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16. Abstract

This study evaluates the practices and costs of mowing, litter pickup, and herbicide spraying maintenance functions. Data are collected to determine the extent of and reason for changes in mowing and vegetation management costs through time series and cross-sectional data analyses. Cost comparisons are made to determine the cost-effectiveness of contract mowing and litter pickup. Overhead costs are also estimated for in-house mowing, contracting mowing, in-house litter pickup, contract litter pickup, and in-house herbicide spraying functions. The herbicide overspraying program to control Johnson grass and other pest plants is evaluated to determine its cost-effectiveness in reducing mechanical mowing and releasing Bermuda grass and various native grasses. A survey of maintenance personnel in 12 districts reveals the expected effects of implementing different vegetation control strategies in the state.

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MOWING, HERBICIDE SPRAYING AND LITTER PICKUP COST COMPARISONS

by

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Research Report 380-1F Vol. II
Research Study Number 2-18-86-380
Cost Comparison of Maintenance Activities and
a Selected Cost-Benefit Application

Sponsored by

Texas State Department of Highways
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PREFACE

The author is indebted to Mr. Larry J. Buttler, Mr. Damon D. Naumann, and Mr. Roy L. Smith of the Safety and Maintenance Division of the State Department of Highways and Public Transportation (SDHPT) for serving as very helpful contact representatives throughout this study. He is also indebted to many other individuals in the 13 districts that provided the data bases for this study. These individuals are too numerous to be named here.

Those of the Texas Transportation Institute staff who assisted with the study include Mr. Jose Acosta who assisted with data entry and analysis. Ms. Margaret K. Chui assisted with the regression modeling and analysis and editing of the report. Dr. Jeffery L. Memmott assisted with interpreting the regression results. Ms. Patricia Holmstrom served as Economics Program secretary and assisted with data entry and typed the research report. The author served as co-study supervisor with Dr. Alberto Garcia-Diaz and developed the theoretical approaches and wrote the report.

SUMMARY OF FINDINGS

This report contains the findings of a study of mowing, litter pickup, and vegetation management practices and costs. These findings are summarized below.

Over 20 factors affecting mowing and vegetation management costs are cited, and many are analyzed using time series and cross-sectional approaches. The regression technique is used for the latter approach with two data bases involving 13 districts. The factors significantly affecting mowing costs are: mowing function used, extent of herbicide spraying, type and number of cycles, crew size, average daily traffic, urban/rural location, SDHPT district, soil type, and vegetation area of the state.

A major thrust of this study deals with cost comparisons of contract versus in-house mowing. A highway section data base from 13 districts is used to determine the size of the cost differential between contract and in-house mowing. Using 1984-85 data, contract mowing is proven to be about $8.54 per acre cheaper than in-house mowing for full-width cycles and $10.95 per acre for strip-width cycles. Adding an overhead cost differential of $0.26 per acre to these direct cost differentials results in total differentials of $8.70 per acre for full-width cycles and $11.11 per acre for strip-width cycles. The overhead costs are estimated using data from four of the 13 districts.

A case study of litter pickup costs reveals a cost differential of $9.29 per acre favoring contracting out litter pickup. The overhead cost differential recommended is $0.12 per acre. When added to the direct cost differential, the total differential becomes $9.41 per acre in favor of contract litter pickup.

The cost effects of using herbicide overspraying to control Johnson grass and other pest plants are evaluated by data collected primarily from three districts that have done extensive overspraying for three or four years. Decreases in mowing costs are greater than the increase in herbicide spraying costs in these three districts, thus producing savings differentials ranging from $1.34 to $12.82 per inventory acre of vegetation. These three districts could save as much as $28.70 per inventory acre in a five year period. Based on 91,117 inventory acres, the total savings could amount to $2,256,057.

In-house herbicide function overhead costs are also estimated with the help of the same four districts used to determine overhead costs for the mowing functions. The 1984-85 overhead for in-house herbicide spraying is $1.22 per inventory acre. If the overhead costs are added to that charged directly to the function, the total in-house cost per inventory acre is $15.38.

Maintenance personnel in the three study districts feel that their over-spraying programs are very effective in controlling Johnson grass and other pest plants and releasing Bermuda and various native grasses. The maintenance personnel from 12 of the 13 study districts think that reduced mowing would increase overspraying operations but that this still would be a cost-effective switch, especially in the long run.

An extended summary, conclusions, and recommendations appears near the back of this report.

IMPLEMENTATION STATEMENT

The research results presented in this report are recommended for implementation by the State Department of Highways and Public Transportation (SDHPT) and could be helpful to transportation agencies in other states.

Contracting Mechanical Mowing

The research findings are conclusive in showing that significant savings can result if the SDHPT requires that all districts contract most of their roadside mowing.

Herbicide Overspraying

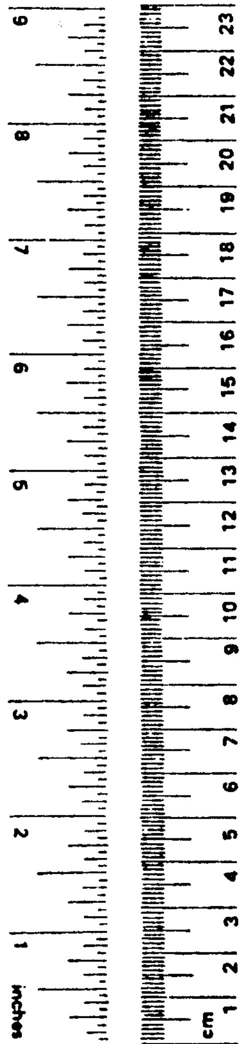
The research findings strongly support expansion of the herbicide overspraying of Johnson grass to release Bermuda and various native grasses. Certainly, those districts that have already started this approach to vegetation management should be encouraged to continue and to become even more effective in the application of herbicides to control Johnson grass and other pest plants. Also, they should be allowed to continue reducing the number of mowing cycles as Johnson grass becomes more and more under control.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

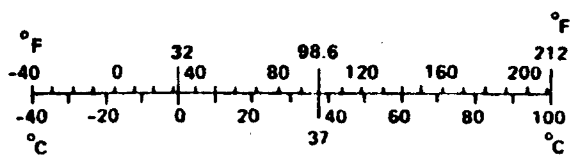
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

A portion of Research Study 2-18-86-380 entitled "Cost Comparison of Maintenance Activities and Selected Cost-Benefit Application" calls for an evaluation of mechanical mowing, herbicide spraying, and litter pickup practices and costs. This report presents the findings on that portion of the study. To follow in this section of the report is a review of background considerations which led the Texas State Department of Highways and Public Transportation (SDHPT) to sponsor this study in cooperation with the Federal Highway Administration of the U. S. Department of Transportation. Also covered in this section are the objectives of the study.

Other sections of the report present the analytical methodology, findings of study, and summary and conclusions.

Background of Study

In January 1970, the SDHPT adopted new right-of-way mowing standards designed to maintain the vegetation along Texas highways. However, these standards serve only as minimum guidelines for the maintenance personnel to follow. Consequently, mowing practices are not necessarily varied according to the condition and type of vegetation or the appearance of the adjacent property.

Actually, the mowing standards specify only one full-width mowing in good wildflower growing areas and only often enough to provide a pleasing appearance to adjacent property in urban areas. Also, the time of the full-width mowing is specified to be deferred until early spring flowers, such as Bluebonnets and Indian Paint Brushes, have matured seeds and preferably deferred until fall in good wildflower areas. Shoulder strip mowing (5 to 15 foot strip from pavement edge) are specified to be done only often enough to maintain maximum safety and conformance with height standards. Where necessary to maintain sight distances, safety and transitional mowings are specified for areas beyond those covered by strip mowing. These areas include medians, inside curves, ramps, intersections, and private entrances. On divided rural highways, safety mowings are to be performed as necessary on medians no more than 70 feet wide and strip and transitional mowings on medians over 70 feet wide.

The maximum height of vegetation in the required mowing areas is 12 inches, except on low traffic FM and RM roads where it is 15 inches. Herbicides are to be used around sign posts, delineators, guardrails, and other highway fixtures. Also, chemical overspraying (mowing) may be used to reduce mechanical mowing.

In 1982, the SDHPT's Safety and Maintenance Division (D-18) requested the SDHPT districts to reduce the frequency of full-width mowings, to contract out more of the mechanical mowing, and to return portions of the roadside to its native grass state with the aid of chemical overspraying and wiping of Johnson grass. Each district apparently complied with this request by designating at least one county as a vegetation management county where the number of full-width mowing cycles was reduced and where portions of the roadside were set aside to be returned to a native grass state.

In 1984, the Department conducted a preliminary study of mowing costs before and after the 1982 change in mowing and vegetation management practices in the 26 designated counties. Although the unpublished results revealed a 23 percent reduction in mowing costs, they could not be used to support new mowing and vegetation management policies. The amount of savings varies widely from district to district, perhaps primarily due to rainfall differences. Also, general application of the study results seemed questionable because the 26 counties studied might not be representative of all the counties in Texas. Therefore, the SDHPT decided that a more extensive study should be made to determine the benefits and costs of different mowing and vegetation management practices in the state. Contract and in-house mowing and litter pickup costs were to be studied, including an estimate of overhead costs to these maintenance functions. Herbicide overspraying operations were to be studied to determine their effectiveness in reducing mowing and vegetation management costs.

Study Objectives

The specific study objectives are as follows:

1. Determine all the factors, benefits, and costs that should be considered in comparing different right-of-way mowing and vegetation control practices.

2. Determine the dollar benefits and costs of different mowing frequencies and practices.
3. Determine the benefits and costs of in-house and contract mowing and litter pickup operations.
4. Explore the possible benefits and costs of implementing a Johnson grass or pest plant control program.

ANALYTICAL METHODOLOGY

The analytical methodology used in this portion of the study is described below more or less according to the listed objectives.

Relevant Factors, Benefits and Costs

A computerized literature review of the files of the National Technical Information Service (NTIS) identifies relevant factors, benefits, and costs for study. Also, the data and results of the 26 county study are helpful to identify relevant factors for evaluating changes in mowing costs.

Changes in Mowing Practices and Costs

Changes in mowing practices are identified primarily by surveying 13 districts scattered throughout the State. Data from the SDHPT's computer files, including the 26 county data base, are used to determine the extent of the cause of changes in mowing costs in the state. Where applicable, both the before-and-after and the cross-sectional analytical approaches are applied to the data base. The multiple regression technique is used in the cross-section analysis.

Cost Comparisons of Contract Versus In-House Mowing

Mowing cost data collected from a selected sample of road sections in 13 districts scattered throughout the State are used to derive an average unit cost per acre differential between in-house and contract mowing operations. The in-house data are supplemented with data collected by field observations in several districts. In addition, the SDHPT's overhead costs to administer in-house and contract mowing are estimated through the help of administrative personnel at the division and district level.

The following cost elements are used to establish the total cost per acre for in-house mowing:

1. Direct charges made to mowing function:
   a. Labor costs (including fringe benefits) - using a maintenance section composite rate applied to the total committed man-hours.
   b. Equipment cost - using equipment rental rate applied to the actual hours of operations.
   c. Miscellaneous costs - including repair parts, warehouse transfers, etc.

2. Overhead costs (estimated):
   a. Maintenance Section (at district level)
      (1) Administration (salaries, office supplies, utilities, car rental, etc.).
      (2) Office space rent - based on local market rate.
      (3) Warehouse and shop space rent - based on local market rate.
   b. District Headquarters
      (1) Administration (salaries, office supplies, utilities, car rental, etc.).
      (2) Office space rent - based on local market rate.
      (3) Warehouse and shop space rent - based on local market rate.
   c. Division 18 (Safety and Maintenance)
      (1) Administration (salaries, office supplies, utilities, car rental, etc.).
      (2) Office space rent - based on local market rate.
   d. Division 3 (Finance)
      (1) Administration (salaries, office supplies, utilities, etc.).
      (2) Office space rent - based on local market rate.
   e. Division 4 (Equipment and Procurement)
      (1) Administration (salaries, office supplies, utilities, etc.).
      (2) Office space rent - based on local market rate.
   f. Division 20 (Insurance)
      (1) Administration (salaries, office supplies, utilities, etc.).
      (2) Office space rent - based on local market rate.

(3) Liability insurance cost - distribution based on the number of automobiles, trucks, tractors, and mowers covered by the policy.

g. Inefficient use of personnel as indicated by:

(1) Off-season work activities

(2) Pay differentials

(3) Value of idle time

h. Inefficient use of equipment as indicated by:

(1) Off-season work activities

(2) Value of idle time

Cost Comparisons of Contract Versus In-House Litter Pickup

Litter pickup cost data are collected on a limited number of highway sections on a case study basis where a contract default occurred or a recent switch is made to contracting from an in-house operation. The cost per acre (not including SDHPT's overhead costs) is the unit of comparison to generate a cost differential between in-house and contractor litter pickup operations.

Benefits and Costs of a Pest Plant Control Program

Data are collected from secondary sources and the SDHPT to identify the possible benefits and costs associated with the implementation of a pest plant control program. The effectiveness of a herbicide overspraying program to reduce vegetation management costs to the Department is determined by the following means:

1. Cost comparison of mowing costs versus herbicide costs using statewide data and data from selected districts which have extensive overspraying operations. The unit of comparison is price per vegetation inventory acre. The in-house cost elements for the herbicide function are the same as those used for the in-house mowing function, except for the materials cost.

2. Opinions of maintenance personnel.

3. Opinions of TTI researcher based on field inspections and photographs of the roadside vegetation maintained with and without overspraying treatments.

FINDINGS OF STUDY

The primary findings of this portion of the study are presented under the same headings as used in the prior section. Other findings are presented in the appendices.

Relevant Factors, Benefits, and Costs

Relevant factors identified by the computerized literature review and the evaluation of the 26 counties SDHPT study are presented in Table 1. Several of these factors are used in the analysis of mowing and vegetation management costs. Some of the factors are mentioned by more than one source. Accidents, litter removal, drainage and erosion, hay harvesting, and fire damage represent factors that can be called benefits or costs when considered in a benefit-cost analysis.

The evaluation of the results of SDHPT's 26 counties study reveals considerable variation in changes in mowing and herbicide spraying costs from 1981-82 to 1982-83, as shown in Table 2. Part of this variation can be attributed to differences in weather conditions. Table 3 shows the effects of differences in the average annual rainfall and the average minimum January temperature on changes in mowing and spraying costs. These and other factors are applied to a more extensive data base and the results are presented later in this report.

Changes in Mowing Practices and Costs

The beforementioned survey of 13 selected districts (2, 4, 5, 6, 8, 10, 11, 13, 14, 15, 17, 20, and 21) reveals some of the mowing practices in operation during the 1980-81, 1984-85, and 1985-86 fiscal years. As indicated in Table 4, current mowing practices such as the number of mowing cycles, width of strip mowing, number of in-house crews, in-house crew sizes, and number of permanent versus summer employees are little different from those of five years ago. Only the pay per manhour for permanent mowing crew members is 37 percent higher, largely due to inflation. Also, there is a 20 percent decrease in the number of summer mowing crew members.

Even though Table 4 shows that mowing practices in the 13 districts have not changed much in the past five years, there are differences in mowing practices among these districts. For instance, Table 5 shows the range of

Table 1. Factors Affecting Mowing and Vegetation Management Costs.

Factors	Cited Reference Number[a]
1. Mowing Height and Width	2, 4, 18, 23
2. Type of Terrain	2, 12, 19, 20
3. Type of Land Use	19
4. Type of Vegetation	2, 19
5. Length of Growing Season	2, 18
6. Amount of Rainfall	2, 12, 18
7. Rural/Urban Location	2
8. Number of Mowing Cycles	2, 18, 23
9. Use of Chemical Spraying	2, 4, 17, 18, 19, 24
10. Number of Accidents (all types)	2, 18, 19, 20, 22
11. Litter Removal	2, 22
12. Drainage and Erosion	2, 22
13. Equipment Types and Speed	2, 4, 12
14. Contracting Mowing	1, 4, 5, 6, 7, 8, 9, 10, 11, 21
15. Hay Harvesting	20, 22
16. Fire Damages	20
17. Highway Type	23
18. Aesthetics	2, 4, 14, 15, 16, 17, 18, 20
19. Good Turf Grass	4, 19, 22
20. Environmental	2, 17, 22

[a]See list of references at end of report.

Table 2. Variation in Mowing and Spraying Costs, as Indicated by 26 County SDHPT Study

Maintenance Function	Average Change From 1981-82 to 1982-83		
	Dollars (000.0)	Percent	Percentage Range
In-house Mowing	-524.6	-32.1	-100.0 to +414.9
Contract Mowing	-150.9	-16.8	- 88.5 to + 6.7
Herbicide Spraying	+203.4	+33.4	- 36.0 to +324.1
Total (All Functions)	-479.1	-15.3	- 38.9 to + 16.8

Table 3. Variation in the Changes in Mowing and Spraying Costs Due to Weather Conditions.[a]

Weather Condition	Average Percentage Change in Cost	
	Mowing	Mowing and Spraying
Average Annual Rainfall		
Less than 22.1 Inches	- 26.1	- 19.0
22.1-34.0 Inches	- 29.1	- 16.1
Over 34.0 Inches	- 18.3	+ 1.0
Average Minimum Temperature[b]		
Less than 31.1°F	- 25.7	- 20.5
31.1°F-38.0°F	- 23.8	- 9.6
Over 38.0°F	- 25.7	- 11.0

[a]Based on changes in mowing and spraying costs from 1981-82 to 1982-83.

[b]Based on minimum January temperatures.

Table 4. Changes in Mowing Practices for Sample Districts.[a]

Mowing Practice	Average Number by Year[b]		
	1980-81	1984-85	1985-86
Mowing Cycles			
Full-width	2(11)	2(11)	2(11)
Strip-width	2(10)	2(10)	2(10)
Strip Cutting Width (Ft.)	15(10)	18(10)	17(10)
Crews[c]	10(10)	8(9)	11(8)
Crew Size[c]			
Full-width	6(10)	5(9)	4(9)
Strip-Width	5(7)	3(8)	3(7)
Mowing Employees[c]			
Permanent	28(9)	21(9)	29(9)
Summer	25(4)	20(4)	20(4)
Pay Per Manhour($) (Including Fringe Benefits)[c]			
Permanent Employees	8.49(10)	10.85(10)	11.66(8)
Summer Employees	6.10(5)	6.43(5)	6.16(5)

[a] Districts 2, 4, 5, 6, 8, 10, 11, 13, 14, 15, 17, 20, and 21.

[b] Number of districts reporting are shown in parentheses.

[c] SDHPT personnel dedicated to in-house mowing.

Table 5. Range of Numbers for Selected Mowing Practices in Sample Districts During 1984-85.[a]

Mowing Practice	Range in Number[b]
Mowing Cycles	
Full-width	1 - 4
Strip-width	1 - 3
Strip Cutting Width (Ft.)	15 - 28
Crew Size	
Full-width	3 - 8
Strip-width	2 - 5
Mowing Employees	
Permanent	2 - 47
Summer	1 - 29
Pay Per Manhour ($) (Including Fringe Benefits)	
Permanent Employees	7.83 - 15.00
Summer Employees	4.75 - 8.09

[a] Based on same districts listed at the bottom of Table 4.

[b] Excludes zero values.

difference in the same mowing practices addressed in Table 4 for the 1984-85 fiscal year. Of course, these differences in mowing practices are also reflected in mowing costs.

Another mowing practice that greatly affects mowing costs among districts is that of contracting out all or a part of the mowing. Of the 13 districts surveyed, all have contracted some mowing during the last five years. However, some of these districts contract most of their mowing while others contract very little mowing which leads to considerable differences in mowing costs among districts.

Still another practice started in the past five years is that of setting aside non-mowed areas in wide medians and near right-of-way lines. Of the 13 districts surveyed, eight report that they are setting aside non-mowed areas. The amount of acreage reported as set aside represents about five percent of the available vegetation acreage.

Finally, several districts have begun a vegetation management program designed to release native grasses and other grasses such as Bermuda, Bahia, Bluestem, and Buffalo. In fact, five of the 13 districts surveyed have such a program. Some of these districts are just starting to overspray Johnson grass to release native grasses, while others are in their third year. This new practice is already affecting mowing costs, as is indicated in Table 2.

As already indicated, differences in mowing and vegetation management practices can greatly affect mowing costs. To determine whether different practices, weather conditions, locational factors, etc. are significantly related to mowing costs, the least squares regression technique is used on a 1984-85 data base containing a total of 124 observations representing all the maintenance sections in the 13 districts. This number is reduced to 111 because some sections overlap more than one county and the costs of each of these sections are assigned to one county but not to the overlapped county. The dependent variables (DV) representing the respective models are described as follows:

(1) TMOWC = Total in-house and contract mowing cost in dollars for each maintenance section

(2) IHMOWC = In-house mowing cost in dollars for each maintenance section

(3) CRMOWC = Contract mowing cost in dollars for each maintenance section

The independent continuous variables (CV) used in one or more estimating equations are as follows:

(1) ACRE = Acres of vegetation inventoried for a maintenance section

(2) CYLF = Number of full-width mowing cycles done on an average in the district where the maintenance section is located

(3) CYCLS = Number of strip-width mowing cycles done on an average in the district where the maintenance section is located

(4) RAINF = Average annual rainfall in the county in which the maintenance section is located

(5) GDAY = Average length of growing season in days for county in which the maintenance section is located

(6) HERBC = Herbicide cost in dollars for the maintenance section

(7) IHMOWC = In-house mowing cost in dollars for the maintenance section

(8) CRMOWC = Contract mowing cost in dollars for the maintenance section

The independent binary variables (BV) used in one or more estimating equations are as follows:

(1) URB = 1 if the maintenance section is located in an urban area in a county with a population of 70,000 plus

= 0 if otherwise

(2) VEGTYP1 = 1 if the maintenance section is located in a county in Pineywoods vegetational area

= 0 if otherwise

(3) VEGTYP2 = 1 if the maintenance section is located in a county in Gulf prairies and marshes vegetational area

= 0 if otherwise

(4) VEGTYP3 = 1 if the maintenance section is located in a county in Post Oak Savannah vegetation area

= 0 if otherwise

(5) VEGTYP4 = 1 if the maintenance section is located in a county in Black Prairies vegetational area

= 0 if otherwise

(6) VEGTYP5 = 1 if the maintenance section is located in a county in Crosstimbers and Prairies vegetational area

= 0 if otherwise

(7) VEGTYP6 = 1 if the maintenance section is located in a county in South Texas Plains vegetational area

= 0 if otherwise

(8) VEGTYP7 = 1 if the maintenance section is located in a county in Edwards Plateau vegetational area

= 0 if otherwise

(9) VEGTYP8 = 1 if the maintenance section is located in a county in Rolling Plains vegetational area

= 0 if otherwise

(10) VEGTYP9 = 1 if the maintenance section is located in a county in High Plains vegetational area

= 0 if otherwise

The vegetational areas used in this analysis are those defined by the Texas A&M University Experiment Station and the rainfall and growing season data are those prepared by the State Climatologist [25]. The vegetational areas are shown in Figure 1.

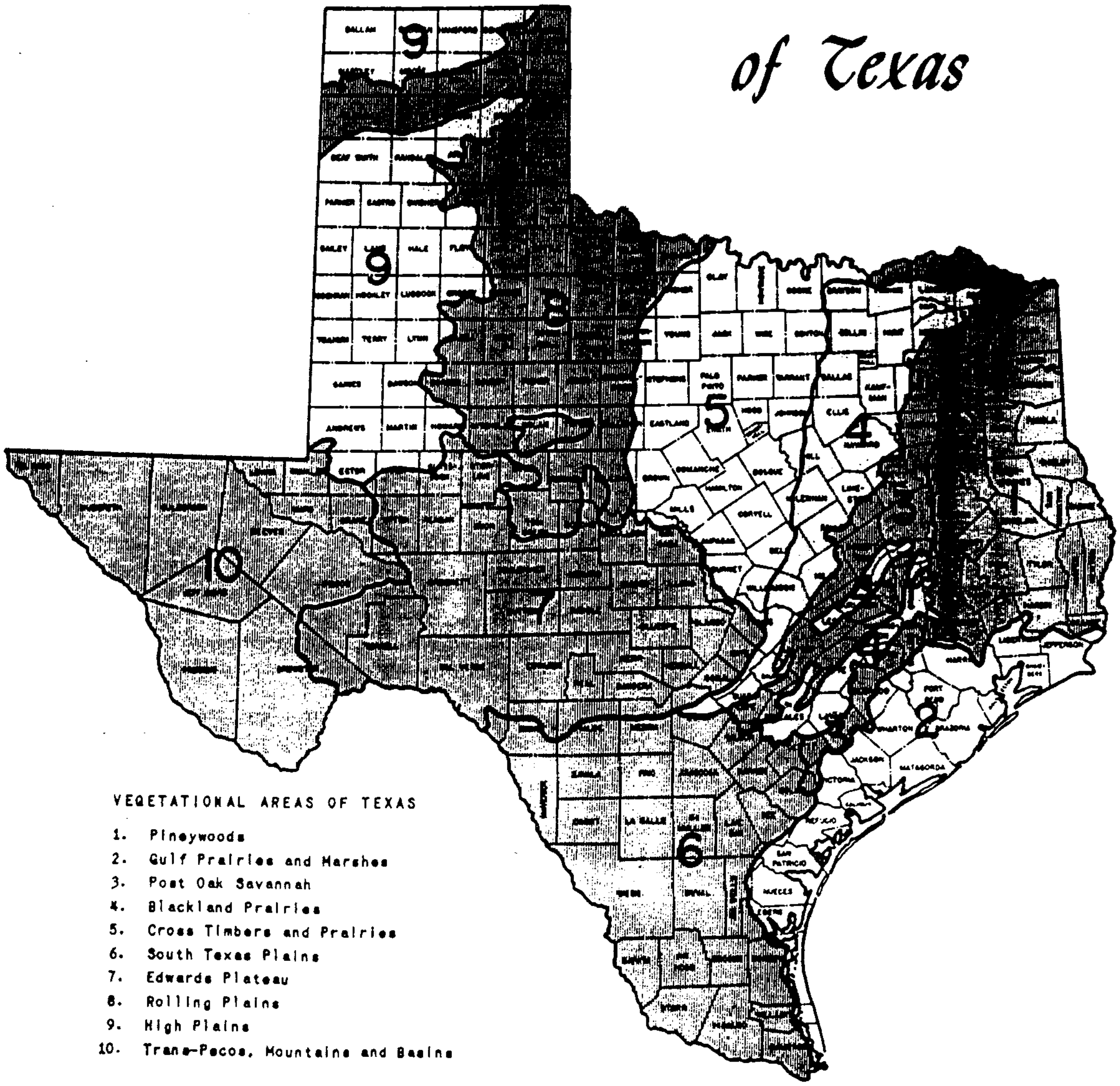
Each dependent variable used in each estimating equation is regressed separately on the exogenous and binary variables to estimate the corresponding regression coefficients. In some equations, one of the dependent variables is treated as another independent continuous variable along with the other continuous and binary variables in the equation. The functional form of the equations solved by the ordinary least squares to estimate the coefficients is as follows:

$$DV_i = a + bCV + cBV + dDV_j$$

where a, b, c, and d are the estimated coefficients in the regression equation, and

i = index for type of mowing cost i = 1 ..., 3, i = j

Vegetational Areas



Source: Texas Agricultural Extension Service and Experiment Station, The Texas A&M University System.

Figure 1. Vegetational Areas of Texas

The estimated regression coefficients for each of four models are presented in Table 6. The level of statistical significance is indicated by asterisks, i.e., * for 10 percent level, ** for 5 percent level, and *** for 1 percent level. Those without an asterisk are not significant at these confidence levels. The urban and vegetational areas explanatory variables are defined as two sets of binary variables. One variable in each set (i.e., rural in the first and vegetational Area 10 in the second) must be taken out in estimating the regression coefficients of the others, because one variable in each set is a linear combination of the others, and are contained in the estimated coefficient for the intercept term. As a result, each estimated coefficient for the binary variables measures the mean difference in mowing cost if the maintenance section is not located in a rural county or Vegetational Area 10. Also, when a continuous explanatory variable (such as acres) is present in the model, the estimated coefficients for the binary variables measure the mean difference for a given level of the continuous explanatory variable. For example, in Model 1, the binary variable URB measures the mean difference in mowing cost between urban and rural areas for a given change in acres. Finally, the inclusion of the other dependent variables, such as IHMOWC and CRMOWC as explanatory variables, generally increases the amount of variation which is explained by the regression model and that is the case with Models 3 and 4.

The R^2s, percentage of explained variation, of all four models are relatively high, ranging from .7343 to .8401. Models 1 and 2, which have the combined in-house and contract mowing cost as the dependent variable, are significantly affected by the same four independent variables, namely, acres of inventoried vegetation (ACRE), number of full-width cycles (CYLF), amount spent on herbicides (HERBL), and being in an urban area (URB). The number of strip-width cycles (CYLS) has no significant effect on mowing costs in either model. The amount of rainfall (RAINF) produces no signficant effect in Model 1 nor in other models containing the two cycle variables. The number of growing days variable (GDAY) included in Models 1 and 2, is not significant in models containing the cycle variables. Model 1 contains none of the vegetational area variables, whereas Model 2 does with none of them significantly affecting mowing cost. However, their inclusion in Model 2 increases its R^2 over that of Model 1.

Table 6. Estimated Regression Coefficients for Models 1 through 4 Using Ordinary Least Squares.

Independent Variable	Model 1 (TMOWC)	Model 2 (TMOWC)	Model 3 (IHMOWC)	Model 4 (CRMOWC)
Constant Term	-79,386.22*** (-4.05)	-74,759.69*** (-3.07)	-69,371.49*** (-4.23)	-66,347.80*** (-4.49)
(1) ACRE	22.51*** (7.54)	+ 22.48*** (6.96)	17.51*** (4.95)	14.16*** (7.36)
(2) CYLF	26,081.22*** (5.62)	+32,138.00*** (3.65)	21,601.80*** (4.42)	30,488.28*** (6.10)
(3) CYLS	7,256.40 (1.62)	- 1,465.84 (-.18)	9,145.54** (2.15)	- 4,422.10 (-.95)
(4) RAINF	-17.77 (-.06)	b	b	b
(5) GDAY	b	b	b	b
(6) HERBC	.6340*** (9.69)	.6500*** (9.46)	.6025*** (9.29)	.1737*** (3.35)
(7) IHMOWC	b	b	b	-.1545*** (-2.60)
(8) CRMOWC	b	b	-.7042*** (-5.63)	b
(9) URB	54,094.15*** (3.97)	53,736.23*** (3.80)	58,984.70*** (4.45)	4,623.19 (.53)
(10) VEGTYP1	b	- 2,734.15 (-.14)	b	38,695.68*** (3.37)
(11) VEGTYP2	b	4,447.77 (.17)	b	31,285.45* (2.12)
(12) VEGTYP3	b	-13,707.03 (-.69)	b	15,713.32 (1.36)
(13) VEGTYP4	b	19,684.92 (.86)	b	28,504.01) (2.20)
(14) VEGTYP5	b	-34,425.13 (-.94)	b	-25,887.56 (-1.24)
(15) VEGTYP6	b	-641.06 (-.03)	b	7,910.07 (.60)
(16) VEGTYP7	b	11,338.23 (.54)	b	-582.08 (-.05)
(17) VEGTYP8	b	11,037.71 (.52)	b	- 4,432.06 (-.36)
(18) VEGTYP9	b	2,712.59 (.13)	b	- 3,819.31 (-.33)
R^2 =	.8261	.8401	.7343	.7848

[a]t-statistic is listed below each coefficient in parenthesis
*Significant at 10 percent confidence level.
**Significant at 5 percent confidence level.
***Significant at 1 percent confidence level.
[b]Tried in other models.

Model 3, which has in-house mowing cost (IHMOWC) as the dependent variable, has six highly significant explanatory variables. In addition to the four significant variables in Models 1 and 2, the number of strip cycles (GYLS) and contract mowing cost (CRMOWC) significantly explain variations in in-house mowing cost. Model 4, which has contract mowing cost (CRMOWC) as the dependent variable, has the highest number of statistically significant explanatory variables, including three of the vegetational area variables. The vegetational areas represented by these three variables are located in the eastern and coastal part of Texas. The number of strip cycles (CYLS) and urban location (URB) variables do not significantly affect contract mowing costs. However, the in-house mowing cost (IHMOWC) variable significantly explains some of the variation in contract mowing costs.

Another regression model, using the 13 district highway section data base used in the contract versus in-house mowing cost analysis, reveals that in-house mowing costs are significantly affected by level of traffic, mowing crew size, soil type (clay loam, waxy) and Districts 6, 11, and 13. This model has an R^2 of .6334, but it is not presented in this report.

In summary, the regression analysis reveals that the number of full-width cycles, acres of inventoried vegetation herbicide costs, in-house mowing costs, contract mowing costs, and urban location explain most of the variation in total mowing costs. In addition, the number of strip cycles and vegetational areas in the eastern and coastal regions of the state explain some of the variation in in-house mowing costs or contract mowing costs. The effects of weather (rainfall and growing season) are explained by other explanatory variables in the models. About 20 percent of the variation is yet to be explained in the four models presented. The model not reported here indicates that the level of traffic, mowing crew sizes, soil type, and district are significant explanatory variables.

Cost Comparisons of Contract and In-house Mowing

Table 7 shows that the percentage change in mowing cost between 1980-81 and 1984-85 for the sample highway sections is nearly the same as that for all the highway sections in the state. Therefore, the sample sections do reflect the same change in mowing cost as experienced by the state as a whole. Table 8 shows the mowing cost changes between 1980-81 and 1984-85 by maintenance

Table 7. Mowing Cost Changes Between 1980-81 and 1984-85 for All Highway Sections in the State and a Sample of Highway Sections in 13 Districts.

Location	Total Mowing Costs($)		Change in Cost	
	1980-81	1984-85	Dollars	Percent
Sample Highway Sections	2,173,414	1,448,302	-725,112	-33.36
All Highway Sections	31,050,202	19,949,090	-11,101,112	-35.80

Table 8. In-house and Contract Mowing Cost Changes for Sample Highway Section Between 1980-81 and 1984-85.

Maintenance Function	Mowing Costs ($)		Change in Cost	
	1980-81	1984-85	Dollars	Percent
In-house Mowing	856,261	760,256	- 96,005	-11.21
Contract Mowing	1,317,153	688,046	-629,107	-47.76
Total Mowing	2,173,414	1,448,302	-725,112	-33.36

function, i.e., in-housing mowing and contract mowing (512). The percentage reduction in contract mowing cost is over four times that for in-house mowing. The reason for this large difference in cost reduction between these two maintenance functions is explored using the detailed data base collected on the sample highway sections.

Data Base

The results of contract and in-house mowing cost comparisons presented here are based on a sample of 137 highway sections in 39 counties selected from the above mentioned 13 districts scattered over the state. Figure 2 shows the location of the study counties where detailed in-house and/or contract mowing data for the 1980-81, 1984-85, and 1985-86 fiscal years were obtained.

The sampling scheme called for selecting 13 representative districts scattered over the state, three counties (one the most urban) from each district, one maintenance section within each county, and at least one highway section for each highway type (IH, US, etc.) in each maintenance section. The maintenance section supervisors were sent a form asking for general information on each study highway section, such as road and roadside characteristics, level of traffic, adjacent land use, and whether any major disturbance of vegetation had occurred due to construction activity during the study years. They were furnished some of the above information from the SDHPT's computer files and a maintenance section map for verification. Also, they were furnished monthly in-house mowing function costs and crew-manhours from the computer files for verification and asked to estimate the acres mowed, section-miles mowed, type of mowing cycle (full or strip), strip cycle width, and crew size (number of persons and tractors) for each mowing cycle performed during each of the study years. They were asked to carefully match up the monthly costs with each mowing cycle identified.

Nine of the study districts reported back usable in-house mowing data. Three districts do only spot safety in-house mowing, and one district failed to report. A total of 336 separate mowing cycle observations gave sufficient information to complete a unit cost per acre. Of these, 240 are observations on full-width (Type II) mowing and 96 are on strip-width (Type I) mowing. After careful screening for measurement and recording errors and for extremely high or low costs per acre, the number of observations was reduced to a total of 277 (196 full-width and 81 strip-width).

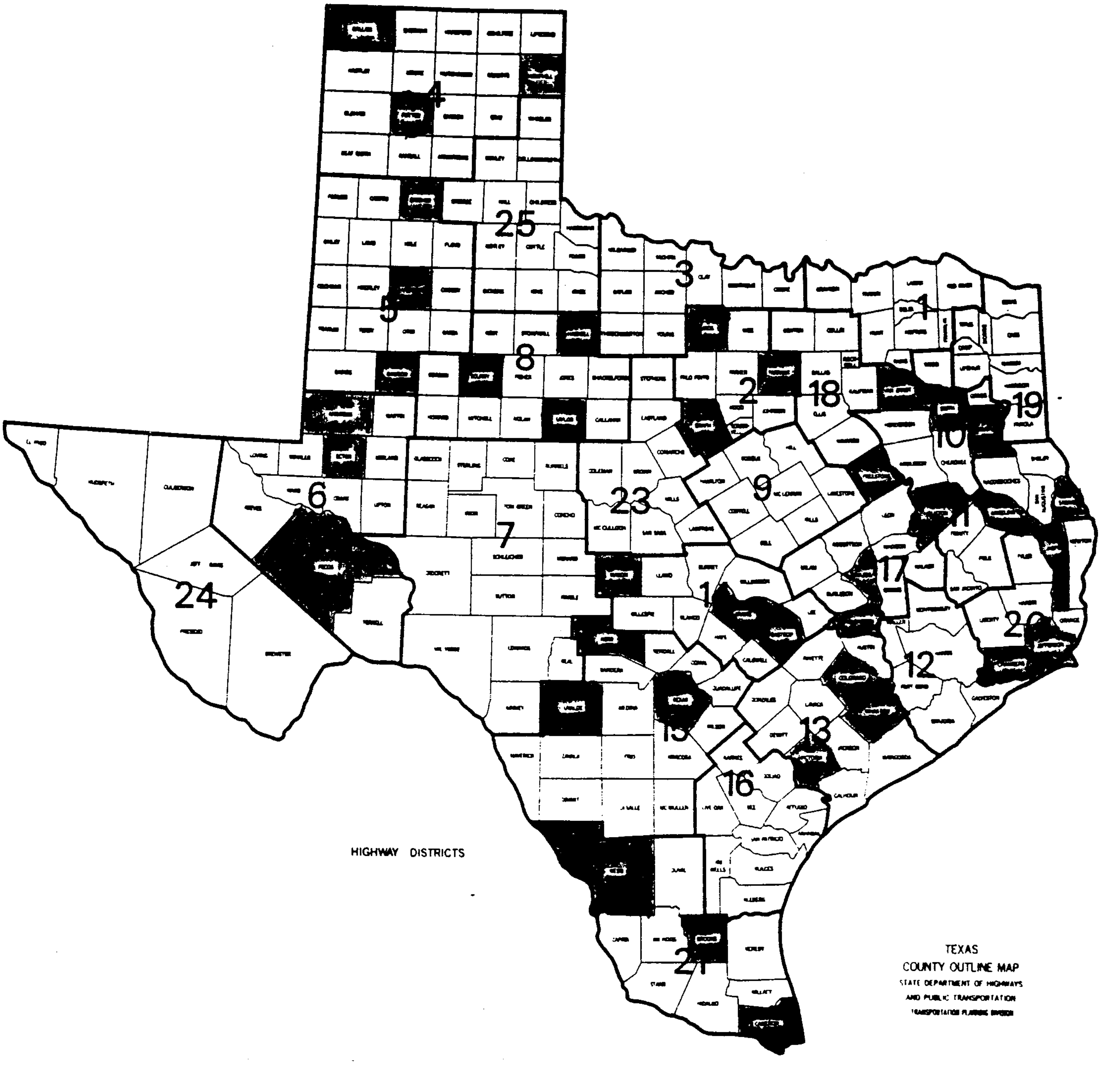


Figure 2. Counties with Sampled Highway Sections

Mowing costs for the contract function are established for the same study years from data collected on the same highway sections sampled to establish in-house mowing costs. When this sample was selected it was not known which highway sections were mowed by in-house personnel or by contractors. All contracts involving the sample of highway sections were pulled from the SDHPT's files and all relevant data were recorded on each type of mowing cycle in each contract. The sample of contracts yields a total of 289 mowing cycle observations, 170 full-width (Type II) and 119 strip-width (Type I).

Independent field studies were conducted in four of the nine districts reporting useable in-house mowing data to observe in-house mowing crews in action and collect relevant data to calculate the unit cost per acre. The number of acres mowed, number of manhours, equipment hours (actual and committed), type of mowing cycle, crew size, equipment type, crew wage rates, maintenance section wage composite rate, and rental rates for equipment used were obtained. Data for a total of 24 days (observations) of mowing were collected. Fifteen days represent full-width mowing and nine represent strip-width mowing.

Function Cost Differentials

As shown in Table 9, a comparison is made of the average cost per acre for in-house and/or contract mowing from the respective 1985-86 data bases. The 1985-86 fiscal year is used because it is the only year that field data could be collected for study. In the case of in-house mowing, the difference between the sample of highway sections data and the field data is about $5.00 per acre for either full-width or strip-width mowing cycles. However, the combined cycle cost difference between the data sources is only slightly over $2.00 per acre. For the cost per acre for the two data sources to be that close supports the overall accuracy of the findings. The two data bases do disagree on which type of mowing cycle costs the most. The field data indicates that full-width cycles cost more per acre than strip-width cycles, whereas, the sample data indicates that strip-width cycles cost more per acre than full-width cycles. The results of the latter seem more realistic because of less efficient equipment and personnel use to do strip mowing. One explanation for the field data yielding a higher full-width cycle cost per acre is that some of the full-width observations involved mowing very tall Johnson grass in and near San Antonio.

Table 9. Mowing Unit Cost per Acre by Mowing Function and Data Source (1985-86).

Mowing Function and Source	Average Cost per Acre[a]		
	Full-Width Cycle	Strip-Width Cycle	Combined Cycles
In-house Mowing			
Sample of Highway Sections	$15.10(46)	$23.54(20)	$17.45(66)
Field Studies	20.24(15)	17.15(9)	19.08(24)
Contract Mowing			
Sample of Highway Sections	11.37(54)	12.57(36)	11.85(90)

[a]The number of observations making up the average Cost per Acre is in parentheses.

In at least one case, the crew double mowed most of the roadside, almost doubling the cost.

Table 9 shows that the highway section data bases yield a much lower cost per acre for the contract mowing function than for the in-house mowing function. However, there is agreement between the two data bases that strip-width mowing cycles cost more per acre than full-width cycles.

By Year: Table 10 shows mowing cost per acre by type of cycle and function for each of the study years. Also shown are the differentials between in-house and contract mowing costs. All of these differentials are statistically significant at least at the 5 percent confidence level. In the case of strip mowing, the differentials for all three years are very nearly the same. However, in the case of full-width mowing, the 1984-85 differential is quite different from those of the other two years. The 1984-85 fiscal year is selected as the primary analysis year because it is the last full fiscal year of in-house mowing data. Therefore, the results for that fiscal year should be the most reliable. Also, the results of the 1986 field studies, presented in Table 9, support a higher differential than suggested by the 1980-81 or 1985-86 highway section data and suggest a lower differential than that indicated by the 1984-85 data. Finally, an analysis of data on highway sections mowed by in-house personnel and by contractor in the same fiscal year yields cost per acre differentials, as shown in Table 11, that support the 1984-85 differentials. Such data should yield the most accurate estimate of the true differential per acre for the years studied.

By District: Tables 12 and 13 present the full-width cycle and strip-width cycle mowing cost differentials by function and study district for the 1984-85 fiscal year. Even though there is considerble variation in the cost per acre, especially for the in-house mowing function, the pattern of giving a positive differential in favor of contract mowing is consistant for every district where a comparison can be made. Obviously, the full-width cycle differential for District 14 is extreme. Also, the strip-width cycle differential for District 4 is too high. These two differentials are supported by only a few contract and/or in-house mowing observations. The same is true for some of the other differentials. However, averaging all the observations for all districts gives more accurate and realistic differentials for making mowing policy decisions.

Table 10. Mowing Cost per Acre by Type of Cycle and Function for Study Years.

Type of Cycle by Fiscal Year	Cost Per Acre by Function[a]		
	Contract	In-House	Differential
1980-81			
Full-Width	$ 10.68(50)	$ 12.93(80)	$ 2.25*
Strip-Width	9.94(45)	20.58(25)	10.91*
Combined	10.33(95)	15.14(107)	4.81**
1984-85			
Full-Width	9.88(66)	18.42(79)	8.54**
Strip-Width	9.21(39)	20.16(38)	10.95**
Combined	9.63(105)	18.89(117)	9.26**
1985-86			
Full-Width	11.37(54)	15.10(46)	3.73*
Strip-Width	12.57(36)	23.54(20)	10.97**
Combined	11.85(90)	17.47(66)	5.62**

[a]Number of observations are shown in parentheses.

*Statistically significant differential at the 5 percent confidence level.

**Statistically significant differential at the 1 percent confidence level.

Table 11. In-house and Contract Cost per Acre Differentials Based on Mowing Same Highway Section by Fiscal Year.

Fiscal Year Compared	Cost Per Acre Differential[a]
1980-1981	$ 8.10 (5)
1984-1985	8.01 (16)
1985-1986	10.24 (15)

[a]Number of observations are shown in parentheses.

Table 12. Full-width Mowing Cost per Acre by Function and Study District (1984-85).

Study District	Cost per Acre by Function[a]		
	Contract	In-house	Differential
2	$ 15.02 (2)	$ b	$
4	13.04 (3)	21.78 (8)	8.74
5	5.70 (10)	12.07 (7)	6.37
6	5.73 (3)	11.43 (13)	5.70
8	5.95 (2)	20.19 (20)	14.24
10	15.20 (2)	b	-
11	11.21 (3)	12.95 (4)	1.74
13	9.63 (3)	19.34 (15)	9.71
14	15.02 (4)	56.36 (2)	41.34
15	8.51 (8)	17.97 (10)	9.46
17	8.15 (3)	b	-
20	9.51 (15)	b	-
21	13.56 (8)	b	-
All Study Districts	9.88 (66)	18.42 (79)	8.54

[a]Number of observations are shown in parentheses.

[b]Only spot or safety mowing done by in-house crews.

Table 13. Strip-width Mowing Cost per Acre by Function and Study District (1984-85).

Study District	Cost per Acre by Function[a]		
	Contract	In-house	Differential
2	$ b	$ c	$ -
4	6.46 (2)	53.21 (6)	46.75
5	5.70 (10)	10.58 (1)	4.88
6	7.53 (3)	8.67 (6)	1.14
8	5.63 (2)	9.60 (4)	3.97
10	15.45 (4)	c	-
11	b	5.91 (1)	-
13	10.08 (3)	7.09 (3)	2.99
14	15.36 (3)	c	-
15	9.22 (7)	28.75 (7)	19.53
17	8.15 (3)	c	-
20	b	c	-
21	14.11 (2)	c	-
All Study Districts	9.21 (39)	20.16 (38)	10.95

[a]Number of observations are shown in parentheses.

[b]No strip-width contracts let in 1984-85.

[c]Only spot or safety mowing done by in-house crews.

By Rural/Urban Location: The regression analysis appearing earlier in this report indicates that the urban/rural locational variable significantly effects mowing costs. The regression analysis uses 1984-85 maintenance section mowing costs in the 13 study districts as a data base. The contract mowing highway section data base somewhat confirms the earlier finding. Table 14 shows urban/rural contract mowing cost differential for all three study years. As can be seen, the differentials for strip-width cycle mowing tend to be larger than those for full-width cycle mowing. Also, mowing done in rural areas tends to be about $2.00 per acre higher than mowing done in urban areas.

A limited comparison can be made of contract versus in-house mowing cost differentials on an urban/rural basis by referring to Table 15. The only data available for computation of the in-house mowing cost per acre in an urban area is the 1986 field data. All of the in-house cost data collected on sample highway sections in urban areas are invalid. The individual observations are extremely high or low in comparison with the field observations. Table 15 indicates that the contract/in-house cost differential is somewhat higher for full-width mowing done in an urban area than in a rural area. Also, the contract/in-house cost differential for strip-width mowing is higher than for full-width mowing in rural area.

Overhead Cost Differentials

Overhead costs to the SDHPT to carry out the contract and in-house mowing functions for the 1980-81 and 1984-85 fiscal years are estimated at the division, district headquarters, and maintenance section levels. Four districts of the 13 study districts were selected to furnish these overhead estimates. Two of these districts (13 and 17) are contracting out most of their mowing and two (8 and 15) are primarily using in-house personnel to mow. Also, the four divisions which have to provide considerable administrative assistance to the two mowing functions were asked to furnish overhead estimates. Appropriate Department maintenance personnel at each level were asked to estimate the various overhead costs described earlier in the methodology section of this report.

Administrative, Office Space, and Warehouse Space Overhead: Table 16 shows the estimated overhead cost per acre for the contract and in-house mowing functions by type of overhead for the study years. As can be seen, the total overhead cost per acre for contract mowing decreased slightly from 1980-81 to

Table 14. Contract Mowing Cost per Acre in Rural and Urban Counties by Type of Mowing Cycle and Study Year.

Type of Cycle and Study Year	Cost per Acre by Location[a]		
	Rural	Urban	Differential
Full-Width Cycle			
1980-81	$ 12.05(17)	$ 9.55(27)	$ 2.50
1984-85	9.33(31)	10.40(40)	1.07
1985-86	10.86(33)	12.15(26)	1.29
Strip-Width Cycle			
1980-81	11.48(24)	8.21(23)	3.27
1984-85	10.68(18)	8.41(21)	2.27
1985-86	13.00(20)	13.77(15)	0.77
Combined Cycles			
1980-81	11.78(51)	8.93(50)	2.85
1984-85	9.83(49)	9.71(61)	0.12
1985-86	11.67(53)	12.74(41)	1.07

[a]Number of observations are in parentheses.

Table 15. Mowing Cost per Acre in Rural and Urban Areas by Function and Type of Cycle (1985-86).

Location and Type of Cycle	Cost Per Acre by Function[a]		
	Contract	In-House	Differential
Rural			
Full-Width	$ 10.86(33)	$ 15.74(26)	$ 4.88
Strip-Width	13.00(20)	28.23(13)	15.23
Combined	11.67(53)	20.78(39)	9.11
Urban			
Full-Width	12.15(26)	17.92(12)[b]	5.77
Strip-Width	13.77(15)	-	-
Combined	12.74(41)	-	-

[a]Number of observations are in parentheses.

[b]Based on field data base.

Table 16. Overhead Costs for Contract and In-house Mowing Functions for 1980-81 and 1984-85.

Type of Overhead by Year	Cost Per Acre by Function		
	Contract	In-House	Differential
District[a]			
1980-81	$ 0.86	$ 0.65	$ 0.21
1984-85	0.76	0.84	0.08
Division[b]			
1980-81	0.08	0.02	0.06
1984-85	0.12	0.02	0.10
Insurance			
1980-81	0.00	0.15	0.15
1984-85	0.00	0.18	0.18
Total			
1980-81	0.94	0.82	0.12
1984-85	0.88	1.04	0.16

[a]Based on Districts 8, 11, 15, and 17.

[b]Includes Divisions 3, 4, 18, and 20.

1984-85. The reverse has happened to in-house mowing. Most of this change has occurred at the district level. As can be seen, the differential overhead cost between contract mowing and in-house mowing is small. Such a small differential may be due to underestimating overhead due to these functions, especially the in-house function.

Other Overhead: Some charge may need to be made to downtime or inefficient use of the mowing crews and equipment during off-season.

During off-season the mowing tractors sit idle 80% of the time and mowing crew trucks sit idle 10% of the time. These estimates of equipment downtime are provided by maintenance personnel surveyed in the 13 study districts. The off-season use of mower tractors consists of pulling dirt, fertilizer, a drag squeeze, and a mower as well as being used in other maintenance activities. These functions are charged the appropriate rental for the use of these tractors in doing such maintenance activities. These maintenance functions seem to be as needed as the mowing function.

The off-season mowing crew trucks are used to haul signs, dirt, and other materials used in patching roads. They also are used as service vehicles for other maintenance functions. The appropriate functions are charged the equipment rental for the use of these trucks.

The mowing crews are used during the off-season to do other maintenance work. The 13 district survey indicates that mowing crews are used in off-season activities in the following amounts: general maintenance 45%, patching 16%, seal coating 9%, dirt work 5%, sign repair 3%, and unspecified activities 22%. However, since the field data indicate that the mowing crews' composite wage rate is $0.65 lower than the composite rate for the whole maintenance section, mowing crews may be subsidizing other maintenance functions during off-season. Therefore, no overhead charge should be made to the in-house mowing function.

Another possible charge to overhead that could be justified is inefficient use of in-house mowing crews and even other maintenance personnel during the regular work season. According to the 13 districts surveyed, the 8-hour day of a mowing crew is distributed as follows: six hours mowing the right-of-way and two hours performing mowing support activities (including traveling to and from the maintenance section headquarters). Consequently, mowing crews do not mow as many acres per day as they could. According to the survey, a crew member averages only 12.4 acres per day with a 5-7 ft. sickle mower and 37.3 acres per day with a 15 ft. rotary mower. If a crew member could mow an additional hour per day, he could increase his mowed acreage by 1.8 acres using a 5-7 ft. sickle mower and 6.2 acres using a 15 ft. rotary mower. Since the survey indicates that in 1985-86 the average full-width crew operates one 5-7 ft. mower and three 15 ft. mowers, an additional hour of mowing time would translate into an additional 20.4 acres per day per crew. In 1985-86, the average strip-width crew operated one 5-7 ft. mower and two 15 ft. mowers. Therefore, the average strip-width crew could mow an additional 14.2 acres per day. In contrast, some of the maintenance personnel indicate that the mowing crews of contractors mow at least eight hours per day. However, it is out of the scope of this study to collect data from contractors that could be used to clearly determine the efficiency of their mowing crews, thus preventing a direct comparison of the daily activities or production performances of contract and in-house mowing crews.

While meeting with maintenance personnel in the 13 districts over the state, the researcher heard very few complaints concerning the quality and appearance of the areas mowed by contract crews. Also, he noticed little difference in the quality and appearance of areas mowed by contract crews compared to those areas mowed by in-house crews.

In conclusion, the crews of contractors must be more efficient and be paid lower wages in order for contractors to survive on $10.00 per acre contracts. However, there may be a problem with double counting if an estimate is made of the cost of inefficient use of in-house mowing crews and equipment and adding that to the normal overhead costs. Further study is in order before making such a charge.

Total Cost Differential

Table 17 shows the total cost per acre for the contract and in-house mowing functions, i.e., direct charges to the maintenance function, plus overhead, for 1984-85. As can be seen, in-house mowing cost per acre is nearly double that for contract mowing, representing significant savings. This differential savings will fluctuate from year to year depending on various factors, such as demand for mowing contractors, wage rates, and the condition of the Texas economy. The differential for the 1980-81 fiscal year is less

Table 17. Total Cost of Contract and In-house Mowing Functions (1984-85).

Type of Cost	Cost Per Acre by Function		
	Contract	In-House	Net Difference
Charged to Function	$ 9.63	$ 18.89	$ 9.26
Overhead	0.88	1.04	0.16
Total	$ 10.51	$ 19.93	$ 9.42

than half the size of that for 1984-85, being only $4.69 per acre and demonstrating how fluid the differential can be in a five-year period.

Cost Comparisons of Contract and In-house Litter Pickup

Only a limited amount of data has been obtained on the cost of litter pickup. All districts that have been contracting some of the litter pickup were contacted to obtain comparative cost information on contract and in-house litter pickup. They were asked about recent contract defaults and new contracts on highways previously having the litter picked up by in-house personnel. Of the defaulted contracts, only one could be used. Also, since the "set-aside" litter pickup program has been in use by most of these districts, no situation was found whereby litter pickup had changed from an in-house to a contractor operation or vice versa.

Function Cost Differentials

District 14 had a default in 1986 on a section of IH-35, and district maintenance personnel were used to pick up the litter in the same manner called for under the contract. The data collected on this case are accurate and useful in establishing a contract/in-house cost differential. Labor, equipment, dump fees, and litter bag costs make up the total in-house cost. The contract amount is used as the contract cost. The total acreage involved was calculated and is used to convert the total in-house and contract cost into a unit cost per acre.

Table 18 shows the results of the above analysis. The differential of $9.29 is almost the same as that calculated for 1984-85 in-house mowing. Obviously, some more case studies need to be developed to test the validity of the results obtained from this first case study. Also, the set-aside program needs to be evaluated, because there is quite a bit of variation in the cost per manhour from district to district.

Overhead Cost Differential

No data were collected to determine litter pickup overhead. Therefore, no differential between in-house and contract litter pickup can be established. However, the overhead for litter pickup is not expected to be much different from that for mowing. Assuming that this assumption is fairly accurate, a

Table 18. Litter Pickup Cost per Acre by Function in 1986 (Based on One Case Study).

Litter Function	Cost Per Acre
In-House	$ 16.29
Contract	7.00
Differential	9.29

differential of $0.12 per acre is recommended, derived from an overhead charge of $.88 for contract litter pickup and $1.00 for in-house litter pickup.

Total Cost Differential

The total differential between contract and in-house litter pickup is derived as follows:

Type of Cost	Contract	In-house	Differential
Direct Charges to Function	$ 7.00	$ 16.29	$ 9.29
Assumed Overhead	0.88	1.00	0.12
Total Cost to Function	$ 7.88	$ 17.29	$ 9.41

The reader is cautioned that the above differential is based only on one case experience and on an assumed overhead amount.

Benefits and Costs of a Pest Plant Control Program

Of the 13 districts studied, three (Districts 10, 11, and 13) are using the herbicide Roundup extensively to control roadside Johnson grass for three or four years. Therefore, the study concentrates on these districts. The other 10 districts either have no overspray program or have just started one.

Overspraying Practices

Table 19 summarizes the overspraying practices of the three districts mentioned above. It presents three years of data for Districts 10 and 11 and four years of data for District 13. The number of spray cycles, spray distance, spray units, and months of overspraying increased after these districts started their overspraying programs. Although not shown in Table 19, the gallons of Roundup also increased until the 1985-86 season, when all three districts show a decrease in the use. Districts 10 and 11 are using a limited amount of Oust with Roundup to kill Johnson grass roots and seed, therefore, making the program more effective. All districts add a drift control agent to help control winddrift. Nalco-trol is the agent presently being used. The added number of overspray units in each of the three districts is allowing more of the roadsides to be sprayed at the optimum time to kill Johnson grass roots and seeds, thus helping the program to be more effective.

Table 19. Overspraying Practices of Study Districts.

Overspray Practice by District	1982-83	1983-84	1984-85	1985-86
District 10				
Types of Herbicide	NA	Rdup/Oust	Rdup/Oust	Rdup/Oust
Spray Cycles (No.)	NA	1	2	2
Spray Distance (Ft.)	NA	10 - 12	10 - 25	12 - 36
Months of Overspraying	NA	June-July	June-July	June-Nov.
Truck Units (No.)	NA	2	5	6
District 11				
Types of Herbicide	NA	Rdup/Oust	Rdup/Oust	Rdup/Oust
Spray Cycles (No.)	NA	1 - 2	2	2
Spray Distance (Ft.)	NA	0 - 30	0 - 30	0 - 30
Months of Overspraying	NA	June-Nov.	June-Nov.	June-Nov.
Truck Units (No.)	NA	2	3	4
District 13				
Types of Herbicide	Roundup	Roundup	Roundup	Roundup
Spray Cycles (No.)	1	1	2	2
Spray Distance (Ft.)	15 - 20	15 - 30	15 - 30	20 - 30
Months of Overspraying	July	July-Aug.	July-Oct.	June-Oct.
Truck Units (No.)	Unk	Unk	6	11

Changes in Herbicide and Mowing Costs

Table 20 shows the level of mowing and herbicide costs for fiscal years 1982-83, 1983-84, and 1984-85 in the three study districts. These costs do not include overhead costs, which are covered later in this report. Also, these costs are not adjusted for inflation. They only include those costs charged directly to the appropriate function code. Table 21 shows the changes in these costs between 1982-83 and 1984-85. As can be seen, total mowing costs (in-house and contract combined) have decreased significantly and herbicide costs have increased significantly. The total cost incurred from mowing and herbicide spraying has decreased nearly 20 percent in District 10 but has increased slightly in Districts 11 and 13. The decrease in total mowing costs in Districts 10 and 11 is partly due to a reduction in the number of strip-width cycles from two to one. District 13 has made no changes in the number of mowing cycles (full or strip). Also, a portion of the decrease in mowing costs in Districts 11 and 13 is a result of switching from in-house to contract mowing. In-house mowing costs actually increased slightly in District 10. It should be noted that total mowing costs decreased more than the increase in herbicide spraying costs in District 10. Since one strip-width mowing cycle was eliminated, part of the reduction in mowing cost can be attributed to the overspraying program. The same is true for District 11.

Table 22 shows the total mowing and herbicide spraying costs for three study districts combined and all other districts combined for 1982-83 and 1984-85. Notice that the total mowing cost for the study districts decreased almost 17 percent more than in the other districts. On the other hand, herbicide spraying cost increased over 100 percent in the study districts but decreased slightly in the other districts. However, the total increase in herbicide spraying cost in the study districts does not offset all of the decrease (savings) in mowing cost. Such results tell us that these districts have experienced a net savings in mowing cost inspite of or because of the increase in herbicide spraying cost. Furthermore, most of the savings in mowing cost due to the herbicide overspraying program in these districts is still forthcoming.

Functional Cost per Acre

Table 23 shows the 1984-85 mowing and herbicide spraying costs in the study districts on a cost per vegetation inventory acre basis. The number of

Table 20. Mowing and Herbicide Spraying Costs in Study Districts for Selected Years.[a]

Maintenance Function by District	1982-83	1983-84	1984-85
District 10			
In-house Mowing	$ 9,511	$ 7,652	$ 13,386
Contract Mowing	1,064,137	769,877	631,457
Herbicide Spraying	166,974	286,606	352,515
Total	1,240,622	1,064,135	997,358
District 11			
In-house Mowing	134,565	101,818	78,582
Contract Mowing	355,067	289,961	301,299
Herbicide Spraying	164,946	185,424	347,643
Total	654,578	577,203	727,524
District 13			
In-House Mowing	534,491	555,355	442,011
Contract Mowing	717,730	462,215	578,940
Herbicide Spraying	267,910	468,880	589,385
Total	1,520,131	1,486,450	1,610,336

[a]Includes only charges made directly to the mowing and herbicide function codes.

Table 21. Changes in Mowing and Herbicide Spraying Costs in Study Districts Between 1982-83 and 1984-85.[a]

Maintenance Function by District	Change in Cost Between 1982-83 and 1984-85	
	Dollars	Percent
District 10		
In-house Mowing	+ 3,875	+ 40.7
Contract Mowing	- 432,680	- 40.7
Total Mowing	- 428,805	- 39.9
Herbicide Spraying	+ 185,541	+ 111.8
Total For All Functions	- 243,264	- 19.6
District 11		
In-house Mowing	- 55,983	- 41.6
Contract Mowing	- 53,768	- 15.1
Total Mowing	- 109,751	- 22.4
Herbicide Spraying	+ 182,697	+ 110.8
Total For All Functions	+ 72,946	+ 11.1
District 13		
In-House Mowing	- 92,480	- 17.3
Contract Mowing	- 138,790	- 19.3
Total Mowing	- 231,270	- 18.5
Herbicide Spraying	+ 321,475	+ 120.0
Total For All Functions	+ 90,205	+ 5.9

[a]Includes only charges made directly to the mowing and herbicide function codes.

Table 22. Changes in Mowing and Herbicide Spraying Costs for Study Districts Vs. Other Districts Between 1982-83 and 1984-85.

District and Function	Total Cost (000)		Change in Cost	
	1982-83	1984-85	Dollar(000)	Percent
Three Study Districts[a]				
Mowing	$ 2,815.5	$ 2,045.7	$ - 769.8	- 27.3%
Herbicide Spraying	599.8	1,289.5	+ 689.7	+ 115.0
All Other Districts				
Mowing	19,999.4	17,903.4	-2,096.0	- 10.5
Herbicide Spraying	6,302.3	6,267.5	- 34.8	- 0.6

[a]Districts 10, 11, and 13.

Table 23. Total Mowing and Herbicide Spraying Cost per Acre for Selected Districts (1984-85).

District	Cost Per Acre by Function[a]		
	Total Mowing	Herbicide Spraying	Differential
10	$ 19.37	$ 10.59	$ 8.78
11	15.73	14.39	1.34
13	30.32	17.50	12.82

[a]Based on vegetation inventory acres as follows: 33,287 acres for District 10, 24,157 acres for District 11, and 33,673 acres for District 13.

inventory acres in each of these districts is shown at the bottom of Table 23. The herbicide spraying cost per inventory acre is considerably less than the mowing cost per inventory acre in two of the three districts, as indicated by the cost differentials. The mowing cost per inventory acre is considerably lower in the district which shows the lowest cost differential. One can compare the three districts' 1984-85 mowing and herbicide spraying costs even more easily by referring to Table 24. The cost per acre is not only put on a vegetation inventory area (acreage) basis, but also on a mowed area, treated area, and involved area basis. As Table 24 shows, the herbicide treated area cost is higher than the mowed area cost. However, the area involved in herbicide overspraying is much larger than the area treated or actually sprayed in the path of the spraying unit. Therefore, the cost per involved acre is considerably lower than the mowed area cost in Districts 10 and 11. As already indicated, the same is true for the mowing and spraying cost per vegetation-inventory acre.

The realized and projected savings from the herbicide overspraying program initiated in the study districts are shown in Table 25. Modest savings are shown for 1984-85 due to initiation of the program only two years before. The projected savings for the next three years are based on 1984-85 costs and on the indicated reductions in mowing and overspraying cycles. Over a five year period, the savings could be about $25 per inventory acre. Based on 91,117 inventory acres, the total savings could amount to $2,256,057.

Overhead Cost per Acre

Overhead costs are estimated for the in-house herbicide spraying function in the same manner as was done for the mowing functions. Table 26 shows a breakdown of the cost per inventory acre for direct charges to the function and division, district, and insurance overhead for the 1984-85 fiscal year. The total overhead cost adds up to $1.22 per inventory acre. This is slightly higher than for the mowing functions.

Effectiveness of Program

The district maintenance headquarters and maintenance section personnel in Districts 10, 11, and 13 were asked to give their opinion of the effectiveness of their overspraying programs from the time they started. They were asked to rate the effectiveness of such a program in (1) establishing desirable grasses,

Table 24. Mowing and Herbicide Spraying Cost per Acre by Type of Area for Selected Districts (1984-85).

Function and Type of Area	Cost Per Acre		
	District 10	District 11	District 13
Mowing			
Mowed Area[a]	$ 11.88	$ 11.21[a]	$ 9.02[a]
Vegetation Area	19.37	15.73	30.32
Herbicide Spraying[b]			
Treated Area	17.63	11.68	11.75
Involved Area	6.72	7.54	9.65
Vegetation Area	10.59	14.39	17.50

[a]Based on one full-width cycle and one strip-width cycle for Districts 10 and 11 and two full-width cycle and three strip-width cycle for District 13.

[b]Based on 2 spraying cycles.

Table 25. Realized and Projected Savings from Herbicide Overspraying Program.

Fiscal Year	Mowing Cycles[a]		Overspray Cycles[a]	Cost Per Acre[b]	
	Full	Strip		Total	Savings
1982-83	1.33	2.33	1	$ 37.48	
1984-85	1.33	1.66	2	36.60	$ 0.88
1985-86 (projected)[c]	1.33	1.66	2[d]	32.09	4.51
1986-87 (projected)[c]	1.00	1.00	1	22.12	9.97
1987-88 (projected)[c]	1.00	0.00	0	8.78	13.34
Total Savings Per Acre					$ 28.70

[a]Average of Districts 10, 11, and 13.
[b]Based on 91,117 vegetation inventory acres and functional costs for 3 districts.
[c]Projections based on 1984-85 costs.
[d]Reduced treated acres by 25%.

Table 26. Total Cost of In-House Herbicide Spraying Function (1984-85).

Type of Cost	Cost Per Acre
Charged to Function[a]	$ 14.16
District Overhead[b]	1.15
Division Overhead	0.05
Insurance Overhead	0.02
Total	15.38

[a]Based on vegetation inventory acres of three study districts.
[b]Based on four study districts used to determine overhead for the mowing functions.

(2) eradicating undesirable grasses, and (3) improving the appearance of the roadsides where sprayed. Table 27 summarizes the results of this survey. The personnel in District 10 gave themselves a 65% rating in all three categories. Those in District 11 gave themselves an even higher rating in all three categories than did those in District 10. Their highest rating was an 85% effectiveness in eradicating undesirable grasses. The District 13 personnel gave themselves a percentage range of effectiveness in accomplishing the three goals.

The field observations of the study supervisor confirm the above ratings as being reasonable. In fact, the District 10 personnel may have been too conservative with their ratings.

Expected Effects of Changes in Vegetation Control Practices

The district maintenance engineers/supervisors of the 13 study districts were surveyed to determine their opinions of the effects of certain changes in mowing and vegetation control practices. One district failed to respond. The results of this survey are summarized below.

Reduction in Mechanical Mowing

The district maintenance personnel were asked to give their opinion on what effect a reduction in mechanical mowing would have on litter removal costs, accident (motorist) costs, fire damage costs, herbicide costs, drainage/ erosion and repair costs; and appearance of the right-of-way. The results are presented in Table 28. The majority of those responding say that accident (motorist) costs, fire damage costs, and drainage/erosion costs would increase as a result of mechanical mowing. In contrast, a majority think that litter removal costs would decrease and that herbicide costs would not change or didn't have a response. Last, they are divided on the effects of reduced mowing on the appearance of the right-of-way.

They were also asked their opinion on what effect a reduction in mechanical mowing would have on their overspraying operations. Table 29 gives their responses and shows that a large majority think that reduced mowing would increase overspraying operations. Also, a majority says that the change to less mowing and more overspraying would be cost-effective. This response is very significant in the light of the present debate over the use of overspraying to reduce mowing.

Table 27. Effectiveness of Overspraying Program Based on the Opinions of SDHPT District and Maintenance Section Personnel.

Overspray Effectiveness by District	1982-83	1983-84	1984-85	1985-86
District 10				
Establishing Desirable Grasses	NA	35	50	65
Eradicating Undesirable Grasses	NA	35	50	65
Improving Appearance	NA	35	50	65
District 11[a]				
Establishing Desirable Grasses	40	50	60	70
Eradicating Undesirable Grasses	60	70	80	85
Improving Appearance	50	55	65	75
District 13[b]				
Establishing Desirable Grasses	0 - 10	10 - 25	15 - 50	30 - 75
Eradicating Undesirable Grasses	5 - 10	10 - 20	30 - 60	40 - 75
Improving Appearance	10 - 40	10 - 50	20 - 60	40 - 70

[a]Applies to Houston County.
[b]Applies to Colorado and Wharton Counties.

Table 28. Expected Effects of a Reduction in Mechanical Mowing on Different Costs.[a]

Type of Cost	Effects by Number of Districts			
	Decrease	Increase	No Change	Other[b]
Litter Removal Costs	6	1	4	1
Accident (Motorist) Costs	0	8	4	0
Fire Damage Costs	0	7	3	2
Herbicide Costs	0	5	4	3
Drainage/Erosion Costs	0	7	5	0
Appearance of Right-of-Way	6	5	0	1

[a]Stated opinions of 12 district maintenance engineers or supervisors.

[b]No response or don't know.

Table 29. Expected Effects of Reductions in Mechanical Mowing on Overspraying Operations.[a]

Question	Response by Number of Districts		
	Yes	No	Other[b]
Would Increase Over-spraying Operations	10	1	1
If Yes, Would Change Be Cost-Effective?	7	3	2

[a]Stated opinions of 12 district maintenance engineers or supervisors.

[b]No response or don't know.

As a follow-up question, the maintenance personnel were asked what effect increased overspraying would have on the different costs enumerated in the earlier question. The results shown in Table 30 indicate that they are more or less divided on the effects of this action on these costs, except for accident (motorist) costs which they say would not change. Also, they are divided on the effects on the appearance of the right-of-way.

Increased Contract Mowing

They were also asked if increased contract mowing would be an acceptable alternative to in-house mowing and, if so, would this change be cost-effective. The results shown in Table 31 reveal that 100 percent think that increased contract mowing is an acceptable alternative to in-house mowing and two-thirds think this change would be cost-effective.

Planned Changes

Last, they were asked what changes are planned for their vegetation control program to make it more cost-effective. As shown in Table 32, the only planned change that was mentioned by nearly half of the respondents is that of increasing overspraying.

Table 30. Expected Effects of Increased Overspraying on Different Costs.[a]

Type of Cost	Effects by Number of Districts			
	Decrease	Increase	No Change	Other[b]
Litter Removal Costs	4	2	5	1
Accident (Motorist) Costs	2	0	7	3
Fire Damage Costs	2	4	3	3
Drainage/Erosion Costs	0	5	5	2
Appearance of Right-of-Way	3	5	1	3

[a]Stated opinions of 12 district maintenance engineers or supervisors.

[b]No response or don't know.

Table 31. Expected Effects of Increased Contract Mowing as an Alternative to In-house Mowing.[a]

Question	Response by Number of Districts		
	Yes	No	Other[b]
Would Increase Over-spraying Operations	12	0	0
If Yes, Would Change Be Cost-Effective?	8	0	4

[a]Stated opinions of 12 district maintenance engineers or supervisors.

[b]No response or don't know.

Table 32. Planned Changes in Vegetation Control Program to Make More Cost-effective.[a]

Type of Change	Increase or Expand	Decrease or Reduce	No Change	Other[b]
Overspraying	5	0	4	3
Herbicides	2	0	0	10
Contract Mowing	1	1	0	10
Safety and Strip Mowing	1	0	0	11
No Mow and Low Maintenance Plant	1	0	0	11

[a]Stated plans of 12 district maintenance engineers or supervisors.

[b]Answer doesn't fit other answer groups, no rsponse, or don't know.

STUDY SUMMARY AND CONCLUSIONS

This report presents the background and objectives, analytical methodology, and findings on that portion of the study dealing with mowing, litter pickup, and herbicide maintenance functions. The basic methodology used ranges from a before-and-after evaluation to a cross-sectional analysis. Besides the literature review, the data base used is from the SDHPT's central computer and contract files, survey forms filled out by SDHPT's district and maintenance section personnel, and field studies conducted by TTI personnel.

Changes in Mowing Practices and Costs

At least 20 factors affecting mowing and vegetation management costs are cited in the literature. Most of these factors are analyzed in this report through a regression analysis to determine their statistical significance to mowing costs. An evaluation of the Department's 26 county data bases suggests a more extensive evaluation of weather conditions as the possible causes of differences in mowing costs in the state.

The results of a survey of 13 selected districts throughout the state reveal that current mowing practices, such as the number of mowing cycles, width of strip-mowing, number of in-house crews, in-house crew sizes, and number of permanent versus summer employees are little different from those of five years ago. Even though the time series analysis reveals little change in mowing practices in these districts, a cross-sectional analysis does reveal some differences in practices among districts. There are differences in mowing cycles, strip-cutting widths, crew sizes, number of mowing employees (permanent and summer), pay per manhour to these employees, amount of contracting out mowing, amount of non-mowed areas, and extent of use of overspraying to control Johnson grass. Eight of the 13 districts are setting aside non-mowed areas and five are overspraying Johnson grass.

A regression analysis of the effects that different factors might have on the cost of the mowing and herbicide functions grouped in various ways reveals several statistically significant factors (variables). Total mowing costs (contract and in-house combined) are significantly affected by vegetation inventories acreages, number of full-width cycles, amount spent on herbicides, and location (rural/urban) in an urban area. In-house mowing costs are significantly affected by these four variables and one other, namely, the amount spent on contract mowing. Contract mowing costs are significantly affected by the same four variables plus the amount spent on in-house mowing, and two vegetation areas located in the eastern and coastal sections of the State. The R^2's, percentage of explained variation, of the four models presented in this report are relatively high, ranging from .7343 to .8401. The in-house mowing cost model has the highest R^2. Another model, using the 13 district highway section data base, reveals that in-house mowing costs are significantly affected by the level of traffic volume, mowing crew size, soil type (clay loam/waxy) and Districts 6, 11, and 13. This model has an R^2 of .6334, but it is not presented in this report.

Contract Versus In-House Cost Comparisons

Contract and in-house mowing cost comparisons are made by using the 13 district highway secton data base. This data base shows about the same percentage change in mowing costs between 1980-81 and 1984-85 as the total of all highway sections in the state. The 13 district sample analysis reveals that contract mowing costs declined over four times that of in-house mowing between 1980-81 and 1984-85. Therefore, contract mowing is making a significant impact on total mowing costs.

The highway section data base, composed of 277 useable in-house mowing observations and 289 useable contract mowing observations, is used to establish the contract versus in-house mowing unit cost per acre differentials. Data obtained in the field confirms the in-house mowing unit cost per acre indicated by the highway section data base.

The contract versus in-house mowing cost differentials established from the highway section data bases for the three study years range from \$2.25 to \$8.54 per acre for full-width cycles and from \$10.91 to \$10.97 per acre for strip-width cycles in favor of contract mowing. On a combined cycle basis, the cost differentials range from \$4.81 to \$9.26 per acre, and the size of these differentials are tending to get larger over time. The largest and the most accurate part of the three year data base is representing the 1984-85 fiscal year. The cost differentials for that year are \$8.54 per acre for full-width cycles and \$10.95 per acre for strip-width cycles. These differentials are supported by a separate analysis of in-house and contract mowing occurring on the same highway section the same year. Therefore, these are the recommended differentials.

The magnitude of these differentials fluctuate fairly widely from district to district but are always positively in favor of contract mowing. Also, there is a small differential between rural and urban mowing costs for both contract and in-house mowing.

Overhead costs to the SDHPT to carry out the contract mowing cost functions for the 1980-81 and 1984-85 fiscal years are estimated through the help of selected districts and divisions. The total estimated overhead cost per acre for contract mowing is $0.94 for 1980-81 and $0.88 for 1984-85. The comparable amounts for in-house mowing are $0.82 for 1980-81 and $1.04 for 1984-85. The resulting contract versus in-house overhead cost differentials are $0.12 per acre for 1980-81 and $0.16 per acre for 1984-85. These differentials include only costs due to administration, office space, and warehouse space assigned to the mowing functions. Although not estimated, some charge may be needed for inefficient use of mowing crew and equipment. During off-season, mowing tractors sit idle 80% of the time. Also, during the mowing season, mowing crews are not used as efficiently as those of contractors. According to the 13 districts surveyed, mowing crews get in an average of only six hours of mowing per day.

The total 1984-85 mowing contract versus in-house cost differentials is $9.42 per acre, counting direct costs to the function and also overhead. Using the 1980-81 differential as an example, the differential savings will fluctuate from year to year depending on various factors.

The contract versus in-house litter pickup cost differential is based on one case study of a 1985-86 contract default. Based on direct charges to the litter pickup functions, a differential of $9.29 per acre in favor of contracting is calculated. This differential is about the same as that for the mowing functions. No data were collected to determine litter pickup overhead. However, the overhead for litter pickup is not expected to be much different from that of mowing. Assuming this assumption is accurate, a differential of $0.12 per acre is recommended. Therefore, the total litter pickup differential recommended is $9.41 per acre.

Changes in Herbicide and Mowing Costs

Of 13 districts studied, three are using Roundup in an extensive over-spraying program to control Johnson grass and thus are releasing Bermuda and native grasses. Therefore, these three districts are the study districts used to determine the effectiveness of such a program in reducing mowing and overall vegetation control costs.

The new overspraying practices have been in place in these three districts for three or four years. The number of overspray units recently added is allowing more of the roadsides to be sprayed at the optimum time to kill Johnson grass roots and seeds, thus, helping the program to be more effective year-by-year. Between 1982-83 and 1984-85, total mowing costs have decreased from 19 to 40 percent in these three districts. However, herbicide spraying costs have increased from 112 to 120 percent, but the combined cost of the herbicide and mowing functions shows a 20 percent decline in one district and only a modest 6 to 11 percent increase in the other districts. Also, it is significant to point out that mowing costs decreased 27 percent in the three study districts compared to only a 10.5 percent decrease in all other districts in the state. In contrast, herbicide costs increased 115 percent in the three districts compared to a one percent decline in the other districts. However, the total increase in herbicide spraying cost in the study districts does not offset all of the decrease (savings) in mowing costs. Such results tell us that these districts have experienced a net savings in mowing costs in spite of or because of the increase in herbicide spraying costs.

A comparison of the unit costs of the herbicide spraying function versus the mowing functions reveals a cost differential of from $1.34 to $12.82 per inventory acre of vegetation in favor of the herbicide function. It is projected that when these three districts finish their five-year overspraying programs at the end of the 1987-88 fiscal year, the total savings will reach a total of $28.70 per inventory acre. Based on 91,117 inventory acres, the total savings could amount to $2,256,057.

Overhead costs for 1980-81 and 1984-85 are estimated for the in-house herbicide spraying function in the same manner as done for the mowing functions. The 1984-85 overhead cost adds up to $1.22 per inventory acre, and when added to the $14.16 per acre charged to the herbicide function, the total cost per inventory acre reaches $15.38.

The district maintenance headquarters and maintenance section personnel in the three study districts were asked to give their opinion of the effectiveness of their overspraying programs from the time they started them. They were asked to rate the effectiveness of such a program in (1) establishing desirable grasses, (2) eradicating undesirable grasses, and (3) improving the appearance of the roadsides where sprayed. By the end of the 1985-86 fiscal year, two districts (10 and 11) give themselves effectiveness ratings of from 65 to 85 percent in all three effectiveness categories. The third district gives itself more modest ratings of from 30 to 75 percent in the three categories. The observations of the study supervisor confirm these ratings as being reasonable.

Expected Effects of Changes in Vegetation Control Practices

The district maintenance engineers/supervisors of the 13 districts study were asked their opinions of the effects of changes in certain mowing and vegetation control practices. Twelve districts gave responses. They were asked about the effect of a reduction in mechanical mowing on various stated costs. The majority response is that a reduction in mowing would increase accident, fire damage, and drainage/erosion costs and decrease litter removal costs. They give a divided response concerning the effects of reduced mowing on the appearance of the right-of-way. In a separate question, they were asked what effect reduced mowing would have on their overspraying operations. The majority response is that reduced mowing would increase overspraying operations and that such effect would be cost-effective.

Another question was asked about what the effect of increased overspraying would have on the same costs mentioned above. Their responses are divided on the effects of increased overspraying on these costs and the appearance of the right-of-way. When asked what changes that they are planning in order to make their vegetation control program more cost-effective, the response of about half of them is to increase overspraying. Finally, when asked if increased contract mowing is an acceptable alternative to in-house mowing, 100 percent affirm and also two-thirds of them think that such action would be cost- effective.

Conclusions and Recommendations

The primary conclusions that can be reached from this study are as follows:

1. There are several factors that significantly affect mowing costs, primary among them being the amount and cost of contracting and the extent of herbicide spraying to control Johnson grass. Others are acres mowed, number and type of mowing cycle, crew size, volume of traffic, urban/ rural location, SDHPT district, soil type, and vegetation area of the state.
2. Contract mowing is considerably cheaper than in-house mowing.
3. Contract litter pickup is also considerably cheaper than in-house litter pickup.
4. The overspraying programs in the three study districts are already producing net savings in mowing costs.
5. The overhead cost estimates for the mowing, litter pickup, and herbicide maintenance functions may be somewhat low due to the method used to make such estimates.
6. Most of 13 districts surveyed think that reduced mechanical mowing would increase overspraying operations and that such an effect would be cost-effective. Also, all 13 districts think that increased contract mowing is an acceptable alternative to in-house mowing, and 75 percent think that such action would be cost-effective.

The following recommendations are made to the sponsors:

1. Implement the findings of the study as soon as possible.
2. Give the three study districts more time to perfect their overspraying programs by allowing them to cut further back on mechanical mowing.
3. Perform a detailed evaluation of contracting procedures to reduce chance of defaults.
4. Determine a reasonable level of in-house backup personnel and equipment to have on hand in case of a default.
5. Determine other feasible alternative actions to take besides using an in-house backup crew in case of default.
6. Continue study of overspraying program to more clearly establish its cost-effectiveness in various parts of the state.
7. Perform a thorough study of litter pickup costs, including the set-aside program.

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