Use of the Highway Performance Monitoring System To Determine Needs and Travel Cost on North Carolina Highways

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Providing current information about the performance of an existing highway system has become an important engineering task. Another perhaps equally important task is to predict the operational and conditional effects that alternative highway policies and programs would have in the future. Analytical procedures within the Highway Performance Monitoring System (HPMS) were designed as a policy-planning tool capable of accomplishing tasks of this nature at the state or national level. This paper provides a description of how the HPMS was applied in a statewide study to (a) establish relationships between investment levels and performance of the existing highway system, (b) estimate highway needs for that system over a 10-year analysis period, and (c) estimate future highway system user costs as a function of investment. There was no attempt to critique either the function or the philosophy of the HPMS. The study results reported in this paper constitute a general assessment of the North Carolina highway system that verifies or identifies, or both, highway statistics, deficiencies, and needs over time. Many of the study findings should provide indispensable information to North Carolina highway administrators and decision makers. On the basis of those findings it was concluded that the HPMS can be used to quantify program needs that, if met, would lead to optimal achievement of a state's highway transportation goals.

In this paper are described several aspects of the North Carolina highway system including its physical condition, operational characteristics, and roadway needs from 1983 through 1993. The focus is on the performance and condition of the existing arterial and collector systems. Local roadway needs were not analyzed because the data base used for the study was limited to Interstate, arterial, and collector highways within the federal functional classification system. Data base limitations also precluded an assessment of bridge needs and requirements for highway construction at new locations. However, these needs have been determined and documented in other studies (*1*).

The Highway Performance Monitoring System (HPMS) is the primary source of information reported here. This data base system supplies timely information about the condition and use of major highway systems and about the capital investments being made to improve them. It can provide personnel involved in highway program development and management with a continuous view of how and where conditions are changing and how investment levels and patterns relate to those changes. The HPMS was developed and implemented jointly by the Federal Highway Administration and state highway agencies. These agencies currently support and maintain this data base system.

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The primary investigative tools used in this study were the analytical models and the inventory data base that are couched within the HPMS environment. Two types of data make up the HPMS inventory. They are generally referred to as (a) universe data and (b) sample section data.

Universe data define the extent of roadway mileage by functional system and jurisdiction. Over and above the universe data are sample section data that are routinely collected on randomly selected sections of the arterial and collector highway systems.

The sample sections are spatially fixed and have homogeneous geometrics. These sample sections were selected in accordance with the *Highway Performance Monitoring System Field Manual* (*2*) and provide the physical and operational data base from which the performance of the highway system can be evaluated.

Several HPMS models were used to accomplish the analyses required for this study. Those models were designed to analyze the sample section data and establish relationships between various levels of capital investment and the resultant performance of the highway system. Study references provide a complete description of these models ranging from an overview of their use for obtaining highway performance information to a detailed discussion of their analytical potential as policy-planning tools (*3–7*).

PRESENT HIGHWAY TRAVEL, CONDITION, AND PERFORMANCE

Definitions

The performance of a highway system is defined as the degree to which the system serves the movement of people and goods safely, efficiently, and economically. A highway performance measure is defined as an indicator of highway service derived from the condition, usage, operation, and physical characteristics at a particular time (i.e., past, present, or future). Important examples of highway performance measures are peak-hour operating speed, volume-to-capacity ratio, pavement condition, roadway cross sections and alignments, system mileage and travel, accidents, and user costs. In this paper are reported some of the more important performance indicators for North Carolina highways, which existed on December 31, 1984, as derived from the HPMS data base. These data are updated annually and are the primary source of information about the physical condition, extent, and usage of the state highway infrastructure (*2*).

Highway Mileage and Travel Estimates

The HPMS estimates of mileage and travel on North Carolina's 1984 highway system are given in Table 1. Data in this table are stratified by the federal functional classification system (*8*) and show that there were 120,083,000 daily vehicle-miles traveled (DVMT) distributed over 92,719 highway miles. It should be noted that the distribution of travel is not directly proportional to mileage. The data in Table 1, for example, indicate that rural highway mileage is nearly 81 percent of the statewide total but carries only 58 percent of the travel. The data also indicate that Interstate highways are less than 1 percent of the highway system yet carry more than 14 percent of the total travel.

The percentages of rural and urban travel are expected to change in the next few years. It is anticipated that urban travel will increase while rural travel decreases. These changes will be due primarily to redefinition of rural areas as urban areas in the 1990 census. The HPMS will be useful in tracking such areal changes in mileage and travel over time.

Highway Performance Relative to Condition, Safety, and Service

Performance of the North Carolina highway system is related to many physical and operational characteristics. Some of these characteristics are relatively fixed (e.g., lane width and alignment) and some can change rapidly (e.g., pavement condition).

HPMS data that can be used to define performance are organized in the three broad categories of condition, safety, and service. Condition data include information on pavement type, pavement condition, and drainage adequacy. Safety data are information on roadway cross-sectional (i.e., lane, shoulder, and median widths) and alignment adequacy. Service data include information on operating speed, volume-to-capacity ratio, and access control. The HPMS analytical models provide information on highway system performance by measuring and reflecting changes in the system's performance indicators.

Condition

Table 2 gives a summary of 1984 pavement condition by functional class. Pavement condition is defined by a present serviceability rating (PSR) code. The range of PSR codes and their meanings are given elsewhere (*2*). It must be pointed out, however, that the derivation of the PSR (as a measure of pavement condition) is not rigorous. It is based on the engineering judgment of state highway personnel and norms acceptable to those engineers.

A pavement with a PSR of 2.5 or lower has deteriorated from a good or fair condition to a point where resurfacing or pavement rehabilitation is needed. The data in Table 2 indicate that the lower functional class systems tend to have a greater percentage of their highway mileage in this PSR category (e.g., 38.3 percent of the urban collector system) than do the higher functional class systems (e.g., 5 percent of the urban Interstate system). The first column of Table 2 shows an all-functional-class total of 6,044 highway miles that needed either resurfacing or pavement rehabilitation in 1984 (*8*).

Safety

The physical features that contribute to overall driving safety on the highway can be specified as either geometric or cross-sectional. Geometric features are the elements used for the roadway's horizontal and vertical alignment. Lane width, shoulder width, divided roadways, or undivided roadways are important cross-sectional features for highway safety.

TABLE 1 NORTH CAROLINA HIGHWAY SYSTEM MILEAGE AND TRAVEL IN 1984

Functional Class	Miles	Percentage of Total Miles	DVMT	Percentage of Total DVMT
Rural				
Interstates	595	0.6	10,993,000	9.2
Other principal arterials	2,014	2.2	12,609,000	10.5
Minor arterials	1,987	11.4	21,869,000	6.4
Major collectors	9,173	9.9	6,750,000	5.7
Local	50,771	54.8	9,900,000	8.2
Subtotal	75,101	81.0	69,846,000	58.2
Urban				
Interstates	201	0.2	6,311,000	5.3
Other freeways and expressways	209	0.2	4,996,000	4.2
Other principal arterials	1,641	1.8	19,373,000	16.0
Minor arterials	2,125	2.3	10,619,000	8.8
Collectors	1,330	1.4	2,289,000	2.0
Local	12,112	13.1	6,649,000	5.5
Subtotal	17,618	19.0	50,237,000	41.8
Total	92,719	100.0	120,083,000	100.0

TABLE 2 NORTH CAROLINA HIGHWAY SYSTEM 1984 PAVEMENT CONDITION MILEAGE GROUPED BY PSR

Functional Classification	PSR 2.5		PSR 2.5–2.9		PSR 3.0–3.4		PSR 3.5–3.9		PSR 4.0		Total	
	mi	%	mi	%	mi	%	mi	%	mi	%	mi	%
Rural												
Interstates	16	2.7	49	8.2	168	28.2	207	34.8	155	26.1	595	100.0
Other principal arterials	309	15.4	307	15.2	135	6.7	244	12.1	1,019	50.6	2,014	100.0
Minor arterials	403	20.3	324	16.3	122	6.1	411	20.7	727	36.6	1,987	100.0
Major collectors	2,108	20.0	1,828	17.3	447	4.2	1,754	16.6	4,424	41.9	10,561	100.0
Minor collectors	2,021	22.0	2,250	24.5	860	9.4	987	10.8	3,055	33.3	9,173	100.0
Urban												
Interstates	10	5.0	25	12.4	39	19.4	57	28.4	70	34.8	201	100.0
Other freeways and expressways	21	10.0	53	25.4	15	7.2	15	7.2	105	50.2	209	100.0
Other principal arterials	343	20.9	170	10.4	164	10.0	193	11.8	771	46.9	1,641	100.0
Minor arterials	311	14.6	237	11.2	272	12.8	274	12.9	1,030	48.5	2,124	100.0
Collectors	502	38.3	109	8.3	136	10.4	238	18.1	327	24.9	1,312	100.0
Total	6,044	20.3	5,352	17.9	2,358	7.9	4,380	14.7	11,683	39.2	29,817	100.0

Divided highways with full access control eliminate most cross traffic conflicts and provide unlimited passing opportunities. Elimination of traffic conflicts explains why divided highways have the lowest fatality rates.

Important features that reduce the potential for accidents on undivided facilities are adequate lane and shoulder widths, proper passing sight distances, and good stopping sight distances.

The HPMS models output both highway mileage and travel by cross-sectional type and functional class (*5*).

Service

Operating speed and levels of congestion tend to be the best indicators of the service component of highway performance. Operating speed is primarily a function of congestion levels in urban areas. Traffic congestion will also limit operating speeds in rural areas but not as much as curves and grades. Levels of congestion depend on highway traffic volumes and capacity.

The service component of highway performance is also quite sensitive to changes in travel growth rate. Indeed, traffic growth can have a significant impact on aggregate highway performance. This impact can become rather acute over the short range because it usually takes a long time to plan, finance, design, and construct highway capacity improvements.

Service component indicators output by the HPMS models include (a) expected traffic growth rate, (b) levels of peak congestion, and (c) speed of trip making during peak periods (*5*).

NORTH CAROLINA HIGHWAY NEEDS ESTIMATE (1984–1993)

Determinants of Highway Needs

The three interrelated variables of present conditions, future travel, and investment levels will determine future highway needs and conditions. These variables are used in HPMS analyses as a basis for establishing investment-performance relationships. By selecting appropriate minimum tolerable conditions (MTCs), types of construction improvement, design standards, travel projections, and funding strategies (*5*), the HPMS user can tailor analyses for the evaluation of specific policies or situations. The HPMS analyses accomplished during this study were tailored to (a) estimate total rural and urban highway needs through 1993, (b) yield relationshipsbetween various levels of capital investment and system performance, and (c) determine the 1993 cost of highway travel in North Carolina relative to three different levels of investment.

Highway Needs Estimate Through 1993

Assessment of needs is the first step in investment-performance analyses. The HPMS defines highway needs in terms of the funding level required to maintain a highway system at or above certain MTCs. Dropping below the chosen MTC-values implies a state of deficiency. The level of funding necessary to correct all deficiencies as they occur is called full needs funding. The needs model determines full needs funding by first identifying deficiencies and then simulating the type and cost of capital improvements required to correct those deficiencies. Such a funding level estimate is objectively based on a cost to maintain the highway system's level of performance defined by MTC-values. It should be noted that HPMS needs assessment is accomplished without regard to revenue availability, user cost distribution, jurisdictional responsibility, or other subjective factors that actually determine highway program direction and investment levels.

Three major types of look-up tables are required by the needs model. These tables contain MTC-values, design standards, and costs for both right-of-way and construction. System default values and standards are national averages. System default values were used for the needs analysis phase of this study. The results of that analysis are shown in Figures 1 and 2, and further data are given in Tables 3 and 4. Costs are in 1981 dollars.

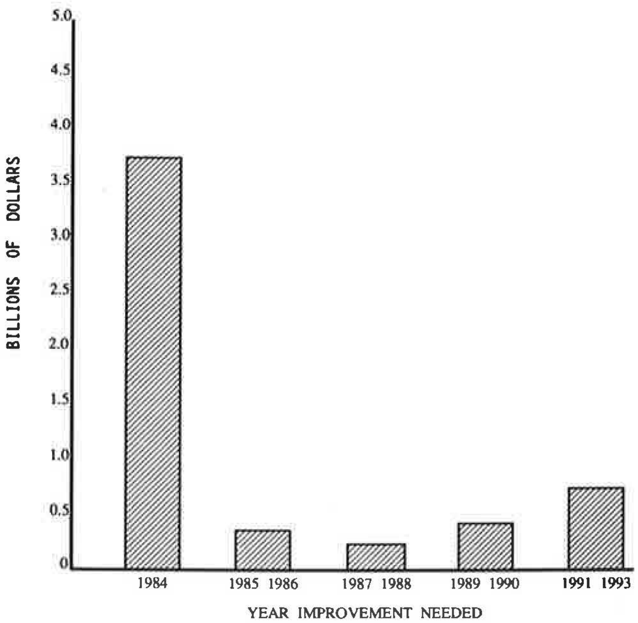

FIGURE 1 Rural highway needs estimate, 1984–1993.

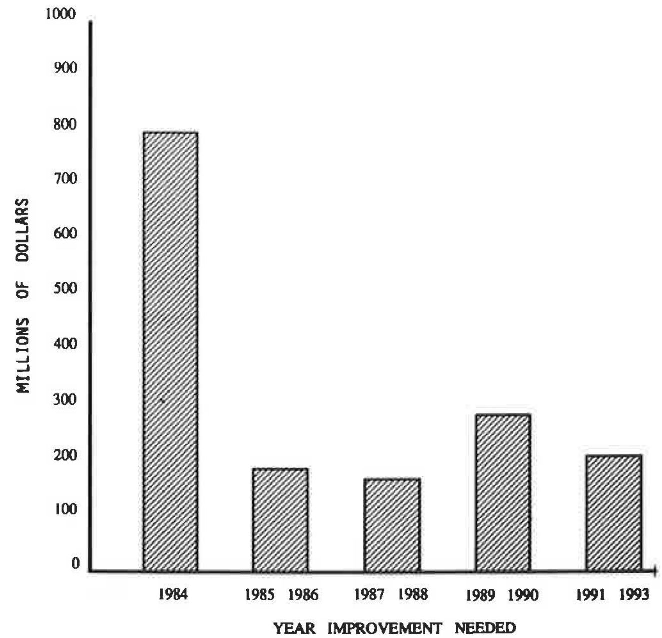

FIGURE 2 Urban highway needs estimate, 1984–1993.

TABLE 3 RURAL COST ($000, 1981)

ALL FUNCTIONAL CLASSES

	1984-1984		1985-1986		1987-1988		1989-1990		1991-1993	
	MILES	COST	MILES	COST	MILES	COST	MILES	COST	MILES	COST
RECONSTRUCT TO FREEWAY	157	351071	29	65821	51	114794	86	193417	55	122744
RECONSTRUCT W/MORE LANES	34	72442	8	19073	0	0	34	80953	8	19068
RECONSTRUCT W/WIDER LANES	1401	1384750	77	78657	0	0	0	0	27	19281
PAVEMENT RECONSTRUCTION	691	599359	0	0	0	0	0	0	15	9821
ISOLATED RECONST (ADD LANES)	2181	571936	137	27212	0	0	0	0	0	0
MAJOR WIDENING (ADD LANES)	107	173814	15	21454	21	26142	56	99889	126	231181
MINOR WIDENING	1137	256274	68	14738	0	0	1	284	266	58530
RESURFACING W/SHLDR IMP	286	65393	108	22383	82	13768	94	16888	168	30504
RESURFACING	910	63614	1293	105830	693	53014	1691	92583	2047	109424
RESURF W/ALIGN & SHLDR IMP	76	60278	0	0	0	0	0	0	0	0
RESURFACING W/ALIGN IMP	66	29008	0	0	0	0	0	0	0	0
TOTAL	7047	3627939	1735	355169	847	207719	1962	484015	2711	600553

TABLE 4 URBAN COST ($000, 1981)

ALL FUNCTIONAL CLASSES

	1984 - 1984		1985 - 1986		1987 - 1988		1989 - 1990		1991 - 1993	
	MILES	COST	MILES	COST	MILES	COST	MILES	COST	MILES	COST
RECONSTRUCT TO FREEWAY	0	0	0	0	0	0	0	0	0	0
RECONSTRUCT W/MORE LANES	24	149641	0	0	0	0	0	0	0	0
RECONSTRUCT W/WIDER LANES	4	6108	0	0	0	0	0	0	0	0
PAVEMENT RECONSTRUCTION	108	160861	12	17593	2	2840	25	84929	49	53429
MAJOR WIDENING (ADD LANES)	21	115713	9	62814	8	50370	14	110589	10	37855
MINOR WIDENING	18	14434	1	4513	0	0	0	0	0	0
RESURFACING W/SHLDR IMP	224	80689	58	16322	20	6020	19	6638	52	22042
RESURFACING	730	270361	272	92635	305	102076	249	88709	366	111325
TRAFFIC ENGINEERING	4	176	1	42	1	29	8	81	1	29
TOTAL	1133	797983	353	193919	336	161335	315	290946	477	224680

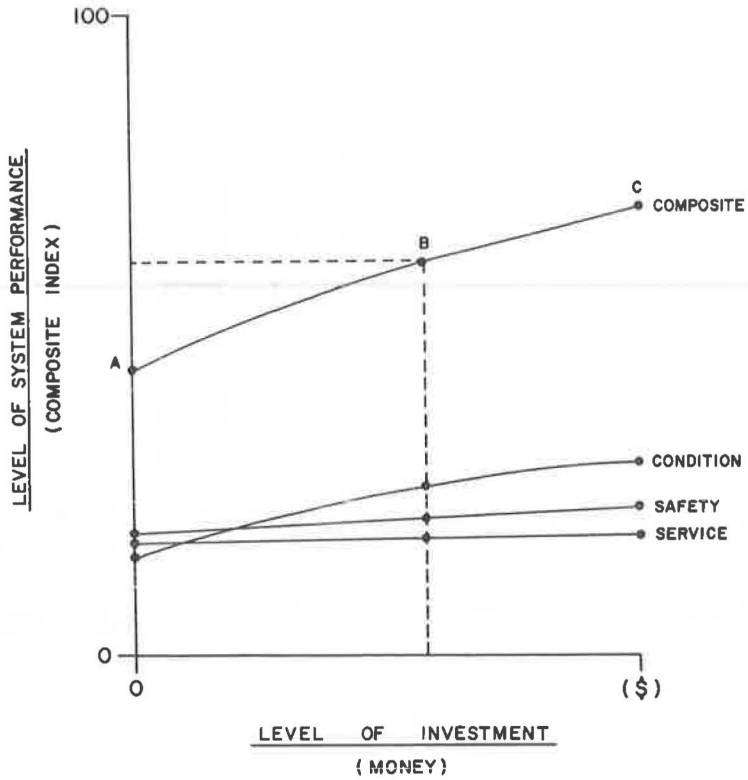

FIGURE 3 Investment-performance relationship (*4*).

NORTH CAROLINA HIGHWAY TRAVEL COST ESTIMATE (1984–1993)

Development of Investment-Performance Relationships

Highway investment-performance relationships output by the HPMS analytical procedure are based on theoretical and empirical research conducted by federal and state governments, AASHTO, and several leading universities (*4*). These relationships, as shown in Figure 3, permit estimates of future performance of a highway system given investment patterns and levels, future travel estimates, and applicable design standards. Such investment-performance curves can be developed for each functional class system from the HPMS investment-level analyses.

The two types of investment-performance analyses that the HPMS can accomplish are known as "investment level" and "funding period" (*5*). Both types were required during this study. Investment-level analysis was used to determine total highway needs and to estimate base year conditions and vehicle performance impacts. Funding-period analysis was used to forecast target year conditions and vehicle performance impacts.

It should be noted that either base or target year conditions can be analyzed by the impact model but that target year conditions and impacts can be analyzed only during a funding-period analysis.

The HPMS investment-level model simulates seven funding levels ranging from full needs investment to no investment at all. The full needs investment level (or 100 percent funding level) simulates highway system effects for all improvements selected by the needs model. The next six funding levels have the respective percentages of 80, 70, 60, 40, 10, and 0 percent of full needs investment. The lower funding levels simulate only a portion of total required improvements, depending on the relative amounts of funds available. The zero funding level simulates the effect of making no capital improvements during the analysis period, which, for this study, was 10 years. The zero funding level is represented by Point A on the composite curve in Figure 3 and the 100 percent funding level is represented by Point C.

After conducting the investment-performance analyses, the HPMS model outputs seven points for each of the safety, service, condition, and composite curves. The shapes of these curves are discretely and uniquely determined by those point sets.

The graphs are developed by plotting the composite index values versus the dollars funded for each level. These graphs can be used to provide answers to many highway programming and budgeting questions. For example, management may desire an estimate of the budget level needed to maintain current or base year conditions on the highway system. The dotted lines in Figure 3 illustrate how that estimate can be obtained. Similar intercepts for other desired levels of performance would yield different investment estimates depending on the slopes of the curves.

Investment-performance graphs were developed for each functional class within the North Carolina highway system.

Changing Highway Conditions and Resultant User Cost Impacts

Changes in pavement conditions, traffic congestion levels, operating speeds, and roadway geometry affect the costs of using the North Carolina highway system. Costs for using that system can be estimated from data output by the HPMS simulation procedures (*5, 9*). Those procedures simulate the way that highway conditions affect vehicle performance. Simulation results are expressed as vehicle performance indicators that include speed, fuel consumption, operating costs, emissions, and accident rates. With the exception of accident rates, all of the performance measures are summarized by vehicle type.

Vehicle performance indicators provide a flexible means of comparing cost of travel estimates for different highway program, policy, or investment strategy scenarios. For example, vehicle performance indicators can be converted to user cost units and (a) compared for base (or existing) and target (or forecast) years to obtain the effects of a single program over time or (b) compared at the target year for several alternative programs to obtain relative cost of travel differences.

For purposes of comparison, the HPMS analytical procedures produce highway travel cost components for both base and target years. Cost components reported by these procedures are (a) average travel speed, (b) accidents, and (c) operating costs. The respective measurement units for these components are miles per hour, accidents per 100 million vehicle miles traveled (VMT), and dollars per 1,000 VMT. These units can be equated to a single unit of money and subsequently combined to yield an economic basis for comparing alternative highway programs.

The task of assigning monetary values to the variables of travel time or accidental death and injury is usually quite difficult and subjective in nature. This task must be accomplished, however, before any analysis designed to yield total user cost differences among highway program alternatives can be conducted. Accident and travel time unit cost values used in this study are given in the following tables (*9*):

Type of Accident	*Unit Cost ($/accident)*
Damaged vehicle	471.00
Nonfatal injury	3,854.00
Fatality	268,727.00

Type of Vehicle	*Unit Cost ($/hr/vehicle)*
Light automobile	5.56
Heavy automobile	5.56
Pickup and van	6.78
Single unit (2 axle)	7.51
Single unit (3+ axle)	10.00
Multiunit (4 axle)	11.00
Multiunit (5+ axle)	11.00

Cost of Travel as a Function of Investment

The final objective of this study was to estimate the 1993 cost of travel on the North Carolina highway system for different levels of funding while all other variables were held constant. This objective was accomplished in two steps. First, vehicle performance measures were determined for each funding scenario by simulation. The second step involved calculating the total cost of travel based on the vehicle performance measures determined in the first step. The methodology used to calculate those costs is outlined in the appendix of the 1985 biennial report to Congress by the U.S. Department of Transportation (*9*). An electronic worksheet will easily accomplish the calculations required by that methodology.

Year 1993 cost of travel calculations were conducted for three funding levels. The zero level provided no money for correcting highway deficiencies during the analysis period, 1984–1993. The maintain-conditions level provided only enough money to maintain a 1984 level of service through 1993. The 100 percent level of funding provided money to correct all deficiencies found on the highway system during the time of analysis. A summary of the calculations for the combined costs and unit costs by area type and functional classification for each funding level at the 1993 target year are given in Tables 5–7.

SUMMARY

Throughout the nation there has been a growing recognition of the necessity of periodically assessing the extent, physical condition, efficiency, economy, and safety of the highway system. In addition to such a general assessment, it is sometimes desired to evaluate the economic impacts of various highway programs and policies. A general assessment of the North Carolina highway system during the 1984–1993 period was the main objective of this study. An important secondary objective was to estimate user costs on that system as a function of investment level. These two objectives were accomplished by using the HPMS analytical procedures. Study results and findings should be of interest to highway administrators and decision makers at all levels of state government.

NORTH CAROLINA HIGHWAY STATISTICS AND COST FINDINGS

Mileage and Travel

Nearly 44 billion VMT occurred on 92,719 mi of North Carolina highways in 1984:

- Fifty-eight percent of all travel occurred in rural areas.
- Forty-two percent of the travel occurred in urban areas that contained only 19 percent of the total highway system mileage.
- More than 14 percent of travel was on the Interstate system.
- The arterial system (including the Interstate) constitutes less than 10 percent of the highway mileage but carried more than 60 percent of the travel.
- The collector system represents 23 percent of the public road mileage and carried 26 percent of the travel.
- The local functional class system represents 68 percent of the total highway mileage but carried only 14 percent of the total travel.

TABLE 5 SUMMARY OF COMBINED COSTS AND UNIT COSTS FOR 1993 (ZERO FUNDING SCENARIO)

	Combined Costs ($ millions)				Unit Costs per 1,000 VMT			
	Operating	Accident	Time	Total	Operating	Accident	Time	Total
Rural								
Interstates	2,656.225	75.811	1,269.601	4,001.637	371.50	10.60	177.57	559.67
Other principal arterials	1,935.560	143.408	1,089.538	3,168.506	291.50	21.59	164.09	477.18
Minor arterials	1,179.174	99.551	754.940	2,033.665	285.10	24.07	182.53	491.7
Major collectors	2,888.817	283.078	1,973.052	5,144.946	273.20	26.77	186.59	486.56
Minor collectors	685.078	79.727	577.654	1,342.459	243.80	28.37	205.57	477.74
Urban								
Interstates	1,459.753	66.983	818.583	2,345.319	360.70	16.55	202.27	579.52
Other freeways and expressways	712.517	46.934	415.260	1,174.711	263.70	17.37	153.69	434.76
Other principal arterials	2,972.785	293.071	3,536.070	6,801.926	295.30	29.11	351.25	675.66
Minor arterials	1,336.634	147.071	1,433.745	2,917.45	262.60	28.59	281.68	573.17
Collectors	360.233	25.507	315.731	701.471	335.10	23.73	293.70	652.53
Total	16,186.776	1,261.143	12,184.177	29,632.096	298.15	23.23	224.42	545.80

TABLE 6 SUMMARY OF COMBINED COSTS AND UNIT COSTS FOR 1993 (MAINTAIN-1984-CONDITIONS SCENARIO)

	Combined Costs ($ millions)				Unit Costs per 1,000 VMT			
	Operating	Accident	Time	Total	Operating	Accident	Time	Total
Rural								
Interstates	1,996.280	75.811	1,051.596	3,123.687	279.20	10.60	147.08	436.88
Other principal arterials	1,760.260	135.802	984.000	2,881.000	265.10	20.45	148.33	433.88
Minor arterials	1,084.050	99.069	674.637	1,857.756	262.10	23.95	163.11	449.16
Major collectors	2,768.270	282.096	1,896.932	4,947.298	261.80	26.68	179.40	467.88
Minor collectors	637.030	79.727	543.883	1,260.640	226.70	28.37	193.55	448.62
Urban								
Interstates	1,085.000	64.092	688.792	1,837.884	268.10	15.84	170.20	454.14
Other freeways and expressways	617.680	44.304	366.330	1,028.314	228.60	16.40	135.58	380.58
Other principal arterials	2,569.100	293.071	3,290.710	6,152.881	255.20	29.11	326.88	611.19
Minor arterials	1,171.210	146.599	1,362.939	2,680.748	230.10	28.80	267.77	526.67
Collectors	308.200	25.511	289.877	623.588	286.70	23.73	269.65	580.08
Total	13,997.080	1,246.082	11,150.714	26,393.876	257.82	22.95	205.39	486.16

TABLE 7 SUMMARY OF COMBINED COSTS AND UNIT COSTS FOR 1993 (100 PERCENT FUNDING SCENARIO)

	Combined Costs ($ millions)				Unit Costs per 1,000 VMT			
	Operating	Accident	Time	Total	Operating	Accident	Time	Total
Rural								
Interstates	1,827.540	75.811	1,006.339	2,909.690	255.60	10.60	140.75	406.95
Other principal arterials	1,553.760	116.861	867.664	2,538.285	234.00	17.60	130.67	382.27
Minor arterials	961.620	96.421	606.202	1,664.243	232.50	23.31	146.57	402.38
Major collectors	2,417.216	277.672	1,730.055	4,424.943	228.60	26.26	163.61	418.47
Minor collectors	543.735	79.727	495.848	1,119.310	193.50	28.37	176.46	398.33
Urban								
Interstates	974.113	63.995	658.881	1,696.989	240.70	15.81	162.81	419.32
Other freeways and expressways	564.718	44.304	351.663	960.685	209.00	16.40	130.15	355.55
Other principal arterials	2,383.866	292.991	3,226.910	5,903.767	236.80	29.10	320.54	586.44
Minor arterials	1,161.029	146.599	1,357.028	2,664.656	228.10	28.80	266.61	523.51
Collectors	250.153	25.511	261.735	537.399	232.70	23.73	243.47	499.90
Total	12,637.750	1,299.894	10,562.327	24,419.971	232.78	22.97	194.55	449.80

Service

Forty-four miles of the rural highway system were operating at traffic speeds of less than 30 mph during peak hours.

Thirty-nine miles of the urban freeway and expressway system were operating at traffic speeds of less than 35 mph during peak periods.

Pavement Condition

Four thousand eight hundred fifty-seven (4,857) miles of the rural and 1,187 mi of the urban arterial and collector road system has deteriorated to a poor or very poor condition (i.e., PSR ≤ 2.5). Local roads were not sampled, and the deteriorated mileage on this system is not known.

Safety

The respective accident rates for fatal and nonfatal injuries were 5.1 and 66 per 100 million VMT in rural areas.

The respective accident rates for fatal and nonfatal injuries were 3.0 and 143 per 100 million VMT in urban areas.

Capacity

The rural arterial and collector highway system had 89 mi operating with traffic congestion during peak periods.

The urban arterial and collector highway systems had 47 mi operating with traffic congestion during peak periods.

Deficiencies

A summary of data on pavement, operational, and geometric deficiencies is given in Table 8.

TABLE 8 PAVEMENT, OPERATIONAL, AND GEOMETRIC DEFICIENCIES

Functional System	Miles Deteriorated	Percentage of System
Pavement Deficiency (may include combinations of deficiencies)		
Rural		
Interstates	65	11
Other principal arterials	525	26
Minor arterials	383	19
Major collectors	809	8
Minor collectors	842	9
Urban		
Interstates	60	30
Other freeways and expressways	74	35
Other principal arterials	446	27
Minor arterials	307	14
Collectors	285	21
Operational Deficiency (may include combinations of deficiencies)		
Rural		
Interstates	34	6
Other principal arterials	174	9
Minor arterials	40	2
Major collectors	107	1
Minor collectors	0	0
Urban		
Interstates	26	13
Other freeways and expressways	27	13
Other principal arterials	NA	NA
Minor arterials	NA	NA
Collectors	NA	NA
Geometric Deficiency (may include combinations of deficiencies)		
Rural		
Interstates	0	0
Other principal arterials	503	25
Minor arterials	652	33
Major collectors	1,299	12
Minor collectors	1,065	12
Urban		
Interstates	NA	NA
Other freeways and expressways	NA	NA
Other principal arterials	NA	NA
Minor arterials	NA	NA
Collectors	NA	NA

Highway Costs

The cost to eliminate the current (1984) backlog of needed improvements and to fund the expected ongoing needs through 1993 is $5.2 billion for rural areas and $1.7 billion for urban areas (Figures 1 and 2).

Annual cost required through 1993 to fund the full-needs scenario is $694.4 million.

Annual cost required through 1993 to fund the maintain-1984-conditions scenario is $408.9 million.

The total annual cost of travel in 1993 including operating, accident, and time components under the zero funding scenario is $29.6 billion. The unit operating cost for this funding scheme is $545.80 per 1,000 VMT (Table 5).

The total annual cost of travel in 1993 including operating, accident, and time components for the maintain-1984-conditions funding scenario is $26.4 billion. The unit operating cost for this funding scheme is $486.16 per 1,000 VMT (Table 6).

The total annual cost of travel in 1993 including operating, accident, and time components for the full-needs scenario is $24.4 billion. The unit operating cost for this funding scheme is $449.80 (Table 7).

The annual cost difference between the full-needs and the maintain-1984-conditions funding scenarios is $285.5 million. The cost of travel difference between these scenarios is $2.0 billion for 1993.

CONCLUSIONS

It is recognized that the North Carolina Department of Transportation's funding capability for construction, reconstruction, resurfacing, restoration, rehabilitation, and normal maintenance of highways is variable and depends on several political, social, and economic factors. It is further recognized that this funding capability is quite sensitive to and can be affected by changes in the level, character, or distribution of funds by local government, or all three. However, given the study findings, it can be concluded that the anticipated funding levels through 1993 will not be adequate to meet ongoing needs or eliminate the backlog of deficiencies on the existing highway system in North Carolina. It can also be concluded that the total 1993 operating cost on that system will be more than $27 billion.

That operating cost could be reduced by approximately $3 billion under the full-needs funding scenario.

A final study conclusion is that the HPMS procedures will continue to be an important tool for identifying highway improvements that should lead to optimal achievement of North Carolina's highway transportation goals.

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