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16. Abstract

The Highway Performance Monitoring System (HPMS) was developed by the Federal Highway Administration to collect sample data on the public highway system in the United States and to provide information to the U. S. Congress and others on the current status of the highway system and future needs. This report examines the procedure to calculate the sample size in each state, the deficiencies in the current procedure, and a method to overcome those deficiencies.

The report also looks at some comparisons of the HPMS output for Texas. These comparisons include the overall twenty-year needs in Texas and performance measures of fuel consumption, vehicle miles, and accidents.

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Highway Performance Monitoring System, HPMS, Sample Size, Performance Measures

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SAMPLE SIZE AND ACCURACY OF HIGHWAY PERFORMANCE MONITORING SYSTEM

by

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Research Report 480-1
Research Study Number 2-10-85-480
Evaluation of Highway Performance Monitoring
System for Use in Texas

Sponsored by

Texas State Department of Highways
and Public Transportation

in cooperation with

U.S. Department of Transportation
Federal Highway Administration

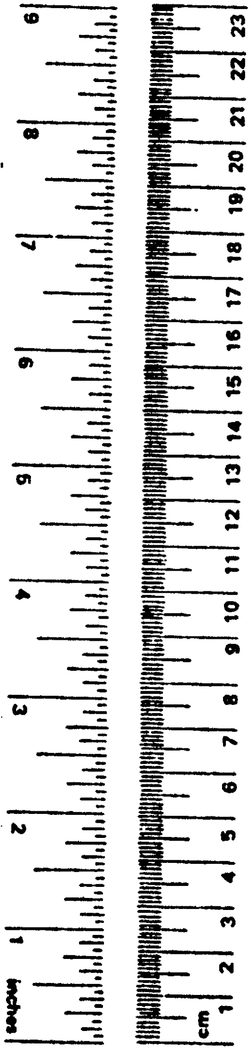
May 1986

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas

METRIC CONVERSION FACTORS

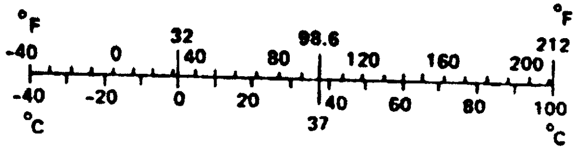
Approximate Conversions to Metric Measures

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



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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*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.

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The contents of this report reflect the views of the author and do not necessarily reflect the official views or policies of the Federal Highway Administration or the State Department of Highways and Transportation. This report does not constitute a standard, a specification, or a regulation.

SUMMARY

This report covers some of the characteristics of the Highway Performance Monitoring System (HPMS) sample in Texas and the validity of the recommended method to select the sample size for each state. A recommended method to correct the deficiencies in the sample size technique is also presented along with some comparisons of HPMS output with data from other sources.

The current HPMS sample in Texas includes a rural sample, small urban sample, and a sample of thirty urbanized areas. Each area is sampled by functional class and AADT volume group within each functional class. The objective is to get close to a homogeneous group of highway sections in each group since the sampled sections are used to represent all sections in that group.

The current sampling procedue is deficient. The method to calculate the sample size in each volume group is not correct and generally results in samples being too large in the lower AADT volume groups and too small in the higher groups. At the higher groups it is possible to have a sample size of one or two no matter how many sections are in the group.

A method is recommended to overcome the deficiencies of the current sample size procedure. The recommended technique involves sampling at the functional class level and distributing the sample to the AADT volume groups. In Texas, the recommended change would require about 1,700 additional samples for statewide use, and about 6,300 additional samples for use at the district level. Most of the additional samples are needed in rural areas.

The output of the HPMS analysis programs is also compared to data from other sources. The HPMS estimate of Texas 20-year needs is compared to the 20-year project list for Texas, which is calculated independent of HPMS by District personnel in Texas. Even though the comparison is not complete, HPMS tends to estimate higher rural rehabilitation needs and somewhat less rural added-capacity needs than is contained in the 20-year list. In comparing HPMS output to some performance measures, such as fuel consumption and accidents, the estimates are reasonably close, indicating some level of confidence in the program assumptions and calculations.

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INTRODUCTION

The Highway Performance Monitoring System (HPMS) (1) was developed by the Federal Highway Administration (FHWA) to provide Congress and others timely and accurate information on the public highway system. This information covers the condition of the existing system as well as future anticipated needs and the impacts if future funding does not cover those needs.

The HPMS program covers two major areas. The first is data on the highway system. A sample of highway sections is used to represent the entire system. Detailed data are collected by the states on these sample sections and that information, along with a small amount of data on all highway sections, are sent to FHWA each year. Statistical methods are used to select the sample size, based upon functional category and AADT volume groups. A random selection process is used to select the samples, which is then maintained over time. A new sample is not taken each year but the same sample is maintained, with only necessary additions or deletions made to conform to the statistical procedure.

A package of computer programs has also been developed to analyze the sample data. The programs provide an analysis of the current or existing condition of the highway system and a number of options to look at future needs as well as impacts of different funding limitations. The basic procedure the computer packages use is first to estimate the current condition of the sample highway sections. Those conditions are then compared to minimum tolerable conditions tables. For those sections which have values falling below those minimum values, an improvement is simulated. Both the type of improvement needed and the construction cost are estimated internally within the program. If a funding limitation is imposed, then the program selects the highest ranked needed improvements until the funds for that period are exhausted. The other improvements are deferred until the next funding period.

This report will cover some of the characteristics of the sample sections selected in Texas, a deficiency in the sample size procedure, and a recommended method to correct that deficiency. Some comparisons of the HPMS output will also be made in an attempt to determine how well the sample is representing the entire Texas public highway system.

HPMS SAMPLE

Current Sampling Procedure

The sampling procedure FHWA recommends for the HPMS sample is relatively simple. All highway sections are first categorized into rural, small urban, or urbanized areas. The urbanized areas are either handled collectively or as individual areas. Currently, there are thirty designated urbanized areas in Texas that are sampled separately. Each area is then broken down into functional classes and then into AADT volume groups within that functional class. The objective is to get close to homogenous groups of highway sections since the sample will represent all highway sections in that group. The current sample size and mileage for Texas is shown in Table 1. The local functional class is not sampled in HPMS.

Each one of the volume groups within each functional class is sampled separately with a minimum of 3 sample sections in each volume group. If the total number of sections is less than three, then all sections should be sampled. The recommended sample size for each AADT group is determined by the following formula taken from Appendix G of the HPMS Field Manual (2):

$$n = F/[1+1/N(F-1)] \quad \text{with } n \geq 3 \qquad (1)$$

where

n = required sample size,
$F = [(Z_\alpha)(C)/d]^2$
Z_α = value of the standard normal statistic for α confidence level (two-sided),
C = AADT coefficient of variation,
d = desired precision rate, and
N = universe or population stratum size.

FHWA has recommended values for both Z_α and d, based upon functional class, with generally higher desired precision and confidence levels for higher functional classes. The critical parameter in the equation is the coefficient of variation. FHWA recommends that a coefficient of variation be calculated for each sampled group of sections and use that calculated value in formula (1). They also provide a table of coefficients of variation if any states do not or cannot calculate their own.

Table 1. HPMS Sample in Texas*

Functional Class	Rural				Small Urban				Urbanized			
	Sections		Mileage		Sections		Mileage		Sections		Mileage	
	Total	Sample	Total	Sample	Total	Sample	Total	Sample	Total	Sample	Total	Sample
Interstate	1,342	142	2,267	1,137	141	34	142	98	527	110	654	453
Other Freeway					44	24	53	48	581	140	590	406
Principal Arterial	7,929	370	8,069	2,843	3,335	231	981	300	3,852	531	2,479	995
Minor Arterial	7,557	132	6,994	1,153	4,071	93	1,227	70	5,245	501	3,675	639
Urban Collector Rural Major Collector	36,381	128	34,953	705	3,229	160	1,142	92	6,785	670	4,032	525
Rural Minor Collector	16,053	169	18,467	684								
Total	69,262	941	70,751	6,522	10,820	542	3,545	610	16,990	1,952	11,429	3,019

*Includes All Public Roads Except Local Functional Class.

There is a fundamental problem with using the AADT coefficient of variation to estimate the sample size within each volume group. The coefficient of variation is calculated by dividing the standard deviation by the mean and is a measure of dispersion, in this case the dispersion of AADT within each volume group. The problem is that the range of AADT values is restricted. Therefore, the mean of AADT within each group will be confined to that range. As sample sizes are calculated from higher volume groups, the mean goes up with corresponding lower coefficients of variation. A lower coefficient of variation in formula (1) results in a lower required sample size.

An example of the impact of restricted volume groups on sample size is shown in Table 2. This example shows a hypothetical situation for rural interstate but the conclusions apply to any functional class. It is assumed there are 100 sections and 1000 sections in each volume group and for simplicity sections are distributed uniformly within each group (any assumed distribution will produce similar results). The impact of volume group is dramatic with a required sample size of 78.5 or 265.3 in the lowest volume group and only 1.2 in volume group 9. Everything else is the same between group 1 and group 9 except the AADT range of each group, group 1 ranges from 0-10,000 and group 9 ranges from 80,000-90,000. The sample size should be about the same, or even higher in the higher volume groups, since congestion and pavement deterioration would tend to be higher.

The original purpose of dividing functional classes into volume groups for sampling purposes was to insure some samples were being taken from the relatively small number of highway sections at the higher volumes. While that is a worthwhile goal, forcing formula (1) to do more than it was designed to do is not the answer. There is another problem at the higher volume groups. With low coefficients of variation at those higher volumes, the universe number of sections becomes insignificant in determining the sample size. In Table 2, the sample size converges for the 100 section column and the 1000 section column. For volume groups 7 and above, the sample size is the same for both universe sizes.

Another way of looking at the same problem is the size of the confidence interval as compared to the volume group range. The confidence interal is defined as a percent of the universe mean in that volume group. For example, if a 90-5 precision is specified, then it means that the sample mean will be

Table 2. Range of Sample Size Using FHWA's Procedure

Volume Group	Range of ADT (Thous.)	Coefficient of Variation (Uniform Dist.)	Hypothetical Rural Interstate Sample Size	
			100 Sections in Each Group	1,000 Sections in Each Group
1	0 - 10	.577	78.5	265.3
2	10 - 20	.192	28.8	38.6
3	20 - 30	.115	12.7	14.2
4	30 - 40	.082	6.9	7.3
5	40 - 50	.064	4.3	4.4
6	50 - 60	.052	2.9	3.0
7	60 - 70	.044	2.1	2.1
8	70 - 80	.038	1.6	1.6
9	80 - 90	.034	1.2	1.2

± 5 percent of the universe mean 90 percent of the time. If a sample were drawn 100 times, the sample mean would be expected to be within 5 percent of the universe mean 90 times. It should be noted here that confidence intervals are generally defined around the sample mean because the universe mean is not known. But, in this case, the universe mean AADT is generally known, so it is valid to define the confidence interval around the universe mean.

The problem is that the confidence interval tends to cover a larger portion of the volume group range at higher volume groups, and in some groups the confidence interval is actually wider than the volume range. Even though volume group ranges tend to increase somewhat as AADT increases, the mean AADT increases much faster, resulting in wider confidence intervals. One example can give an indication of the problem. The precision level for minor arterials in individually sampled urbanized areas is 70-15. The Houston urbanized area has 154 sections in volume group 5 of the minor arterial functional class, with a mean AADT of 17,003. The confidence interval is then 17,003(1-.15) to 17,003(1+.15), or 14,453 to 19,553. However, the AADT range of volume group 5 is 15,000 to 19,999. Only a small fraction of the volume group, from 19,553 to 19,999, is not covered by the confidence interval. In this case, none of the 154 sections are in that part of the range, so all 154 sections are in the range of the confidence interval.

Since all sections are within the confidence interval, it would be impossible to select a sample with a sample mean outside the confidence interval, even if the sample size were one. Since the precision criteria only requires that 70 percent of the sample means fall within the confidence interval, the required sample size using formula (1) is less than one, in this case n = .2936.

Just the opposite occurs at the lowest volume groups, with very narrow confidence intervals in relation to the volume group range, with a corresponding increase in the required sample size. For example, in volume group 1 of Houston urbanized minor arterials, there are 40 sections with a mean AADT of 1426. The same 70-15 precision level applies, so the confidence interval is 1212 to 1640. The volume group range goes from 0 to 2,499, with the confidence interval covering only 15 percent of that range. As a result the required sample size is relatively high, n = 11.34, even though only 70 percent of the sample means are required, on average, to fall within the confidence interval.

Proposed Sampling Procedure

It is clear from the analysis of sample size that it is not appropriate to use formula (1) to determine the sample size within each volume group. The formula is valid, however, for the entire range of AADT within each functional class. Formula (1) could be used to determine the sample for each functional class, for example Rural Interstate, rather than within each volume group. Calculating the sample size at the functional class level, rather than at the volume group level will tend to increase the sample size. The precision level could be adjusted to keep the overall sample size for each functional class approximately the same size as the current sample, but would probably not be advisable in the case of Texas because of the very low sampling rates in some rural functional classes.

It should be noted that the current sample covers a higher percentage of the highway mileage than the highway sections, but the percentages are still very low in both rural major collector and rural minor collector. In addition, the mileage percentage is higher because samples were extended to include parts of adjacent sections which exhibited similar characteristics. Covering a higher percentage of the highway mileage in this fashion does not necessarily improve the sample. This is because the sample is chosen randomly and if enough samples are taken then the sample tends to represent the sections that are not in the sample. Extending some samples may bias the sample if some group of highways tend to be extended more than others. For example, if sample sections in West Texas tend to be extended more than samples in East Texas, then the sample would be biased towards conditions and needs in West Texas.

If formula (1) is used to calculate the sample size at the functional class level and the current precision rates are used, then the required sample size for use in Texas would increase and is shown in Table 3. This shows the increased sample size needed to use HPMS on the state highway system at the state level and district level. It would not be necessary to increase the samples on public highways off the state system and these are not included in Table 3.

After the sample size is determined for each functional class, the sample must be allocated to each volume group. There are several ways this could be done. One simple way is to allocate the sample proportionately based upon the total sections in each volume group. Another technique is called the optimal allocation because it minimizes the variance for a given sample size. The

Table 3. Recommended Change in Sample Size for Use in Texas

	Rural	Small Urban	Urbanized	Total
Total Sections State System	64,852	6,373	5,323	76,548
Current Sample (1983)	913	328	715	1,956
Recommended Sample for State-wide Use	1,840	643	1,182	3,665
Recommended Sample for District Use	5,652	1,271	1,358	8,281

weights for each volume group are the number of sections times the standard deviation. The problem with both of these techniques is that in some functional classes the number of sections in each volume group varies dramatically. For example, in rural major collectors there are 30,021 sections in volume group 1; 6,331 sections in volume groups 2, 3, and 4; and only 29 sections in volume groups 5, 7, and 8. This results in very low sample sizes for higher volume groups, even though requiring a minimum sample size of three does reduce the problem somewhat. For these situations of highly unequal numbers in different volume groups, the allocation could be structured so that the higher volume groups receive a higher representation in the sample. That can be accomplished by distributing the sample over the volume groups weighted by vehicle miles.

$$n_{ij} = n_j(DVM_{ij}/DVM_j) \text{ with } n_{ij} \geq 3$$

where

n_{ij} = required sample size for volume group i in functional class j,

n_j = required sample size for functional class j, calculated from formula (1),

DVM_{ij} = daily vehicle miles for volume group i in functional class j,

DVM_j = total daily vehicle miles for functional class j.

The procedures described above for allocating the sample to volume groups each have certain advantages and will be studied further. It may be that some combination of the techniques will be most useful.

Limitations of Sample

While the above recommended changes to sample size calculations will reduce or eliminate some problems with the current procedures, they will not eliminate all problems with samples in general or with this particular sample. A sample is selected to represent the entire universe of highway sections but it cannot represent it perfectly. There is some error any time a sample is used. In addition, a sample cannot be used to describe individual sections outside the sample. For example, the sample cannot be used to pinpoint all sections which need improvements. A 100% sample or an inventory of the highway section would be required for that purpose.

Another aspect of this particular sampling procedure is that it is only sampling AADT. For example, a desired precision of ±5 percent with 90 percent confidence as used in formula (1) applies only to how good the sample AADT mean is as a measure of the population AADT mean. In this case, the sample AADT mean would be within ±5 percent of the population AADT mean with 90 percent confidence. That question by itself is usually trivial because the population AADT mean is usually already known. The population AADT mean is used to calculate the coefficient of variation which, in turn, is used to calculate the sample size. The assumption is that AADT is a good predictor of items which are not known in the population, such as pavement condition and future anticipated congestion. The next section looks at some comparisons of the HPMS output which have some implications for the accuracy of the Texas sample.

HPMS OUTPUT

Comparison to 20-Year Plan

As mentioned in the Introduction, HPMS consists of a package of computer programs to analyze the sample data collected in each state. Table 4 shows a summary of the output for Texas using the default assumptions and parameters. A number of these parameters can be adjusted for Texas conditions and data will be collected during the coming year to accomplish that.

Table 4 also uses a type of analysis which allows for analysis over four 5-year periods. Improvements are simulated for each period on each sample section with a deficiency during that period. That also allows for more than one improvement on a particular section. It would be possible, though unlikely, for an improvement to be simulated on a particular section in each 5-year period. This table also assumes no funding restrictions or right-of-way restrictions, so it represents the total 20-year needs of Texas as represented by the sample and the assumptions of the model. The calculated needs are very high over the twenty year period, about $30 billion in rural areas and $48 billion in urban areas. It is also interesting to note how the amounts change over time. The first five years are the highest, indicating a backlog of current needs of $11 billion in rural areas and $19 billion in urban areas.

Table 5 makes a comparison of the HPMS output to the 20-year project list for Texas. This 20-year list does not include any funding restrictions. HPMS does not estimate new location construction needs, and the 20-year plan does not include maintenance activities, such as resurfacing, so they are not directly comparable, but for some categories of projects, some comparisons can be made. In the 20-year HPMS output comparison, HPMS is predicting much higher rehabilitation needs, especially in rural areas, higher added capacity costs over less mileage, and somewhat lower upgrade-to-standards costs over more miles.

The biggest discrepancy in construction costs comes in the urban added capacity category. The cost per project is over three times greater in HPMS than in the 20-year plan. Even though different design standards and traffic growth could be responsible for some of the differences, they would probably not be sufficient to explain such a large difference. That would indicate a need to examine the assumed construction costs in HPMS and revise them to more

Table 4

HPMS OUTPUT WITH FOUR FUNDING CATEGORIES ON STATE HIGHWAY SYSTEM

(Costs in Million Dollars)

Rural

Highway Type	1985-1989		1990-1994		1995-1999		2000-2004		Total	
	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost
Added Capacity	659	1,353.2	427	833.1	931	1,730.6	733	1,345.0	2,750	5,261.9
Upgrade to Standard	15,809	3,282.6	9,030	1,224.6	3,001	472.8	2,213	329.6	30,053	5,309.6
Rehabilitation	5,879	4,701.6	5,727	3,925.3	4,687	3,166.9	2,987	1,794.8	19,280	13,588.6
Resurfacing and Traffic Engineering	15,140	1,400.6	11,531	820.2	18,051	1,521.7	21,893	1,467.2	66,615	5,209.7
Total	37,487	10,738.2	26,716	6,803.2	26,672	6,892.0	27,825	4,936.5	118,700	29,369.9

Urban

Highway Type	1985-1989		1990-1994		1995-1999		2000-2004		Total	
	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost
Added Capacity	1,077	17,501.8	244	3,222.5	490	11,474.7	399	9,897.1	2,210	42,096.1
Upgrade to Standard	424	277.0	204	94.7	55	32.7	8	5.3	691	409.7
Rehabilitation	222	351.2	212	302.8	222	232.3	5	8.3	661	885.6
Resurfacing and Traffic Engineering	1,865	1,023.1	1,509	1,086.7	1,975	1,376.4	2,019	1,554.9	7,368	5,041.1
Total	3,588	19,153.1	2,170	4,706.8	2,742	13,107.3	2,432	11,465.5	10,932	48,432.7

Table 5

COMPARISON OF HPMS 20 YEAR IMPROVEMENT ESTIMATES WITH 20 YEAR PROJECT LIST FOR TEXAS

(Costs in Million Dollars)

	Rural				Urban				Total			
	HPMS		20 Year Plan		HPMS		20 Year Plan		HPMS		20 Year Plan	
	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost
Added Capacity	2,950	5,261.9	5,805	8,737.2	2,210	42,096.1	3,224	18,184.3	4,960	47,358.0	9,028	26,921.5
New Location			4,984	3,937.9			738	3,944.8			5,611	7,882.7
Upgrade to Standard	30,053	5,309.6	16,021	5,331.4	691	409.7	1,652	1,484.6	30,744	5,719.3	17,672	6,816.1
Rehabilitation	19,280	13,588.6	4,337	1,337.1	661	885.6	808	373.6	19,941	14,474.2	5,144	1,710.7
Resurfacing and Traffic Engineering	66,615	5,209.7			7,368	5,041.1			73,983	10,250.8		
Total	118,700	29,369.9	31,036	19,343.6	10,932	48,437.7	6,421	23,987.3	129,632	77,802.6	37,457	43,330.9

COMPARISON OF HPMS 5 YEAR IMPROVEMENT ESTIMATES WITH 20 YEAR PROJECT LIST FOR TEXAS

(Costs in Million Dollars)

	Rural				Urban				Total			
	HPMS		20 Year Plan		HPMS		20 Year Plan		HPMS		20 Year Plan	
	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost
Added Capacity	659	1,353.2	5,805	8,737.2	1,077	17,501.8	3,224	18,184.3	1,736	18,855.0	9,028	26,921.5
New Location			4,984	3,937.9			738	3,944.8			5,611	7,882.7
Upgrade to Standard	15,809	3,282.6	16,021	5,331.4	424	277.0	1,652	1,484.6	16,233	3,559.6	17,672	6,816.1
Rehabilitation	5,879	4,701.6	4,337	1,337.1	222	351.2	808	373.6	6,101	5,052.8	5,144	1,710.7
Resurfacing and Traffic Engineering	15,140	1,400.6			1,865	1,023.1			17,005	2,423.7		
Total	37,487	10,738.2	31,036	19,343.6	3,588	19,153.1	6,421	23,987.3	41,075	29,891.3	37,457	43,330.9

Table 5

COMPARISON OF HPMS 20 YEAR IMPROVEMENT ESTIMATES WITH 20 YEAR PROJECT LIST FOR TEXAS

(Costs in Million Dollars)

	Rural				Urban				Total			
	HPMS		20 Year Plan		HPMS		20 Year Plan		HPMS		20 Year Plan	
	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost
Added Capacity	2,950	5,261.9	5,805	8,737.2	2,210	42,096.1	3,224	18,184.3	4,960	47,358.0	9,028	26,921.5
New Location			4,984	3,937.9			738	3,944.8			5,611	7,882.7
Upgrade to Standard	30,053	5,309.6	16,021	5,331.4	691	409.7	1,652	1,484.6	30,744	5,719.3	17,672	6,816.1
Rehabilitation	19,280	13,588.6	4,337	1,337.1	661	885.6	808	373.6	19,941	14,474.2	5,144	1,710.7
Resurfacing and Traffic Engineering	66,615	5,209.7			7,368	5,041.1			73,983	10,250.8		
Total	118,700	29,369.9	31,036	19,343.6	10,932	48,437.7	6,421	23,987.3	129,632	77,802.6	37,457	43,330.9

COMPARISON OF HPMS 5 YEAR IMPROVEMENT ESTIMATES WITH 20 YEAR PROJECT LIST FOR TEXAS

(Costs in Million Dollars)

	Rural				Urban				Total			
	HPMS		20 Year Plan		HPMS		20 Year Plan		HPMS		20 Year Plan	
	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost	Miles	Cost
Added Capacity	659	1,353.2	5,805	8,737.2	1,077	17,501.8	3,224	18,184.3	1,736	18,855.0	9,028	26,921.5
New Location			4,984	3,937.9			738	3,944.8			5,611	7,882.7
Upgrade to Standard	15,809	3,282.6	16,021	5,331.4	424	277.0	1,652	1,484.6	16,233	3,559.6	17,672	6,816.1
Rehabilitation	5,879	4,701.6	4,337	1,337.1	222	351.2	808	373.6	6,101	5,052.8	5,144	1,710.7
Resurfacing and Traffic Engineering	15,140	1,400.6			1,865	1,023.1			17,005	2,423.7		
Total	37,487	10,738.2	31,036	19,343.6	3,588	19,153.1	6,421	23,987.3	41,075	29,891.3	37,457	43,330.9

closely reflect Texas costs. The biggest difference in mileage comes in rural estimates, with HPMS predicting higher mileage needs for rehabilitation and upgrade-to-standards, and less for added capacity. One of the reasons for larger mileage needs in HPMS is because up to four improvements can be simulated on each section over the twenty year period, whereas the 20-year plan includes relatively little staging and is restricted to added capacity stages of construction. Another reason may be the way projects are developed. For example, if a highway needs upgrade-to-standards or rehabilitation, and if there is a chance added capacity may be required in the future, it may be included in the proposed project even if the added capacity by itself is only marginal.

A better comparison may be possible on the lower portion of Table 5. This compares the first 5 years of HPMS output to the 20-year plan. The reason this may be a more valid comparison is because the 20-year plan tends to concentrate on current needs or anticipated needs in the near future. In rural areas, HPMS is predicting much lower added capacity needs and higher rehabilitation needs, with upgrade-to-standards almost the same. The urban comparisons are all similar, with the added-capacity and upgrade-to-standards showing the biggest difference.

With adjustments to the assumptions and parameters, HPMS seems to have a potential for being used to estimate current and future highway needs in Texas. Any eventual discrepancies will have to be evaluated critically to determine if some systematic error is being introduced which can be corrected.

Output Evaluations

Some of the output from the HPMS analysis can be checked against other sources to determine how well those values are being calculated within the program and how well the sample sections represent the universe of highway sections in Texas. These comparisons are given in Table 6.

As can be seen in Table 6, vehicle miles and injury accidents are being predicted almost exactly with some larger errors in fuel consumption, property damage accidents, and fatal accidents. The output seems to be doing a reasonably good job of calculating these values and, even though HPMS would probably not be used to estimate these types of numbers, it would indicate that overall the sample seems to be fairly representative of the entire highway network.

Table 6. Comparison of HPMS Output

	1983 Value[1]	1983 HPMS Estimate[2]
Fuel Consumption (Gallons of Fuel per 1000 vehicle-miles)	73.1	99.6
Total Highway Fuel Consumption (Millions of Gallons)	7,953.3	10,537.7
Vehicle-Miles (Billions)	108.8	105.8
Accident Rate (per 100 million vehicle-miles)		
Property Damage	234.2	326.7
Injury Accidents	106.5	105.5
Fatal Accidents	2.6	3.6
Total	343.3	435.8

[1] Fuel consumption figures and vehicle miles taken from Highway Statistics, 1983 (3), and adjusted to exclude local functional class. Accident rates taken from Motor Vehicle Traffic Accidents, 1983 (4), and includes statewide accidents divided by total vehicle miles including local functional class.

[2] HPMS samples cover all functional classes except local functional class and are expanded to represent all state highway sections excluding local functional class.

CONCLUSION AND RECOMMENDATIONS

The HPMS sample data and analysis package was designed to provide pertinent information on the current status of the highway system and estimates of future needs. The following are recommended short-range changes to HPMS so that it can be used for that purpose in Texas.

1. Increase the sample size to give better coverage at the functional class level. The number of samples should be increased about 1,700 for HPMS use at the state level, and increased by about 6,300 for use at the district level.
2. Adjust the design standards and minimum tolerable conditions to reflect Texas conditions. These include pavement condition, shoulder width, lane width, and operating speed.
3. Adjust project costs to reflect Texas conditions. This would include both right-of-way costs and construction costs.

If HPMS is to be used as a project planning tool, then more extensive changes need to be made. The following are long-range recommended changes which would allow HPMS to be used at the project planning level.

1. Use one definition of highway sections for the Texas highway system. Currently there are incompatable definitions based upon mile points or mile posts. One consistent definition is needed to economize on data collection efforts and increase the usefulness of existing data and data systems.
2. Combine data collection efforts of HPMS with other data gathering, such as data for the pavement evaluation system.
3. Establish an inventory of HPMS data on all highway sections on the state system. By going to a 100 percent sample, all deficiencies could be identified, which could then be used as the first step in the project planning process or as a check on the current procedure.

REFERENCES

1. Highway Performance Monitoring System Analytical Process, Volume 2: Technical Manual. Office of Highway Planning, FHWA, March 1983.
2. Highway Performance Monitoring System Field Manual. Office of Highway Planning, FHWA, January 1984.
3. Highway Statistics, 1983. U. S. Department of Transportation, Federal Highway Administration.
4. Motor Vehicle Traffic Accidents, 1983. Texas Department of Public Safety.