EXAMINATION OF HIGHWAY MAINTENANCE GARAGES IN THE U.S. 30 CORRIDOR BETWEEN AMES AND CEDAR RAPIDS

FINAL REPORT

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Abstract

A linear programming model is used to optimally assign highway segments to highway maintenance garages using existing facilities. The model is also used to determine possible operational savings or losses associated with four alternatives for expanding, closing and/or relocating some of the garages in a study area. The study area contains 16 highway maintenance garages and 139 highway segments.

The study recommends alternative No. 3 (close Tama and Blairstown garages and relocate new garage at Jct. U.S. 30 and Iowa 21) at an annual operational savings of approximately $16,250. These operational savings, however, are only the guidelines for decisionmakers and are subject to the required assumptions of the model used and limitations of the study.

Key Words

Optimum allocation, maintenance garages, cost multiplier, basic maintenance cost, travel time adjusted cost, overhead costs.

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EXECUTIVE SUMMARY

An optimum allocation model is used in this study to examine the current allocation of highway segments to maintenance garages in the U.S. 30 corridor between Ames and Cedar Rapids. Using the model, only 19 of the 139 highway segments would be reallocated to different garages, resulting in an annual operational savings of approximately $16,800.

The linear programming model is also used to determine operational savings/losses for each of the following four options:

Option 1: Close Marshalltown, Colo, and Blairstown garages, build New garage at Tama, and expand Ames, Cedar Rapids, Colfax, and Grundy Center garages;

Option 2: Close Tama and Blairstown garages and expand Traer and Cedar Rapids garages;

Option 3: Close Tama and Blairstown garages and relocate new garage at Jct. U.S. 30 and Iowa 21; and

Option 4: Close Blairstown garage, build new garage at Tama, and expand Cedar Rapids garage.

The model indicates the approximate operational savings or losses for each option examined:

Option	Estimated Annual Savings/(Losses) ($)
1.	(19,700)
2.	8,500
3.	16,250
4.	(49,100)

The study concludes that Option 3 seems to be the best among the options examined. However, these operational savings are only the guidelines for decision-makers and not the final solution. The savings are based on the assumptions of the model and limitations of the study.

I. INTRODUCTION

The Iowa Department of Transportation (Iowa DOT) is responsible, among other transportation activities, for maintaining Iowa's interstate and primary highways in a safe and serviceable condition. However, the lack of financial resources has long affected the Department's ability to properly accomplish its highway maintenance work programs. In fiscal 1986 the Iowa DOT spent more than $69.6 million maintaining the state's highway system.

In view of the limited financial resources, the Department has constantly been searching for ways to provide better and more coordinated transportation facilities at a minimum cost to the public. One of the ways to achieve this goal in the maintenance area is to examine the locations of highway maintenance garages to determine if some of these could be closed or relocated, thereby using available resources more efficiently and effectively. A highway maintenance garage must be optimally located within its maintenance area to minimize the loss in productivity associated with time spent traveling to the work locations.

In 1981 the Iowa DOT completed a study, "An Optimum Allocation Approach to Closing or Relocating Highway Maintenance Garages in Iowa" (1). The study identified an "Optimum Allocation Model" which was used by the Alabama Department of Transportation. This linear programming model, using the input data currently available at the Iowa DOT, can optimally assign highway segments to maintenance garages. It can, with some limitations, also determine the operational savings/losses of closing and/or relocating specified garages within a study area. This model will be used to examine several garage locations in the U.S. 30 corridor between Ames and Cedar Rapids.

II. OBJECTIVE

The purpose of this study is to use the "Optimum Allocation Model" (developed in state study No. 81-3) to examine the possibility of closing and/or relocating several highway maintenance garage locations in the U.S. 30 corridor between Ames and Cedar Rapids. The linear programming model is used to:

1. Optimally assign highway segments to maintenance garages in the study area; and

2. Determine operational savings/losses of closing and/or relocating highway maintenance garages for each of the following four options:

    Option 1: Close Marshalltown, Colo, and Blairstown garages, build new garage at Tama, and expand Ames, Cedar Rapids, Colfax, and Grundy Center garages;

    Option 2: Close Tama and Blairstown garages and expand Traer and Cedar Rapids garages;

    Option 3: Close Tama and Blairstown garages and relocate new garage at Jct. U.S. 30 and Iowa 21; and

    Option 4: Close Blairstown garage, build new garage at Tama, and expand Cedar Rapids garage.

The Office of Maintenance provided these options for examination.

III. REQUIREMENTS OF THE MODEL

The following describes the assumptions, key input data, computer program, etc., which are needed to apply the optimum allocation model to a given study area.

A. Assumptions

1. With the concurrence of the Office of Maintenance, highway maintenance vehicles are assumed to travel at average speeds of 35 mph for snow and ice control activities and 40 mph for other maintenance activities. These average speeds are used to determine a weighted average speed which is then used to estimate travel times from garages to highway segments.
2. The travel times from garage "X" to segment "Y" and from segment "Y" to garage "X" are assumed to be the same.
3. Any highway segment formed is represented by its midpoint. Thus the highway maintenance cost of a segment is assumed to be concentrated at its midpoint. Also, travel times are calculated from garages to midpoints of highway segments.
4. The cost of servicing a highway segment from a maintenance garage is assumed to vary as a function of travel time between the garage and the segment. The relationship is quantified by the use of "cost multipliers," which is shown in Table 1 (page 10).
5. The highway maintenance cost for a route in a given maintenance area is assumed to be uniformly distributed along the route.
6. The garages in the study area are assumed to have unlimited capacities. This means the garages can be expanded, if necessary, to service all the segments optimally assigned to them.
7. Capital costs are not considered.

B. Study Area

The study area for this project is the U.S. 30 corridor between Ames and Cedar Rapids. It consists of 15 "active" highway maintenance garages and is shown in Appendix 1.

C. Highway Segments

1. All the routes in the study area were broken up into suitable segments; and
2. The end points of a highway segment should be suitable for turning maintenance vehicles around (junction, intersection or town).

A total of 139 highway segments, ranging from 0.29 mile to 20.21 miles in length, were formed in the study area. These segments are shown in Appendix 2.

D. Source of Data

The Office of Maintenance provided the necessary information and the fiscal year 1986 labor, equipment and garage overhead costs for all the routes in the study area. These costs are shown in Appendix 7.

E. Basic Maintenance and Overhead Costs

The fiscal year 1986 labor, equipment and overhead costs were adjusted for inflation to reflect what these costs would be if the same maintenance activities were done in fiscal year 1987. The Office of Maintenance provided the following inflation factors:

Labor 5%
Equipment 3.5%
Overhead 5%

The inflation-adjusted labor and equipment costs for a route were combined to form a single cost. This single cost is referred to as the "basic maintenance" cost for that route. The "basic maintenance" cost associated with each route is proportionally allocated (with respect to length) to the segments forming that route.

Sometimes the overhead cost of each maintenance garage in the study area is not readily available. In certain maintenance areas, the overhead costs for some garages are combined during the record-keeping process. In such situations, the Office of Maintenance recommends the overhead costs of the garages involved be determined according to the relative percentages of the number of persons and/or the number of miles of highway associated with each garage.

F. Key Input Data

The following is used for developing the input data for the model:

1. Operating costs for all the routes in the study area; and
2. Crew travel times from garages to work sites.

The Office of Maintenance does not keep records of crew travel times. The technique for estimating crew travel times for use is explained later in this report.

G. Output Data

For a given set of garage locations, the model's output consists of the following:

1. Annual operating costs for the entire study area; and
2. The optimum allocation of all highway segments to maintenance garages and their respective operating costs in the study area.

H. Computer Program

The model uses a computer program (MPSX) developed by the International Business Machine (IBM). The program is available for lease from IBM and is also available at the Iowa State University at Ames. It is a highly efficient computer program designed to solve large-scale linear programming problems. The project has used the computer program at the Iowa State University Computation Center. Samples of the computer input and output data are shown in Appendices 21 and 22.

I. Weighted Average Speed

The optimum allocation model is sensitive to small changes in speed and thus is sensitive to small changes in travel time. For a given highway segment, the travel time from a given garage to the segment is generally greater for snow and ice control activities than it is for the other maintenance activities. Therefore, a "weighted" average speed rather than a "simple" average speed is used in this study.

A weighted average speed of 38 mph is used. It was determined as shown below. All the data is provided by the Office of Maintenance.

% of snow and ice control activities = 32.2%

Average speed for snow and ice control activities = 35 mph

Average speed for other maintenance activities = 40 mph

Therefore,

$$\text{Weighted average speed} = (0.322)(35) + (1.0 - 0.322)(40)$$
$$= 11.27 + 27.12$$
$$= 38.39 \text{ mph} \qquad \text{Use } \underline{38} \text{ mph}$$

J. Travel Time Estimation

The following is the basic formula that is used in estimating travel times from garages to highway segments:

$$\begin{array}{c}\text{Travel Time}\\ \text{(in minutes)}\end{array} = \frac{\text{Distance (in Miles)}}{\text{Speed (Miles Per Hour)}} \times 60$$

The shortest and most logical travel distances from garage locations to midpoint of segments were calculated using the Primary Road Inventory and Mileage Summary (3) and the Maintenance Area Responsibility Maps (2).

As an example, the travel time from segment No. 1 to the garage at Ames is calculated as follows:

Length of segment No. 1 = 11.41 miles (from map--page 9)

(the shortest distance from Ames garage--G1 to the midpoint of segment No. 1) $= \frac{11.41}{2}$ miles

$= 5.70$ miles

Vehicle weighted average speed $= 38.00$ mph

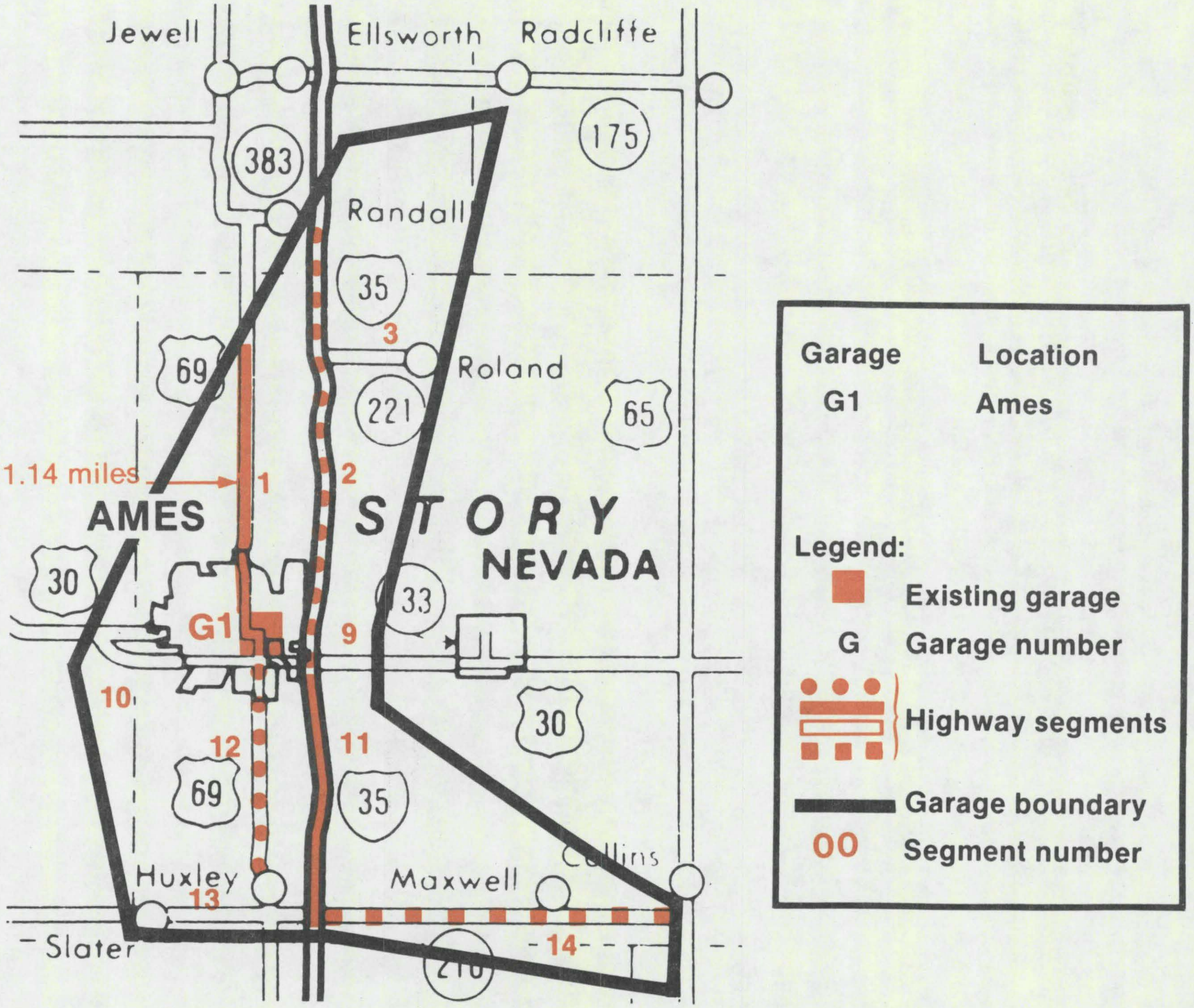
Therefore,

Travel Time $= \frac{5.70}{38.00} \times 60$ minutes

$= \underline{9 \text{ minutes}}$

A computer program was used to estimate travel times from garages to highway segments for the entire study area.

Existing Allocation of Highway Segments at Ames Garage



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K. Travel Time Adjusted Costs

The basic maintenance cost for each highway segment was adjusted using its travel time from the garage and the corresponding cost multiplier as determined from Table 1. The concept of cost multipliers is based on the assumptions that one-way travel time less than 45 minutes would result in more than six hours of productive work (for an eight-hour work day) at the work site. This would result in less cost associated with nonproductive travel. One the other hand, travel time greater than 45 minutes would result in less productive work and consequently in greater maintenance cost. This relationship was developed in a project prepared for the Alabama DOT (1).

The travel time adjusted costs are called "operating costs" in this study. Sample calculations are shown below.

Table 1
Basic Maintenance Cost Multiplier as a
Function of Travel Time (Eight-Hour Work Day)

One-Way Travel Time from Garage to Segment (Minutes)	Productive Work (Hours)	Basic Maintenance Cost Multiplier
00 - 15	7.5 - 7.0	0.8
15 - 75	7.0 - 5.0	0.8 - 1.2
75 - 135	5.0 - 3.0	1.2 - 2.0
135 - 165	3.0 - 2.0	2.0 - 3.0
$\geq$ 165	$\leq$ 2.0	8.0

Source: Reference No. 1

a. Sample Calculation of Cost Multiplier

Basic Logic (from Table 1):

(45 minutes one-way) (Travel Time) is equivalent to (=) 6 hours of productive work.

and

(6 hours of Productive Work) = a Cost Multiplier of 1.0

thus

(i) (7 hours of Productive Work) = to a Cost Multiplier of 0.8 (i.e. $\frac{6}{7}$)

(ii) (5 hours of Productive Work) = to a Cost Multiplier of 1.2 (i.e. $\frac{6}{5}$)

The basic maintenance cost for any highway segment in the study area is multiplied by the appropriate cost multiplier to obtain the maintenance cost adjusted for its travel time from a particular garage under consideration.

b. Sample Calculations of Travel Time Adjusted Cost

Consider highway segment No. 1 in Ames maintenance area.
Basic Maintenance Cost = $31,359

(Travel Time from Ames Garage to Midpoint of Segment 1) = 9 minutes

Cost Multiplier (Using Table 1) = 0.8

Therefore,

(Travel Time Adjusted Cost) = (Cost Multiplier) x (Basic Maintenance Cost)

= (0.8) (31,359)

= $25,087

The travel time adjusted costs (operating costs) for the 139 highway segments as serviced from each of the 16 garages were calculated using a computer program.

IV. THE APPLICATION OF THE MODEL

A. Existing and Optimum Allocations

The optimum allocation model was first used to examine the existing allocation of highway segments to the maintenance garages in the given study area.

The "existing allocation" (Appendix 1) refers to the current maintenance areas which were determined by the Office of Maintenance without the use of the optimum allocation model. These two allocations (existing and optimum) were compared on the basis of operating costs only. To ensure compatibility in cost, the operating costs pertaining to the existing allocation were also determined from travel time adjusted costs by utilizing the cost multipliers and the travel times as determined by the existing allocation system.

The application of the model to the existing allocation system resulted in the reallocation of 19 segments of the 139 highway segments with the associated cost savings of approximately $16,800. The optimal highway segments allocations are shown in Appendix 2. The reallocated highway segments and the corresponding cost savings are shown in Table 2.

B. Examination of Options

The optimum allocation technique was also used to evaluate the financial effect of closing and/or relocating garages for four options as described earlier under "objective" of the research project.

A highway maintenance garage must be optimally located within its maintenance area to minimize the loss in productivity. Closing a highway maintenance garage increases travel cost. On the other hand, maintaining a garage involves overhead costs. Closing a garage, therefore, is cost beneficial only when the resulting increase in travel cost is less than the overhead costs of that garage.

The results of the cost analysis for each of the four options are shown in Tables 3, 4, 5 and 6, respectively. A summary of the estimated savings/(loss) for each option considered is shown in Table 7. Appendices 3 through 6 indicate the optimal highway segments allocations to garages for options 1 through 4, respectively.

Table 2
ANNUAL SAVINGS
DUE TO
SEGMENTS REALLOCATED UNDER OPTIMUM ALLOCATION
(U.S. 30 CORRIDOR BETWEEN AMES AND CEDAR RAPIDS)

	Existing Allocation		Optimum Allocation		
Highway Segment No.	Assigned to Garage at:	1987 Operating Costs* (Dollars/Yr.)	Assigned to Garage at:	1987 Operating Costs* (Dollars/Yr.)	Annual Savings Using Optimum Allocation (1987 $)
14	Ames	25,090	Colo	24,716	374
28	Marshalltown	8,189	Colo	7,799	390
32	Marshalltown	21,582	Tama	21,414	168
36	Marshalltown	19,223	Colo	18,180	1,043
41	Newton	12,757	Marshalltown	11,805	952
53	Colfax	43,008	Newton	41,151	1,857
71	Tama	15,068	Malcolm	14,470	598
73	Tama	1,582	Blairstown	1,570	12
78	Traer	14,257	Tama	13,060	1,197
80	Traer	16,491	Tama	16,221	270
88	Urbana	29,868	Traer	26,660	3,208
99	Urbana	33,710	Blairstown	32,201	1,509
100	Urbana	1,431	Blairstown	1,213	218
107	Urbana	10,645	Blairstown	8,870	1,775
111	Blairstown	5,299	Cedar Rapids	5,139	160
112	Blairstown	9,983	Cedar Rapids	9,238	745
119	Williamsburg	40,645	Malcolm	39,516	1,129
120	Williamsburg	3,034	Malcolm	2,989	45
125	Marion	26,497	Cedar Rapids	25,345	1,152
					Total = $16,802

* Operating costs are based on travel time adjusted costs.

Table 2a.
DESCRIPTION OF HIGHWAY SEGMENTS
REALLOCATED UNDER OPTUMUM ALLOCATION PROCEDURES

Highway Segment No.	Route	Description From	Description To
14	210	Jct. U.S. 65 & Ia. 210	Jct. I-35 & Ia. 210
28	930	State Center	Story Co. Line
32	146	Jct. U.S. 30 & Ia. 146	Tama Co. Line
36	330	Jct. U.S. 30 & Ia. 330	Jct. U.S. 65 & Ia. 330
41	14	Laurel	Jct. Ia. 14 & Ia. 224
53	163	Monroe	Pella
71	63	Poweshiek Co. Line	Jct. U.S. 6 & U.S. 63
73	21	Jct. Ia. 21 & U.S. 30	Jct. Ia. 21 & Ia. 212
78	229	Jct. U.S. 63 & Ia. 229	Garwin
80	63	Jct. U.S. 63 & Ia. 96	Jct. U.S. 63 & Ia. 229
88	218	Laporte City	Jct. Ia. 8 & U.S. 218
99	218	Vinton	Jct. Ia. 199 & U.S. 218
100	199	Jct. Ia. 199 & U.S. 218	Van Horne
107	218	Jct. Ia. 199 & U.S. 218	Jct. U.S. 30 & U.S. 218
111	279	Atkins	Jct. U.S. 30 & Ia. 279
112	30	Linn Co. Line	Cedar Rapids
119	21	Jct. Ia. 21 & Ia. 212	Jct. U.S. 6 & Ia. 21
120	419	Jct. U.S. 6 & Ia. 419	Victor
125	1	Jct. Ia. 1 & U.S. 30	Solon

Table 3

OPTION 1: Cost analysis of closing garages at Marshalltown, Colo, and Blairstown; build new garage at Tama and expand Ames, Cedar Rapids, Colfax, and Grundy Center garages using optimum allocation model

(1) Item	(2) Garages Not Closed ($)	(3) Garages Closed ($)	(4) Increased Travel Cost (3) - (2) ($)	(5) Overhead Cost of Garages Closed - (Overhead at Tama and Increase In Overhead After Expanding Ames, C. Rapids, Colfax & Grundy Center) ($)	(6) Estimated Savings/(Loss) (5) - (4) ($)
All Garages	3,471,770				
Close Marshalltown, Colo & Blairstown; new garage at Tama; expand Ames, Cedar Rapids, Colfax & Grundy Center		3,548,601	76,831	57,144	(19,687)

Note: All costs shown are 1987 costs. See Appendix 11 for overhead costs.

Col. (5) = (78,597 + 45,506 + 22,344) - (57,803 + 9,450 + 6,300 + 9,450 + 6,300) = $57,144

Table 4

OPTION 2: Cost anlaysis of closing garages at Tama and Blairstown and expanding Traer and Cedar Rapids garages using optimum alloction model

(1) Item	(2) Garages Not Closed ($)	(3) Garages Closed ($)	(4) Increased Travel Cost (3) - (2) ($)	(5) Overhead Cost of Garages Closed - (Increase in Overhead After Expanding) ($)	(6) Estimated Savings/(Loss) (5) - (4) ($)
All Garages	3,471,770				
Close Tama and Blairstown; expand Traer and C. Rapids		3,513,943	42,173	50,655	8,482

Note: All costs shown are 1987 costs. See Appendix 14 for overhead costs.

Col. (5): (40,911 + 22,344) - (6,300 + 6,300) = $50,655

Table 5

OPTION 3: Cost analysis of closing garages at Tama and Blairstown and constructing new garage at the intersection of U.S. 30 and Iowa 21 using optimum alloction model

(1) Item	(2) Garages Not Closed ($)	(3) Garages Closed ($)	(4) Increased Travel Cost (3) - (2) ($)	(5) Overhead Cost of Garages Closed - (Overhead at New Location) ($)	(6) Estimated Savings/(Loss) (5) - (4) ($)
All Garages	3,471,770				
Close Tama & Blairstown; construct new garage at inters. U.S. 30 & Ia. 21		3,473,546	1,776	18,031	16,255

Note: All costs shown are 1987 costs. See Appendix 17 for overhead costs.

Col. (5) = (40,911 + 22,344) - (45,224) = $18,301

Table 6

OPTION 4: Cost analysis of closing Blairstown garage; build new garage at Tama and expand Cedar Rapids using optimum allocation model

(1) Item	(2) Garages Not Closed ($)	(3) Garages Closed ($)	(4) Increased Travel Cost (3) - (2) ($)	(5) Overhead Cost of Garages Closed - (Overhead at Tama and Increase in Overhead Afer Expanding Cedar Rapids) ($)	(6) Estimated Savings/(Loss) (5 - (4) ($)
All Garages	3,471,770				
Close Blairstown; new garage at Tama; expand C. Rapids		3,491,714	19,944	-29,180	(49,124)

Note: All costs shown are 1987 costs. See Appendix 20 for overhead costs.

Col. (5) = 22,344 - (45,224 + 6,300) = -$29,180

Table 7

SUMMARY OF
COST ANALYSIS OF MAINTENANCE GARAGES IN THE U.S. 30 CORRIDOR BETWEEN AMES AND CEDAR RAPIDS

Option	(1) Item	(2) Garage(s) Not Closed ($)	(3) Garages(s) Closed ($)	(4) Increased Travel Costs (3) - (2) ($)	(5) Overhead Cost of Garages(s) Closed - Increase in Overhead After Expanding/New Garage ($)	(6) Estimated Savings/(Loss) (5) - (4) ($)
	All Garages	3,471,770				
1.	Close (MCB), build new garage at Tama & expand (ACRCGC)		3,548,601	76,831	57,144	(19,687)
2.	Close (TB) & expand (TRCR)		3,513,943	42,173	50,655	8,482
3.	Close (TB) & construct new garage at inter. U.S. 30 & Ia. 21		3,473,546	1,776	18,031	16,255
4.	Close (B), build new garage at Tama & expand CR		3,491,714	19,944	-29,180	(49,124)

LEGEND

(MCB) Marshalltown, Colo, and Blairstown
(ACRCGC) Ames, Cedar Rapids, Colfax, and Grundy Center
(TB) Tama and Blairstown
(TRCR) Traer and Cedar Rapids
(B) Blairstown
(CR) Cedar Rapids

Note: All costs shown are 1987 costs.

V. CONCLUSION

The optimum allocation model was used to examine several highway maintenance garage locations in the U.S. 30 corridor between Ames and Cedar Rapids.

First, the model examined the current allocation of highway segments to maintenance garages in the study area. It reallocated only 19 segments of the total 139 highway segments to different maintenance garages. The study concludes there would be an annual operational savings of approximately $16,800 if the Highway Segments Allocation System, as determined by the model, is used.

Secondly, the model also examined the four options selected by the Office of Maintenance. These options are described under 'objective' of the study. The study finds the following operational savings or losses for each of the options examined.

Options	Estimated Annual Operational Savings/(Losses) ($)
1.	(19,700)
2.	8,500
3.	16,250
4.	(49,100)

It appears option No. 3 would generate the maximum annual operational savings for the Department. These operational savings, however, should be used only as guidelines by the managers in the decision-making process. This is not the final solution, and the results of the study must be viewed in relation to the limitations of the study which are stated in Section VI.

VI. LIMITATIONS OF STUDY

The accuracy of the cost savings reported in this study is subject to:

1. The reliability of the historical cost data provided for use in this study.
2. The accuracy of the apportionment of an overhead cost in cases where two or more garages have a combined overhead cost.
3. The accuracy of the average speeds of maintenance vehicles used to calculate the weighed average speed.
4. The garage overhead costs.
5. Capital costs are not considered.

VII. REFERENCES

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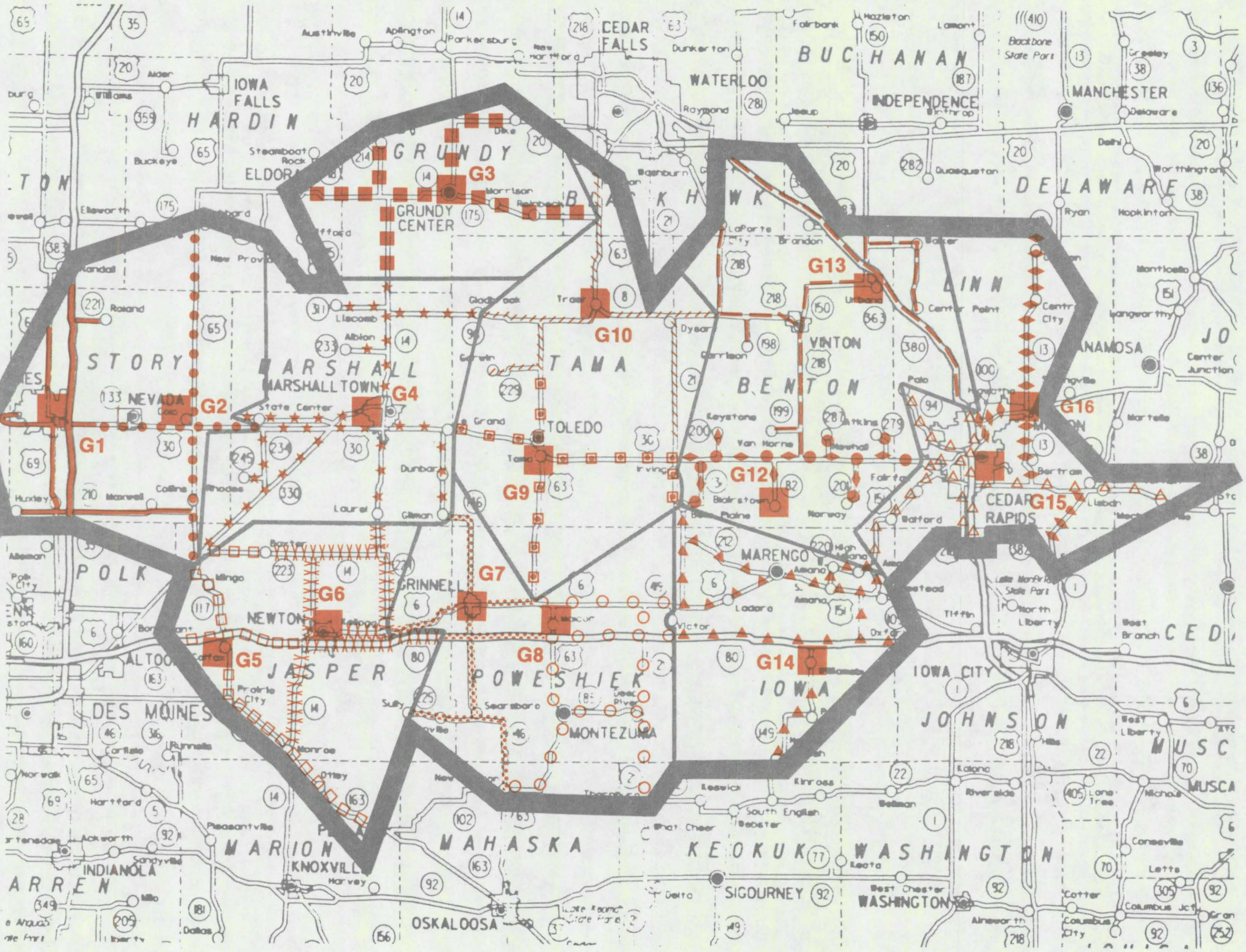
APPENDICES

Study Area Showing Existing Highway Segments Allocations

Appendix 1



Segment Served	Location
▬▬	Ames (G1)
● ● ●	Colo (G2)
■ ■ ■	Grundy Center (G3)
★ ★ ★	Marshalltown (G4)
□ □ □	Colfax (G5)
XXXX	Newton (G6)
∿∿∿	Grinnell (G7)
///	Traer (G10)
○ ○	Malcolm (G8)
▣▣▣	Tama (G9)
◆●◆	Blairstown (G12)
— —	Urbana (G13)
▲ ▲	Williamsburg (G14)
△ △	Cedar Rapids (G15)
♦♦♦	Marion (G16)

Legend:

- ■ Existing garage
- G Garage number
- ▬ Study boundary area

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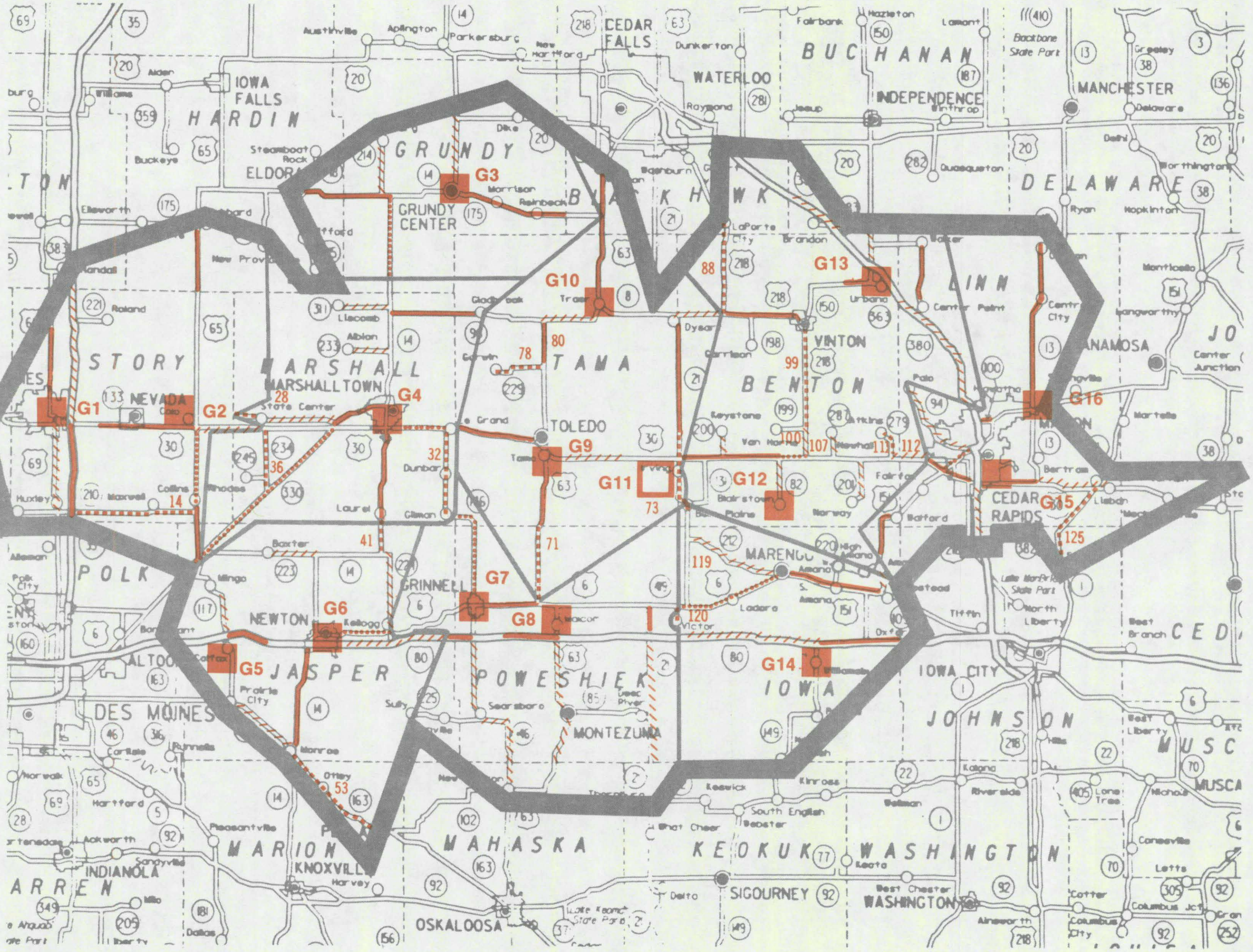
Optimal Highway Segments Allocations
16 Garages and 139 Highway Segments

Appendix 2



Garage	Location
G1	Ames
G2	Colo
G3	Grundy Center
G4	Marshalltown
G5	Colfax
G6	Newton
G7	Grinnell
G8	Malcolm
G9	Tama
G10	Traer
G11	Jct. US 30 & Iowa 21 (New garage to be built later)
G12	Blairstown
G13	Urbana
G14	Williamsburg
G15	Cedar Rapids
G16	Marion

Legend:

- Existing garage
- New garage to be built
- G Garage number
- Highway segments
- Study boundary area
- 00 Segment number (Reallocated)

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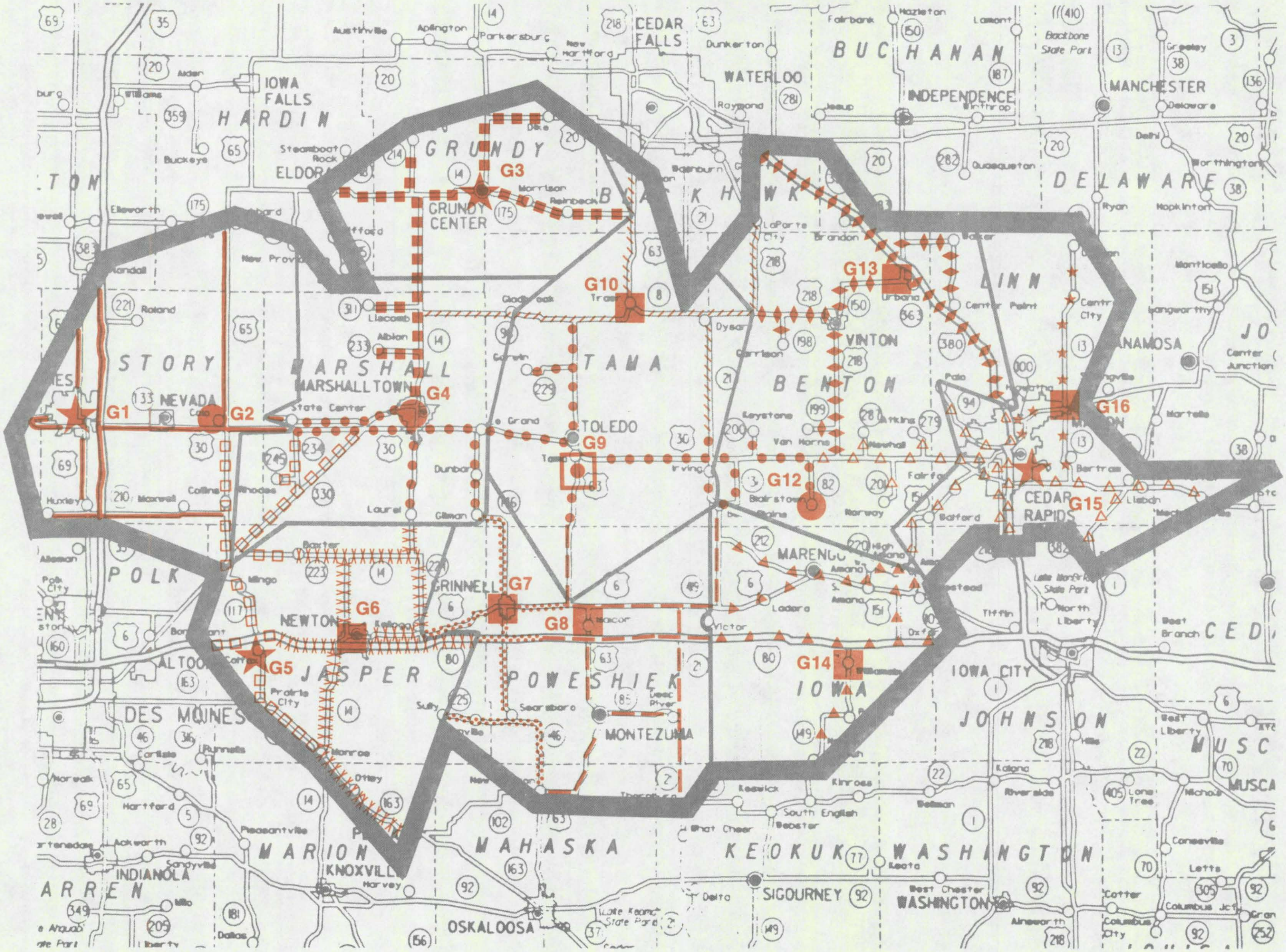
Option No. 1
Optimal Highway Segment Allocations
(Close Marshalltown, Colo, & Blairstown Garages, Build New Garage at Tama, Expand Ames, Cedar Rapids, Colfax & Grundy Center Garages)

Appendix 3



Segment Served	Location
▬	Ames (G1 Expand)
	Colo (G2 Closed)
■ ■ ■	Grundy Center (G3 Expand)
	Marshalltown (G4 Closed)
□ □ □	Colfax (G5 Expand)
XXXXX	Newton (G6)
	Grinnell (G7)
— —	Malcolm (G8)
● ● ●	Tama (G9 Expand)
/////	Traer (G10)
	Blairstown (G12 Closed)
♦ ♦ ♦	Urbana (G13)
▲ ▲ ▲	Williamsburg (G14)
△ △ △	Cedar Rapids (G15 Expand)
★ ★ ★	Marion (G16)

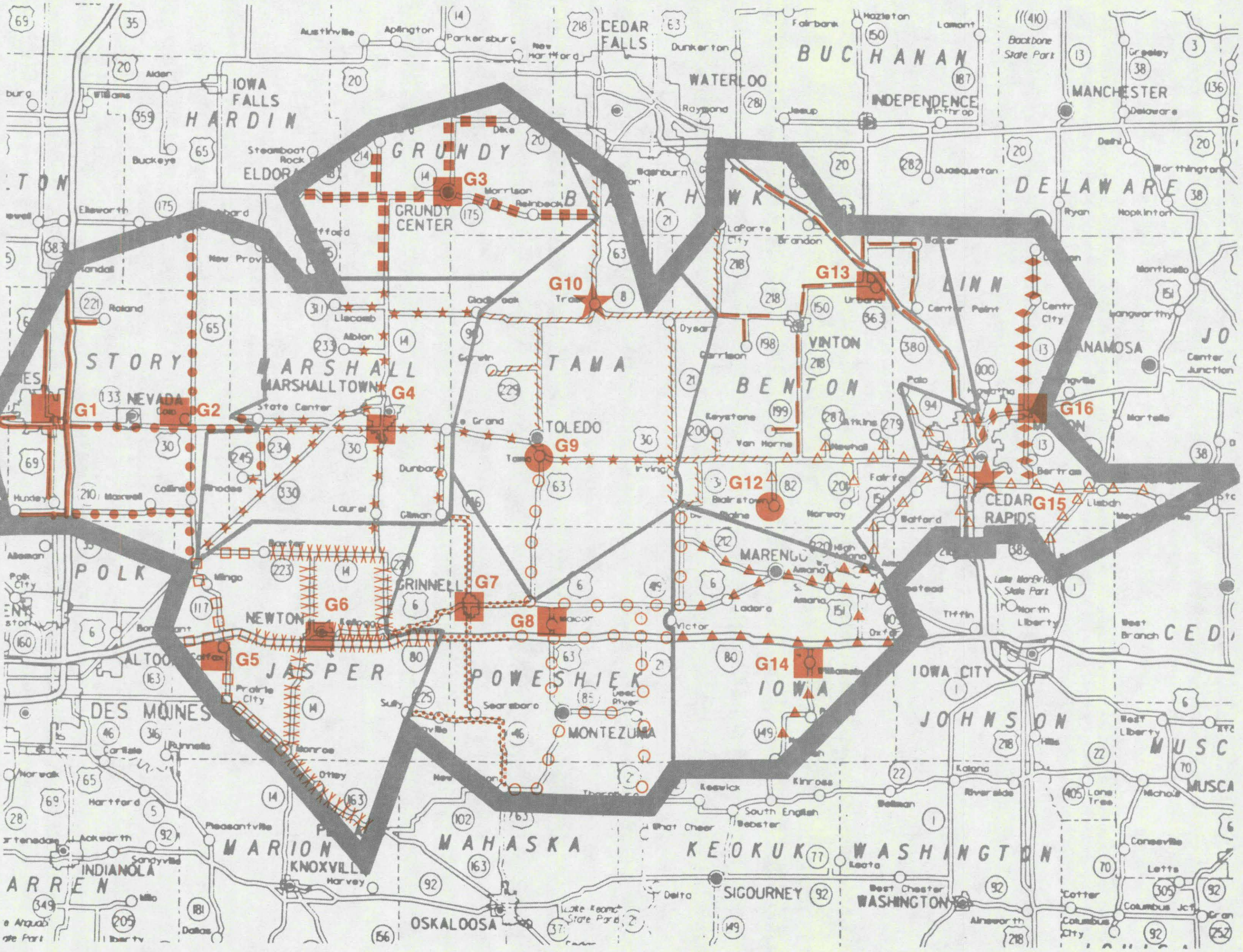
Legend:

- ■ Existing garage
- ● Closed garage
- ★ Expand garage
- ▣ New Garage
- G Garage number
- ▬ Study boundary area

Gra. 368A
2510 2/17/87

Option No. 2
Optimal Highway Segment Allocations
(Close Tama & Blairstown Garages, Expand Traer & Cedar Rapids Garages)

Appendix 4



Segment Served	Location
▬▬	Ames (G1)
● ● ●	Colo (G2)
■ ■ ■	Grundy Center (G3)
★ ★ ★	Marshalltown (G4)
□ □ □	Colfax (G5)
XXXX	Newton (G6)
ˣˣˣˣ	Grinnell (G7)
○ ○	Malcolm (G8)
	Tama (G9 Closed)
/////	Traer (G10 Expand)
	Blairstown (G12 Closed)
— —	Urbana (G13)
▲ ▲	Williamsburg (G14)
△ △	Cedar Rapids (G15 Expand)
♦ ♦ ♦	Marion (G16)

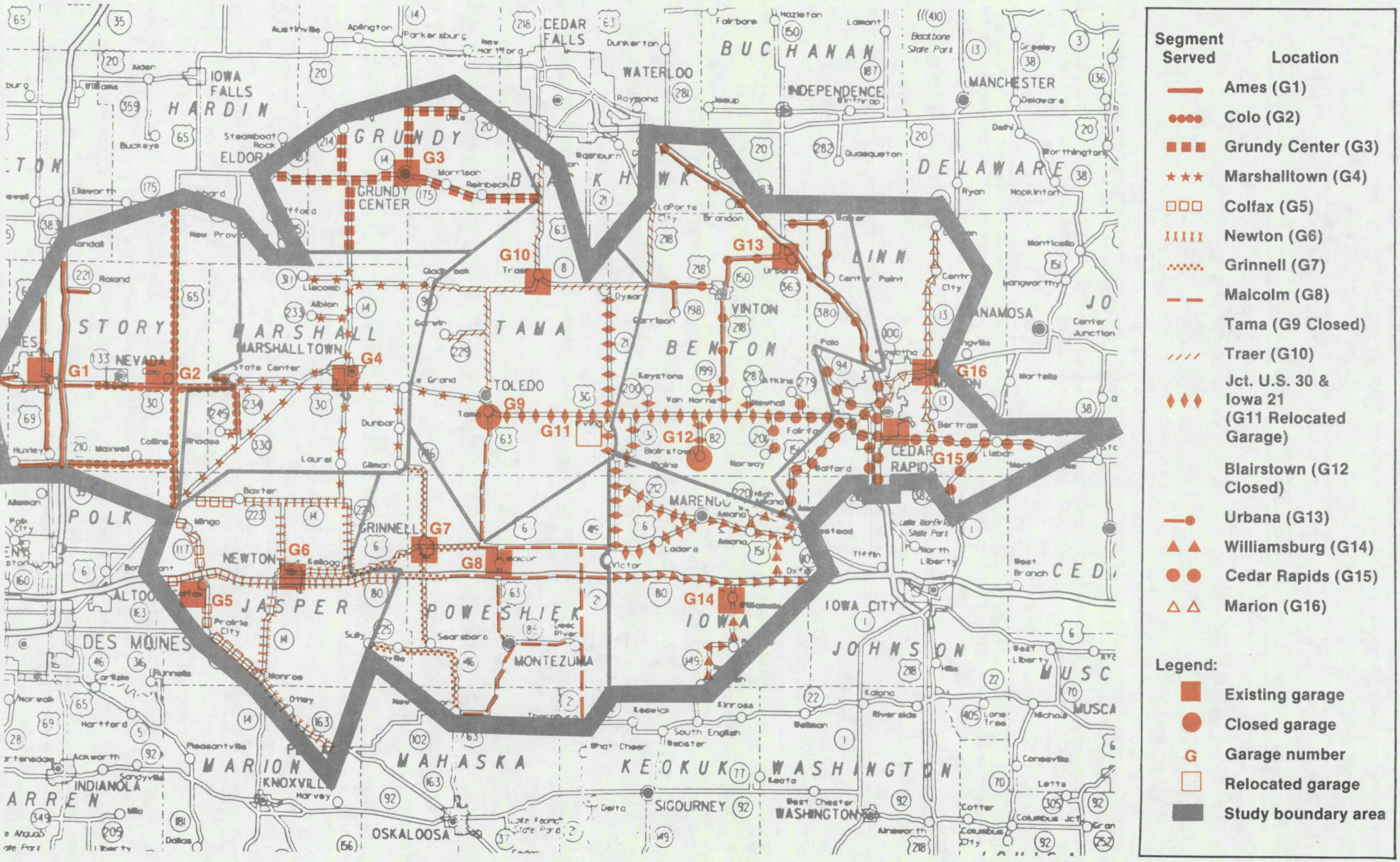
Legend:

- ■ Existing garage
- ● Closed garage
- ★ Expand garage
- G Garage number
- ▬ Study boundary area

-27-

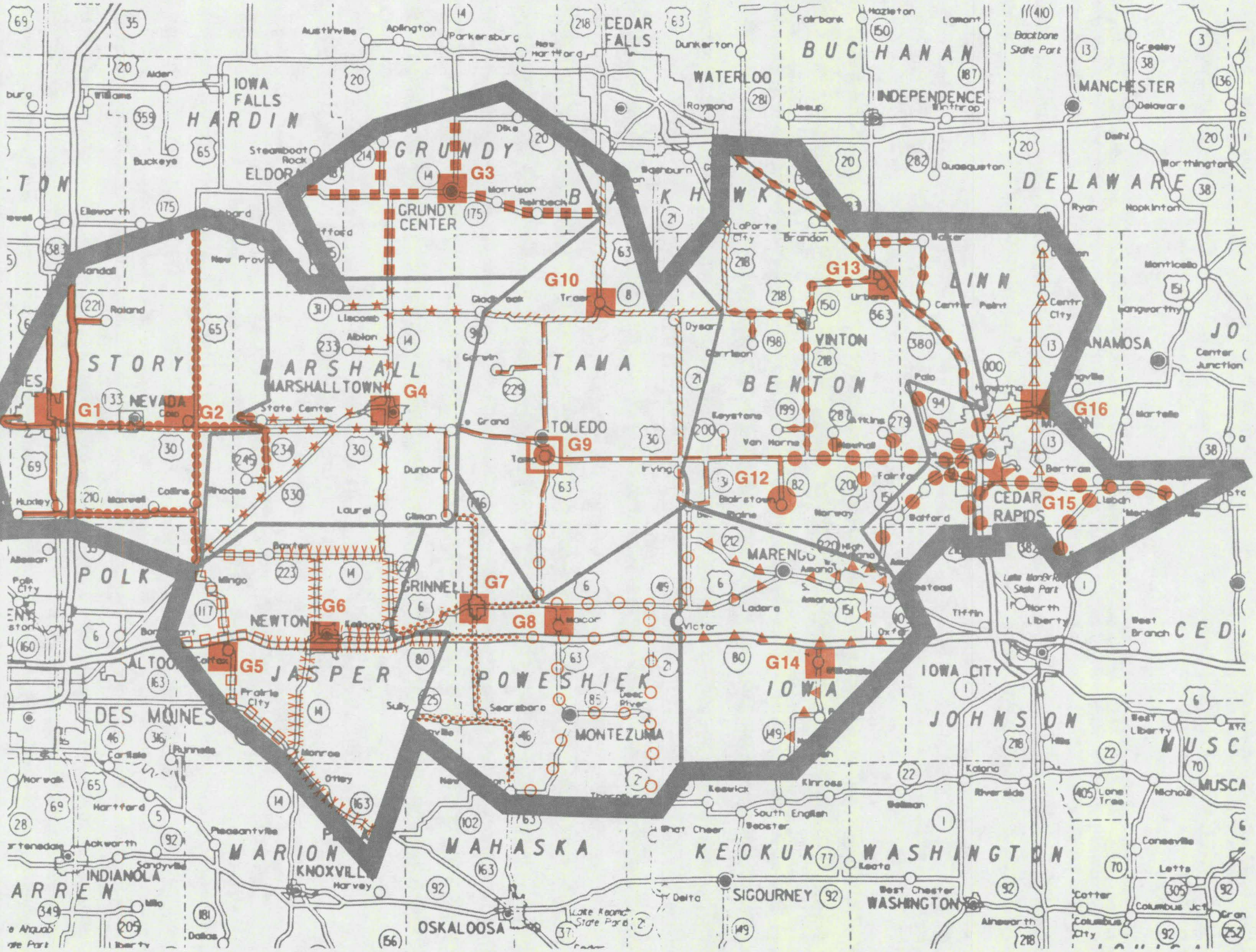
Option No. 3
Optimal Highway Segment Allocations
(Close Tama & Blairstown Garages,
Relocate New Garage at Jct. U.S. 30 & Iowa 21)

Appendix 5



Option No. 4
Optimal Highway Segment Allocations
(Blairstown Garage Closed, Build New Garage at Tama, Expand Cedar Rapids)

Appendix 6



Segment Served	Location
▬	Ames (G1)
●●●●	Colo (G2)
■ ■ ■	Grundy Center (G3)
★ ★ ★	Marshalltown (G4)
□ □ □	Colfax (G5)
XXXXX	Newton (G6)
········	Grinnell (G7)
○ ○	Malcolm (G8)
— —	Tama (G9 Build New Garage)
/////	Traer (G10)
	Blairstown (G12 Closed)
◆●	Urbana (G13)
▲▲▲	Williamsburg (G14)
● ●	Cedar Rapids (G15 Expand)
△△△	Marion (G16)

Legend:

- ■ Existing garage
- ● Closed garage
- ★ Expand garage
- ▣ New Garage
- G Garage number
- ▬ Study boundary area

-29-

Gra. 368B
2510 2/17/87

APPENDIX 7

FISCAL YEAR 1986
LABOR, EQUIPMENT AND OVERHEAD COSTS
FOR THE ROUTES AND GARAGES IN U.S. 30 CORRIDOR
BETWEEN AMES AND CEDAR RAPIDS

Location and Number of Garages	1986 Garage Overhead Cost (Dollars)	Routes Served by Garage	1986 Labor Cost (Dollars)	1986 Equipment Cost (Dollars)
Grundy Center (1101)	$ 49,526	14	$ 41,888	$ 34,882
		57	9,182	6,683
		175	33,233	29,489
		214	4,949	4,386
Marshalltown (1104)	74,854	14	37,039	35,034
		30	32,506	29,977
		96	17,341	13,675
		146	12,350	11,906
		233	6,549	6,812
		234	10,379	11,067
		245	3,353	2,528
		311	3,733	3,781
		330	31,308	32,465
		930	14,245	15,154
Ames (1105)	144,984	30	37,578	52,286
		35	76,285	92,537
		69	24,508	31,380
		210	17,578	21,357
		221	6,863	6,695
Colo (1106)	43,339	30	19,855	13,533
		65	59,989	40,724
		133	1,490	906
		947	530	217
Newton (1304)	65,339	6	14,338	9,680
		14	55,062	46,752
		80	46,619	34,815
		223	3,657	3,003
		224	5,690	5,688
Grinnell (1305)	59,676	6	32,840	18,458
		80	44,715	26,293
		146	58,688	32,805
		225	11,609	5,384
Malcom (1306)	52,610	6	15,768	10,933
		21	29,954	20,170
		63	57,031	37,167
		80	50,752	27,236
		85	6,750	2,805

APPENDIX 7 (Continued)

Location and Number of Garages	1986 Garage Overhead Cost (Dollars)	Routes Served by Garage	1986 Labor Cost (Dollars)	1986 Equipment Cost (Dollars)
Tama (1308)	38,963	21	$ 944	$ 806
		30	48,364	37,077
		63	27,891	21,874
Traer (1309)	42,700	8	12,459	10,254
		21	11,725	12,831
		63	41,620	37,830
		96	4,988	5,131
		229	9,330	6,307
Blairstown (6101)	21,280	21	922	483
		30	43,818	33,017
		82	16,406	10,734
		131	15,939	9,625
		200	1,060	558
		201	7,690	4,369
		279	3,190	2,537
		287	1,343	1,176
		940	0	0
Urbana (6102)	89,376	21	732	1,773
		30	11,510	11,665
		150	21,884	20,273
		198	3,207	2,032
		199	917	510
		218	60,290	53,479
		363	1,161	1,930
		380	83,071	70,918
		919	599	123
		920	13,273	12,787
Williamsburg (6405)	90,062	6	21,244	18,050
		21	23,289	17,279
		80	97,990	84,766
		149	26,725	26,853
		151	14,108	14,140
		212	13,801	11,906
		220	14,514	13,754
		419	1,790	1,465
Colfax (1301)	53,182	80	51,153	26,906
		117	29,916	17,445
		163	55,167	34,135
		223	10,057	4,213
Cedar Rapids (6106)	183,660	30	60,381	75,540
		94	18,026	19,302
		151	38,080	48,543
		380	164,482	186,992
		941	43,789	43,506
		965	3,126	3,901

APPENDIX 7 (Continued)

Location and Number of Garages	1986 Garage Overhead Cost (Dollars)	Routes Served by Garage	1986 Labor Cost (Dollars)	1986 Equipment Cost (Dollars)
Marion (6107)	66,785	1	$ 12,977	$ 14,662
		13	56,757	69,870
		100	32,053	35,594
		151	5,509	4,686

Note: The garage overhead costs include utilities, field supervision, maintenance garage and yard operations, maintenance area administrative work and other support activities.

Source: Office of Maintenance, Highway Division, Iowa DOT

APPENDIX 8

Existing Segment Allocation and Basic Maintenance Costs:
(U.S. 30 Corridor Between Ames and Cedar Rapids)

Highway Segment No.	Route	Assigned to Garage at:	*Basic Maintenance Costs (1987) Dollars)
1	69	Ames	31,359
2	35	Ames	112,273
3	221	Ames	14,135
10	30	Ames	93,572
11	35	Ames	63,602
12	69	Ames	26,852
13	210	Ames	12,476
14	210	Ames	28,086
101	200	Blairstown	1,691
102	30	Blairstown	31,537
103	131	Blairstown	26,698
104	21	Blairstown	1,468
105	82	Blairstown	28,336
106	30	Blairstown	8,698
108	30	Blairstown	28,772
109	287	Blairstown	2,627
110	201	Blairstown	12,597
111	279	Blairstown	5,976
112	30	Blairstown	11,175
124	30	Cedar Rapids	25,245
126	30	Cedar Rapids	43,993
127	30	Cedar Rapids	30,906
128	380	Cedar Rapids	139,340
129	965	Cedar Rapids	6,674
130	151	Cedar Rapids	50,138
131	151	Cedar Rapids	40,088
132	30	Cedar Rapids	41,440
133	941	Cedar Rapids	91,008
134	94	Cedar Rapids	38,905
135	380	Cedar Rapids	226,903
38	223	Colfax	14,921
44	117	Colfax	34,426
45	80	Colfax	33,717
46	80	Colfax	19,274
47	80	Colfax	28,570
51	117	Colfax	15,042
52	163	Colfax	46,844
53	163	Colfax	46,411
4	65	Colo	20,614
5	65	Colo	42,833
6	30	Colo	16,724
7	65	Colo	30,829
8	30	Colo	18,131
9	133	Colo	2,503
15	65	Colo	10,862

APPENDIX 8 (Continued)

Highway Segment No.	Route	Assigned to Garage at:	*Basic Maintenance Costs (1987) Dollars)
54	225	Grinnell	17,762
55	146	Grinnell	51,747
65	6	Grinnell	26,394
66	80	Grinnell	26,169
67	80	Grinnell	26,169
68	80	Grinnell	21,826
69	146	Grinnell	43,828
70	6	Grinnell	27,193
16	20	Grundy Center	16,558
17	14	Grundy Center	25,386
18	214	Grundy Center	9,737
19	175	Grundy Center	23,006
20	14	Grundy Center	30,430
21	14	Grundy Center	24,269
22	175	Grundy Center	32,087
23	175	Grundy Center	10,323
56	63	Malcolm	26,665
57	63	Malcolm	55,480
58	21	Malcolm	10,203
59	21	Malcolm	33,262
60	85	Malcolm	9,991
61	80	Malcolm	81,479
62	21	Malcolm	8,863
63	6	Malcolm	27,872
64	63	Malcolm	16,206
125	1	Marion	28,801
136	13	Marion	40,399
137	151	Marion	10,635
138	13	Marion	91,512
139	100	Marion	69,250
24	14	Marshalltown	47,210
25	311	Marshalltown	7,833
26	96	Marshalltown	32,362
27	233	Marshalltown	13,927
28	930	Marshalltown	9,749
29	930	Marshalltown	20,892
30	330	Marshalltown	17,210
31	30	Marshalltown	27,712
32	146	Marshalltown	25,291
33	14	Marshalltown	27,941
34	30	Marshalltown	37,445
35	330	Marshalltown	49,264
36	234	Marshalltown	22,352
37	245	Marshalltown	6,138

APPENDIX 8 (Continued)

Highway Segment No.	Route	Assigned to Garage at:	*Basic Maintenance Costs (1987) Dollars)
39	223	Newton	6,948
40	14	Newton	23,423
41	14	Newton	14,280
42	224	Newton	11,862
43	14	Newton	28,961
48	6	Newton	25,074
49	80	Newton	84,985
50	14	Newton	39,538
71	63	Tama	17,939
72	63	Tama	20,299
73	21	Tama	1,825
74	30	Tama	27,447
75	30	Tama	27,447
76	63	Tama	13,688
77	30	Tama	34,263
78	229	Traer	16,325
79	96	Traer	10,548
80	63	Traer	20,276
81	63	Traer	21,463
82	8	Traer	14,941
83	21	Traer	25,591
84	8	Traer	8,754
85	63	Traer	41,116
86	380	Urbana	30,163
87	380	Urbana	29,252
88	218	Urbana	30,068
89	380	Urbana	39,798
90	150	Urbana	8,876
91	920	Urbana	6,594
92	920	Urbana	20,578
93	380	Urbana	61,412
94	919	Urbana	756
95	363	Urbana	3,217
96	150	Urbana	35,085
97	218	Urbana	39,765
98	198	Urbana	5,470
99	218	Urbana	37,735
100	199	Urbana	1,491
107	218	Urbana	11,088
113	151	Williamsburg	10,324
114	220	Williamsburg	29,475
115	151	Williamsburg	19,124
116	6	Williamsburg	18,867
117	212	Williamsburg	26,814
118	6	Williamsburg	22,121
119	21	Williamsburg	42,338
120	419	Williamsburg	3,396
121	80	Williamsburg	107,468
122	149	Williamsburg	55,854
123	80	Williamsburg	83,153

* 1987 Labor and equipment costs based on the 1986 cost adjusted for inflation.

APPENDIX 9

Operating Costs for Segments Optimally Reallocated Under Option 1

Highway Segment No.	Segment Length (Miles)	Route	Originally Assigned to:	Optimally Assigned to:	*Operating Costs (1987 Dollars)
24	15.19	14	Marshalltown	Grundy Center	44,692
33	8.99	14	Marshalltown	Tama	26,078
31	8.74	30	Marshalltown	Tama	23,463
34	11.81	30	Marshalltown	Tama	35,698
26	10.04	96	Marshalltown	Traer	28,910
32	9.04	146	Marshalltown	Tama	21,413
27	5.3	233	Marshalltown	Grundy Center	13,463
36	6.72	234	Marshalltown	Colfax	21,607
37	1.24	245	Marshalltown	Colfax	5,852
25	4.73	311	Marshalltown	Grundy Center	7,206
30	7.06	330	Marshalltown	Tama	16,522
35	20.21	330	Marshalltown	Colfax	45,980
28	3.36	930	Marshalltown	Ames	9,489
29	7.2	930	Marshalltown	Tama	20,613
6	7.37	30	Colo	Ames	15,386
8	7.99	30	Colo	Ames	15,109
4	6.68	65	Colo	Ames	21,851
5	13.88	65	Colo	Ames	40,834
7	9.99	65	Colo	Colfax	28,157
15	3.52	65	Colo	Colfax	9,197
9	.97	133	Colo	Ames	2,019
104	2.12	21	Blairstown	Tama	1,429
102	10.95	30	Blairstown	Tama	29,014
106	3.02	30	Blairstown	Cedar Rapids	8,408

APPENDIX 9 (Continued)

Highway Segment No.	Segment Length (Miles)	Route	Originally Assigned to:	Optimally Assigned to:	*Operating Costs (1987 Dollars)
108	9.99	30	Blairstown	Cedar Rapids	25,895
112	3.88	30	Blairstown	Cedar Rapids	9,238
105	3.75	82	Blairstown	Tama	28,336
103	6.47	131	Blairstown	Tama	24,740
101	2.16	200	Blairstown	Tama	1,567
110	4.77	201	Blairstown	Cedar Rapids	11,505
111	1.98	279	Blairstown	Cedar Rapids	5,139
109	1.93	287	Blairstown	Cedar Rapids	2,434

* Operating costs are based on travel time adjusted costs.

APPENDIX 10

Additional Mileages Served by Garages Under Option 1

Garage	Increase in Miles Served	% Increase in Miles
Tama	78.29	35
Colfax	41.68	19
Ames	40.25	18
Cedar Rapids	25.57	12
Grundy Center	25.22	11
Traer	10.04	5
TOTAL	221.05	100

APPENDIX 11

OVERHEAD COSTS - OPTION 1

Garage	(1) Overhead Cost (1986 $)	(2) Overhead Cost (1) x (1.05) (1987 $)	(3) Overhead Cost After Expansion (1986 $)	(4) Overhead Cost After Expansion (3) x (1.05) (1987 $)	(5) Increase in Overhead Cost After Expanding (4) - (2) (1987 $)
Marshalltown	74,854	78,597			
Colo	43,339	45,506			
Blairstown	21,280	22,344			
Tama	38,963	40,911	55,050 1/	57,803	16,892
Ames	144,984	152,233	153,984 2/	161,683	9,450
Cedar Rapids	183,660	192,843	189,660 3/	199,143	6,300
Colfax	53,182	55,841	62,182 4/	65,291	9,450
Grundy Center	49,526	52,002	55,526 5/	58,302	6,300

1/ New garage (14 stalls)
2/ Three additional stalls
3/ Two additional stalls
4/ Three additional stalls
5/ Two additional stalls

Note: 1986 costs and information on additional stalls are provided by the Office of Maintenance. 1987 costs are adjusted for inflation.

The garage overhead costs include utilities, field supervision, maintenance garage and yard operations, maintenance area administrative work and other support activities.

APPENDIX 12

Operating Costs for Segments Optimally Reallocated Under Option 2

Highway Segment No.	Segment Length (Miles)	Route	Originally Assigned to:	Optimally Assigned to:	*Operating Costs (1987 Dollars)
73	6.97	21	Tama	Traer	1,740
74	7.77	30	Tama	Marshalltown	28,179
75	7.77	30	Tama	Marshalltown	25,983
77	9.7	30	Tama	Marshalltown	29,238
71	8.06	63	Tama	Malcolm	14,471
72	9.12	63	Tama	Malcolm	18,269
76	6.15	63	Tama	Traer	12,045
104	2.12	21	Blairstown	Malcolm	1,458
102	10.95	30	Blairstown	Traer	31,747
106	3.02	30	Blairstown	Cedar Rapids	8,408
108	9.99	30	Blairstown	Cedar Rapids	25,895
112	3.88	30	Blairstown	Cedar Rapids	9,238
105	3.75	82	Blairstown	Urbana	29,091
103	6.47	131	Blairstown	Traer	27,054
101	2.16	200	Blairstown	Traer	1,702
110	4.77	201	Blairstown	Cedar Rapids	11,505
111	1.98	279	Blairstown	Cedar Rapids	5,139
109	1.93	287	Blairstown	Cedar Rapids	2,434

* Operating costs are based on travel time adjusted costs.

APPENDIX 13

Additional Mileages Served by Garages Under Option 2

Garage	Increase in Miles Served	% Increase in Miles
Traer	32.7	31
Cedar Rapids	25.57	24
Marshalltown	25.24	24
Malcolm	19.3	18
Urbana	3.75	3
TOTAL	106.56	100

APPENDIX 14

OVERHEAD COSTS - OPTION 2

Garage	(1) Overhead Cost (1986 $)	(2) Overhead Cost (1) x (1.05) (1987 $)	(3) Overhead Cost After Expansion (1986 $)	(4) Overhead Cost After Expansion (3) x (1.05) (1987 $)	(5) Increase in Overhead Cost After Expanding (4) - (2) (1987 $)
Tama	38,963	40,911			
Blairstown	21,280	22,344			
Traer	42,700	44,835	48,700 1/	51,135	6,300
Cedar Rapids	183,660	192,843	189,660 2/	199,143	6,300

1/ Two additional stalls

2/ Two additional stalls

Note: 1986 costs and information on additional stalls are provided by the Office of Maintenance. 1987 costs are adjusted for inflation.

APPENDIX 15

Operating Costs for Segments Optimally Reallocated Under Option 3

Highway Segment No.	Segment Length (Miles)	Route	Originally Assigned to:	Optimally Assigned to:	*Operating Costs (1987 Dollars)
73	6.97	21	Tama	Jct. U.S. 30 & Ia. 21	1,460
74	7.77	30	Tama	Jct. U.S. 30 & Ia. 21	21,958
75	7.77	30	Tama	Jct. U.S. 30 & Ia. 21	22,507
77	9.7	30	Tama	Marshalltown	29,238
71	8.06	63	Tama	Malcolm	14,471
72	9.12	63	Tama	Malcolm	18,269
76	6.15	63	Tama	Traer	12,045
104	2.12	21	Blairstown	Jct. U.S. 30 & Ia. 21	1,174
102	10.95	30	Blairstown	Jct. U.S. 30 & Ia. 21	25,230
106	3.02	30	Blairstown	Jct. U.S. 30 & Ia. 21	7,190
108	9.99	30	Blairstown	Jct. U.S. 30 & Ia. 21	25,895
112	3.88	30	Blairstown	Cedar Rapids	9,238
105	3.75	82	Blairstown	Jct. U.S. 30 & Ia. 21	23,613
103	6.47	131	Blairstown	Jct. U.S. 30 & Ia. 21	21,358
101	2.16	200	Blairstown	Jct. U.S. 30 & Ia. 21	1,353
110	4.77	201	Blairstown	Cedar Rapids	11,505
111	1.98	279	Blairstown	Cedar Rapids	5,139
109	1.93	287	Blairstown	Jct. U.S. 30 & Ia. 21	2,329

* Operating costs are based on travel time adusted costs.

APPENDIX 16

Additional Mileages Served by Garages Under Option 3

Garage	Total Miles Served by New Garage/Increase in Miles Served	% Miles Allocated to New Garage/% Increase in Miles
Jct. U.S. 30 & Ia. 21 1/	62.9	59
Malcolm	17.18	16
Cedar Rapids	10.63	10
Marshalltown	9.7	9
Traer	6.15	6
TOTAL	106.56	100

1/ New garage.

APPENDIX 17

OVERHEAD COSTS - OPTION 3

Garage	(1) Overhead Cost (1986 $)	(2) Overhead Cost (1) x (1.05) (1987 $)
Intersection U.S. 30 & Ia. 21	43,070 1/	45,224

1/ New garage (10 stalls)

Note: 1986 costs and information on number of stalls are provided by the Office of Maintenance. 1987 costs are adjusted for inflation.

APPENDIX 18

Operating Costs for Segments Optimally Reallocated Under Option 4

Highway Segment No.	Segment Length (Miles)	Route	Originally Assigned to:	Optimally Assigned to:	*Operating Costs (1987 Dollars)
104	2.12	21	Blairstown	Tama	1,429
102	10.95	30	Blairstown	Tama	29,014
106	3.02	30	Blairstown	Cedar Rapids	8,408
108	9.99	30	Blairstown	Cedar Rapids	25,895
112	3.88	30	Blairstown	Cedar Rapids	9,238
105	3.75	82	Blairstown	Tama	28,336
103	6.47	131	Blairstown	Tama	24,740
101	2.16	200	Blairstown	Tama	1,567
110	4.77	201	Blairstown	Cedar Rapids	11,505
111	1.98	279	Blairstown	Cedar Rapids	5,139
109	1.93	287	Blairstown	Cedar Rapids	2,434

* Operating costs are based on travel time adjusted costs.

APPENDIX 19

Additional Mileages Served by Garages Under Option 4

Garage	Increase in Miles Served	% Increase in Miles
Tama	25.45	50
Cedar Rapids	25.57	50
TOTAL	51.02	100

APPENDIX 20

OVERHEAD COSTS - OPTION 4

	(1)	(2)	(3)	(4)	(5)
Garage	Overhead Cost (1986 $)	Overhead Cost (1) x (1.05) (1987 $)	Overhead Cost After Expansion (1986 $)	Overhead Cost After Expansion (3) x (1.05) (1987 $)	Increase in Overhead Cost After Expanding (4) - (2) (1987 $)
Blairstown	21,280	22,344			
Tama	38,963	40,911	43,070 1/	45,224	4,313
Cedar Rapids	183,660	192,843	189,660 2/	199,143	6,300

1/ New garage (10 stalls)

2/ Two additional stalls

Note: 1986 costs and information on additional stalls are provided by the Office of Maintenance. 1987 costs are adjusted for inflation.

APPENDIX 21

Sample Input for MPSX Computer Program

```
//V417 JOB
/*JOBPARM L=70
//S1  EXEC  MPSX
//MPSCOMP SYSIN DD *
            PROGRAM
            INITIALZ
            MOVE(XDATA,'VIC')
            MOVE(XPBNAME,'GARSTUDY')
            CONVERT('SUMMARY')
            BCDOUT
            SETUP('MIN')
            MOVE(XOBJ,'COST')
            MOVE(XRHS,'MCOST')
            PRIMAL
            SOLUTION
            EXIT
            PEND
/*
//MPSEXEC SYSIN DD *
NAME            VIC
ROWS
 N  COST
 E  NOD1
 E  NOD2
 E  NOD3
 E  NOD4
 E  NOD5
 E  NOD6
 E  NOD7
 E  NOD8
 E  NOD9
 E  NOD10
 E  NOD11
 E  NOD12
 E  NOD13
 E  NOD14
 E  NOD15
 E  NOD16
 E  NOD17
 E  NOD18
 E  NOD19
 E  NOD20
 E  NOD21
 E  NOD22
 E  NOD23
 E  NOD24
 E  NOD25
 E  NOD26
 E  NOD27
 E  NOD28
 E  NOD29
 E  NOD30
 E  NOD31
 E  NOD32
 E  NOD33
 E  NOD34
 E  NOD35
 E  NOD36
 E  NOD37
 E  NOD38
```

Notes

V417 is a box number to be provided by Iowa State University

70 is to print 70,000 lines (depends on the size of the job)

'VIC' is a user supplied name** for the data

'GARSTUDY' is a user supplied name** for the program

'COST' is a user supplied name** for the cost of servicing a highway segment

'MCOST' is a user supplied name** for the total maintenance cost

VIC is as explained above

COST is as explained above

NOD1 is a user supplied name for highway segment No. 1, etc.

** Any name used should not be more than eight letters or characters.

							Notes
121.	E	NOD99					
122.	E	NOD100					
123.	E	NOD101					
124.	E	NOD102					
125.	E	NOD103					
126.	E	NOD104					
127.	E	NOD105					
128.	E	NOD106					
129.	E	NOD107					
130.	E	NOD108					
131.	E	NOD109					
132.	E	NOD110					
133.	E	NOD111					
134.	E	NOD112					
135.	E	NOD113					
136.	E	NOD114					
137.	E	NOD115					
138.	E	NOD116					
139.	E	NOD117					
140.	E	NOD118					
141.	E	NOD119					
142.	E	NOD120					
143.	E	NOD121					
144.	E	NOD122					
145.	E	NOD123					
146.	E	NOD124					
147.	E	NOD125					
148.	E	NOD126					
149.	E	NOD127					
150.	E	NOD128					
151.	E	NOD129					
152.	E	NOD130					
153.	E	NOD131					
154.	E	NOD132					
155.	E	NOD133					
156.	E	NOD134					
157.	E	NOD135					
158.	E	NOD136					
159.	E	NOD137					
160.	E	NOD138					NOD139 is a user supplied name** for highway segment No. 139. It is the last segment formed in the study
161.	E	NOD139					
162.	E	CLOS9					CLOS9is a user supplied name** for the first garage to be closed. In this case it is Tama (G9)
163.	E	CLOS11					CLOS11 is a user supplied name** for the 2nd garage to be closed.In this case US 30 & Ia 21(G11)new garage
164.	E	CLOS12					CLOS12 is a user supplied name** for the third garage to be closed. In this case it is Blairstown (G12)
165.	COLUMNS						
166.		X1	COST	25087.2	NOD1	1.0	XI is the fraction of segment No. 1 allocated to G(1). $25087.2
167.		X2	COST	250872.0	NOD1	1.0	is the travel time adjusted cost from G1 to segment No. 1, etc.
168.		X3	COST	250872.0	NOD1	1.0	
169.		X4	COST	250872.0	NOD1	1.0	
170.		X5	COST	250872.0	NOD1	1.0	
171.		X6	COST	250872.0	NOD1	1.0	
172.		X7	COST	250872.0	NOD1	1.0	
173.		X8	COST	250872.0	NOD1	1.0	
174.		X9	COST	250872.0	NOD1	1.0	
175.		X9	CLOS9	1.0			
176.		X10	COST	250872.0	NOD1	1.0	
177.		X11	COST	250872.0	NOD1	1.0	
178.		X11	CLOS11	1.0			
179.		X12	COST	250872.0	NOD1	1.0	
180.		X12	CLOS12	1.0			

```
          MCOST     NOD27     1.0                 NOD28     1 ^
          MCOST     NOD29     1.0                 NOD30     1
          MCOST     NOD31     1.0                 NOD32     1.υ
          MCOST     NOD33     1.0                 NOD34     1.0
          MCOST     NOD35     1.0                 NOD36     1.0
          MCOST     NOD37     1.0                 NOD38     1.0
          MCOST     NOD39     1.0                 NOD40     1.0
          MCOST     NOD41     1.0                 NOD42     1.0
          MCOST     NOD43     1.0                 NOD44     1.0
          MCOST     NOD45     1.0                 NOD46     1.0
          MCOST     NOD47     1.0                 NOD48     1.0
          MCOST     NOD49     1.0                 NOD50     1.0
          MCOST     NOD51     1.0                 NOD52     1.0
          MCOST     NOD53     1.0                 NOD54     1.0
          MCOST     NOD55     1.0                 NOD56     1.0
          MCOST     NOD57     1.0                 NOD58     1.0
          MCOST     NOD59     1.0                 NOD60     1.0
          MCOST     NOD61     1.0                 NOD62     1.0
          MCOST     NOD63     1.0                 NOD64     1.0
          MCOST     NOD65     1.0                 NOD66     1.0
          MCOST     NOD67     1.0                 NOD68     1.0
          MCOST     NOD69     1.0                 NOD70     1.0
          MCOST     NOD71     1.0                 NOD72     1.0
          MCOST     NOD73     1.0                 NOD74     1.0
          MCOST     NOD75     1.0                 NOD76     1.0
          MCOST     NOD77     1.0                 NOD78     1.0
          MCOST     NOD79     1.0                 NOD80     1.0
          MCOST     NOD81     1.0                 NOD82     1.0
          MCOST     NOD83     1.0                 NOD84     1.0
          MCOST     NOD85     1.0                 NOD86     1.0
          MCOST     NOD87     1.0                 NOD88     1.0
          MCOST     NOD89     1.0                 NOD90     1.0
          MCOST     NOD91     1.0                 NOD92     1.0
          MCOST     NOD93     1.0                 NOD94     1.0
          MCOST     NOD95     1.0                 NOD96     1.0
          MCOST     NOD97     1.0                 NOD98     1.0
          MCOST     NOD99     1.0                 NOD100    1.0
          MCOST     NOD101    1.0                 NOD102    1.0
          MCOST     NOD103    1.0                 NOD104    1.0
          MCOST     NOD105    1.0                 NOD106    1.0
          MCOST     NOD107    1.0                 NOD108    1.0
          MCOST     NOD109    1.0                 NOD110    1.0
          MCOST     NOD111    1.0                 NOD112    1.0
          MCOST     NOD113    1.0                 NOD114    1.0
          MCOST     NOD115    1.0                 NOD116    1.0
          MCOST     NOD117    1.0                 NOD118    1.0
          MCOST     NOD119    1.0                 NOD120    1.0
          MCOST     NOD121    1.0                 NOD122    1.0
          MCOST     NOD123    1.0                 NOD124    1.0
          MCOST     NOD125    1.0                 NOD126    1.0
          MCOST     NOD127    1.0                 NOD128    1.0
          MCOST     NOD129    1.0                 NOD130    1.0
          MCOST     NOD131    1.0                 NOD132    1.0
          MCOST     NOD133    1.0                 NOD134    1.0
          MCOST     NOD135    1.0                 NOD136    1.0
          MCOST     NOD137    1.0                 NOD138    1.0
          MCOST     NOD139    1.0
      ENDATA
      /*
      //
```

APPENDIX 21 (continued)

							Notes
2761.		X2187	COST	85080.0	NOD137	1.0	
2762.		X2187	CLOS11	1.0			
2763.		X2188	COST	85080.0	NOD137	1.0	
2764.		X2188	CLOS12	1.0			
2765.		X2189	COST	85080.0	NOD137	1.0	
2766.		X2190	COST	85080.0	NOD137	1.0	
2767.		X2191	COST	8508.0	NOD137	1.0	
2768.		X2192	COST	8508.0	NOD137	1.0	
2769.		X2193	COST	732096.0	NOD138	1.0	
2770.		X2194	COST	732096.0	NOD138	1.0	
2771.		X2195	COST	732096.0	NOD138	1.0	
2772.		X2196	COST	732096.0	NOD138	1.0	
2773.		X2197	COST	732096.0	NOD138	1.0	
2774.		X2198	COST	732096.0	NOD138	1.0	
2775.		X2199	COST	732096.0	NOD138	1.0	
2776.		X2200	COST	732096.0	NOD138	1.0	
2777.		X2201	COST	732096.0	NOD138	1.0	
2778.		X2201	CLOS9	1.0			
2779.		X2202	COST	732096.0	NOD138	1.0	
2780.		X2203	COST	732096.0	NOD138	1.0	
2781.		X2203	CLOS11	1.0			
2782.		X2204	COST	732096.0	NOD138	1.0	
2783.		X2204	CLOS12	1.0			
2784.		X2205	COST	732096.0	NOD138	1.0	
2785.		X2206	COST	732096.0	NOD138	1.0	
2786.		X2207	COST	732096.0	NOD138	1.0	
2787.		X2208	COST	74429.8	NOD138	1.0	
2788.		X2209	COST	554000.0	NOD139	1.0	
2789.		X2210	COST	554000.0	NOD139	1.0	
2790.		X2211	COST	554000.0	NOD139	1.0	
2791.		X2212	COST	554000.0	NOD139	1.0	
2792.		X2213	COST	554000.0	NOD139	1.0	
2793.		X2214	COST	554000.0	NOD139	1.0	
2794.		X2215	COST	554000.0	NOD139	1.0	
2795.		X2216	COST	554000.0	NOD139	1.0	
2796.		X2217	COST	554000.0	NOD139	1.0	
2797.		X2217	CLOS9	1.0			
2798.		X2218	COST	554000.0	NOD139	1.0	
2799.		X2219	COST	554000.0	NOD139	1.0	
2800.		X2219	CLOS11	1.0			
2801.		X2220	COST	554000.0	NOD139	1.0	
2802.		X2220	CLOS12	1.0			
2803.		X2221	COST	554000.0	NOD139	1.0	
2804.		X2222	COST	554000.0	NOD139	1.0	
2805.		X2223	COST	554000.0	NOD139	1.0	
2806.		X2224	COST	55400.0	NOD139	1.0	X2224 is the fraction of segment No. 139 allocated to G(16). $55400.0 is the travel time adjusted cost from G(16) to segment No. 139
2807.	RHS						
2808.		MCOST	NOD1	1.0	NOD2	1.0	
2809.		MCOST	NOD3	1.0	NOD4	1.0	
2810.		MCOST	NOD5	1.0	NOD6	1.0	
2811.		MCOST	NOD7	1.0	NOD8	1.0	
2812.		MCOST	NOD9	1.0	NOD10	1.0	
2813.		MCOST	NOD11	1.0	NOD12	1.0	
2814.		MCOST	NOD13	1.0	NOD14	1.0	
2815.		MCOST	NOD15	1.0	NOD16	1.0	
2816.		MCOST	NOD17	1.0	NOD18	1.0	
2817.		MCOST	NOD19	1.0	NOD20	1.0	
2818.		MCOST	NOD21	1.0	NOD22	1.0	
2819.		MCOST	NOD23	1.0	NOD24	1.0	
2820.		MCOST	NOD25	1.0	NOD26	1.0	

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APPENDIX 22
Sample Output for MPSX Computer Program

SOLUTION (OPTIMAL)

TIME = 0.02 MINS. ITERATION NUMBER = 165

...NAME...	...ACTIVITY...	DEFINED AS
FUNCTIONAL	3513942.89997	COST
RESTRAINTS		MCOST

Notes

Total maintenance cost = $3,513,942.89997

NUMBER	COLUMN	AT	ACTIVITY	INPUT COST	LOWER LIMIT	UPPER LIMIT	REDUCED COST
2027	X1886	BS	1.00000	20351.30000	.	NONE	.
2028	X1887	LL	.	176968.00000	.	NONE	156616.70000
2029	X1888	LL	.	176968.00000	.	NONE	156616.70000
2030	X1889	LL	.	338704.00000	.	NONE	299188.50000
2031	X1890	LL	.	338704.00000	.	NONE	299188.50000
2032	X1891	LL	.	338704.00000	.	NONE	299188.50000
2033	X1892	LL	.	338704.00000	.	NONE	299188.50000
2034	X1893	LL	.	338704.00000	.	NONE	299188.50000
2035	X1894	LL	.	338704.00000	.	NONE	299188.50000
2036	X1895	LL	.	338704.00000	.	NONE	299188.50000
2037	X1896	BS	1.00000	39515.50000	.	NONE	.
2038	X1897	LL	.	338704.00000	.	NONE	299188.50000
2039	X1898	LL	.	338704.00000	.	NONE	299188.50000
2040	X1899	BS	.	33870.40000	.	NONE	.
2041	X1900	LL	.	39797.70000	.	NONE	282.20000
2042	X1901	LL	.	338704.00000	.	NONE	299188.50000
2043	X1902	LL	.	40644.50000	.	NONE	1129.00000
2044	X1903	LL	.	338704.00000	.	NONE	299188.50000
2045	X1904	LL	.	338704.00000	.	NONE	299188.50000
2046	X1905	LL	.	27168.00000	.	NONE	24179.50000
2047	X1906	LL	.	27168.00000	.	NONE	24179.50000
2048	X1907	LL	.	27168.00000	.	NONE	24179.50000
2049	X1908	LL	.	27168.00000	.	NONE	24179.50000
2050	X1909	LL	.	27168.00000	.	NONE	24179.50000
2051	X1910	LL	.	27168.00000	.	NONE	24179.50000
2052	X1911	LL	.	27168.00000	.	NONE	24179.50000
2053	X1912	BS	1.00000	2988.50000	.	NONE	.
2054	X1913	LL	.	27168.00000	.	NONE	24179.50000
2055	X1914	LL	.	27168.00000	.	NONE	24179.50000
2056	X1915	LL	.	2875.30000	.	NONE	5531.90000
2057	X1916	LL	.	27168.00000	.	NONE	24179.50000
2058	X1917	LL	.	27168.00000	.	NONE	24179.50000
2059	X1918	LL	.	3033.80000	.	NONE	45.30000
2060	X1919	LL	.	27168.00000	.	NONE	24179.50000
2061	X1920	LL	.	27168.00000	.	NONE	24179.50000
2062	X1921	LL	.	859744.00000	.	NONE	773769.60000
2063	X1922	LL	.	859744.00000	.	NONE	773769.60000
2064	X1923	LL	.	859744.00000	.	NONE	773769.60000
2065	X1924	LL	.	859744.00000	.	NONE	773769.60000
2066	X1925	LL	.	859744.00000	.	NONE	773769.60000
2067	X1926	LL	.	859744.00000	.	NONE	773769.60000
2068	X1927	LL	.	859744.00000	.	NONE	773769.60000
2069	X1928	LL	.	859744.00000	.	NONE	773769.60000
2070	X1929	LL	.	859744.00000	.	NONE	773769.60000
2071	X1930	LL	.	859744.00000	.	NONE	773769.60000
2072	X1931	LL	.	859744.00000	.	NONE	779414.70000
2073	X1932	LL	.	859744.00000	.	NONE	773769.60000
2074	X1933	LL	.	859744.00000	.	NONE	773769.60000
2075	X1934	BS	1.00000	85974.40000	.	NONE	.
2076	X1935	LL	.	859744.00000	.	NONE	773769.60000
2077	X1936	LL	.	859744.00000	.	NONE	773769.60000

Notes

Segment No. 119 is optimally allocated to G(8) with a service cost of $39,515.5. Savings of $1129 is realized due to segment reallocated under optimum allocation. Refer to Table 2.

Segment No. 120 is optimally allocated to G(8) with a service cost of $2988.5. Savings of $45.3 is realized due to segment reallocated under optimum allocation.