

HIGHWAY RESEARCH CIRCULAR

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Subject Area: Highway Design
Maintenance General
Highway Safety
Traffic Control and Operations
Traffic Flow

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RESEARCH PROBLEM STATEMENTS

The work reported in the following pages was produced with the assistance of and under the general guidance of the Freeway Operations Committee members.

The detailed report was prepared by a four-man subcommittee with valuable support work contributed by their individual staff members.

COMMITTEE ACTIVITY

OPERATION AND MAINTENANCE OF TRANSPORTATION FACILITIES

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1.0 INTRODUCTION

One of the important functions of Highway Research Board Committees is to develop statements of needed research so that financial sponsors, the academic community, governmental agencies and practicing professionals are provided guidance for allocation of scarce financial and manpower resources for research work.

The assignment, by the Chairman of the Freeway Operations Committee, was to prepare a list of high priority research areas for freeway operations and to expand that list into a series of problem statements.

It is believed, in recognition of the dynamic characteristics of research, that preparation of problem statements is a necessary ongoing activity. Therefore, the Committee intends to supplement information contained in the following report by preparing a revised edition at approximately two year intervals.

2.0 ANALYSIS METHOD

Given limited time and resources, the Subcommittee reviewed such possible approaches to completing its charge as 1) extensive literature review, 2) widespread distribution of questionnaires, 3) interviews and 4) solicitation of problem descriptions from many sources.

It eventually became evident that, since individual members of the Freeway Operations Committee represent a very good cross section of professionals with experience, knowledge and interest in freeway operations, these men would constitute a reasonably reliable statistical sample of freeway experts and could provide valuable input.

An initial list of suggested project titles was sent to the committee members and they were asked to add other titles of their choosing and then to provide priority index numbers which could later, after analysis of the composite, be rank ordered. Since small decimal index numbers (with Σ index numbers = 1.0) are rather awkward to work with, especially when the list of alternatives is long, a monetary base was used instead.

The respondents were told they had \$1 million and could spend it any way they wished on research projects. The result, of course, was a set of decimal index numbers.

A decided advantage, in using the monetary index, is that many of the important factors for which data were not readily available were, in fact, considered by the committee members. For example, the individual's knowledge of research in progress, his "feel" for the problem's importance and his experience with similar work, all influenced his decision on whether a particular project would speak to a problem worth solving and whether it could be solved by current technology.

To check the respondents for possible biases, and to cross check the method, questions were also posed asking for independent assessments of project worth, urgency, range of effect and success. As will be seen in the following analysis of returns, monetary allocation was as good a predictor of priority as any of the other subjective methods. An important advantage was a simple indication of magnitude of priority.

3.0 PRIORITY RANKING ANALYSIS

On October 23, 1970, a questionnaire (Appendix A) was sent to committee members and the results were analyzed as described later in this section. Essentially the questionnaire was a series of proposed project titles which were to be rank ordered. Additional titles were solicited with the idea that similar topic areas could be grouped.

Before describing the analysis, the reader's attention is directed to some factors which he may wish to consider in reviewing the work.

Despite a subjective belief of the subcommittee to the contrary, current work in progress may not be reflected in the recommended priorities. Any suggested project title may have been given a high priority by some members although they knew work was under way, while others may have ranked the subject low for the same reason. The subcommittee was unable to determine if this biased the results.

By virtue of using such ranking terms as "Urgency" and "Priority" there no doubt is some bias in favor of applied research at the expense of theoretical investigation. The analysis did not, however, show any correlations among the subjective evaluation factors of range-urgency, range-worth, range-success or worth-success. There was correlation of each of the factors with the estimate of money to allocate to individual projects. The weighted monetary assignments were used for rank ordering the projects.

Some few additional titles were suggested by the members but in all cases received only one vote, so were not included in the analysis. The additional titles are:

1. Develop criteria for scheduling, and procedures for handling unusual or slow moving traffic on freeways (e.g. sweeping, striping, oversize loads).
2. Basic human factors studies in information processing characteristics of freeway drivers.
3. Develop procedures and techniques for alternate routing (mandatory and advisory) in highway networks.
4. Improved design and signing for lane drops on freeways.
5. Learn the processes and factors which determine roadway traffic capacity.
6. Determine warrants for ramp metering or closure for the purpose of increasing the quality of peak period freeway flow.
7. Conduct in-depth capacity and level-of-service of various freeway elements, through actual field observations, to overcome the many assumptions and uses of known faulty criteria now necessary in freeway design.

Also, during the analysis process an independent activity was underway in the Freeway Operations Task Group on Airport Access. The task group produced three problem statements which have not been analyzed for priority but are included for the reader who may have an interest in this area. The three statements are included in Section 7.3.

3.1 DATA ANALYSIS

3.1.1 Data Extension

Highway Research Board
Freeway Operations Committee
Research Problem Priorities

A: Urgency B: Range of Effect
C: Worth D: Success

SAMPLE SIZE: 18 QUESTIONNAIRES RETURNED

| Statement Number * | 18 | 18 | 18 | 18 | 18 | 18 |
|-----------------------|------------|------------|------------|------------|--------------------|----------------|
| | Σ A i=1 | Σ B i=1 | Σ C i=1 | Σ D i=1 | Σ Ax Bx CxD i=1 | Funding i=1 |
| 1 | 108 | 71 | 97 | 88 | 13646 | 4.45 |
| 2 | 96 | 104 | 101 | 99 | 29848 | 3.75 |
| 3 | 116 | 110 | 112 | 105 | 36171 | 7.90 |
| 4 | 97 | 103 | 89 | 97 | 26716 | 5.20 |
| 5 | 107 | 82 | 107 | 127 | 34361 | 6.70 |
| 6 | 88 | 95 | 97 | 101 | 33617 | 6.05 |
| 7 | 97 | 118 | 94 | 86 | 23897 | 6.15 |
| 8 | 92 | 115 | 92 | 102 | 27992 | 4.52 |
| 9 | 100 | 86 | 99 | 100 | 26465 | 6.00 |
| 10 | 92 | 105 | 93 | 83 | 23863 | 2.90 |
| 11 | 96 | 123 | 87 | 109 | 25984 | 4.66 |
| 12 | 105 | 112 | 94 | 105 | 31032 | 4.74 |
| 13 | 80 | 82 | 69 | 78 | 15242 | 4.65 |
| 14 | 75 | 100 | 62 | 104 | 11230 | 2.80 |
| 15 | 116 | 129 | 117 | 129 | 44217 | 9.91 |
| 16 | 98 | 87 | 103 | 90 | 14627 | 2.65 |
| 17 | 104 | 104 | 83 | 108 | 25816 | 5.63 |
| 18 | 137 | 121 | 122 | 123 | 58244 | 13.88 |
| 19 | 134 | 117 | 113 | 113 | 43644 | 12.95 |
| 20 | 113 | 76 | 107 | 98 | 29575 | 4.66 |
| 21 | 93 | 90 | 92 | 107 | 22919 | 5.24 |
| 22 | 117 | 115 | 113 | 130 | 46303 | 11.93 |
| 23 | 99 | 117 | 87 | 104 | 31607 | 6.30 |
| 24 | 135 | 117 | 116 | 121 | 56000 | 15.75 |
| 25 | 101 | 118 | 88 | 129 | 29747 | 8.56 |

*Full statements appear later renumbered according to priority.

3.1.2 Analysis Method

1. Sum and rank research according to:

- a) Urgency
- b) Range of Effect
- c) Worth
- d) Success
- e) Funding

2. Sum and rank weighted indicator I_i

$$I_i = \sum (\text{urgency}) \times (\text{range}) \times (\text{worth}) \times (\text{success})$$

for $i = 1, 2, \dots, 26 \dots n$

3. Check correlation between I_i and (funding) i

PREDICTED VS. ACTUAL RESULTS

| (| SUM, | FUND) | |
|---------|---------|-----------|----------|
| OBS NO. | ACTUAL | PREDICTED | RESIDUAL |
| 1 | 4.4500 | 2.2207 | 2.2293 |
| 2 | 3.7500 | 6.5406 | -2.7906 |
| 3 | 7.9000 | 8.2264 | -0.3264 |
| 4 | 5.2000 | 5.7055 | -0.5055 |
| 5 | 6.7000 | 7.7438 | -1.0438 |
| 6 | 6.0500 | 7.5455 | -1.4955 |
| 7 | 6.1500 | 4.9539 | 1.1961 |
| 8 | 4.5200 | 6.0457 | -1.5257 |
| 9 | 6.0000 | 5.6386 | 0.3614 |
| 10 | 2.9000 | 4.9448 | -2.0448 |
| 11 | 4.6600 | 5.5103 | -0.8503 |
| 12 | 4.7400 | 6.8562 | -2.1162 |
| 13 | 4.6500 | 2.6462 | 2.0038 |
| 14 | 2.8000 | 1.5765 | 1.2235 |
| 15 | 9.9100 | 10.3717 | -0.4617 |
| 16 | 2.6500 | 2.4823 | 0.1677 |
| 17 | 5.6300 | 5.4655 | 0.1645 |
| 18 | 13.8800 | 14.1116 | -0.2316 |
| 19 | 12.9500 | 10.2189 | 2.7311 |
| 20 | 4.6600 | 6.4678 | -1.8078 |
| 21 | 5.2400 | 4.6931 | 0.5469 |
| 22 | 11.9300 | 10.9279 | 1.0021 |
| 23 | 6.3000 | 7.0095 | -0.7095 |
| 24 | 15.7500 | 13.5133 | 2.2367 |
| 25 | 8.5600 | 6.5136 | 2.0464 |

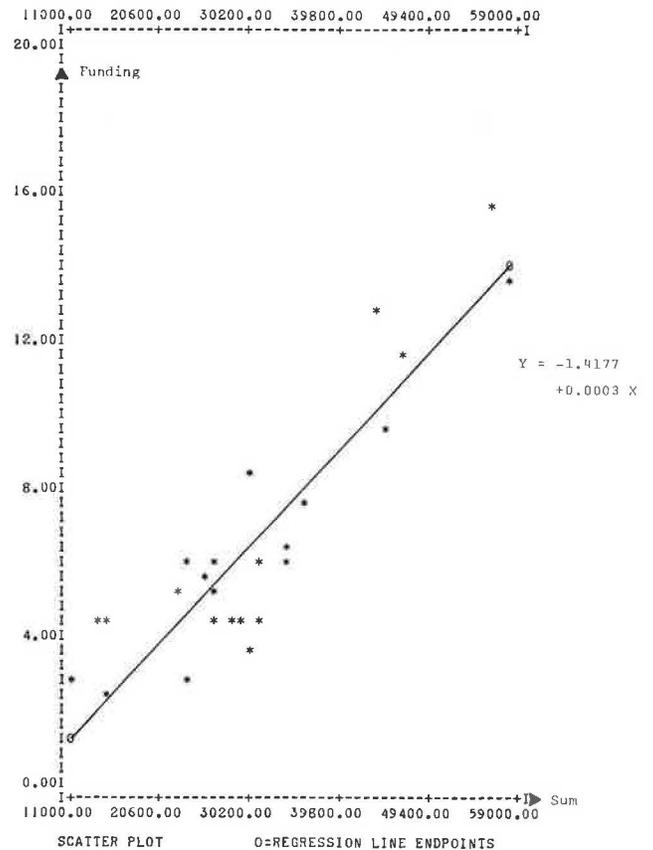


Figure 1.

4. Correlation analysis among urgency (A), range (B), worth (C), success (D) and funding (F)

Sample correlation coefficients matrix has been calculated as follows:

| | A | B | C | D | F |
|---|------|------|------|------|---|
| A | 1 | | | | |
| B | 0.34 | 1 | | | |
| C | 0.85 | 0.23 | 1 | | |
| D | 0.57 | 0.49 | 0.49 | 1 | |
| F | 0.85 | 0.51 | 0.67 | 0.69 | 1 |

For 99% confidence interval, the critical point for R is equal to 0.50125, hence the correlations among these factors are determined as shown in the following chart:

| | urgency | range | worth | success | funding |
|---------|---------|-------|-------|---------|---------|
| urgency | YES | | | | |
| range | NO | YES | | | |
| worth | YES | NO | YES | | |
| success | YES | NO | NO | YES | |
| funding | YES | YES | YES | YES | YES |

3.1.3 Data Analysis

a) Regression Analysis of sum ($I_i = A_i \times B_i \times C_i \times D_i$)

25 pairs of data for 25 statements have been fit for linear equation (see Figure 1) with correlation coefficient $R(X,Y) = 0.902$.

b) To test: if this correlation is significant,

$$\text{Statistic } Z = \frac{\frac{1}{2} \ln \frac{1+R}{1-R} - \frac{1}{2} \ln \frac{1+\rho}{1-\rho}}{\frac{1}{\sqrt{n-3}}}$$

has standard normal distribution

$$Z_{xy} = \left(\frac{1}{2} \ln \frac{1+0.902}{1-0.902} \right) / \frac{1}{\sqrt{22}}$$

$$= 6,9544 > Z_{.99}$$

Therefore $\rho \neq 0$ There is significant correlation between sum (I_i) and funding i with predicted equation $Y = -1.4177 + 0.0003 X$

$$Y = \text{Funding}_i$$

$$x = \text{Sum } I_i$$

3.1.4 Conclusion

1. There is a positive linear relation between I_i and $Funding_i$. Therefore, we can rate the priority by rating the funding, which yields:

| <u>Priority</u> | <u>Statement</u> | <u>Priority</u> | <u>Statement</u> |
|-----------------|------------------|-----------------|------------------|
| 1 | 24 | 14 | 21 |
| 2 | 18 | 15 | 4 |
| 3 | 19 | 16 | 12 |
| 4 | 22 | *17 | 20 |
| 5 | 16 | *17 | 11 |
| 6 | 25 | 18 | 13 |
| 7 | 3 | 19 | 8 |
| 8 | 5 | 20 | 1 |
| 9 | 23 | 21 | 2 |
| 10 | 7 | 22 | 10 |
| 11 | 6 | 23 | 14 |
| 12 | 9 | 24 | 16 |
| 13 | 17 | | |

*Tie-score

2. a) All the factors are closely related with funding, which not only confirms the conclusion, but also shows all the factors have the same trend toward funding.

b) Urgency is significantly correlated with worth and success; however, the remaining intercorrelations among urgency, range, worth and success are not proven.

3.1.5. Recommendation

Freeway Operations Research Problem Statements should be given a priority ranking as follows:

1. Determine the appropriate methods for handling vehicles which are disabled or involved in accidents on urban freeways.
2. Continue to investigate improved methods for freeway incident detection and means of qualitatively identifying the character of the incident.
3. Develop improved detection devices for measuring traffic flow characteristics.
4. Produce criteria for the performance and scheduling of maintenance activities on freeways. Scheduling would include the possibility of total closures for extensive maintenance activities.
5. Investigate and suggest improved methods for traffic control within and approaching construction areas.
6. The completion of urban and rural freeway systems has focused the attention of the motorist on the need for improved service facilities. Determine the nature of services to be provided for the traveling public, including both vehicle services and personal services.
7. Identify, quantify and show cause and effect relationship between freeway accidents and freeway environmental elements.
8. Prepare warrants for installation of impact attenuators and vehicle redirection devices (relates to #15), and also investigate improved designs for transitions from attenuators to redirection devices.
9. Determine what aspects of freeway driving should be included in driver education curriculum and/or in driver licensing standards.
10. Examine and suggest criteria for regulating vehicle design elements as they relate to and correlate with roadway design elements.

11. Devise improved cost effectiveness methods applicable to preparing spot improvement construction program priorities.
12. Devise improved pavement marking systems for northern climates.
13. Investigate the feasibility of traffic responsive changeable message speed limit signing.
14. Continue with additional projects to perfect ice and frost warning devices for freeway bridges. Consideration should be given to development of mathematical predictor models which can be used to actuate automatic de-icing equipment.
15. Determine the optimum level of design for traffic characteristics and traffic control devices. Conversely determine the acceptable failure rate of design.
16. Define the guidance information requirements for four categories of freeway drivers. These categories are:
 - a) Non-resident not familiar with the roadway
 - b) Local resident not familiar with the roadway
 - c) Non-resident who is familiar with the roadway
 - d) Local resident who is familiar with the roadway
- *17. Review present freeway guide signing practices, particularly in areas of legend size, letter style and quantity and quality of information required by the driver.
- *17. Search for improved methods of detecting and preventing wrong-way driving on freeways.
18. Devise standardized laboratory methods for pre-selection screening of alternate proposed new traffic control devices.
19. Investigate the traffic operations and safety usefulness of roadway tactile stimuli such as rumble strips.
20. Investigate the frequency, location and characteristics (including departure angles and speeds) of single vehicle run-off roadway accidents.
21. Devise standard methods other than accident records for detection and priority listing of traffic operation on safety problem locations, and also for evaluation of the effectiveness of corrective treatments.
22. Investigate the need for aids for the driver in judging distances and speeds on freeways.
23. Determine the optimum sign brightness levels for reflective sheeting used on freeway signs and concurrently establish warrants for external illumination of guide signs.
24. Develop snow removal techniques and ice control methods which are non-destructive to pavement surfaces and traffic control appurtenances which may be attached thereto.

*Tie score

4.0 HIGH PRIORITY RESEARCH STATEMENTS

Based on the preceding conclusions, Sections 4.0 and 5.0 will present a series of complete problem statements for each of the listed project titles.

For reasons of emphasis and to highlight the problems which are considered to be of the very highest priority, only eight statements will be reported here. The remainder will be found in 5.0.

An examination of Figure 1 shows that most of the suggested projects are closely grouped after the first eight and probably can be considered to be of about equal priority. Fortunately, the top eight are clearly separated and are distinct as to priority.

RESEARCH PROBLEM STATEMENTS

Priority No.: 1

Research Project Title:

Determine the appropriate methods for handling vehicles which are disabled or involved in accidents on urban freeways.

General Problem Area: Freeway Operations

Research Problem Statement:

The operation of urban freeways is continuously disrupted by the presence of disabled vehicles or those involved in accidents. Capacity past the incident is decreased to an amount significantly lower than the normal capacity of the remaining open lanes. In addition, the longer the vehicles remain in the roadway or in the vicinity of the roadway, the more the resulting congestion is compounded.

Research is needed to determine the frequency of incidents of varying degrees of severity, the degree of assistance needed, the methods of removing these vehicles, the most effective type or types of equipment necessary to accomplish this task and procedures for storing or disposing of the vehicles until they are retrieved by their owners such that their presence will not constitute a hazard to traffic or a visual distraction capable of slowing traffic and causing congestion.

Objectives:

1. To determine the frequency of occurrence of incidents of various types and severity.
2. To determine the degree of assistance needed to remove each of these types of incidents from the roadway.
3. To conduct a study of various cities' techniques and equipment presently being used to handle disabled vehicles, and evaluate the effectiveness of each.
4. To determine whether other means not presently being used might be more effective.
5. To determine the type or types of equipment necessary to accomplish this removal.
6. To determine the quantities of the various types of equipment required to handle the anticipated number of incidents of each degree of severity.
7. To determine methods and places of storage for these vehicles so that they will not be left on the shoulder of the road to constitute a continuing hazard or a visual distraction to passing traffic, and so that the vehicle will be afforded a reasonable degree of security from theft or vandalism until it is retrieved by the owner.

Priority No.: 2

Research Project Title:

Continue to investigate improved methods for freeway incident detection and means of qualitatively identifying the character of the incident.

General Problem Area: Freeway Operations

Research Problem Statement:

A major share of the congestion on urban freeways is caused by incidents occurring in or near the roadway which block lanes of the freeway or which reduce the speed of traffic to such a degree that even reasonable traffic demands cannot be satisfied. The most effective means of incident disposal cannot be implemented unless the incident is detected and evaluated so that appropriate assistance can be dispatched. The magnitude of the effect of the incident is compounded as the response time to the incident increases. The ideal system for incident detection would be one capable of observing the entire area of the roadway and providing information on the nature of the incident so that the appropriate assistance would be dispatched in the quickest possible time.

Research is necessary to develop; a) a detector capable of providing this type of information or something equivalent thereto, b) the equipment configuration necessary to provide adequate coverage of the roadway to provide meaningful information, and c) the necessary programs and evaluation techniques necessary to reliably identify incidents, to reject false incidents, and to identify the character of the incident so that appropriate assistance can be dispatched.

Objectives:

1. Classify the various types of incidents, and identify in detail their traffic flow characteristics.
2. Identify the desired function of the detector and the detection system.
3. Prepare a functional specification and subsequently develop a detector capable of reliably carrying out the desired function.
4. Prepare a functional specification and develop the equipment configuration necessary for a candidate system or systems capable of performing the desired function.
5. Develop the necessary techniques and programs that will enable the detection system to quickly and reliably respond to, qualitatively evaluate and warn of incidents on the freeway. A high degree of confidence must be sustained by reliable sensing of true incidents, without generating alarms by the apparent detection of false incidents.

Priority No.: 3

Research Project Title:

Develop Standardized Measurement Criteria and Techniques for Evaluating the Merit of Vehicle Detectors for Traffic Flow Measurements.

General Problem Area: Freeway Operations

Research Problem Statement:

Vehicle detection devices are required in order to implement the automated measurement of traffic flow characteristics.

A variety of detection devices are now on the market. They detect passing vehicles in a variety of ways, i.e.:

- Change in inductance of a loop buried in the roadway
- Disturbance in earth's magnetic field
- Treadle actuation by weight of vehicle
- Pneumatic tube actuation by weight of vehicle
- Interruption of light beam
- Radar return (both radio frequency and ultrasonic)

It is believed that suitable detection equipment is available. There are, however, large variables which influence the successful application of the detection equipment. These variables include vehicle size, temperature range and installation geometry. Manufacturers technical data is generally inadequate to make quantitative performance comparisons.

Research is therefore needed to classify vehicles and quantitatively define those characteristics of the vehicle which influences the detector; classify and define typical application geometries; define test equipment and test methods for measuring the phenomenon being used for vehicle detection and establish "Figures of Merit" for each detector classification.

Objectives:

1. Obtain a variety of vehicle detector types for testing.
2. Make measurements of detector performance for each of the various combinations of variables.
3. Classify the resultant data and define standards for future measurements and comparison tests, i.e., for inductive loop detectors, standard loop configurations should be defined and different sized vehicles could be classified in ranges at magnetic permeability.

4. Define detector "Figures of Merit", i.e., for an inductive loop detector the "Figure of Merit" could be the "change of inductance" obtained from a standard vehicle in a certain position on a standard loop geometry.

5. Determine minimum detection thresholds so that the probability of detecting a vehicle is maximized and "false detections" are minimized.

6. Compile the results in a report by detector category. The results are to enable a user to select a detector suitable for the measurements to be made and so that he will have quantitative numerical values of detector performance required for that purpose and the description of the measurement techniques required to verify if the detector performance is being realized.

Priority No.: 4

Research Project Title:

Scheduling Freeway Maintenance Activities

General Problem Area: Maintenance, Freeway Operations

Research Problem Statement:

Maintenance activities on freeways can result in time-consuming congestion and delay to freeway users and in increased accident potential, whether the work is within or outside the traveled way. At the same time, the cost of maintenance work on freeways is high because of the need to provide elaborate traffic control through the work area, the necessity of limiting certain types of work to light traffic periods, and the low productivity resulting from limited working area adjacent to the heavy volume or high speed traffic flow.

Under certain conditions, it may be economical to fully close one or both freeway roadways during major structural repairs. The cost to the maintaining agency may be lessened if complete closure results in a much faster return to normal operation.

There is a need for improved techniques for scheduling maintenance activities so as to minimize the time required for operations which adversely influence traffic movement and to result in an optimal balance of maintenance costs and adverse traffic effects. There is a need for improved methods of controlling traffic through work areas, so as to minimize traffic delay, disruption and accident potential, and at the same to make necessary maintenance work less costly. There is a need for guidance on the conditions under which closure of a freeway roadway may be justified for extensive maintenance work.

Objectives:

1. Review and summarize present practices on freeway maintenance operations with particular attention to methods of scheduling maintenance activities to minimize traffic disruption. The review should include collection and analysis of data of freeway maintenance costs, and the assembly of available information from previous studies on the traffic effects of freeway maintenance activities.

2. Develop recommended standard practices on the selection of materials and equipment which will minimize the time for the frequently-encountered maintenance operations.

3. Prepare a manual on freeway maintenance operations, outlining techniques for scheduling maintenance activities, presenting recommended practices for the control of traffic through work areas, and including guidelines for determining the feasibility of constructing temporary detours or otherwise allowing full closure of a freeway roadway. The manual should include recommended practices for the commonly-encountered freeway maintenance activities, including traffic striping, sweeping, landscaping maintenance, and guard rail repair and painting, as well as roadbed and surfacing repairs. The manual should include recommended practices on the selection of materials and equipment to minimize the time for maintenance activities which adversely affect freeway traffic operation.

Priority No.: 5

Research Project Title:

Traffic control through construction areas on freeways

General Problem Area: Construction; Maintenance; Traffic Operation; Freeway Operations

Research Problem Statement:

The control of traffic through work areas on freeways requires treatments markedly different from practices which are acceptable on surface highways. The high travel speeds and heavy traffic volumes generally found on freeways impose special problems in providing adequate warning and direction of traffic affected by maintenance and construction operations. The adverse effects of work activities within or adjacent to the roadway are more far-reaching and more costly to the freeway user than the effects of similar activities on normal highways.

There is considerable variation in the operational treatment of construction and maintenance areas. Standard practices on the control of traffic through work areas should be developed for the guidance of designers, contractors and maintenance personnel.

Objectives:

1. Review and summarize present practices on the control of traffic through work areas on freeways.
2. Evaluate alternative means of controlling traffic through work areas, including the development and test of innovative methods and devices.
3. Develop recommended standard practices for traffic control through work areas, including recommendations on the design and placement of traffic control devices and recommended rules for their use.

Priority No.: 6

Research Project Title:

Improved Service Facilities for the Traveling Public

General Problem Area: Freeway Operations

Research Problem Statement:

With the completion of urban and rural freeway systems, and the increased user demand for these facilities must come a corresponding improvement of user service facilities. Questions to be answered are the locations, and the extent of services to be provided, based on an investigation into the needs and desires of the traveling public.

Research is needed that will result in recommended plans for the creation of improved service facilities for the traveling public.

Objectives:

1. Literature search for studies pertinent to this research problem.
2. Determination of the service needs and desires of the traveling public.
3. Recommended implementation plans for providing the required services.
4. Evaluation of existing services and recommended improvements.

Priority No.: 7

Research Project Title:

Relationship Between Freeway Accidents and Freeway Environmental Elements

General Problem Area: Freeway Operations

Research Problem Statement:

Freeway environmental elements often contribute to and are sometimes the cause of freeway accidents. Among these environmental elements are weather conditions, time of day, landscaping and freeway design, etc.

Research is needed to identify, quantify and show cause and effect relationship between freeway accidents and the various environmental elements. The research should result in recommendations leading to early development of corrective measures to reduce the effect of environmental elements on freeway accidents.

Objectives:

1. Review of earlier studies.
2. Review of accident data to uncover effect of freeway environmental element on freeway accidents.
3. Determination of cause and effect relationship between freeway accidents and environmental elements.
4. Recommendation of immediate and future remedial measures.

Priority No.: 8

Research Project Title:

Prepare warrants for installation of impact attenuators and vehicle redirection devices and also investigate improved designs for transitions from attenuators to redirection devices.

General Problem Area: Highway Design, Freeway Operations

Research Problem Statement:

There are several types and designs of impact attenuators and redirecting systems available on the market and experience and trial installation has indicated that some can be considered operational. It is desired from an economic standpoint that the lowest priced unit consistent with satisfactory performance be specified or developed.

Research is needed that will determine acceptable levels of performance regarding vehicle and driver damage, and safety to other drivers, for various roadway and volume and dynamic conditions, and to develop, investigate and improve transitions from impact attenuators to redirection devices.

Objectives:

Review past and present studies and performance records and designs of impact attenuating and redirecting devices.

Considering some or all of the following influencing factors, prepare and test samples for a matrix chart recommending applications for existing specific devices.

Also consider the basic dynamic influencing factors and needs, and attempt to design and test improved transition systems such as suggested below:

Some Considerations in Selecting Warrants for Impact Attenuator Use:

- Alignment present (vertical and horizontal)
- Delineation
- Illumination
- Cross-Section
- Shape, size and color of hazard
- Background color
- Number and types of choices at bifurcations
- Escape areas
- Frequency of past contacts by vehicles
- Volumes and types of traffic
- Time of peaks
- Other possible treatments
- Possible elimination of problem

Possible transition systems, considerations and designs for evaluation:

- Twisted sloping end sections
- Vertical shearing or other special post connections on sloping end sections
- Triggered hooks, nets or special devices on end sections
- Triggered horizontal redirecting devices to use vehicle kinetic energy to redirect vehicle
- Extending post above rail

5.0 ADDITIONAL RESEARCH STATEMENTS

Priority No.: 9

Research Project Title:

Aspects of Freeway Driving to be Included in Driver Education Curriculum and/or in Driver Licensing Standards

General Problem Area: Freeway Operations

Research Problem Statement:

Driver education curricula and driver licensing standards generally are not oriented toward freeway driving.

Research is needed to determine the unique characteristics of freeway driving and recommendations made for including the most important of these into the normal driver education curriculum and/or licensing standards.

Objectives:

1. Review existing material on this subject. Material should be obtained from at least:
 - a. HRB Committee on freeway driving
 - b. Existing state curricula and standards
 - c. FHWA standards
2. Identify those characteristics of freeway driving that are unique to freeways and which would not normally appear in existing material. Examples that should be considered are:
 - a. Signing
 - i. Interstate numbering system
 - ii. Positioning of through lane vs exit lane arrows
 - iii. Ramp vs freeway reflector colors
 - iv. Gore markings
 - v. Service symbols
 - b. Driving maneuvers
 - i. Acceleration lanes and merging
 - ii. Deceleration lane
 - iii. Lane changing
 - iv. Braking
 - v. Weaving section
 - vi. Breakdown lanes
 - c. Special Safety Procedures
 - i. Tailgating and chain reaction collisions
 - ii. Aborted merging maneuvers
 - iii. Safety when making repairs in a breakdown lane
3. Rank the material in order of importance.
4. Rank the material in order of acceptability in terms of conforming to existing State ordinances.
5. Correlate the material with the most current highway standards
6. Recommend a staged implementation plan including specific recommendations to State ordinances.

Priority No.: 10

Research Project Title:

Regulation of vehicle design elements related to roadway design.

General Problem Area: Design, Freeway Operations

Research Problem Statement:

The system involved in moving goods and services from place to place by free-wheeled vehicles necessarily includes roadway, vehicle and operator. A good deal of attention has been given to each area separately, yet it seems axiomatic that the three must be considered as concurrent elements of a single system. Historically, variations in vehicle design have made roadway facilities obsolete long before their time.

Research is needed to identify the controllable elements of vehicle design and roadway design which have direct bearing on each other and to formulate procedures by which inter-dependent changes can be brought about on a related basis. The study should consider the need for and means of regulating changes in vehicle design so as to prevent uneconomical obsolescence of existing highways.

Objectives:

1. Review past and current research pertaining to the interrelated elements of vehicle performance and roadway design; review present means of controlling the related design features.
2. Prepare a "state-of-the-art" summary of the results of the research review; identify the controllable elements of vehicle-roadway design in order of importance.
3. Formulate means of regulating the related design elements so as to achieve an optimal level of performance of highway facilities, considering the investment of both public and private funds.

Priority No.: 11

Research Project Title:

Preparing Spot Improvement Construction Program Priorities

General Problem Area: Freeway Operations

Research Problem Statement:

Spot improvement construction is a necessary component of modern freeway maintenance. The higher speeds attainable in modern freeways and the increased user demand for these facilities require continuous freeway improvement.

Historically, cost effectiveness methods for project priorities have contained uncertainties and inaccuracies. Research is needed to make cost effectiveness analysis reflect more fully the total cost and value of an improvement. This research should result in improved cost effectiveness methods applicable to preparing spot improvement construction program priorities.

Objectives:

1. Review of past and present methods.
2. Determination of factors to be included in the development of possible alternatives.
3. Evaluation of possible alternatives leading to recommended methods.

Priority No.: 12

Research Project Title:

Improved Pavement Marking Systems for Northern Climates

General Problem Area: Adequate fulltime guidance and delineation, Freeway Operations

Research Problem Statement:

A working scheme is needed that will provide adequate driver guidance under wet and night conditions and all seasons, and which will have adequate durability and retention for year round guidance.

This evolves in the Northern climates from two factors unique to Northern latitudes. These are cold weather and snowplowing action as a result. The first factor precludes application of conventional markings to roadways and the second factor removes all earlier applications placed in warm weather. A third factor is, of course, wetness that removes visibility year round, particularly at night.

Research directed toward elimination of the effects of these three factors remains a dire need.

NOTE: NCHRP Project No. 5-5b "Pavement Marking Systems for Improved Wet-Night Visibility Where Snowplowing is Prevalent" should be seeking answers to overcome the three factors mentioned above. As such, a project proposed under the heading of this statement must be structured so as to not be a duplicate of Project 5-5b.

Priority No.: 13

Research Project Title:

Feasibility of Traffic Responsive Changeable Message Speed Signing

General Problem Area: Freeway Operations

Research Problem Statement:

Existing projects utilizing variable speed signs for control include: John C. Lodge, Detroit; Seattle, Washington; and N.J. Turnpike. The results to date indicate that motorists ignore messages unless there is an "obvious" reason for obeying it.

Coupling of speed with a more informative message like "accident ahead" works better BUT the time between when the message is presented to the driver and when he is able to confirm its truth is critical. These times need to be determined (i.e., condition response mechanism).

Objectives:

The order in which the research should be undertaken is as follows:

1. Determine a set of events which should have a corresponding speed associated with it.
2. Determine if reinforcing messages are required for each event and what the message should be.
3. Determine acceptable ranges of "confirmation times" for each unit.
4. After completing 1, 2, and 3 determine if there are measurable "traffic characteristics" that can be used to determine that an event has taken place.
5. Develop representative geometries of the relative location of detection equipment, speed sign, reinforcing message sign and the location of the event for each of the selected events.
6. Recommend a set of experiments for each of the "events" that have met all of the above criteria. These experiments to be conducted in a subsequent research effort to evaluate motorist response to the traffic responsive speed signs.

ADDENDA:

It is believed that the intent of the original statement was to also include feasibility of automatic feedback of information from Item 4 to automatically select the speed message to be displayed as conditions change.

Priority No.: 14

Research Project Title:

Additional project to perfect ice and frost warning devices for freeway bridges.

General Problem Area: Freeway Operations

Research Problem Statement:

The research, development and evaluation of systems to detect frost and ice is well under way and should not be the prime consideration for this study.

What is needed is an economic justification by cost analysis of methods to provide the motorists with freeway bridges free of unsuspected ice and frost. The items to be studied are:

1. Continue de-icing bridges as needed.
2. Use simplified detection equipment and de-ice automatically even if not needed.
3. Use better detection equipment and alert and/or spread de-icing materials as frost and ice forms.
4. Build predictive model and use equipment capable of predicting before the ice and frost will form.

It may become necessary in the near future to consider the ecology involved in using certain de-icing materials. Other type chemicals and/or means of removing the frost and ice and alerting the driver may become the important factor.

Objectives:

Provide a cost analysis method to determine best method of detecting ice and frost, and the best way to remove the slippery condition and/or alert driver.

Priority No.: 15

Research Project Title:

Optimum Level of Design for Traffic Characteristics and Traffic Control Devices

General Problem Area: Freeway Operations

Research Problem Statement:

The level of design achieved for traffic characteristics and traffic control will naturally determine the quality of the service to be provided. Among the factors to consider are the costs associated with an incremental improvement in the level of design and the consequences of high failure rates.

Research is needed to determine the sensitivity of good traffic operation to various levels of design for traffic characteristics and traffic control devices. This research should result in the determination of optimum design level with acceptable failure rates of design.

Objectives:

1. Review past and current research pertaining to optimum level of design for traffic characteristics and traffic control devices.
2. Determine factors to be considered and their relative importance.
3. Recommended optimum level of design for traffic characteristics and traffic control devices.

Priority No.: 16

Research Project Title:

Guidance Information Requirements for Freeway Drivers

General Problem Area: Traffic Operations, Freeway Operations

Research Problem Statement:

Freeway guide sign requirements are thought to differ appreciably for four categories of freeway users:

1. The local resident who is familiar with the roadway
2. The local resident who is not familiar with the roadway
3. The non-resident who is familiar with the roadway
4. The non-resident who is not familiar with the roadway

In the design of freeway guide signs, the emphasis given to each user category varies from jurisdiction to jurisdiction, and sometimes from project to project within a given jurisdiction. Variations in sign design include features such as use of freeway names, use of place names vs. compass direction and use of exit numbers vs. connecting street names or community identification.

Research is needed on the relative importance of guidance information for each category of freeway user, for urban freeways and for rural freeways, and on the type of information needed for each category. Further study is needed to determine the type of signing which will best serve all freeway users; that is, to determine if the signing should be designed specifically for one category of user, or if it should be designed to serve all categories, possibly at varying levels. Concurrently, research is needed on the design of guide sign features which will best provide the needed information.

Objectives:

1. Determine the principal information needs of each of the four categories of freeway drivers.
2. Determine the relative importance of providing guide sign information to drivers in each of the four categories, for both rural and urban freeways.
3. Identify guide sign features which will satisfy the more important user information needs, and those features which are less important.
4. Evaluate present practices in the design of freeway guide signs and make recommendations on design changes to better serve freeway user needs.

Priority No.: 17-1

Research Project Title:

Freeway Guide Signs

General Problem Area: Traffic Operations; Traffic Signs; Freeway Operations

Research Problem Statement:

There is a lack of factual data on the information needs of freeway drivers as related to the design of guide signs. There is a need for additional research on the design of messages to adequately inform the driver, and on the optimum size and placement of freeway guide signs and their components.

Present practices in the design and placement of freeway guide signs have evolved from practices followed over the years on surface highways. These practices have resulted in instances of unnecessary and confusing signing, and in instances of inadequately informing the driver of information needed to complete his trip safely and with least confusion and uncertainty. There is a lack of uniformity in the design of sign legends, in the style and size of letters used, in the use of symbols and in the placement of sign structures.

Present freeway signing practices should be reviewed and those practices should be evaluated against the results on driver information needs.

Objectives:

1. Review the results of previous research on freeway driver information needs.
2. Formulate and conduct additional research studies to identify freeway driver information needs as related to guide signing.
3. Review present practices in the design of freeway guide signs and evaluate those practices against the criteria for driver information needs.
4. Prepare recommendations for the design and placement of guide signs to provide an optimal level of information to the driver, considering factors such as legend design, letter size, letter and background color, use of standardized formats and symbols and placement of signs with respect to the roadway and with respect to points of egress from the freeway.

Priority No.: 17-2

Research Project Title:

Determine Methods for the Prevention of Wrong-Way Driving on Freeways

General Problem Area: Freeway Operations

Research Problem Statement:

Current work in this area has concentrated on the use of fixed message signing and careful attention to the geometry of the exit ramp (curbing, etc.) to make it difficult for a car to enter an exit ramp. These techniques, however, are not enough since people can still get on the wrong way.

Research needs to be done on what to do about the driver who gets on the exit ramp the wrong way in spite of the other precautions. Detecting that a driver is driving the wrong way may be accomplished with commercially available directional detectors. The key problem is what can be done after the driver is on the ramp - going the wrong way and you or a system knows that he is.

Objectives:

1. Review work done to date.
2. Select several of the most commonly used geometries of exit ramps for study.
3. Assume the driver is on the ramp.
4. For each of the selected geometries
 - a. Establish where detectors should be placed.
 - b. Investigate changes in the geometry for escape lanes and turning the motorist around in a safe manner.
 - c. Investigate actuated illuminated warning signs.
 - d. Investigate mechanical devices and barriers that can safely perform the desired function.
5. Submit recommendations for experiments to be conducted in the field.

Priority No.: 18

Research Project Title:

Preselection Screening of Alternate Proposed New Traffic Control Devices

General Problem Area: Freeway Operations

Research Problem Statement:

The propagation of traffic control problems to most of our cities, as well as the need for traffic control wherever heavy traffic volumes are present, has created a great need for new traffic control methods and devices. Selection of the appropriate device or method must be made from a set of proposed alternatives. The decision mechanism for selecting the most appropriate device method for a given problem must be made to reflect all the desired characteristics such as reliability, flexibility, ease of maintenance, etc.

Research is needed to devise standardized laboratory methods for preselection screening of alternate proposed new traffic control devices and methodologies.

Objectives:

1. Determine characteristics of importance in traffic control devices and their relative position on a scale (i.e., mean time between failure, ease of maintenance, cost, etc.).
2. Evaluate alternate proposed new traffic control devices based on characteristics defined in #1 above.

Priority No.: 19

Research Project Title:

Investigate the traffic operations and safety usefulness of roadway tactile stimuli such as rumble strips

General Problem Area: Freeway Operations

Research Problem Statement:

The safe operation of vehicles sometimes requires attracting the driver's attention to an unusual or unpredictable situation such as a freeway ending, lane drop, construction area, temporary maintenance and freeway changes.

The standard traffic control devices such as barricades, lane markings, warning lights, signals, signing and channeling are usually adequate.

To provide additional stimuli at problem areas, road surface devices such as raised markers, rumble strips and pavement configurations have been used to stimulate drivers through vehicle tires. However, very little research has been done to study the effects of:

1. Safety of driver when vehicle strikes raised markers
2. Placement, size and installation procedures
3. Development of warrants as to volumes, speeds, noise, roughness as related to roadway condition.

Objectives:

Study of this type could provide warrants for the use of road surface stimuli. This would provide additional traffic control devices to be used in alerting drivers of a sudden change in roadway geometrics.

Priority No.: 20

Research Project Title:

Investigate the frequency, location and characteristics (including departure angles and speeds) of single vehicle run-off roadway accidents.

General Problem Area: Highway Safety, Freeway Operations

Research Problem Statement:

In order to better locate, estimate and evaluate the effect of and on impact attenuators and redirection system, it is desired that more definite quantitative information be available on the frequency, location and characteristics of single vehicle ran-off roadway accidents, particularly the vehicle path, velocities and recoverability of the driver.

Objectives:

Review past and present studies and data on the subject and prepare state-of-the-art summary. Plan and carry out a statistically sound study to provide additional quantitative data to provide a complete picture of the desired information as indicated in the following list of considerations in Characteristics of the Ran-Off Roadway Single Vehicle Accidents:

Measurements needed

Measuring methods available

Location

Time of Day

Velocity initially and along path

Which way wheels turned

Condition of driver

Point of driver alert

Vehicle type

Vehicle path and final position and heading and condition

Geometrics and operational devices including informational signs in the area

Perception distraction factors

Priority No.: 21

Research Project Title:

Detection and Priority Listing of Traffic Operation or Safety Problem Locations

General Problem Area: Freeway Operations

Research Problem Statement:

Detection of safety problem locations is among the most important deterrents of traffic accidents. Certain factors have been found to lead to unsafe conditions. Among these congestion, physical condition of the road, lack of law enforcement, etc.

Research is needed to develop standard methods, other than accident records for detection and priority listing of traffic operation of safety problem locations. Research should also be conducted to develop standard methods for the evaluation of corrective measures.

Objectives:

1. Determine factors contributing to unsafe conditions.
2. Examine existing design and traffic control criteria resulting in these unsafe conditions and recommend necessary changes.
3. Develop standard methods for detecting safety problem locations.

Priority No.: 22

Research Project Title:

Driver Aid for Judging Distances and Speed on Freeways

General Problem Area: Freeway Operations

Research Problem Statement:

Recent studies have shown that drivers driving at high speed on freeways have considerable difficulty judging distance, absolute speed and closing speeds. These difficulties present problems in determining when to decelerate for toll booths, turn offs and how much distance is required to perform a safe braking maneuver.

To provide the driver with equipment similar to what airplane pilots have for this purpose appears to be prohibitively expensive for use in an automobile.

Therefore, research needs to be directed to provide visual and/or audible cues to aid the driver.

Objectives:

Research should be directed toward utilizing techniques that are relatively easy to implement such as paint, signing and standards of signing to achieve these objectives.

The use of paint, signing and standards are intended to be indicative of the techniques desired. Innovations, however, are encouraged.

Examples of the type of research desired follow for guidance:

1. Paint: The spacing of paint stripes approaching toll booths has been used to assist the driver in braking maneuvers. This could be used elsewhere. Rumble strips might also be used in a similar manner to combine both visual and auditory stimuli.

2. Signing: Exit signing including rest areas, could utilize signs such as are used on the German autobahns. These are signs that are equally spaced from an exit. The farthest out sign has three diagonal lines on it, the second two, and the third one. Also on the sign is the numerical distance. The drivers, by custom, get used to the spacing and normally look for the diagonal stripes for their cues.

3. Standardization: There are two aspects of standardization of the location of an informative sign ahead of a "decision point".

a. Utilize the same spacing all the time so people get used to it.

b. Locate the sign in terms of the time it takes to make a decision, the maximum or high average speeds experienced on the road and therefore locate the sign far enough upstream so the motorist can make his decision before he must execute a maneuver.

The research should document guidelines, numerical tables and suggestions for improving existing standards.

Priority No.: 23

Research Project Title:

Recommended brightness levels for illuminated and reflective signs, and warrants for externally illuminated freeway signs

General Problem Area: Traffic Operations; Traffic Signs; Freeway Operations

Research Problem Statement:

Present practice in the design of freeway guide signs, route markers and information signs includes the use of distinctive sign background colors. Information clues provided by the background color should be available to the driver at night as well as in daylight. Two means are available of providing nighttime visibility of sign colors: reflective sheeting and direct illumination. Directly illuminated signs most commonly employ exterior mounted lighting fixtures.

Additional information is needed on the relative merits of reflective and illuminated signs under the various conditions found in practice. Specifically, information is needed on the conditions under which the more costly installation of directly illuminated signs are justified.

There has been limited research on the proper brightness levels of sign legend and background either for directly illuminated or reflective signs. Information is needed on these aspects of sign design for the varied conditions found in practice.

Objectives:

1. Review current and past research on the relation between sign brightness and legibility; prepare a "state-of-the-art" summary; identify needed additional research to ascertain optimum brightness levels of sign legend and background for the several types of freeway signs in use, and for a variety of the conditions found in practice.
2. Prepare recommendations on proper brightness levels for directly illuminated signs, and for signs employing reflective sheeting for background.
3. Formulate recommendations on the desirable reflective qualities for reflective sheeting for a representative variety of sign types, sizes, colors and placements.
4. Identify the conditions under which directly illuminated signs should be used, and the conditions under which redirective materials are appropriate for freeway signs.

Priority No.: 24

Research Project Title:

Develop snow removal techniques and ice control methods which are non-destructive to pavement surfaces and traffic control appurtenances which may be attached thereto.

General Problem Area: Traffic Control and Operations, Freeway Operations

Research Problem Statement:

Although there have been many varied attempts to achieve a low cost completely satisfactory clear surface in winter, most of the methods fall short of desired results either due to destruction of paint lines or to high initial or continuing costs.

Research is needed considering but not necessarily limited to the below listed factors to provide a snow and ice control system that will not destroy paint lines, delineators, etc., and yet will be reasonable in cost.*

Objectives:

Review past and current research pertaining to the problem of non-damaging snow and ice control.

Prepare a state-of-the-art summary and prepare a study plan to supply information not already available toward developing a satisfactory solution for limited or total application.

*Some Considerations in Non-Damaging Snow Removal and Ice Control:

Tolerable damage level to pavement and pavement markings.

Alternatives available: blowing, rubbing, melting, roller-edged or flapper-edged scraper blade, NASA findings, surface treatments (bond breakers), and deposit redirectors such as electro-static collectors and natural or man-made wind currents.

Advantages vs. costs of alternatives.

Basic scientific factors - tolerable rolling wt/in² on lines

Methods of protecting existing appurtenances

Ice crushing and breaking angle

Ice crushing load compared to pavement surface strength

Shot blasting

Chemical melters

Electric melters

Flexible surface

Pavement vibration

Depressed line

Notched blade and sweeper

Priority No.: 25

Research Project Title:

Slow-moving vehicles on freeways

General Problem Area: Maintenance; Traffic Operations, Freeway Operations

Research Problem Statement:

Certain types of vehicles must necessarily travel on freeways at speeds considerably below prevailing traffic speeds. Hence, these vehicles present serious potential for traffic accidents either involving the slow-speed vehicles or resulting from abrupt speed changes or passing maneuvers by following vehicles traveling at much higher speeds.

Among the types of vehicles falling in the slow-moving category are special purpose maintenance equipment, such as traffic stripers and sweepers, and vehicles carrying unusual loads, such as overweight vehicles traveling under permit.

Some jurisdictions have developed practices intended to protect slow-moving equipment and to guide and warn other traffic. An example is the use of a large truck following a traffic striper or sweeper, equipped with unusually large signs or warning devices and visible for a considerable distance from the rear. However, there is no uniformity of treatment from jurisdiction to jurisdiction.

A review should be made of existing practices for treating special equipment necessarily moving at slow speeds on freeways. Those practices should be evaluated and recommended standard practices should be formulated.

Study should be made of alternate means of preventing the hazards imposed by slow-moving vehicles. Possibly, present equipment could be redesigned or modified to permit operation at or near freeway speeds. Conceivably, new vehicle designs can be developed. Certain maintenance procedures, such as sweeping and traffic striping, might be modified through changes in equipment or materials or by modifying scheduling practices. Present maintenance practices should be reviewed and analyzed. Recommendations should be developed for improved scheduling or for modification of materials, equipment or procedures.

Objectives:

1. Review and summarize present practices on the treatment of slow-moving vehicles on freeways; analyze the adequacy of existing practices; develop recommended standard practices, where necessary, to provide adequate protection for the slow-moving vehicles and to minimize the hazards to other traffic.

2. Evaluate the need for improved devices for warning and directing traffic approaching slow-moving vehicles; develop performance requirements; prepare specifications for prototype development and test.

3. Analyze the performance characteristics of slow-moving equipment frequently used on freeways; evaluate the feasibility of redesigning existing equipment, or of developing new equipment design, to provide more suitable operating characteristics for freeway use; prepare performance specifications and specifications for prototype development.

Priority No.: 26

Research Project Title:

Information Processing Characteristics of Freeway Drivers

General Problem Area: Freeway Operations

Research Problem Statement:

The reaction of freeway drivers to external stimuli is of importance in freeway design and traffic control, and depends on the drivers' information processing characteristics.

Research is needed to identify the information processing characteristics of freeway drivers. This research must be directed to the development of an understanding of the basic limitations, capabilities and reactions of the freeway driver with regards to information processing as well as the distribution of these characteristics among the driver population.

Objectives:

1. Literature search pertaining to basic human information processing characteristics.
2. Determine those factors important to freeway driving indicating their pertinence to freeway design and traffic control.

Priority No.: 27

Research Project Title:

Procedures and Techniques for Alternate Routing in Highway Networks

General Problem Area: Traffic Control and Operations - Freeway Operations

Research Problem Statement:

Whenever there are capacity reducing incidents or conditions on the freeways, there is desire or sometimes necessity to supply information to the driver as to alternate routes available in the same corridor.

Research is needed toward developing procedures, techniques and equipment for optimizing both advisory and mandatory alternate routing in highway networks.

Objectives:

Review past and present studies and performance records and designs of special traffic information and instruction signs.

Gather and organize information on types and locations and frequency of problems and drivers information need for use of supplemental routes.

Identify and quantify levels of need for supplemental systems and signing.

Identify one or more types of supplemental systems based on capacity and environmental level of the alternate routes.

Develop optimum shape, size and message for proposed supplemental signing.

Recommend automatic or other methods for actuating supplemental route instructions and signing.

Priority No.: 28

Research Project Title:

Improved Design and Signing of Lane Drops

General Problem Area: Design - Freeway Operations

Research Problem Statement:

Freeway designs frequently include changes in the number of lanes on the through roadway. When a lane is ended - generally at an exit ramp or interchange transition roadway - a hazardous condition can result.

General design treatments have been recommended to minimize the adverse operating features of necessary lane drops. ("Highway Design and Operational Practices Related to Highway Safety", American Association of State Highway Officials, Washington, D.C., 1967, pp. 16-17, 47.) However, research is needed to evaluate the effectiveness of the recommended treatments, and to develop more specific design recommendations covering a greater number of the conditions found in practice. Similarly, there is a need to review and summarize current practices on signing and delineating lane drops and to develop recommended practices for use in the design of new facilities and to aid in the reconstruction of existing freeways. The research should take into account the need for advance warning of the change in roadway conditions, and the need for delineating the transition area.

Objectives:

1. Review past and current research and present practices on the design of lane drops on freeways.
2. Review past and current research and present design practices on signing and delineating lane drops, including advance warning of the change in condition.
3. Prepare a "state-of-the-art" summary of the review.
4. Evaluate present design practices and formulate recommendations for improved treatments, both for future facilities and for the redesign of existing problem locations.

Priority No.: 29

Research Project Title:

Processes and Factors which Determine Roadway Traffic Capacity

General Problem Area: Freeway Operations

Research Problem Statement:

The concept of capacity is fundamental to good design of new installations and to the efficient use of existing facilities. Many assumptions and faulty criteria form the foundation of the present concept of capacity.

Research is needed to define the processes and factors which determine roadway traffic capacity.

Objectives:

1. Review past and current research pertaining to the problem of roadway traffic capacity.
2. Prepare a state-of-the-art summary of the review.
3. Define the processes and factors which determine roadway traffic capacity.
4. Evaluate existing criteria and recommend necessary changes.
5. Develop recommendations for follow-on research on the problem.

Priority No.: 31

Research Project Title:

Warrants for Ramp Metering or Closure (For additional information see Appendix 7.2)

General Problem Area: Traffic Control and Operation, Freeway Operations

Research Problem Statement:

As the present system and that which money is available to build becomes more overloaded, repeated need will develop for decisions to go to ramp metering or closure. To aid in these decisions, studies are needed toward developing warrants for or effects of metering and closure on capacity, accidents, inconvenience, other modes of transportation, etc.

Objectives:

1. Identify effects of ramp metering and closure.
2. Quantify each effect.
3. Discuss and recommend warrants or show curves or tables for selection of warrants for ramp metering and closure.

Priority No.: 31

Research Project Title:

In-Depth Study of Capacity and Level-of-Service of Various Freeway Elements

General Problem Area: Traffic Flow, Freeway Operations

Research Problem Statement:

As with most engineering productions, the end product is usually made up of several components of various capabilities and quality depending upon the level of service desired from the end product. This project proposes to study the elements of the freeway design and operation, and quantify their influence on capacity for various levels of service.

Objectives:

1. Review available information on quantitative effect of various designs of freeway components.
2. Develop plan for obtaining any needed additional information.
3. Produce tables or graphs showing the influence of component design on capacity or quality of service of the facility.
4. Recommend points on these curves to produce optimum level of service.

6.0 RECOMMENDATION

The preceding work cannot be taken as an absolute since the input to the analysis is fundamentally subjective and also since the priorities are constantly in flux. As progress is made, old problems are solved and new ones are discovered, or possibly the importance is revalued through time for other reasons.

For these reasons, the following recommendations are made:

1. Use the priority listing as a guide for establishing research programs for freeway operations. These programs can be of varying levels of complexity ranging from a Master's thesis to multisponsor cooperative projects.
2. Periodically repeat and update the above analytic process. This will provide the research community with an up-to-date position of the Highway Research Board on the current needs in freeway operations improvements.
3. When the report is updated, add one step to the analytic process. That is, ask all committee members for suggested project titles before asking for priority ranking. This will eliminate a possible source of bias in the findings. At that time the six statements listed in the report but not analyzed plus the three statements on airport access should be reviewed for possible inclusion in the list.

7.0 APPENDIX

7.1 Questionnaire

The following questionnaire has a simple purpose. It provides a quantitative method by which to reflect the expertise of the members of the Freeway Operations Committee into the process of setting priorities for potential research projects.

The format of the questionnaire is designed to allow ease of data processing by use of the most rudimentary manual techniques available. Please cooperate. The requirements are modest.

To complete the questionnaire properly you need only enter a number from 0 to 10 in each of the appropriate boxes. The boxes in the first row reflect the urgency you attach to each particular project; 0 indicates the work is absolutely unnecessary, while 10 reflects that immediate action is absolutely necessary.

The boxes in the second row reflect the extent to which the research affects the population of users. For this row, 10 indicates all users benefit, while 0 indicates little or nothing of value will be saved.

The fourth row is your estimate of the probability of success in finding useful results. The scale is once again from 0 to 10 with 10 indicating the highest expectation of success.

The last row is associated with your estimate of how to budget funds; you have a total of ten notes, each worth one hundred thousand dollars (i.e. \$100,000 bills). How would you distribute them along the candidate projects? Remember, you have only \$1,000,000; spend it wisely. You can save some if you wish, but you may not go into debt.

To simplify processing, we have placed all answer boxes on a single sheet. Please complete this sheet and return it to the Chairman of the Freeway Operations Subcommittee on Research Problem Statements today. Your response will only require a few minutes of your valuable time, and it will directly affect the Committee's recommendations as to how several millions of dollars in research funds should be spent.

As a final note, please be advised that the Subcommittee is most anxious to receive your thoughts on what research is most warranted. If you have a problem area that is of concern to you, and it is not on the list, please enter the relevant information in slot #26 (and beyond).

RESEARCH STATEMENTS SUBCOMMITTEE

1. Investigate the frequency, location and characteristics (including departure angles and speeds) of single vehicle run-off roadway accidents.
2. Devise standard methods other than accident records for detection and priority listing of traffic operation on safety problem locations, and also for evaluation of the effectiveness of corrective treatments.
3. Identify, quantify and show cause and effect relationship between freeway accidents and freeway environmental elements.
4. Determine the optimum level of design for traffic characteristics and traffic control devices. Conversely determine the acceptable failure rate of design.
5. Prepare warrants for installation of impact attenuators and vehicle redirection devices (relates to #4 above), and also investigate improved designs for transitions from attenuators to redirection devices.
6. Devise improved cost effectiveness methods applicable to preparing spot improvement construction program priorities.
7. Examine and suggest criteria for regulating vehicle design elements as they relate to and correlate with roadway design elements.
8. Investigate the traffic operations and safety usefulness of roadway tactile stimuli such as rumble strips.
9. Devise improved pavement marking systems for northern climates.
10. Investigate the need for aids for the driver in judging distances and speeds on freeways.
11. Review present freeway guide signing practices, particularly in areas of legend size, letter style and quantity and quality of information required by the driver.
12. Define the guidance information requirements for four categories of freeway drivers. These categories are:
 - a) Non-resident not familiar with the roadway
 - b) Local resident not familiar with the roadway
 - c) Non-resident who is familiar with the roadway
 - d) Local resident who is familiar with the roadway
13. Devise standardized laboratory methods for pre-selection screening of alternate proposed new traffic control devices.
14. Determine the optimum sign brightness levels for reflective sheeting used on freeway signs and concurrently establish warrants for external illumination of guide signs.

15. Investigate and suggest improved methods for traffic control within and approaching construction areas.
16. Develop snow removal techniques and ice control methods which are non-destructive to pavement surfaces and traffic control appurtenances which may be attached thereto.
17. Investigate the feasibility of traffic responsive changeable message speed limit signing.
18. Continue to investigate improved methods for freeway incident detection and means of qualitatively identifying the character of the incident.
19. Develop improved detection devices for measuring traffic flow characteristics.
20. Search for improved methods of detecting and preventing wrong-way driving on freeways.
21. Continue with additional projects to perfect ice and frost warning devices for freeway bridges. Consideration should be given to development of mathematical predictor models which can be used to actuate automatic de-icing equipment.
22. Produce criteria for the performance and scheduling of maintenance activities on freeways. Scheduling would include the possibility of total closures for extensive maintenance activities.
23. Determine what aspects of freeway driving should be included in driver education curriculum and/or in driver licensing standards.
24. Determine the appropriate methods for handling vehicles which are disabled or involved in accidents on urban freeways.
25. The completion of urban and rural freeway systems has focused the attention of the motorist on the need for improved service facilities. Determine the nature of services to be provided for the traveling public, including both vehicle services and personal services.
26. Other:

ANSWER SHEET

| QUESTION | URGENCY | RANGE | WORTH | SUCCESS | FUNDING |
|----------|---------|-------|-------|---------|---------|
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ANALYSIS METHOD (To be used by Subcommittee)

1. Sum and rank research according to:
 - a) Urgency
 - b) Range of Effect
 - c) Worth
 - d) Success
 - e) Funding
2. Sum and rank weighted indicator I_i
 $I_i = \sum (\text{urgency}) \times (\text{range}) \times (\text{worth}) \times (\text{success})$
for $i = 1, 2, \dots, 26 \dots n$
3. Check correlation between I_i and $(\text{funding})_i$

7.2 Draft Copy of Suggested Warrants for Entrance Ramp Control Signals

1. Definition and Application

Freeway entrance ramp control signals (ramp metering signals) are traffic signals used to control the rate at which vehicles are permitted to enter the through lanes of a freeway from an entrance ramp.

Freeway entrance ramp signals are used to reduce congestion on a freeway caused by traffic demands in excess of the capacity of the freeway, or to reduce accident potential or localized congestion attributable to inadequate ramp merging area.

Ramp metering signals may be used on a permanent basis for the reduction or prevention of recurring congestion, where the freeway is constructed to ultimate width and to present design standards, or as a temporary measure pending widening or other freeway improvements. Entrance ramp control is not a desirable alternative to construction of adequate ramp merging areas; consequently, ramp metering signals may be considered as an interim measure where used because of substandard geometric features. Ramp metering may be useful in reducing short-period congestion on freeways caused by peak loads of recreational or special-event traffic.

Ramp metering signals have been used successfully to reduce peak-period congestion and delay on a freeway where suitable alternate routes are available and where the ramp configuration permits storage of waiting vehicles without restricting traffic flow on the connecting surface arterials. In such applications, a portion of the normal on-ramp traffic is diverted to other routes; hence, suitable alternate routes must be available. Preferably, the alternate routes should have excess capacity.

Ramp configuration and placement of the ramp control signals should permit storage of waiting traffic without adverse effect upon adjoining surface arterials. Ramp widening or reconstruction may be necessary.

Experience with entrance ramp control indicates that ramp metering can reduce freeway congestion and delay appreciably. Where the preceding conditions are met, overall delay in the freeway corridor will be reduced. That is, the reduction in delay to freeway users may exceed the added delay to ramp traffic, diverted traffic and normal traffic on the diversion routes.

It has been found that ramp control to alleviate peak-period congestion is generally accompanied by a reduction in accident experience during the control periods.

There has been limited experience with ramp metering to reduce localized congestion due to inadequate ramp merging area. Good results have been reported where used on high-volume ramps with inadequate acceleration lanes. In these instances, the decrease in freeway congestion has been accompanied by a marked reduction in peak-period accident rate.

At some locations, entrance ramp control has also permitted priority assignment of access to special vehicles, such as buses.

2. Warrants

There has not as yet been sufficient experience with freeway entrance ramp control signals to permit developing numerical warrants applicable to the wide variety of conditions found in practice. However, general guidelines have been identified for successful application of ramp metering control.

The installation of ramp metering signals should be considered only if the expected reduction in delay to freeway traffic exceeds the expected delay to ramp users and added travel time for diverted traffic and traffic on the alternate surface routes. Under these circumstances, preferential access may be accommodated.

If there is adequate storage space for the vehicles which will be delayed and if there are suitable alternate surface routes available having capacity for traffic diverted from the freeway ramps, then freeway entrance ramp metering signals may be warranted when:

- a. There is recurring congestion on the freeway due to traffic demand in excess of the capacity; or
- b. there is recurring congestion or a severe accident hazard at the freeway entrance because of inadequate ramp merging area.

Freeway entrance ramp control signals may be warranted to reduce sporadic congestion on isolated sections of freeways caused by short-period peak traffic loads from special events or from severe peak loads of recreational traffic.

The installation of ramp metering signals should be preceded by an engineering analysis of the physical and traffic conditions on the highway facilities likely to be affected. The study should include the ramps and ramp connections, and the surface streets which would carry diverted traffic, as well as the freeway section concerned. Types of traffic data which should be obtained include but is not limited to traffic volumes, traffic accidents, travel time and delay on the freeway and on alternate surface routes.

Capacities should be determined, and the locations and causes of capacity restrictions should be identified. From these and other data, estimates can be made of desirable metering rates, probable reductions in delay to freeway traffic, and likely increases in delay to traffic on ramps and surface streets.

Before installing ramp control signals, consideration should be given to alternate means of increasing the capacity or improving the operating characteristics of the freeway.

7.3 Addendum: Airport Access Problem Statements

The subcommittee recognizes that airport accessibility is directly related to the total transportation system problem of the urban area. Although in some areas public transit services are available, in general the development of adequate mass transit facilities in meeting the travel requirements of airport-oriented ground travel has not kept pace with the steady growth of air traffic. The private automobile is the dominant mode of transportation while the freeway system has become a prominent means for airport trips.

If the highway network system is deficient, improvements in a particular route may not solve the total problem of getting to the airport. Although interim solutions may be available to help alleviate one facet of the problem, the ultimate solution will require an effective planning process for coordinating airport location, design, operation, etc., with all elements of the urban system.

Research Project Title:

Staggered Work Hours Along Airport Access Facilities

General Problem Area: Operations

Research Problem Statement:

Available land adjacent to the airport has become very attractive locations for industrial and commercial developments. Most of these developments are large employment centers which at times generate traffic volumes equal to or greater than that of the airport itself.

In some urban areas these developments occur without the benefit of additional highway facilities. Consequently, both airport traffic and that generated by the many industrial parks, offices, hotels, restaurants, etc., must be carried by the airport access facility. Since the peak demand characteristics normally coincide, severe congestion results.

Staggered work hours of the organizations along the access facility may reduce the effects of the concentration of trips in time.

Objectives:

1. Make field studies to obtain complete quantitative data of travel patterns contributing to traffic congestion on airport access facilities.
2. Determine levels of traffic operation necessary to achieve desired levels of service. The required volume reduction comprises the goals to be achieved from staggering work hours.
3. Consult with organizations located along the access facility regarding objectives and feasibility of staggered work hours. To obtain the required effect it would be desirable, especially in the initial stages of implementation, to work with a minimum number of the largest employers. Exploratory discussions with selected firms should include attitude surveys of employees to determine preferences to advancing or retarding starting and quitting times.
4. Implement staggered work hour strategies.
5. Perform field studies to evaluate full effects of implementation. These would include the effects of volume changes throughout the affected travel area as well as behavioral and attitudinal surveys of employees and employers concerning the effects of changed hours on their business and private lives.
6. Document results and make recommendations for further implementation.

Research Project Title:

Airport Related Directional Information Requirements

General Problem Area: Signing

Research Problem Statement:

With the steady growth of air traffic, and the general lack of parallel development of adequate mass transit facilities to airports, airports are becoming an ever more important destination for trips on metropolitan freeway systems. Airport users generally fall into the stranger, or local stranger, classification insofar as knowledge of the proper route is concerned. Peak hours of airport traffic coincide generally with rush hours on the freeway system thus adding great situational pressures to the demands of the route finding task. Airport users are generally under some form of time pressure to reach their destination.

Research is needed that will define, quantitatively as well as qualitatively, the problem of proper directional guidance from and to airports and develop feasible and implementable solutions thereto.

Objectives:

1. Review the State of the Art and current practices for giving airport related directional guidance information.
2. Determine type of locations, on the freeway system as well as at ramp terminals, at which airport related guidance information is needed.
3. Determine types of destination (e.g. downtown, civic center) for which guidance information is required for trips originating at the airport.
4. Develop potential solutions to the problem.
5. Test most promising solutions. Laboratory, other simulated trip conditions, or actual test signing installation methods may be used.
6. Recommend a solution to the problem. The recommendation should be sufficiently detailed, as to form and location, so that it can be submitted, via the NJCUTCD, to the Federal Highway Administrator for inclusion in the pertinent Manuals.
7. Investigate and define the problem of alternate routes, with the alternate route to the airport depending on the final destination within the airport or on traffic or other conditions, and develop a research program to find a solution.

Note: The research effort should address itself, and be applicable, to metropolitan areas (e.g. New York, Chicago) with multiple airports as well as those with only a single airport. Only airports with an appreciable number of scheduled flights should be considered.

The installation of ramp metering signals should be considered only if the expected reduction in delay to freeway traffic exceeds the expected delay to ramp users and added travel time for diverted traffic and traffic on the alternate surface routes. Under these circumstances, preferential access may be accommodated.

If there is adequate storage space for the vehicles which will be delayed and if there are suitable alternate surface routes available having capacity for traffic diverted from the freeway ramps, then freeway entrance ramp metering signals may be warranted when:

- a. There is recurring congestion on the freeway due to traffic demand in excess of the capacity; or
- b. there is recurring congestion or a severe accident hazard at the freeway entrance because of inadequate ramp merging area.

Freeway entrance ramp control signals may be warranted to reduce sporadic congestion on isolated sections of freeways caused by short-period peak traffic loads from special events or from severe peak loads of recreational traffic.

The installation of ramp metering signals should be preceded by an engineering analysis of the physical and traffic conditions on the highway facilities likely to be affected. The study should include the ramps and ramp connections, and the surface streets which would carry diverted traffic, as well as the freeway section concerned. Types of traffic data which should be obtained include but is not limited to traffic volumes, traffic accidents, travel time and delay on the freeway and on alternate surface routes.

Capacities should be determined, and the locations and causes of capacity restrictions should be identified. From these and other data, estimates can be made of desirable metering rates, probable reductions in delay to freeway traffic, and likely increases in delay to traffic on ramps and surface streets.

Before installing ramp control signals, consideration should be given to alternate means of increasing the capacity or improving the operating characteristics of the freeway.

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The subcommittee recognizes that airport accessibility is directly related to the total transportation system problem of the urban area. Although in some areas public transit services are available, in general the development of adequate mass transit facilities in meeting the travel requirements of airport-oriented ground travel has not kept pace with the steady growth of air traffic. The private automobile is the dominant mode of transportation while the freeway system has become a prominent means for airport trips.

If the highway network system is deficient, improvements in a particular route may not solve the total problem of getting to the airport. Although interim solutions may be available to help alleviate one facet of the problem, the ultimate solution will require an effective planning process for coordinating airport location, design, operation, etc., with all elements of the urban system.

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Staggered Work Hours Along Airport Access Facilities

General Problem Area: Operations

Research Problem Statement:

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Staggered work hours of the organizations along the access facility may reduce the effects of the concentration of trips in time.

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1. Make field studies to obtain complete quantitative data of travel patterns contributing to traffic congestion on airport access facilities.
2. Determine levels of traffic operation necessary to achieve desired levels of service. The required volume reduction comprises the goals to be achieved from staggering work hours.
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Research Project Title:

Airport Related Directional Information Requirements

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Research Problem Statement:

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Research is needed that will define, quantitatively as well as qualitatively, the problem of proper directional guidance from and to airports and develop feasible and implementable solutions thereto.

Objectives:

1. Review the State of the Art and current practices for giving airport related directional guidance information.
2. Determine type of locations, on the freeway system as well as at ramp terminals, at which airport related guidance information is needed.
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7. Investigate and define the problem of alternate routes, with the alternate route to the airport depending on the final destination within the airport or on traffic or other conditions, and develop a research program to find a solution.

Note: The research effort should address itself, and be applicable, to metropolitan areas (e.g. New York, Chicago) with multiple airports as well as those with only a single airport. Only airports with an appreciable number of scheduled flights should be considered.

Research Project Title:

Interface Between Freeways and Airport Service Roads

General Problem Area: Design; Operations

Research Problem Statement:

Although many airports have good service roads within the airport, the connections between these service roads and the nearest freeway intersection are often inadequate. Traffic congestion at many airports frequently is affected by congested on-and-off ramps and excessive weaving movements between these ramps and the signalized intersection. These problems are indicative of the inadequacy of connections between the freeway and the airport service roads. There is a need for establishing design guidelines for the interface between the freeway and airport service roads.

Objectives:

1. Review and summarize present design practices for freeway to airport service road interface.
2. Evaluate alternative methods of accommodating traffic from the freeway to the airport service roads and subsequently back to the freeway. The evaluation should include the application of direct connecting ramps.
3. Develop recommended guidelines for the design of the interface between the freeway and airport service roads so as to achieve an optimal level of performance.