EXAMINATION OF EXISTING HIGHWAY MAINTENANCE GARAGE LOCATIONS IN TWO STUDY AREAS IN IOWA

FINAL REPORT

PREPARED BY
OFFICE OF TRANSPORTATION RESEARCH
PLANNING AND RESEARCH DIVISION
IOWA DEPARTMENT OF TRANSPORTATION

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I. EXECUTIVE SUMMARY

During the 1980-81 fiscal year, the Office of Transportation Research conducted a study (1) to examine the existing locations of highway maintenance garages in a study area provided by the Office of Maintenance. The study successfully identified a model referred to as an "Optimum Allocation Model" for examining highway maintenance garage locations in a given area. This model can optimally assign highway segments to maintenance garages and can also be used to evaluate the financial impact of closing or relocating a highway maintenance garage utilizing the highway maintenance-related data currently available at the Iowa DOT.

The present study employs the optimum allocation model to examine the existing highway maintenance garage locations in two selected areas in the southeastern and southwestern parts of the state. These areas were selected by the Office of Maintenance and are referred to as "Study Area No. 1" and "Study Area No. 2" in this study. These study areas are shown in Appendices 1 and 2, respectively.

The investigation shows that in each study area the existing allocation of highway segments to the maintenance garages is good for all practical purposes. In fact, only three of 61 highway segments (segments No. 14, 46 & 52) in Study Area No. 1, and two of 67 segments (segments No. 49 and 56) were reallocated under optimum allocation procedures. It was found, however, substantial cost savings could be achieved by closing some of the maintenance garages. In particular, it is noted that:

1. Annual savings of approximately $12,700 would be achieved in Study Area No. 1 if the garage at Columbus Junction was closed. The garage at Nichols is already officially closed.

2. A greater savings (approximately $18,500 per year) would be achieved in Study Area No. 1 if the garage at Nichols were re-opened, while the garages at Iowa City and Columbus Junction were simultaneously closed.

3. The closure of the garage at Nichols is expected to yield only a small savings (approximately $1800 per year). Also, with the garage at Nichols closed only a small savings (approximately $5,500 per year) is achievable by closing the garage at Iowa City.

4. There would be an annual savings of approximately $22,700 in Study Area No. 2, without unduly increasing dead-end travel time, if the garages at Emerson and Shenandoah were closed.

In summary, it is recommended the closure of the maintenance garage at Nichols be re-evaluated by the Office of Maintenance in the light of the findings of this study and other considerations. In particular, the re-opening of the Nichols garage with simultaneous closure of the garages at Iowa City and Columbus Junction (estimated savings of $18,500 per year) should be carefully compared with the alternative of closing the garages at Nichols and Columbus Junction (estimated savings of $12,700 per year). It is further recommended that serious consideration be given to closing the garages at Emerson and Shenandoah (estimated savings of $22,700 per year).

Capital costs and staffing needs have not been considered in this study. Also, in view of the assumptions made in this study (Section III. A.) and stated limitations (Section VI), it is recommended the estimated cost savings reported here be utilized as only the "guiding tools" in any decision-making process pertaining to the garages studied.

II. INTRODUCTION AND OBJECTIVES

During the 1980-81 fiscal year, the Office of Transportation Research conducted a study to examine the existing locations of highway maintenance garages in a given study area provided by the Office of Maintenance. The purpose of the study was to determine the feasibility of closing and/or relocating some of the highway maintenance garages to achieve more effective and efficient use of available resources.

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 impact of closing or relocating a specified maintenance garage 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 two selected areas in the southeastern and southwestern parts of the state. The model was used to:

1. Optimally assign highway segments to maintenance garages in each study area.
2. Evaluate the financial impact of closing and/or relocating a specified number of maintenance garages in each study area.

III. THE OPTIMUM ALLOCATION MODEL

The following subsections describe the assumptions required by the optimum allocation model, the study areas 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 areas 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 Areas

The study areas for this project were provided by the Office of Maintenance. Study Area No. 1 is in the southeastern part of Iowa and is shown in Appendix 1. It consists of 10 "active" maintenance garages and one "non-active" maintenance garage. Study Area No. 2 is in the southwestern part of Iowa and is shown in Appendix 2. It consists of 11 "active" maintenance garages.

C. Source of Data

The fiscal year 1981 labor and equipment costs for all the routes in the two study areas were supplied by the Office of Maintenance. The overhead costs for the garages in each of the two study areas were also supplied by the same office. These costs are shown in Appendix 3 for Study Area No. 1 and in Appendix 4 for study Area No. 2.

D. Basic Maintenance and Basic Overhead Costs

The fiscal year 1981 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 1982. The adjustments were made as shown on the next page.

Labor - - - 8%

Equipment - 13%

Overhead - 15%

These inflation rates were provided by the Office of Maintenance.

The inflation-adjusted labor and equipment costs for a route were combined to 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 for 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 61 segments, ranging from four miles to 17 miles in length, were formed in Study Area No. 1. These segments are shown in Appendix 1. In Study Area No. 2 a total of 67 segments ranging from three miles to 21 miles in length were formed. These segments are shown in Appendix 2.

F. Weighted Average Speed

The optimum allocation model has been found to be 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: (1) the average speeds pertaining to snow and ice control activitites and the other maintenance activities; and (2) the relative percentages of snow and ice control activities and the other maintenance activities.

In this study a weighted average speed of 39 mph was used for both study areas. It was determined as shown on the next page (all data provided by the Office of Maintenance):

Study Area No. 1

% of snow and ice control activities = 19.7%

Average speed for snow and ice control activities = 35 mph

Average speed for other maintenance activities = 40 mph

Therefore,

$$\begin{aligned}\text{Weighted average speed} &= (0.197(35) + (0.803)(40) \\ &= 6.9 + 32.1 \\ &= \underline{39}\text{ mph}\end{aligned}$$

Study Area No. 2

% of snow and ice control activities = 18.8%

Average speed for snow and ice control activities = 35 mph

Average speed for other maintenance activities = 40 mph

Therefore,

$$\begin{aligned}\text{Weighted average speed} &= (0.188(35) + (0.812)(40) \\ &= 6.58 + 32.48 \\ &\approx \underline{39}\text{ mph}\end{aligned}$$

G. Travel Time-Adjusted Costs

Two sets of travel times corresponding to the two study areas were calculated using a weighted average speed of 39 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 cost 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 two given study areas. The following subsections describe the results obtained.

A. Investigation of Study Area No. 1

1. 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
(Study Area No. 1)

	Existing Allocation		Optimum Allocation		Cost Savings Using Optimum Allocation (Dollars/Yr.)
Segment No.	Assigned to Garage at:	Operating Costs* (Dollars/Yr.)	Assigned to Garage at:	Operating Costs* (Dollars/Yr.)	
14	Washington	$18,207	Iowa City	$17,659	$548
46	Muscatine	10,152	Tipton	9,990	162
52	Muscatine	8,596	Tipton	8,122	474
				Total =	1,184

* Operating costs are based on travel time adjusted costs.

Table 1 shows only three segments (segment Nos. 14, 46 and 52) were reallocated under optimum allocation procedures, resulting in annual savings of approximately $1,184. This savings is very small. 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.

2. Closing of Garages

The optimum allocation model was used to evaluate the financial impact of closing one or more garages in Study Area No. 1. The results are shown in Table 2 on the next page.

TABLE 2

COST ANALYSIS OF CLOSING SPECIFIED GARAGES USING OPTIMUM ALLOCATION

(Study Area No. 1)

	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 (Dollars)	(6) Estimated Cost Savings (1982 Dollars) (5) - (4)
All Garages	$1,438,282				
Wapello, Nichols Columbus Jct.		$1,456,171	$17,889	$24,417	$+6,528
Wapello, Nichols		1,448,264	9,982	9,872	-110
Wapello, Columbus Jct.		1,449,466	11,184	18,181	+6,997
Columbus Jct. Nichols		1,446,315	8,033	20,781	+12,748
Iowa City, Columbus Jct.		1,444,197	5,915	24,422	+18,507
Iowa City, Nichols		1,448,867	10,585	16,113	+5,528
Iowa City		1,442,757	4,475	9,877**	+5,402
Wapello		1,443,807	5,525	3,636**	-1,889
Columbus Jct.		1,439,723	1,441	14,545**	+13,104
Nichols		1,442,739	4,457	6,236**	+1,779

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

** Overhead cost was estimated from "combined overhead costs".

It is observed from Table 2:

- (a) If the garage at Nichols is not closed:
    - i. The greatest savings (approximately $18,507 per year) could be achieved by simultaneously closing the garages at Iowa City and Columbus Junction; and
    - ii. A significant savings could also be achieved by closing the garage at Columbus Junction (savings of approximately $13,104 per year).
- (b) If the garage at Nichols is closed (as is currently the case):
    - i. Closing the garage at Columbus Junction would yield the greatest amount of savings (approximately $12,748 per year).
    - ii. Closing the garage at Iowa City would only yield approximately $5,528 in annual savings.
- (c) Only a minimal savings (approximately $1,779 per year) would be realized from the closure of the garage at Nichols; and
- (d) Closing the garage at Wapello does not produce any cost savings. In fact, a loss of approximately $1,889 would be incurred annually.

Whenever a garage is closed there is always a reallocation of the highway segments in the study area. Appendix 5 shows the optimal assignment of highway segments to garages in Study Area No. 1 for the various cases investigated.

B. Investigation of Study Area No. 2

1. Existing and Optimum Allocations

The existing and optimum allocations for Study Area No. 2 were also compared using the same procedure outlined in Section IV.A.1. The results are shown in Table 3 on the next page.

TABLE 3

SEGMENTS REALLOCATED UNDER OPTIMUM ALLOCATION
(STUDY AREA NO. 2)

	Existing Allocation		Optimum Allocation		Cost Savings Using
Segment No.	Assigned to Garage at:	Operating Costs* (Dollars/Yr.)	Assigned to Garage at:	Operating Costs* (Dollar/Yr.)	Optimum Allocation (Dollars/Yr.)
49	Red Oak	$18,488	Shenandoah	$18,339	$149
56	Atlantic	6,442	Red Oak	6,113	329
				Total =	478

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

Table 3 shows only two segments (segment Nos. 49 and 56) were reallocated under optimum allocation procedures. The amount of resulting savings is insignificant ($478 per year). It can, therefore, be concluded the current allocation of highway segments to existing garages within the study area is good for all practical purposes.

2. Closing and Relocation of Garages.

The optimum allocation model was used to evaluate the financial impact of closing and/or relocating specified garages in Study Area No. 2. The results are shown in Table 4 on the next page.

TABLE 4

COST ANALYSIS OF CLOSING AND RELOCATING SPECIFIED GARAGES USING OPTIMUM ALLOCATION (Study Area No. 2)

	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 (Dollars)	(6) Estimated Cost Savings (1982 Dollars) (5) - (4)
All Garages	$1,653,397				
Oakland, Emerson Shenandoah		$1,679,058	$25,661	$53,317	$27,656
Oakland, Shenandoah		1,672,361	18,964	40,900	21,936
Emerson, Shenandoah		1,665,171	11,774	34,479	22,705
Shenandoah		1,660,184	6,787	22,062**	15,275
Emerson		1,656,814	3,417	12,417**	9,000
Oakland Relocated		1,653,835	438	---	---
Oakland Relocated, Emerson, Shenandoah		1,664,818	11,421	34,479	23,058
Oakland Relocated, Emerson		1,656,460	3,063	12,417	9,354

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

** Overhead cost was estimated from a "combined overhead costs".

Table 4 shows:

1. Closing the garages at Oakland, Emerson and Shenandoah yields the greatest savings (approximately $27,656 per year).
2. Significant savings can also be achieved by either closing the garages at Emerson and Shenandoah (estimated savings of $22,705 per year) or closing the garages at Oakland and Shenandoah (estimated savings of $21,936 per year).
3. Relocating Oakland garage at the intersection of U.S. 59 and Iowa 92 slightly increased travel cost by $438 per year. However, if the garages at Emerson and Shenandoah are closed while the Oakland garage is relocated to the U.S. 59 and Iowa 92 intersection, there could be a slight increase in estimated savings (from $22,705 per year to $23,058 per year).

The optimal assignment of highway segments to garages in Study Area No. 2 for the various cases investigated is shown in Appendix 6.

V. CONCLUSION AND RECOMMENDATIONS

The optimum allocation model has been used to examine the existing highway maintenance garage locations in two selected areas. Based on these investigations, the study concludes the existing allocation of highway segments to the maintenance garages in each study area is good for all practical purposes.

In Study Area No. 1, the examination reveals an annual savings of approximately $12,700 would be achieved if the garage at Columbus Junction were closed while the garage at Nichols is already closed. However, it is noted if the garage at Nichols were not closed, a greater savings (approximately $18,500 per year) would be achieved by closing the garages at Columbus Junction and Iowa City.

It also appears that with the garage at Nichols officially closed, only a small savings (approximately $5,500 per year) is achievable by closing the garage at Iowa city. A further analysis shows that only a minimal savings (approximately $1,800 per year) can be achieved by closing the garage at Nichols.

In Study Area No. 2, the examination shows annual savings of approximately $22,700 would be achieved, without unduly increasing dead-end travel time, if garages at Emerson and Shenandoah were closed. It is also noted that relocating the Oakland Garage to the intersection of U.S. 59 and Iowa 92 would not result in any significant savings (approximately $400 per year).

It is recommended:

1. Closing the Maintenance Garage at Nichols be re-evaluated by the Office of Maintenance in the light of the findings of this study and other considerations. In particular, the re-opening of the Nichols

Garage with simultaneous closure of garages at Iowa city and Columbus Junction (estimated savings of $18,500 per year) should be carefully compared with the alternative of closing the garages at Nichols and Columbus Junction (estimated savings of $12,700 per year).

2. Serious consideration should be given to closing the garages at Emerson and Shenandoah (estimated savings of $22,700 per year).

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.

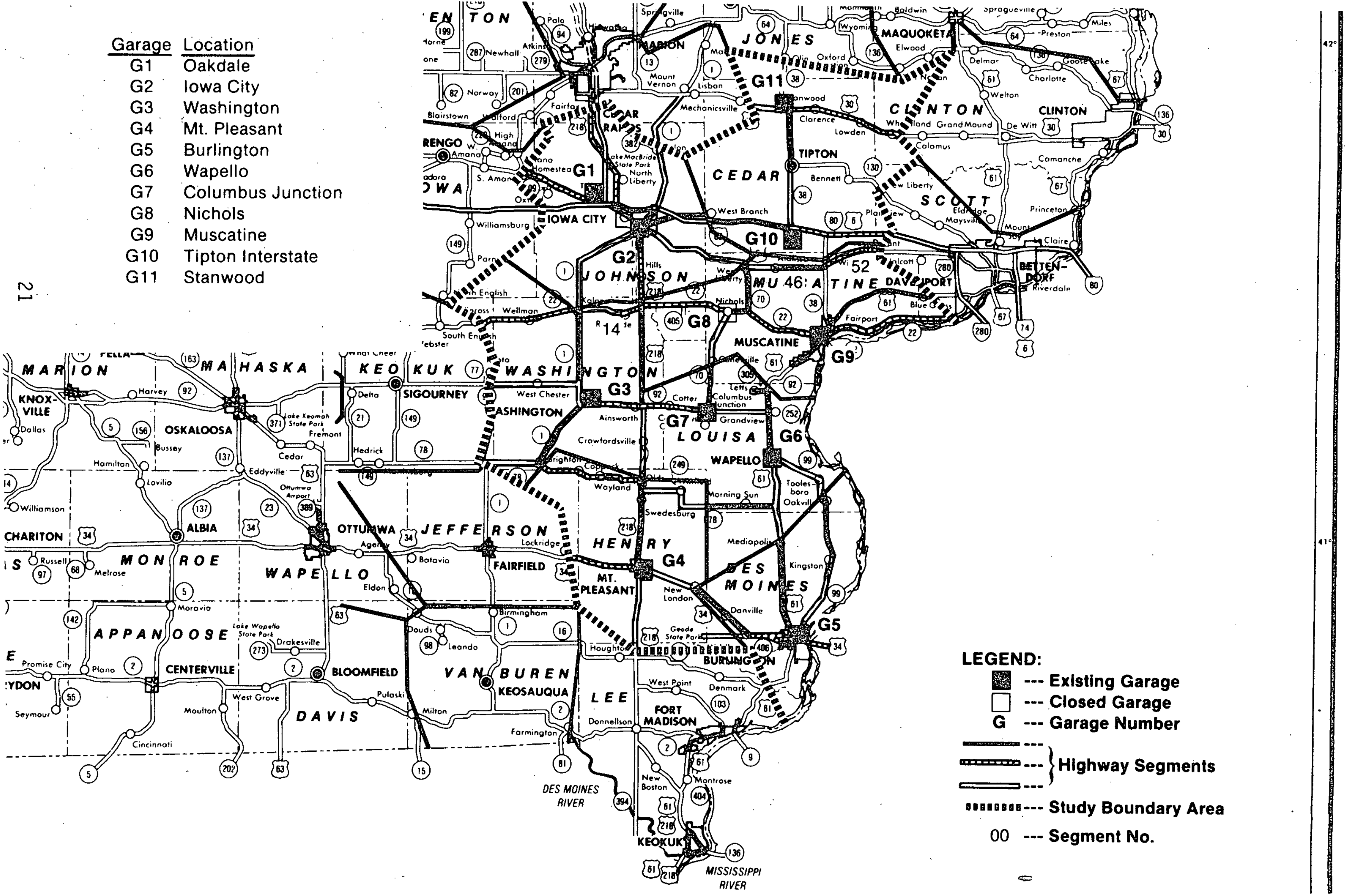
2. Iowa Department of Transportation, Office of Maintenance, Maintenance Area Responsibility Maps. July 1981.

APPENDICES

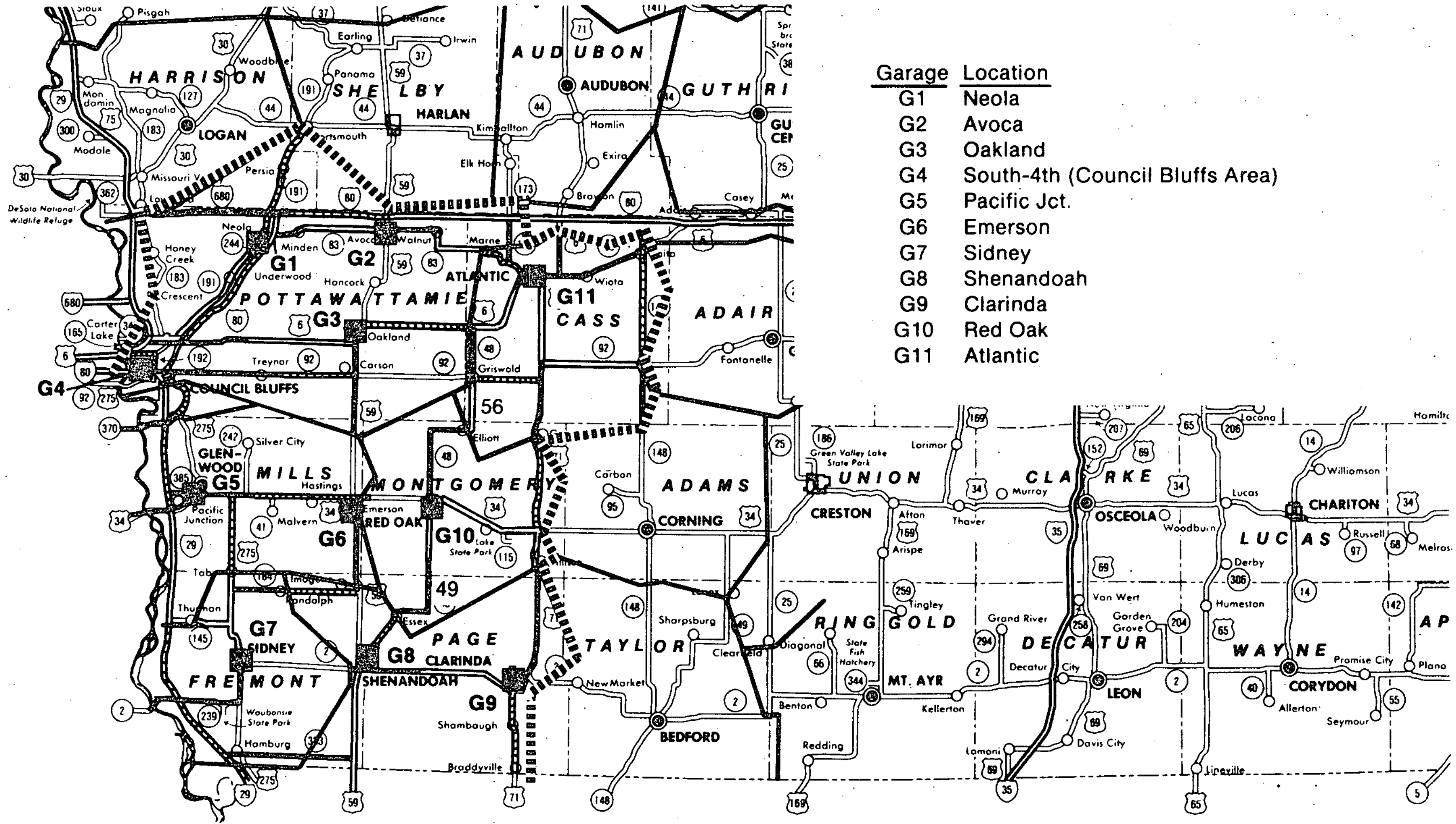
APPENDIX 1

Study Area No. 1 Showing 11 Garages and 61 Highway Segments

Garage	Location
G1	Oakdale
G2	Iowa City
G3	Washington
G4	Mt. Pleasant
G5	Burlington
G6	Wapello
G7	Columbus Junction
G8	Nichols
G9	Muscatine
G10	Tipton Interstate
G11	Stanwood



APPENDIX 2
Study Area No. 2 Showing 11 Garages and 67 Highway Segments



Garage	Location
G1	Neola
G2	Avoca
G3	Oakland
G4	South-4th (Council Bluffs Area)
G5	Pacific Jct.
G6	Emerson
G7	Sidney
G8	Shenandoah
G9	Clarinda
G10	Red Oak
G11	Atlantic

LEGEND:

▩ --- **Existing Garage**
G --- **Garage Number**
▬ ---
▭ --- } **Highway Segments**
▭ ---
▪▪▪▪▪ --- **Study Boundary Area**
00 --- **Segment No.**

APPENDIX 3

FISCAL YEAR 1981 LABOR, EQUIPMENT AND OVERHEAD COSTS FOR THE ROUTES AND GARAGES IN STUDY AREA NO. 1

Location and Number of Garages	1981 Garage Related Costs (Dollars)	Routes Served by Garage	1981 Labor Cost (Dollars)	1981 Equipment Cost (Dollars)
Burlington (5401)	$65,400	34	$42,757	$28,538
		61	53,639	39,165
		79	5,486	4,381
		97	180	155
		99	25,325	19,125
		406	2,516	2,165
		935	771	699
Mt. Pleasant (5402)	20,581	34	26,095	18,339
		78	25,367	16,463
		123	3,698	2,546
		125	2,171	1,863
		218	39,760	26,901
		249	321	411
		976	1,858	1,740
		6,616	1,906	2,426
Columbus Junction (5403)	15,810	61	11,870	12,728
		70	7,423	6,804
		78	3,558	3,282
		92	18,437	19,736
		99	3,727	3,339
		252	830	545
		305	530	568
Wapello (5404)	Combined with Garage 5403	61	9,000	7,434
		70	493	476
		78	2,249	2,188
		92	1,908	1,580
		99	2,089	1,979
		252	173	254
		305	87	117
Muscatine (5405)	27,112	6	13,594	14,154
		22	51,277	41,461
		38	6,505	6,547
		61	19,869	14,159
		70	5,393	4,571
		92	329	362
		405	177	80
		953	189	277

APPENDIX 3 (continued)

Location and Number of Garages	1981 Garage Related Costs (Dollars)	Routes Served by Garage	1981 Labor Cost (Dollars)	1981 Equipment Cost (Dollars)
Nichols (5406)	Combined with Garage 5405	6	$ 1,840	$ 1,644
		22	13,916	12,372
		38	510	684
		61	2,143	1,867
		70	2,761	2,033
		953	128	106
Washington (5408)	$21,317	1	20,910	15,176
		22	25,447	24,137
		78	3,830	2,553
		92	21,775	16,163
		114	1,484	673
		218	35,441	28,616
Tipton (6401)	34,962	30	5,917	5,015
		38	16,083	13,349
		80	94,649	67,571
		130	6,554	5,966
		979	478	437
Stanwood (6402)	Combined with Garage 6401	30	18,192	13,156
		38	11,468	8,045
		80	9,593	4,546
		130	7,813	5,262
Iowa City (6406)	Combined with Garage 6407	1	9,453	4,961
		6	7,177	3,624
		80	9,757	4,753
		109	256	65
		149	148	96
		218	7,010	2,724
		380	2,515	874
		382	701	196
		518	3,025	2,594
		979	501	101
Oakdale (6407)	85,884	1	38,997	31,272
		6	30,634	27,446
		80	61,208	45,643
		109	520	433
		218	29,647	25,496
		380	25,101	21,605
		382	3,291	1,592
		518	2,386	1,710
		979	1,580	1,691
		6,626	761	1,045
		7,724	213	331

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

APPENDIX 4

FISCAL YEAR 1981 LABOR, EQUIPMENT AND OVERHEAD COSTS FOR THE ROUTES AND GARAGES IN STUDY AREA NO. 2

Location and Number of Garages	1981 Garage Related Costs (Dollars)	Routes Served by Garage	1981 Labor Cost (Dollars)	1981 Equipment Cost (Dollars)
Avoca (4101)	$23,982	59	$ 3,047	$ 3,246
		80	108,024	80,460
		83	23,696	20,255
		92	26	11
		168	1,054	632
		680	2,387	1,506
South 4th Street (4104)	42,957	6	9,280	8,551
		29	13,639	11,396
		80	26,814	28,300
		92	18,560	19,087
		183	57	137
		191	229	196
		192	2,967	2,738
		275	6,789	9,089
		6,627	516	228
		8,876	136	18
Oakland (4105)	16,381	6	23,531	16,188
		59	18,666	12,519
		80	176	127
		92	44,382	29,381
		191	135	72
		362	665	182
Neola (4106)	22,595	29	70	32
		80	72,386	49,625
		83	24	60
		92	52	516
		191	29,386	18,603
		244	1,915	844
		680	50,502	32,717
Sidney (4201)	35,904	2	39,306	22,017
		29	29,917	23,774
		36	69	71
		42	2,048	1,392
		59	14	119
		145	15,313	11,390
		184	4,249	3,051
		239	398	79
		275	28,073	20,089
		333	325	201

APPENDIX 4 (continued)

Location and Number of Garages	1981 Garage Related Costs (Dollars)	Routes Served by Garage	1981 Labor Cost (Dollars)	1981 Equipment Cost (Dollars)
Emerson (4202)	Combined with Garage 4210	29.	$ 158	$ 84
		34	11,755	5,231
		41	1,307	864
		59	21,892	12,342
		242	122	117
		275	1,352	1,218
		949	989	477
Red Oak (4204)	$16,695	34	38,618	25,088
		48	39,467	26,052
		71	13,926	9,522
		115	799	403
		120	59	136
		6,626	696	169
Clarinda (4205)	Combined with Garage 4208	2	10,352	4,446
		59	283	54
		71	28,481	14,761
		184	261	227
		333	1,184	228
		999	60	82
		7,703	239	227
Shenandoah (4208)	25,579	2	19,414	16,790
		48	5,701	5,323
		59	23,825	23,101
		184	1,743	1,889
		333	19,523	14,800
		343	13,367	8,989
Pacific Junction (4210)	53,988	29	34,520	29,667
		34	35,209	28,665
		41	4,678	2,218
		59	7,730	6,660
		242	3,136	2,586
		275	27,987	23,652
		370	3,846	3,158
		385	3,081	2,321
		949	4,149	3,314
		978	4,397	4,676
		7,706	245	354

APPENDIX 4 (continued)

Location and Number of Garages	1981 Garage Related Costs (Dollars)	Routes Served by Garage	1981 Labor Cost (Dollars)	1981 Equipment Cost (Dollars)
Atlantic (4404)	$46,021	6	$37,761	$22,780
		48	6,956	4,274
		71	22,942	13,920
		80	452	472
		83	26,966	22,024
		92	22,441	19,985
		148	9,504	6,695
		173	2,345	916
		6,669	225	178

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

APPENDIX 5

OPTIMAL ASSIGNMENT OF HIGHWAY SEGMENTS TO GARAGES IN STUDY AREA NO. 1

Highway Segment No.	GARAGE										
	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
1	X*										
2	X										
3	X										
4	X										
5	$X^{2,7}$**	X									
6		X									
7	$X^{2,7}$	X									
8		X									
9		X									
10	X2,7	X									
11	$X^{2,7}$	X									
12	$X^{2,7}$	X									
13			X								
14		X						X2,7			
15			X								
16			X								
17			X								
18			X								
19			X								
20			X								
21			X								
22				X							
23				X							
24				X							

Highway Segment No.	GARAGE										
	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
25				X							
26				X							
27				X							
28					X						
29					X						
30					X						
31					X						
32					X						
33					X						
34					X						
35						X					
36						X					
37						X					
38						X					
39						X[2,7] X[7,8]	X				
40			X[2,7] X[7,8]				X				
41						X[7,8]	X	X[2,7]			
42								X	X[7,8]		
43		X[7,8]						X			
44								X	X[7,8]		
45								X		X[7,8]	
46									X	X[7,8]	
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		
51									X		
52										X	
53										X	
54										X	
55										X	
56										X	
57											X
58											X
59											X
60											X
61											X

LEGEND: X -- Optimal Assignment of Segment to Garage

$X^{i,j}$ -- Optimal Assignment of Segment to Garage when Garages "i" and "j" are closed.

APPENDIX 6

OPTIMAL ASSIGNMENT OF HIGHWAY SEGMENTS TO GARAGES IN STUDY AREA NO. 2

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							

APPENDIX 6 (continued)

Highway Segment No.	GARAGE										
	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
25				X							
26				X							
27					X						
28						X				X6,8	
29						X				$X^{6,8}$	
30					X6,8	X					
31					X						
32					X						
33					X						
34							X				
35							X				
36							X				
37							X				
38							X				
39							X				
40							X6,8	X			
41							$X^{6,8}$	X			
42								X	X6,8		
43									X		
44									X		
45									X		
46							X6,8	X			
47							$X^{6,8}$	X			
48							X6,8	X			
49								X		$X^{6,8}$	

APPENDIX 6 (continued)

GARAGE

Highway Segment No.	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
50										X	
51										X	
52										X	
53										X	
54										X	
55										X	
56										X	
57											X
58											X
59											X
60											X
61											X
62											X
63											X
64											X
65											X
66											X
67											X

LEGEND:

X -- Optimal Assignment of Segment to Garage

$X^{i,j}$ -- Optimal Assignment of Segment to Garage when Garages "i" and "j" are closed.