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RESEARCH PROBLEM STATEMENTS

mode

1 highway transportation

subject areas

51 transportation safety
52 human factors
54 operations and traffic control
55 traffic flow, capacity, and measurements

TRAFFIC CONTROL DEVICES COMMITTEE (A3A02)
as of January 31, 1983

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OPERATION AND MAINTENANCE OF TRANSPORTATION FACILITIES

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FOREWORD

The following procedure was used by the Subcommittee on Research Needs in assembling these research problem statements. First, at the time of its appointment, the Subcommittee received seven problem statements previously completed by committee member G. F. King. Additional topics were solicited from committee members and affiliates.

The Subcommittee compiled a list of topics thus generated and distributed it to committee members for rating. Instructions were given to consider the following: perceived need, researchability, and relevance to the scope of interest of the Committee on Traffic Control Devices. The topics were to be rated by their level of importance as: high, medium, low, or omit. Members were also requested to support their ratings by comments.

The results of this survey were summarized by the Subcommittee in a new list. Topics were grouped by subject matter. The ratings, a summary of the comments, and a ranking based on the summary of ratings for each topic were presented. This information was distributed to the whole committee with instructions to study the results of the first survey and to rate the topics again.

The results of this second survey were used to select a final list of topics. Several research problem statements were developed then by individuals, mostly members of the committee, who had expressed interest in one or more topics. The remaining topics on the list were assigned to Subcommittee members who completed the problem statements.

The Subcommittee chairman compiled and edited these research problem statements and presented the report to the Committee at the January, 1983 Annual Meeting. The Committee recommended that the research problem statements be submitted to Group 3 for publication, and that the attention of both FHWA and AASHTO should be called to them.

Members of the Subcommittee on Research Needs were:

Zoltan A. Nemeth, Chairman
Professor of Civil Engineering
Ohio State University
Columbus, Ohio

Paul H. Fowler
C. Arthur Geurts
Hugh W. McGee
Peter S. Parsonson
Harold C. Rhudy
Ronald E. Stemmler
James I. Taylor
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PROBLEM NO. 1

1. TITLE - EFFECTS OF BUDGETARY LIMITATIONS ON TRAFFIC CONTROL STRATEGIES

2. PROBLEM - Although budgetary limits are always a factor in traffic control strategies, a number of agencies have experienced severe cutbacks in funds in recent years and now operate under even more austere conditions. As agencies find they can not even maintain "standard practices," selective cuts must be made in installation and maintenance of traffic control devices -- and in related studies of traffic operations (e.g., retiming traffic signals). Guidance is needed in selecting the cuts to be made so that resulting damages will be minimized.

3. OBJECTIVE - The object of this study is to formulate guidelines for controlling traffic where severe budgetary limitations exist. Alternative strategies will be reassessed with a higher regard for the costs incurred by the agency responsible for operating the street or highway system. Relative values of accident reductions, vehicle delays, motorist inconvenience, ease in finding destinations, vehicle-pedestrian conflicts, etc. are to be established -- with attention to the costs to the users, society in general, and the operating agency in particular. As many more projects will have a positive net benefit than can possibly be implemented, an acceptable and operable philosophical rationale for giving extra weight to the agencies costs is required. Benefits will be in terms of minimizing damages from the necessary cuts in traffic control devices.

4. KEY WORDS - Benefits; costs; economic analysis; traffic control devices; value judgments.

5. RELATED WORK - All of the work dealing with value judgments of benefits and indirect costs associated with traffic control devices is relevant. Transportation System Management (TSM) work is also relevant, as much of this research deals with trade-offs on value judgments (even though not specifically for traffic control devices in many cases). NHTSA and NSC work on appropriate values for accident losses is particularly pertinent.

6. URGENCY/PRIORITY - This project has a high priority because many highway agencies are faced with sharply reduced budgets for traffic operations, and basic philosophies and value assessments made at this time will influence agency policies and implementation actions for a considerable time in the future.

7. COST - $250,000. ($100,000 to establish philosophical basis; $150,000 to develop application guidelines for specific control devices/ situations.)

8. IMPLEMENTATION - The findings will be useful in guiding highway officials in assessing the relative merits of traffic operations strategies so that they can minimize the negative impact of reductions in their budgets. Implementation will consist of choosing which things not to do -- i.e., those things that can be given up with least resultant damage. User Manuals and short courses may be required.

9. EFFECTIVENESS - Losses to society due to restricted activities of highway agencies will be minimized if guidelines can be formulated effectively so that highway officials will follow them. Truly valuable programs and traffic control devices will not be eliminated in the attempt to bring budgets to new, lower levels. Measures of effectiveness will still be accident losses, vehicle delay, etc., but emphasis will be on measuring the negative impacts of the new policies (objective being a minimal change), rather than on measuring gains.

PROBLEM NO. 2

1. TITLE - SIGNING FOR HIGH SPEED SIGNALIZED APPROACHES

2. PROBLEM - A high accident potential exists in areas where signalization is introduced on high speed (greater than 45 mph), four-lane rural type expressways.

3. OBJECTIVE - Several agencies have used different types of signs and associated flashers to better advise the driver of the presence of the signal and the fact that it is about to turn red. However, not all signals on high speed roads need advance warning devices. Some method of evaluation of the need for advance warning is needed.

4. KEY WORD - Advance Signs for Signalized Approaches

5. RELATED WORK - Several concepts have been developed by California and Georgia Tech but addressed the issue of safety through different concepts of detector placement. This has reduced some of the problems; however, no work has been done to evaluate the need for or the potential benefits to be derived for advance warning under various conditions.

6. URGENCY - Since the number of signals is increasing on high speed multi-lane roadways and the accident problem is increasing, it is suggested that the project be done quickly in order to provide maximum safety at these intersections.

7. COST - $150,000

8. IMPLEMENTATION - Agencies could identify critical locations where advance warning should be implemented to improve highway safety.

9. EFFECTIVENESS - Accident reduction.

PROBLEM NO. 3

1. TITLE - TRAFFIC CONTROL DEVICES MAINTENANCE AND SAFETY

2. PROBLEM - Two of the basic requirements of a traffic control device, as outlined in the Manual on Uniform Traffic Control Devices, are; command attention and command respect. Both intimate the requirement for adequate maintenance. Maintenance can be performed for esthetic purposes or for the pragmatic goal of fulfilling motorist needs. The difference is not at present clearly defined.

   With the advent of increased tort liability claims against implementers of the Manual it is

incumbent that the distinction be made by scientific study rather than various and sundry litigations.

3. OBJECTIVE - The objectives of this research would be to provide substantive relationship between maintenance and the safety effectiveness of various traffic control devices. Because of the extensive number of possibilities, this statement is intended to serve as an open ended initiation.

4. KEY WORDS - Too numerous to list, however, specific names of each traffic control device and elements thereof, i.e., Reflective sheeting (signs), etc.

5. RELATED WORK - Not known.

6. URGENCY - With the increase of liability claims, verifiable data of varying performance levels of traffic control devices of varying maintenance quality will be of inestimable value in the defense of tort claims.

7. COST - Open ended. Dependent upon number of devices evaluated.

8. IMPLEMENTATION - Scientific production of evidence in defense of court claims is vastly preferred to the vastly varying opinions of the "experts." The findings will significantly contribute to the establishment of quality control of traffic control device maintenance.

9. EFFECTIVENESS - The primary benefit of this research is in preparation of objectively, verifiable data for the defense of tort claim cases. Secondary benefits are expected in the form of economical management of traffic control devices maintenance management.

PROBLEM NO. 4

1. TITLE - MANUAL FOR INSTALLATION AND OPERATION OF UNIFORM TRAFFIC CONTROL DEVICES (MIOUTDC)

2. PROBLEM - Transportation departments and agencies are notoriously labor-intensive, yet most traffic control device research investigations are devoted either to improvements in existing materials and equipment or to the design of new materials and equipment. The materials and equipment component of the total unit cost general falls in the range of one-fifth to one-third of total unit cost. We in transportation research, then, are faced with a situation wherein 99% of the research is directed towards controlling the effectiveness of, say, 25% of the expenditures.

   Admittedly the effectiveness of traffic control devices is directly related to the materials and equipment utilized in their implementation. But the cost of implementation is almost always more intensive in the labor component than in any other component. Therefore the greatest opportunity for cost/benefit efficiency lies in this component.

   The less time required to complete a given task the less costly the employee labor component will be. Sound techniques of Industrial Engineering and Systems Analysis are available for addressing this question. Success has been achieved in the industrial sector, in the military sector, in the health care sector, and in the support services sector. It is time to address the transportation sector. Attention should be given to the engineering of work methods for installing and operating traffic control devices in order to minimize the allocation of resources required for the labor component. Success with this problem will free those resources for other uses.

3. OBJECTIVE - The purpose of the proposed research is to extend the scope of the Manual on Uniform Traffic Control Devices to include the installation and operation of those devices with specific attention given to the labor component of the total unit cost. This purpose will be met through the accomplishment of several primary research objectives. Because of its scope, it will be necessary to accomplish the research in several sequential and/or simultaneous phases.

   It is expected that research towards developing a Manual for Installation and Operation of Uniform Traffic Control Devices will result in the establishing of standard operating procedures and schedules. Transportation agencies may use this Manual for Work Planning, Manpower Scheduling, Job Assignments, and Project Evaluation. Its use will help to assure that efficient techniques are employed in installing and operating roadway signs, signal systems, pavement markings, and roadway lighting. The cost of such research will be returned many times over in savings through the application of efficient labor methods and procedures.

   There are several possible ways to divide the research into phases. The proposing agencies can be expected to suggest a variety of plans. Generally, a method or procedure that considers the following subject areas should be required:

   Phase I: Project Management: Feasibility analysis, project planning and scheduling

   Phase II: Installation and Operation of Signs: Methods, Procedures, and Standards

   Phase III: Installation and Operation of Signals: Methods, Procedures, and Standards

   Phase IV: Installation and Operation of Pavement Markings: Methods, Procedures, and Standards

   Phase V: Installation and Operation of Highway Lighting: Methods, Procedures, and Standards

   Phase VI: Technical Coordination and Reporting/Publishing: Compilations, Presentations, Recommendations, and Adoptions

   Individual research tasks and objectives within each phase must also be defined. It may be reasonable to fund Phase I with the expectation that output from Phase I will serve as a plan for the successive phases.

4. KEY WORDS - Traffic Control Devices, Work Methods, Labor Costs, Industrial Engineering, Operating Costs, Installation Costs, Labor Efficiency, Productivity, Cost Control, Methods Improvement, Work Planning, Job Analysis, Project Management, Scheduling.

5. RELATED WORK - None known.

6. URGENCY/PRIORITY - The subcommittee on research problem statements has ranked this statement as number 8 out of the 35 considered, certainly a strong indication of urgency and priority. There is strong consensus that it is time to consider the labor component in the total unit cost analysis for traffic engineering.

7. COST - Development of a manual for Installation and Operation of Uniform Traffic Control Devices will require several years and possibly millions of dollars. Returns in benefits over the years should repay this investment tenfold. Funding of the first phase, feasibility analysis and project planning, can be expected to cost between $250,000 and $500,000.

8. IMPLEMENTATION - Adoption of an MIOUTCD by several state and local transportation agencies can almost be assured. Installation and operation of a typical unique traffic control device today is done in a myriad of ways, usually depending on the individual actually doing each subtask. A uniform installation and operation manual with standard practices and procedures will be eagerly awaited.

9. EFFECTIVENESS - Reduced installation and operation costs can easily run into many millions of dollars per year due to standardized work methods. In these times of limited operating budgets, this problem area would be a most welcome research endeavor.

PROBLEM NO. 5

1. TITLE - TRAFFIC SIGNAL WARRANTS FOR HIGH SPEED, MULTILANE HIGHWAYS

2. PROBLEM - The MUTCD gives one set of warrants for the installation of traffic signals without regard to location (e.g. urban vs. rural) or speed. In many cases, signals installed on high speed, multilaned highways cause severe rear-end and even angle accident problems, more so than signals installed on low speed, two laned highways.

   Isolated signalized intersections on high speed highways are unexpected, especially when separated by long distances and, therefore, can be particularly hazardous.

3. OBJECTIVE - The objective should be to determine the need for and, if appropriate, develop separate warrants for traffic signal control of high speed, multilaned highways. Both a volume warrant and accident warrant should be considered. Warrant should be developed that could be used by engineers with traffic engineering responsibilities in local, county and state jurisdictions.

4. KEY WORDS - Traffic Signals, Warrant, High Speed, Accidents, Delay, Gaps.

5. RELATED WORK - The Federal Highway Administration has a research study underway which is examining the feasibility of establishing traffic signal warrants on the basis of available gaps in traffic. This method would be particularly suited to the high speed, multilane intersection.

6. URGENCY/PRIORITY - The project has been rated as a high priority by the committee on Traffic Control Devices. As a new warrant may produce a safer situation for the motoring public, it should be considered urgent and given high priority.

7. COST - It is estimated to cost $200,000.

8. IMPLEMENTATION - The findings of this research could lead to a warrant for the special situation of traffic signals at high speed multilaned intersection. Such a warrant would be used by local, and state traffic engineers in determining the need for a traffic signal. It could also lead to the development of other techniques to be used at these type of intersections to improve traffic safety and reduce delay.

9. EFFECTIVENESS - The ultimate goal of this study is to improve the safety at high speed, multilane intersections through an improved traffic signal warrant. The impacts on society are reduced accidents and injury as well as reduced travel time and delay.

PROBLEM NO. 6

1. TITLE - MOTORIST RESPONSE TO PROTECTED-PERMISSIVE LEFT TURN SIGNAL

2. PROBLEM - Where a leading left turn arrow and circular green are displayed simultaneously in the same signal face, termination of the left arrow but continuation of the circular green appears to provoke a measurable difference in motorist response between a customary five-section vertical "stack" arrangement and a five-section "cluster" arrangement (two arrows on the left, two circular indications on the right, and a single circular red centered above).

   Both arrangements are appearing in the Los Angeles metropolitan area. Counter allegations have surfaced that appearance of the yellow arrow in the "stack" arrangement produces panic stops by thru traffic, and that the "cluster" arrangement results in lost capacity because left turning vehicles fail to turn permissively after the arrows are terminated. The latter supposition may be based on a misconception that the circular green on the right applies only to thru traffic. Human factors research is needed to determine a uniform standard display.

3. OBJECTIVES - The objectives of this research are to measure difference in motorist response to "stack" and "cluster" signal face arrangements and to apply the results to the development of a uniform standard display.

   To meet the objectives, one or more of the following may be undertaken;

   (1) "Before and After" studies of motorist

actions at signalized intersections where left turn phasing is provided. One or more intersections of each of the following types could be studied:

"Before"	"After"
Stack arrangement	Cluster arrangement
Cluster arrangement	Stack arrangement

(2) Long-term observations of intersections where left turn phasing is introduced by both "stack" and "cluster" arrangements. Indications of panic stops or lost capacity should be recorded.

This type of study may show whether or not motorists learn to interpret the signal indications correctly over time. Both peak and off-peak observations should be made.

(3) A survey of police officers' and traffic engineers' observations and/or experience with the use of "stack" and "cluster" signal face arrangements. Remarks should be solicited from those professionals who fully understand traffic engineering concepts but not from the driving public. Observation of motorists will produce the most useful record of their responses.

4. KEY WORDS - Traffic Operations, Traffic Signals, Lens Arrangements in Signal Faces, Protected-Permissive Left Turn Signals

5. RELATED WORK - We acknowledge the following works:

(1) "Meaning and Application of Color and Arrow Indications for Traffic Signals" by R. W. Plummer and L. King, Record 445, Highway Research Board, 1973.

(2) "A Study of Clearance Intervals, Flashing Operation, and Left Turn Phasing of Traffic Signals" by B. Benioff and T. Rorabaugh, FHWA-RD-78-46, Federal Highway Administration, May 1980.

(3) "An Evaluation of Permissive Left-Turn Phasing" by K. R. Agent, Kentucky Bureau of Highways, April 1979.

6. PRIORITY - This problem ranked 10th of 35 suggested research problems generated by the committee.

7. COST - This work is suitable for university research. Costs should be in the $100,000 range.

8. IMPLEMENTATION - The findings of this proposed research may be used to develop a uniform national standard for the arrangement of signal indications when five-section signal heads are used for left turn phasing. Previous reports on protected-permissive left turn phasing have recognized the need for this standard.

9. EFFECTIVENESS - If a uniform national standard as described above is adopted, its effectiveness will be dependent on the extent to which the prescribed arrangement is used. If differences of motorist responses to "stack" and "cluster" arrangements are found, then the use of one arrangement over the other will lessen motorists' confusion and reduce purported panic stops or lost capacity, depending on the standard arrangement. Once a standard has been adopted, traffic officials will have basis for motorists' education on the correct behavior at protected-permissive left turn signals.

PROBLEM NO. 7

1. TITLE - WARRANT CONDITIONS FOR FLASHING BEACONS

2. PROBLEM - Current MUTCD conditions for installation of an intersection control beacon are limited to "...in order to provide adequate visibility..." and "...where traffic or physical conditions do not justify conventional traffic signals but where high accident rates indicate a special hazard." As a result of the ambiguity of anticipated benefits of an intersection control beacon, tradition has developed in many parts of the country to provide flashing beacons as an alternate to traffic signal installation.

   Since flashing beacons represent a substantial investment in installation and maintenance, more precise data should be available to the traffic engineer to evaluate the impact of installation. The development of safety and/or efficiency warrants would satisfy this need.

3. OBJECTIVES - The goal of research in this area would be to establish the salient parameters for safety and their benefit in warrant format for intersection control beacons. Hazard identification, speed limit, and stop sign beacons should be included as ancillary elements.

4. KEY WORDS - Flashing Beacons, Flashers, and Flasher Safety.

5. CURRENT ACTIVITIES - NCHRP Project 3-20 "Traffic Signal Warrants" provides a limited observation and foundation for extension. The statement, "The installation of flashing beacons to supplement stop sign control appears generally to produce a favorable effect on accident patterns," serves only to suggest that definitive extension and application formating are desirable. Other - none.

6. URGENCY - Since flashing beacons serve as supplements to existing devices, it is not anticipated that energy savings would be a significant result of findings. Accident reduction and/or severity decrease would be the result of identified parameters and defined warrants delineating safety benefits.

7. COST - a. $100,000 if supported with State's data

   b. $500,000 if field data to be gathered

8. IMPLEMENTATION - Determination of benefits provides the final element for economical sound judgment for or against installation of intersection flashers.

9. EFFECTIVENESS - Should remove the determination of installation from subjective to more objective based upon nationwide findings. Also should serve as deterrent to pacification use of intersection flashers.

PROBLEM NO. 8

1. TITLE - RIGHT-TURN-ON-RED (RTOR) SIGNAL EXPERIENCE

2. PROBLEM - The almost universal nationwide legalization, adoption and implementation over the last few years of RTOR at signalized intersections, and left-turn-on-red (LTOR) at locations where one-way patterns permit such a regulation, represents one of the most far-reaching changes in traffic control in recent history. This change, advocated on the basis of anticipated improvements in traffic operations, fuel consumption and vehicular emissions, was justified on the basis of apparently successful implementation in a number of Western states and on the basis of a generally favorable feasibility study sponsored by FHWA.

   One recent evaluation of RTOR experience indicates that perhaps this traffic control technique is not as safe as originally estimated. Also, current guidelines for prohibiting RTOR are too vague and have led to varying levels of implementation. These statements are especially true in regard to pedestrians. How RTOR affects pedestrian movements and accidents has not yet been well defined. Consequently, the current guideline does not give the practicing engineer enough guidance on when and where RTOR should be prohibited because of pedestrians.

   With RTOR and LTOR now firmly established and with a large body of operational and accident data accumulating constantly, the opportunities for, and need of, a major evaluation of these regulations now exists.

3. OBJECTIVES - This evaluation should address such issues as:

   1) Whether the claimed benefits and adverse consequences of RTOR and LTOR have, in fact, materialized.

   2) Whether any unanticipated consequences, adverse or beneficial, can be identified and quantified.

   3) Whether current guidelines for prohibiting RTOR and LTOR are adequate, and if not, what revisions are necessary.

   Such an evaluation study would confirm whether or not the current national policy on RTOR and LTOR is appropriate and provide practicing engineers with better data and guidelines to determine at which intersections it should be prohibited.

4. KEY WORDS - RTOR, LTOR, Accidents, Pedestrians, Fuel Delay, Impacts, Guidelines

5. RELATED WORK - Currently the NHTSA is sponsoring a pedestrian safety study being conducted by Dunlap and Associates. One of these tasks was to evaluate the impact of RTOR on pedestrian safety. Results of this study are not yet available.

   Recently the Insurance Institute for Highway Safety conducted its own evaluation of the safety impact of RTOR and concluded that it has caused more accidents than was estimated by the 1976 FHWA study.

6. URGENCY/PRIORITY - The urgency and need for such an evaluation is based on the continued interest and discussion of the merits and disbenefits of RTOR by practicing engineers. The Institute of Transportation Engineers in a position adopted by its Board of Direction states that a "national set of guidelines needs to be developed for use by agencies in determining those intersections where RTOR should be prohibited."

7. COST - Estimated at $300,000.

8. IMPLEMENTATION - The findings of the research would be used:

   1) to support or revise the current RTOR regulations

   2) to provide better implementation guidelines.

9. EFFECTIVENESS - RTOR/LTOR has benefits in the form of reduced fuel usage, less delay and improved traffic flow which can be offset by increase in accidents and injury with motorists and pedestrians. These are all societal costs which impact all users of the highway system.

PROBLEM NO. 9

1. TITLE - BATTERY-OPERATED SIGNAL BACK-UP SYSTEMS

2. PROBLEM - Traffic signal systems are dependent upon electric energy and in the event of power failure become inoperative. What is required is an economically feasible back-up system, possibly solar-powered and/or battery-operated, which will provide traffic signal indications under emergency conditions.

   Traffic safety hazards arise when signalized intersections fail. Power outages, either due to electrical storms, power grid failures, or accidents, are not uncommon. The railroad industry has created battery-operated back-up systems of varying sophistication for use online and at roadway crossings. Their success serves as a model for highway applications. The major problem remaining is that of recharging the batteries quickly and economically. Additional research is required.

3. OBJECTIVE - The purpose of the proposed research project is to determine the practicality and economic feasibility of providing traffic signal redundancy through a back-up, battery-powered standby system. This purpose will be met through accomplishing the following primary objectives.

   1) Ascertain the State-of-the-Art in signal back-up systems for highways, railroads, etc.

   2) Determine the expected costs for designing and specifying a standby redundant system for traffic signal control.

   3) Investigate the nature and likelihood of expected improvements in accident statistics.

   4) Determine the expected improvement in signal availability due to the continuation of electrical power during public utility power outages.

5) Provide a cost/benefit analysis of the feasibility of providing a battery-operated traffic signal back-up system for use during power emergencies.

4. KEY WORDS - Traffic signals, redundancy, back-up systems, fail-safe systems, power failure, battery-operated signals, solar powered signals, emergency signalization.

5. RELATED WORK - None known, but indications that Frisco Railroad has done some work on emergency signalization.

6. URGENCY/PRIORITY - The subcommittee on research problem statements has ranked this statement as number 15 out of the 35 considered, i.e., in the top 40%. The relatively short duration of power failures and their infrequent occurrence indicates that this is not a major problem area. But if the back-up system used by the railroad industry can be modified economically then the research would be valuable.

7. COST - An investigation of the existing battery-operated, signal back-up systems used by the railroad industry and a determination of the design and modification costs to provide a similar system for roadway signals should cost between $50,000 and $100,000. If the research determines that a back-up system is feasible, private enterprise can then assume the developmental costs.

8. IMPLEMENTATION - A feasibility study that determines the viability of battery-operated signal back-up systems would be of great importance to signal manufacturers. If those systems are found to be economically desirable, private enterprise will likely begin designing and developing the appropriate hardware, circuitry, and instrumentation.

9. EFFECTIVENESS - Increasing the availability of operating traffic signals during electrical storms provides a marginal improvement to the existing system. The nominal cost of research can be easily underwritten by the cost savings attributable to just a small improvement in accident statistics. Research should show the likelihood of such improvement in accident statistics.

PROBLEM NO. 10

1. TITLE - STOP SIGN VIOLATIONS: HUMAN FACTORS CAUSES AND METHODS TO REDUCE VIOLATIONS

2. PROBLEM - Although increasing sophisticated intersection signal control measures are constantly being introduced, and although yield control has in the past 30 years found a definite useful niche in the arsenal of the traffic engineer, the STOP sign in either two-way or multi-way configuration remains by far the most prevalent means of intersection control and right-of-way assignment.

   Observation, as well as the results of both formal and informal studies, clearly indicates that this type of control is being violated by a considerable proportion of the traffic stream. Complete, as well as partial (rolling stop), disobedience can be noted at almost any STOP sign controlled intersection approach.

   Although this problem has been quantified to some extent, no comprehensive study of the basic reason for this prevalent type of driver behavior has been reported. A clear understanding of the psychological and perceptual human factors leading to STOP sign violations is required. Furthermore, the consequences of this type of behavior, in terms of the safety and operational efficiency of the traffic stream, have not received adequate study.

   Traffic engineers have used a number of methods to try to minimize this type of violation. These methods include, in addition to increased enforcement levels:

   1) Increasing the size of the sign.

   2) Increasing the number of signs displayed for a particular approach.

   3) Use of advance signing possibly supplemented with flashers or other attention-getting devices.

   4) Pavement markings, including both verbal and non-verbal messages, on the stopped approach.

   5) Rumble strips and other kinesthetically active devices.

   However, no rationally based set of decision rules exists which can be used by the traffic engineer to select the most appropriate combination of these measures for a given set of geometric, traffic and environmental factors or for a specific driving population. Such a set of guidelines cannot be developed until the root causes and contributing factors of the stop sign violation problem are clearly understood.

   Research is needed to develop such an understanding and to form the basis for a comprehensive set of guidelines for the application of STOP control. The research should address the two problems of the conditions under which this type of control should be implemented and the method by which it should be implemented. The research should cover all driver and location related factors which may have a bearing on the problem.

3. OBJECTIVE - The primary objectives of the proposed research are as follows:

   1) Define and review the State-of-the-Art of the use of STOP control for intersection approaches. The review should take a broad look at the subject matter and cover such aspects as numerical and qualitative warrants for the installation of STOP signs; design configuration of STOP controlled approaches including auxiliary devices; the relationship of STOP control to other types of intersection control and current standards and practices.

   2) Identify all previous studies of the accident experience on STOP controlled approaches. Assemble and analyze this data base and determine what additional accident studies are required. Plan and implement such studies and analyze the results thereof.

3) Identify all previous studies of traffic operations through STOP controlled intersections including frequency and type of violations and traffic behavior on the uncontrolled approaches. Assemble and analyze this data base and determine what additional operational studies are required. Plan and implement such studies and analyze the results thereof.

4) Perform a comprehensive human factor analysis of the STOP sign violation problem. The study should address such factors as attention, vigilance, risk taking and respect for authority. Attitudinal and behavioral factors should be investigated by analytical, laboratory and field experiment methods.

5) Synthesize the results obtained in 1) through 4) to develop a comprehensive understanding of the STOP sign violation problem.

6) Using the synthesis of 5) develop recommendations for engineering, enforcement and education measures as required to alleviate the STOP sign violation problem.

7) Field test the measures developed under 6) and revise these as indicated by the results of the field tests.

8) Prepare Implementation Package covering guidelines for the implementation of STOP sign control.

9) Prepare recommendations as required for changes in the MANUAL OF UNIFORM TRAFFIC CONTROL DEVICES, the UNIFORM VEHICLE CODE and other pertinent standards and documents.

The research effort throughout should include all commonly encountered combinations of traffic, geometric, topographic and environmental variables and should take differences in driver populations into account.

4. KEY WORDS - Traffic Control Devices; Stop Controls; Human Factors; Violations

5. RELATED WORK - There are a number of studies completed or underway regarding the warrants for stop controls. This proposed research would supplement these other works but would be directed specifically at the human factors questions pertinent to stop sign violations and the effectiveness of traffic operational measures aimed at reducing stop sign violations.

6. URGENCY/PRIORITY - The Traffic Control Devices Committee has ranked this problem statement #16 out of 35.

7. COST - $250,000

8. IMPLEMENTATION - The findings of the proposed research could be used to give traffic engineers better criteria and guidelines for measures that can be used to reduce stop sign violations. The information on what actions are most effective in various situations would be useful in developing revisions to the MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES.

9. EFFECTIVENESS - A better understanding of the human factors involved in stop sign violations will aid in engineering education and enforcement. This in turn should reduce accident experience related to stop sign violations.

PROBLEM NO. 11

1. TITLE - COMPARATIVE WEAR CHARACTERISTICS OF VARIOUS TYPES OF PAVEMENT MARKING MATERIALS

2. PROBLEM - Many types of pavement markings are currently being used throughout the country to mark streets and highways. These include standard traffic paint (with or without pre-mixed glass beads), thermoplastic, chlorinated rubber paints, epoxy paint, and others. Selection of these materials by users has been based largely on initial cost and some experience with various types of markings at certain locations. There have been no scientific laboratory tests that have compared the effective life of each pavement marking material (including the most recently developed types) on each type of pavement surface and under similar conditions of accelerated wear and weathering. The laboratory tests are needed to develop a comparative life index for each of the materials in terms of nighttime retro-reflectivity and daytime brightness, using appropriate light-measuring equipment.

3. OBJECTIVE - The research should develop effective life index criteria that could be used with material prices to aid in selecting the most economical material for given conditions (snowfall, temperatures, pavement type, ADT, lane widths, number of lanes, percent heavy vehicles, curvature, speed, etc.). The benefits of the research center on the provision of scientifically-determined criteria that will be a basis for sound economic decisions on the selection of pavement marking materials.

4. KEY WORDS - Pavement Markings; Wear Characteristics; Effective Life Index; Retro-reflectivity; Brightness

5. RELATED WORK - There is no related work of a similar scale that is currently underway or recently completed.

6. URGENCY/PRIORITY - Pavement marking materials are petrochemical products that have escalated greatly in price while State and local budgets for installing and maintaining pavement markings have been limited by decreasing highway revenues. The Traffic Control Devices Committee has ranked this problem statement #7 and #17 (out of 35) in the first and second rankings, respectively, using the Delphi technique.

7. COST - $300,000

8. IMPLEMENTATION - The results of the research could be implemented by State and local jurisdictions and other users of pavement marking materials as a basis of making sound economic decisions in choosing marking materials that will be most cost-effective for any given set of conditions.

9. EFFECTIVENESS - This research should improve the cost-effectiveness of pavement markings installations, thereby improving the utilization of limited available resources.

PROBLEM NO. 12

1. TITLE - TRAFFIC SIGNAL DESIGN CONFIGURATION FOR LEFT TURN CONTROL

2. PROBLEM - In recent years, traffic engineers have increasingly come to realize that left turns at signalized intersections represent one of the major obstacles to achieving smooth, progressive traffic flow, safe traffic operations and the maximization of capacity. A number of different methods of separating left turning traffic from competing traffic streams have been advocated and tried. This separation can be achieved by spatial (channelization) or temporal (signal phasing) methods and often by a combination of the two. Current research projects are addressing the problems of determining the best left turn treatment to use, for a given set of conditions, including the possibility of banning or relocating the turning movement.

   When signal phasing is used as the method of left turn control, either by itself or in combination with channelization, the motorist must be informed about:

   1) the times during which the left turn movement can legally be made

   2) whether this movement will be opposed (permissive) or unopposed (protected) by a conflicting traffic stream

   This information is transmitted to the driver by traffic signal indications using arrow and/or circular lenses. These signals indications may depend on position to indicate their purpose or they may be supplemented by signing. Considerable research has been done on the optimum design of arrows and on drivers' understanding of various combinations of arrow and circular indications.

   Research is needed, however, in a number of different aspects of left turn signalization. This research should cover the three major types of signal control for left turns:

   1) left turn on green arrow only (protected left turn)

   2) left turn on green arrow or on green circular indication (protected or permissive left turn)

   3) left turn or green circular indication only (no special left turn phasing)

   Emphasis should be placed on high speed operations or divided highways with separate left turn lanes. The major aspect to be covered is the location, in all three dimensions, of the primary signal indication for the control of left turning traffic. Other aspects to be considered include the size and intensity requirements of the left turn indication and the use, location and design of required advisory and regulatory signing. The optimum location of the left turn interval within the entire signal sequence should be determined. Finally, the optimum use and design application of programmed visibility signal heads for left turn control needs to be investigated.

3. OBJECTIVE - The purpose of the proposed research project is to investigate improved traffic signal configurations for left turn control to achieve smooth and progressive traffic control, to insure safe traffic operations, and to maximize the capacity usage for left turn traffic volumes. This purpose may be met through the accomplishment of several major research objectives. The primary objectives of the proposed research project are to determine:

   1) The optimum location of the primary signal indication for left turning traffic for each of the three possible methods of controlling such traffic.

   2) The optimum size and intensity of arrow indications used for left turn control. All three possible arrow colors should be considered and attention should be paid to all possible background and ambient lighting conditions.

   3) The appropriate use of programmed visibility signal indications for left turn control indlucing the effect of the use of such indications on the results obtained under the first two objectives.

   NOTE: For the first three objectives, the interaction between all aspects of the left turn indications and the signal configuration provided for through and right turning traffic should be specifically addressed.

   4) The optimum location, within the overall signal cycle, for inserting permissive and/or protected left turn intervals. Both the basic two plans as well as complex, multi-phase cycles should be included. Hardware limitations, as presented by currently available signal control equipment, should be considered but should not be the deciding factor.

   5) The appropriate clearance indication following the left turn interval for each of the sequences considered in 4).

   Both empirical and analytical methods should be used to achieve these objectives. While laboratory type experiment may prove valuable, the final validation of any recommendations emanating from the proposed research must rest on the results of dynamic field studies under "real life" conditions.

   The research effort should address the operational as well as the safety effects of the various alternatives considered. Cost, maintenance and energy consumption aspects should also be considered.

4. KEY WORDS - Traffic Signals, Signal Warrants, Left-Turn Control, Protected Left Turns, Permissive Left Turns, Left Turn Signals, Left Turn Channelizing.

5. RELATED WORK - None known, but it has been reported that FHWA has limited research results available.

6. URGENCY/PRIORITY - The subcommittee on research problem statements has ranked this statement as number 18 out of the thirty-five considered, i.e., half ranked higher and half ranked lower.

Left turn warranting continues to be highly controversial and consensus can be enhanced only through successful research reporting.

7. COST - The combination of empirical and analytical research methodology is both the most expensive and the most likely to be successful. Costs well in excess of $200,000 are possible in multi-phasic research effort. No amount over $400,000 should be considered until preliminary research has been undertaken and reported successfully.

8. IMPLEMENTATION - Because of the controversy surrounding warrants for left-turn phasing, it is unlikely that many research results can be implemented rapidly. However, any significant findings affecting accident statistics would be rapidly disseminated and the database for left turn configuration design will immediately be improved.

9. EFFECTIVENESS - Left turn accident statistics continue to offer some of the greatest opportunities for improvement. The comprehensive and complete research project proposed herein should effectively enhance those accident statistics. No other measure of effectivensss is more important to left-turn configurations.

PROBLEM NO. 13

1. TITLE - DESCRIPTION OF "IDEAL" RxR CROSSINGS

2. PROBLEM - Are there any ideally effective crossings where drivers always respond safely? If so, how do these crossings differ from similar crossings (in appearance, # of lanes, speeds, volumes, etc.)? In other words what are the human factors that are causing differences in driving behavior?

3. OBJECTIVE - To find out if any "ideal" crossing exist where all drivers behave safely? If not, what is the best we can achieve and how can it be described and related to crossing design and protective devices?

4. KEY WORDS - Safety, Driver Behavior, Traffic Control Devices

5. RELATED WORK - Previous studies have skirted around this issue but have not directly set out to determine what is the most we can expect to achieve in the way of driver behavior at crossings. Perhaps previous work has assumed some model of ideal behavior but not actually described it in ways that lend themselves to measurement.

6. URGENCY/PRIORITY - This problem is basic to railroad crossing traffic control. Until it is known what is the upper limit of driver behavior at approaches to crossings, we are just working assumptions and actually allowing the courts to decide what reasonable behavior is, after the accident. If it were known what behavior is maximally expectable then it would be an end point to use in determining reasonable behavior. The costs in terms of court judgments and out of court settlements might be reduceable if we had the basic information about driver behavior at approaches to crossings.

7. COST - This study could be conducted in two phases, namely, development of measuring techniques and data collection at crossings. The initial phase would cost between $100,000 and $250,000 over a period of 2 years or more. The second phase, data collection, would vary from $500,000 to $1,000,000 depending upon the sampling plan and the territory(s) to be covered. At least 2 years of time will be needed.

8. IMPLEMENTATION - Research findings will have direct applicability in law suits and indirect impact on standards for traffic control devices, driver training, law enforcement and traffic engineering.

9. EFFECTIVENESS - The impact on court cases and tendencies toward out of court settlements will be directly knowable by involving appropriate associations of defense attorneys and insurance companies and the Insurance Institute for Highway Safety.

PROBLEM NO. 14

1. TITLE - EVALUATION OF THE SIGNAL OPERATION ANALYSIS PACKAGE (SOAP)

2. PROBLEM STATEMENT - In July of 1979, The Federal Highway Administration, Office of Research and Development, Implementation Division, released an implementation package for the SOAP program package. This Computer Program package was designed to assist the traffic engineer in dealing with a wide range of common problems encountered in the design, evaluation and analysis of operations on arterial street signal systems.

   There is a need to develop a comprehensive evaluation of the program package This evaluation should be based on the experience of the many users in many states, representing different driver populations, geometric standards, and geography, etc.

3. OBJECTIVES - To evaluate the program package to determine its reliability in real world intersection design throughout the country.

4. KEY WORDS - SOAP, Signal, Analysis

5. RELATED WORK - SOAP 82 being tested by Florida DOT. Some work has been done at Ohio State University.

6. URGENCY/PRIORITY - This study should be given a high priority because of the current emphasis on energy conservation and traffic safety.

7. COST - $200,000

8. IMPLEMENTATION - Guidelines should be developed that point out the weak and strong points of the package.

9. EFFECTIVENESS - Encourage the optimized operation of traffic signals thus reducing delay, queue lengths, and travel time.

PROBLEM NO. 15

1. TITLE - USE OF EDUCATIONAL PLAQUES WITH SYMBOL SIGNS

2. PROBLEM - Section 2A-13 of the National Manual on Traffic Control Devices states that new warning or regulatory symbol signs not readily recognizable by the public shall be accompanied by an educational plaque (word message) for a minimum of 3 years after the initial introduction of the symbol. The implication is that approximately a three year learning period is sufficient.

   Several studies indicate that motorists still have a misunderstanding of some symbol signs and that removal of the plaques may lead to driver confusion and contribute to driver error.

3. OBJECTIVE -

   1) Conduct studies to measure motorists' understanding and interpretation of symbol signs

   2) Develop standards for acceptable levels of performance in interpreting various symbol signs.

   3) Determine when educational plaques can be deleted from individual symbol signs.

4. KEY WORDS - Meaning, Interpretation, Signing

5. RELATED WORK - Michigan DOT survey on driver recognition and interpretation of symbol signs. Studies by Michigan State University, AAA Foundation for Traffic Safety, and the Province of Quebec.

6. URGENCY/PRIORITY - This study should be given a high priority since many symbol signs have been in use over three years and apparently there is still uncertainty as to the meaning of them by a significant portion of drivers.

7. COST - $50,000

8. IMPLEMENTATION - Guidelines would be developed giving guidance for removal of educational plaques.

9. EFFECTIVENESS - Transportation agencies would have more confidence that motorists understand individual symbol signs before the "word message" is removed.

PROBLEM NO. 16

1. TITLE - AN IMPROVED WARRANT FOR USE OF STOP AND YIELD CONTROL AT "T" INTERSECTIONS

2. PROBLEM - A recent study conducted by Upchurch (1) demonstrated that there could be extremely large savings in fuel consumption, vehicle operating cost, motorist delay, vehicle emissions, and accident costs if sign controls (Yield, Two-way Stop, and Four-way Stop control) were more efficiently applied at four-legged intersections. In general, current application of these devices was shown to be overly restrictive and to result in inefficient (uneconomical) operation. If these devices were more effectively applied on a nationwide basis, the potential savings to the motorist could be as much as $15 billion per year.

   Due to resource constraints, the recent study was limited to four-legged (cross) intersections. To develop a complete warrant or procedure for selection of sign control type at an intersection, there is a need to expand the previous work to include "T" intersections. "T" intersections have operating characteristics which are much different from four-legged intersections and, hence, the results of the previous study are not directly applicable to "T" intersections. Additional research is needed to determine which sign control types are most economically employed for various intersection conditions.

3. OBJECTIVE - To determine which sign control type (Yield or Stop control) is most economical in terms of fuel, vehicle operating, delay, and accident costs for various intersection conditions (approach volumes, approach speeds, sight distance restrictions) at "T" intersections.

4. KEY WORDS - Traffic Control, Signs, User Costs

5. RELATED WORK - See "PROBLEM" section above.

6. COST - Estimated to be $60,000.

7. IMPLEMENTATION - The research findings would be used to develop objective criteria for the use of Yield and Stop control which would minimize costs to the highway user.

8. EFFECTIVENESS - The research results would be used to develop objective criteria (a warrant) for the use of Yield and Stop control. Previous research suggests that development of improved criteria for "T" intersections could save the U.S. motoring public as much as several billion dollars per year.

   (1) Upchurch, Jonathan E. "Development of an Improved Warrant for the Use of Stop and Yield Control at Four-Legged Intersections". Doctoral dissertation, University of Maryland, April, 1982.

PROBLEM NO. 17

1. TITLE - SCHOOL ZONE AND CROSSING TRAFFIC CONTROL; SAFETY BENEFITS

2. PROBLEM - Part VII, Traffic Controls for School Areas, Manual on Uniform Traffic Control Devices, provides standards for the use of various elements of school zone traffic control without guidance or objective values for selection of alternatives. With the high incidence of Tort Liability claims against users of the manual, the need for definitive guidelines is most apparent. As example; What is the basis of selection of an active school zone sign (flasher) as compared to a passive school zone (when children present).

3. OBJECTIVES - To develop objective selection criteria for installation of traffic control elements within a school zone. To review the effectiveness of each individually and in combination.

4. KEY WORDS - Schools, School Safety, and School Traffic Control

5. RELATED WORK - None

6. URGENCY - The anticipated discovery of safety criteria and basis for selection justifies

early initiation. The additional support for Tort defense further substantiates high priority.

7. COST - Relative based upon extent of inquiry. Range $250,000 - $1,000,000.

8. IMPLEMENTATION - Neglecting political considerations, the sole justification for school area traffic control is safety. Selective safety criteria will provide decision makers with the ability to make sound economical judgments in the selection of appropriate traffic control and will also serve as definitive defense in Tort Liability court cases.

9. EFFECTIVENESS - Study results should serve as basis for accident reduction, life saving and court defense.

PROBLEM NO. 18

1. TITLE - ACCIDENT IMPACTS OF CONVERTING FROM TWO-WAY STOP TO YIELD CONTROL

2. PROBLEM - A recent study conducted by Upchurch (1) demonstrated that there could be extremely large savings in fuel consumption, vehicle operating cost, motorist delay, and vehicle emissions if Yield control were used more extensively. These savings could potentially be in the magnitude of billions of dollars per year, on a nationwide basis, provided that the accident penalty was relatively small. Unfortunately, only two studies have been conducted which compare the accident experience of Stop and Yield control (2,3). The two studies present conflicting results and, hence, are inconclusive. Quantification of the accident relationship between these two control types, combined with the previous research by Upchurch, would allow the development of more definitive criteria for the use of Stop and Yield controls.

3. OBJECTIVE - To determine the accident relationship of Two-Way Stop versus Yield control. The relative accident experience for the two control types should be determined as a function of traffic volumes, approach speed, approach geometry, and sight distance restrictions.

4. KEY WORDS - Traffic Control, Intersection, Safety

5. RELATED WORK - See PROBLEM section, above.

6. COST - Estimated to be $80,000.

7. IMPLEMENTATION - The research findings would be used to develop objective criteria for the use of Yield and Two-way Stop control which would minimize costs to the highway user. Individual traffic engineers would use the study results to evaluate the two control types for possible use at specific locations.

8. EFFECTIVENESS - The research results would be used to develop objective criteria for the use of Yield and Two-way Stop control. Previous research suggests that development of improved criteria could save the U.S. motoring public as much as several billion dollars per year.

(1) Upchurch, Jonathan E., "Development of an Improved Warrant for the Use of Stop and Yield Control at Four-Legged Intersections". Doctoral dissertation, University of Maryland, April, 1982

(2) Kell, James H. THE DEVELOPMENT AND APPLICATION OF YIELD RIGHT-OF-WAY SIGNS, Berkeley, California: University of California, January, 1958.

(3) Leisch, Jack E., Pfefer, Ronald C., Moran, Patrick J. EFFECTS OF CONTROL DEVICES ON TRAFFIC OPERATIONS (NCHRP Report 41). Washington, D.C.: Highway Research Board, 1967.

PROBLEM NO. 19

1. TITLE - DELINEATION IN COMBINATION

2. PROBLEM - While extensive research has been conducted on various delineation devices promulgated by the Manual on Traffic Control Devices (MUTCD), relatively little is known of the benefits of multiple use. Conceivable combinations could extend to four or five devices defining the traveled portion of the roadway. Economic and judicious use of delineation devices requires an objective method of combination selection.

3. OBJECTIVE - The objective of this research would be to establish a range of safety values of various combinations of delineation devices naturally existing in actual practice and artificially created in the existing environment.

4. KEY WORDS - Delineator, Pavement Marker, Delineator, Chevrons, Shoulder Strip, and Night-Time Driving.

5. RELATED WORK - Extensive research exists on each individual component of delineation, but little or none exists for varying combination usage. FHWA has plans to sponsor research on visibility requirements for delineation as related to the complexity of roadway conditions.

6. URGENCY - Research findings should provide a pragmatic and objective basis for extended delineator device installation. Economical prescription and expected safety benefits for varying combinations would expand the information available for decision making.

7. COST -

   1) $200,000 with State provided data

   2) $600,000 with self-contained research

8. IMPLEMENTATION - Findings should provide decision makers with extended information to evaluate the additional safety increment of adding subsequent delineation devices to existing configurations.

9. EFFECTIVENESS - The research findings should lead to improved highway safety through economical expenditure.

PROBLEM NO. 20

1. TITLE - PUBLIC UNDERSTANDING OF NON-VERBAL SYMBOLIZED SIGNS AND SIGNALS

2. PROBLEM - In recent years there is an increasing trend towards the use of symbols and logotypes to replace word messages on certain signs and pedestrian signals. There is also increasing use of arrow markings, color coding, and diagrammatic guides in signing. Many of these non-verbal, graphic displays were adopted from the European or Canadian standards of traffic control devices. Others were uniquely developed by transportation engineering organizations in the United States. There have also been new standardized colors and standardized shapes for signs which are gaining widespread application. Overall, the trend may be characterized as a continuing departure from strict reliance on verbal messages and in increasing use of combination verbal/symbol messages to guide, instruct, and warn both motorists and pedestrians.

   Study and evaluation of combined verbal/symbol messages and strictly symbolized signs and signals is barely underway. Major studies have been reported for only a few of these newer devices: diagrammatic guide signs, use of symbols for pedestrian signals, and use of traffic signal arrow indications. Scattered studies of a few other devices have been reported. It is likely that still others have been studied "in-house" without formal reporting of results. Many of the evaluative results have been published in either Europe or Canada. It remains questionable just how those studies would apply to conditions in the United States.

   There exists no cohesive and integrated body of practical knowledge that a traffic engineer can use to warrant the application and measure the effectiveness of these devices. There is presently no data base available that can be used to determine which of these devices are capable of fulfilling their intended function and which require redesign or replacement. Such a data base should include the optimum conditions of use in terms of traffic volumes, roadway geometries, environmental factors, and driver and pedestrian population variables. The development and compilation of such a data base is needed. Existing information must be collected and coordinated, future data needs must be identified, and new research and development programs to generate the data base must be implemented.

3. OBJECTIVE - The purpose of this Research Problem Statement is to increase the public understanding of Symbolized Signs and Signals to Augment the Verbal Messages presently used. Three major objectives must be met: COLLECTION AND COLLATION OF EXISTING INFORMATION CONCERNING NON-VERBAL MESSAGES, IDENTIFICATION AND DEFINITION OF ADDITIONAL INFORMATION REQUIREMENTS, AND COMPLETION AND REPORTING OF RESEARCH DIRECTED TOWARDS THE IMPLEMENTATION OF NEW NON-VERBAL, SYMBOLIZED SIGNS AND SIGNALS. These objectives should be met through the accomplishment of several task-objectives, including:

   1) Identify, obtain, analyze and synthesize all past research results published or unpublished dealing with the public understanding, effectiveness and conditions of use of traffic control devices with non-verbal messages.

   2) Identify all gaps in the present state-of-the art bearing on these topics.

   3) Develop and implement an empirical testing program designed to generate the information necessary to close the major gaps identified. The program should include surveys and both attitudinal and behavioral studies. Surveys and attitudinal studies should address all major variations of non-verbal messages. Behavioral studies, either field or laboratory, can be limited to selected devices and be used as a check on the validity of the conclusions derived from survey and attitudinal data.

   4) Identify the types and classes of devices with non-verbal messages which require major redesign or replacement and which, with their present design, should not be used or used only under limited defined conditions. Outline a research and development program designed to arrive at the required revised design of these devices.

4. KEY WORDS - Diagrammatics, Signing, Pedestrian Signals, Traffic Control Devices, Graphic Displays, Nonverbal Messages

5. RELATED WORK - Not known, but it has been reported that AAA and FHWA have completed some studies.

6. URGENCY/PRIORITY - The subcommittee on research problem statements has ranked this statement as number 27 out of the 35 considered, i.e., three out of four research problem statements ranked higher.

7. COST - An initial feasibility study should cost no more than $30,000. A complete study dedicated to accomplishing all tasks and objectives can be expected to cost in excess of $100,000 but should not exceed $150,000.

8. IMPLEMENTATION - The results of this research can be reported immediately and benefits begin accurring. Implementation of successful research results should begin within 18 months of the beginning of the research projects. The most effective output of this research would be in the form of warrants for non-verbal messages.

9. EFFECTIVENESS - The effectiveness of this research project is directly related to the effectiveness of non-verbal messages in reducing accident statistics and costs and is inversely related to the length of time it takes the public to learn and accept new non-verbal, symbolized signs and signals.

PROBLEM NO. 21

1. TITLE - APPLICATION AND RESPONSE TO RED AND YELLOW ARROW SIGNAL INDICATIONS

2. PROBLEM - Recent technical advances in traffic control hardware, combined with the absolute necessity of maximizing intersection perform-

ance and minimizing energy consumption and emissions without physical reconstruction of the highway system has made it feasible and desirable to institute more elaborate and sophisticated signal phasing schemes. In many cases, these phasing schemes involve segregating individual movements, straight through and turns, in various portions of the signal cycle and including timing or omitting these intervals in response to the demand for the specific movement and for all potentially conflicting movements.

These finely tuned phasing schemes cannot be effective unless the motorist is informed in a timely unequivocal and effective manner of the exact status of the movement he intends to make. Green arrow signal indications have long been used to indicate to the motorist that a particular movement is permitted. More and more the corresponding yellow and red arrow indications are being used by traffic engineers to indicate that specific movements are being terminated, or not permitted during a specific interval, while other movements from the same approach, are being permitted to continue.

Although the use of yellow and red arrow indications under certain conditions is sanctioned by the MUTCD, and although scattered evaluation studies of this type of application have been reported; e.g. Washington, DC, no comprehensive body of research exists concerning the application, effectiveness and operational and safety aspects of these devices. Such research is needed to give traffic engineers guidance in their application.

3. OBJECTIVE - The objectives of the proposed research are as follows:

   1) Identify, obtain, analyze and synthesize all past research results, published or unpublished, dealing with the public understanding, effectiveness, operational and safety implications and conditions of use of red and yellow arrow traffic signal indications.

   2) Identify all gaps in the present state-of-the-art bearing on these topics.

   3) Develop and implement an empirical testing program designed to generate the information necessary to close the major gaps identified. The program should include both attitudinal and behavioral studies. The accident experience and accident potential, conflict type studies, associated with the use of red and yellow arrow indications, should be investigated.

   4) Prepare an implementation package detailing the traffic, geometric and environmental conditions under which the use of red and yellow arrow indications is appropriate and recommended. Guidelines should be included for the design of traffic signal configurations which incorporate signal heads with red and yellow arrow indications. The implications of the use of red and yellow arrow indications for signal phasing and timing practices should be covered.

4. KEY WORDS - Traffic Signals; Arrow Indications; Signal Design.

5. RELATED WORK - An evaluation of the use of red and yellow arrow signal indications in Washington, DC was completed in the 1970's and published by the Federal Highway Administration. This research was localized in scope and very limited in the types of conditions where red and yellow arrows might be used.

6. URGENCY/PRIORITY - The Traffic Control Devices Committee ranked this problem #17 and #29 (out of 35) in the first and second rankings, respectively, using the Delphi technique.

7. COST - $200,000

8. IMPLEMENTATION - The findings of the research could be implemented by possible revisions to the MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES regarding criteria for use of red and yellow arrow indications, and by giving traffic engineers better guidelines for application of these devices.

9. EFFECTIVENESS - Better criteria for application of red and yellow arrow signal indications will aid in the efforts to maximize the performance of signalized intersections while reducing accident potential, energy consumption, and emissions.

PROBLEM NO. 22

1. TITLE - EVALUATION OF A PASSIVE BUS PRIORITY SYSTEM

2. PROBLEM - In February of 1979, the Federal Highway Administration released four reports (i.e., FHWA-RD-77-120, 77-121,77-122, and 77-123) documenting contract No. DOT-FH-11-8149 "Vehicle Detection Phase III Passive Bus Detector Intersection Priority Development".

   These reports were a result of a contract with Honeywell, Inc., to develop a production prototype of the Passive Bus Detector (PBD). The prototype was the outgrowth of the engineering model of the Passive Bus Detector/Intersection Priority System which was developed in the earlier part of the contract. In the production prototype model, the system concept was reconfigured to remove the controller, thus making the system more flexible in terms of hardware system configuration.

   According to the contract final report (FHWA-RD-77-122) the system was evaluated at one intersection connected to a typical traffic controller. The report also indicates that the system was successfully operated for one two month period.

   There is a need to expand evaluation of the device by the further testing of it on a computerized traffic signal system of some 300 signalized intersections.

3. OBJECTIVES -

   1) To determine the relative economics and feasibility of installing this device in a large urban area covering a significant number of signalized intersections.

   2) Develop procedures for tuning the device to identify three or more different type buses

and the reliability of detecting such a number of buses.

3) Compare and contrast the device with the active type now on the market.

4. KEY WORDS - Trolley, Detector, Passive, Active

5. RELATED WORK - See PROBLEM.

6. URGENCY/PRIORITY - This study should be given a high priority because of the current emphasis on energy conservation and mass transit operation.

7. COST - $300,000

8. IMPLEMENTATION - Guidelines should be developed describing how to maintain the device. Also to make tuning the device a relatively easy matter.

When the device is proven to be reliable a major effort should be made to interest manufacturers in its manufacture.

9. EFFECTIVENESS - This device would permit transit operators to use any bus in their inventory on a route and still obtain bus priority without the need of installing an active device on the bus. On a route where these detectors are installed at signalized intersections, bus travel time will be reduced.

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