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A transportation logistics model for site support scheduling

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A TRANSPORTATION LOGISTICS MODEL FOR

SITE SUPPORT SCHEDULING

By

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CHAPTER I

INTRODUCTION

The dispatch of missile crews to their duty locations in the 341st Strategic Missile Wing is a complex logistical problem. A daily deployment is required, utilizing considerable inputs of missile crews and vehicles.

The Wing is headquartered at Malmstrom Air Force Base, Great Falls, Montana. The missile complex, defined as the geographical area throughout which Minuteman missiles are dispersed, encompasses thousands of square miles in Northcentral Montana. Located in this complex are twenty Launch Control Facilities (LCFs) and 200 Launch Facilities (LFs). The LCFs are underground control centers from which a missile crew, consisting of two officers, monitors the status of ten Minuteman Missiles located at dispersed, unmanned LFs. LCFs are designated by the military phonetic letters Alpha (A) through Tango (T). The Wing is divided into four missile squadrons, each divided into five flights of ten missiles. Geographically, two squadrons are located east of Great Falls, and two west. Because of the distances separating the two sets of squadrons, they can be thought of as separate entities.

Manning at each LCF requires that a new crew relieve the one presently on duty each day. Therefore, a contingent of twenty crews must be dispatched throughout the missile complex daily. Crews travel in a Chevrolet Carryall. This vehicle is limited to carrying three crews and their associated equipment, plus an occasional student crew for on-site training purposes.

The dispatch of missile crews is complicated by various factors besides the obvious ones of manning and transport, or operating expenses. One, the Air Force funding for new vehicles requires that present vehicles remain in service as long as possible. Two, the cost of fuel demands that the most efficient routes be traveled each day. Finally, the crews are constrained to travel on routes approved by the Traffic Control Center (TCC). Due to the vast size of the missile complex, this last constraint is necessary in case of vehicle breakdown, especially during the winter months. In some cases, this implies that a crew cannot travel the shortest route between sites.

Figure 1 is a graphical representation of the present method by which crews are dispatched throughout the missile complex. The segments connecting the various sites form an idealized network, rather than an actual roadmap. Sites with two paths leaving them, such as Papa, Charlie and Mike, signify prepositioning of a vehicle. In such cases, three crews arrive at a site, one remains, one continues on, and the last drives the prepositioned vehicle to a third site. In all cases, lines of travel are outward from Malmstrom. These conventions of Figure 1 also apply to similar figures throughout this paper.

After analyzing the current logistic transportation situation, the problem undertaken in this study was an investigation of the current method of crew deployment for deficiencies in excess mileage and/or number of vehicles utilized daily. It was proposed that this be

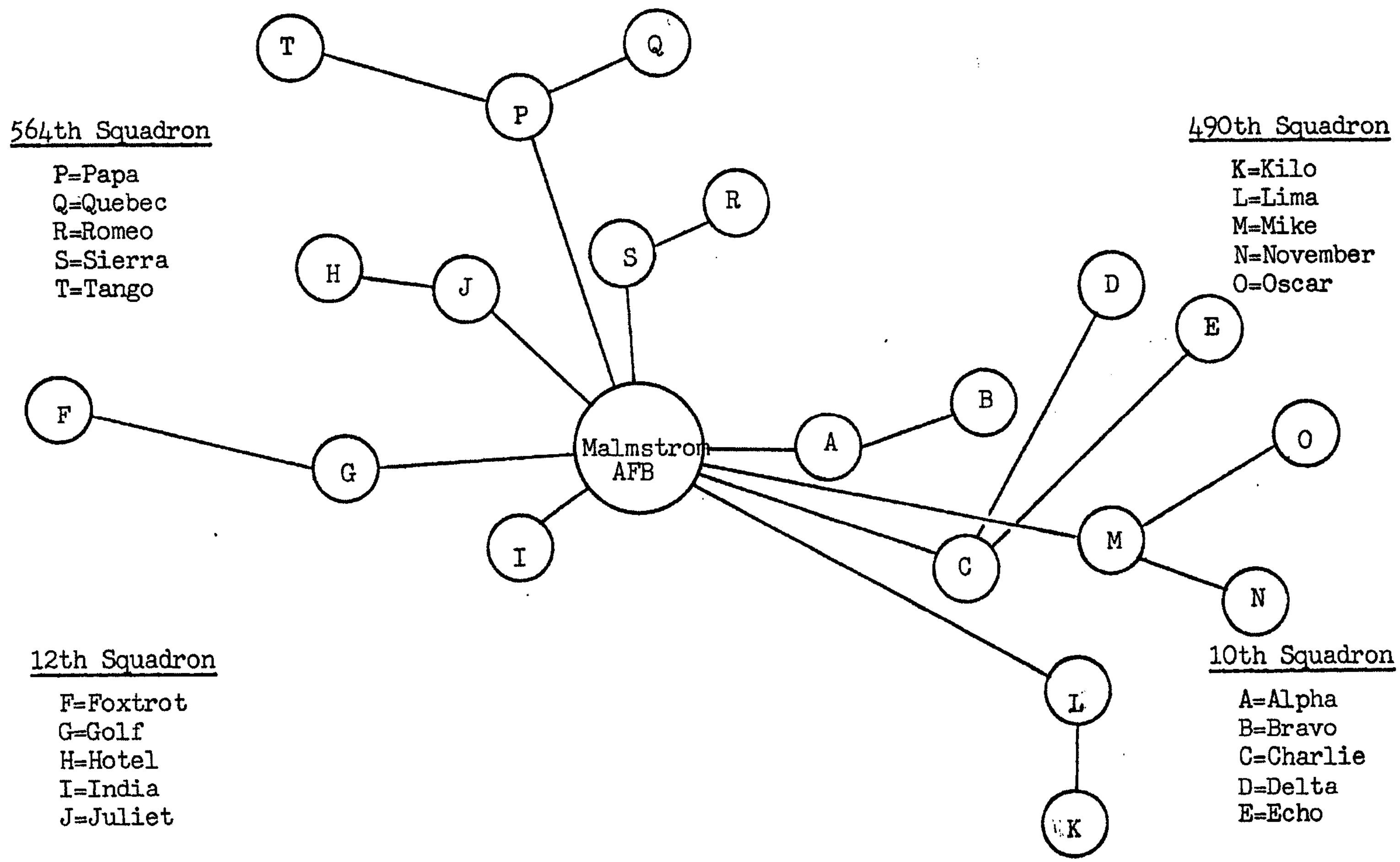

Fig. 1.—Graphic representation of actual crew transport network.

accomplished by applying the analytical tool of linear programming.

Research Objectives

The principal objective of this paper is to develop an alternative crew transportation method to the current one shown in Figure 1. This alternative method should provide a better, if not optimal, solution with respect to transportation costs than the present system. The research objectives were to:

1. Develop a model of crew logistics.
2. Demonstrate capabilities of the model for realistically saving costs by reducing: (1) mileage traveled daily, and (2) the number of vehicles required daily.
3. Modify the transportation problem technique of linear programming by allowing the costs of transport to be allotted to the mode of transport, in this case trucks, rather than to the products being shipped, which in this application are missile crews.

Past Research

Little past research is available on the crew transport problem. Major Art Hanna first suggested the problem in a linear programming sense in BA 691, Linear Programming, a seminar offered at the University of Montana MBA Program at Malmstrom AFB.[1] He proposed that the solution

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[1]Arthur L. Hanna, Jr., "A Transhipment Model for Optimal Vehicle Use and Minimal Mileage," December 6, 1974.

be attained by formulating it as a transhipment problem. His proposal described the problem of site scheduling and pointed out such peculiarities as pre-positioning of vehicles. Although no attempt was made at solving the problem, his proposal did act as an impetus for this research.

In 1973, Captains William E. Bayless and Carson E. Anderson attempted a systems analysis of the crew transport problem as part of a University of Southern California (USC) extension course at Malmstrom AFB.[2] This project was qualitative in nature and centered on proposed alternative means of transportation such as buses. However, their work provided no quantitative solution suitable for replanning purposes.

Another modeling study was conducted in 1975 in a similar USC extension course by a group of officers headed by Captain James Hines.[3] This systems study was basically along the same lines as the previously mentioned paper.

On the basis of cost figures alone, this study selected the Chevrolet Carryall to be the most economical of all means of transport. available at Malmstrom AFB. This is not to imply that a more economical vehicle is not available on the market. However, it was not the purpose of this study to make such a determination.

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[2]William E. Bayless and Carson E. Anderson, "A Systems Analysis of Crew Transportation Methods," May 2, 1974.

[3]"F" Team, "Systems Analysis Report for SSM 665," May 1, 1975.

CHAPTER II

A MISSILE CREW TRANSPORT MODEL

The model chosen for this paper was a transportation linear programming formulation. Its origins were in the more specific form of a transhipment type of transportation problem. The principal activity of this model is the daily dispatching of missile crews from Malmstrom AFB throughout the missile complex. Inputs are crews and vehicles, and outputs consist of optimal routings, crews per vehicle and number of vehicles.

The number of crews inputed is a constant of twenty per day. Mileage traveled is variable due to the size of the missile complex and the numerous possibilities of dispatching crews. Since it is possible for as many as three crews to travel in one vehicle and be routed through two sites to a final destination, the number of vehicles is also variable.

The transport model has the following basic form:

Minimize: mileage traveled and number of vehicles

Subject to: constraints imposed by vehicle requirements, passenger limitations and number available; constraints created by crew demand; and constraints required to link the vehicle and crew constraints.

The selection of linear programming as a solution technique has made the outcome of this problem subject to certain of its properties. The effects are as follow:

1. The additivity of the output implies that the final solution

will be a realistic figure of actual mileages traveled.

2. Proportionality indicates that the objective function and constraint set will have as much reliability concerning a small application of the model as a large one. This fact is further supported by the method of model validation described later.

3. The property of divisibility indicates that solution values need not be integer-valued. The impact of this statement is explored later, but it is an unfortunate drawback of a linear programming formulation of the problem at hand.

The applicability of linear programming as a solution technique is supported by the similarity of the problem to the general class of fixed-charge transportation problems, in which m suppliers can ship to n destinations at fixed shipping costs. Studies such as the one by Gray point out the similarity of this problem's formulation to other fixed-cost transportation problems.[1] Another study by Kennington pointed out the need for an integer programming solution algorithm for the fixed-charge problem.[2] This is a deficiency in the present application as pointed out above.

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[1]Paul Gray, "Exact Solution of the Fixed-Charge Transportation Problem," Operations Research, October 1971, pp. 1529-1538.

[2]J.L. Kennington, "Group-Theoretic Structure in the Fixed-Charge Transportation Problem," Operations Research, September 1973, pp. 1142-1153.

Origins of the Model

The possibility of more than one crew being transported in a vehicle routed through various sites indicated that the problem might be modeled accurately as a transhipment problem. The transhipment formulation is closely related to the transportation problem wherein there are supply sources and demand destinations. However, transhipment allows for the additional aspect of each destination acting as a source. The following example supports the use of a transhipment problem formulation to solve this crew transport problem.

Suppose that three crews leave Malmstrom in a single vehicle. Their first destination is the LCF Alpha; once there, the destination of the two remaining crews is the LCF Bravo, and of the final crew, the LCF Charlie. The crews going to Bravo and Charlie were, in fact, transhipped through Alpha since it acted as a source for further shipment.

The general formulation followed for the origin of this model is the transhipment problem presented in Hillier and Liberman's Introduction to Operations Research.[3]

The format used in this application is given in Appendix I. Its sample output, shown in Figure 2, is for the 564th Squadron. As these results demonstrate, the costs associated with segments over which more than one crew travel are multiplied by the number of crews involved. Additionally, as shown in Figure 2, two crews prepositioned at Papa do not truly represent a prepositioned vehicle, but rather, simulate

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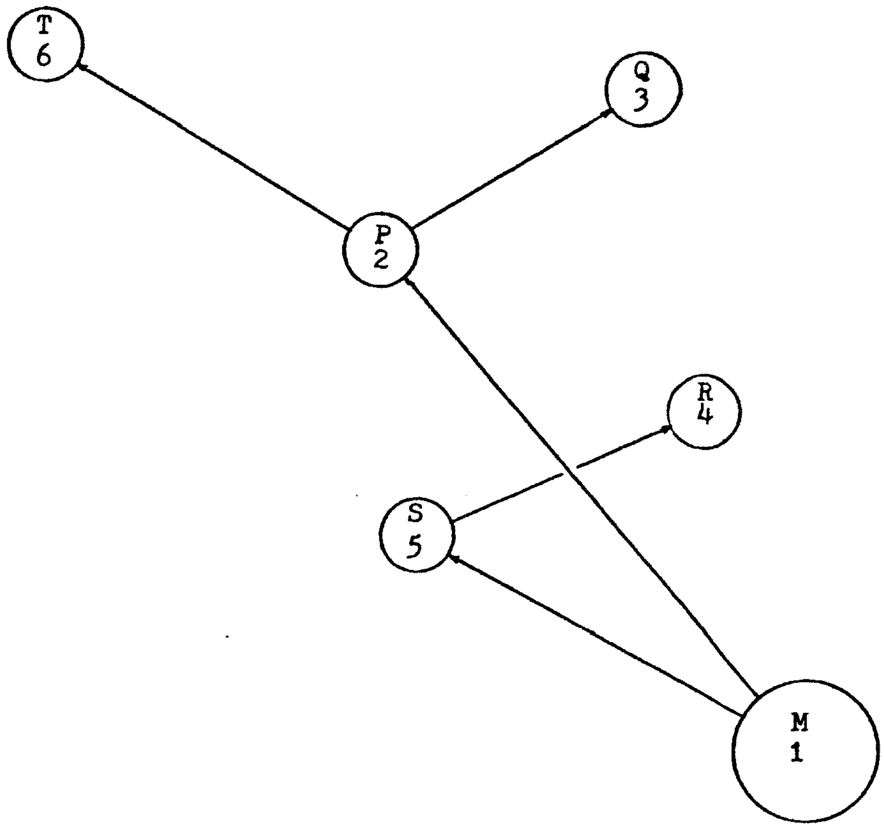
[3]Hillier and Liberman, Introduction to Operations Research (San Francisco: Holden-Day, Inc., 1967), pp. 194-198.



Model Output

Segment	Miles	Crews	Cost (Miles x Crews)
1-5	55	2	110
5-4	15	1	15
1-2	68	3	68
2-3	20	1	20
2-6	38	1	38

Actual Mileage = 196 miles — 251 miles

Fig. 2.--Sample output of Transhipment Analysis

prepositioning.

Additional Limitations of the Transport Model

The classical transhipment formulation clearly needed extra constraints to more fully simulate the actual activity of transporting crews to the missile complex. The need for a more complete model was pointed out by the succeeding deficiencies:

1. No constraint was put on the number of vehicles available. Theoretically, if five sites were equidistant from the Base, five paths and five vehicles would be used.
2. No limit was put on the number of crews being transhipped through a given site.
3. The objective function value was not a true indication of mileage traveled.

The full development of the general transport model had to include all of these additional limitations, and is described in the next section.

Model Variables and Parameters

The large model had 200 variables and 141 constraints. These were used for analysis of both the two eastern and the two western squadrons. As was pointed out in CHAPTER I, because of the distance separating the two pairs of squadrons, it is suggested that each set be treated as a separate problem. The variables in the model are the mileages separating pairs of LCFs. And since the number of LCFs is the same for both pairs of squadrons, the same general model can be used to solve what amounts to two separate transhipment problems. Table 1 gives a complete description of each variable and shows the use of the model in which it is involved. The succeeding model description is general in nature. Its form is applicable for the large model, or for the small one used in validation. Figure 3 gives the relationship of the interplay between the variables and parameters of the model.

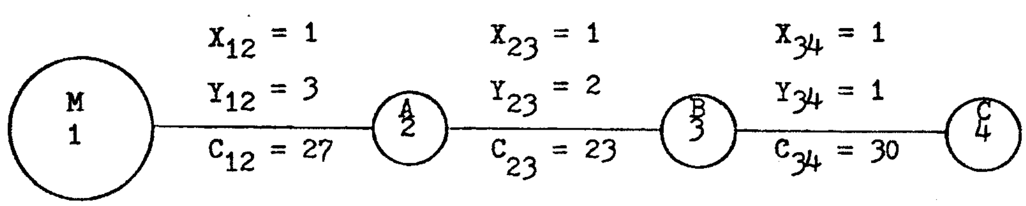


Fig. 3.--Model Variables and Parameters

One-half (100) of the variables deal with vehicle assignments and have the form as follows:

X_{ij} = assignment of a vehicle from i to j

where i = 1, 2, ..., n, n+1 points
j = 2, 3,., n, n+1 sites

Their number for a given number of sites, or n, is determined by the variable n^2. For the assignment network, there will be n+1 points; that is, n sites plus Malmstrom, where i = 1 = Malmstrom.

The number of crew variables equals the number of vehicle variables in the general model, and has the following form:

Y_{ij} = number of crews of the X_{ij} assignment

where i = 1, 2, ..., n, n+1 points
j = 2, 3,., n, n+1 sites

Parameters in the model consist of the costs of transport between a pair of LCFs. These costs appear as follow:

TABLE 1

SPECIFICATION OF MODEL VARIABLES

VARIABLE[a]	VARIABLE DEFINITION							
	LARGE MODEL					SMALL MODEL		
	COMPUTER[b] OUTPUT	EAST FROM	EAST TO	WEST FROM	WEST TO	COMPUTER OUTPUT	564th Sqd. FROM	564th Sqd. TO
X_{12}	1	M	A	M	F	1	M	P
X_{13}	2	M	B	M	G	2	M	Q
X_{14}	3	M	C	M	H	3	M	R
X_{15}	4	M	D	M	I	4	M	S
X_{16}	5	M	E	M	J	5	M	T
X_{17}	6	M	K	M	P			
X_{18}	7	M	L	M	Q			
X_{19}	8	M	M_1	M	R			
X_{110}	9	M	N	M	S			
X_{111}	10	M	O	M	T			
X_{23}	11	A	B	F	G	6	P	Q
X_{24}	12	A	C	F	H	7	P	R
X_{25}	13	A	D	F	I	8	P	S
X_{26}	14	A	E	F	J	9	P	T
X_{27}	15	A	K	F	P			
X_{28}	16	A	L	F	Q			
X_{29}	17	A	M	F	R			
X_{210}	18	A	N	F	S			
X_{211}	19	A	O	F	T			
X_{32}	20	B	A	G	F	10	Q	P

TABLE 1--Continued

VARIABLE[a]	VARIABLE DEFINITION							
	LARGE MODEL					SMALL MODEL		
	COMPUTER OUTPUT[b]	EAST FROM	EAST TO	WEST FROM	WEST TO	COMPUTER OUTPUT	564th Sqd. FROM	564th Sqd. TO
X_{34}	21	B	C	G	H	11	Q	R
X_{35}	22	B	D	G	I	12	Q	S
X_{36}	23	B	E	G	J	13	Q	T
X_{37}	24	B	K	G	P			
X_{38}	25	B	L	G	Q			
X_{39}	26	B	M	G	R			
X_{310}	27	B	N	G	S			
X_{311}	28	B	O	G	T			
X_{42}	29	C	A	H	F	14	R	P
X_{43}	30	C	B	H	G	15	R	Q
X_{45}	31	C	D	H	I	16	R	S
X_{46}	32	C	E	H	J	17	R	T
X_{47}	33	C	K	H	P			
X_{48}	34	C	L	H	Q			
X_{49}	35	C	M	H	R			
X_{410}	36	C	N	H	S			
X_{411}	37	C	O	H	T			
X_{52}	38	D	A	I	F	18	S	P
X_{53}	39	D	B	I	G	19	S	Q
X_{54}	40	D	C	I	H	20	S	R
X_{56}	41	D	E	I	J	21	S	T

TABLE 1--Continued

VARIABLE [a]	VARIABLE DEFINITION							
	LARGE MODEL					SMALL MODEL		
	COMPUTER[b] OUTPUT	EAST FROM	EAST TO	WEST FROM	WEST TO	COMPUTER OUTPUT	564th Sqd. FROM	564th Sqd. TO
X_{57}	42	D	K	I	P			
X_{58}	43	D	L	I	Q			
X_{59}	44	D	M	I	R			
X_{510}	45	D	N	I	S			
X_{511}	46	D	O	I	T			
X_{62}	47	E	A	J	F	22	T	P
X_{63}	48	E	B	J	G	23	T	Q
X_{64}	49	E	C	J	H	24	T	R
X_{65}	50	E	D	J	I	25	T	S
X_{67}	51	E	K	J	P			
X_{68}	52	E	L	J	Q			
X_{69}	53	E	M	J	R			
X_{610}	54	E	N	J	S			
X_{611}	55	E	O	J	T			
X_{72}	56	K	A	P	F			
X_{73}	57	K	B	P	G			
X_{74}	58	K	C	P	H			
X_{75}	59	K	D	P	I			
X_{76}	60	K	E	P	J			
X_{78}	61	K	L	P	Q			
X_{79}	62	K	M	P	R			

TABLE 1--Continued

VARIABLE[a]	VARIABLE DEFINITION							
	LARGE MODEL					SMALL MODEL		
	COMPUTER[b] OUTPUT	EAST FROM	EAST TO	WEST FROM	WEST TO	COMPUTER OUTPUT	564th Sqd. FROM	564th Sqd. TO
X_{710}	63	K	N	P	S			
X_{711}	64	K	O	P	T			
X_{82}	65	L	A	Q	F			
X_{83}	66	L	B	Q	G			
X_{84}	67	L	C	Q	H			
X_{85}	68	L	D	Q	I			
X_{86}	69	L	E	Q	J			
X_{87}	70	L	K	Q	P			
X_{89}	71	L	M	Q	R			
X_{810}	72	L	N	Q	S			
X_{811}	73	L	O	Q	T			
X_{92}	74	M	A	R	F			
X_{93}	75	M	B	R	G			
X_{94}	76	M	C	R	H			
X_{95}	77	M	D	R	I			
X_{96}	78	M	E	R	J			
X_{97}	79	M	K	R	P			
X_{98}	80	M	L	R	Q			
X_{910}	81	M	N	R	S			
X_{911}	82	M	O	R	T			
X_{102}	83	N	A	S	F			

TABLE 1--Continued

VARIABLE[a]	VARIABLE DEFINITION							
	LARGE MODEL					SMALL MODEL		
	COMPUTER[b] OUTPUT	EAST FROM	EAST TO	WEST FROM	WEST TO	COMPUTER OUTPUT	564th Sqd. FROM	564th Sqd. TO
X_{103}	84	N	B	S	G			
X_{104}	85	N	C	S	H			
X_{105}	86	N	D	S	I			
X_{106}	87	N	E	S	J			
X_{107}	88	N	K	S	P			
X_{108}	89	N	L	S	Q			
X_{109}	90	N	M	S	R			
X_{1011}	91	N	O	S	T			
X_{112}	92	O	A	T	F			
X_{113}	93	O	B	T	G			
X_{114}	94	O	C	T	H			
X_{115}	95	O	D	T	I			
X_{116}	96	O	E	T	J			
X_{117}	97	O	K	T	P			
X_{118}	98	O	L	T	Q			
X_{119}	99	O	M	T	R			
X_{1110}	100	O	N	T	S			

[a]For crew variables, substitute Y for X in the Variable column.

[b]For crew variables, add 100 to the computer output number.

C_{ij} = miles (cost) between points i and j

where i = 1, 2, ..., n, n+1 points
j = 2, 3,.., n, n+1 sites

Cost parameters are applied only to the vehicle variables. The C_{ij}'s for the crew variables are all zero to avoid the multiple effects noted in the description of the pure transhipment analysis. The C_{ij}'s follow the same progression as the X_{ij}'s given, and the Y_{ij}'s referred to, in Table 1.

Model Constraints

There are three basic types of constraints present in the model: (1) those having to do with vehicles, (2) those dealing with crews, and (3) constraints required to link the crew assigned to a destination with a vehicle traveling from some other source to that same destination.

The total constraint set originated in the following order:

1. One Vehicle per Site Constraints.
2. Vehicle Sources from Vehicle Destinations Constraints.
3. Vehicle Prepositioning Constraint(s).
4. Vehicle Supply Constraints.
5. One Crew per Site Constraints.
6. Vehicle Passenger Constraints.
7. Crew/Vehicle Linking Constraints.

The same constraints are of course applicable to both the small and large models.

One Vehicle per Site Constraints

This set of constraints ensures that there is an assignment of a vehicle to each site. The general form of these constraints is presented in the following equation:

(1) $$\sum_{\substack{i=1 \\ i \neq j}}^{n+1} X_{ij} = 1 \quad \text{for } j = 2, 3, \ldots, n, n+1 \text{ sites}$$

e.g.: $n = 5$

$$X_{12} + X_{32} + X_{42} + X_{52} + X_{62} = 1 \quad \text{where } j = 2; \ 1 = \text{Malmstrom}$$

There will be n of these constraints in a given model application.

Vehicle Sources from Vehicle Destinations Constraints

These constraints assure that vehicles will be supplied to a site only from another LCF, or from Malmstrom. This concept has its origins in the basic transhipment theme that each source can act as a supply point. In mathematical form, these constraints appear as follow:

(2) $$\underbrace{\sum_{\substack{j=2 \\ j \neq k}}^{n+1} X_{kj}}_{\text{From } k} \leq \underbrace{\sum_{\substack{i=1 \\ i \neq k}}^{n+1} X_{ik}}_{\text{To } k} \quad \text{for } k = 2, 3, \ldots, n, n+1 \text{ sites minus the site(s) picked for prepositioning of vehicles}$$

e.g.: $n = 5$

$$X_{23} + X_{24} + X_{25} + X_{26} \leq X_{12} + X_{32} + X_{42} + X_{52} + X_{62}$$

where $k = 2$; $1 =$ Malmstrom

The number of these constraints in the model is variable due to the prepositioning constraints which follow. There will be a maximum of n of these constraints.

Vehicle Prepositioning Constraint(s)

This constraint(s) causes the previous number of constraints to vary. Essentially, this occurs because of a Vehicle Prepositioning Constraint(s) being subtracted from the previous constraint set. This limitation is necessary to allow for the prepositioning of a vehicle at distant sites in order to decrease mileage. The mathematical form of this constraint is similar to the previous constraint set:

(3) $$\sum_{\substack{j=2 \\ j\neq k}}^{n+1} X_{kj} \leq \sum_{\substack{i=1 \\ i\neq k}}^{n+1} X_{ik} + 1 \quad \text{for } k = \text{sites picked for prepositioning of a vehicle}$$

e.g.: $n = 5$

$$X_{23} + X_{24} + X_{25} + X_{26} \leq X_{12} + X_{32} + X_{42} + X_{52} + X_{62} + 1$$

where $k = 2$; 1 = Malmstrom

The number of such constraints included in the model is determined by inspection.

The sum of the Vehicle Prepositioning Constraints and the Vehicle Source from Vehicle Destination Constraints always equals n.

Vehicle Supply Constraints

One objective of this research is to decrease the number of vehicles used daily. Consequently, this constraint is employed to control the number of vehicles available from Malmstrom. The ensuing format applies:

(4) $$\sum_{j=2}^{n+1} X_{1j} = C \quad \text{where } C = \text{constant number of vehicles}$$

e.g.: $n = 5$, $C = 3$

$$X_{12} + X_{13} + X_{14} + X_{15} + X_{16} = 3 \quad \text{where } 1 = \text{Malmstrom}$$

There is one of these constraints in any formulation of the problem.

One Crew per Site Constraints

This set is taken from the exact formulation of a demand constraint found in the general transhipment problem by Hillier and Liberman, mentioned previously. The amount demanded will always equal one, the number of crews required at each site. This constraint has the following format:

(5)
$$\sum_{\substack{j=2 \\ j \neq k}}^{n+1} Y_{kj} = \sum_{\substack{i=1 \\ i \neq k}}^{n+1} Y_{ik} - 1 \quad k = 2, 3, \ldots, n, n+1 \text{ sites}$$

From k To k

e.g.: $n = 5$

$$Y_{23} + Y_{24} + Y_{25} + Y_{26} = Y_{12} + Y_{32} + Y_{42} + Y_{52} + Y_{62} - 1$$

$k = 2$; 1 = Malmstrom

There is a demand equation for every site, hence, there are n of these demand constraints in the general formulation of the model.

Vehicle Passenger Constraints

As previously stated, the number of crews being dispatched in a given vehicle is limited to three. Consequently, a set of constraints is needed to limit the number of crews leaving Malmstrom in one vehicle to at most three. The makeup of this set follows:

(6)
$$Y_{1j} \leq 3 \quad j = 2, 3, \ldots, n, n+1 \text{ sites where } 1 = \text{Malmstrom}$$

e.g.: $j = 2$

$$Y_{12} \leq 3$$

There are n of these constraints in the model.

Crew/Vehicle Linking Constraints

These constraints are required to insure that a crew variable is in solution along with a vehicle variable going between a given pair of points. Since the objective function's purpose is to minimize cost, the implication is that primarily crew variables would come into solution because of their zero cost factor. Therefore, by linking complementary vehicle and crew variables, the solution to a given model application contains the true cost in miles. This set of constraints allows either three, two, or one crews to travel between two sites only if the value of the vehicle assigned is one. The general format of this constraint set is as follows:

$$Y_{ij} \leq 3X_{ij} \quad \text{for } i = 1, 2, \ldots, n, n+1 \text{ points}$$
$$\qquad\qquad\qquad j = 2, \ldots, n, n+1 \text{ sites} \qquad (7)$$
$$i \neq j$$

e.g.: $j = 2$

$$Y_{12} \leq 3X_{12} \quad \text{where } 1 = \text{Malmstrom}$$

The linear programming property of linearity implies that the X_{ij}'s and Y_{ij}'s are not limited to integer values. Thus, this model would be expected to give integer-valued solutions only through an integer programming code. Since no codes are available as a resource to this project, the implications of this constraint set cannot be fully appreciated. There are n^2 of these constraints in the formulation of this model, where n equals the number of sites.

Model Objective Function

The objective function seeks to minimize the cost, in terms of miles, of transporting missile crews. Costs are allocated only to the vehicle variables, while the crew variables have zero cost. This greatly simplifies the task of computing the exact cost of transporting a crew between two sites in the missile complex. The objective function has the general algebraic form below:

$$\text{Minimize } Z = \sum_{\substack{i=1 \\ i \neq j}}^{n+1} \sum_{j=2}^{n+1} C_{ij} X_{ij} + \sum_{\substack{i=1 \\ i \neq j}}^{n+1} \sum_{j=2}^{n+1} 0\, Y_{ij}$$

Model Validation

Once proposed, the algebraic formulation of the model required validation to ensure all constraints were appropriate to the desired type of solution. The large model required the use of considerable computer core capacity. Computer resources available at the AFIT Detachment at Malmstrom AFB consist of a PDP-11/E 10. Its 16K core is not adequate for the large problem formulation.[4] Consequently, the decision was made to devise a small application for one squadron, the 564th. It was felt that the results of a small application would adequately evaluate the constraints of the model and give answers analogous to a large application.

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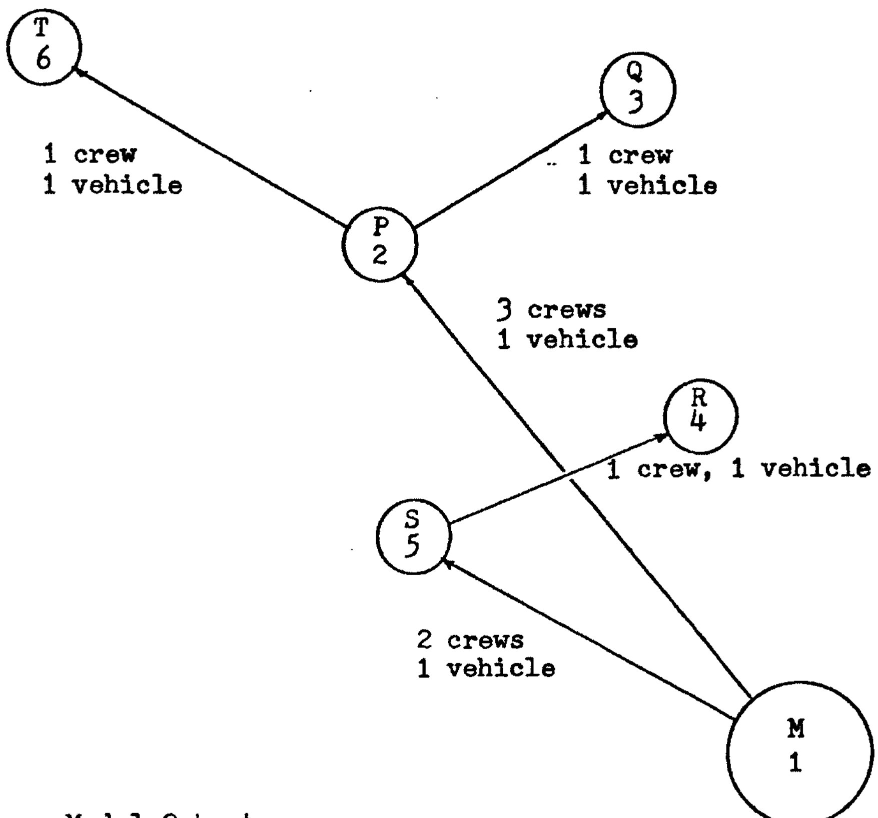
[4]Actual computer core capacity requirement for the large formulation is 41K, the limit set by the SIGMA 7 computer at Montana State University, Bozeman, Montana.

Appendix II gives the composition of the model for the 564th Squadron. The output is given in Figure 4. Vehicle prepositioning was selected for Papa because of its distance from Malmstrom and its proximity to the Tango and Quebec LCFs. All constraints were exercised, and perfromed as expected. The objective function value was consistent with mileages in Appendix III. Also, the deficiencies of the pure transhipment formulation were overcome.



Model Output

Segment	Cost (Miles)
1-5	55
5-4	15
1-2	68
2-3	20
2-6	38
	196 miles

Actual Mileage = 196 miles

Fig. 4.--Output of transport model validation

CHAPTER III

PRACTICAL APPLICATION OF THE MODEL

The second objective of this study, saving costs in crew transport, was approached by applying the proposed model to the entire 341st Strategic Missile Wing. As previously mentioned, the method chosen was to treat the squadrons to the east of Malmstrom (the 490th and 10th) and to the west (the 12th and 564th) as single problems. The results of each application were then combined to give cost figures for the entire Wing.

Analytical Description

The objective function for a pair of squadrons had the following format:

$$\text{Minimize } Z = \sum_{i=1}^{11} \sum_{\substack{j=2 \\ i \neq j}}^{11} C_{ij} X_{ij} + \sum_{i=1}^{11} \sum_{\substack{j=2 \\ i \neq j}}^{11} 0 \; Y_{ij}$$

The values of the C_{ij}'s are given in Table III-1 and Table III-2 of Appendix III, for the Eastern and Western squadrons, respectively. The objective function contained 200 variables, of which 100 were for vehicles and 100 for crews. The objective function was to be minimized subject to the following type of constraints (representative of LCF number j). A Vehicle Prepositioning Constraint was assumed to be required for LCF number six.

CONSTRAINT TYPE		NUMBER OF CONSTRAINTS
One Vehicle per Site:		
$\sum_{\substack{i=1 \\ i \neq j}}^{11} X_{ij} = 1$	for all LCFs	10
Vehicle Sources from Vehicle Destinations:		
$\sum_{\substack{j=2 \\ j \neq k}}^{11} X_{kj} \leq \sum_{\substack{i=1 \\ i \neq k}}^{11} X_{ik}$	for all LCFs except 6	9
Vehicle Prepositioning:		
$\sum_{\substack{j=2 \\ j \neq k}}^{11} X_{6j} \leq \sum_{\substack{i=1 \\ i \neq k}}^{11} X_{i6} + 1$	for LCF No. 6	1
Vehicle Supply:		
$\sum_{j=2}^{11} X_{1j} = 4$	for Malmstrom	1
One Crew per Site:		
$\sum_{\substack{i=1 \\ i \neq k}}^{11} Y_{ik} - \sum_{\substack{j=2 \\ j \neq k}}^{11} Y_{kj} = 1$	for all LCF's	10
Vehicle Passenger:		
$Y_{1j} \leq 3$	for all LCF's	10
Crew/Vehicle Linking:		
$- 3X_{ij} + Y_{ij} \leq 0 \quad i \neq j$	for all ij pairs	100
	Total:	141

As implicated by the 200 variables and 141 constraints, the problem size demanded the use of considerable computer core. A description of the computerized form of the model is given in Appendix IV. Included is a description of the FORTRAN matrix generator that was written to allow efficient and quick data input. The similarity of application to the two pairs of squadrons required that only the objective function coefficients and choice of prepositioned vehicle constraint(s) be changed for various solutions.

Computer Input/Output Analysis

The large applications of the model were solved by MFOR, a large-scale linear programming code. Ideally, the problem should have utilized an integer-programming code, which allows only integer-valued variables in solution. However, a code of the size needed was not available. Consequently, an attempt was made by the mode of data input to overcome the expected non-integer solution variables. The following example explains the method used to circumvent the non-integer values in solution.

Consider the two Eastern squadrons, the 10th and the 490th. The Vehicle Supply Constraint specifies the number of vehicles available from Malmstrom. If the constraint equals a small number such as four, the nearest sites (Alpha, Bravo and Charlie) are allocated whole vehicles, while the farthest sites (Mike, Echo and Oscar) are allocated fractions of vehicles. However, if a large number of vehicles such as seven is supplied, the nearer sites are still allocated the same vehicles, but the farther sites are able to utilize whole vehicles due to the excess number available. An intermediate number of vehicles such as five gives integer-valued solutions to vehicle allocations between intermediate sites. These sites are defined as the farthest sites of the closest squadron to Malmstrom and the nearest sites of the farthest squadron from the Base. By combining the computer outputs that use different vehicle availabilities, composite alternatives to the present method were formulated. Throughout these various model solutions the prepositioning of vehicles was also varied. The final result was an iterative process from which a single alternative evolved that combined the least number of vehicles and best sites for vehicle prepositioning. The variables of vehicle number and prepositioning in this final solution were then used as inputs in a final computer run. The resulting solution gave a final reinforcement of the iterative process described. However, this outcome was also subject to the possibility of non-integer valued solution variables. Therefore, in order to obtain a final alternative containing realistic integer values, a visual inspection process was used to eliminate all non-integer values.

Essentially, this process involved looking at the non-integer variables in solution. These variables for an integer solution had to be either driven to zero or some positive integer value. In the computer outputs graphically shown in Figures 5 and 6, the three-tenths of vehicles were made zero and the seven-tenths given a unit value. In the case of the Western squadrons, this alteration of the final computer output resulted in a transportation network essentially the same as the final outcome suggested by the iterative process. The Eastern squadrons required some additional manipulation for the final alternative proposal. This was due mainly to the greater number of

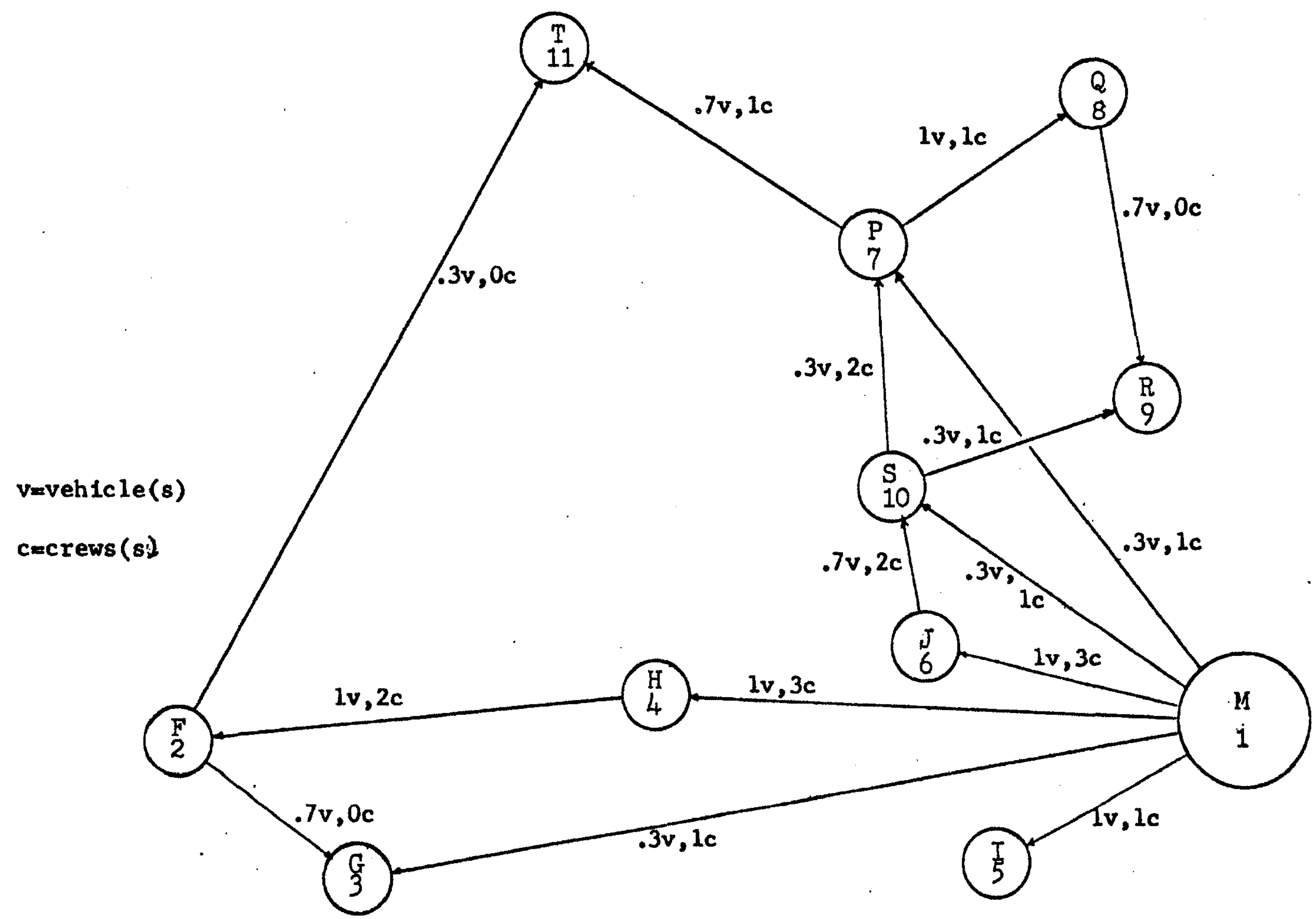


Fig. 5.--Final Computer Transportation Network: Western Squadrons

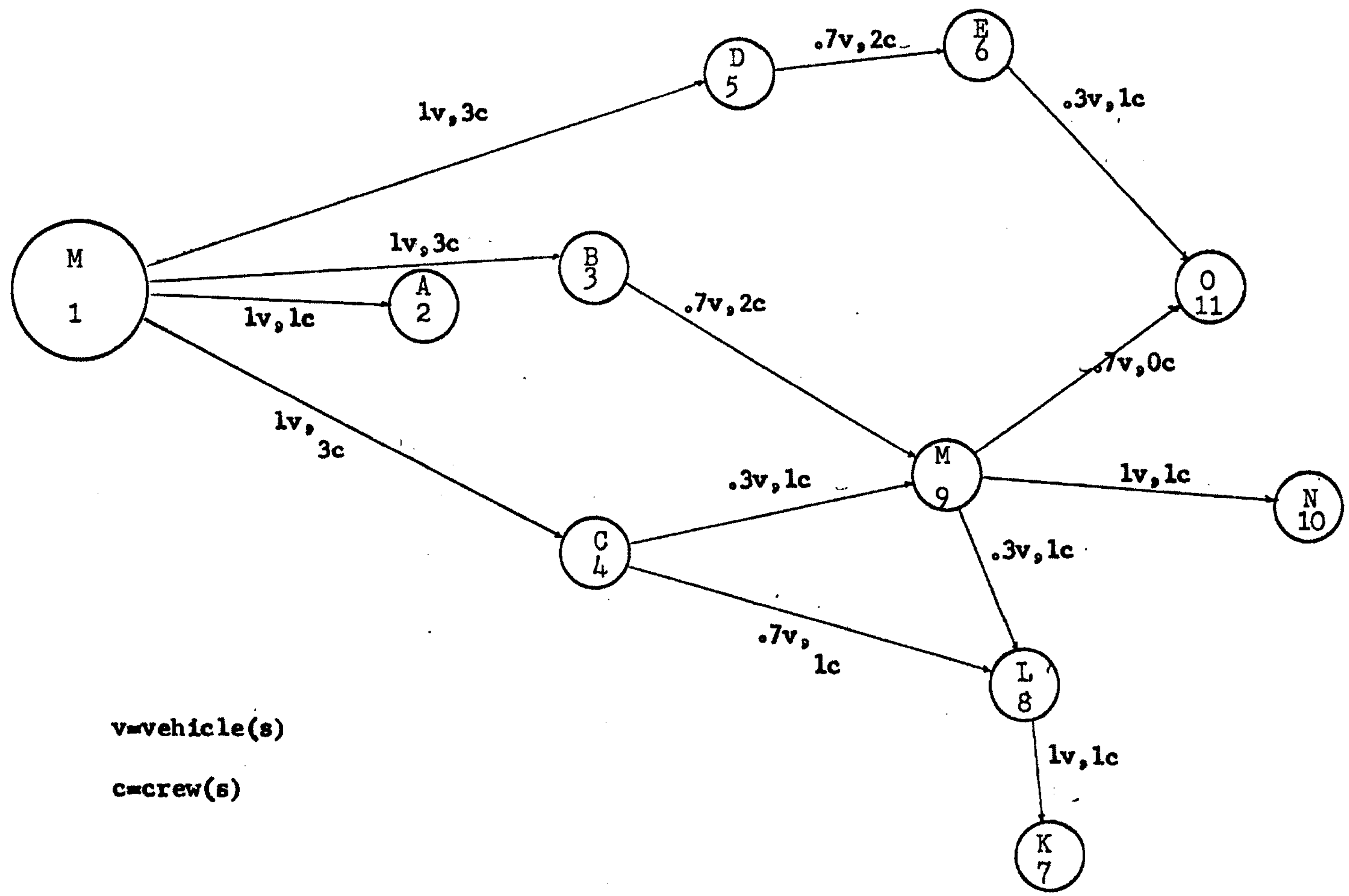


Fig. 6.--Final Computer Transportation Network: Eastern Squadrons

Eastern LCFs closer to Malmstrom.

The output of all computer runs is given in Appendix V. The proposed final alternative solution is given in Table 2 and Figure 7. Prepositioned vehicles are located at Papa and Mike LCFs. This contrasts with the present method found in Figure 1.

Analysis of Cost Savings

The alternative crew transportation network proposed was worthwhile only if the total mileage and/or number of vehicles was decreased. Table 3 gives a comparison of current daily mileage and vehicle requirements versus those proposed as a result of this study. True daily cost savings require that one-way mileage to the missile complex be doubled, since crews return from, and depart to, the LCFs daily.

TABLE 3

COMPARISON OF CURRENT AND ALTERNATIVE TRANSPORT METHODS

	Number of Vehicles	Daily Mileage
Current Method	12	1818
Alternative Method	10	1682
Savings	2	136

These results clearly demonstrate improvements in both mileage and vehicle requirements.

Actual cost savings were based on the information given in Table 4[1].

---

[1]Information supplied by the 341st Transportation Squadron, for the third quarter of Fiscal Year 1975.

TABLE 2

CURRENT VERSUS PROPOSED ONE-WAY MILEAGES

East

Current	Proposed
M to A = 27	M to A = 27
A to B = 23	A to B = 23
M to C = 64	M to C = 64
C to D = 46	C to L = 39
C to E = 71	L to K = 18
M to M = 94	M to M = 94
M to N = 28	M to N = 28
M to O = 45	M to O = 45
M to L = 103	M to D = 98
L to K = 18	D to E = 55
519	491

TABLE 2 (continued)

West

Current	Proposed
M to J = 40	M to J = 40
J to H = 51	J to S = 30
M to G = 52	S to R = 15
G to F = 25	M to H = 47
M to I = 26	H to F = 41
M to S = 55	F to G = 25
S to R = 15	M to I = 26
M to P = 68	M to P = 68
P to T = 38	P to T = 38
P to Q = 20	P to Q = 20
390	350

Current East + West = 909 mi.

Proposed East + West = 841 mi.

Current - Proposed = 909 - 841 = 68 mi/day

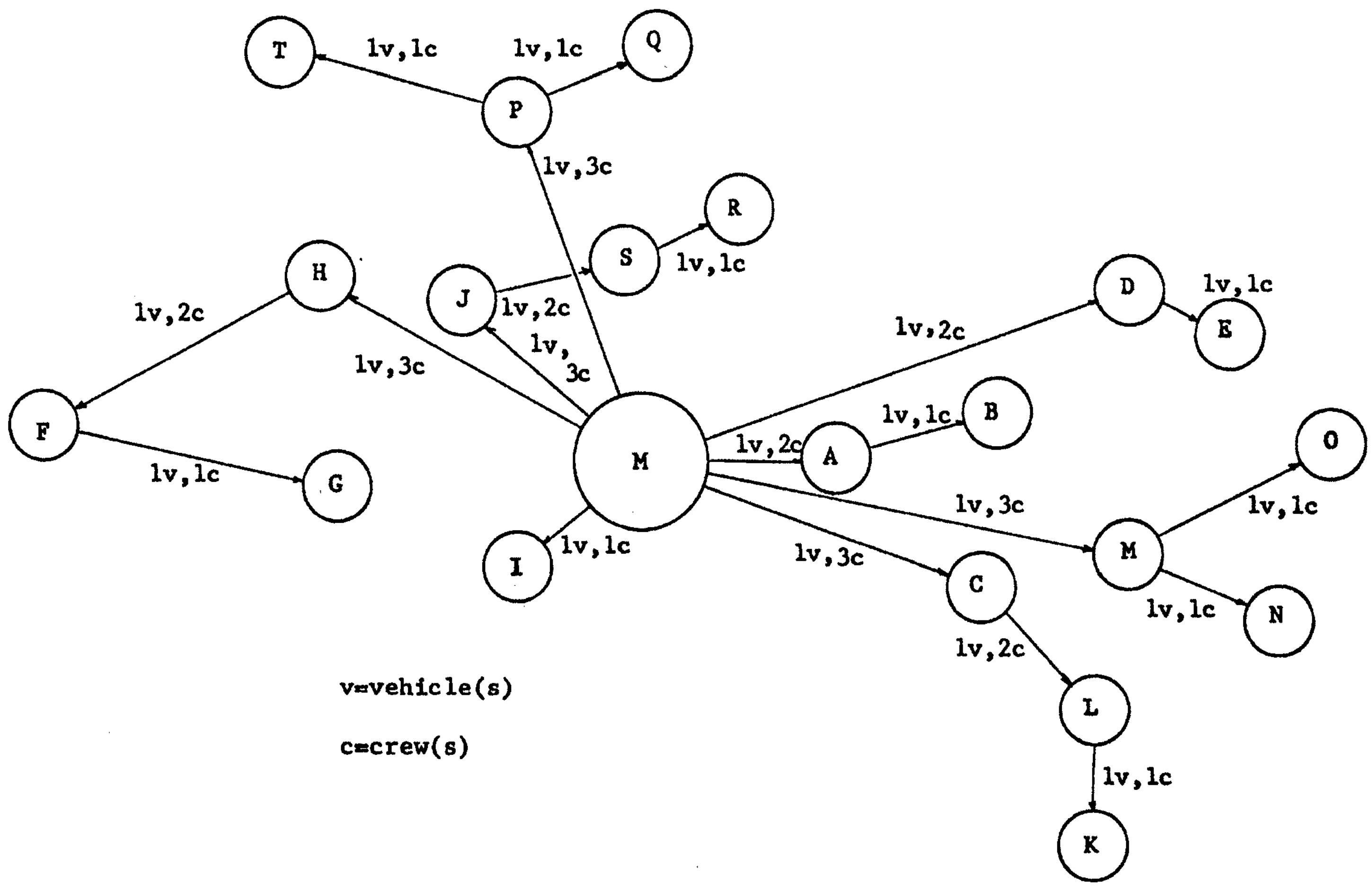


Fig. 7.--Final Alternative Crew Transportation Network

Replacement cost is the purchase price of the vehicle. This cost cannot be used as a future purchase price for a replacement vehicle since manufacturers' price increases and inflation preclude estimation of a future purchase price. The operating cost includes daily routine maintenance, labor, fuel and oil. This cost is deceptively low due to the large daily mileages upon which it is based. Miles per gallon vary due to vehicle differences; hence, an average of eleven miles per gallon was taken. Life expectancy considers use as a crew vehicle only. Once this mileage is reached, the vehicle is turned over to other Base organizations, where they are utilized until they are no longer serviceable or capable of repair. Hence, eventually a vehicle depreciates to its scrap value.

TABLE 4

COST DATA OF CREW VEHICLES

Vehicle	Replacement Cost	Operating Cost per Mile	Miles per Gal.	Life Expectancy (Miles)
Chevrolet Carryall	$4,530.00	$.12	10-12	100,000

The savings possible in daily mileage and in vehicles can be expressed in the following different ways:

1. The yearly mileage saved by the proposed alternative is:
   136 mi/day x 365 days/yr. = 49,640 mi/yr.
2. The daily savings of 136 miles converts to the following yearly savings in gallons of gasoline:

$$\frac{136 \text{ mi/day} \times 365 \text{ days/yr.}}{11 \text{ mi/gal.}} = \underline{4,512 \text{ gal/yr.}}$$

3. The cost of gasoline to the Missile Wing at the end of the third quarter of fiscal year 1975 was $.47/gal. Consequently, the yearly savings in gasoline converts to the following dollar amount:

$$4,512 \text{ gal/yr.} \times \$.47/\text{gal.} = \underline{\$2,121/\text{yr.}}$$

4. The operating cost figure for a year's time is the following:

$$136 \text{ mi/day} \times 365 \text{ days/yr.} \times \$.12/\text{mi.} = \underline{\$5,957/\text{yr.}}$$

Part of this amount includes the cost of gasoline.

5. It is estimated that a crew vehicle depreciates to approximately one-half of its original value at the completion of 100,000 miles. Consequently, the depreciation per mile is the following:

$$\frac{\$4,530 \times .5}{100,000 \text{ mi.}} = \underline{\$.023/\text{mi.}}$$

The total savings in depreciation converts to the following amount:

$$49,640 \text{ mi/yr.} \times \$.023/\text{mi.} = \underline{\$1,142/\text{yr.}}$$

The percent depreciation used is considered to be a conservative estimate.

These quantitative estimates of fuel and cost savings are summarized in the following tables:

TABLE 5

SUMMARY OF FUEL SAVINGS

	Vehicles	Mileage (mi/yr)	Fuel (gal/yr)	Fuel Cost/Yr.
Current Method	12	663,570	60,325	$28.353
Alternative Method	10	613,930	55,813	$26,232
Savings	2	49,460	4,512	$2,121

TABLE 6

SUMMARY OF COST SAVINGS

	Vehicles	Mileage (mi/yr)	Operating Costs	Depreciation
Current Method	12	663,570	$79,628	$15,262
Alternative Method	10	613,930	$73,671	$14,120
Saving	2	49,640	$5,957	$1,142

Total Cost Savings = $7,099

Besides these quantifiable measures of defining cost savings, there are other qualitative aspects that are not as obvious. Fewer vehicles being dispatched daily require fewer manhours spent on daily vehicle preparation. This time savings can be put to use in other work areas assigned to vehicle maintenance personnel. Less miles traveled daily result in less crew travel time. Reduction in such tedious travel time has positive benefits in terms of crew morale. Finally, because vehicles are only sold for scrap value, the new vehicle allocation to the Base will remain at present numbers. The vehicles released from crew transport duty put needed slack in a tight vehicle allocation base-wide.

CHAPTER IV

CONCLUSIONS AND EVALUATION OF THE STUDY

The model employed in this study was shown to be a useful tool in analyzing the crew transport problem. The first part of this chapter looks at the degree of validity in the model. Next, an examination is made of some limitations encountered during the study. The first section concludes with an analysis of the physical implementation of the model in computerized form. The second section of the chapter concludes the study with some suggestions for further study.

Evaluation of the Model

Model Validity

The model developed in this study proved to be a close approximation of the actual crew transport system. It controlled the movement and integration of vehicles and crews in a comparable manner with the actual daily deployment of both. A limitation of fractional vehicle solution variables, to be discussed later, detracted from the valid representation of reality. However, such a limitation was known to be present from the beginning due to the nature of linear programming and available computer resources. Nevertheless, the results were considered to be close approximations of pure integer solutions. And, by the method of computer input manipulation described earlier, the effects of non-integer solution variables were greatly reduced.

A principal consideration in this study was the model's usefulness as a tool in proposing alternative crew logistic networks. The extent to which the model gave suggestions for alternative transport networks, however, was implicit in the model. This can be contrasted with a model which provides absolute results, defined here as an exact and complete set of alternative transporting networks. A possibility for such results exists and this idea is expanded on in the section on future study. Nonetheless, the expected suggestive results were extremely useful and manipulative in providing a final improved transport network.

Limitations of the Model

The practical application of the model revealed some limitations concerning its employment. These were of a computational nature and principally affected the solution and validity of the model. They were:

1. The increased size of the model compared to its origins in pure transhipment theory. This sufficiently limited model application for problems of similar size to institutions possessing adequate computer facilities. The limitation was less apparent for model application to problems of considerably less size.
2. The presence of non-integer valued variables in solution limiting the model from providing the "actual" solutions mentioned earlier. This limitation arose from the Crew/Vehicle Linking Constraint formulation. It is of interest that in small applications, such as the one used to verify the model constraint set, this limitation did not appear.
3. The limitation caused by the use of linear programming restrict-

ing the assignment of whole vehicles to the closest sites. This was closely associated with the previous limitation and might have been alleviated with an integer-programming code. The effect of this limitation was that the proposed alternative solution had to contain some network manipulation by inspection.

The principal impact of these limitations was that they provided solutions which required further manipulation. The model is capable of eliminating these shortcomings, given an alternative means of solution, namely an integer-programming computer code.

Operational Characteristics

Computerized solutions of the model for the entire 341st Strategic Missile Wing were obtained using a SIGMA 7 computer, specifically, by utilizing MFOR, a linear programming code capable of handling very large problems with considerable flexibility of input. Depending on problem size, any adequate linear programming code may be used for output.

The crew transport application required the use of 41,000 words of core memory and 1.74 minutes of central processing unit execution time. This processing time included some parametric manipulation of right-hand side variables. This feature of MFOR allowed for successive runs of a problem with little additional processing time and cost.

The implementation of the model necessarily called for a large input of data, especially for a problem of the size forund in this study. Consequently, it was found useful to generate the coefficients of the constraint set and objective function by means of a matrix generator. This is more fully explained in Appendix IV. MFOR, with its considerable variation of input, was easily modified to accept a FORTRAN matrix data generator.

Suggested Future Research

Further research into the problem discussed in this study divides itself into two categories: (1) modification of the present form of the model, and (2) extension of the model to other related problems.

Modification of Present Form

The current form of the model presented some deficiencies in solution which further research might correct. These are presented mainly for improvement of results obtained by a linear programming code, since this type is much more prevalent than an integer code. Possible solutions to these deficiencies are to:

1. Reformulate the constraint used to link vehicles with crews. This particular constraint appears to cause the non-integer variables to enter solution.
2. Change the constraint set to allow for alternative means of crew transport such as buses.

Extensions of the Model:

The application of the model to other related problems is a viable field of future research. Related problems are those in which vehicle availability for daily dispatch is limited, but daily deployment throughout a given transport network is mandatory. Several suggested extensions are:

1. A bus line, in which daily routes are constant and inputs such

as fuel and vehicles are major cost items.

2. A milk route with a network consisting of a municipal area. Such a problem might involve an independent dealer or a fleet of dairy trucks.

3. Extension of the model to incorporate random passenger inputs, such as a charter airline.

These possible applications of the model all have common inputs of vehicles, cargo of some type, and a possible network over which to travel. Each has as primary considerations fuel, vehicle cost and minimum time spent in transport. Any given application requires certain modifications of the constraint set. However, the general scheme of the model's method of solution should remain constant. Thus, the experience gained in this study provides a close approximation to the desired solutions of these representative possible problems.

APPENDIX I

PURE TRANSHIPMENT FORMULATION FOR THE 564th CREW TRANSPORT PROBLEM

The Transhipment Problem may be stated as:

$$\text{Minimize } Z = \sum_{i=1}^{m+n} \sum_{\substack{j=1 \\ i \neq j}}^{m+n} C'_{ij} X_{ij}$$

$$\text{Subject to: } \sum_{\substack{j=1 \\ j \neq i}}^{m+n} (X_{ij} - X_{ji}) = \begin{cases} a_i, & \text{for } i = 1, 2, \ldots, m \\ -b_{i-m}, & \text{for } i = m+1, \ldots, m+n \end{cases}$$

Where C'_{ij} = unit cost of shipment between points i to j

X_{ij} = number of units shipped between points i and j

a_i = supply from point i

$-b_{i-m}$ = demand from destination i[1]

To apply the mathematical formulation of the above general description to the 564th squadron, the following analogies must be made:

1. There are two supply points (a_i) in the 564th problem, Malmstrom and Papa. ($m = 2$)
2. There are five destinations ($-b_{i-m}$), Papa through Tango, m + P through m + T, respectively, with Papa also a source ($n = 4$).
3. The cost of shipment is the miles between points i and j.
4. The units shipped are crews (designated as Y_{ij} in this case).

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[1]Hillier and Liberman, Introduction to Operations Research, pp. 194-198.

APPENDIX I (continued)

In tabular form:

TABLE I - 1

TRANSHIPMENT COSTS AND REQUIREMENTS

	M	P	M+P	M+Q	M+R	M+S	M+T	SUPPLY (a_i)
M	C'_{MM}	C'_{MP}	C_{MP}	C_{MQ}	C_{MR}	C_{MS}	C_{MT}	3
P	C'_{PM}	C'_{PP}	C_{PP}	C_{PQ}	C_{PR}	C_{PS}	C_{PT}	2
M+P	C'_{PM}	C'_{PP}	C_{PP}	C_{PQ}	C_{PR}	C_{PS}	C_{PT}	0
M+Q	C'_{QM}	C'_{QP}	C_{QP}	C_{QQ}	C_{QR}	C_{QS}	C_{QT}	0
M+R	C'_{RM}	C'_{RP}	C_{RP}	C_{RQ}	C_{RR}	C_{RS}	C_{RT}	0
M+S	C'_{SM}	C'_{SP}	C_{SP}	C_{SQ}	C_{SR}	C_{SS}	C_{ST}	0
M+T	C'_{TM}	C'_{TP}	C_{TP}	C_{TQ}	C_{TR}	C_{TS}	C_{TT}	$\underline{0}$
Demand	0	0	1	1	1	1	1	5

Where $C'_{ij} = C_{i(j-M)}$ (i.e.: $C'_{MP} = C_{M\,(M+P-M)} = C_{MP}$)

$C_{ij} = 0$ for $i = j$

The accompanying algebraic form is:

$$\text{Minimize } Z = \sum_{i=1}^{6} \sum_{j=1}^{6} C'_{ij} \; Y_{ij}$$

Subject to:

APPENDIX I (continued)

CONSTRAINT	NUMBER
Supply from Malmstrom:	
$\sum_{j=2}^{6} Y_{1j} = 3$	1
Supply from Papa:	
$\sum_{j=3}^{6} Y_{2j} = 2$	1
Six Demand Equations of the Form:	
$\sum_{j=1}^{6} (Y_{ij} - Y_{ji}) = 1 \quad i = 1, 2, 3, 4, 5, 6$	5
Total	7

Where M = 1, P = 2, Q = 3, R = 4, S = 5, T = 6

The results of this formulation are given in Chapter 2, Figure 2.

APPENDIX II

MODEL VALIDATION FOR THE 564th SQUADRON

The following application of the general crew transport model was used for its validation. The 564th squadron was chosen since the pure transhipment analysis looked at the same squadron. By comparing the results of this formulation and pure transhipment, an immediate comparison was available to insure that the deficiencies of the transhipment approach were corrected.

The costs of transport for the 564th squadron are given in the following table:

TABLE II-1

COSTS OF TRANSPORT (MILES)

(1)	M	68	84	70	55	97
	(2)	P	30	31	25	38
		(3)	Q	47	23	44
			(4)	R	15	60
				(5)	S	47
					(6)	T

The objective function had the following general and specific formats, respectively:

$$(1)\quad \text{Minimize } Z = \sum_{i=1}^{6} \sum_{\substack{j=2 \\ i \neq j}}^{6} C_{ij} X_{ij} + \sum_{i=1}^{6} \sum_{\substack{j=2 \\ i \neq j}}^{6} 0\, Y_{ij}$$

APPENDIX II (continued)

(2) Minimize $Z = 68X_{12} + 84X_{13} + 70X_{14} + 55X_{15} + 97X_{16} + 30X_{23} + 31X_{24} + 25X_{25} + 38X_{26} + 30X_{32} + 47X_{34} + 23X_{35} + 44X_{36} + 31X_{42} + 47X_{43} + 15X_{45} + 60X_{46} + 25X_{52} + 23X_{53} + 15X_{54} + 47X_{56} + 38X_{62} + 44X_{63} + 60X_{64} + 47X_{65} + 0\ Y_{12} + 0\ Y_{13} + 0\ Y_{14} + 0\ Y_{15} + 0\ Y_{16} + 0\ Y_{23} + 0\ Y_{24} + 0\ Y_{25} + 0\ Y_{26} + 0\ Y_{32} + 0\ Y_{34} + 0\ Y_{35} + 0\ Y_{36} + 0\ Y_{42} + 0\ Y_{43} + 0\ Y_{45} + 0\ Y_{46} + 0\ Y_{52} + 0\ Y_{53} + 0\ Y_{54} + 0\ Y_{56} + 0\ Y_{62} + 0\ Y_{63} + 0\ Y_{64} + 0\ Y_{65}$

This objective function is subject to the following representative constraints:

CONSTRAINT	NUMBER
One Vehicle per Site: $X_{12} + X_{32} + X_{42} + X_{52} + X_{62} = 1$	5
Vehicle Sources from Vehicle Destinations: $X_{32} + X_{34} + X_{35} + X_{36} - X_{13} - X_{23} - X_{43} - X_{53} - X_{63} \leq 0$	4
Vehicle Prepositioning: $X_{23} + X_{24} + X_{25} + X_{26} - X_{12} - X_{32} - X_{42} - X_{52} - X_{62} \leq 1$	1
Vehicle Supply: $X_{12} + X_{13} + X_{14} + X_{15} + X_{16} = 2$	1
One Crew per Site: $Y_{13} + Y_{23} + Y_{43} + Y_{53} + Y_{63} - Y_{32} - Y_{34} - Y_{35} - Y_{36} = 1$	5
Vehicle Passenger: $Y_{12} \leq 3$	5
Crew/Vehicle Linking $-3X_{12} + Y_{12} \leq 0$	25
Total	46

APPENDIX II (continued)

The solution to this formulation is given in Chapter 2, Figure 4.

APPENDIX III

MILEAGES BETWEEN EASTERN SITES AND BETWEEN WESTERN SITES

TABLE III-1

MILEAGES GOING EAST

(1)	M	27	51	64	98	135	123	103	94	122	139
(2)	A		23	37	71	108	96	76	66	94	111
(3)	B			30	64	100	89	60	59	87	104
(4)	C				46	71	59	39	29	58	74
(5)	D					55	105	87	56	66	63
(6)	E						86	68	41	52	43
(7)	K							18	45	73	90
(8)	L								30	55	72
(9)	M									28	45
(10)	N										41
(11)	O										

(11) ← b, O ← a

a = Site Designations (letters)

b = Variable Designations (numbers)

APPENDIX III (continued)

TABLE III-2

MILEAGES GOING WEST

(1)	M̄	67	52	47	51	40	68	84	70	55	97
(2)	F		25	41	118	71	99	115	100	86	120
(3)	G			46	103	55	99	119	84	70	112
(4)	H				98	51	79	95	80	66	108
(5)	I					91	101	117	102	88	130
(6)	J						33	54	44	30	67
(7)	P							20	31	25	38
(8)	Q								47	23	44
(9)	R									15	60
(10)	S										47
(11)	T										

a = Site Designations (letters)

b = Variable Designations (numbers)

APPENDIX IV

COMPUTERIZED FORM OF THE MODEL

The model used to analyze the crew logistics problem was solved using two linear programming codes. The small model for one squadron utilized a linear programming code available on the AFIT detatchment's computer at Malmstrom AFB. This was a small-scale linear programming code utilizing the simplex method. The large model for two squadrons was solved using MFOR, a large-scale linear programming code originally developed by the Rand Corporation and now available at Montana State University.[1] This code is an independent algorithm using the product form of the inverse method. All computations are done in core on a standard matrix. MFOR provides flexibility of input, and, perhaps, its greatest advantage is the large problems it can solve. The program is capable of solving problems with 2000 columns, 511 rows and 6000 non-zero matrix entries. The following analysis of computer input and output is concerned with only the large application of the model.

Data Input

The MFOR program required that each non-zero matrix entry be entered on a separate card. To preclude using 1135 cards, a matrix generator was written in FORTRAN, to input data to MFOR in the required format.

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[1]For detailed reference on MFOR, see: SIGMA 5/7 MFOR Linear Programming Code, Scientific Data Systems, 1968.

APPENDIX IV (continued)

Considerable time was saved in preparing data input because the matrix generator required that only 210 cards be punched.

Each line of data input required the column and row names of non-zero elements in the main constraint matrix. To facilitate the writing of the matrix generator, column and row names were simply one to three digit numerics. Analysis of standard solution outputs was easily accomplished by comparison with Table 1, Chapter II. The computerized form of the model had 142 rows and 386 columns, the objective function being counted as a row.

Control Procedure for Generating Problem Solutions

The desired form of solution to the MFOR code was managed by means of a program made of suggestive mnemonic control words. This program allowed runs to be stacked, a run being all the computations required on a given set of constraints and the objective function.

This control program solved the problem for an initial optimal solution and then parametrically varied right-hand side values to provide additional solutions.

The different runs of the model for the Eastern and Western squadrons required slightly differing formulations of the MFOR control program. However, the format was the same and followed the general sequence of: (1) a file for the data created by the matrix generator, (2) a command to generate the initial optimal solution, (3) a command to alter right-hand side values, and (4) a command to generate a new

APPENDIX IV (continued)

solution with the parametrically altered right-hand side vector.

The altering of the right-hand side vector was used to simulate the prepositioning of vehicles and/or to change the number of vehicles supplied from Malmstrom.

This method resulted in considerable savings in processing time and cost since additional solutions were obtained using the final iteration of the initial primal feasible solution as a starting basis.

Solution Output

The output of a representative run consisted of the following:

1. A listing of the statistics for the given run. Included here were the problem size and the number of iterations required until an optimal solution occured.
2. A row output giving the column in which a pivot was done for a given row. Included were the variable value, and the dual solution, sometimes referred to as "the shadow price."
3. The column output. Each variable name was given along with its value.

This sequence was repeated as often as necessary with a given control card program requiring sequential runs. A sample output for two successive runs is contained in Appendix VI.

APPENDIX V

SAMPLE COMPUTER OUTPUT FOR THE CREW TRANSPORT MODEL

The first page of computer output gives the statistics for a given computer run. The principle information supplied was the following: (1) The number of slack variables installed, (2) the iteration number at which the problem first became feasible, and (3) the number of pivot steps required before the problem was feasible.

Explanation of Short Output

Preceding the actual column output values is the "short output" for the computer run. The example in this appendix resulted in an optimal solution. Included in the short output was:

1. The identification of the matrix and right hand side identifiers.
2. The number of iterations, steps and pivots needed for the optimal solution.
3. The objective function value.
4. The number of infeasibilities.
5. The last column to enter solution.
6. The last column to leave the solution.
7. The last pivot row.

APPENDIX V (continued)

Identification of Column Headings

Row Output Section

Heading	Explanation
Name	Column in which a pivot was done for the row.
Value	Variable value for the column given in the Name portion.
Row	Row name.
RHS	Value of the right hand side (as input).
Price	The negative of the dual solution.
(Column number)	Contents of temporary storage in the last column to be transformed.

Column Output Section

Heading	Explanation
Name	Name of variable in objective function.
Value	Variables value in solution.
True/Cost/	Objective function coefficient for the given variable.
Reduced	The reduced cost.
Row	Pivot row for a given column.

```
RUN
 BEGIN
 ROW      COST
 RHS
 MATRIX

    PROBLEM HAS 187 ROWS,  365 COLUMNS, AND 1157 MATRIX ENTRIES.
 SETI
 SOLVE
 ''INSTALLED   165 SLACKS,      0 NON-SLACKS

  REINVERTING AFTER     0TH ITERATION.    0 TRANSFORMATIONS WITH     0 ENTRIES, TIME=       .0000 TYPE 0
 *INVERSION COMPLETED  165 SLACKS,  190 POOR COLS,   10 TRANSFORMATIONS WITH   51 ENTRIES, TIME=       .0000

  REINVERTING AFTER    24TH ITERATION.   46 TRANSFORMATIONS WITH   806 ENTRIES, TIME=       .0000 TYPE 1
 *INVERSION COMPLETED  140 SLACKS,    0 POOR COLS,   45 TRANSFORMATIONS WITH  279 ENTRIES, TIME=       .0000

 MAX ERR ON ROW   COST=  -.28422E-13, SUM=  .35971E-13

 *FEASIBLE ON ITERATION  25,    37 STEPS

  REINVERTING AFTER    48TH ITERATION.   80 TRANSFORMATIONS WITH  1172 ENTRIES, TIME=       .0000 TYPE 1
 *INVERSION COMPLETED  130 SLACKS,    0 POOR COLS,   56 TRANSFORMATIONS WITH  388 ENTRIES, TIME=       .0000

 MAX ERR ON ROW   COST=   .94882E-14, SUM=  .15248E-13

 MAX ERR ON COL     90=   .11990E-13, SUM=  .10791E-12
```

```
REINVERTING AFTER    72TH ITERATION.   99 TRANSFORMATIONS WITH  1607 ENTRIES, TIME=        .0000 TYPE 1
.INVERSION COMPLETED  108 SLACKS,     0 POOR COLS,   78 TRANSFORMATIONS WITH  607 ENTRIES, TIME=        .0000

MAX ERR ON ROW   COST=  -.11724E-12, SUM=  .12183E-12

MAX ERR ON COL     19=  -.17764E-13, SUM=  .11147E-12
```

*OPTIMAL SOLUTION

(3) MATRIX	R.H.S.	ITER	STEPS	PIVS	OBJECTIVE	COST	0 INFEAS	DETERMINANT	MIN. R/COST	NEW COL	OLD COL	PIV
)(Y<	000000	81	126	315		376.133333	.000	8.47289E 11	-.0000000	345	108	

NAME	VALUE	ROW	RHS	PRICE	172
	-376.133333	COST	.000000	1.000000	-.000000
201	3.000000	1	3.000000	.000000	.000000
202	2.000000	2	3.000000	.000000	.000000
203	1.000000	3	3.000000	.000000	.000000
204	2.000000	4	3.000000	.000000	.000000
205	2.000000	5	3.000000	.000000	.000000
206	1.000000	6	3.000000	.000000	.000000
207	3.000000	7	3.000000	.000000	.000000
208	3.000000	8	3.000000	.000000	.000000
209	.000000	9	3.000000	.000000	-.000000
210	3.000000	10	3.000000	.000000	.000000
211	1.000000	11	1.000000	.000000	.000000
212	.333333	12	1.000000	.000000	-.000000
213	1.000000	13	1.000000	.000000	.000000
214	1.000000	14	1.000000	.000000	.000000
215	1.000000	15	1.000000	.000000	.000000
216	1.000000	16	1.000000	.000000	.000000
217	1.000000	17	1.000000	.000000	.000000
218	1.000000	18	1.000000	.000000	.000000
219	1.000000	19	1.000000	.000000	.000000
220	1.000000	20	1.000000	.000000	.000000
221	1.000000	21	1.000000	.000000	.000000
222	1.000000	22	1.000000	.000000	.000000
223	1.000000	23	1.000000	.000000	.000000
224	1.000000	24	1.000000	.000000	.000000
225	1.000000	25	1.000000	.000000	.000000
226	1.000000	26	1.000000	.000000	.000000
227	1.000000	27	1.000000	.000000	.000000
228	1.000000	28	1.000000	.000000	.000000
229	1.000000	29	1.000000	.000000	.000000
230	1.000000	30	1.000000	.000000	.000000
231	1.000000	31	1.000000	.000000	.000000
232	1.000000	32	1.000000	.000000	.000000

233	1.000000	33	1.000000	.000000	.000000
234	1.000000	34	1.000000	.000000	.000000
235	1.000000	35	1.000000	.000000	.000000
236	1.000000	36	1.000000	.000000	.000000
237	1.000000	37	1.000000	.000000	.000000
238	1.000000	38	1.000000	.000000	.000000
239	1.000000	39	1.000000	.000000	.000000
240	1.000000	40	1.000000	.000000	.000000
241	1.000000	41	1.000000	.000000	.000000
242	1.000000	42	1.000000	.000000	.000000
243	1.000000	43	1.000000	.000000	.000000
244	1.000000	44	1.000000	.000000	.000000
245	1.000000	45	1.000000	.000000	.000000
246	.666667	46	1.000000	.000000	.000000
247	1.000000	47	1.000000	.000000	.000000
248	1.000000	48	1.000000	.000000	.000000
249	.000000	49	1.000000	.000000	.000000
129	1.000000	50	1.000000	4.600000	.000000
251	1.000000	51	1.000000	.000000	.000000
252	1.000000	52	1.000000	.000000	.000000
253	.000000	53	1.000000	.000000	.000000
254	1.000000	54	1.000000	.000000	.000000
255	1.000000	55	1.000000	.000000	.000000
256	1.000000	56	.000000	.000000	.000000
257	2.000000	57	.000000	.000000	.000000
258	1.000000	58	.000000	.000000	.000000
259	2.000000	59	.000000	.000000	.000000
260	2.000000	60	.000000	.000000	.000000
6	.666667	61	.000000	6.466667	.000000
7	.000000	62	.000000	10.800000	.000000
345	1.000000	63	.000000	6.633333	1.000000
109	3.000000	64	.000000	6.466667	.000000
119	.000000	65	.000000	9.933333	.000000
11	.000000	66	.000000	2.700000	.000000
12	.000000	67	.000000	5.366667	.000000
268	.000000	68	.000000	.000000	.000000
269	.000000	69	.000000	.000000	.000000
115	.000000	70	.000000	6.466667	.000000
116	.000000	71	.000000	6.466667	.000000
17	.000000	72	.000000	17.300000	.000000
118	.000000	73	.000000	6.466667	.000000

106	2.000000	74	.000000	6.466667	.000000
275	.000000	75	.000000	.000000	.000000
276	.000000	76	.000000	.000000	.000000
277	.000000	77	.000000	.000000	.000000
278	.000000	78	.000000	.000000	.000000
124	.000000	79	.000000	6.466667	.000000
125	.000000	80	.000000	6.466667	.000000
126	.000000	81	.000000	6.465667	.000000
127	.000000	82	.000000	6.466667	.000000
128	.000000	83	.000000	6.466667	.000000
284	1.000000	84	.000000	.000000	.000000
130	.000000	85	.000000	.000000	.000000
286	.000000	86	.000000	.000000	.000000
287	.000000	87	.000000	.000000	.000000
133	.000000	88	.000000	6.466667	.000000
134	.000000	89	.000000	6.465667	.000000
35	.000000	90	.000000	12.833333	.000000
136	.000000	91	.000000	6.466667	.000000
137	.000000	92	.000000	6.465667	.000000
138	.000000	93	.000000	-.000000	.000000
139	.000000	94	.000000	.000000	.000000
140	.000000	95	.000000	.000000	.000000
41	.000000	96	.000000	19.700000	.000000
142	.000000	97	.000000	6.465667	.000000
143	.000000	98	.000000	6.466667	.000000
144	.000000	99	.000000	6.466667	.000000
145	.000000	100	.000000	6.466667	.000000
146	.000000	101	.000000	6.465667	.000000
147	.000000	102	.000000	-.000000	.000000
148	.000000	103	.000000	.000000	.000000
49	.000000	104	.000000	4.400000	.000000
50	.000000	105	.000000	24.000000	.000000
151	.000000	106	.000000	6.464667	.000000
152	.000000	107	.000000	6.466667	.000000
153	.000000	108	.000000	6.466667	.000000
154	.000000	109	.000000	6.466667	.000000
155	.000000	110	.000000	6.466667	.000000
311	.000000	111	.000000	.000000	.000000
312	.000000	112	.000000	.000000	.000000
313	.000000	113	.000000	.000000	.000000
314	.000000	114	.000000	.000000	.000000

60	.000000	115	.000000	27.866667	.000000
89	.000000	116	.000000	.000000	.000000
317	.000000	117	.000000	.000000	.000000
63	.000000	118	.000000	5.433333	.000000
319	2.000000	119	.000000	.000000	-.000000
320	.000000	120	.000000	.000000	.000000
321	.000000	121	.000000	.000000	.000000
67	.000000	122	.000000	21.033333	.000000
323	.000000	123	.000000	.000000	.000000
69	.000000	124	.000000	32.200000	.000000
325	1.000000	125	.000000	.000000	-.000000
164	1.000000	126	.000000	1.800000	.000000
327	.000000	127	.000000	.000000	1.000000
335	2.000000	128	.000000	.500000	1.000000
329	.000000	129	.000000	.000000	.000000
330	.000000	130	.000000	.000000	.000000
331	.000000	131	.000000	.000000	.000000
332	.000000	132	.000000	.000000	.000000
333	.000000	133	.000000	.000000	.000000
79	.000000	134	.000000	1.666667	.000000
180	1.000000	135	.000000	-.000000	-1.000000
81	.000000	136	.000000	3.633333	.000000
337	.000000	137	.000000	.000000	.000000
338	.000000	138	.000000	.000000	.000000
339	.000000	139	.000000	.000000	.000000
340	.000000	140	.000000	.000000	.000000
341	.000000	141	.000000	.000000	.000000
342	.000000	142	.000000	.000000	.000000
343	.000000	143	.000000	.000000	.000000
316	.000000	144	.000000	.933333	.000000
190	2.000000	145	.000000	.000000	-1.000000
91	.000000	146	.000000	2.933333	.000000
92	.000000	147	.000000	8.733333	.000000
93	.000000	148	.000000	37.633333	.000000
349	.000000	149	.000000	.000000	.000000
350	.000000	150	.000000	.000000	.000000
351	.000000	151	.000000	.000000	.000000
97	.000000	152	.000000	3.600000	.000000
98	.000000	153	.000000	4.100000	.000000
199	.000000	154	.000000	.000000	.000000
355	.000000	155	.000000	.000000	.000000

356	1.000000	156	.000000	.000000	.000000
357	1.000000	157	.000000	.000000	.000000
358	.333333	158	.000000	.000000	-.000000
359	1.000000	159	.000000	.000000	.000000
360	1.000000	160	.000000	.000000	.000000
61	.000000	161	.000000	6.800000	-.000000
362	.666667	162	.000000	.000000	.000000
363	.000000	163	.000000	.000000	-.000000
88	.000000	164	.000000	3.800000	.000000
365	1.000000	165	.000000	.000000	.000000
10	.000000	166	1.000000	.000000	-.000000
102	1.000000	167	1.000000	.000000	.000000
103	2.000000	168	1.000000	.000000	.000000
104	1.000000	169	1.000000	.000000	.000000
105	1.000000	170	1.000000	.000000	.000000
170	.000000	171	1.000000	-6.466667	-.000000
80	1.000000	172	1.000000	-6.466667	.000000
8	.000000	173	1.000000	-6.466667	-.000000
9	1.000000	174	1.000000	-6.466667	.000000
19	.000000	175	1.000000	-6.466667	-.000000
1	.333333	176	1.000000	-28.100000	-.000000
2	1.000000	177	1.000000	-23.400000	.000000
3	1.000000	178	1.000000	-12.000000	.000000
4	1.000000	179	1.000000	6.300000	.000000
5	1.000000	180	1.000000	-6.600000	.000000
70	.333333	181	1.000000	-10.500000	-.000000
64	1.000000	182	1.000000	-24.100000	.000000
71	.000000	183	1.000000	-18.700000	.000000
90	1.000000	184	1.000000	-.200000	-.000000
73	.000000	185	1.000000	-34.900000	.000000
29	.666667	186	6.000000	-32.700000	.000000

NAME	VALUE	TRUE /COST/	REDUCED	ROW
1	.333333	60.800000	.000000	176
2	1.000000	56.100000	.000000	177
3	1.000000	44.700000	.000000	178
4	1.000000	26.400000	.000000	179
5	1.000000	39.300000	.000000	180
6	.666667	69.400000	-.000000	61

7	.000000	89.200000	.000000	62
8	.000000	71.300000	-.000000	173
9	1.000000	56.100000	.000000	174
10	.000000	97.400000	-.000000	166
11	.000000	31.500000	.000000	66
12	.000000	28.100000	.000000	67
13	.000000	87.200000	93.500000	
14	.000000	52.300000	45.700000	
15	.000000	70.000000	33.300000	
16	.000000	84.900000	41.400000	
17	.000000	70.600000	.000000	72
18	.000000	55.700000	32.300000	
19	.000000	54.300000	-.000000	175
20	.000000	31.500000	3.400000	
21	.000000	51.000000	39.000000	
22	.000000	82.500000	88.800000	
23	.000000	61.700000	55.100000	
24	.000000	108.300000	71.600000	
25	.000000	123.200000	79.700000	
25	.000000	110.200000	72.100000	
27	.000000	95.000000	71.600000	
28	.000000	136.300000	82.000000	
29	.666667	28.100000	.000000	186
30	.000000	51.000000	27.600000	
31	.000000	71.100000	77.400000	
32	.000000	25.200000	18.600000	
33	.000000	59.400000	22.700000	
34	.000000	75.100000	31.600000	
35	.000000	57.200000	-.000000	90
36	.000000	42.000000	18.600000	
37	.000000	83.300000	29.000000	
38	.000000	87.200000	59.100000	
39	.000000	82.500000	59.100000	
40	.000000	71.100000	59.100000	
41	.000000	65.700000	.000000	96
42	.000000	95.800000	59.100000	
43	.000000	115.600000	72.100000	
44	.000000	97.700000	59.600000	
45	.000000	82.500000	59.100000	
46	.000000	123.800000	69.500000	
47	.000000	52.300000	24.200000	

48	.000000	61.700000	38.300000	
49	.000000	25.200000	.000000	104
50	.000000	65.700000	.000000	105
51	.000000	83.400000	46.700000	
52	.000000	103.200000	59.700000	
53	.000000	85.300000	47.200000	
54	.000000	23.800000	.400000	
55	.000000	111.400000	57.100000	
56	.000000	70.000000	48.700000	
57	.000000	108.000000	91.400000	
58	.000000	59.400000	54.200000	
59	.000000	95.800000	108.900000	
60	.000000	83.400000	.000000	115
61	.000000	17.300000	.000000	161
62	.000000	22.300000	10.400000	
63	.000000	13.500000	.000000	118
64	1.000000	28.100000	.000000	182
65	.000000	84.900000	56.800000	
66	.000000	123.200000	99.800000	
67	.000000	75.100000	.000000	122
68	.000000	115.600000	121.900000	
69	.000000	103.200000	.000000	124
70	.333333	17.300000	.000000	181
71	.000000	19.500000	.000000	183
72	.000000	23.100000	19.100000	
73	.000000	36.400000	.000000	185
74	.000000	70.600000	42.500000	
75	.000000	110.200000	86.800000	
76	.000000	57.200000	45.200000	
77	.000000	97.700000	104.000000	
78	.000000	85.300000	78.700000	
79	.000000	22.300000	.000000	134
80	1.000000	19.500000	.000000	172
81	.000000	14.900000	-.000000	136
82	.000000	50.600000	15.700000	
83	.000000	55.700000	31.400000	
84	.000000	95.000000	75.400000	
85	.000000	42.000000	33.800000	
86	.000000	82.500000	92.600000	
87	.000000	23.800000	21.000000	
88	.000000	13.500000	.000000	164

89	.000000	23.100000	.000000	116
90	1.000000	14.900000	-.000000	184
91	.000000	39.900000	.000000	146
92	.000000	54.300000	.000000	147
93	.000000	136.300000	.000000	148
94	.000000	83.300000	71.300000	
95	.000000	123.800000	130.100000	
96	.000000	111.400000	104.800000	
97	.000000	28.100000	.000000	152
98	.000000	36.400000	.000000	153
99	.000000	50.600000	31.900000	
100	.000000	39.900000	35.900000	
101	.000000	.000000	.000000	
102	1.000000	.000000	.000000	167
103	2.000000	.000000	.000000	168
104	1.000000	.000000	.000000	169
105	1.000000	.000000	.000000	170
106	2.000000	.000000	.000000	74
107	.000000	.000000	4.333333	
108	.000000	.000000	.166667	
109	3.000000	.000000	.000000	64
110	.000000	.000000	3.466667	
111	.000000	.000000	2.700000	
112	.000000	.000000	5.366667	
113	.000000	.000000	-.000000	
114	.000000	.000000	-.000000	
115	.000000	.000000	.000000	70
116	.000000	.000000	.000000	71
117	.000000	.000000	10.833333	
118	.000000	.000000	.000000	73
119	.000000	.000000	.000000	65
120	.000000	.000000	.000000	
121	.000000	.000000	.000000	
122	.000000	.000000	.000000	
123	.000000	.000000	.000000	
124	.000000	.000000	.000000	79
125	.000000	.000000	.000000	80
126	.000000	.000000	.000000	81
127	.000000	.000000	.000000	82
128	.000000	.000000	.000000	83
129	1.000000	.000000	.000000	50

130	.000000	.000000	.000000	85
131	.000000	.000000	.000000	
132	.000000	.000000	.000000	
133	.000000	.000000	.000000	88
134	.000000	.000000	.000000	89
135	.000000	.000000	6.366667	
136	.000000	.000000	.000000	91
137	.000000	.000000	.000000	92
138	.000000	.000000	.000000	93
139	.000000	.000000	.000000	94
140	.000000	.000000	.000000	95
141	.000000	.000000	19.700000	
142	.000000	.000000	.000000	97
143	.000000	.000000	.000000	98
144	.000000	.000000	.000000	99
145	.000000	.000000	.000000	100
146	.000000	.000000	.000000	101
147	.000000	.000000	.000000	102
148	.000000	.000000	.000000	103
149	.000000	.000000	4.400000	
150	.000000	.000000	24.000000	
151	.000000	.000000	.000000	106
152	.000000	.000000	.000000	107
153	.000000	.000000	.000000	108
154	.000000	.000000	.000000	109
155	.000000	.000000	.000000	110
156	.000000	.000000	6.466667	
157	.000000	.000000	6.466667	
158	.000000	.000000	6.466667	
159	.000000	.000000	6.466667	
160	.000000	.000000	34.333333	
161	.000000	.000000	.000000	
162	.000000	.000000	-.000000	
163	.000000	.000000	5.433333	
164	1.000000	.000000	-.000000	126
165	.000000	.000000	6.466667	
166	.000000	.000000	6.466667	
167	.000000	.000000	27.500000	
168	.000000	.000000	6.466667	
169	.000000	.000000	38.666667	
170	.000000	.000000	.000000	171

171	.000000	.000000	1.800000	
172	.000000	.000000	.000000	
173	.000000	.000000	.500000	
174	.000000	.000000	6.466667	
175	.000000	.000000	6.466667	
176	.000000	.000000	6.466667	
177	.000000	.000000	6.466667	
178	.000000	.000000	6.466667	
179	.000000	.000000	1.666667	
180	1.000000	.000000	.000000	135
181	.000000	.000000	3.633333	
182	.000000	.000000	.000000	
183	.000000	.000000	6.466667	
184	.000000	.000000	6.466667	
185	.000000	.000000	6.466667	
186	.000000	.000000	6.466667	
187	.000000	.000000	6.466667	
188	.000000	.000000	-.000000	
189	.000000	.000000	.933333	
190	2.000000	.000000	.000000	145
191	.000000	.000000	2.933333	
192	.000000	.000000	15.200000	
193	.000000	.000000	44.100000	
194	.000000	.000000	6.466667	
195	.000000	.000000	6.466667	
196	.000000	.000000	6.466667	
197	.000000	.000000	3.600000	
198	.000000	.000000	4.100000	
199	.000000	.000000	.000000	154
200	.000000	.000000	.000000	
201	3.000000	.000000	.000000	1
202	2.000000	.000000	.000000	2
203	1.000000	.000000	.000000	3
204	2.000000	.000000	.000000	4
205	2.000000	.000000	.000000	5
206	1.000000	.000000	.000000	6
207	3.000000	.000000	.000000	7
208	3.000000	.000000	.000000	8
209	.000000	.000000	.000000	9
210	3.000000	.000000	.000000	10
211	1.000000	.000000	.000000	11

212	.333333	.000000	.000000	12
213	1.000000	.000000	.000000	13
214	1.000000	.000000	.000000	14
215	1.000000	.000000	.000000	15
216	1.000000	.000000	.000000	16
217	1.000000	.000000	.000000	17
218	1.000000	.000000	.000000	18
219	1.000000	.000000	.000000	19
220	1.000000	.000000	.000000	20
221	1.000000	.000000	.000000	21
222	1.000000	.000000	.000000	22
223	1.000000	.000000	.000000	23
224	1.000000	.000000	.000000	24
225	1.000000	.000000	.000000	25
226	1.000000	.000000	.000000	26
227	1.000000	.000000	.000000	27
228	1.000000	.000000	.000000	28
229	1.000000	.000000	.000000	29
230	1.000000	.000000	.000000	30
231	1.000000	.000000	.000000	31
232	1.000000	.000000	.000000	32
233	1.000000	.000000	.000000	33
234	1.000000	.000000	.000000	34
235	1.000000	.000000	.000000	35
236	1.000000	.000000	.000000	36
237	1.000000	.000000	.000000	37
238	1.000000	.000000	.000000	38
239	1.000000	.000000	.000000	39
240	1.000000	.000000	.000000	40
241	1.000000	.000000	.000000	41
242	1.000000	.000000	.000000	42
243	1.000000	.000000	.000000	43
244	1.000000	.000000	.000000	44
245	1.000000	.000000	.000000	45
246	.666667	.000000	.000000	46
247	1.000000	.000000	.000000	47
248	1.000000	.000000	.000000	48
249	.000000	.000000	.000000	49
250	.000000	.000000	4.600000	
251	1.000000	.000000	.000000	51
252	1.000000	.000000	.000000	52

253	.000000	.000000	.000000	53
254	1.000000	.000000	.000000	54
255	1.000000	.000000	.000000	55
256	1.000000	.000000	.000000	56
257	2.000000	.000000	.000000	57
258	1.000000	.000000	.000000	58
259	2.000000	.000000	.000000	59
260	2.000000	.000000	.000000	60
261	.000000	.000000	6.466667	
262	.000000	.000000	10.800000	
263	.000000	.000000	6.633333	
264	.000000	.000000	6.466667	
265	.000000	.000000	9.933333	
266	.000000	.000000	2.700000	
267	.000000	.000000	5.366667	
268	.000000	.000000	.000000	68
269	.000000	.000000	.000000	69
270	.000000	.000000	6.466667	
271	.000000	.000000	6.466667	
272	.000000	.000000	17.300000	
273	.000000	.000000	6.466667	
274	.000000	.000000	6.466667	
275	.000000	.000000	.000000	75
276	.000000	.000000	.000000	76
277	.000000	.000000	.000000	77
278	.000000	.000000	.000000	78
279	.000000	.000000	6.466667	
280	.000000	.000000	6.466667	
281	.000000	.000000	6.466667	
282	.000000	.000000	6.466667	
283	.000000	.000000	6.466667	
284	1.000000	.000000	.000000	84
285	.000000	.000000	.000000	
286	.000000	.000000	.000000	86
287	.000000	.000000	.000000	87
288	.000000	.000000	6.466667	
289	.000000	.000000	6.466667	
290	.000000	.000000	12.833333	
291	.000000	.000000	6.466667	
292	.000000	.000000	6.466667	
293	.000000	.000000	-.000000	

294	.000000	.000000	.000000	
295	.000000	.000000	.000000	
296	.000000	.000000	19.700000	
297	.000000	.000000	6.466667	
298	.000000	.000000	6.466667	
299	.000000	.000000	6.466667	
300	.000000	.000000	6.466667	
301	.000000	.000000	6.466667	
302	.000000	.000000	-.000000	
303	.000000	.000000	.000000	
304	.000000	.000000	4.400000	
305	.000000	.000000	24.000000	
306	.000000	.000000	6.466667	
307	.000000	.000000	6.466667	
308	.000000	.000000	6.466667	
309	.000000	.000000	6.466667	
310	.000000	.000000	6.466667	
311	.000000	.000000	.000000	111
312	.000000	.000000	.000000	112
313	.000000	.000000	.000000	113
314	.000000	.000000	.000000	114
315	.000000	.000000	27.866667	
316	.000000	.000000	.000000	144
317	.000000	.000000	.000000	117
318	.000000	.000000	5.433333	
319	2.000000	.000000	.000000	119
320	.000000	.000000	.000000	120
321	.000000	.000000	.000000	121
322	.000000	.000000	21.033333	
323	.000000	.000000	.000000	123
324	.000000	.000000	32.200000	
325	1.000000	.000000	.000000	125
326	.000000	.000000	1.800000	
327	.000000	.000000	.000000	127
328	.000000	.000000	.500000	
329	.000000	.000000	.000000	129
330	.000000	.000000	.000000	130
331	.000000	.000000	.000000	131
332	.000000	.000000	.000000	132
333	.000000	.000000	.000000	133
334	.000000	.000000	1.666667	

335	2.000000	.000000	-.000000	128
336	.000000	.000000	3.633333	
337	.000000	.000000	.000000	137
338	.000000	.000000	.000000	138
339	.000000	.000000	.000000	139
340	.000000	.000000	.000000	140
341	.000000	.000000	.000000	141
342	.000000	.000000	.000000	142
343	.000000	.000000	.000000	143
344	.000000	.000000	.933333	
345	1.000000	.000000	.000000	63
346	.000000	.000000	2.933333	
347	.000000	.000000	8.733333	
348	.000000	.000000	37.633333	
349	.000000	.000000	.000000	149
350	.000000	.000000	.000000	150
351	.000000	.000000	.000000	151
352	.000000	.000000	3.600000	
353	.000000	.000000	4.100000	
354	.000000	.000000	.000000	
355	.000000	.000000	.000000	155
356	1.000000	.000000	.000000	156
357	1.000000	.000000	.000000	157
358	.333333	.000000	.000000	158
359	1.000000	.000000	.000000	159
360	1.000000	.000000	.000000	160
361	.000000	.000000	6.800000	
362	.666667	.000000	.000000	162
363	.000000	.000000	.000000	163
364	.000000	.000000	3.800000	
365	1.000000	.000000	.000000	165

```
MAX ERR ON ROW   COST=  -.60396E-13, SUM=  .67737E-13

MAX ERR ON COL     19=  -.28422E-13, SUM=  .14300E-12

ALTB
NEWX
SOLVE
''INSTALLED   165 SLACKS,     0 NON-SLACKS

 REINVERTING AFTER    81TH ITERATION.    0 TRANSFORMATIONS WITH     0 ENTRIES, TIME=       .0000 TYPE 0
*INVERSION COMPLETED  165 SLACKS,  190 POOR COLS,   10 TRANSFORMATIONS WITH   51 ENTRIES, TIME=       .0000

 REINVERTING AFTER   105TH ITERATION.   46 TRANSFORMATIONS WITH   806 ENTRIES, TIME=       .0000 TYPE 1
*INVERSION COMPLETED  140 SLACKS,    0 POOR COLS,   45 TRANSFORMATIONS WITH  279 ENTRIES, TIME=       .0000

MAX ERR ON ROW   COST=  -.28422E-13, SUM=  .36193E-13

*FEASIBLE ON ITERATION 106,    163 STEPS

 REINVERTING AFTER   129TH ITERATION.   80 TRANSFORMATIONS WITH  1172 ENTRIES, TIME=       .0000 TYPE 1
*INVERSION COMPLETED  133 SLACKS,    0 POOR COLS,   56 TRANSFORMATIONS WITH  388 ENTRIES, TIME=       .0000

MAX ERR ON ROW   COST=   .94882E-14, SUM=  .15275E-13

MAX ERR ON COL     90=   .11990E-13, SUM=  .10791E-12
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REINVERTING AFTER   153TH ITERATION.   99 TRANSFORMATIONS WITH  1593 ENTRIES, TIME=       .0000 TYPE 1
.INVERSION COMPLETED  109 SLACKS,    0 POOR COLS,   77 TRANSFORMATIONS WITH  499 ENTRIES, TIME=        .0000

MAX ERR ON ROW   COST=    .42633E-13, SUM=   .46528E-13

MAX ERR ON COL      9=   -.10658E-13, SUM=   .88596E-13
```

OPTIMAL SOLUTION

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(3) MATRIX R.H.S. ITER STEPS PIVS OBJECTIVE    COST     0 INFEAS  DETERMINANT MIN. R/COST  NEW COL  OLD COL  PIV
     )(Y< 000000   163   256  633           374.200000      .000  3.13811E 10 -.0000000   161      325
```

NAME	VALUE	ROW	RHS	PRICE	161
	-374.200000	COST	.000000	1.000000	-.466667
201	3.000000	1	3.000000	.000000	.000000
202	2.000000	2	3.000000	.000000	.000000
203	1.000000	3	3.000000	.000000	.000000
204	2.000000	4	3.000000	.000000	.000000
205	2.000000	5	3.000000	.000000	.000000
206	1.000000	6	3.000000	.000000	.000000
207	3.000000	7	3.000000	.000000	.000000
208	3.000000	8	3.000000	.000000	.000000
109	3.000000	9	3.000000	.133333	.000000
210	3.000000	10	3.000000	.000000	.000000
211	1.000000	11	1.000000	.000000	.000000
212	.333333	12	1.000000	.000000	.000000
213	1.000000	13	1.000000	.000000	.000000
214	1.000000	14	1.000000	.000000	.000000
215	1.000000	15	1.000000	.000000	.000000
216	1.000000	16	1.000000	.000000	.000000
217	1.000000	17	1.000000	.000000	.000000
218	1.000000	18	1.000000	.000000	.000000
219	1.000000	19	1.000000	.000000	.000000
220	1.000000	20	1.000000	.000000	.000000
221	1.000000	21	1.000000	.000000	.000000
222	1.000000	22	1.000000	.000000	.000000
223	1.000000	23	1.000000	.000000	.000000
224	1.000000	24	1.000000	.000000	.000000
225	1.000000	25	1.000000	.000000	.000000
226	1.000000	26	1.000000	.000000	.000000
227	1.000000	27	1.000000	.000000	.000000
228	1.000000	28	1.000000	.000000	.000000
229	1.000000	29	1.000000	.000000	.000000
230	1.000000	30	1.000000	.000000	.000000
231	1.000000	31	1.000000	.000000	.000000
232	1.000000	32	1.000000	.000000	.000000

233	1.000000	33	1.000000	.000000	.000000
234	1.000000	34	1.000000	.000000	.000000
235	1.000000	35	1.000000	.000000	.000000
236	1.000000	36	1.000000	.000000	.000000
237	1.000000	37	1.000000	.000000	.000000
238	1.000000	38	1.000000	.000000	.000000
239	1.000000	39	1.000000	.000000	.000000
240	1.000000	40	1.000000	.000000	.000000
241	1.000000	41	1.000000	.000000	.000000
242	1.000000	42	1.000000	.000000	.000000
243	1.000000	43	1.000000	.000000	.000000
244	1.000000	44	1.000000	.000000	.000000
245	1.000000	45	1.000000	.000000	.000000
161	1.000000	46	1.000000	2.200000	1.000000
247	1.000000	47	1.000000	.000000	.000000
248	.666667	48	1.000000	.000000	.333333
249	.000000	49	1.000000	.000000	.000000
250	.666667	50	1.000000	.000000	.000000
251	1.000000	51	1.000000	.000000	.000000
252	1.000000	52	1.000000	.000000	.000000
253	.333333	53	1.000000	.000000	.333333
254	1.000000	54	1.000000	.000000	.000000
255	1.000000	55	1.000000	.000000	.000000
256	1.000000	56	.000000	.000000	.000000
257	2.000000	57	.000000	.000000	.000000
258	1.000000	58	.000000	.000000	.000000
259	2.000000	59	.000000	.000000	.000000
260	2.000000	60	.000000	.000000	.000000
106	2.000000	61	.000000	6.200000	.000000
7	.000000	62	.000000	12.333333	.000000
8	.000000	63	.000000	6.366667	.000000
9	1.000000	64	.000000	6.066667	.000000
345	1.000000	65	.000000	12.200000	.000000
11	.000000	66	.000000	2.700000	.000000
267	.000000	67	.000000	.000000	.000000
268	.000000	68	.000000	.000000	.000000
269	.000000	69	.000000	.000000	.000000
115	.000000	70	.000000	6.200000	.000000
116	.000000	71	.000000	6.200000	.000000
17	.000000	72	.000000	17.033333	.000000
118	.000000	73	.000000	6.200000	.000000

164	1.000000	74	.000000	8.733333	.000000
275	.000000	75	.000000	.000000	.000000
276	.000000	76	.000000	.000000	.000000
277	.000000	77	.000000	.000000	.000000
278	.000000	78	.000000	.000000	.000000
124	.000000	79	.000000	6.200000	.000000
125	.000000	80	.000000	6.200000	.000000
126	.000000	81	.000000	6.200000	.000000
127	.000000	82	.000000	6.200000	.000000
128	.000000	83	.000000	6.200000	.000000
254	1.000000	84	.000000	.000000	.000000
130	.000000	85	.000000	.000000	.000000
286	.000000	86	.000000	.000000	.000000
287	.000000	87	.000000	.000000	.000000
133	.000000	88	.000000	6.200000	.000000
134	.000000	89	.000000	6.200000	.000000
35	.000000	90	.000000	12.566667	.000000
136	.000000	91	.000000	6.200000	.000000
137	.000000	92	.000000	6.200000	.000000
138	.000000	93	.000000	-.000000	.000000
139	.000000	94	.000000	.000000	.000000
140	.000000	95	.000000	.000000	.000000
41	.000000	96	.000000	19.700000	.000000
142	.000000	97	.000000	6.200000	.000000
143	.000000	98	.000000	6.200000	.000000
144	.000000	99	.000000	6.200000	.000000
145	.000000	100	.000000	6.200000	.000000
146	.000000	101	.000000	6.200000	.000000
147	.000000	102	.000000	-.000000	.000000
148	.000000	103	.000000	.000000	.000000
49	.000000	104	.000000	4.400000	.000000
50	.000000	105	.000000	24.000000	.000000
151	.000000	106	.000000	6.200000	.000000
152	.000000	107	.000000	6.200000	.000000
153	.000000	108	.000000	6.200000	.000000
154	.000000	109	.000000	6.200000	.000000
155	.000000	110	.000000	6.200000	.000000
311	.000000	111	.000000	.000000	.000000
312	.000000	112	.000000	.000000	.000000
313	.000000	113	.000000	.000000	.000000
314	.000000	114	.000000	.000000	.000000

60	.000000	115	.000000	25.600000	.000000
316	2.000000	116	.000000	.000000	.000000
317	.000000	117	.000000	-.000000	.000000
63	.000000	118	.000000	2.766667	.000000
319	2.000000	119	.000000	.000000	.000000
320	.000000	120	.000000	.000000	.000000
321	.000000	121	.000000	.000000	.000000
67	.000000	122	.000000	21.033333	.000000
323	.000000	123	.000000	.000000	.000000
69	.000000	124	.000000	32.200000	.000000
129	1.000000	125	.000000	.466667	.000000
326	1.000000	126	.000000	.000000	-1.000000
327	.000000	127	.000000	.000000	.000000
328	.000000	128	.000000	-.000000	.000000
329	.000000	129	.000000	.000000	.000000
330	.000000	130	.000000	.000000	.000000
331	.000000	131	.000000	.000000	.000000
332	.000000	132	.000000	.000000	.000000
333	.000000	133	.000000	.000000	.000000
79	.000000	134	.000000	1.400000	.000000
180	.000000	135	.000000	.000000	1.000000
336	.000000	136	.000000	.000000	.000000
182	.000000	137	.000000	.000000	.000000
338	.000000	138	.000000	.000000	.000000
339	.000000	139	.000000	.000000	.000000
340	.000000	140	.000000	.000000	.000000
341	.000000	141	.000000	.000000	.000000
342	.000000	142	.000000	.000000	.000000
343	.000000	143	.000000	.000000	.000000
189	.000000	144	.000000	.000000	.000000
190	1.000000	145	.000000	-.000000	1.000000
91	.000000	146	.000000	5.466667	.000000
92	.000000	147	.000000	8.733333	.000000
93	.000000	148	.000000	37.633333	.000000
349	.000000	149	.000000	.000000	.000000
350	.000000	150	.000000	.000000	.000000
351	.000000	151	.000000	.000000	.000000
352	.000000	152	.000000	.000000	.000000
98	.000000	153	.000000	5.633333	.000000
354	.000000	154	.000000	-.000000	.000000
355	.000000	155	.000000	.000000	.000000

356	1.000000	156	.000000	.000000	-.000000
357	1.000000	157	.000000	.000000	.000000
358	.333333	158	.000000	.000000	.000000
359	1.000000	159	.000000	.000000	.000000
360	1.000000	160	.000000	.000000	.000000
361	.000000	161	1.000000	.000000	.333333
362	.666667	162	.000000	.000000	.000000
363	1.000000	163	.000000	.000000	-.333333
88	.333333	164	.000000	4.600000	-.333333
365	1.000000	165	.000000	.000000	.000000
10	.000000	166	1.000000	.000000	-.000000
102	1.000000	167	1.000000	.000000	.000000
103	2.000000	168	1.000000	.000000	.000000
104	1.000000	169	1.000000	.000000	.000000
105	1.000000	170	1.000000	.000000	.000000
188	1.000000	171	1.000000	-6.200000	-1.000000
6	.666667	172	1.000000	-6.200000	.000000
80	.000000	173	1.000000	-6.200000	.333333
54	.000000	174	1.000000	-6.200000	.000000
19	.000000	175	1.000000	-6.200000	.000000
1	.333333	176	1.000000	-28.100000	.000000
2	1.000000	177	1.000000	-23.400000	.000000
3	1.000000	178	1.000000	-12.000000	.000000
4	1.000000	179	1.000000	6.300000	.000000
5	1.000000	180	1.000000	-6.600000	.000000
70	.000000	181	1.000000	-18.100000	.333333
61	1.000000	182	1.000000	-19.500000	-.333333
71	.333333	183	1.000000	-19.500000	-.333333
90	.666667	184	1.000000	-.600000	.333333
64	1.000000	185	1.000000	-28.100000	.000000
29	.666667	186	6.000000	-32.700000	.000000

NAME	VALUE	TRUE /COST/	REDUCED	ROW
1	.333333	60.800000	.000000	176
2	1.000000	56.100000	.000000	177
3	1.000000	44.700000	.000000	178
4	1.000000	26.400000	.000000	179
5	1.000000	39.300000	.000000	180
6	.666667	69.400000	-.000000	172

7	.000000	89.200000	-.000000	62
8	.000000	71.300000	-.000000	63
9	1.000000	56.100000	-.000000	64
10	.000000	97.400000	-.000000	166
11	.000000	31.500000	.000000	66
12	.000000	28.100000	16.100000	
13	.000000	87.200000	93.500000	
14	.000000	52.300000	45.700000	
15	.000000	70.000000	33.300000	
16	.000000	84.900000	46.800000	
17	.000000	70.600000	-.000000	72
18	.000000	55.700000	31.900000	
19	.000000	54.300000	-.000000	175
20	.000000	31.500000	3.400000	
21	.000000	51.000000	39.000000	
22	.000000	82.500000	88.800000	
23	.000000	61.700000	55.100000	
24	.000000	108.300000	71.600000	
25	.000000	123.200000	85.100000	
26	.000000	110.200000	72.100000	
27	.000000	95.000000	71.200000	
28	.000000	136.300000	89.600000	
29	.666667	28.100000	.000000	186
30	.000000	51.000000	27.600000	
31	.000000	71.100000	77.400000	
32	.000000	25.200000	18.600000	
33	.000000	59.400000	22.700000	
34	.000000	75.100000	37.000000	
35	.000000	57.200000	-.000000	90
36	.000000	42.000000	18.200000	
37	.000000	83.300000	36.600000	
38	.000000	87.200000	59.100000	
39	.000000	82.500000	59.100000	
40	.000000	71.100000	59.100000	
41	.000000	65.700000	.000000	96
42	.000000	95.800000	59.100000	
43	.000000	115.600000	77.500000	
44	.000000	97.700000	59.600000	
45	.000000	82.500000	58.700000	
46	.000000	123.800000	77.100000	
47	.000000	52.300000	24.200000	

48	.000000	61.700000	38.300000	
49	.000000	25.200000	.000000	104
50	.000000	65.700000	.000000	105
51	.000000	83.400000	46.700000	
52	.000000	103.200000	65.100000	
53	.000000	85.300000	47.200000	
54	.000000	23.800000	.000000	174
55	.000000	111.400000	64.700000	
56	.000000	70.000000	41.900000	
57	.000000	108.000000	84.600000	
58	.000000	59.400000	47.400000	
59	.000000	95.800000	102.100000	
60	.000000	83.400000	.000000	115
61	1.000000	17.300000	.000000	182
62	.000000	22.300000	2.800000	
63	.000000	13.500000	-.000000	118
64	1.000000	28.100000	.000000	185
65	.000000	84.900000	56.800000	
66	.000000	123.200000	99.800000	
67	.000000	75.100000	.000000	122
68	.000000	115.600000	121.900000	
69	.000000	103.200000	.000000	124
70	.000000	17.300000	.000000	181
71	.333333	19.500000	.000000	183
72	.000000	23.100000	17.900000	
73	.000000	36.400000	8.300000	
74	.000000	70.600000	42.500000	
75	.000000	110.200000	86.800000	
76	.000000	57.200000	45.200000	
77	.000000	97.700000	104.000000	
78	.000000	85.300000	78.700000	
79	.000000	22.300000	.000000	134
80	.000000	19.500000	-.000000	173
81	.000000	14.900000	9.700000	
82	.000000	50.600000	22.500000	
83	.000000	55.700000	32.200000	
84	.000000	95.000000	76.200000	
85	.000000	42.000000	34.600000	
86	.000000	82.500000	93.400000	
87	.000000	23.800000	21.800000	
88	.333333	13.500000	.000000	164

89	.000000	23.100000	8.200000	
90	.666667	14.900000	.000000	184
91	.000000	39.900000	.000000	146
92	.000000	54.300000	.000000	147
93	.000000	135.300000	-.000000	148
94	.000000	83.300000	71.300000	
95	.000000	123.800000	130.100000	
96	.000000	111.400000	104.800000	
97	.000000	28.100000	10.000000	
98	.000000	36.400000	.000000	153
99	.000000	50.600000	31.100000	
100	.000000	39.900000	34.700000	
101	.000000	.000000	.000000	
102	1.000000	.000000	.000000	167
103	2.000000	.000000	.000000	168
104	1.000000	.000000	.000000	169
105	1.000000	.000000	.000000	170
106	2.000000	.000000	.000000	61
107	.000000	.000000	6.133333	
108	.000000	.000000	.166667	
109	3.000000	.000000	.000000	9
110	.000000	.000000	6.000000	
111	.000000	.000000	2.700000	
112	.000000	.000000	-.000000	
113	.000000	.000000	-.000000	
114	.000000	.000000	.000000	
115	.000000	.000000	.000000	70
116	.000000	.000000	.000000	71
117	.000000	.000000	10.833333	
118	.000000	.000000	.000000	73
119	.000000	.000000	2.533333	
120	.000000	.000000	.000000	
121	.000000	.000000	.000000	
122	.000000	.000000	.000000	
123	.000000	.000000	.000000	
124	.000000	.000000	.000000	79
125	.000000	.000000	.000000	80
126	.000000	.000000	.000000	81
127	.000000	.000000	.000000	82
128	.000000	.000000	.000000	83
129	1.000000	.000000	.000000	125

130	.000000	.000000	.000000	85
131	.000000	.000000	.000000	
132	.000000	.000000	.000000	
133	.000000	.000000	.000000	88
134	.000000	.000000	.000000	89
135	.000000	.000000	6.366667	
136	.000000	.000000	.000000	91
137	.000000	.000000	.000000	92
138	.000000	.000000	-.000000	93
139	.000000	.000000	.000000	94
140	.000000	.000000	.000000	95
141	.000000	.000000	19.700000	
142	.000000	.000000	.000000	97
143	.000000	.000000	.000000	98
144	.000000	.000000	.000000	99
145	.000000	.000000	.000000	100
146	.000000	.000000	.000000	101
147	.000000	.000000	-.000000	102
148	.000000	.000000	.000000	103
149	.000000	.000000	4.400000	
150	.000000	.000000	24.000000	
151	.000000	.000000	.000000	106
152	.000000	.000000	.000000	107
153	.000000	.000000	.000000	108
154	.000000	.000000	.000000	109
155	.000000	.000000	.000000	110
156	.000000	.000000	6.200000	
157	.000000	.000000	6.200000	
158	.000000	.000000	6.200000	
159	.000000	.000000	6.200000	
160	.000000	.000000	31.800000	
161	1.000000	.000000	.000000	46
162	.000000	.000000	.000000	
163	.000000	.000000	2.766667	
164	1.000000	.000000	.000000	74
165	.000000	.000000	6.200000	
166	.000000	.000000	6.200000	
167	.000000	.000000	27.233333	
168	.000000	.000000	6.200000	
169	.000000	.000000	38.400000	
170	.000000	.000000	.466667	

171	.000000	.000000	.000000	
172	.000000	.000000	.000000	
173	.000000	.000000	-.000000	
174	.000000	.000000	6.200000	
175	.000000	.000000	6.200000	
176	.000000	.000000	6.200000	
177	.000000	.000000	6.200000	
178	.000000	.000000	6.200000	
179	.000000	.000000	1.400000	
180	.000000	.000000	.000000	135
181	.000000	.000000	-.000000	
182	.000000	.000000	-.000000	137
183	.000000	.000000	6.200000	
184	.000000	.000000	6.200000	
185	.000000	.000000	6.200000	
186	.000000	.000000	6.200000	
187	.000000	.000000	6.200000	
188	1.000000	.000000	-.000000	171
189	.000000	.000000	.000000	144
190	1.000000	.000000	.000000	145
191	.000000	.000000	5.466667	
192	.000000	.000000	14.933333	
193	.000000	.000000	43.833333	
194	.000000	.000000	6.200000	
195	.000000	.000000	6.200000	
196	.000000	.000000	6.200000	
197	.000000	.000000	.000000	
198	.000000	.000000	5.633333	
199	.000000	.000000	.000000	
200	.000000	.000000	.000000	
201	3.000000	.000000	.000000	1
202	2.000000	.000000	.000000	2
203	1.000000	.000000	.000000	3
204	2.000000	.000000	.000000	4
205	2.000000	.000000	.000000	5
206	1.000000	.000000	.000000	6
207	3.000000	.000000	.000000	7
208	3.000000	.000000	.000000	8
209	.000000	.000000	.133333	
210	3.000000	.000000	.000000	10
211	1.000000	.000000	.000000	11

212	.333333	.000000	.000000	12
213	1.000000	.000000	.000000	13
214	1.000000	.000000	.000000	14
215	1.000000	.000000	.000000	15
216	1.000000	.000000	.000000	16
217	1.000000	.000000	.000000	17
218	1.000000	.000000	.000000	18
219	1.000000	.000000	.000000	19
220	1.000000	.000000	.000000	20
221	1.000000	.000000	.000000	21
222	1.000000	.000000	.000000	22
223	1.000000	.000000	.000000	23
224	1.000000	.000000	.000000	24
225	1.000000	.000000	.000000	25
226	1.000000	.000000	.000000	26
227	1.000000	.000000	.000000	27
228	1.000000	.000000	.000000	28
229	1.000000	.000000	.000000	29
230	1.000000	.000000	.000000	30
231	1.000000	.000000	.000000	31
232	1.000000	.000000	.000000	32
233	1.000000	.000000	.000000	33
234	1.000000	.000000	.000000	34
235	1.000000	.000000	.000000	35
236	1.000000	.000000	.000000	36
237	1.000000	.000000	.000000	37
238	1.000000	.000000	.000000	38
239	1.000000	.000000	.000000	39
240	1.000000	.000000	.000000	40
241	1.000000	.000000	.000000	41
242	1.000000	.000000	.000000	42
243	1.000000	.000000	.000000	43
244	1.000000	.000000	.000000	44
245	1.000000	.000000	.000000	45
246	.000000	.000000	2.200000	
247	1.000000	.000000	.000000	47
248	.666667	.000000	.000000	48
249	.000000	.000000	.000000	49
250	.666667	.000000	.000000	50
251	1.000000	.000000	.000000	51
252	1.000000	.000000	.000000	52

253	.333333	.000000	.000000	53
254	1.000000	.000000	.000000	54
255	1.000000	.000000	.000000	55
256	1.000000	.000000	.000000	56
257	2.000000	.000000	.000000	57
258	1.000000	.000000	.000000	58
259	2.000000	.000000	.000000	59
260	2.000000	.000000	.000000	60
261	.000000	.000000	6.200000	
262	.000000	.000000	12.333333	
263	.000000	.000000	6.366667	
264	.000000	.000000	6.066667	
265	.000000	.000000	12.200000	
266	.000000	.000000	2.700000	
267	.000000	.000000	-.000000	67
268	.000000	.000000	-.000000	68
269	.000000	.000000	.000000	69
270	.000000	.000000	6.200000	
271	.000000	.000000	6.200000	
272	.000000	.000000	17.033333	
273	.000000	.000000	6.200000	
274	.000000	.000000	8.733333	
275	.000000	.000000	.000000	75
276	.000000	.000000	.000000	76
277	.000000	.000000	.000000	77
278	.000000	.000000	.000000	78
279	.000000	.000000	6.200000	
280	.000000	.000000	6.200000	
281	.000000	.000000	6.200000	
282	.000000	.000000	6.200000	
283	.000000	.000000	6.200000	
284	1.000000	.000000	.000000	84
285	.000000	.000000	.000000	
286	.000000	.000000	.000000	86
287	.000000	.000000	.000000	87
288	.000000	.000000	6.200000	
289	.000000	.000000	6.200000	
290	.000000	.000000	12.566667	
291	.000000	.000000	6.200000	
292	.000000	.000000	6.200000	
293	.000000	.000000	-.000000	

294	.000000	.000000	.000000	
295	.000000	.000000	.000000	
296	.000000	.000000	19.700000	
297	.000000	.000000	6.200000	
298	.000000	.000000	6.200000	
299	.000000	.000000	6.200000	
300	.000000	.000000	6.200000	
301	.000000	.000000	6.200000	
302	.000000	.000000	-.000000	
303	.000000	.000000	.000000	
304	.000000	.000000	4.400000	
305	.000000	.000000	24.000000	
306	.000000	.000000	6.200000	
307	.000000	.000000	6.200000	
308	.000000	.000000	6.200000	
309	.000000	.000000	6.200000	
310	.000000	.000000	6.200000	
311	.000000	.000000	.000000	111
312	.000000	.000000	.000000	112
313	.000000	.000000	.000000	113
314	.000000	.000000	.000000	114
315	.000000	.000000	25.600000	
316	2.000000	.000000	.000000	116
317	.000000	.000000	-.000000	117
318	.000000	.000000	2.766667	
319	2.000000	.000000	.000000	119
320	.000000	.000000	.000000	120
321	.000000	.000000	.000000	121
322	.000000	.000000	21.033333	
323	.000000	.000000	.000000	123
324	.000000	.000000	32.200000	
325	.000000	.000000	.466667	
326	1.000000	.000000	.000000	126
327	.000000	.000000	.000000	127
328	.000000	.000000	-.000000	128
329	.000000	.000000	.000000	129
330	.000000	.000000	.000000	130
331	.000000	.000000	.000000	131
332	.000000	.000000	.000000	132
333	.000000	.000000	.000000	133
334	.000000	.000000	1.400000	

335	.000000	.000000	.000000	
336	.000000	.000000	.000000	136
337	.000000	.000000	.000000	
338	.000000	.000000	.000000	138
339	.000000	.000000	.000000	139
340	.000000	.000000	.000000	140
341	.000000	.000000	.000000	141
342	.000000	.000000	.000000	142
343	.000000	.000000	.000000	143
344	.000000	.000000	.000000	
345	1.000000	.000000	-.000000	65
346	.000000	.000000	5.466667	
347	.000000	.000000	8.733333	
348	.000000	.000000	37.633333	
349	.000000	.000000	.000000	149
350	.000000	.000000	.000000	150
351	.000000	.000000	.000000	151
352	.000000	.000000	.000000	152
353	.000000	.000000	5.633333	
354	.000000	.000000	-.000000	154
355	.000000	.000000	.000000	155
356	1.000000	.000000	.000000	156
357	1.000000	.000000	.000000	157
358	.333333	.000000	.000000	158
359	1.000000	.000000	.000000	159
360	1.000000	.000000	.000000	160
361	.000000	.000000	.000000	161
362	.666667	.000000	.000000	162
363	1.000000	.000000	.000000	163
364	.000000	.000000	4.600000	
365	1.000000	.000000	.000000	165

APPENDIX VI

GRAPHIC SUMMARY OF COMPUTER OUTPUTS

TABLE VI-1

SYNOPSIS OF APPENDIX VI ILLUSTRATIONS

Figure Number	Number of Vehicles from Malmstrom	Vehicle Prepositioned Site
	Computer Runs for Eastern Sites	
VI-1	4	C
VI-2	4	M
VI-3	5	
VI-4	6	
VI-5	6	M
	Computer Runs for Western Sites	
VI-6	4	
VI-7	4	P
VI-8	5	
VI-9	6	
VI-10	6	P

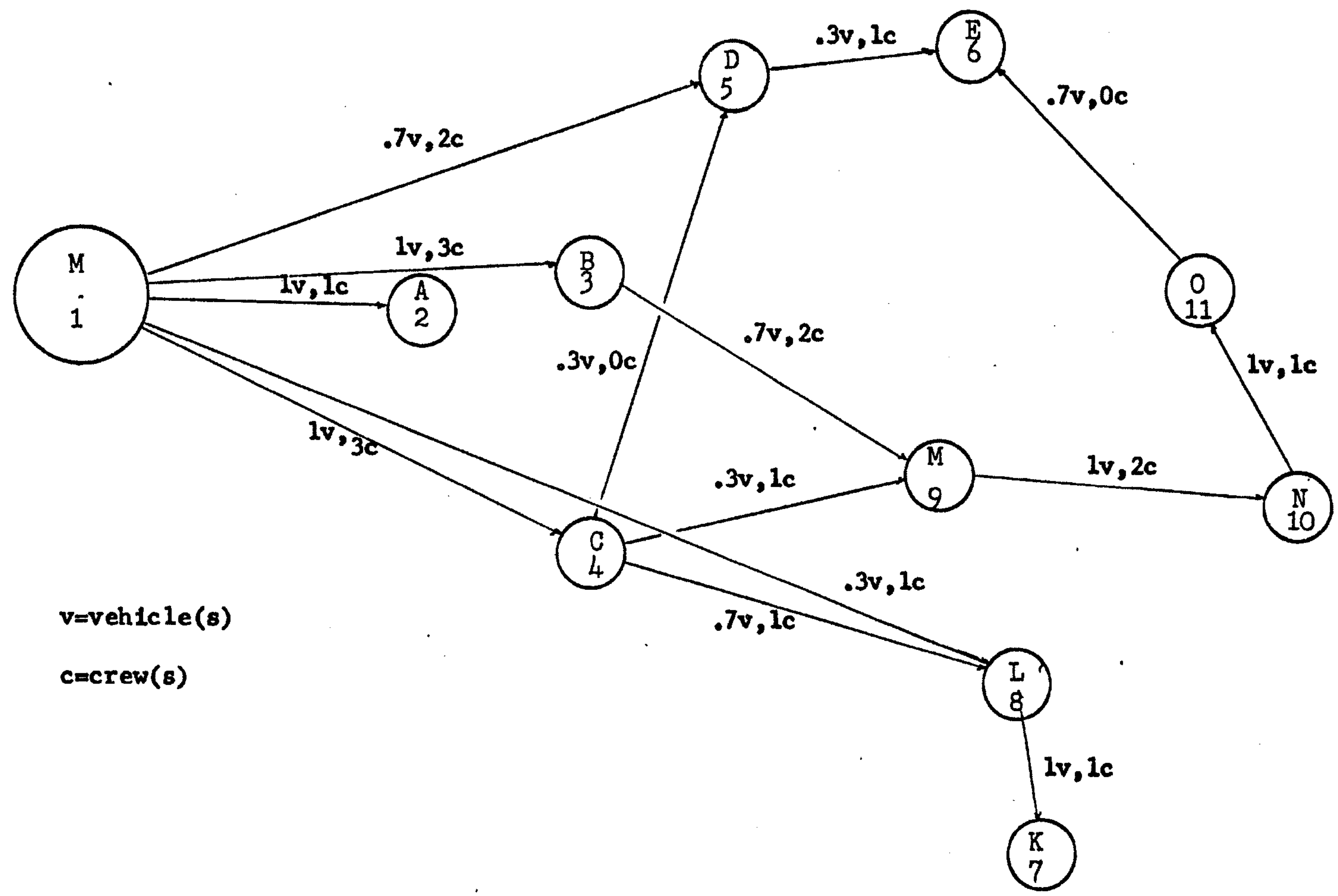


Fig. VI-1.--First Computer Run for Eastern Sites

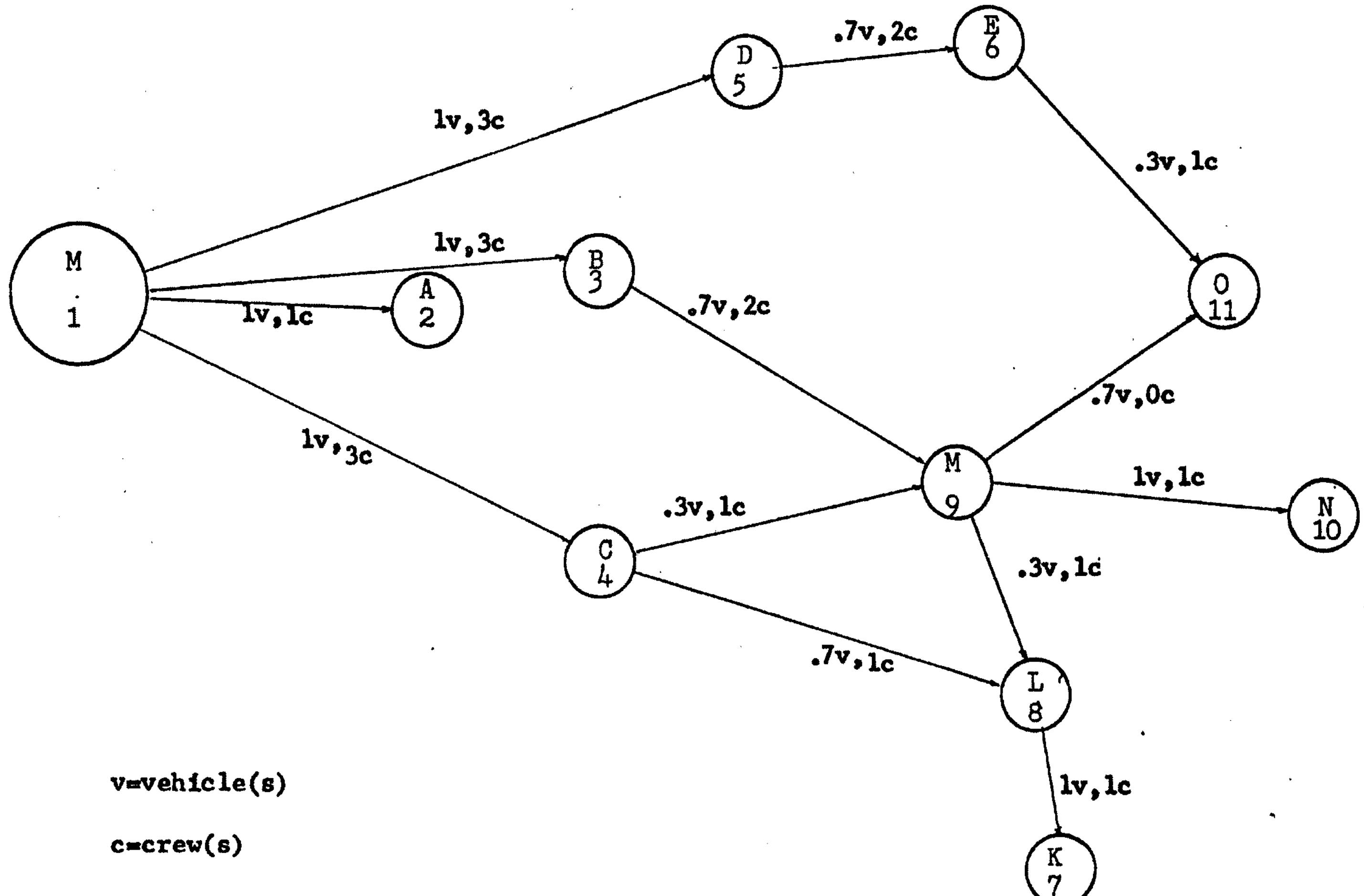


Fig. VI-2.--Second Computer Run for Eastern Sites

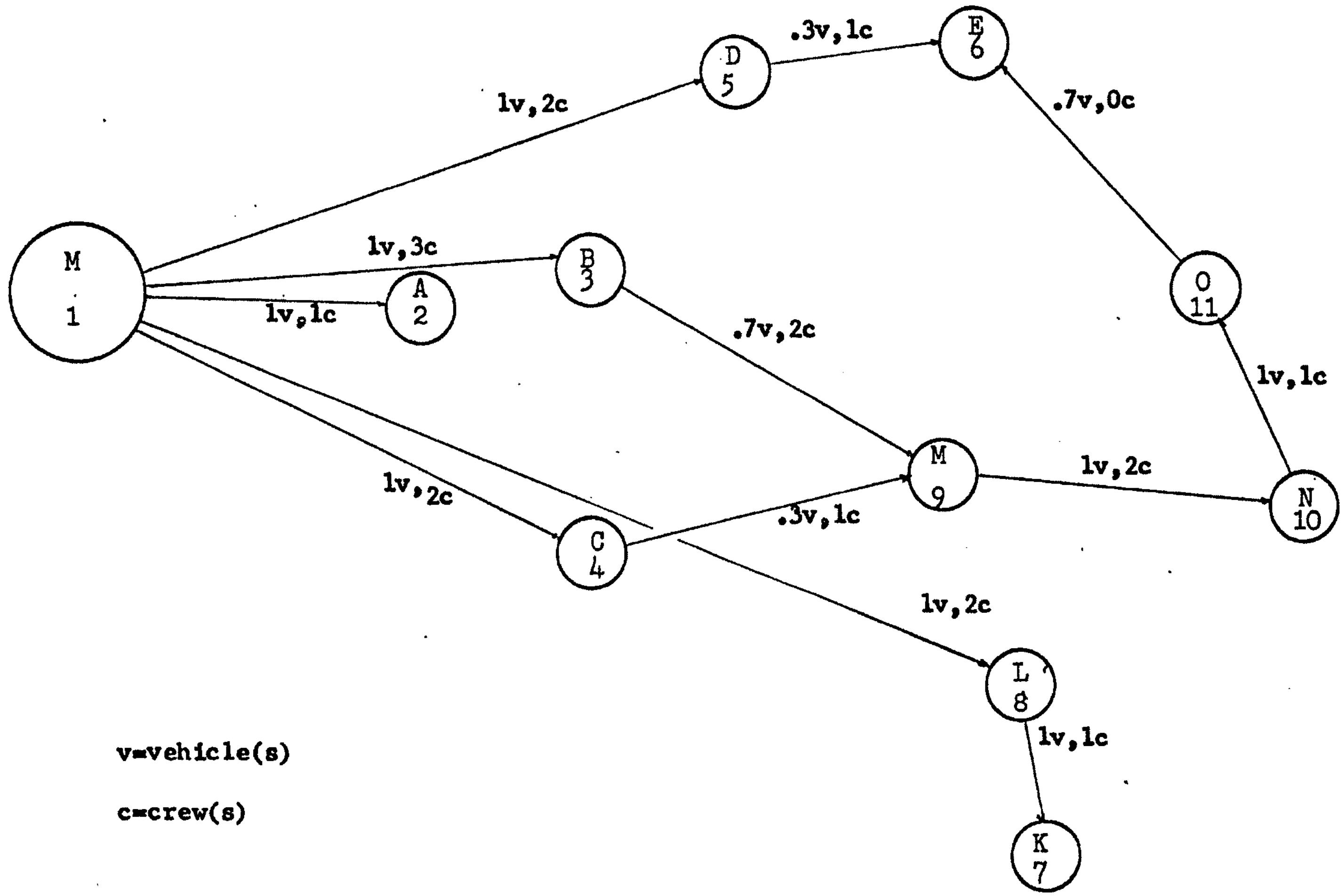


Fig. VI-3--Third Computer Run for Eastern Sites

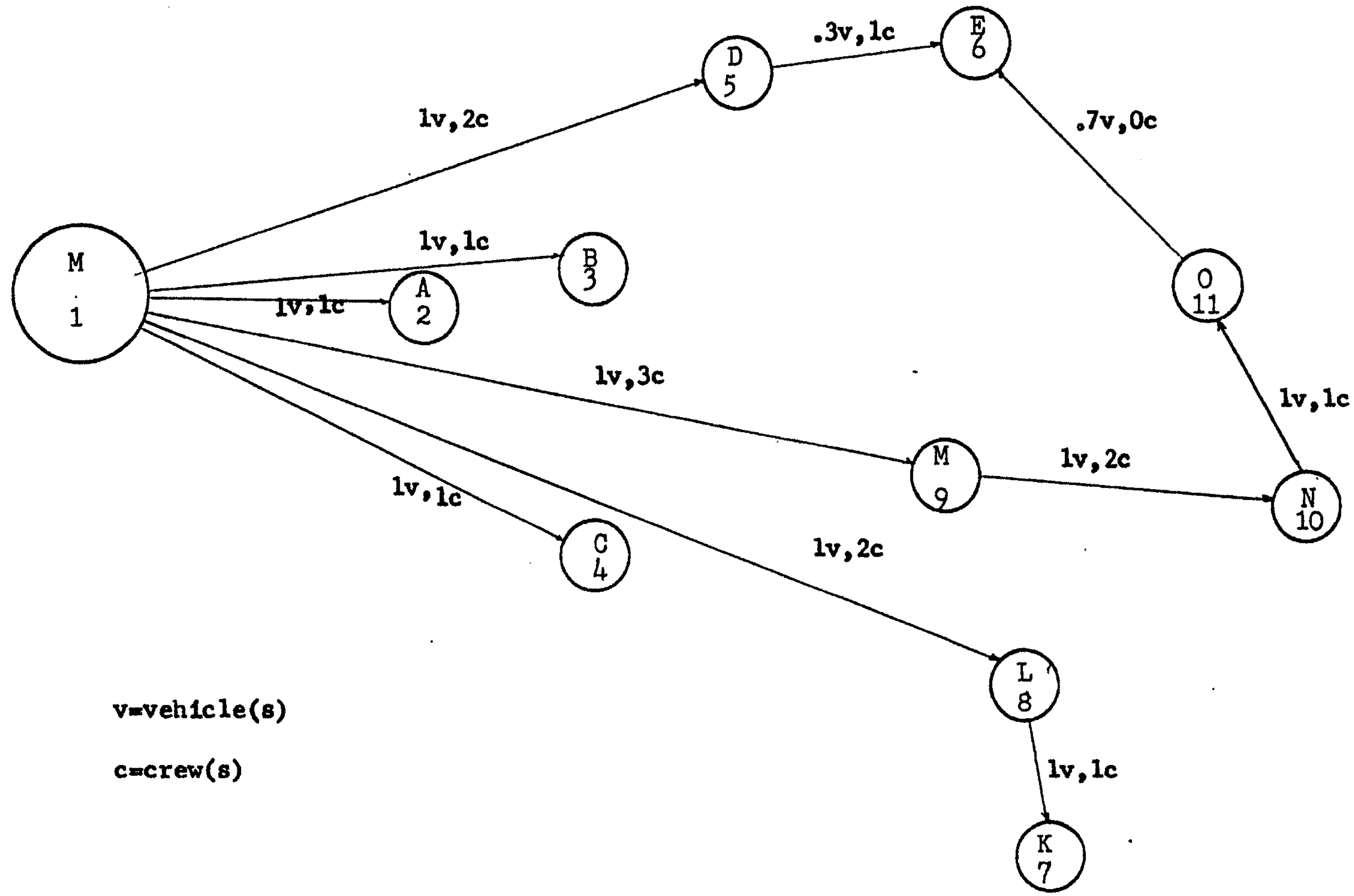
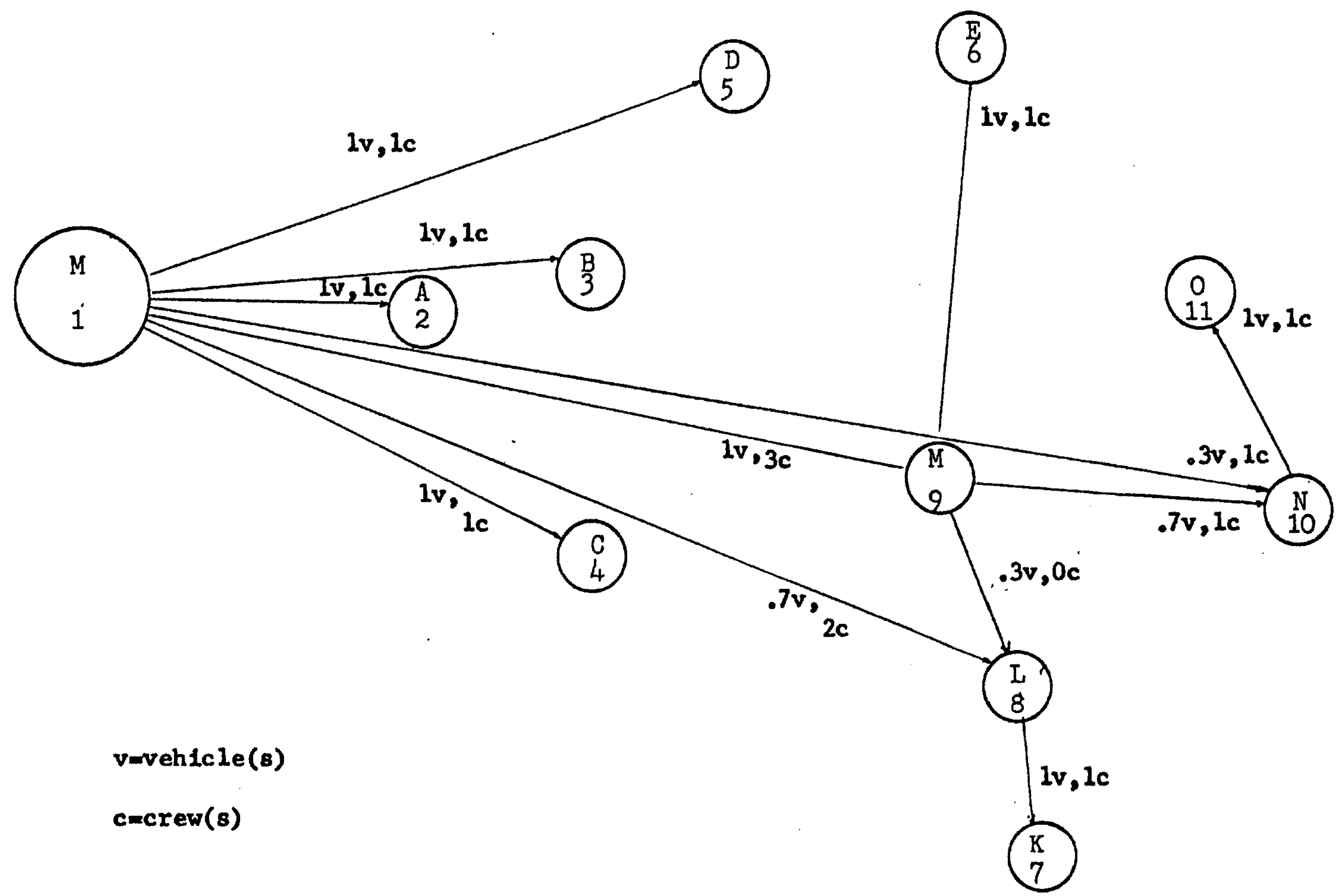


Fig. VI-4.--Forth Computer Run for Eastern Sites



v=vehicle(s)

c=crew(s)

Fig. VI-5.--Fifth Computer Run for Eastern Sites

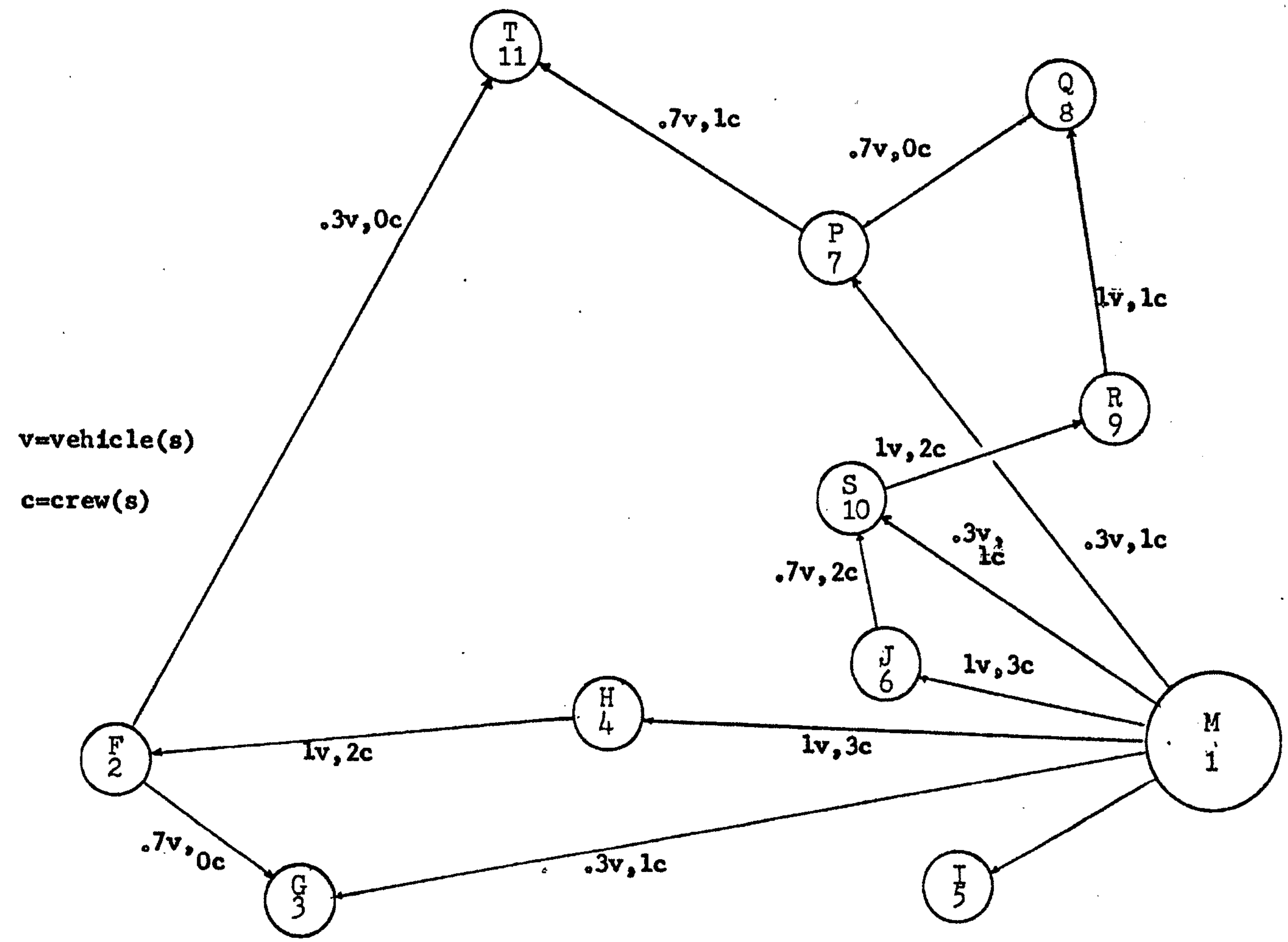
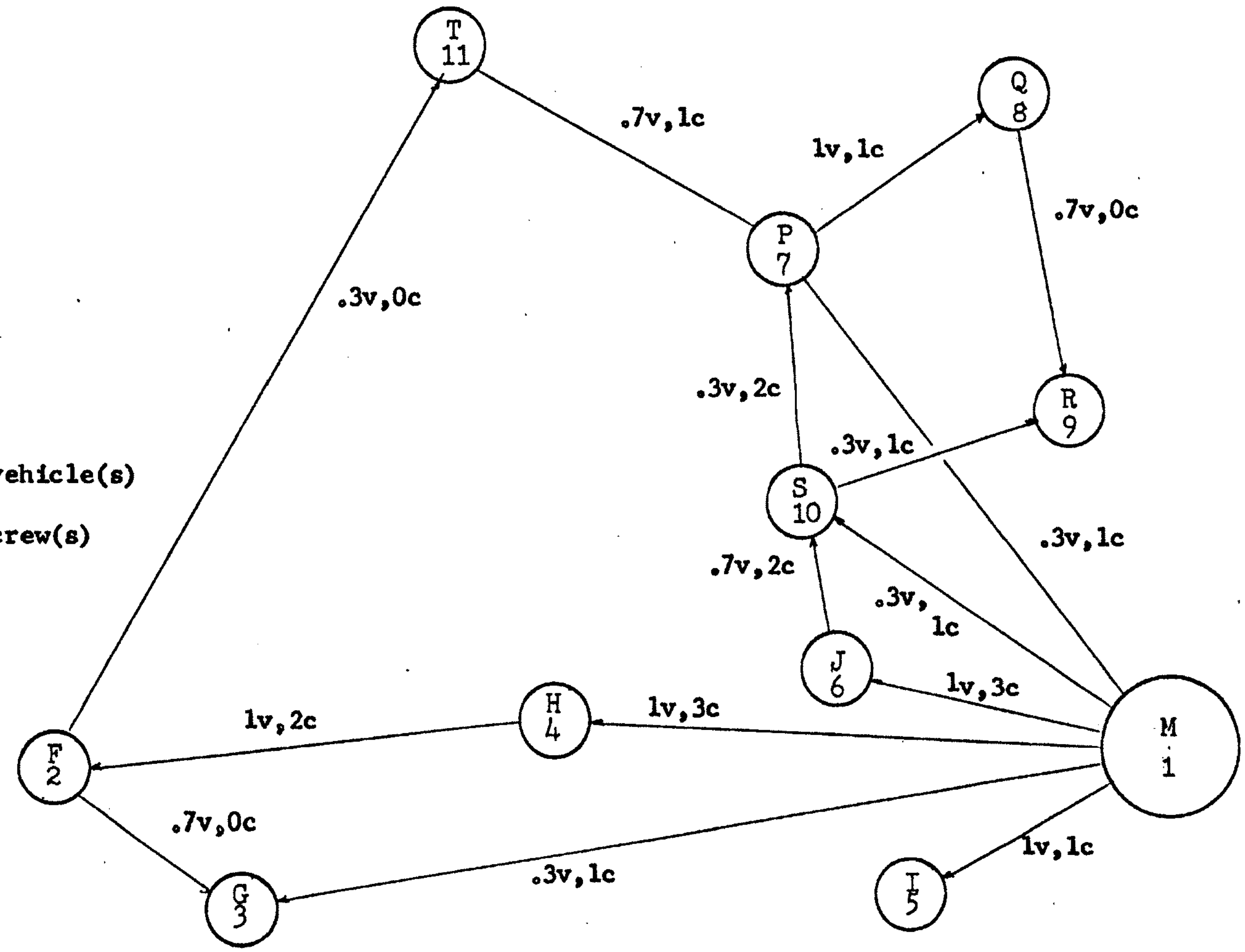


Fig. VI-6.--First Computer Run for Western Sites



v=vehicle(s)

c=crew(s)

Fig. VI-7.--Second Computer Run for Western Sites

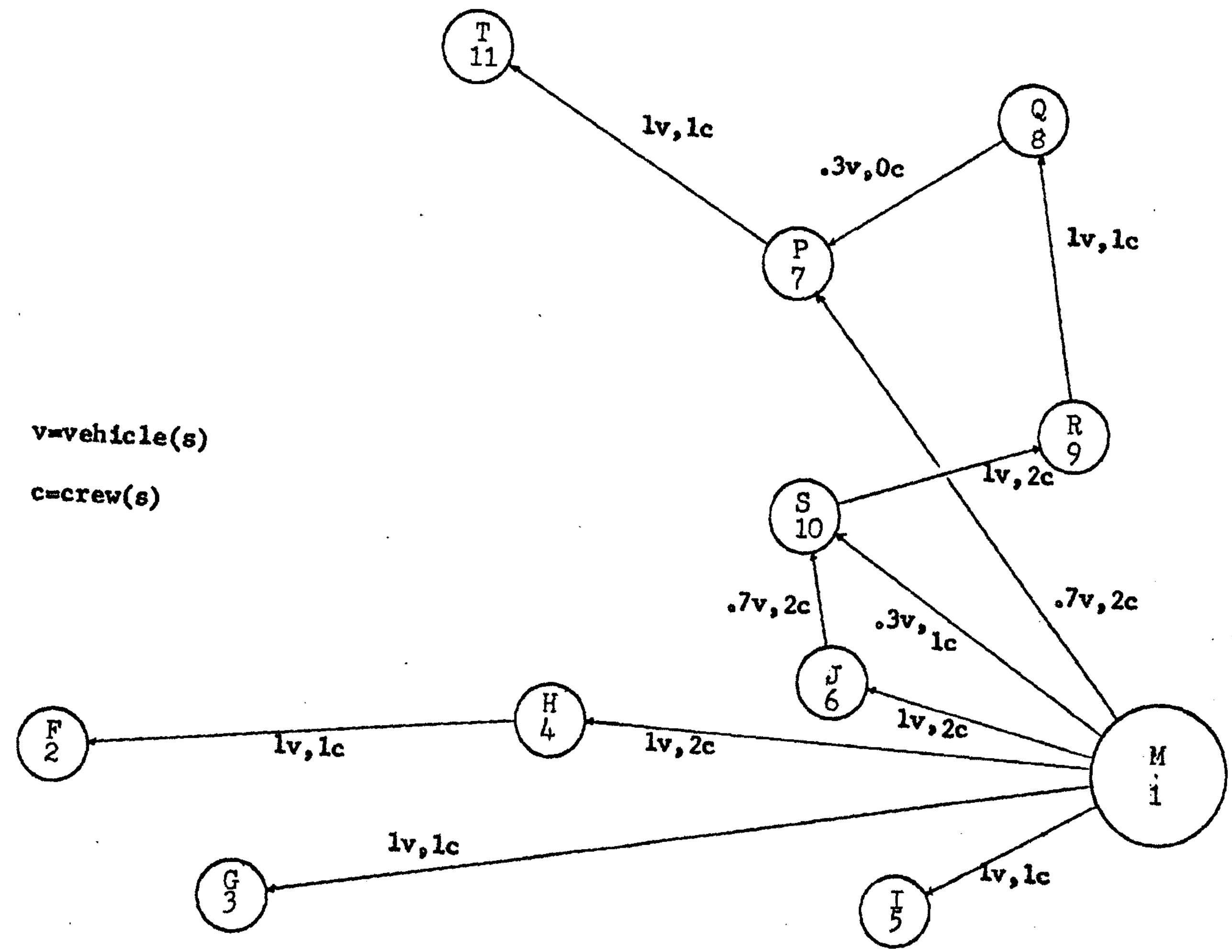


Fig. VI-8.—Third Computer Run for Western Sites

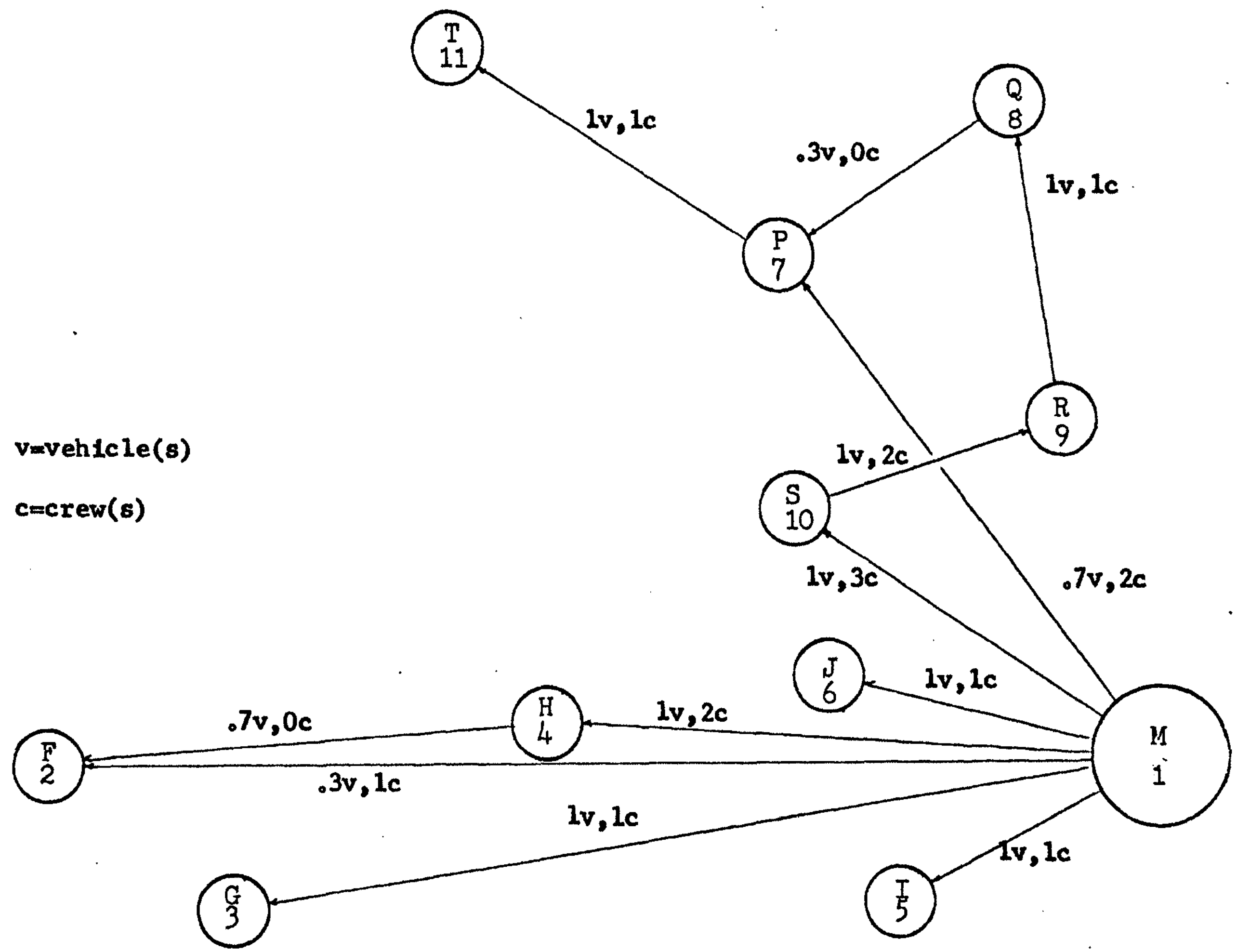


Fig. VI-9.--Fourth Computer Run for Western Sites

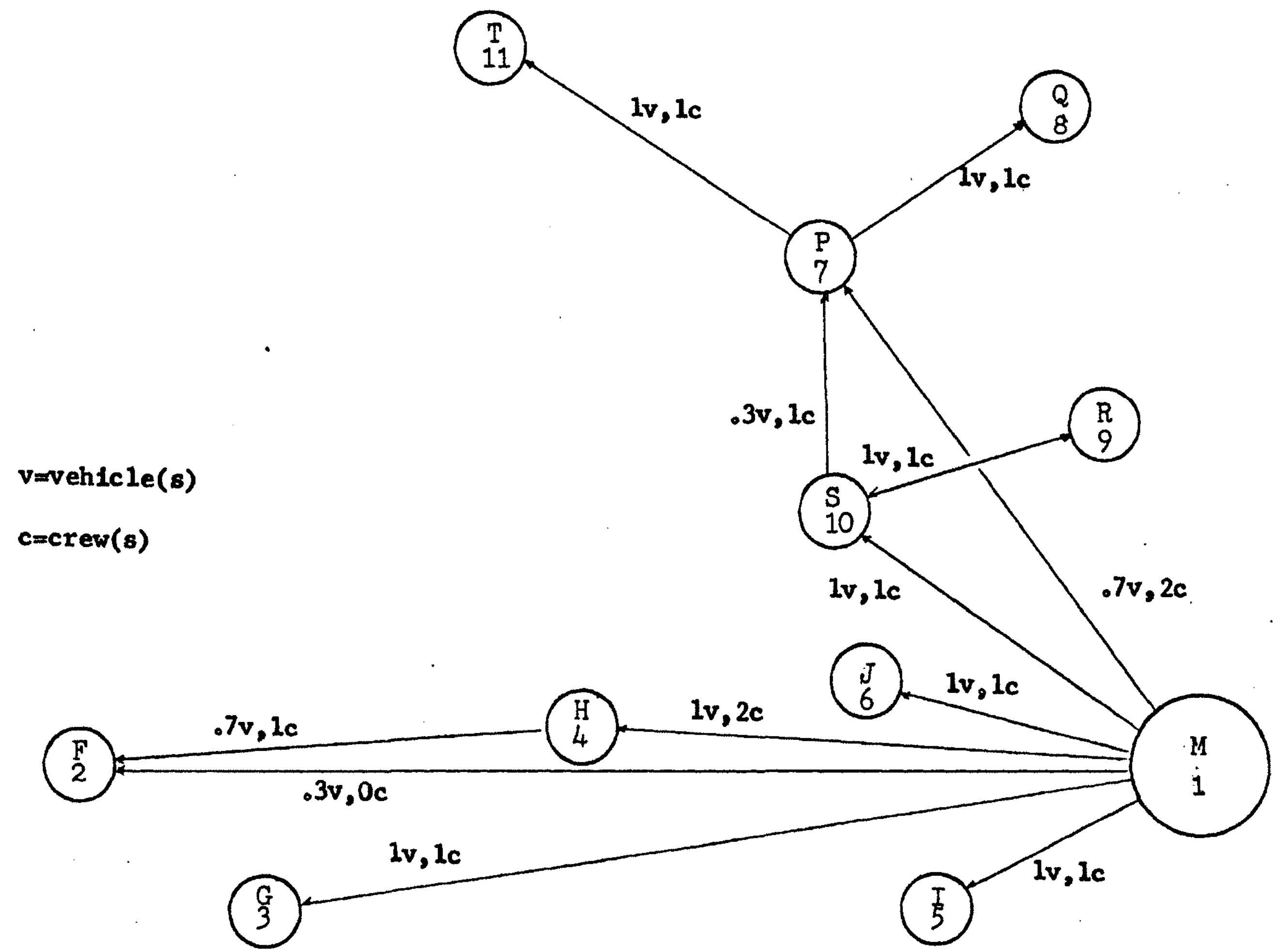


Fig. VI-10.--Fifth Computer Run for Western Sites

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