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RESEARCH PROBLEM STATEMENTS: TRAFFIC SIGNAL SYSTEMS

mode

1 highway transportation

subject areas

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

FOREWORD

The Traffic Signal Systems Committee has developed the following nine research problem statements as part of a continuing subcommittee activity chaired by William D. Berg. The problem statements reflect current needs and are ranked in descending order of priority. The committee will be generating additional problem statements and updating those listed in this publication as new information becomes available.

PROBLEM NO. 1

1. TITLE - COMMUNICATIONS ALTERNATIVES FOR TRAFFIC SIGNAL SYSTEMS

2. PROBLEM - At the present time, the most serious obstacle to the integration of groups of signals into effectively coordinated systems is their implementation cost. While electronic technology has significantly reduced the cost and improved the performance capabilities of central masters and controller equipment, communications costs are continuing to escalate. Time-base coordinators (TBC) offer an alternative to the expense of installing an extensive hard-wired communications system, but they do not represent a complete solution since they cannot provide the flexibility and capabilities of centralized control. Although studies have been performed in the past that compared existing communications technology and evaluated new approaches that might be considered, these studies were performed prior to the recent maturation of a number of communications technologies that might possibly be used by the traffic engineering community [illegible] cable television, fiber optics, low-cost satellite communications, FM side-band communications, low-cost/low-power UHF radio communications, and cellular communications.

3. OBJECTIVE - The objective of this research is to review and perform a critical assessment of existing communications technology for the purpose of identifying those areas which offer adequate promise to justify further development and evaluation. The research conducted should include the following elements:

   1) Definition of the functional communications requirements of both conventional and computerized traffic signal systems.
   2) Review of the entire range of communications advances within the past five years to identify the specific techniques which offer the potential to satisfy the requirements defined in Step (1).
   3) Critical assessment of the maturity, cost and characteristics of each technique identified in Step (2) to determine its potential capabilities for signal control applications.
   4) Estimation of the potential cost of each of the techniques and identification of those techniques which might prove to be less costly than the communications services presently in use.
   5) Preparation of a final set of recommendations that lists the communications techniques that should be studied in further detail and identifies the needed research and development steps required to adapt them to traffic control applications.

4. KEY WORDS - Cable Television, Fiber Optics, FM Side-Band, UHF Radio, Cellular Communications, Time Base Coordinators.

5. RELATED WORK - FHWA Research Project entitled "Standardization of Communication for Traffic Control" considers the termination and interface equipment for a communications system. The proposed project would use information developed on the standardization project as a starting point for comparing alternative media. A previous FHWA research project conducted approximately five years ago considered alternative media. However, the state-of-the-art has changed substantially and the communications costs of traditional twisted pair installations have significantly increased since that time.

6. URGENCY/PRIORITY - This is a high priority activity because of the high capital investment involved in a communications installation. This study is urgent because of the recent deregulation of the communications industry.

7. COST - $150,000.

8. USER COMMUNITY- Practicing traffic engineers at all levels of government and in the private sector.

9. IMPLEMENTATION - Technology sharing materials distributed to practicing engineers.

10. EFFECTIVENESS - Availabilities of low-cost communications alternatives would increase the number of traffic control systems being installed, resulting in improved traffic control in many urban communities.

PROBLEM NO. 2

1. TITLE - COST-EFFECTIVE METHODS FOR LOCATING DETECTORS IN TRAFFIC RESPONSIVE SIGNAL SYSTEMS

2. PROBLEM - At the present time, there are no guidelines for the location or number of system detectors for computerized traffic control systems in the "traffic responsive" mode. Detectors are placed according to the judgment of the system designer. While this is often very good, it is also occasionally inadequate. In either case, it places a large burden on the designer.

3. OBJECTIVE - The objective of this proposed research is to develop a methodology for identifying which links and lanes need system detectors so that the computer system can accurately identify traffic patterns.

4. KEY WORDS - Traffic Responsive, Detectors, Sensors.

5. RELATED WORK - "Locating Detectors for Advanced Traffic Control Strategies" by Kay, Henry, Smith and Bruggeman is the only published material that attempts to cover this subject. It gives the results of the UTCS experiments for "first" and "second generation" traffic control systems. However, significant experience has been gained with new control systems since this reference was published in 1975 and modern interests are tending toward "one and one-half generation" control

strategies which are totally beyond the concept of this reference. An updated and expanded reference is critically needed. In other related work, Tarnoff has shown that traffic data from adjacent links are not well correlated, and Kreer has researched problems of pattern identification reliability.

6. URGENCY/PRIORITY - High.

7. COST - $250,000.

8. USER COMMUNITY - Traffic control system designers and installers.

9. IMPLEMENTATION - Publish guidelines and incorporate them into NHI and ITE courses on signal design.

10. EFFECTIVENESS - Because this research will introduce a "standard" into detector placement, it will make system design more reliable and effective, and fault detection and correction much easier. More accurate recognition of traffic flow patterns will further the ability of the signal system to reduce user costs, fuel consumption, and exhaust emissions.

PROBLEM NO. 3

1. THE ACTIVE MANAGEMENT OF URBAN TRAFFIC SYSTEMS

2. PROBLEM - The control strategies of the current generation of area traffic control systems are based on maximizing mobility in a network by minimizing total stops and delays. The optimal timing plans for the signal splits and offsets are usually determined from off-line traffic signal optimization programs such as TRANSYT or SIGOP. Since these programs cannot handle saturated or over-saturated conditions, the tendency is for traffic to be moved more quickly into the CBD, or to an urban freeway, than the rate at which it can be absorbed under peak demand conditions, resulting in severe congestion. Another problem exists with respect to the access of various competing user groups to a given facility such as a freeway under chronically congested conditions.

3. OBJECTIVE- There is an opportunity to develop control strategies which systematically delay (i.e., manage) network traffic during certain periods to control the buildup of congestion in the CBD and/or major freeways. Such control, which would use the available storage in the network to maximum advantage, could well be optimal from an overall system point of view, and could remove the need for freeway ramp metering. It is, in fact, equivalent to ramp metering but on a network-wide basis. Where congestion is unavoidable, there is an opportunity to develop strategies to "manage" traffic to allow various competing users equitable access to a facility.

4. KEY WORDS - Traffic Management, Urban Traffic Systems, Congestion, Saturated Conditions.

5. RELATED WORK - The Europeans have implemented techniques which are variously known as 'flow metering', 'throttling' or 'gatekeeping' which deliberately restrict traffic at certain times to control congestion. The intent of the proposed research is to expand on this work to develop the principle of system-wide traffic systems management (see OECD Report "Integrated Urban Traffic Management," 1977).

6. URGENCY/PRIORITY - High, since there is considerable lead time required for development and demonstration of new traffic management techniques and strategies.

7. COST - Initial research and development about $200,000; demonstration project $400,000.

8. USER COMMUNITY - Federal and local engineers, and freeway traffic control authorities.

9. IMPLEMENTATION - A demonstration project would be necessary.

10. EFFECTIVENESS - The active management of urban traffic systems will provide a flexibility and choice of control strategies which is not available at present.

PROBLEM NO. 4

1. TITLE - INTEGRATED FREEWAY AND AREA TRAFFIC CONTROL

2. PROBLEM - Many large urban centers have installed both area traffic control systems and freeway ramp metering control systems to alleviate congestion on their street networks and urban freeways. The problem is that most of these systems operate essentially independently of one another. In fact, they often operate at cross purposes, particularly under severe congestion, since there is no integrated overall control strategy which attempts to optimize simultaneously the performance of traffic flow both on the street and on the freeway. Control of on-ramp queue spillback on the freeway are obvious examples where integrated control is highly desirable.

3. OBJECTIVE - The objective is to develop design guidelines and integrated optimal control strategies for the simultaneous control of traffic flow on urban freeways and the local street network, and to demonstrate their effectiveness by a field test in a suitable location.

4. KEY WORDS - Area Traffic Control, System Optimization, Ramp Metering.

5. RELATED WORK - Virtually all area traffic control systems in use today employ so-called First Generation Control in which pre-stored plans are called up on either a time-of-day or traffic responsive basis. The timing plans for the splits and offsets are usually determined from an off-line traffic signal optimization program such as TRANSYT or SIGOP. Many freeway control systems also use time-of-day control with pre-stored plans. The plans are usually determined manually from consideration of freeway capacity and demand, although there are some off-line programs which determine optimum metering rates (e.g., FREQ3C). It is not clear how these two approaches could be combined for integrated control. Most likely, a new approach is needed. This research would go beyond the freeway corridor control problem which has been mainly concerned with optimal distribution of the corridor demand between the

freeway and the parallel alternate routes. Both parallel and perpendicular arterial traffic must be considered for integrated control of the freeway and the local network.

6. URGENCY/PRIORITY - There is some urgency to establish at least preliminary guidelines for integrated control if only to allow the designers of area traffic control or freeway control systems to allow for possible system interface and additional computer capacity to meet future integrated control requirements (shared data base, etc.).

7. COST - $500,000 to $1,000,000, including a field test program.

8. USER COMMUNITY - Practicing urban traffic engineers.

9. IMPLEMENTATION - Findings should be implemented first in a demonstration project.

10. EFFECTIVENESS - Integrated control would produce greater total benefits (less waste of time and energy resources, etc.) than both freeway and area control systems operating independently.

PROBLEM NO. 5

1. TITLE - DEVELOPMENT OF GUIDELINES FOR SELECTING COST-EFFECTIVE DIAMOND INTERCHANGE CONTROL

2. PROBLEM - Traffic demand is continuing to rise within most urban freeway corridors with some peak periods of flow lasting several hours. Recurrent traffic congestion is becoming a serious operational problem. Freeway maintenance and reconstruction periodically generates additional corridor bottlenecks and diverted traffic demand. Consequently, transportation operating agencies are faced with the complex task of increasing the capacity and operational efficiency of signalized diamond interchanges that often provide the principal interface between the freeway and corridor surface street system. Since the geometric capacity of most diamond interchanges is basically fixed, without major capital investment, cost-effective improvements in signal design and operations are the only viable alternative. Very little information is available to aid in selection of the best type of control and detectorization plan.

3. OBJECTIVE - The objective of this study is to develop a set of operational and design guidelines for selecting and implementing cost-effective diamond interchange control for the usual variety of geometric and daily traffic patterns found along urban freeways. Freeways with and without frontage roads will be considered.

4. KEY WORDS - Traffic-Actuated Control, Detectors, Freeway Corridors.

5. RELATED WORK - Limited operational studies of diamond interchange operations will be completed in late 1984 in Texas. Preliminary results of these studies have demonstrated a viable field study technique, and that differences in operational performance can be expected depending on geometry, traffic volumes and types of signal control. Sample sizes and limited geographical distribution do not permit extrapolation of study results to a national level.

6. URGENCY/PRIORITY - With increasing traffic volumes, there is a need to provide optimum operation at the diamond interchange as well as on the freeway lanes. The current reconstruction of many freeways, with the resulting increased traffic volumes, lends urgency to the need for the research and makes this a medium priority project.

7. COST - $250,000.

8. USER COMMUNITY - Practicing traffic engineers in the private sector and at all levels of government.

9. IMPLEMENTATION - A document describing the background of the study and application guidelines for selecting cost-effective signalized diamond interchange control should be prepared and distributed to all state departments of transportation. Articles in TRB, ITE and IMSA would also promote dissemination of technology. Traffic control projects, individually or in combination with freeway reconstruction programs, would implement the study results.

10. EFFECTIVENESS - Traffic operations along congested freeway corridors would be considerably improved under many existing traffic conditions, resulting in lower traffic delays, fuel consumption and air pollution.

PROBLEM NO. 6

1. TITLE - THE EFFECT OF TRAFFIC SIGNAL SYSTEMS ON HIGHWAY SAFETY

2. PROBLEM - Advanced traffic signal control systems are capable of rapid changes in the four basic signal control variables: cycle length, split, offset and phasing. These new systems can alter the sequence of phases to help improve traffic flow efficiency. It is not clear how drivers react to these more responsive timings, particularly changes in phasing. If drivers become confused, they may make incorrect decisions, increasing the risk of accidents. On the other hand, these new systems contain substantial malfunction detection capability which can quickly detect controller errors, potentially reducing the risk of accidents caused by controller malfunctions.

3. OBJECTIVE - The proposed research would seek to determine if a clear link exists between advanced traffic signal control systems and highway safety. As computers become more powerful, signal systems are likely to become even more flexible. It is important to understand how drivers react to this flexibility so that safe and efficient systems are designed and implemented.

4. KEY WORDS - Phasing, Timing Plans, Human Factors, Safety, Malfunction-Detection.

5. RELATED WORK - Some safety analysis was conducted on the FACTSS system in Houston and

reported at the January 1984 TRB Annual Meeting; more studies of this type are needed.

6. URGENCY/PRIORITY - Medium.

7. COST - $100,000.

8. USER COMMUNITY - Practicing traffic engineers in the private sector and at all levels of government.

9. IMPLEMENTATION - Findings of proposed research are likely to be suitable for direct implementation. The results of the detailed studies will guide implementation and design of new systems.

10. EFFECTIVENESS - Could provide important societal benefits by reducing accidents through more consistent investment decisions and explicit inclusion of safety in signal system design.

PROBLEM NO. 7

1. TITLE - GUIDELINES FOR PEDESTRIAN PHASING AND CONTROL IN SIGNAL SYSTEMS

2. PROBLEM - One of the most critical constraints on traffic signal systems is the need to provide adequate street crossing time for pedestrians. This constraint is particularly limiting because it typically means that long green times must be given to minor streets for pedestrians crossing the major street. In handling pedestrian requirements, two basic strategies have evolved: "pedestrian present" and "no pedestrian." In the "pedestrian present" strategy, signal timing plans are developed assuming pedestrian demand on all crossings. In the absence of pedestrian actuations in the field, excess green time is reassigned to one or another phase to improve vehicle flow. In the "no pedestrian" strategy, signal timing plans are developed assuming no pedestrian demands. When pedestrian actuations occur in the field, the local controller usually is cut free from the system to serve the pedestrians, followed by re-synchronization over two or three cycles. The two strategies are usually both implemented in the same signal system.

3. OBJECTIVE - The primary research problem is to identify when and how to employ the two control strategies. The systems goal is to achieve a good balance of strategies that provides both optimum vehicle and optimum pedestrian flow. A concurrent need is to offer a safe operating environment for pedestrians. Another aspect of the research would address alternate pedestrian phasings: concurrent, early release, late release, split, and scramble ("Barnes Dance"). This aspect may be secondary in that concurrent vehicle/pedestrian timing is by far the accepted standard of control.

4. KEY WORDS - Pedestrian Crossings, Pedestrian Delay, Signal System Optimization.

5. RELATED WORK - Recently completed study by Goodell-Grivas, Inc., entitled "Pedestrian Signalization Alternatives," for FHWA.

6. URGENCY/PRIORITY - Low.

7. COST - $150,000.

8. USER COMMUNITY - Practicing traffic engineers in the private sector and at all levels of government.

9. IMPLEMENTATION - The primary implementation would be by municipal traffic engineering agencies and other agencies responsible for signal system operation.

10. EFFECTIVENESS - The research would provide more efficient traffic signal systems in terms of reduced vehicle and pedestrian delay. The work might aid software/hardware development by providing better understanding of pedestrian control requirements. Safety benefits in terms of reduced vehicle/pedestrian accidents also might accrue.

PROBLEM NO. 8

1. TITLE - STANDARDIZED PROCEDURES FOR EVALUATION OF COMPUTERIZED TRAFFIC SIGNAL SYSTEM MODELS

2. PROBLEM - It has been observed that macroscopic and microscopic simulation models of signalized networks differ in their numerical estimates of delay, stops, fuel use, and emissions. Further, documentation of the validity of models in their application to real world data is not readily available. Experiments must be reported in a form so that the validation can be analyzed in detail by others. Believable and complete validations must be readily available to maintain the credibility of the models.

3. OBJECTIVE - The objective is to develop a procedure that future validations should follow. This will include the collection of input data, model runs, comparison with field observations, and reporting of results. In addition, previous validations will be researched and, as far as possible, placed in this format.

4. KEY WORDS - Model Evaluation Procedures, Traffic Signals, Computer Models, Validation

5. RELATED WORK - Research at Purdue found field observations inconsistent with NETSIM output. Also relevant are validation studies for NETSIM, TRANSYT-7F, TRANSYT -6C, SIGOP-III, and SSTOP.

6. URGENCY/PRIORITY - Low.

7. COST - $250,000.

8. USER COMMUNITY - Practicing traffic engineers in the private sector and at all levels of government.

9. IMPLEMENTATION - Publication of standardized validation procedures in a form that is easily accessible and believable.

10. EFFECTIVENESS - Better validated models would result in improved representations of reality and thus better traffic performance. There would be less controversy among traffic engineering professionals, more confidence in the results, and improved credibility with the public.

PROBLEM NO. 9

1. TITLE - SIGNAL SYSTEM CONTROL FOR NON-LOCALIZED FLOW DISRUPTIONS

2. PROBLEM - Disruptions of system flow and control occur due to non-localized events such as: 1) railroad pre-emption, 2) emergency vehicle pre-emption, and 3) transit system pre-emption. Emergency vehicle pre-emption can be either on random routing or fixed routing. The latter case is similar to transit system pre-emption assuming fixed routing. Railroad pre-emption will generally be semi-random, with known routing, and potentially long duration. Major traffic diversions may occur that effectively change traffic demand patterns. In the case of transit pre-emption, the need for pre-emption is not as strong as in the other cases. Some signal systems can theoretically handle these situations, but field experience is limited.

3. OBJECTIVE - To investigate strategies and hardware for handling such events. Specifically, the research must address: 1) going into pre-emption (when, how to do detection, signal displays), 2) holding pre-emption (how long, what method of signal displays), and 3) coming out of pre-emption (recovery from or enhancement of pre-emption effects). The research must be sensitive to human factors, and limitations imposed by National Joint Committee on Uniform Traffic Control Devices (e.g., when is it appropriate to shorten pedestrian clearance times?).

4. KEY WORDS - Incident Detection, Railroad Pre-emption, Emergency Vehicle Pre-emption, Transit/Bus Priority, Incident Occurrence.

5. RELATED WORK - Unknown.

6. URGENCY/PRIORITY - Low.

7. COST - $150,000.

8. USER COMMUNITY - Practicing traffic engineers in the private sector and at all levels of government.

9. IMPLEMENTATION - Implementation through design of traffic signal system hardware and software, and through operation of traffic signal systems (cities, counties, etc.).

10. EFFECTIVENESS - The results will cause less system delay (and associated operating cost, energy and air-quality impacts), and increase capacity by better utilization of available green time.