EXAMINATION OF EXISTING HIGHWAY MAINTENANCE GARAGE LOCATIONS IN TAMA AND BLAIRSTOWN STUDY AREA

FINAL REPORT

Prepared By
Office of Transportation Research
Planning and Research Division
Iowa Department of Transportation
August 1983

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FINAL REPORT

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I. ABSTRACT

An optimum allocation model has been utilized to examine the existing allocation of highway segments to maintenance garages in the Tama and Blairstown study area. The model has also been used to evaluate the financial impact of closing the highway maintenance garages at Tama and Blairstown and building a new garage at the junction of U.S. 30 and Iowa 21.

The examination of the study area shows that only 13 of 91 highway segments were reallocated under optimum procedures at an annual operational savings of approximately $13,200.

The study concludes there would be an annual operational savings of approximately $48,200 if the garages at Tama and Blairstown were closed and a new garage was built at the junction of U.S. 30 and Iowa 21.

II. INTRODUCTION AND OBJECTIVES

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 associated with closing and/or relocating some of the highway maintenance garages.

The study, "An Optimum Allocation Approach to Closing or Relocating Highway Maintenance Garages in Iowa," (1) had successfully identified a model referred to as an "optimum allocation model." This model was developed by utilizing the highway maintenance-related data currently available at the Iowa Department of Transportation. It can optimally assign highway segments to maintenance garages and evaluate the financial effect of closing or relocating specified maintenance garages in a given study area.

The current project was undertaken at the request of the Office of Maintenance. The objective of this study was to utilize the "optimum allocation model" to examine the existing highway maintenance garage locations in Tama and Blairstown area. The model was used to:

1. Optimally assign highway segments to maintenance garages in the study area.
2. Evaluate the financial effect of relocating the garages at Tama and Blairstown to the junction of U.S. 30 and Iowa 21.

III. THE OPTIMUM ALLOCATION MODEL

The following subsections describe the assumptions required by the optimum allocation model, the study area to be investigated using the model, and the steps necessary to get the type of data usable by the model.

A. Assumptions

1. For the purpose of this study and 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 derive a weighted average speed which is then used to estimate travel times.
2. The highway maintenance cost associated with a route in a given maintenance area is assumed to be uniformly distributed along the route.
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 travel times from garage "X" to segment "Y" and from segment "Y" to garage "X" are assumed to be the same.
5. 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. In the optimum allocation model, the relationship has been quantified by the use of "cost multipliers" (1).
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. Whenever a garage relocation possibility is studied, the garage overhead cost before and after its relocation is assumed to be the same.

8. Capital costs and staffing needs are not considered.

B. Study Area

The study area for this project was provided by the Office of Maintenance. The study area is the Tama and Blairstown part of Iowa and is shown in Appendix 1. It consists of 10 "active" maintenance garages.

C. Source of Data

The fiscal year 1982 labor and equipment costs for all the routes in the study area were supplied by the Office of Maintenance. The overhead costs for the garages in the study area were also supplied by the same office. These costs are shown in Appendix 4.

D. Basic Maintenance and Basic Overhead Costs

The fiscal year 1982 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 1983. The adjustments were made as shown below.

Labor - - - 8%

Equipment - - - 10%

Overhead - - - 8%

These inflation rates were provided by the Office of Maintenance.

The inflation-adjusted labor and equipment costs for a route were combined to a form a single cost. This single cost was referred to as the "basic maintenance" cost for that route. The inflation-adjusted overhead cost for a garage was simply referred to as the "basic overhead" cost of the garage.

The optimum allocation model requires knowledge of the overhead cost of each maintenance garage in the study area. Sometimes such data is not available because in certain maintenance areas the overhead costs for some garages are combined during the record-keeping process. In such situations it was recommended by the Office of Maintenance that 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.

E. Highway Segments

All the routes in each study area were broken up into suitable segments according to the following criteria:

1. Segments should not be more than 25 miles long (per Office of Maintenance).
2. Segments should be reasonably short, so as to increase the accuracy of the model.
3. Segments should be reasonably long, so as to minimize the computation time involved and hence reduce the costs associated with the model.

A total of 91 segments, ranging from one mile to 18 miles in length, were formed in the study area. These segments are shown in Appendix 2.

F. Weighted Average Speed

The optimum allocation model is sensitive to small changes in speed (1), 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. Consequently, it would be erroneous to use a "simple" average speed for all the maintenance activities.

To reduce this type of error, Nkansah and Baig (1) suggested that a "weighted" average speed be used. That "weighted" speed is derived from: the average speeds pertaining to snow and ice control activities and the other maintenance activities; and the relative percentages of snow and ice control activities and the other maintenance activities.

In this study a weighted average speed of 38 mph was used. It was determined as shown below (all data provided by the Office of Maintenance):

% of snow and ice control activities	=	39.1%
Average speed for snow and ice control activities	=	35 mph
Average speed for other maintenance activities	=	40 mph

Therefore,

$$\text{Weighted average speed} = (0.391)(35) + (0.609)(40)$$
$$= 13.7 + 24.4$$
$$= 38 \text{ mph}$$

G. Travel Time-Adjusted Costs

One set of travel times corresponding to the study area was calculated using a weighted average speed of 38 mph and the distances as shown in the July 1981 Maintenance Area Responsibility Maps (2). These travel times were then utilized to adjust the basic maintenance costs of each highway segment through the cost multiplier concept (1).

IV. THE OPTIMUM ALLOCATION MODEL RESULTS

The optimum allocation model was used to investigate the given study area. The following subsections describe the results obtained.

A. Existing and Optimum Allocations

The "existing allocation" refers to the current maintenance areas in the study area. These maintenance areas 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.

The operating costs pertaining to the optimum allocation were determined by applying the optimum allocation model to the study area. To ensure compatibility in cost, the operating costs pertaining to the existing allocation were also determined from travel time-adjusted costs. In this case, however, the travel time-adjusted costs were calculated by utilizing the cost multipliers and the travel times as determined by the existing allocation system. A summary of the results is shown in Table 1 on the next page.

TABLE 1

SEGMENTS REALLOCATED UNDER OPTIMUM ALLOCATION
(Tama and Blairstown Study Area)

	Existing Allocation		Optimum Allocation		
Segment No.	Assigned to Garage at:	Operating Costs* (Dollars/Yr.)	Assigned to Garage at:	Operating Costs* (Dollars/Yr.)	Savings Using Optimum Allocation (Dollars/Yr.)
26	Tama	$16,159	Malcolm	$15,157	$1,002
29	Traer	5,959	Tama	5,730	229
39	Williamsburg	992	Malcolm	942	50
41	Williamsburg	29,312	Malcolm	28,706	606
56	Urbana	8,917	Blairstown	7,482	1,435
57	Urbana	1,203	Blairstown	1,026	177
58	Urbana	28,207	Blairstown	27,146	1,061
59	Urbana	899	Traer	860	39
61	Urbana	25,012	Traer	22,477	2,535
66	Blairstown	2,002	Cedar Rapids	1,941	61
68	Blairstown	15,290	Cedar Rapids	13,491	1,799
73	Cedar Rapids	23,441	Marion	23,069	372
86	Marion	27,702	Urbana	23,828	3,874
				Total =	$13,240

* Operating costs are based on travel time adjusted costs.

Table 1 shows only 13 segments were reallocated under optimum allocation procedures, resulting in annual savings of approximately $13,240. These savings are reasonable. Thus, it can be concluded that the current allocation of highway segments to existing garages within the study area is good for all practical purposes.

B. Relocation of Garages

The optimum allocation model was used to evaluate the financial effect of relocating the garages at Tama and Blairstown to the junction of U.S. 30 and Iowa 21. The results are shown in Table 2.

TABLE 2

COST ANALYSIS OF RELOCATING THE GARAGES AT TAMA AND BLAIRSTOWN TO JUNCTION U.S. 30 AND IOWA 21 USING OPTIMUM ALLOCATION

	Operating Costs*				
(1) Item	(2) Garage(s) Not Closed (Dollars)	(3) Garage(s) Closed (Dollars)	(4) Increased Travel Cost (Dollars) (3) - (2)	(5) Overhead Cost of Garages Closed Less Overhead at New Location (Dollars)	(6) Estimated Savings (1983 Dollars) (5) - (4)
All Garages	$2,053,807				
Tama & Blairstown Relocated		$2,057,017	$3,210	$51,469**	$48,259

* Operating costs are based on travel time-adjusted costs.

** Estimate of $35,000 for overhead costs at new location given by the Office of Maintenance, Highway Division, Iowa Department of Transportation.

Table 2 shows that relocating Tama and Blairstown garages at Jct. U.S. 30 and Iowa 21 slightly increased travel cost by approximately $3,210. However, there is an annual operational savings of approximately $48,259.

The optimal assignment of highway segments to garages in the study area for the case investigated is shown in Appendix 5.

V. CONCLUSION

In this study an optimum allocation model has been used to examine the highway maintenance area served by Tama and Blairstown study area.

The findings indicate that the existing allocation of highway segments to the maintenance garages is good for all practical purposes. In fact, only 13 of 91 highway segments were reallocated under optimum procedures resulting in operational savings estimate of approximately $13,200.

Relocation of the garages at Tama and Blairstown to Jct. U.S. 30 and Iowa 21 would result in annual operational savings of approximately $48,200.

These are reasonable savings and worthy of pursuit subject to the assumptions and limitations of the study as discussed in Sections III. A. and VI., respectively.

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 (for various maintenance activities) used to calculate the weighted average speed.
4. The garage overhead costs before and after its relocation are assumed to be the same.
5. Capital costs and staffing needs are not considered.

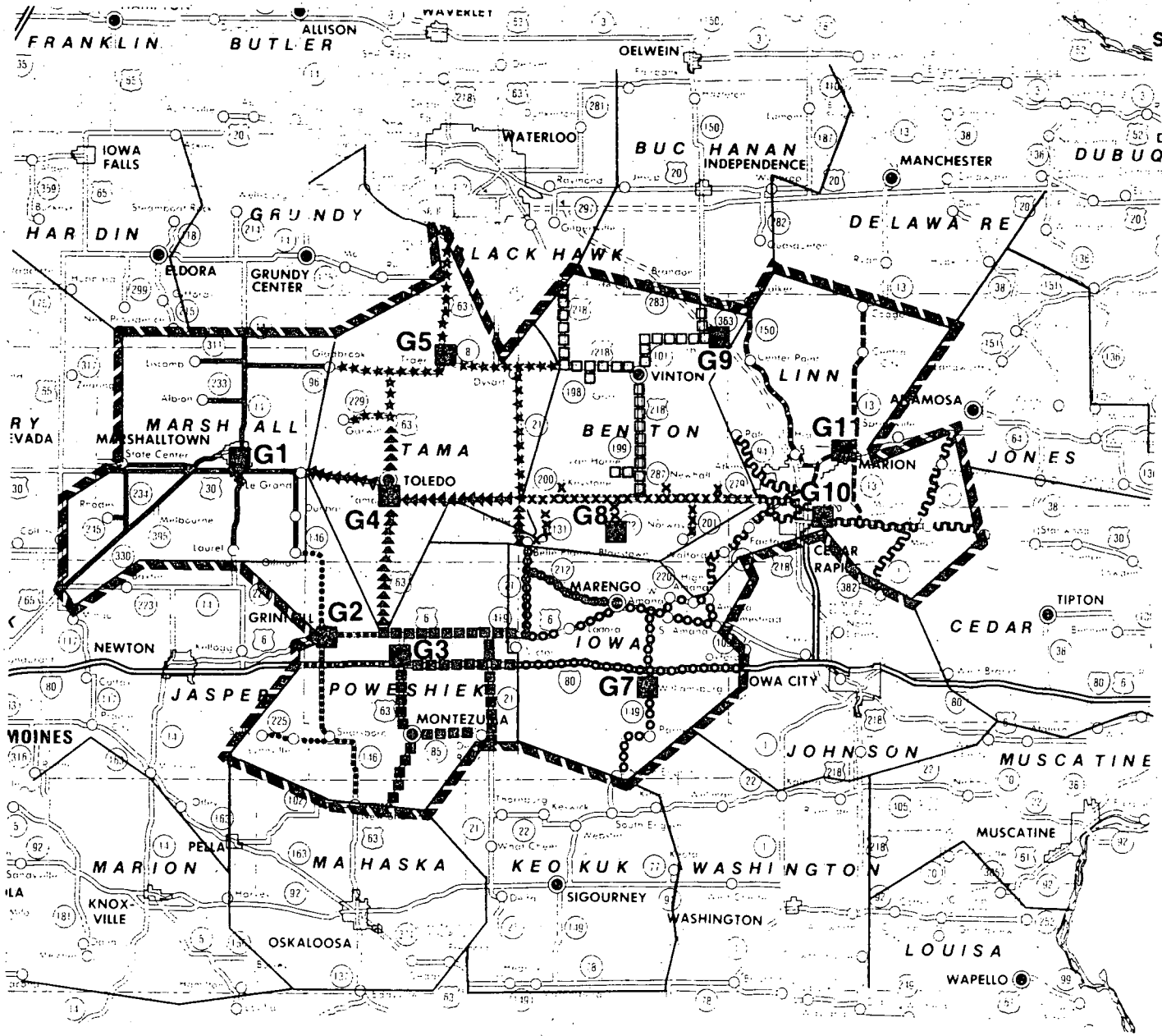
VII. REFERENCES

1. Paul T. Nkansah and Saleem Baig. An Optimum Allocation Approach to Closing or Relocating Highway Maintenance Garages in Iowa. Final Report. Office of Transportation Research, Planning and Research Division, Iowa Department of Transportation. June 1981.

2. Iowa Department of Transportation, Office of Maintenance, Maintenance Area Responsibility Maps. July 1981.

APPENDICES

Appendix 1
Tama and Blairstown Study Area Showing Existing Highway Segments Allocations

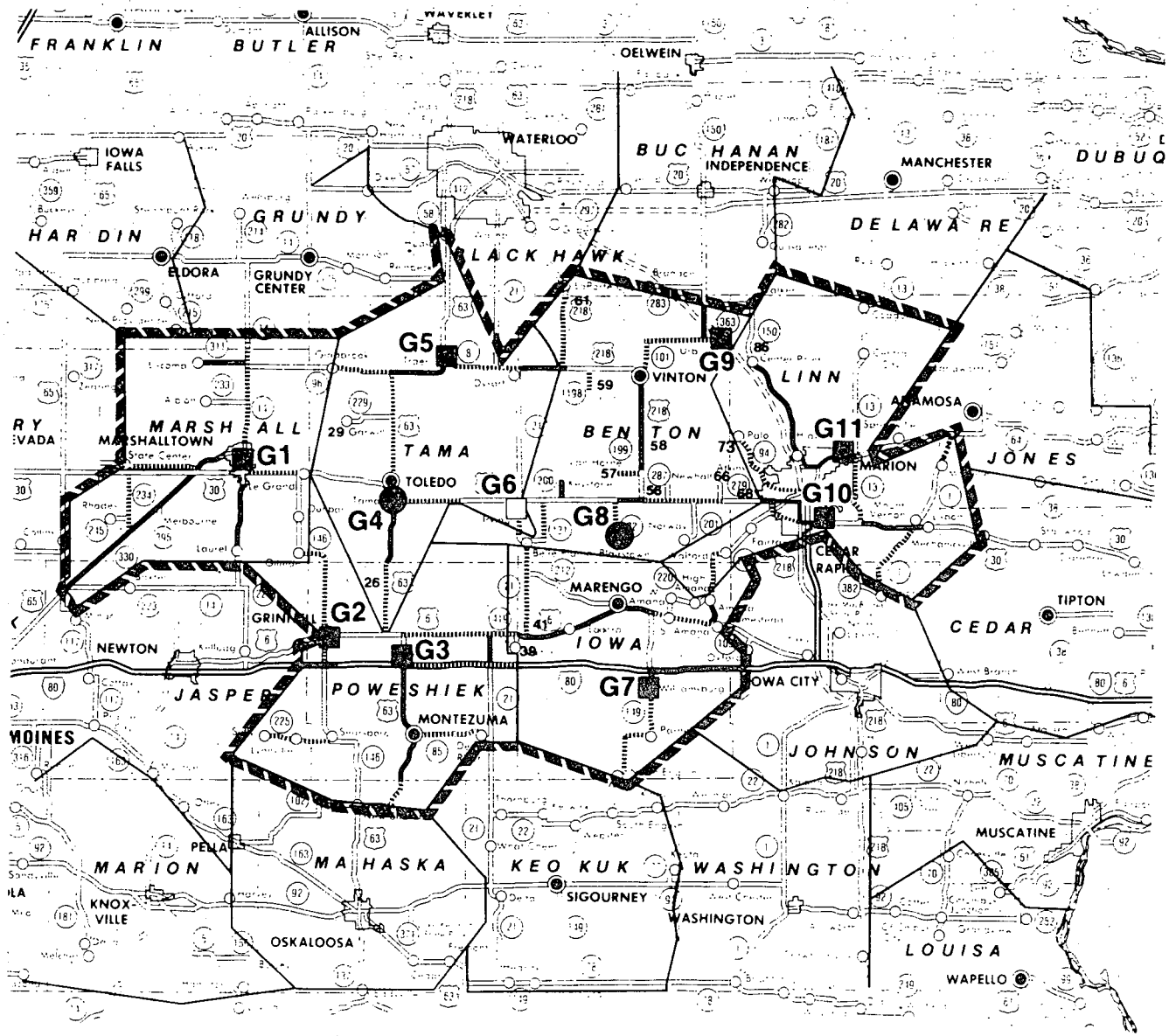


Segment Served	Location
—	Marshalltown (G1)
•••	Grinnell (G2)
▬	Malcolm (G3)
◀◀◀	Tama (G4)
★★	Traer (G5)
∞∞	Williamsburg (G7)
×××	Blairstown (G8)
□□	Urbana (G9)
∪∪	Cedar Rapids (G10)
--	Marion (G11)

Legend:

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

Appendix 2
Tama and Blairstown Study Area Showing Optimal Highway Segments Allocations 11 Garages and 91 Highway Segments

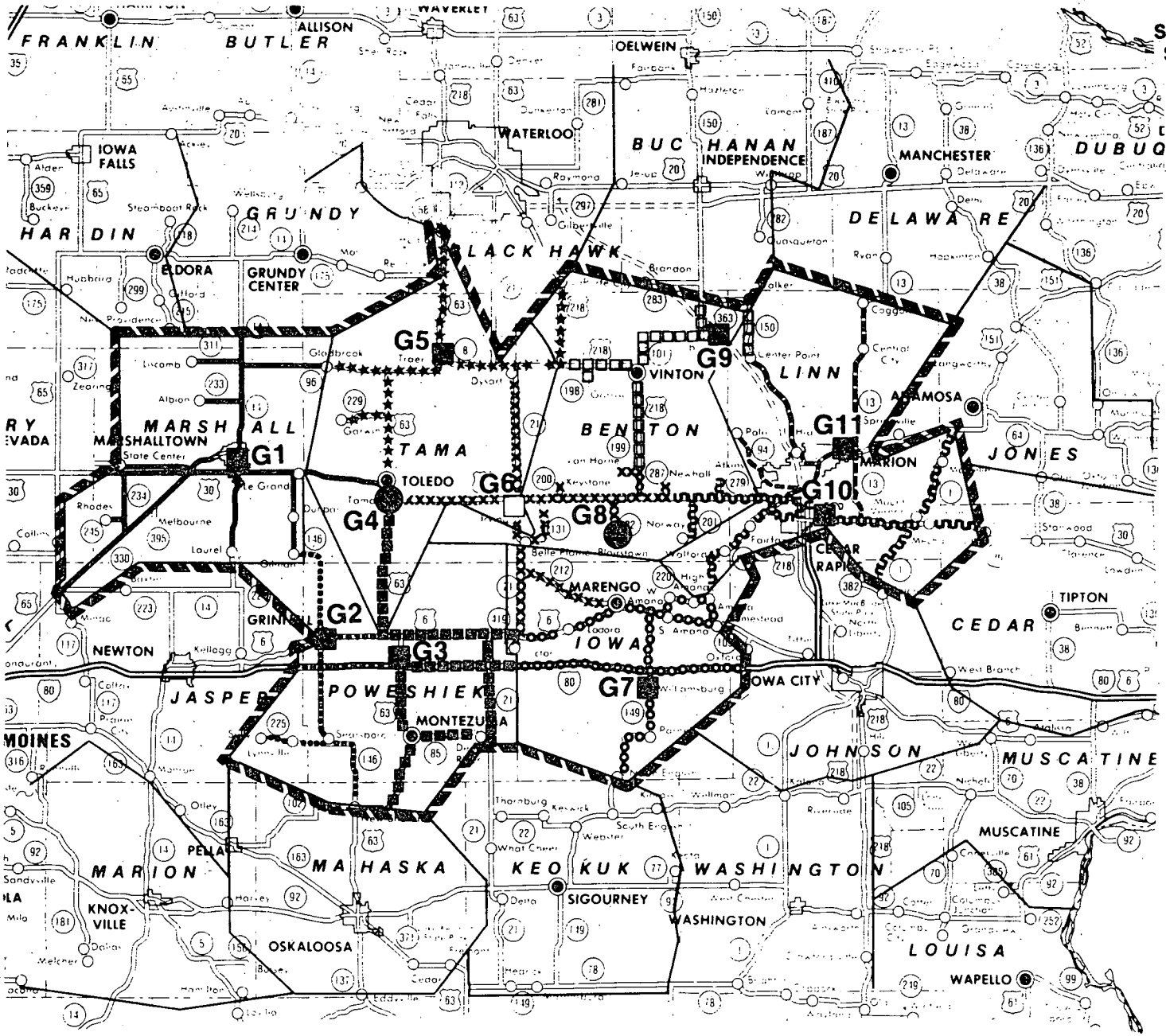


Garage	Location
G1	Marshalltown
G2	Grinnell
G3	Malcolm
G4	Tama (to be closed later)
G5	Traer
G6	Jct. U.S. 30 & Iowa 21 (New garage to be built later)
G7	Williamsburg
G8	Blairstown (to be closed later)
G9	Urbana
G10	Cedar Rapids
G11	Marion

Legend:

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

Study Area Showing Optimal Highway Segment Allocations (Tama & Blairstown Garages Closed, new garage relocated at Jct. U.S. 30 & Iowa 21)



Segment Served	Location
—	Marshalltown (G1)
●●●	Grinnell (G2)
■■■	Malcolm (G3)
	Tama (G4 Closed)
★★	Traer (G5)
×××	(Jct. U.S. 30 & Iowa 21 (G6 Relocated garage)
○○○	Williamsburg (G7)
	Blairstown (G8 Closed)
□□	Urbana (G9)
∽∽	Cedar Rapids (G10)
--	Marion (G11)

Legend:

- ■ Existing garage
- ● Closed garage
- G Garage number
- □ Relocated garage
- ▬▬ Study boundary area

APPENDIX 4

FISCAL YEAR 1982
LABOR, EQUIPMENT AND OVERHEAD COSTS
FOR THE ROUTES AND GARAGES IN TAMA AND BLAIRSTOWN STUDY AREA

Location and Number of Garages	1982 Garage Related Costs (Dollars)	Routes Served by Garage	1982 Labor Cost (Dollars)	1982 Equipment Cost (Dollars)
Marshalltown (1104)	$69,890	14	$41,233	$40,502
		30	26,351	26,772
		96	8,408	9,368
		146	7,579	11,222
		233	3,712	3,257
		234	7,178	7,149
		245	586	490
		311	2,383	2,679
		330	36,892	34,359
		395	38	39
		930	10,828	10,660
Grinnel (1305)	58,310	6	23,666	20,254
		80	40,549	33,114
		146	26,359	24,173
		225	6,938	5,221
Malcom (1306)	62,477	6	11,125	8,776
		21	18,600	19,825
		63	44,155	36,742
		80	43,718	35,020
		85	4,912	5,344
		146	461	194
Tama (1308)	34,675	21	3,448	3,895
		30	48,984	42,278
		63	25,015	25,088
Traer (1309)	35,945	8	11,370	6,994
		21	11,759	11,280
		63	42,105	31,699
		96	3,975	2,998
		229	2,559	3,738
Blairstown (6101)	45,389	21	488	294
		30	33,668	39,118
		82	5,766	5,737
		131	5,736	4,177
		200	929	1,316
		201	2,946	2,900
		218	5,180	3,890
		279	1,046	1,057
		287	148	98

APPENDIX 4 (continued)

Location and Number of Garages	1982 Garage Related Costs (Dollars)	Routes Served by Garage	1982 Labor Cost (Dollars)	1982 Equipment Cost (Dollars)
Vinton (6102)	$45,389	21	$ 570	$ 819
		30	5,117	7,126
		101	12,588	11,772
		198	401	488
		199	363	791
		218	41,393	41,325
		363	1017	779
Cedar Rapids (6106)	96,000	1	29,831	29,121
		30	70,506	79,556
		94	11,533	14,045
		149	31,820	30,455
		218	5,108	6,316
		380	92,457	123,486
Marion (6107)	41,847	13	42,949	41,460
		150	52,514	47,159
		151	9,124	8,386
		941	15,420	13,720
Williamsburg (6405)	76,878	6	20,637	18,886
		21	14,170	13,654
		80	77,849	71,439
		149	42,532	35,519
		212	8,074	7,707
		220	6,128	5,831
		419	609	368

Source: Office of Maintenance, Highway Division, Iowa Department of Transportation.

APPENDIX 5

OPTIMAL ASSIGNMENT OF HIGHWAY SEGMENTS TO GARAGES
IN TAMA AND BLAIRSTOWN STUDY AREA

Highway Segment No.	Garage G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
1	x										
2	x										
3	x										
4	x										
5	x										
6	x										
7	x										
8	x										
9	x										
10	x										
11	x										
12	x										
13	x										
14		x									
15		x									
16		x									
17		x									
18		x									
19			x								
20			x								
21			x								
22			x								
23			x								
24			x								
25	x[4,8]			x							
26			x								
27			x[4,8]	x							
28				x	x[4,8]						
29				x	x[4,8]						
30					x						
31					x						
32				x		x[4,8]					
33				x		x[4,8]					
34				x		x[4,8]					
35					x	x[4,8]					
36					x						
37					x						
38					x						
39			x			x[4,8]					
40							x				
41			x			x[4,8]					
42						x[4,8]	x				
43							x				
44							x				
45							x				
46							x				
47							x				
48							x				

APPENDIX 5 (continued)

Highway Segment No.	Garage										
	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
49							x				
50						$x^{4,8}$		x			
51						$x^{4,8}$		x			
52						$x^{4,8}$		x			
53						$x^{4,8}$		x			
54						$x^{4,8}$		x			
55						$x^{4,8}$		x			
56						$x^{4,8}$		x			
57						$x^{4,8}$		x			
58								x	$x^{4,8}$		
59					x						
60									x		
61					x						
62									x		
63						$x^{4,8}$		x			
64								x		$x^{4,8}$	
65								x		$x^{4,8}$	
66										x	
67									x		
68										x	
69										x	
70										x	
71										x	
72										x	
73											x
74											x
75											x
76										x	
77										x	
78										x	
79											x
80											x
81										x	
82										x	
83										x	
84										x	
85									x		
86									x		
87	x										
88		x									
89			x								
90			x								
91										x	

Legend: x - Optimal Assignment of Segment to Garage

$x^{i,j}$ - Optimal Assignment of Segment to Garages When Garages "i" and "j" Are Closed

Appendix 6

Sample Output of the MPSX Computer Program Using a Partial Data Set

COLUMNS				
X1	COST	1015.70000	NOD1	1.00000
X2	COST	9376.00000	NOD1	1.00000
X3	COST	9376.00000	NOD1	1.00000
X4	COST	9376.00000	NOD1	1.00000
X4	CLOS4	1.00000		
X5	COST	9376.00000	NOD1	1.00000
X6	COST	9376.00000	NOD1	1.00000
X7	COST	9376.00000	NOD1	1.00000
X8	COST	9376.00000	NOD1	1.00000
X8	CLOS8	1.00000		
X9	COST	9376.00000	NOD1	1.00000
X10	COST	9376.00000	NOD1	1.00000
X11	COST	9376.00000	NOD1	1.00000
X12	COST	13429.80000	NOD2	1.00000
X13	COST	124928.0000	NOD2	1.00000
X14	COST	124928.0000	NOD2	1.00000
X15	COST	124928.0000	NOD2	1.00000
X15	CLOS4	1.00000		
X16	COST	124928.0000	NOD2	1.00000
X17	COST	124928.0000	NOD2	1.00000
X18	COST	124928.0000	NOD2	1.00000
X19	COST	124928.0000	NOD2	1.00000
X19	CLOS8	1.00000		
X20	COST	124928.0000	NOD2	1.00000
X21	COST	124928.0000	NOD2	1.00000
X22	COST	124928.0000	NOD2	1.00000
X23	COST	49507.00000	NOD3	1.00000
X24	COST	464128.0000	NOD3	1.00000
X25	COST	464128.0000	NOD3	1.00000
X26	COST	464128.0000	NOD3	1.00000
X26	CLOS4	1.00000		
X27	COST	464128.0000	NOD3	1.00000
X28	COST	464128.0000	NOD3	1.00000
X29	COST	464128.0000	NOD3	1.00000
X30	COST	464128.0000	NOD3	1.00000
X30	CLOS8	1.00000		
X31	COST	464128.0000	NOD3	1.00000
X32	COST	464128.0000	NOD3	1.00000
X33	COST	464128.0000	NOD3	1.00000
X34	COST	67.80000	NOD4	1.00000
X35	COST	672.00000	NOD4	1.00000
X36	COST	672.00000	NOD4	1.00000
X37	COST	672.00000	NOD4	1.00000
X37	CLOS4	1.00000		
X38	COST	672.00000	NOD4	1.00000
X39	COST	672.00000	NOD4	1.00000
X40	COST	672.00000	NOD4	1.00000
X41	COST	672.00000	NOD4	1.00000
X41	CLOS8	1.00000		
X42	COST	672.00000	NOD4	1.00000
X43	COST	672.00000	NOD4	1.00000
X44	COST	672.00000	NOD4	1.00000
X45	COST	266232.20000	NOD5	1.00000
X46	COST	266232.0000	NOD5	1.00000
X47	COST	266232.0000	NOD5	1.00000
X48	COST	266232.0000	NOD5	1.00000
X48	CLOS4	1.00000		
X49	COST	266232.0000	NOD5	1.00000
X50	COST	266232.0000	NOD5	1.00000
X51	COST	266232.0000	NOD5	1.00000
X52	COST	266232.0000	NOD5	1.00000

NOTES:

X1 is the fraction of segment No. 1 allocated to garage No. 1. $1,015.7 is the travel time-adjusted cost from garage No. 1 to segment No. 1.

"

"

"

"

X11 is the fraction of segment No. 1 allocated to garage No. 11. $9,376 is the travel time-adjusted cost from garage No. 11 to segment No. 1.

X12 is the fraction of segment No. 2 allocated to garage No. 1. $13,429.8 is the travel time-adjusted cost from garage No. 1 to segment No. 2,, etc.

CLOS4 and CLOS8 is the user supplied name for closing garages 4 and 8 respectively.

MPSX-PTF19.. EXECUTOR. MPSX RELEASE 1 MOD LEVEL 6

SECTION 2 - COLUMNS

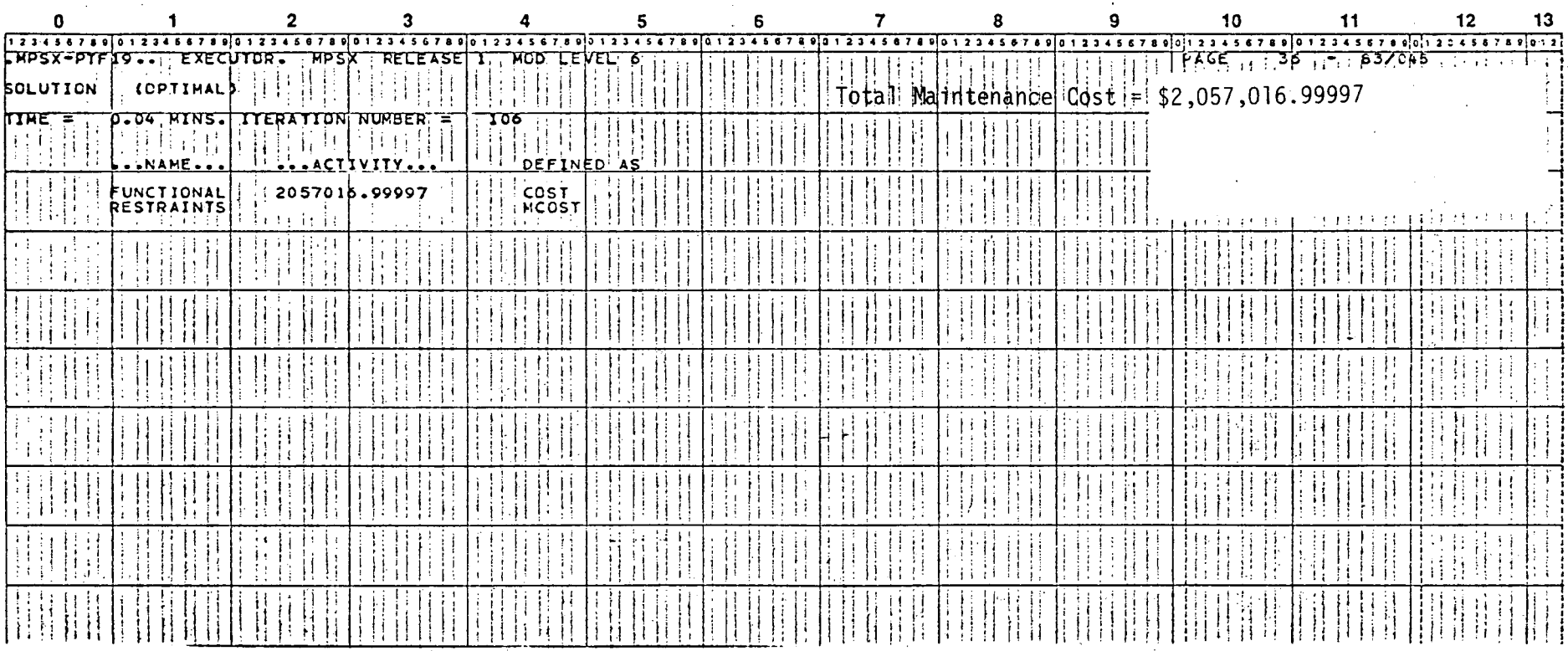
NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST
95	X1	BS	1.00000	1015.70000	.	NONE	.
96	X2	LL	.	9376.00000	.	NONE	8360.30000
97	X3	LL	.	9376.00000	.	NONE	8360.30000
98	X4	LL	.	9376.00000	.	NONE	10345.40000
99	X5	LL	.	9376.00000	.	NONE	8360.30000
100	X6	LL	.	9376.00000	.	NONE	8360.30000
101	X7	LL	.	9376.00000	.	NONE	8360.30000
102	X8	LL	.	9376.00000	.	NONE	9839.40000
103	X9	LL	.	9376.00000	.	NONE	8360.30000
104	X10	LL	.	9376.00000	.	NONE	8360.30000
105	X11	LL	.	9376.00000	.	NONE	8360.30000
106	X12	BS	1.00000	13429.80000	.	NONE	.
107	X13	LL	.	124928.00000	.	NONE	111498.20000
108	X14	LL	.	124928.00000	.	NONE	111498.20000
109	X15	LL	.	124928.00000	.	NONE	113463.30000
110	X16	LL	.	124928.00000	.	NONE	111498.20000
111	X17	LL	.	124928.00000	.	NONE	111498.20000
112	X18	LL	.	124928.00000	.	NONE	111498.20000
113	X19	LL	.	124928.00000	.	NONE	112977.30000
114	X20	LL	.	124928.00000	.	NONE	111498.20000
115	X21	LL	.	124928.00000	.	NONE	111498.20000
116	X22	LL	.	124928.00000	.	NONE	111498.20000
117	X23	BS	1.00000	49507.60000	.	NONE	.
118	X24	LL	.	464128.00000	.	NONE	414621.00000
119	X25	LL	.	464128.00000	.	NONE	414621.00000
120	X26	LL	.	464128.00000	.	NONE	416606.10000
121	X27	LL	.	464128.00000	.	NONE	414621.00000
122	X28	LL	.	464128.00000	.	NONE	414621.00000
123	X29	LL	.	464128.00000	.	NONE	414621.00000
124	X30	LL	.	464128.00000	.	NONE	416100.10000
125	X31	LL	.	464128.00000	.	NONE	414621.00000
126	X32	LL	.	464128.00000	.	NONE	414621.00000
127	X33	LL	.	464128.00000	.	NONE	414621.00000
128	X34	BS	1.00000	67.60000	.	NONE	.
129	X35	LL	.	672.00000	.	NONE	604.20000
130	X36	LL	.	672.00000	.	NONE	604.20000
131	X37	LL	.	672.00000	.	NONE	2589.30000
132	X38	LL	.	672.00000	.	NONE	604.20000
133	X39	LL	.	672.00000	.	NONE	604.20000
134	X40	LL	.	672.00000	.	NONE	604.20000
135	X41	LL	.	672.00000	.	NONE	2083.30000
136	X42	LL	.	672.00000	.	NONE	604.20000
137	X43	LL	.	672.00000	.	NONE	604.20000
138	X44	LL	.	672.00000	.	NONE	604.20000
139	X45	BS	1.00000	26623.20000	.	NONE	.
140	X46	LL	.	266232.00000	.	NONE	239608.80000
141	X47	LL	.	266232.00000	.	NONE	239608.80000
142	X48	LL	.	266232.00000	.	NONE	241593.90000
143	X49	LL	.	266232.00000	.	NONE	239608.80000

Notes:

Segment No. 1 is allocated to garage No. 1 with a service cost of $1,015.7. Segment No. 2 is allocated to garage No. 1 with a service cost of $13,429.8, etc.
The column "reduced cost" is the amount of savings in dollars associated with the given allocation.

Appendix 6 (Continued)

NOTES:



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SOLUTION (OPTIMAL) Total Maintenance Cost = $2,057,016.99997

TIME = 0.04 MINS. ITERATION NUMBER = 106

...NAME...	...ACTIVITY...	DEFINED AS
FUNCTIONAL RESTRAINTS	2057016.99997	COST MCOST

APPENDIX 7
SEGMENTS REALLOCATED UNDER OPTIMUM ALLOCATION
(TAMA & BLAIRSTOWN STUDY AREA)

Highway Segment No.	Length of Segment (Miles)	Route No.	Originally Assigned to	Optimally Assigned to	*Basic Maintenance Costs (1983 Dollars)
26	8.04	63	Tama	Malcolm	$18,790
29	5.41	229	Traer	Tama	6,876
39	1.04	419	Williamsburg	Malcolm	1,063
41	9.82	21	Williamsburg	Malcolm	30,323
56	2.95	218	Urbana	Blairstown	9,353
57	2.67	199	Urbana	Blairstown	1,262
58	10.04	218	Urbana	Blairstown	31,812
59	2.24	198	Urbana	Traer	970
61	8.00	218	Urbana	Traer	25,350
66	1.98	279	Blairstown	Cedar Rapids	2,293
68	5.33	30	Blairstown	Cedar Rapids	16,864
73	11.16	94	Cedar Rapids	Marion	27,906
86	6.12	150	Marion	Urbana	29,059

* 1983 labor and equipment costs based on the 1982 cost adjusted for inflation.

APPENDIX 8
SEGMENTS REALLOCATED UNDER OPTIMUM ALLOCATION
(TAMA & BLAIRSTOWN GARAGES CLOSED,
GARAGE AT JUNCTION U.S. 30 and IOWA 21 OPENED)

Highway Segment No.	Length of Segment (Miles)	Route No.	Originally Assigned to	Optimally Assigned to	*Basic Maintenance Costs (1983 Dollars)
25	9.70	30	Tama	Marshalltown	$38,219
27	9.10	63	Tama	Malcolm	21,269
28	12.96	63	Tama	Traer	34,014
32	7.77	30	Tama	Jct. U.S. 30 & Ia. 21	30,595
33	7.77	30	Tama	Jct. U.S. 30 & Ia. 21	30,595
34	4.00	21	Tama	Jct. U.S. 30 & Ia. 21	4,596
35	14.96	21	Traer	Jct. U.S. 30 & Ia. 21	28,521
39	1.04	419	Williamsburg	Jct. U.S. 30 & Ia. 21	1,063
41	9.82	21	Williamsburg	Jct. U.S. 30 & Ia. 21	30,323
42	12.22	212	Williamsburg	Jct. U.S. 30 & Ia. 21	17,198
50	2.12	21	Blairstown	Jct. U.S. 30 & Ia. 21	2,367
51	6.47	131	Blairstown	Jct. U.S. 30 & Ia. 21	10,790
52	10.95	30	Blairstown	Jct. U.S. 30 & Ia. 21	34,638
53	2.16	200	Blairstown	Jct. U.S. 30 & Ia. 21	2,451

APPENDIX 8 (Continued)

Highway Segment No.	Length of Segment (Miles)	Route No.	Originally Assigned to	Optimally Assigned to	*Basic Maintenance Costs (1983 Dollars)
54	3.02	30	Blairstown	Jct. U.S. 30 & Ia. 21	$ 9,559
55	3.75	82	Blairstown	Jct. U.S. 30 & Ia. 21	12,538
56	2.95	218	Urbana	Jct. U.S. 30 & Ia. 21	9,353
57	2.67	199	Urbana	Jct. U.S. 30 & Ia. 21	1,262
63	1.93	287	Blairstown	Jct. U.S. 30 & Ia. 21	268
64	10.02	30	Blairstown	Cedar Rapids	31,697
65	4.77	201	Blairstown	Cedar Rapids	6,372

* 1983 labor and equipment costs based on the 1982 cost adjusted for inflation.