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HIGHWAY PERFORMANCE MONITORING SYSTEM (HPMS)

NEW JERSEY'S EXPERIENCE

BY

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A. BACKGROUND

1. General Discussion

Funding limitations have long plagued the NJDOT. In the past, program funding and investment strategies were dictated more by dire necessity than rational choice. Recent improvements in the availability of resources will permit the Department to make trade-offs on future construction programs while managing the enormous backlog that has accumulated.

Making the decisions on those program areas where funds will be allocated requires a knowledge and understanding of the effects of the subsequent improvements. The Federal Highway Administration developed a system whereby an existing highway network can be analyzed over long periods of time to determine the needs, make the improvements by bringing the particular segments up to design standards, and analyze investment strategies. HPMS has been used in this regard to determine the impacts of varying the investment of financial resources.

The types of output resulting from an analysis yields: a) total mileage and cost for both the need and improvements by b) functional class of road, c) within discrete time periods. Comparisons of the overall condition of the highway network, operating costs, vehicle operating speed, and fuel consumption are generated as a result of the improvements made in each time period. Comparisons of these impacts can be made between the base year condition (without improvements) and a target year condition (with improvements funded).

Certain limitations exist with the use of HPMS. These limitations are primarily as follows:

a) only the existing network is analyzed; new alignments are not incorporated into the analysis;

b) bridge rehabilitation needs must be considered separately because of the uniqueness of their treatment;

c) certain items of data must be accurately defined beause of their importance in the overall analysis; namely, AADT, capacity, and widening feasibility; and

d) road segments are not treated contiguously -- each segment is considered discretely for improvement.

It must be kept in mind that HPMS is a resource allocation tool which makes trade-offs between different categories of improvements and is not a project selection program. Project selection is an exercise that should be relegated to each group of needs within a particular functional class of road.

B. CONCLUSIONS

HPMS has been modified for use by the NJDOT to reflect: 1) those conditions which we feel are minimum roadway conditions for our road system; 2) a set of design standards which the Department feels the road system should be elevated to; 3) a selection process which yields a minimum of expenditures over time; and 4) an improvement to our road system whereby a steady state of acceptable conditions exists.

This analysis has resulted in a few important conclusions:

1) Pavement deterioration is both predictable and within the financial capabilites of the state to manage. Unless pavements

are allowed to deteriorate to a stage where major reconstruction is required, we can find ourselves within 10 years to have managed our backlog of needs and maintain our resurfacing program as resurfacing requirements come about.

2) Congestion problems are unpredictable and unmanageable within the confines of the road system on which they occur. Limitations to the widening capability of an arterial forces congestion periods to extend the times of congestion both in the day and over time. There are definite capacity constraints on the existing system which can only be relieved by means other than the conventional widening improvements.

3) Needs are not "static." They cannot be determined today for an indefinite period into the future. The quantity of need depends on the level of investment. The lower the investment the greater will the need become. The total cost to improve the system over a long period of time will be minimized with the following two investment strategies:

   a) the financial investment is closer to the need (relatively high), and

   b) the pavement needs are addressed early.

4) The allocation of resources to each functional class of road should be made on the basis of need. The use of the combination of needs and vehicle-miles travelled results in a less efficient allocation of funds.

C. HPMS - LOGIC & DATA NEEDS

Logic Discussion

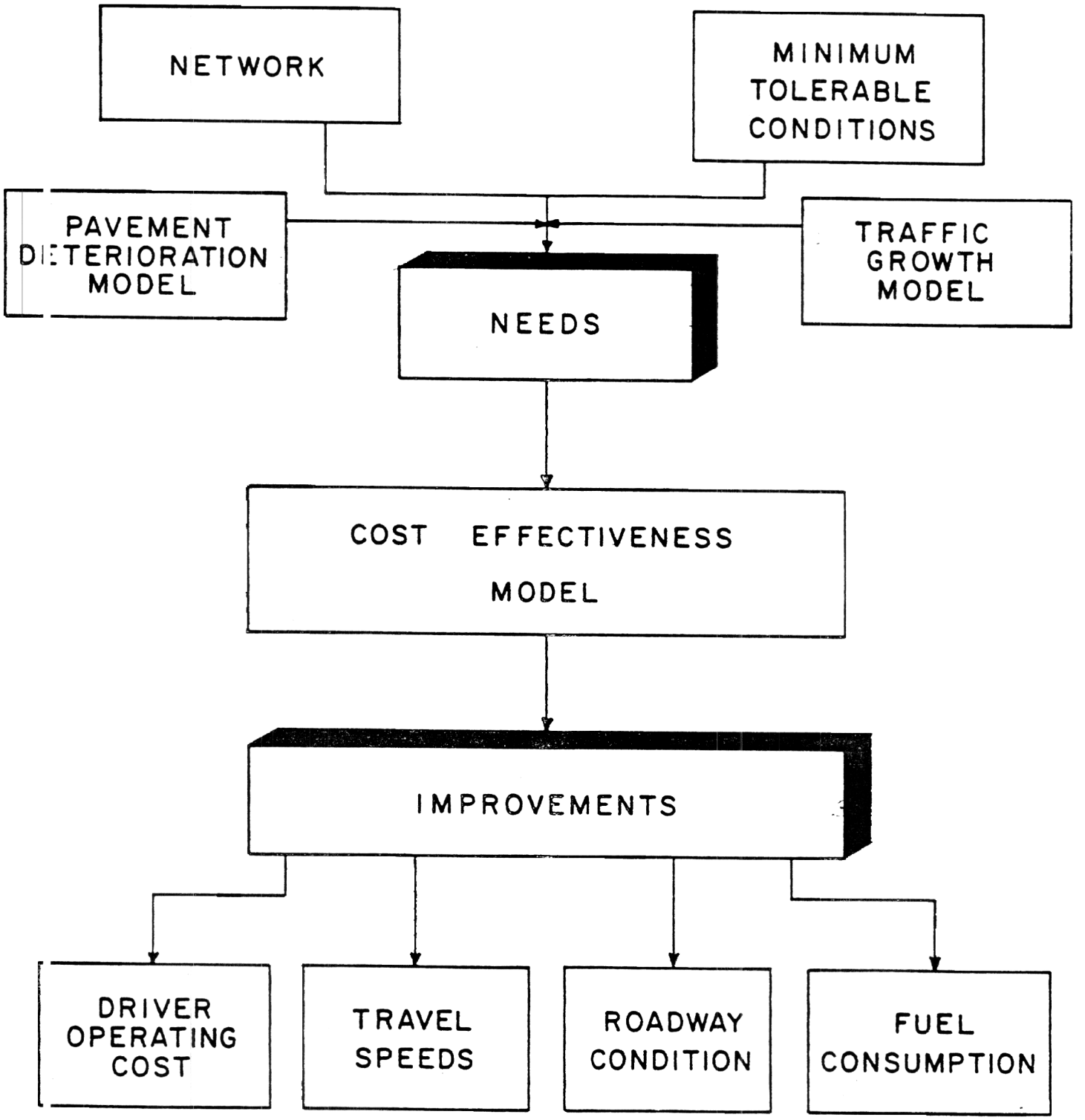
To understand the findings and conclusions as they are delineated, a brief explanation of how HPMS operates will be given (see Figure 1). With a fully described network (over 3,500 segments for the state highway system) and estimates of cost for right-of-way and by type of improvement, each segment of the road network is compared to minimum tolerable conditions (MTC) to determine deficiencies. When a deficiency is noted in a road segment, this segment is brought to a predetermined level of design standards. Within the time period of analysis for which all segments are analyzed, the segments requiring improvement are prioritized by functional class of road. This process of prioritization is based on a cost-effectiveness index where the prioritization ranking of projects is dependent on the following factors by order of importance: cost of improvement, AADT, section length, change in overall state of roadway system, and a factor for the economic life of the improvement.

When all roadway segments requiring improvements are listed, a limited funding is superimposed within the functional class (on the basis of total need), and only those segments whose accumulated cost fall within this funding are selected in that particular time period. Those segments which have not been selected within this time period will be carried over to future periods for consideration there.

One of the models working within this overall program deals with the deterioration of pavements. If a road segment requiring resurfacing is not funded within a time period, the segment may deteriorate to the point of warranting reconstruction in a subsequent time period.

Figure

HPMS PROCESS



At the same time, if traffic volume has built to the point of warranting an increase in capacity, a segment of road that would normally deteriorate to the point of warranting reconstruction may be improved to the level of the freeway. Hence, there is a progressive change to the required improvements as time advances.

In addition to the performance impacts generated by HPMS for each of the target years of improvement, there is also a listing of the unfunded improvements for each of these periods. This item is considered to be very important in comparing the different funding scenarios. Unfunded improvements (or unmet needs) are a primary result of insufficient funding. The lower the funding available for needs, the greater the "unmet needs" will become due to the continuing deterioration of the road network, as described above. But the level of unmet needs may not be accurately stated for two reasons. First, there is a maximum allowable "width" that an arterial can be widened to; when an arterial has reached this width HPMS will not list it as having a "need" even though the operating conditions are poor. Second, the description of an arterial may reflect that widening is feasible, when there is no ability to add additional lanes due to land use, etc. A close accounting should be kept of those arterials that fall in these categories.

2. Data Needs

The entire New Jersey state highway network has been coded for analysis by the HPMS program. For the 3,500 roadway segments, a full description is made of the geometric conditions, traffic characteristics, pavement condition, and operational factors. In addition, detailed information on improvement costs and right-of-way costs are

also required. Within the logic of HPMS, certain items of data appear of primary importance, namely, the current and projected traffic volume levels, the current pavement condition, the estimated capacity of each of the road segments, and the factor for the widening feasibility of the segment.

3. Funding Choices

Of the methods available to estimate the available funds that could be applied to the highway network needs, the most reasonable is to make projections based on the current level of funding. The Jersey Transportation Trust Fund projects an estimated expenditure of about $500 million per year for the state highway network for the combined bridge, new alignment, and existing system needs. estimate is shown for the existing system as the "Current" level of investment in Table 1. To determine that level of funding which would be available for the existing system susbequent to the first time period, estimates of bridge needs and new alignment needs have been subtracted from the $500 million. Table 1 shows the resulting funding levels for each time period through 2001. "Full" funding (100%) was determined by using HPMS.

TABLE 1

EXISTING SYSTEM FUNDING

(1984 Dollars)

Level of Investment	1984 - 1988*	1989 - 1991	1991 - 1996	1997 - 2001	Total
Full (100%)	750m	1300m	2500m	2100m	$6650m
Current (70%)	750m	810m	1600m	1600m	$4760m
Low (35%)	750m	400m	800m	800m	$2750m

*The Transportation Trust Fund investment of $750 million was used for all three levels of investment in the first time period.

The effect of inflation has not been considered either for projections of funding or need. Three alternative funding scenarios have been suggested to reflect the relative change in condition of the highway network with increasing funding levels.

It is highly improbable that the "Full" funding level (100%) will be attained. It is used to show the condition of the road network and the impacts on the users of maintaining the existing network as needs arise. As our findings will show, many of the capacity needs cannot be practically met and will not be shown because of constraints to widening arterials due to the existing development on the highway system.

The "Low" funding level may also be improbable because it is considered to be so far below both needs and anticipated resources.

D. DISCUSSION OF FINDINGS

1. Effects of Varying Levels of Investment

The best methods of judging the effects of varying the levels of investment in the highway network are comparing:

the unmet needs,

the resulting change in the overall state of the roadway system, and

the trend in vehicle operating costs (which accounts for travel speed and fuel consumption).

Using the funding scenarios described in Table 1, the relative changes in these factors is shown in Figure 2. The unmet needs are highest for the lowest level of investment reflecting a "need" that just grows in time to a much larger cost

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MPACT OF VARY NG LEVELS

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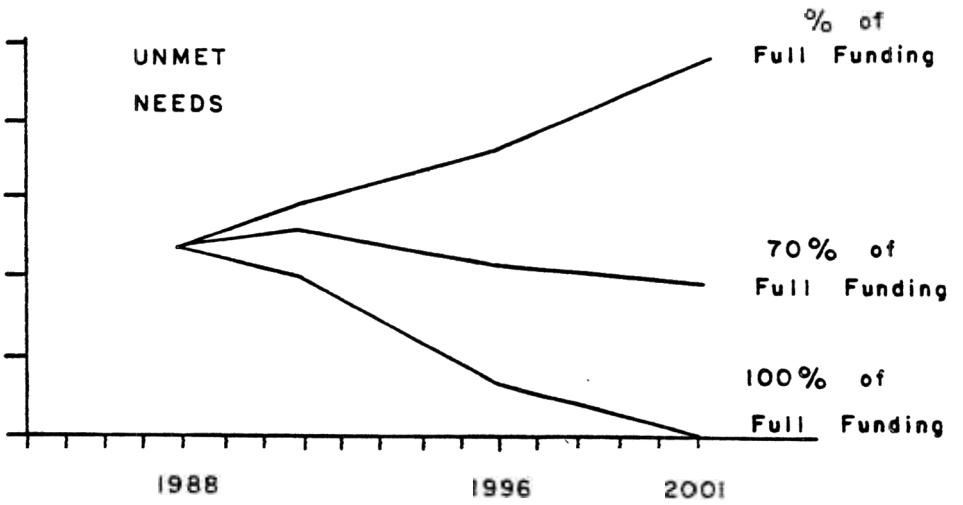
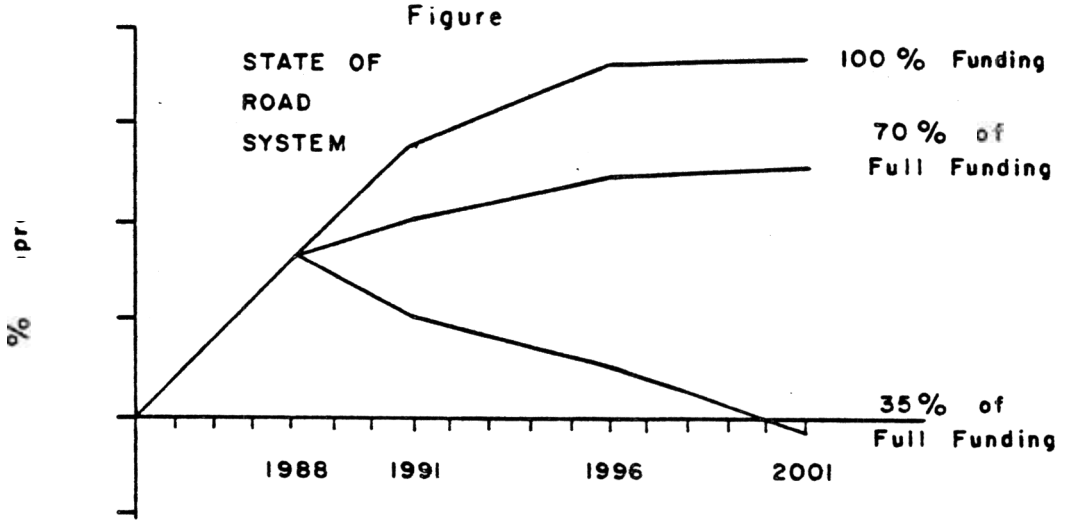


Figure



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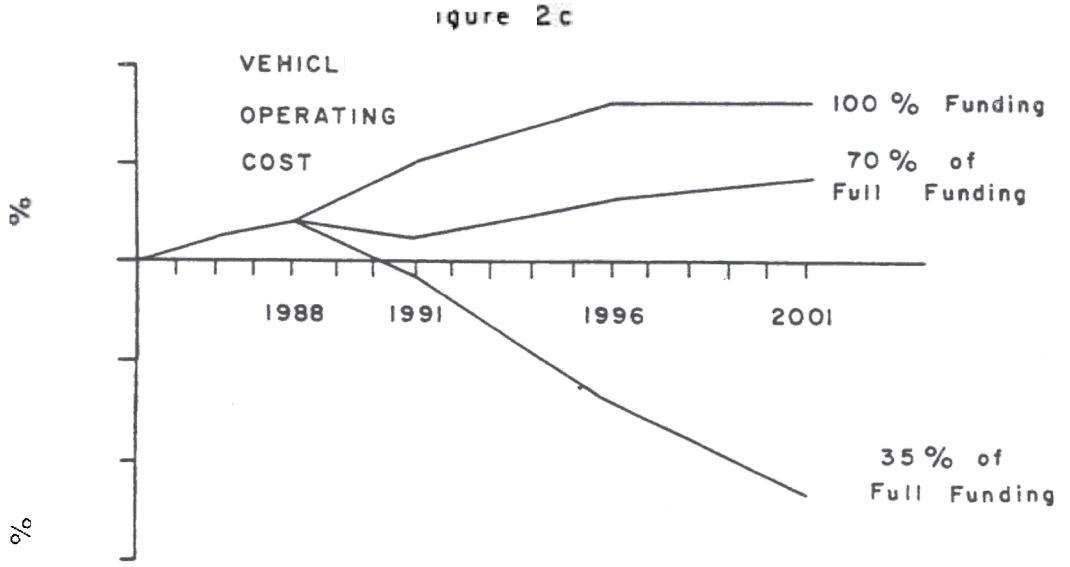

The other impact changes are as expected - resulting in a much improved road system and operating costs for the driver with larger levels of investment. At the 70% level of funding, a steady state condition can be achieved for both the overall roadway network and driver operating costs. The network needs will always be out of reach of the available funds, but there will be no deterioration below the levels achieved, at the 70% funding level.

2. Optimizing Types of Improvements

Numerous factors can be varied in the HPMS analysis of making investments into the highway network. The resulting impacts can be just as variable. However, there are optimum improvement strategies that will yield the least total required capital expenditure, the lowest operating cost to the driver, and the best overall state of the highway network. Using the three levels of investment described in the previous section, the optimized expenditures by major improvement categories can be defined as follows:

a) Pavement Improvements

Regardless of the level of investment, it is obvious that the backlog of resurfacing needs should be given a high initial priority. Approximately 8% of the road system per year is listed for improvement in the first five-year period. Thereafter, the annual resurfacing requirements drop to a range of 2%-5% of the system's mileage per year.

Although the pavement deterioration model reflects a recurring resurfacing need of about 2%-5% per year, two factors affect this need:

1) Reconstructions and major widenings automatically improve the pavement condition; there are over 3%

of the system's mileage per year that fall within these categories.

2) The backlog of needs is so high that more miles of road resurfacing is listed within the first five-year period that fewer miles remain to be improved.

The 12-25 year cycling period of pavement needs results in a "High" need in the 1996-2001 time period, reflecting the reoccurrence of resurfacing needs of those roads which were improved in the 1984-1988 time period.

b) Capacity Improvements

The importance of treating the backlog of pavement condition needs cannot be overly stressed. Hence, the initial time period allocates relatively equal funds between the pavement and capacity needs. Once the bulk of pavement needs are improved, the capacity problems are addressed by investing over 80 percent of the funds in them. As indicated earlier, the logic of the pavement deterioration model will force "resurfacing" segments of highway into the "reconstruction" category of improvement. With this condition minimized by heavy initial investments into resurfacings, the capacity needs are then invested in overwhelmingly.

3. Effect of Emphasizing Particular Types of Improvements

If a policy is adopted to emphasize either pavement or capacity improvements, the impact on the road network over time can be approximated. Regardless of the level of investment, there is an extraordinary increase in the total cost of improving the network if the decision is made to provide a low level of investment to the

backlog of pavement needs. Conversely, if capacity needs receive the investments that could have gone to the pavement needs, the total network needs cost increases. Figure 3 summarizes the total needs (actual investment plus the cost of the unfunded needs) for the three levels of investment.

The impact of emphasizing pavement improvements over capacity improvements is also evident in Figure 4. Over the long term, both the state of the road system and vehicle operating costs favor the higher initial investment in pavement related needs.

A high level of pavement investment is not carried throughout the study period (1984-2001) because of the very large initial backlog of pavement needs. Once this initial backlog of needs is "met" with a high investment, the available funds in subsequent time periods are used for the other needs, namely, capacity improvements.

In effect, the comparison of emphasizing a particular type of improvement is evident only in the initial time period. Thereafter, there is little variation in the suggested investment level for each major type improvement.

4. Emphasize Travel (VMT)/Need as the Basis for Investment to a Functional Class of Road

Up to this point, funds were made available to functional classes of road in the network on the basis of need. Another method of allocating funds is on the basis of a multiple of vehicle miles travelled (VMT) and need. Those functional classes in the network that have low VMT but high needs will receive limited funds.

A measure of the practicality of this investment is a comparison of the total needs (investments plus unmet needs) for the needs-based

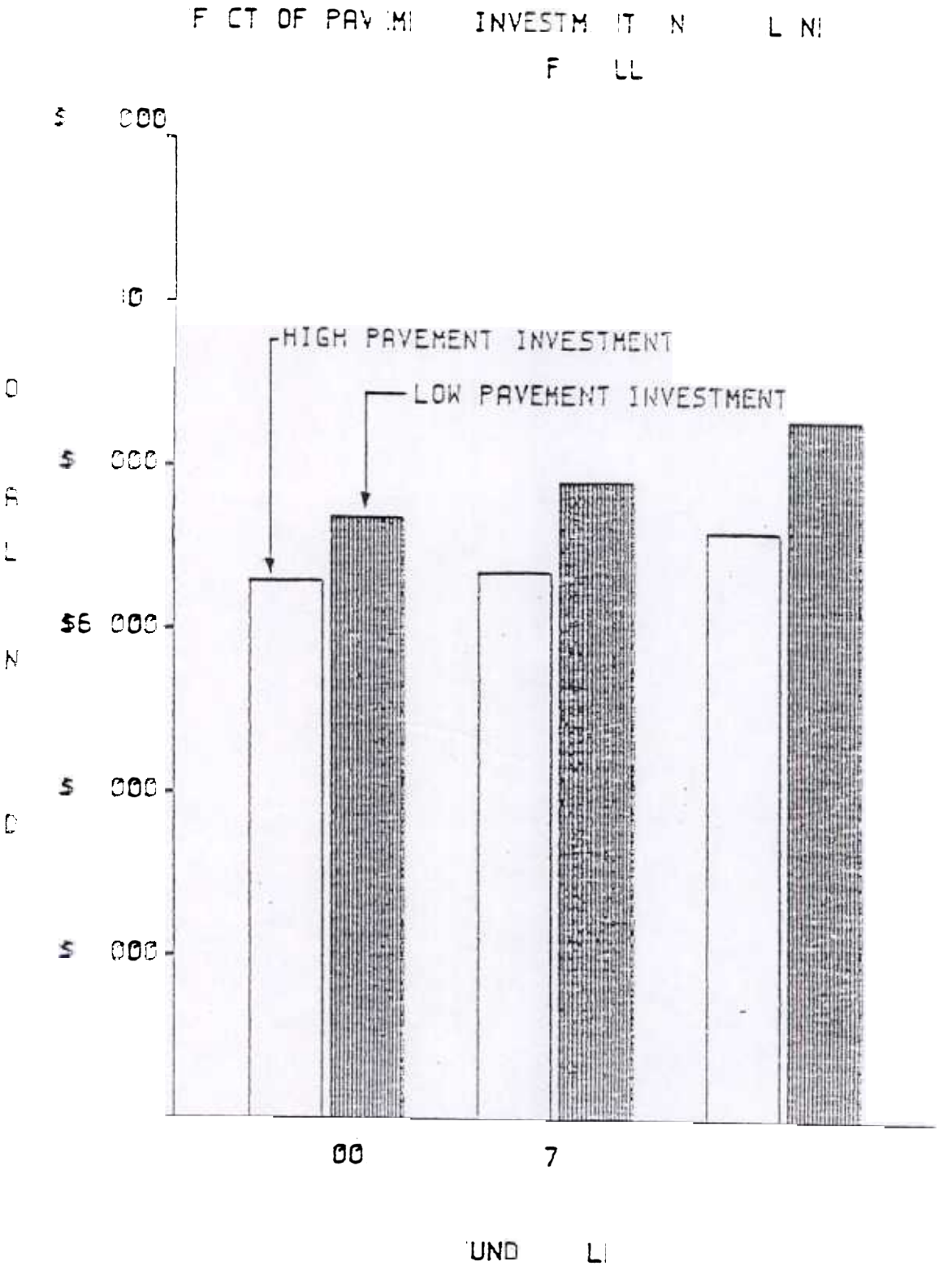
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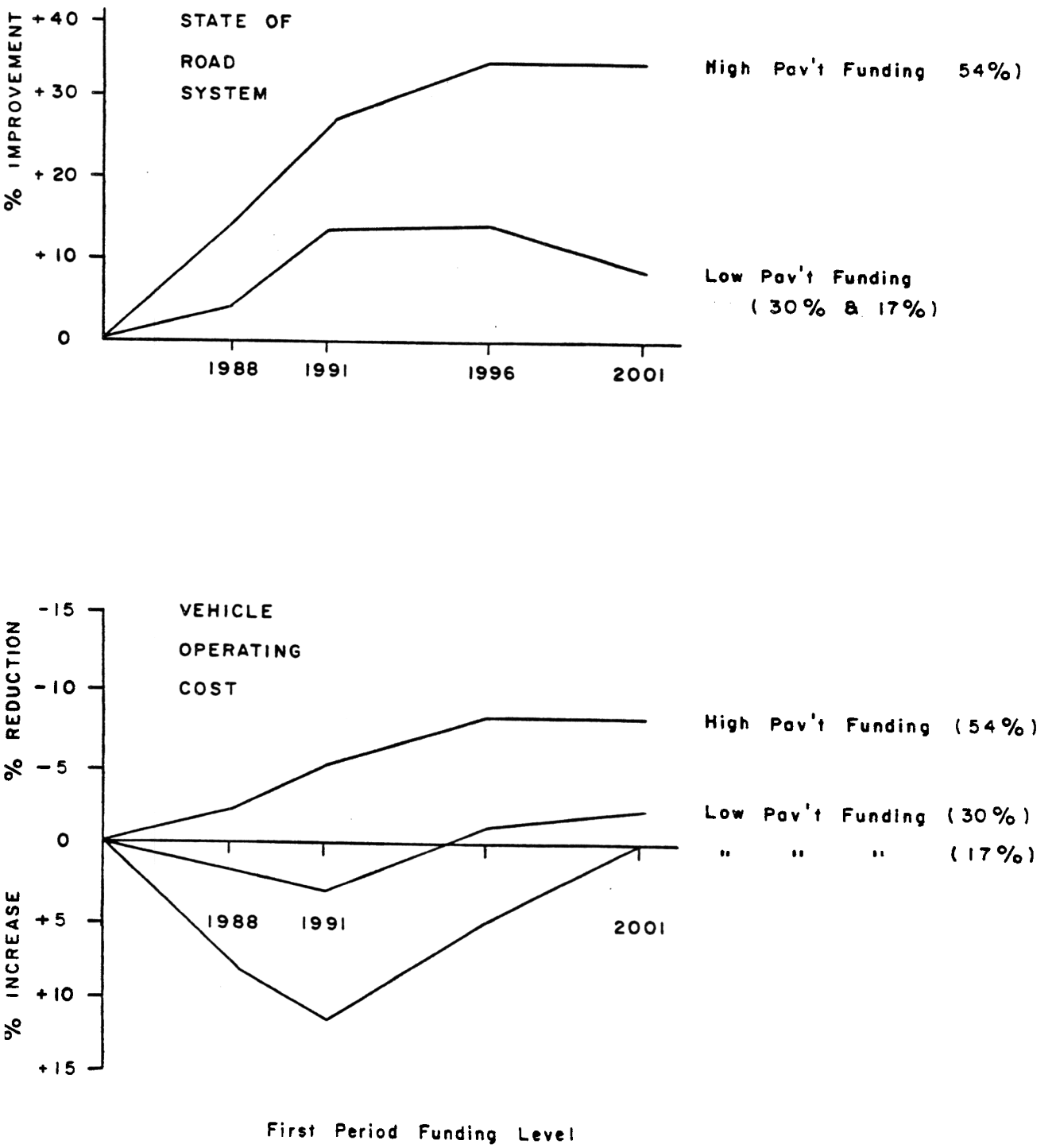
FIGURE 4

IMPACTS OF EMPHASIZING PARTICULAR TYPES OF IMPROVEMENTS



and the VMT-needs based apportionments. This comparison is shown in Table 2 (for the time period 1984-2001).

TABLE 2

COMPARISON OF NEEDS VS. VMT APPORTIONED FUNDING

	Total Needs		
Level of Funding	"Needs" Based	"VMT" Based	% Difference
Full (100%)	$6590m	$7000m	6
Current (70%)	$6710m	$7420m	11

The "VMT" based method of apportionment of funds to the functional classes of road result in higher long-term needs than the "needs" based apportionment method. As with the pavement/capacity comparison, the needs increase in time with reduced overall levels of funding.

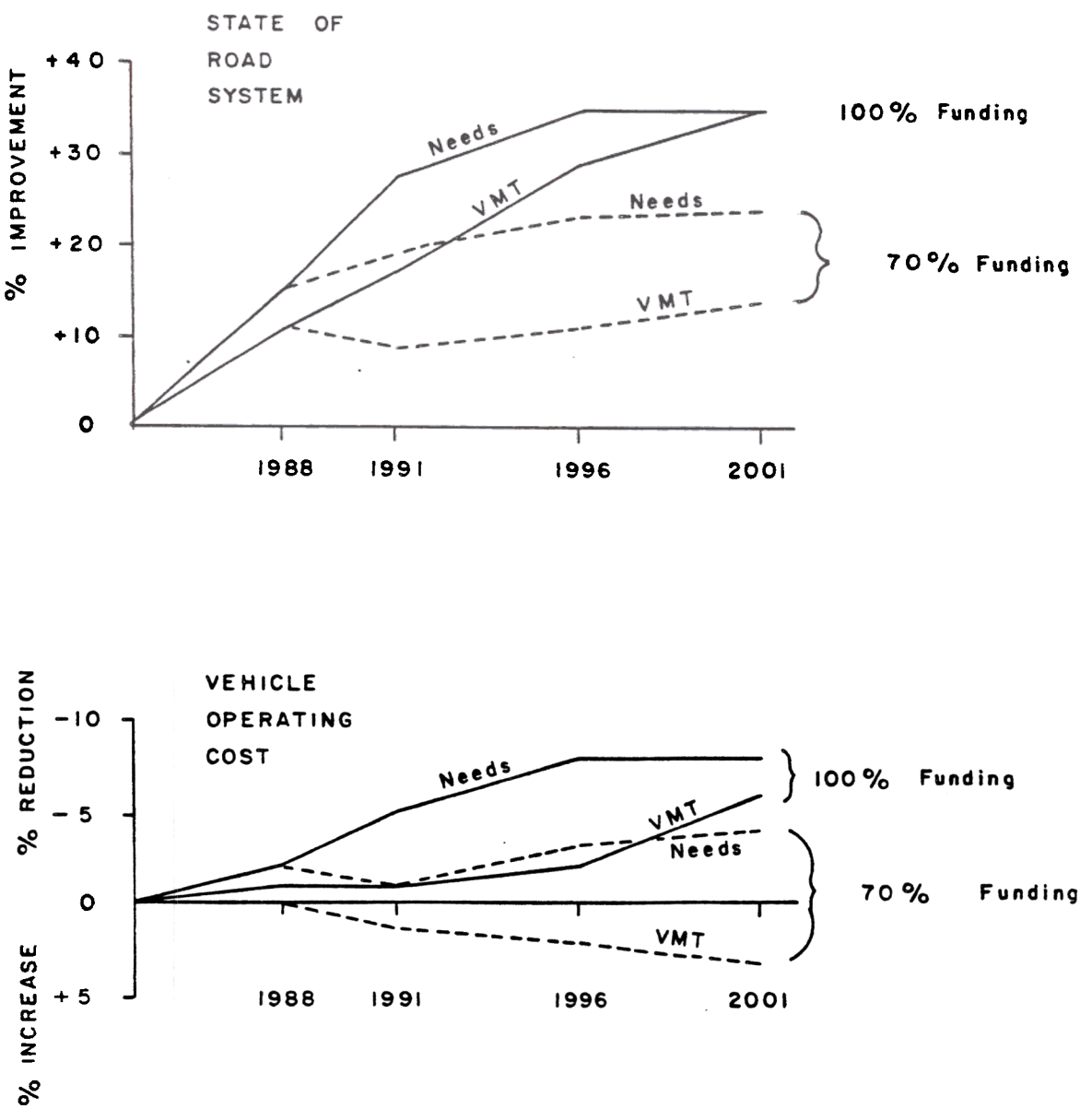
In addition, a comparison of the percent change in the state of the road system and vehicle operating cost is also made (Figure 5). inefficiency of the VMT-based method of apportionment is further shown by the less desirable comparison of these factors.

5. Determining the Weights for Components of the Composite Index

One of the important initial considerations to using HPMS deciding on the weights which were to be used for the condition, service, and safety components of the composite index. composite index is a useful index which describes the overall roadway; it is used to compare the change in conditions as well as being an important factor in the cost effectiveness index (which is the needs prioritizing model).

FIGURE 5

COMPARISON OF "NEEDS - APPORTIONED," VS. "VMT - APPORTIONED" FUNDING



A wide range of weights were tested and the results of the total needs (Figure 6), percent change in roadway index, and percent change in vehicle operating costs (Figure 7) were compared. The "high" weighting given to condition reflects the efficiency attached to investing in pavement needs.

6. Comparison of HPMS Model Investments and Those Made by Transportation Trust Fund Package

The method used by HPMS to select the types of improvements has been explained in Section C; it should be noted that no allowance is made for policy, political, or safety factors in the improvement selection process. Accordingly, there is the expectation that substantial differences could exist between the expenditures made by the Trust Fund (New Jersey's capital expenditure program through 1988) and the program resulting from the use of HPMS. Table 3 shows a comparison of the two; HPMS values are shown for a range in investments. The optimum improvement program (as determined on the basis of total cost and network impact using HPMS) is underlined in the table.

The largest discrepancies occur in the categories:

pavement reconstruction,

resurfacing with shoulder improvements,

traffic engineering improvements, and

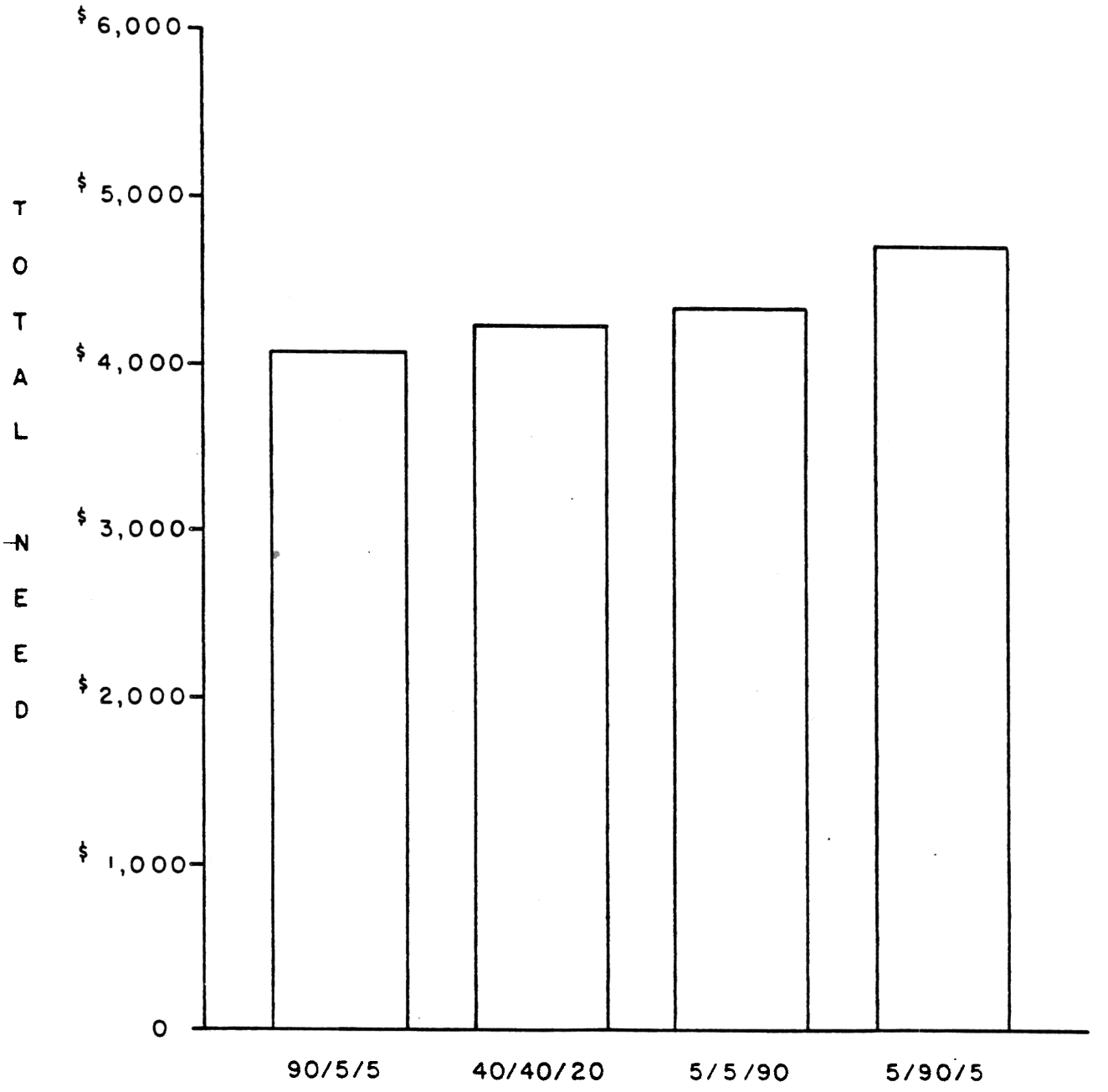
miscellaneous improvements.

On inspection, the traffic engineering category can be combined with major widenings, since they both accomplish the same thing -- capacity improvements. The miscellaneous category is an important one that HPMS cannot address. It includes such improvements as

FIGURE 6

COMPARISON OF WEIGHTS FOR CONDITION SERVICE & SAFETY COMPONENTS

(TOTAL NEED)



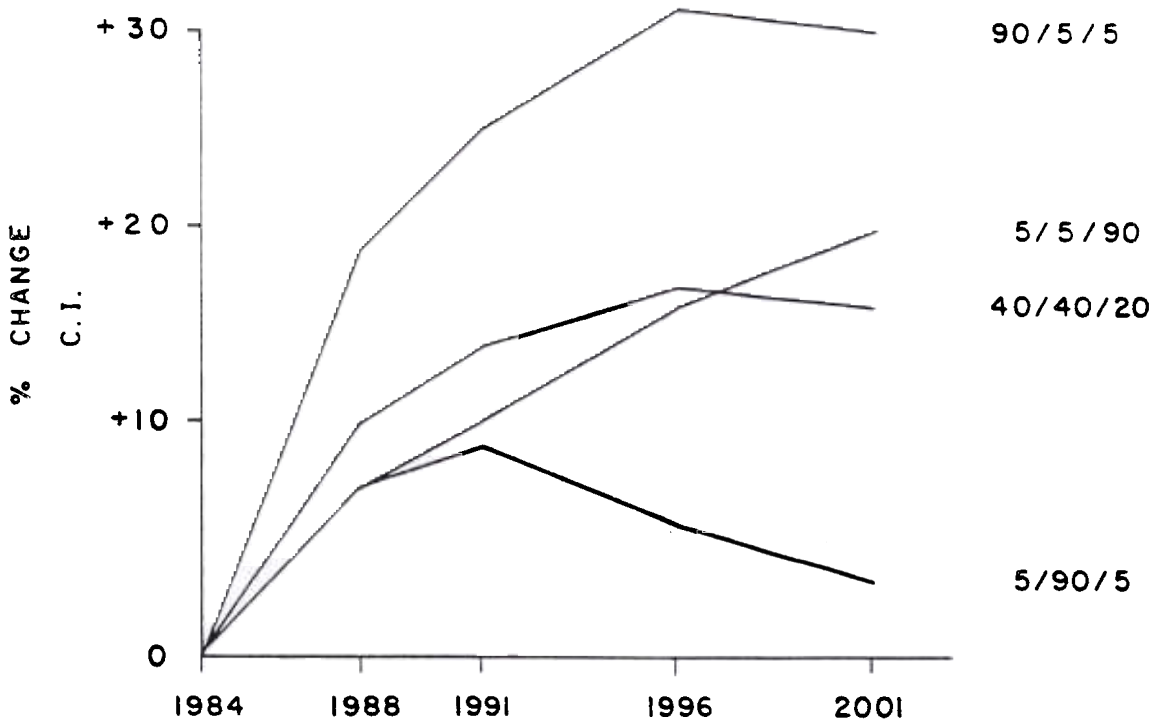
* NOTES [Condition / Service / Safety]

2. 70% of full funding was used for the investment level

FIGURE 7

COMPARISON OF WEIGHTS FOR CONDITION, SERVICE & SAFETY COMPONENTS

(Percent Change In Composite Index & Vehicle Operating Cost)



NOTES 1. Condition / Service / Safety

2. 70% of full funding was used for the investment level

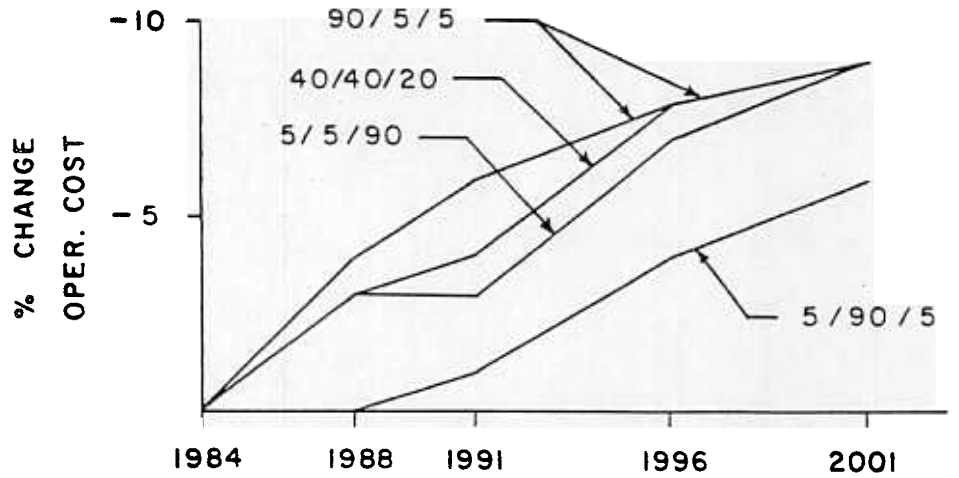


TABLE 3

PERCENT OF EXPENDITURE BY TYPE OF IMPROVEMENT

TYPE OF IMPROVEMENT	HPMS	TRUST FUND
Reconstruct to full	3-4%	1%
Reconstruct w/more lanes		1
Reconstruct w/wider lanes		
Reconstruct pavement		13
Major widening	38-60	42
Minor widening	4-5	7
Resurface w/shoulder	7-26	3
Resurface	23-28	19
Traffic Engineering		9
Miscellaneous (safety, lighting, barriers, drainage)		5

Figures shown are the percent of the total funds invested.

The underlined percentages are the pavement emphasis expenditures.

lighting, fencing, ramp improvements, and drainage. Although pavement improvements are high with the Trust Fund (35%), HPMS recommends a substantially higher investment (54%).

With the differences noted, it can be expected that there will be a less desirable impact on the existing highway network with Trust Fund improvements as compared to HPMS.