Adequacy of the Sample Size and Accuracy of the Highway Performance Monitoring System for Use in Texas

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In this paper, some of the characteristics of the Highway Performance Monitoring System (HPMS) sample in Texas, 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, and some comparisons of HPMS output with data from other sources are discussed. The current HPMS sample in Texas includes a rural area, small urban area, and 30 urbanized areas. Each area is sampled by functional class and average annual daily traffic (AADT) volume group within each functional class. Calculating the sample size within each volume group is not correct and generally results in samples being too large in the smaller AADT volume groups and too small in the larger groups. In the larger groups it is possible to have a calculated sample size of 1 or 2 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. The output data of the HPMS analysis programs are 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 independently of HPMS by district personnel in Texas. Even though the comparison is not complete, HPMS tends to estimate larger rural rehabilitation needs but smaller rural added-capacity needs than are contained in the 20-year list. In comparing HPMS output to performance measures such as fuel consumption and accidents, the estimates are reasonably close in most cases, indicating some level of confidence in the program assumptions and calculations.

The Highway Performance Monitoring System (HPMS) *(1)* was developed by 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 effects 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. This information and 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 average annual daily traffic (AADT) volume groups. A random selection process is used to select the samples, which are then maintained over time. A new sample is not taken each year, but the same sample is maintained with only additions or deletions made that are necessary to conform to the statistical procedure.

A package of computer programs to analyze the sample data has also been developed. 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 that have values less than 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, 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.

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 are discussed. Some comparisons of the HPMS output are made in an attempt to determine how well the sample represents 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 handled either collectively or as individual areas. Currently, there are 30 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 each functional class. The objective is to get as close as possible to homogeneous groups of highway sections because the sample will represent all highway sections in a group. The 1983 sample size and mileage for Texas are presented 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 three sample sections in each volume group. If the total number of sections is less

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than three, then all sections should be sampled or combined with the next adjoining group. The recommended sample size for each AADT group is determined by the following formula taken from Appendix G of the HPMS Field Manual *(2)*:

$$n = F/\{1 + 1/[N(F - 1)]\}, \quad n \geq 3, \tag{1}$$

where

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

FHWA has recommended values for both Z_α and d based on functional class with generally greater 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 that the calculated value be used in Equation 1. FHWA also provides a table of coefficients of variation for states that do not or cannot calculate their own.

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, calculated by dividing the standard deviation by the mean, 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 AADT within each group will be confined to that range. As sample sizes are calculated from larger-volume groups, the mean increases with correspondingly smaller coefficients of variation. A smaller coefficient of variation in Equation 1 results in a smaller required sample size.

An example of the impact of restricted volume groups on sample size is presented in Table 2. This example shows a hypothetical situation for rural Interstate highways but the conclusions apply to any functional class. It is assumed there are 100 and 1,000 sections in each volume group, and for simplicity sections are distributed uniformly within each group. (All assumed distributions produce similar results.) The impact of volume group is dramatic, with a required sample size of 78.5 or 265.3 in Volume Group 1 and only 1.2 in Volume Group 9. Everything else is the same among Volume Groups 1 to 9 except the AADT range of each group—Volume Group 1 ranges from 0 to 10,000, Volume Group 9 from 80,000 to 90,000. The sample should be about the same size or even larger in the larger-volume groups because there are more congestion and pavement deterioration.

The original purposes of dividing functional classes into volume groups for sampling purposes was to ensure some samples were being taken from the relatively small number of highway sections at the larger volumes. Although that is a worthwhile goal, forcing Equation 1 to do more than it was designed to do is not the answer. There is another problem at the larger-volume groups. With small coefficients of variation at larger volumes, the universe number of sections becomes insignificant in determining the sample size. In Table 2, the sample size converges for both the 100-section column and the 1,000-section column. For Volume Groups 7–9, 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 interval is defined as a percent of the universe mean in that volume group. For example, if a 90–5 precision is

TABLE 1 HPMS SAMPLE IN TEXAS (1983)

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.

specified the sample mean will be within ±5 percent of the universe mean 90 percent of the time. If a sample is drawn 100 times, the sample mean is expected to be within 5 percent of the universe mean 90 times. 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; 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 – 0.15) to 17,003(1 + 0.15), 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 AADT 19,553 to 19,999, is not covered by the confidence interval, but none of the 154 sections are in this part of the range.

Because 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 1. Because the precision criterion only requires that 70 percent of the sample means fall within the confidence interval, the required sample size using Equation 1 is less than 1, in this case $n = 0.2936$.

Just the opposite occurs at the smallest volume groups, with narrow confidence intervals in relation to the volume group range, and 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 1,426. The same 70–15 precision level applies, so the confidence interval is 1,212 to 1,640. The volume group range is 0 to 2,499, with the confidence interval covering only 15 percent of the range. As a result, the required sample size is relatively large ($n = 11.34$), 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 Equation 1 to determine the sample size within each volume group. However, the formula is valid for the entire range of AADT within each functional class. Equation 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 tends 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 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 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 that exhibited similar characteristics. Covering a higher percentage of the highway mileage in this fashion does not necessarily improve the sample because the sample is chosen randomly. If enough samples are taken, the sample

TABLE 2 RANGE OF SAMPLE SIZE USING FHWA FORMULA

Volume Group	Range of ADT (Thous.)	Coefficient of Variation (Uniform Dist.)	Hypothetical Rural Interstate Sample Size: 100 Sections in Each Group	Hypothetical Rural Interstate Sample Size: 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*

*Since the formula would give a sample size of less than three in these cases, the minimum sample size of three would be used in actual application.

tends to represent the sections that are not in the sample. Extending some samples may bias the sample if some group of highways tends to be extended more than others. For example, if sample sections in West Texas tend to be extended more than samples in East Texas, the sample would be biased towards conditions and needs in West Texas.

If Equation 1 is used to calculate the sample size at the functional class level and the current precision rates are used, the required sample size for use in Texas increases. Table 3 presents the increased sample size needed to use HPMS on the state highway system at the state and district levels. It is not necessary to increase the samples on public highways off the state system and these are not included in Table 3.

There is another advantage in calculating the sample size at the functional class level rather than the volume group level. In Appendix I of the HPMS Field Manual *(2)*, sample size requirements for estimating proportions are discussed. The sample size must be large enough to detect a 10 percent change in proportions with 80 percent confidence. A formula and a graph are provided for estimating the required sample size. The problem is that the sample size for proportions is to be estimated at the functional class level, which makes it incompatible with Equation 1, which is currently used at the volume group level.

Under current procedures, Equation 1 is used to calculate a sample size for each volume group. The sample sizes are then summed to a total for each functional class. The sample size is then checked for the accuracy requirements for proportions. If additional samples are required, then the additional samples are distributed proportionately among the volume groups within the functional class.

If both procedures used the functional class level as the basis for estimating sample size, there would be no need to go through a multistep process; the one that gave the greater required sample size would be used. Equation 1 would be used if

$$F \geq 83.2(N - 1)/N \quad (2)$$

Otherwise the proportions formula, which assumes the required precision of ±10 percent with 80 percent confidence, would be used:

$$n_p = 83.2/(1 + 83.2/N) \quad (3)$$

where n_p equals the required sample size for estimating proportions.

After the sample size is determined for each functional class, the sample must be allocated to each volume group. There are several ways this allocation 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 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 difference results in small sample sizes for larger-volume groups, even though requiring a minimum sample size of three does reduce the problem somewhat. For these situations of unequal numbers in different volume groups, the allocation could be structured so that the larger-volume groups receive a larger representation in the sample, which can be accomplished by distributing the sample over the volume groups weighted by vehicle-miles.

$$n_{ij} = n_j(DVM_{ij}/DVM_j), \quad n_{ij} \geq 3, \quad (4)$$

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 Equation 1;
DVM_{ij} = daily volume in vehicle-miles for Volume Group i in Functional Class j; and
DVM_j = total daily volume in vehicle-miles for Functional Class j.

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

Each of the procedures for allocating the sample to volume groups has certain advantages and has to be studied further. Some combination of the techniques may be most useful.

Limitations of Sample

Whereas the 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 selected to represent the entire universe of highway sections 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 that need improvements. A 100 percent 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 Equation 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 that are not known in the population, such as pavement condition and future anticipated congestion. In the next section, some comparisons of the HPMS output that have some implications for the accuracy of the Texas sample are examined.

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 presents a summary of the output for Texas using the default assumptions and parameters. In order to adjust a number of these parameters for Texas conditions, data are being collected.

Table 4 also uses a type of analysis that 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. Table 4 also assumes no funding 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 large over the 20-year period,

TABLE 4 HPMS OUTPUT WITH FOUR FUNDING CATEGORIES ON TEXAS STATE HIGHWAY SYSTEM

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

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 5 years are the largest, indicating a backlog of current needs of $11 billion in rural areas and $19 billion in urban areas.

Table 5 presents 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 larger rehabilitation needs (specially in rural areas), larger added-capacity costs over less mileage, and somewhat smaller upgrade-to-standards costs over more mileage.

The biggest discrepancy in construction costs comes in the urban added-capacity category. The cost per project is more than 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. This would indicate a need to examine the assumed construction costs in HPMS and to revise them to more closely reflect Texas costs. The biggest difference in mileage comes in rural estimates, with HPMS predicting larger 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 20-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

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

	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

TABLE 6 COMPARISON OF HPMS 5-YEAR IMPROVEMENT ESTIMATES WITH 20-YEAR PROJECT LIST FOR TEXAS

	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

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 from the data presented in 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 smaller added-capacity needs and higher rehabilitation needs, with upgrade to standards almost the same. The urban comparisons are all similar, with added capacity and upgrade to standards showing the largest difference.

With adjustments to the assumptions and parameters, HPMS appears to have potential for being used to estimate current and future highway needs in Texas. Eventual discrepancies have to be evaluated critically to determine if some correctable systematic error is being introduced.

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 presented in Table 6.

As can be seen in Table 7, vehicle-miles and injury accidents are being predicted almost exactly, but larger errors occur in fuel consumption, property damage accidents, and fatal accidents. The output appears to be doing a reasonably good job of calculating these values, and even though HPMS would probably not be used to estimate these numbers, it indicates that overall the sample appears to be representative of the entire highway network.

CONCLUSION

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. It represents a

TABLE 7 COMPARISON OF HPMS OUTPUT IN TEXAS

	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.

significant improvement over previous attempts to measure highway needs and should be a valuable tool in future years for highway-related policy planning.

There is, however, an error in the use of the sample size formula at the volume group level within each functional class. The problem is masked because there tend to be far fewer highway sections in higher-volume groups, so the bias of the formula in calculating higher sampling rates for lower-volume groups is not readily apparent.

At the national level, the bias in sampling rates is probably small compared to the size of the sample and may not be causing distortions in the estimates, but at the state or substate level it could have some impact. In addition, the problem will be increasing in the future as traffic volumes increase and more highway sections move into larger-volume groups. The error should be corrected before it becomes a significant problem.

The comparison of HPMS output with data from other sources in Texas gives some degree of confidence in the output and a good base to build upon. It is evident, however, that a larger sample is needed for use in Texas, specially in the rural areas. Adjustments are also needed in the design standards, minimum tolerable conditions, and construction costs assumed in the model.

There are several changes currently being made to the HPMS analytical package by FHWA that should improve the accuracy of the estimates and the usefulness of the data. These changes include improved pavement deterioration curves, more flexibility in the summary output, and the possibility of using benefit-cost criteria in selecting improvements with a budget constraint. It is hoped that efforts to improve the model will continue in the future.

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