.000000	4.000000
X422	0.000000	4.000000
X423	0.000000	4.000000
X424	0.000000	4.000000
X425	0.000000	4.000000
X426	0.000000	4.000000
X427	0.000000	4.000000
X431	0.000000	4.000000
X432	0.000000	4.000000
X433	0.000000	4.000000
X434	0.000000	4.000000
X435	0.000000	4.000000
X436	0.000000	4.000000
X437	0.000000	4.000000
X511	0.000000	5.000000
X512	0.000000	5.000000
X513	0.000000	5.000000
X514	0.000000	5.000000
X515	0.000000	5.000000
X516	0.000000	5.000000
X517	0.000000	5.000000
X521	0.000000	5.000000
X522	0.000000	5.000000
X523	0.000000	5.000000
X524	0.000000	5.000000
X525	0.000000	5.000000
X526	0.000000	5.000000
X527	0.000000	5.000000
X531	0.000000	5.000000
X532	0.000000	5.000000
X533	0.000000	5.000000
X534	0.000000	5.000000
X535	0.000000	5.000000
X536	0.000000	5.000000
X537	0.000000	5.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
MONHOURS)	0.000000	0.000000
TUEHOURS)	0.000000	0.000000
WEDHOURS)	0.000000	0.000000
TRKMON)	0.000000	0.000000
TRKTUE)	0.000000	0.000000
TRKWED)	0.000000	0.000000
RTE1)	0.000000	0.000000
RTE2)	0.000000	0.000000
RTE3)	0.000000	0.000000
RTE4)	0.000000	0.000000
RTE5)	0.000000	0.000000
RTE6)	0.000000	0.000000
RTE7)	0.000000	0.000000
MAXTRK11)	0.000000	0.000000
MAXTRK21)	0.000000	0.000000
MAXTRK31)	3.000000	0.000000

MAXTRK41)	3.000000	0.000000
MAXTRK51)	3.000000	0.000000
MAXTRK13)	1.000000	0.000000
MAXTRK23)	2.000000	0.000000
MAXTRK33)	0.000000	0.000000
MAXTRK43)	6.000000	0.000000
MAXTRK53)	6.000000	0.000000

NO. ITERATIONS= 0
 BRANCHES= 9 DETERM.= 1.000E 0

RANGES IN WHICH THE BASIS IS UNCHANGED

VARIABLE	CURRENT COEF	OBJ COEFFICIENT RANGES	
		ALLOWABLE INCREASE	ALLOWABLE DECREASE
X111	1.000000	INFINITY	1.000000
X112	1.000000	INFINITY	1.000000
X113	1.000000	INFINITY	1.000000
X114	1.000000	INFINITY	1.000000
X115	1.000000	-1.000000	INFINITY
X116	1.000000	INFINITY	1.000000
X117	1.000000	INFINITY	1.000000
X121	1.000000	INFINITY	1.000000
X122	1.000000	-1.000000	INFINITY
X123	1.000000	INFINITY	1.000000
X124	1.000000	INFINITY	1.000000
X125	1.000000	INFINITY	1.000000
X126	1.000000	INFINITY	1.000000
X127	1.000000	INFINITY	1.000000
X131	1.000000	INFINITY	1.000000
X132	1.000000	INFINITY	1.000000
X133	1.000000	-1.000000	INFINITY
X134	1.000000	INFINITY	1.000000
X135	1.000000	INFINITY	1.000000
X136	1.000000	-1.000000	INFINITY
X137	1.000000	INFINITY	1.000000
X211	2.000000	-2.000000	INFINITY
X212	2.000000	INFINITY	2.000000
X213	2.000000	INFINITY	2.000000
X214	2.000000	INFINITY	2.000000
X215	2.000000	INFINITY	2.000000
X216	2.000000	INFINITY	2.000000
X217	2.000000	INFINITY	2.000000
X221	2.000000	INFINITY	2.000000
X222	2.000000	INFINITY	2.000000
X223	2.000000	INFINITY	2.000000
X224	2.000000	INFINITY	2.000000
X225	2.000000	INFINITY	2.000000
X226	2.000000	INFINITY	2.000000
X227	2.000000	INFINITY	2.000000
X231	2.000000	INFINITY	2.000000
X232	2.000000	INFINITY	2.000000
X233	2.000000	INFINITY	2.000000

X234	2.000000	INFINITY	2.000000
X235	2.000000	INFINITY	2.000000
X236	2.000000	INFINITY	2.000000
X237	2.000000	-2.000000	INFINITY
X311	3.000000	INFINITY	3.000000
X312	3.000000	INFINITY	3.000000
X313	3.000000	INFINITY	3.000000
X314	3.000000	INFINITY	3.000000
X315	3.000000	INFINITY	3.000000
X316	3.000000	INFINITY	3.000000
X317	3.000000	INFINITY	3.000000
X321	3.000000	INFINITY	3.000000
X322	3.000000	INFINITY	3.000000
X323	3.000000	INFINITY	3.000000
X324	3.000000	INFINITY	3.000000
X325	3.000000	INFINITY	3.000000
X326	3.000000	INFINITY	3.000000
X327	3.000000	INFINITY	3.000000
X331	3.000000	INFINITY	3.000000
X332	3.000000	INFINITY	3.000000
X333	3.000000	INFINITY	3.000000
X334	3.000000	-3.000000	INFINITY
X335	3.000000	INFINITY	3.000000
X336	3.000000	INFINITY	3.000000
X337	3.000000	INFINITY	3.000000
X411	4.000000	INFINITY	4.000000
X412	4.000000	INFINITY	4.000000
X413	4.000000	INFINITY	4.000000
X414	4.000000	INFINITY	4.000000
X415	4.000000	INFINITY	4.000000
X416	4.000000	INFINITY	4.000000
X417	4.000000	INFINITY	4.000000
X421	4.000000	INFINITY	4.000000
X422	4.000000	INFINITY	4.000000
X423	4.000000	INFINITY	4.000000
X424	4.000000	INFINITY	4.000000
X425	4.000000	INFINITY	4.000000
X426	4.000000	INFINITY	4.000000
X427	4.000000	INFINITY	4.000000
X431	4.000000	INFINITY	4.000000
X432	4.000000	INFINITY	4.000000
X433	4.000000	INFINITY	4.000000
X434	4.000000	INFINITY	4.000000
X435	4.000000	INFINITY	4.000000
X436	4.000000	INFINITY	4.000000
X437	4.000000	INFINITY	4.000000
X511	5.000000	INFINITY	5.000000
X512	5.000000	INFINITY	5.000000
X513	5.000000	INFINITY	5.000000
X514	5.000000	INFINITY	5.000000
X515	5.000000	INFINITY	5.000000
X516	5.000000	INFINITY	5.000000
X517	5.000000	INFINITY	5.000000
X521	5.000000	INFINITY	5.000000
X522	5.000000	INFINITY	5.000000

X523	5.000000	INFINITY	5.000000
X524	5.000000	INFINITY	5.000000
X525	5.000000	INFINITY	5.000000
X526	5.000000	INFINITY	5.000000
X527	5.000000	INFINITY	5.000000
X531	5.000000	INFINITY	5.000000
X532	5.000000	INFINITY	5.000000
X533	5.000000	INFINITY	5.000000
X534	5.000000	INFINITY	5.000000
X535	5.000000	INFINITY	5.000000
X536	5.000000	INFINITY	5.000000
X537	5.000000	INFINITY	5.000000

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
MONHOURS	6.000000	INFINITY	0.000000
TUEHOURS	4.000000	INFINITY	0.000000
WEDHOURS	15.000000	INFINITY	0.000000
TRKMON	2.000000	INFINITY	0.000000
TRKTUE	1.000000	INFINITY	0.000000
TRKWED	4.000000	INFINITY	0.000000
RTE1	1.000000	INFINITY	0.000000
RTE2	1.000000	INFINITY	0.000000
RTE3	1.000000	INFINITY	0.000000
RTE4	1.000000	INFINITY	0.000000
RTE5	1.000000	INFINITY	0.000000
RTE6	1.000000	INFINITY	0.000000
RTE7	1.000000	INFINITY	0.000000
MAXTRK11	3.000000	INFINITY	0.000000
MAXTRK21	3.000000	INFINITY	0.000000
MAXTRK31	3.000000	INFINITY	3.000000
MAXTRK41	3.000000	INFINITY	3.000000
MAXTRK51	3.000000	INFINITY	3.000000
MAXTRK13	6.000000	INFINITY	1.000000
MAXTRK23	6.000000	INFINITY	2.000000
MAXTRK33	6.000000	INFINITY	0.000000
MAXTRK43	6.000000	INFINITY	6.000000
MAXTRK53	6.000000	INFINITY	6.000000

APPENDIX D

LOGGING TO 'BASLOG' LOG IS ON.

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* LOAD TUP1

121 LINES LOADED. 'TUP1' IS THE WORKSPACE NAME.

* LIST

```
100 REM #####
110 REM THIS PROGRAM IS A RECURSIVE VERSION OF THE TRAVELING SALESMAN
120 REM PROBLEM. IT ALLOWS INPUT FOR THE NUMBER OF CITIES AND ASSUMES
130 REM THAT, IN THIS CASE, THE TRUCK WILL LEAVE AND RETURN TO THE
140 REM WAREHOUSE. IT UTILIZES A DATA STRUCTURE CALLED COUNTER WHICH
150 REM FINDS UNIQUE SET OF STOPS. AFTER FINDING A UNIQUE PATH, IT
160 REM CALCULATES THE COSTS OF TRAVELING THIS ROUTE. IF THIS IS THE
170 REM MINIMUM ROUTE, IT STORES THIS ROUTE AND GETS THE NEXT UNIQUE
180 REM PATH. AFTER ALL HAVE BEEN TRIED, IT PRINTS OUT MINIMUM.
190 REM #####
200 DIM CITY$(10),DIST(10,10),USED(10),COUNTER(10),PATH(10)
210 STPS = 'FALSE'
220 FINALS = 'FALSE'
230 INPUT "ROUTE NUMBER:":ROUTE
240 INPUT "NUMBER OF STOPS":NUM
250 REM $$$$$$THIS READS IN CITY NAMES.$$$$$$
260 FOR ROW = 1 TO NUM
270 PRINT " INPUT VERTICE #",ROW,"NAME."
280 INPUT NAMES
290 CITY$(ROW) = NAMES
300 NEXT ROW
310 REM $$$$$$THIS READS IN COST$$$$$$$
320 FOR ROW = 1 TO NUM
330 FOR COLUMN = 1 TO NUM
340 PRINT "WHAT IS THE DISTANCE FROM ";CITY$(ROW);" TO ";CITY$(COLUMN)
350 INPUT DAT
360 DIST(ROW,COLUMN) = DAT
370 NEXT COLUMN
380 NEXT ROW
390 REM #####THIS INITIALIZES VARIABLES AND ARRAYS USED#####
400 MINDIST = 99999
410 COUNT = 1
420 FOR N = 1 TO NUM
430 USED(N) = 0
440 COUNTER(N) = N
450 PATH(N)=0
460 NEXT N
470 USED(1) = 1
480 REM #####
490 REM THIS SECTION DETERMINES IF A PATH IS UNIQUE BY USE OF 2
500 REM ARRAYS. PATH KEEPS TRACK OF THE ORDER OF THE STOPS.
510 REM USED DETERMINES IF THAT PARTICULAR STOP HAS BEEN USED
520 REM IN THIS REPRESENTATION--THIS KEEPS THE STIPULATION
530 REM OF NOT VISITING A CITY MORE THAN ONCE. COUNTER MERELY
540 REM DEFINES NUMBER IN A SPECIFIC ORDER SO AS TO GET EVERY
550 REM COMBINATION. THIS SECTION GOES THROUGH AND PUTS THEM
560 REM IN PLACE.
570 REM #####
580 PATH(1) = 1
590 FOR N = 2 TO NUM
```

```
600 X = COUNTER(N)
610 IF USED(X) <> 1 AND PATH(N) = 0 THEN GOTO 620 ELSE GOTO 650
620 PATH(N) = X
630 USED(X) = 1
640 COUNT = COUNT + 1
650 NEXT N
660 IF COUNT = NUM THEN GOSUB 900
670 REM GOING TO MINIMUM
680 Z = NUM
690 GOSUB 1180
700 IF FINALS <> 'TRUE' THEN GOTO 570
710 REM ##### THE PRINTOUT #####
720 PRINT "#####"
730 PRINT "          SHORTEST PATH          "
740 PRINT "#####"
750 PRINT "ROUTE NUMBER",ROUTE
760 FOR N = 1 TO NUM
770 X = MINPATH(N)
780 PRINT CITY$(X); " ";
790 NEXT N
800 X = MINPATH(1)
810 PRINT CITY$(X)
820 PRINT "  MIN DIST OF PATH IS:",MINDIST
830 STOP
840 REM #####
850 REM SUBROUTINE MINIMUM IS CALLED AFTER A UNIQUE PATH HAS BEEN
860 REM FOUND. IT CALCULATES THE COST FROM THE CITIES IN THE ORDER
870 REM FOUND. IF THE COST IS A MIN, THEN THIS MINIMUM AND THE MIN
880 REM PATH ARE STORED. CONTROL IS RETURNED TO 'FINDPATH' WHICH
890 REM FINDS THE NEXT PATH.
900 REM #####
910 PATH(NUM+1) = 1
920 ADDIST = 0
930 SOURCE = 1
940 FOR N = 2 TO NUM+1
950 DEST = PATH(N)
960 ADDIST = ADDIST + DIST(SOURCE,DEST)
970 SOURCE = DEST
980 NEXT N
990 IF ADDIST < MINDIST THEN GOTO 1000 ELSE GOTO 1040
1000 MINDIST = ADDIST
1010 FOR N = 1 TO NUM+1
1020 MINPATH(N) = PATH(N)
1030 NEXT N
1040 COUNT = 1
1050 FOR N = 2 TO NUM
1060 USED(N) = 0
1070 PATH(N) = 0
1080 NEXT N
1090 RETURN
1100 REM #####
1110 REM SUBROUTINE UPDATE CONTROLS THE DATA STRUCTURE COUNTER. TO
1120 REM CALCULATE THE PERMUTATIONS, THE LEFT NUMBERS ARE HELD CONSTANT
1130 REM AND THE CHANGE OCCURS FROM RIGHT. OF COURSE, SOURCE REMAINS
1140 REM CONSTANT AT THE WAREHOUSE. THE STOP VARIABLE IS USED TO WARN
```

```
1150 REM OF THE NEXT TO LAST TIME TO GO THROUGH THE MINIMIZATION, WHILE
1160 REM FINAL WARNS OF THE FINAL TIME WHICH ENDS THE PROGRAM.
1170 REM *****
1180 IF STPS = 'TRUE' THEN FINAL$ = 'TRUE'
1190 WARNS = 'FALSE'
1200 FLG = NUM
1210 IF COUNTER(2) = NUM THEN FLG = NUM-1
1220 IF COUNTER(Z) < FLG THEN WARNS = 'TRUE'
1230 IF COUNTER(Z)=FLG AND WARNS<>'TRUE' AND FINAL$<>'TRUE' AND STPS<>'TRUE' THE
N GOTO 1240 ELSE GOTO 1280
1240 COUNTER(Z) = 2
1250 IF FLG = NUM-1 AND Z = 3 THEN STPS = 'TRUE'
1260 Z = Z-1
1270 GOTO 1180
1280 IF WARNS = 'TRUE' THEN COUNTER(Z) = COUNTER(Z) + 1
1290 RETURN
1300 END
```

```
*
*
*
*
```

```
* RUN
```

```
ROUTE NUMBER: 3
NUMBER OF STOPS 6
```

INPUT VERTICE #	1	NAME.
? WHSE		
INPUT VERTICE #	2	NAME.
? ALVAREZ		
INPUT VERTICE #	3	NAME.
? GONZALEZ		
INPUT VERTICE #	4	NAME.
? BRANCH		
INPUT VERTICE #	5	NAME.
? OROZCO		
INPUT VERTICE #	6	NAME.
? ALAMANZA		

```
WHAT IS THE DISTANCE FROM WHSE TO WHSE
```

```
? 0
```

```
WHAT IS THE DISTANCE FROM WHSE TO ALVAREZ
```

```
? 16.8
```

```
WHAT IS THE DISTANCE FROM WHSE TO GONZALEZ
```

```
? 13.8
```

```
WHAT IS THE DISTANCE FROM WHSE TO BRANCH
```

```
? 18.4
```

```
WHAT IS THE DISTANCE FROM WHSE TO OROZCO
```

```
? 16.3
```

```
WHAT IS THE DISTANCE FROM WHSE TO ALAMANZA
```

```
? 15.6
```

```
WHAT IS THE DISTANCE FROM ALVAREZ TO WHSE
```

```
? 16.8
```

```
WHAT IS THE DISTANCE FROM ALVAREZ TO ALVAREZ
```

```
? 0
```

```
WHAT IS THE DISTANCE FROM ALVAREZ TO GONZALEZ
```

```
? 3
```

```
WHAT IS THE DISTANCE FROM ALVAREZ TO BRANCH
```

? 8.8
WHAT IS THE DISTANCE FROM ALVAREZ TO OROZCO
? 1.2
WHAT IS THE DISTANCE FROM ALVAREZ TO ALAMANZA
? 1.3
WHAT IS THE DISTANCE FROM GONZALEZ TO WHSE
? 13.8
WHAT IS THE DISTANCE FROM GONZALEZ TO ALVAREZ
? 3
WHAT IS THE DISTANCE FROM GONZALEZ TO GONZALEZ
? 0
WHAT IS THE DISTANCE FROM GONZALEZ TO BRANCH
? 6
WHAT IS THE DISTANCE FROM GONZALEZ TO OROZCO
? 2.5
WHAT IS THE DISTANCE FROM GONZALEZ TO ALAMANZA
? 1.8
WHAT IS THE DISTANCE FROM BRANCH TO WHSE
? 18.4
WHAT IS THE DISTANCE FROM BRANCH TO ALVAREZ
? 8.8
WHAT IS THE DISTANCE FROM BRANCH TO GONZALEZ
? 6
WHAT IS THE DISTANCE FROM BRANCH TO BRANCH
? 0
WHAT IS THE DISTANCE FROM BRANCH TO OROZCO
? 7.9
WHAT IS THE DISTANCE FROM BRANCH TO ALAMANZA
? 7.4
WHAT IS THE DISTANCE FROM OROZCO TO WHSE
? 16.3
WHAT IS THE DISTANCE FROM OROZCO TO ALVAREZ
? 1.2
WHAT IS THE DISTANCE FROM OROZCO TO GONZALEZ
? 2.5
WHAT IS THE DISTANCE FROM OROZCO TO BRANCH
? 7.9
WHAT IS THE DISTANCE FROM OROZCO TO OROZCO
? 0
WHAT IS THE DISTANCE FROM OROZCO TO ALAMANZA
? .7
WHAT IS THE DISTANCE FROM ALAMANZA TO WHSE
? 15.6
WHAT IS THE DISTANCE FROM ALAMANZA TO ALVAREZ
? 1.3
WHAT IS THE DISTANCE FROM ALAMANZA TO GONZALEZ
? 1.8
WHAT IS THE DISTANCE FROM ALAMANZA TO BRANCH
? 7.4
WHAT IS THE DISTANCE FROM ALAMANZA TO OROZCO
? .7
WHAT IS THE DISTANCE FROM ALAMANZA TO ALAMANZA
? 0

SHORTEST PATH

ROUTE NUMBER 3
WHSE GONZALEZ ALAMANZA ALVAREZ OROZCO BRANCH WHSE
MIN DIST OF PATH IS: 44.4
STOP AT LINE 830. RETURN CODE IS 0.
* QUIT

LOGGING TO 'BASLOG' LOG IS ON.
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* LOAD TUP1
121 LINES LOADED. 'TUP1' IS THE WORKSPACE NAME.

* RUN

ROUTE NUMBER: 1

NUMBER OF STOPS 8

INPUT VERTICE # 1 NAME.

? WAREHOUSE

INPUT VERTICE # 2 NAME.

? DAVIES

INPUT VERTICE # 3 NAME.

? MARSHALL

INPUT VERTICE # 4 NAME.

? COOKE

INPUT VERTICE # 5 NAME.

? COFFEE

INPUT VERTICE # 6 NAME.

? SWEAT

INPUT VERTICE # 7 NAME.

? LOKKE

INPUT VERTICE # 8 NAME.

? RITNER

WHAT IS THE DISTANCE FROM WAREHOUSE TO WAREHOUSE

? 0

WHAT IS THE DISTANCE FROM WAREHOUSE TO DAVIES

? 12.9

WHAT IS THE DISTANCE FROM WAREHOUSE TO MARSHALL

? 12.6

WHAT IS THE DISTANCE FROM WAREHOUSE TO COOKE

? 9.6

WHAT IS THE DISTANCE FROM WAREHOUSE TO COFFEE

? 15.3

WHAT IS THE DISTANCE FROM WAREHOUSE TO SWEAT

? 14.9

WHAT IS THE DISTANCE FROM WAREHOUSE TO LOKKE

? 16.6

WHAT IS THE DISTANCE FROM WAREHOUSE TO RITNER

? 12.4

WHAT IS THE DISTANCE FROM DAVIES TO WAREHOUSE

? 12.9

WHAT IS THE DISTANCE FROM DAVIES TO DAVIES

? 0

WHAT IS THE DISTANCE FROM DAVIES TO MARSHALL

? .8

WHAT IS THE DISTANCE FROM DAVIES TO COOKE

? 3.4

WHAT IS THE DISTANCE FROM DAVIES TO COFFEE

? 7.2

WHAT IS THE DISTANCE FROM DAVIES TO SWEAT

? 9.5

WHAT IS THE DISTANCE FROM DAVIES TO LOKKE

? 7.9

WHAT IS THE DISTANCE FROM DAVIES TO RITNER

? 7

WHAT IS THE DISTANCE FROM MARSHALL TO WAREHOUSE
? 12.6
WHAT IS THE DISTANCE FROM MARSHALL TO DAVIES
? .8
WHAT IS THE DISTANCE FROM MARSHALL TO MARSHALL
? 0
WHAT IS THE DISTANCE FROM MARSHALL TO COOKE
? 3.3
WHAT IS THE DISTANCE FROM MARSHALL TO COFFEE
? 6.5
WHAT IS THE DISTANCE FROM MARSHALL TO SWEAT
? 8.7
WHAT IS THE DISTANCE FROM MARSHALL TO LOKKE
? 7.4
WHAT IS THE DISTANCE FROM MARSHALL TO RITNER
? 6.1
WHAT IS THE DISTANCE FROM COOKE TO WAREHOUSE
? 9.6
WHAT IS THE DISTANCE FROM COOKE TO DAVIES
? 3.4
WHAT IS THE DISTANCE FROM COOKE TO MARSHALL
? 3.3
WHAT IS THE DISTANCE FROM COOKE TO COOKE
? 0
WHAT IS THE DISTANCE FROM COOKE TO COFFEE
? 8.8
WHAT IS THE DISTANCE FROM COOKE TO SWEAT
? 10.3
WHAT IS THE DISTANCE FROM COOKE TO LOKKE
? 10
WHAT IS THE DISTANCE FROM COOKE TO RITNER
? 7.4
WHAT IS THE DISTANCE FROM COFFEE TO WAREHOUSE
? 15.3
WHAT IS THE DISTANCE FROM COFFEE TO DAVIES
? 7.2
WHAT IS THE DISTANCE FROM COFFEE TO MARSHALL
? 6.5
WHAT IS THE DISTANCE FROM COFFEE TO COOKE
? 8.8
WHAT IS THE DISTANCE FROM COFFEE TO COFFEE
? 0
WHAT IS THE DISTANCE FROM COFFEE TO SWEAT
? 3
WHAT IS THE DISTANCE FROM COFFEE TO LOKKE
? 1.5
WHAT IS THE DISTANCE FROM COFFEE TO RITNER
? 3.1
WHAT IS THE DISTANCE FROM SWEAT TO WAREHOUSE
? 14.9
WHAT IS THE DISTANCE FROM SWEAT TO DAVIES
? 9.5
WHAT IS THE DISTANCE FROM SWEAT TO MARSHALL
? 8.7
WHAT IS THE DISTANCE FROM SWEAT TO COOKE

? 10.3
WHAT IS THE DISTANCE FROM SWEAT TO COFFEE
? 3
WHAT IS THE DISTANCE FROM SWEAT TO SWEAT
? 0
WHAT IS THE DISTANCE FROM SWEAT TO LOKKE
? 3.8
WHAT IS THE DISTANCE FROM SWEAT TO RITNER
? 3
WHAT IS THE DISTANCE FROM LOKKE TO WAREHOUSE
? 16.6
WHAT IS THE DISTANCE FROM LOKKE TO DAVIES
? 7.9
WHAT IS THE DISTANCE FROM LOKKE TO MARSHALL
? 7.4
WHAT IS THE DISTANCE FROM LOKKE TO COOKE
? 10
WHAT IS THE DISTANCE FROM LOKKE TO COFFEE
? 1.5
WHAT IS THE DISTANCE FROM LOKKE TO SWEAT
? 3.8
WHAT IS THE DISTANCE FROM LOKKE TO LOKKE
? 0
WHAT IS THE DISTANCE FROM LOKKE TO RITNER
? 4.5
WHAT IS THE DISTANCE FROM RITNER TO WAREHOUSE
? 12.4
WHAT IS THE DISTANCE FROM RITNER TO DAVIES
? 7
WHAT IS THE DISTANCE FROM RITNER TO MARSHALL
? 6.1
WHAT IS THE DISTANCE FROM RITNER TO COOKE
? 7.4
WHAT IS THE DISTANCE FROM RITNER TO COFFEE
? 3.1
WHAT IS THE DISTANCE FROM RITNER TO SWEAT
? 3
WHAT IS THE DISTANCE FROM RITNER TO LOKKE
? 3
WHAT IS THE DISTANCE FROM RITNER TO RITNER
? 0

SHORTEST PATH

ROUTE NUMBER 1
WAREHOUSE RITNER SWEAT COFFEE LOKKE MARSHALL DAVIES COOKE
WAREHOUSE
MIN DIST OF PATH IS: 41.1
STOP AT LINE 830. RETURN CODE IS 0.

*
*
*
*
*
*

*
*
* QUIT



LOGGING TO 'BASLOG' LOG IS ON.
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* RUN

ROUTE NUMBER: 2

NUMBER OF STOPS 8

INPUT VERTICE # 1 NAME.

? WAREHOUSE

INPUT VERTICE # 2 NAME.

? FOLK

INPUT VERTICE # 3 NAME.

? BROWN

INPUT VERTICE # 4 NAME.

? FEUERBACHER

INPUT VERTICE # 5 NAME.

? LANE

INPUT VERTICE # 6 NAME.

? POSTON

INPUT VERTICE # 7 NAME.

? MACIAS

INPUT VERTICE # 8 NAME.

? SWINDELL

WHAT IS THE DISTANCE FROM WAREHOUSE TO WAREHOUSE

? 0

WHAT IS THE DISTANCE FROM WAREHOUSE TO FOLK

? 19.2

WHAT IS THE DISTANCE FROM WAREHOUSE TO BROWN

? 22.3

WHAT IS THE DISTANCE FROM WAREHOUSE TO FEUERBACHER

? 29.1

WHAT IS THE DISTANCE FROM WAREHOUSE TO LANE

? 30.2

WHAT IS THE DISTANCE FROM WAREHOUSE TO POSTON

? 32.5

WHAT IS THE DISTANCE FROM WAREHOUSE TO MACIAS

? 30

WHAT IS THE DISTANCE FROM WAREHOUSE TO SWINDELL

? 28.3

WHAT IS THE DISTANCE FROM FOLK TO WAREHOUSE

? 19.2

WHAT IS THE DISTANCE FROM FOLK TO FOLK

? 0

WHAT IS THE DISTANCE FROM FOLK TO BROWN

? 4

WHAT IS THE DISTANCE FROM FOLK TO FEUERBACHER

? 9

WHAT IS THE DISTANCE FROM FOLK TO LANE

? 9.7

WHAT IS THE DISTANCE FROM FOLK TO POSTON

? 12.3

WHAT IS THE DISTANCE FROM FOLK TO MACIAS

? 7.9

WHAT IS THE DISTANCE FROM FOLK TO SWINDELL

? 7.4

WHAT IS THE DISTANCE FROM BROWN TO WAREHOUSE

? 22.3

WHAT IS THE DISTANCE FROM BROWN TO FOLK
? 4
WHAT IS THE DISTANCE FROM BROWN TO BROWN
? 0
WHAT IS THE DISTANCE FROM BROWN TO FEUERBACHER
? 8.8
WHAT IS THE DISTANCE FROM BROWN TO LANE
? 9.9
WHAT IS THE DISTANCE FROM BROWN TO POSTON
? 12
WHAT IS THE DISTANCE FROM BROWN TO MACIAS
? 11.1
WHAT IS THE DISTANCE FROM BROWN TO SWINDELL
? 8.6
WHAT IS THE DISTANCE FROM FEUERBACHER TO WAREHOUSE
? 29.1
WHAT IS THE DISTANCE FROM FEUERBACHER TO FOLK
? 9
WHAT IS THE DISTANCE FROM FEUERBACHER TO BROWN
? 8.8
WHAT IS THE DISTANCE FROM FEUERBACHER TO FEUERBACHER
? 0
WHAT IS THE DISTANCE FROM FEUERBACHER TO LANE
? 1.2
WHAT IS THE DISTANCE FROM FEUERBACHER TO POSTON
? 3.4
WHAT IS THE DISTANCE FROM FEUERBACHER TO MACIAS
? 6.8
WHAT IS THE DISTANCE FROM FEUERBACHER TO SWINDELL
? 2.7
WHAT IS THE DISTANCE FROM LANE TO WAREHOUSE
? 30.2
WHAT IS THE DISTANCE FROM LANE TO FOLK
? 9.7
WHAT IS THE DISTANCE FROM LANE TO BROWN
? 9.9
WHAT IS THE DISTANCE FROM LANE TO FEUERBACHER
? 1.2
WHAT IS THE DISTANCE FROM LANE TO LANE
? 0
WHAT IS THE DISTANCE FROM LANE TO POSTON
? 2.5
WHAT IS THE DISTANCE FROM LANE TO MACIAS
? 6.6
WHAT IS THE DISTANCE FROM LANE TO SWINDELL
? 3
WHAT IS THE DISTANCE FROM POSTON TO WAREHOUSE
? 32.5
WHAT IS THE DISTANCE FROM POSTON TO FOLK
? 12.3
WHAT IS THE DISTANCE FROM POSTON TO BROWN
? 12
WHAT IS THE DISTANCE FROM POSTON TO FEUERBACHER
? 3.4
WHAT IS THE DISTANCE FROM POSTON TO LANE

? 2.5
WHAT IS THE DISTANCE FROM POSTON TO POSTON
? 0
WHAT IS THE DISTANCE FROM POSTON TO MACIAS
? 8.1
WHAT IS THE DISTANCE FROM POSTON TO SWINDELL
? 5.4
WHAT IS THE DISTANCE FROM MACIAS TO WAREHOUSE
? 30
WHAT IS THE DISTANCE FROM MACIAS TO FOLK
? 7.9
WHAT IS THE DISTANCE FROM MACIAS TO BROWN
? 11.1
WHAT IS THE DISTANCE FROM MACIAS TO FEUERBACHER
? 6.8
WHAT IS THE DISTANCE FROM MACIAS TO LANE
? 6.6
WHAT IS THE DISTANCE FROM MACIAS TO POSTON
? 8.1
WHAT IS THE DISTANCE FROM MACIAS TO MACIAS
? 0
WHAT IS THE DISTANCE FROM MACIAS TO SWINDELL
? 4.1
WHAT IS THE DISTANCE FROM SWINDELL TO WAREHOUSE
? 28.3
WHAT IS THE DISTANCE FROM SWINDELL TO FOLK
? 7.4
WHAT IS THE DISTANCE FROM SWINDELL TO BROWN
? 8.6
WHAT IS THE DISTANCE FROM SWINDELL TO FEUERBACHER
? 2.7
WHAT IS THE DISTANCE FROM SWINDELL TO LANE
? 3
WHAT IS THE DISTANCE FROM SWINDELL TO POSTON
? 5.4
WHAT IS THE DISTANCE FROM SWINDELL TO MACIAS
? 4.1
WHAT IS THE DISTANCE FROM SWINDELL TO SWINDELL
? 0

SHORTEST PATH

ROUTE NUMBER 2
WAREHOUSE FOLK MACIAS SWINDELL POSTON LANE FEUERBACHER
BROWN WAREHOUSE
MIN DIST OF PATH IS: 71.4
STOP AT LINE 830. RETURN CODE IS 0.

*
*
*
*
*
*
*
*

*

* QUIT

LOGGING TO 'BASLOG' LOG IS ON.
IBM BASIC/VM VERSION 1 RELEASE 1.1 1986/04/26 22:39

*
* LOAD TUP1
121 LINES LOADED. 'TUP1' IS THE WORKSPACE NAME.

*
* RUN
ROUTE NUMBER: 4
NUMBER OF STOPS 8
INPUT VERTICE # 1 NAME.
? WAREHOUSE
INPUT VERTICE # 2 NAME.
? GARDINER
INPUT VERTICE # 3 NAME.
? BARDER
INPUT VERTICE # 4 NAME.
? COOPER
INPUT VERTICE # 5 NAME.
? COWARD
INPUT VERTICE # 6 NAME.
? HARD
INPUT VERTICE # 7 NAME.
? BEVILL
INPUT VERTICE # 8 NAME.
? EASLEY
WHAT IS THE DISTANCE FROM WAREHOUSE TO WAREHOUSE
? 0
WHAT IS THE DISTANCE FROM WAREHOUSE TO GARDINER
? 40.2
WHAT IS THE DISTANCE FROM WAREHOUSE TO BARDER
? 34.3
WHAT IS THE DISTANCE FROM WAREHOUSE TO COOPER
? 23.7
WHAT IS THE DISTANCE FROM WAREHOUSE TO COWARD
? 40
WHAT IS THE DISTANCE FROM WAREHOUSE TO HARD
? 41
WHAT IS THE DISTANCE FROM WAREHOUSE TO BEVILL
? 38.8
WHAT IS THE DISTANCE FROM WAREHOUSE TO EASLEY
? 40
WHAT IS THE DISTANCE FROM GARDINER TO WAREHOUSE
? 40.2
WHAT IS THE DISTANCE FROM GARDINER TO GARDINER
? 0
WHAT IS THE DISTANCE FROM GARDINER TO BARDER
? 5.9
WHAT IS THE DISTANCE FROM GARDINER TO COOPER
? 19.6
WHAT IS THE DISTANCE FROM GARDINER TO COWARD
? 15.3
WHAT IS THE DISTANCE FROM GARDINER TO HARD
? 17.8
WHAT IS THE DISTANCE FROM GARDINER TO BEVILL

? 2.9
WHAT IS THE DISTANCE FROM GARDINER TO EASLEY
? 2.7
WHAT IS THE DISTANCE FROM BARDER TO WAREHOUSE
? 34.3
WHAT IS THE DISTANCE FROM BARDER TO GARDINER
? 5.9
WHAT IS THE DISTANCE FROM BARDER TO BARDER
? 0
WHAT IS THE DISTANCE FROM BARDER TO COOPER
? 18
WHAT IS THE DISTANCE FROM BARDER TO COWARD
? 11
WHAT IS THE DISTANCE FROM BARDER TO HARD
? 12
WHAT IS THE DISTANCE FROM BARDER TO BEVILL
? 4.5
WHAT IS THE DISTANCE FROM BARDER TO EASLEY
? 5.5
WHAT IS THE DISTANCE FROM COOPER TO WAREHOUSE
? 23.7
WHAT IS THE DISTANCE FROM COOPER TO GARDINER
? 19.6
WHAT IS THE DISTANCE FROM COOPER TO BARDER
? 18
WHAT IS THE DISTANCE FROM COOPER TO COOPER
? 0
WHAT IS THE DISTANCE FROM COOPER TO COWARD
? 15
WHAT IS THE DISTANCE FROM COOPER TO HARD
? 18
WHAT IS THE DISTANCE FROM COOPER TO BEVILL
? 20.8
WHAT IS THE DISTANCE FROM COOPER TO EASLEY
? 21.6
WHAT IS THE DISTANCE FROM COWARD TO WAREHOUSE
? 40
WHAT IS THE DISTANCE FROM COWARD TO GARDINER
? 15.3
WHAT IS THE DISTANCE FROM COWARD TO BARDER
? 11
WHAT IS THE DISTANCE FROM COWARD TO COOPER
? 15
WHAT IS THE DISTANCE FROM COWARD TO COWARD
? 0
WHAT IS THE DISTANCE FROM COWARD TO HARD
? 2
WHAT IS THE DISTANCE FROM COWARD TO BEVILL
? 10.9
WHAT IS THE DISTANCE FROM COWARD TO EASLEY
? 11.1
WHAT IS THE DISTANCE FROM HARD TO WAREHOUSE
? 41
WHAT IS THE DISTANCE FROM HARD TO GARDINER
? 17.8

WHAT IS THE DISTANCE FROM HARD TO BARDER
? 12
WHAT IS THE DISTANCE FROM HARD TO COOPER
? 18
WHAT IS THE DISTANCE FROM HARD TO COWARD
? 2
WHAT IS THE DISTANCE FROM HARD TO HARD
? 0
WHAT IS THE DISTANCE FROM HARD TO BEVILL
? 9
WHAT IS THE DISTANCE FROM HARD TO EASLEY
? 9
WHAT IS THE DISTANCE FROM BEVILL TO WAREHOUSE
? 38.8
WHAT IS THE DISTANCE FROM BEVILL TO GARDINER
? 2.9
WHAT IS THE DISTANCE FROM BEVILL TO BARDER
? 4.5
WHAT IS THE DISTANCE FROM BEVILL TO COOPER
? 20.8
WHAT IS THE DISTANCE FROM BEVILL TO COWARD
? 10.9
WHAT IS THE DISTANCE FROM BEVILL TO HARD
? 9
WHAT IS THE DISTANCE FROM BEVILL TO BEVILL
? 0
WHAT IS THE DISTANCE FROM BEVILL TO EASLEY
? 9.2
WHAT IS THE DISTANCE FROM EASLEY TO WAREHOUSE
? 40
WHAT IS THE DISTANCE FROM EASLEY TO GARDINER
? 2.7
WHAT IS THE DISTANCE FROM EASLEY TO BARDER
? 5.6
WHAT IS THE DISTANCE FROM EASLEY TO COOPER
? 21.6
WHAT IS THE DISTANCE FROM EASLEY TO COWARD
? 11.1
WHAT IS THE DISTANCE FROM EASLEY TO HARD
? 9
WHAT IS THE DISTANCE FROM EASLEY TO BEVILL
? 1.2
WHAT IS THE DISTANCE FROM EASLEY TO EASLEY
? 0
ATTENTION INTERRUPT AT LINE 1280.

*

SHORTEST PATH

ROUTE NUMBER 4
WAREHOUSE BARDER GARDINER EASLEY BEVILL HARD COWARD COOPER
WAREHOUSE
MIN DIST OF PATH IS: 93.8
STOP AT LINE 830. RETURN CODE IS 0.
*

*
*
*
* QUIT

LOGGING TO 'BASLOG' LOG IS ON.
 IBM BASIC/VM VERSION 1 RELEASE 1.1 1986/04/26 22:44
 * LOAD TUP1
 121 LINES LOADED. 'TUP1' IS THE WORKSPACE NAME.
 * RUHN

1
 ###1) BAS30013S PRECEDING IDENTIFIER IS NEITHER A COMMAND NOR A STATEMENT
 KEYWORD. '=' '(' OR ',' EXPECTED FOR ASSIGNMENT STATEMENT.

* RUN
 ROUTE NUMBER: 5
 NUMBER OF STOPS 8

INPUT VERTICE #	1	NAME.
? WAREHOUSE		
INPUT VERTICE #	2	NAME.
? JONES		
INPUT VERTICE #	3	NAME.
? STEWARD		
INPUT VERTICE #	4	NAME.
? NEALY		
INPUT VERTICE #	5	NAME.
? BUSH		
INPUT VERTICE #	6	NAME.
? WALL		
INPUT VERTICE #	7	NAME.
? RICHARDS		
INPUT VERTICE #	8	NAME.
? CLEVELAND		

WHAT IS THE DISTANCE FROM WAREHOUSE TO WAREHOUSE
 ? 0
 WHAT IS THE DISTANCE FROM WAREHOUSE TO JONES
 ? 22.3
 WHAT IS THE DISTANCE FROM WAREHOUSE TO STEWARD
 ? 23.9
 WHAT IS THE DISTANCE FROM WAREHOUSE TO NEALY
 ? 24.9
 WHAT IS THE DISTANCE FROM WAREHOUSE TO BUSH
 ? 18.6
 WHAT IS THE DISTANCE FROM WAREHOUSE TO WALL
 ? 21.5
 WHAT IS THE DISTANCE FROM WAREHOUSE TO RICHARDS
 ? 25.3
 WHAT IS THE DISTANCE FROM WAREHOUSE TO CLEVELAND
 ? 22.8
 WHAT IS THE DISTANCE FROM JONES TO WAREHOUSE
 ? 22.3
 WHAT IS THE DISTANCE FROM JONES TO JONES
 ? 0
 WHAT IS THE DISTANCE FROM JONES TO STEWARD
 ? 2.9
 WHAT IS THE DISTANCE FROM JONES TO NEALY
 ? 2.4
 WHAT IS THE DISTANCE FROM JONES TO BUSH
 ? 4.2
 WHAT IS THE DISTANCE FROM JONES TO WALL
 ? 5.6

WHAT IS THE DISTANCE FROM JONES TO RICHARDS
? 3.5
WHAT IS THE DISTANCE FROM JONES TO CLEVELAND
? 4.7
WHAT IS THE DISTANCE FROM STEWARD TO WAREHOUSE
? 23.9
WHAT IS THE DISTANCE FROM STEWARD TO JONES
? 2.9
WHAT IS THE DISTANCE FROM STEWARD TO STEWARD
? 0
WHAT IS THE DISTANCE FROM STEWARD TO NEALY
? 2.6
WHAT IS THE DISTANCE FROM STEWARD TO BUSH
? 6.7
WHAT IS THE DISTANCE FROM STEWARD TO WALL
? 8.5
WHAT IS THE DISTANCE FROM STEWARD TO RICHARDS
? 1.5
WHAT IS THE DISTANCE FROM STEWARD TO CLEVELAND
? 7.5
WHAT IS THE DISTANCE FROM NEALY TO WAREHOUSE
? 24.9
WHAT IS THE DISTANCE FROM NEALY TO JONES
? 2.4
WHAT IS THE DISTANCE FROM NEALY TO STEWARD
? 2.6
WHAT IS THE DISTANCE FROM NEALY TO NEALY
? 0
WHAT IS THE DISTANCE FROM NEALY TO BUSH
? 6.6
WHAT IS THE DISTANCE FROM NEALY TO WALL
? 3.8
WHAT IS THE DISTANCE FROM NEALY TO RICHARDS
? 1.8
WHAT IS THE DISTANCE FROM NEALY TO CLEVELAND
? 5.8
WHAT IS THE DISTANCE FROM BUSH TO WAREHOUSE
? 18.6
WHAT IS THE DISTANCE FROM BUSH TO JONES
? 4.2
WHAT IS THE DISTANCE FROM BUSH TO STEWARD
? 6.7
WHAT IS THE DISTANCE FROM BUSH TO NEALY
? 6.6
WHAT IS THE DISTANCE FROM BUSH TO BUSH
? 0
WHAT IS THE DISTANCE FROM BUSH TO WALL
? 3.8
WHAT IS THE DISTANCE FROM BUSH TO RICHARDS
? 7.6
WHAT IS THE DISTANCE FROM BUSH TO CLEVELAND
? 4.6
WHAT IS THE DISTANCE FROM WALL TO WAREHOUSE
? 21.5
WHAT IS THE DISTANCE FROM WALL TO JONES

? 5.6
WHAT IS THE DISTANCE FROM WALL TO STEWARD
? 8.5
WHAT IS THE DISTANCE FROM WALL TO NEALY
? 3.8
WHAT IS THE DISTANCE FROM WALL TO BUSH
? 3.8
WHAT IS THE DISTANCE FROM WALL TO WALL
? 0
WHAT IS THE DISTANCE FROM WALL TO RICHARDS
? 8.8
WHAT IS THE DISTANCE FROM WALL TO CLEVELAND
? 1.8
WHAT IS THE DISTANCE FROM RICHARDS TO WAREHOUSE
? 25.3
WHAT IS THE DISTANCE FROM RICHARDS TO JONES
? 3.5
WHAT IS THE DISTANCE FROM RICHARDS TO STEWARD
? 1.5
WHAT IS THE DISTANCE FROM RICHARDS TO NEALY
? 1.8
WHAT IS THE DISTANCE FROM RICHARDS TO BUSH
? 7.6
WHAT IS THE DISTANCE FROM RICHARDS TO WALL
? 8.8
WHAT IS THE DISTANCE FROM RICHARDS TO RICHARDS
? 0
WHAT IS THE DISTANCE FROM RICHARDS TO CLEVELAND
? 7.6
WHAT IS THE DISTANCE FROM CLEVELAND TO WAREHOUSE
? 22.8
WHAT IS THE DISTANCE FROM CLEVELAND TO JONES
? 4.7
WHAT IS THE DISTANCE FROM CLEVELAND TO STEWARD
? 7.5
WHAT IS THE DISTANCE FROM CLEVELAND TO NEALY
? 5.8
WHAT IS THE DISTANCE FROM CLEVELAND TO BUSH
? 4.6
WHAT IS THE DISTANCE FROM CLEVELAND TO WALL
? 1.8
WHAT IS THE DISTANCE FROM CLEVELAND TO RICHARDS
? 7.6
WHAT IS THE DISTANCE FROM CLEVELAND TO CLEVELAND
? 0

ATTENTION INTERRUPT AT LINE 650.

*

SHORTEST PATH

ROUTE NUMBER 5
WAREHOUSE BUSH CLEVELAND WALL NEALY RICHARDS STEWARD JONES
WAREHOUSE
MIN DIST OF PATH IS: 57.3
STOP AT LINE 830. RETURN CODE IS 0.

*
*
*
*
*
*
* QUIT

LOGGING TO 'BASLOG' LOG IS ON.

IBM BASIC/VM VERSION 1 RELEASE 1.1 1986/04/26 22:48

* LOAD TUP1

121 LINES LOADED. 'TUP1' IS THE WORKSPACE NAME.

* RUN

ROUTE NUMBER: 6

NUMBER OF STOPS 7

INPUT VERTICE # 1 NAME.

? WAREHOUSE INPUT VERTICE # 2 NAME.

? CRUISE INPUT VERTICE # 3 NAME.

? FAIRCHILD INPUT VERTICE # 4 NAME.

? NEAL INPUT VERTICE # 5 NAME.

? LINDEN INPUT VERTICE # 6 NAME.

? WARD INPUT VERTICE # 7 NAME.

? FOSTER

WHAT IS THE DISTANCE FROM WAREHOUSE TO WAREHOUSE

? 0

WHAT IS THE DISTANCE FROM WAREHOUSE TO CRUISE

? 6.6

WHAT IS THE DISTANCE FROM WAREHOUSE TO FAIRCHILD

? 4.4

WHAT IS THE DISTANCE FROM WAREHOUSE TO NEAL

? 20

WHAT IS THE DISTANCE FROM WAREHOUSE TO LINDEN

? 20

WHAT IS THE DISTANCE FROM WAREHOUSE TO WARD

? 20

WHAT IS THE DISTANCE FROM WAREHOUSE TO FOSTER

? 1.7

WHAT IS THE DISTANCE FROM CRUISE TO WAREHOUSE

? 6.6

WHAT IS THE DISTANCE FROM CRUISE TO CRUISE

? 0

WHAT IS THE DISTANCE FROM CRUISE TO FAIRCHILD

? 2.3

WHAT IS THE DISTANCE FROM CRUISE TO NEAL

? 20.2

WHAT IS THE DISTANCE FROM CRUISE TO LINDEN

? 20.2

WHAT IS THE DISTANCE FROM CRUISE TO WARD

? 20.2

WHAT IS THE DISTANCE FROM CRUISE TO FOSTER

? 6

WHAT IS THE DISTANCE FROM FAIRCHILD TO WAREHOUSE

? 4.4

WHAT IS THE DISTANCE FROM FAIRCHILD TO CRUISE

? 2.3

WHAT IS THE DISTANCE FROM FAIRCHILD TO FAIRCHILD

? 0

WHAT IS THE DISTANCE FROM FAIRCHILD TO NEAL
? 20.2
WHAT IS THE DISTANCE FROM FAIRCHILD TO LINDEN
? 20.2
WHAT IS THE DISTANCE FROM FAIRCHILD TO WARD
? 20.2
WHAT IS THE DISTANCE FROM FAIRCHILD TO FOSTER
? 3.8
WHAT IS THE DISTANCE FROM NEAL TO WAREHOUSE
? 20
WHAT IS THE DISTANCE FROM NEAL TO CRUISE
? 20.2
WHAT IS THE DISTANCE FROM NEAL TO FAIRCHILD
? 20.2
WHAT IS THE DISTANCE FROM NEAL TO NEAL
? 0
WHAT IS THE DISTANCE FROM NEAL TO LINDEN
? .1
WHAT IS THE DISTANCE FROM NEAL TO WARD
? .1
WHAT IS THE DISTANCE FROM NEAL TO FOSTER
? 21.7
WHAT IS THE DISTANCE FROM LINDEN TO WAREHOUSE
? 20
WHAT IS THE DISTANCE FROM LINDEN TO CRUISE
? 20.2
WHAT IS THE DISTANCE FROM LINDEN TO FAIRCHILD
? 20.2
WHAT IS THE DISTANCE FROM LINDEN TO NEAL
? .1
WHAT IS THE DISTANCE FROM LINDEN TO LINDEN
? 0
WHAT IS THE DISTANCE FROM LINDEN TO WARD
? .1
WHAT IS THE DISTANCE FROM LINDEN TO FOSTER
? 21.7
WHAT IS THE DISTANCE FROM WARD TO WAREHOUSE
? 20
WHAT IS THE DISTANCE FROM WARD TO CRUISE
? 20.2
WHAT IS THE DISTANCE FROM WARD TO FAIRCHILD
? 20.2
WHAT IS THE DISTANCE FROM WARD TO NEAL
? .1
WHAT IS THE DISTANCE FROM WARD TO LINDEN
? .1
WHAT IS THE DISTANCE FROM WARD TO WARD
? 0
WHAT IS THE DISTANCE FROM WARD TO FOSTER
? 21.7
WHAT IS THE DISTANCE FROM FOSTER TO WAREHOUSE
? 1.7
WHAT IS THE DISTANCE FROM FOSTER TO CRUISE
? 6
WHAT IS THE DISTANCE FROM FOSTER TO FAIRCHILD

? 3.8
WHAT IS THE DISTANCE FROM FOSTER TO NEAL
? 21.7
WHAT IS THE DISTANCE FROM FOSTER TO LINDEN
? 21.7
WHAT IS THE DISTANCE FROM FOSTER TO WARD
? 21.7
WHAT IS THE DISTANCE FROM FOSTER TO FOSTER
? 0

SHORTEST PATH

ROUTE NUMBER 6
WAREHOUSE FOSTER FAIRCHILD CRUISE LINDEN WARD NEAL
WAREHOUSE

MIN DIST OF PATH IS: 48.2
STOP AT LINE 830. RETURN CODE IS 0.

*
* QUIT

LOGGING TO 'BASLOG' LOG IS ON.

IBM BASIC/VM VERSION 1 RELEASE 1.1 1986/04/26 22:52

* LOAD TUPS

BAS00128S PROGRAM FILE 'TUPS' ERROR (FILE CANNOT BE FOUND). COMMAND
IGNORED.

* LOAD TUP1

121 LINES LOADED. 'TUP1' IS THE WORKSPACE NAME.

* RUN

ROUTE NUMBER: 7

NUMBER OF STOPS 8

INPUT VERTICE # 1 NAME.

? WAREHOUSE

INPUT VERTICE # 2 NAME.

? BAKER

INPUT VERTICE # 3 NAME.

? PHILLIPSW

INPUT VERTICE # 4 NAME.

? WOOD

INPUT VERTICE # 5 NAME.

? THOMPSON

INPUT VERTICE # 6 NAME.

? CASTON

INPUT VERTICE # 7 NAME.

? SCOTT

INPUT VERTICE # 8 NAME.

? HOOKS

WHAT IS THE DISTANCE FROM WAREHOUSE TO WAREHOUSE

? 0

WHAT IS THE DISTANCE FROM WAREHOUSE TO BAKER

? 19.6

WHAT IS THE DISTANCE FROM WAREHOUSE TO PHILLIPSW

? 15.6

WHAT IS THE DISTANCE FROM WAREHOUSE TO WOOD

? 16

WHAT IS THE DISTANCE FROM WAREHOUSE TO THOMPSON

? 18.6

WHAT IS THE DISTANCE FROM WAREHOUSE TO CASTON

? 17.1

WHAT IS THE DISTANCE FROM WAREHOUSE TO SCOTT

? 11.5

WHAT IS THE DISTANCE FROM WAREHOUSE TO HOOKS

? 15.6

WHAT IS THE DISTANCE FROM BAKER TO WAREHOUSE

? 19.6

WHAT IS THE DISTANCE FROM BAKER TO BAKER

? 0

WHAT IS THE DISTANCE FROM BAKER TO PHILLIPSW

? 5.6

WHAT IS THE DISTANCE FROM BAKER TO WOOD

? 3.7

WHAT IS THE DISTANCE FROM BAKER TO THOMPSON

? 6.1

WHAT IS THE DISTANCE FROM BAKER TO CASTON

? 3.3

WHAT IS THE DISTANCE FROM BAKER TO SCOTT

? 8
WHAT IS THE DISTANCE FROM BAKER TO HOOKS
? 4.9
WHAT IS THE DISTANCE FROM PHILLIPSW TO WAREHOUSE
? 15.6
WHAT IS THE DISTANCE FROM PHILLIPSW TO BAKER
? 5.6
WHAT IS THE DISTANCE FROM PHILLIPSW TO PHILLIPSW
? 0
WHAT IS THE DISTANCE FROM PHILLIPSW TO WOOD
? 2.8
WHAT IS THE DISTANCE FROM PHILLIPSW TO THOMPSON
? 3
WHAT IS THE DISTANCE FROM PHILLIPSW TO CASTON
? 7.9
WHAT IS THE DISTANCE FROM PHILLIPSW TO SCOTT
? 5.1
WHAT IS THE DISTANCE FROM PHILLIPSW TO HOOKS
? 1
WHAT IS THE DISTANCE FROM WOOD TO WAREHOUSE
? 16
WHAT IS THE DISTANCE FROM WOOD TO BAKER
? 3.7
WHAT IS THE DISTANCE FROM WOOD TO PHILLIPSW
? 2.8
WHAT IS THE DISTANCE FROM WOOD TO WOOD
? 0
WHAT IS THE DISTANCE FROM WOOD TO THOMPSON
? 4.9
WHAT IS THE DISTANCE FROM WOOD TO CASTON
? 3.2
WHAT IS THE DISTANCE FROM WOOD TO SCOTT
? 4.5
WHAT IS THE DISTANCE FROM WOOD TO HOOKS
? 1.8
WHAT IS THE DISTANCE FROM THOMPSON TO WAREHOUSE
? 18.6
WHAT IS THE DISTANCE FROM THOMPSON TO BAKER
? 6.1
WHAT IS THE DISTANCE FROM THOMPSON TO PHILLIPSW
? 3
WHAT IS THE DISTANCE FROM THOMPSON TO WOOD
? 4.9
WHAT IS THE DISTANCE FROM THOMPSON TO THOMPSON
? 0
WHAT IS THE DISTANCE FROM THOMPSON TO CASTON
? 7.7
WHAT IS THE DISTANCE FROM THOMPSON TO SCOTT
? 8.2
WHAT IS THE DISTANCE FROM THOMPSON TO HOOKS
? 3.7
WHAT IS THE DISTANCE FROM CASTON TO WAREHOUSE
? 17.1
WHAT IS THE DISTANCE FROM CASTON TO BAKER
? 3.3

WHAT IS THE DISTANCE FROM CASTON TO PHILLIPSW
? 7.9
WHAT IS THE DISTANCE FROM CASTON TO WOOD
? 3.2
WHAT IS THE DISTANCE FROM CASTON TO THOMPSON
? 7.7
WHAT IS THE DISTANCE FROM CASTON TO CASTON
? 0
WHAT IS THE DISTANCE FROM CASTON TO SCOTT
? 5.9
WHAT IS THE DISTANCE FROM CASTON TO HOOKS
? 5
WHAT IS THE DISTANCE FROM SCOTT TO WAREHOUSE
? 11.5
WHAT IS THE DISTANCE FROM SCOTT TO BAKER
? 8
WHAT IS THE DISTANCE FROM SCOTT TO PHILLIPSW
? 5.1
WHAT IS THE DISTANCE FROM SCOTT TO WOOD
? 4.5
WHAT IS THE DISTANCE FROM SCOTT TO THOMPSON
? 8.2
WHAT IS THE DISTANCE FROM SCOTT TO CASTON
? 5.9
WHAT IS THE DISTANCE FROM SCOTT TO SCOTT
? 0
WHAT IS THE DISTANCE FROM SCOTT TO HOOKS
? 4.6
WHAT IS THE DISTANCE FROM HOOKS TO WAREHOUSE
? 15.6
WHAT IS THE DISTANCE FROM HOOKS TO BAKER
? 4.9
WHAT IS THE DISTANCE FROM HOOKS TO PHILLIPSW
? 1
WHAT IS THE DISTANCE FROM HOOKS TO WOOD
? 1.8
WHAT IS THE DISTANCE FROM HOOKS TO THOMPSON
? 3.7
WHAT IS THE DISTANCE FROM HOOKS TO CASTON
? 5
WHAT IS THE DISTANCE FROM HOOKS TO SCOTT
? 4.6
WHAT IS THE DISTANCE FROM HOOKS TO HOOKS
? 0

ATTENTION INTERRUPT AT LINE 590.

SHORTEST PATH

ROUTE NUMBER 7
WAREHOUSE SCOTT CASTON BAKER WOOD HOOKS THOMPSON PHILLIPSW
WAREHOUSE
MIN DIST OF PATH IS: 48.5
STOP AT LINE 830. RETURN CODE IS 0.

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* QUIT



APPENDIX E

AN EXAMPLE OF ONE OF THE SEVEN DISTANCE MATRICES USED FOR INPUT TO OUR SHORTEST PATH PROGRAM

Distance Matrix

	<u>W</u>	<u>F</u>	<u>B</u>	<u>F</u>	<u>L</u>	<u>P</u>	<u>M</u>	<u>S</u>
Whse	0	19.2	22.3	29.1	30.2	32.5	30	28.3
Folk	19.2	0	4	9	9.7	12.3	7.9	7.4
Brown	22.3	4	0	8.8	9.9	12	11.1	8.6
Feueb	29.1	9	8.8	0	1.2	3.4	6.8	2.7
Lane	30.2	9.7	9.9	1.2	0	2.5	6.6	3
Postin	32.5	12.3	12	3.4	2.5	0	8.1	5.4
Macias	30	7.9	11.1	6.8	6.6	8.1	0.0	4.1
Swinde	28.3	7.4	8.6	2.7	3	5.4	4.1	0

Distances for the other 6 routes can be found by viewing the input to the program in Appendix D.

APPENDIX F

The following is an in-depth technical description of the BASIC traveling salesman problem. The description refers to the program we developed which can be seen in Appendix D.

The program is a recursive version of the traveling salesman problem. It allows input for the number of stops on a route and assumes that the truck will leave and return to the warehouse. It utilizes a data structure called **Counter** which finds a unique set of stops. After finding a unique path, it calculates the distance of traveling this route. If this is the minimum route, the program stores this route and finds the next unique path. After all possible paths have been tried, it prints out the minimum path and the associated distance of this path.

Arrays within Program:

Array **City\$** holds the names of the stops on the routes. Array **Dist** is an n by n matrix that holds the distances from each stop on a route to every other stop. Array **Used** is an array that holds 0's or 1's. This array is used to make sure that within the combinations determined by **Counter**, every stop on the route is unique. For example, **Counter** may produce the combination 1-3-3-4-2-1 which would be undesirable. Array **Used** will not allow the distances to be computed for a combination of this type. A '1' is used when the stop has been used in the representation, a '0' is used until that stop is visited. Array **Counter** is the control previously described. For an n-stop route, it will start at 1 1 1 1 1 and updates itself until every combination up to n n n n n is tried. It adds 1 to the right hand column until the value in the right hand column=n at which point it updates the next to last column. This procedure is continued until it reaches n n n n n.

Basically, the program is counting in base n. Array **Used** rejects combinations that are not unique. Array **Path** holds the combination of unique stops that **Counter** generates and **Used** accepts. **Path** holds a list of positions--not the actual stops

themselves. This avoids the shifting of all the elements of all the arrays. If **Path**(2) = 3, then the 3rd stop would be in the second position of the path. The name of this 3rd stop is stored in Array **City\$**. Array **Minpath** is like Array **Path** above except this array holds the minimum path. This path will be updated until the minimum path is found.

Variables in Program

Stp\$, **False\$**, and **Warn\$** are stopping variables used for alerting **Counter** that every combination has been tried. **Route** holds the route number. **Num** is the number of stops on the route. **Mindist** is the minimum distance for a path. **Count** determines when n unique stops are found and thus, a unique path.

The Program

Lines 210-220 Initializing lines

Lines 230-280 Reads in route number, number of stops, stop names, and distances between stops.

Lines 390-470 Initializes variables and arrays.

Lines 580-700 Determines if a path is unique by the use of the 2 arrays, **Path** and **Used**. **Path** keeps track of the order of the stops and **Used** determines if that particular stop has been used in this representation--this, again, stipulates not visiting a stop more than once. **Used** is set to '1' in line 630 when a stop is included and **Path**(n) = position of stop. When n unique stops have been found, **Count** = n and control shifts to line 900.

Lines 710-830 Print lines. The minimum path is printed as well as its associated distance.

Lines 900-1090 'Subroutine Minimum' is called after a unique path has been found. It calculates the distance of the route. If the calculated distance is

less than the value stored in the minimum value, this path becomes the new **Minpath** and its associated distance becomes the new **Mincost**. Variables are initialized for next path.

Lines 1180-1300 'Subroutine Update' controls the data structure **Counter**.

To calculate the combinations, the left numbers are held constant and the change occurs from the right. Of course, the source remains constant at the warehouse. The **Stop** variable is used to warn of the next to last time to go through the minimization process, while **Final** warns of the final time which ends the program. Our procedure to end the program is not good programming style, but it is effective.

As stated in the paper, computation time is a major consideration for $n > 8$. For large values of n , a heuristic should be used rather than this or similar algorithms.