National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

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Guidelines for Design and Operation of Ramp Control Systems

An NCHRP staff digest of the essential findings from NCHRP Project 3-22, conducted by Stanford Research Institute, Menlo Park, California. Members of the research team included D. P. Masher, D. W. Ross, P. J. Wong, P. L. Tuan, H. M. Zeidler, and S. Petracek. Important contributions to the project were made by three consultants: Dr. A. D. May, Dr. J. Wattleworth, and Mr. K. G. Courage.

THE PROBLEM AND ITS SOLUTION

Many governmental units are increasingly interested in the design and construction of ramp control systems to reduce accidents and delay. A considerable investment in ramp control systems will be made during the next decade, but adequate design guidelines for installing and operating such systems have not been available. Guidelines are necessary in order to facilitate the selection of the most cost-effective ramp control systems and to prevent their early obsolescence.

The objectives of this project were to analyze existing ramp control techniques and to develop design procedures for freeway ramp control systems. The research considered the types of ramp control requiring a minimum of manual operation that keep freeways operating at or near capacity during peak periods.

User-oriented guidelines were prepared that are useful to highway planners, administrators, and other individuals charged with ramp metering system design and implementation. The guidelines are primarily aimed at the working traffic engineer who has had a minimum of freeway operations experience. As a first step, guidance is provided in determining whether a proposed metering system is potentially effective. Assuming that cost and related criteria are also met, guidelines are given for the design, implementation, and operation of systems having three types of metering: pretimed, locally-actuated, and centralized/interconnected. Multiple-system metering is also treated briefly.

FINDINGS

This Digest is limited to a summary of the results from a survey of all 50 states that was conducted to determine the factors to be addressed in the guidelines. Such limitation results from the fact that the survey findings are not included in the final report.

With some notable exceptions, most of the questionnaire responses showed limited acquaintance with ramp metering concepts. Of the 40 states providing usable responses, ten states expressed minimal interest in ramp metering at this time. In general, these were the less populous states in which freeways are not burdened by recurring congestion or breakdown.

The questionnaire requested two types of information. First, an attempt was made to identify high-priority needs in planning and designing a ramp metering installation. Although wide disparity of needs was reported, the following areas were considered to be of greatest importance:

- Need to know what control strategies to use and the potential incremental benefits that accrue from increasing levels of sophistication.
- Need to have an engineering manual that presents sufficient trade-off information on the various aspects of ramp control systems so that design can be accomplished in-house.
- Need to know the state of the art in regard to electronic equipment for detectors, ramp controllers, computers, communications gear, etc., as well as recommendations on the use of such equipment and associated costs.
- Need to know how to plan a system that can be upgraded from a simple, low-cost format to a more complex integrated system.

The following areas were considered to be of lesser immediate importance:

- Need to know the approximate costs of different types on installations, ranging from pretimed having no automatic surveillance to real-time surveillance and control having advanced traffic-responsive strategies.
- Need to know about problems that may arise when the system becomes operational, regarding drivers who reroute themselves or drivers who do not comply with the ramp control measures.
- Data indicating the length of ramp queues that drivers will tolerate relative to their potential time saving by using the freeway.
- A need for guidelines on the types of communication suited to ramp metering and the associated cost.
- A need for signal head standards, detector configuration standards, signing standards, and mainline detector locations.

The second type of information requested in the questionnaire addressed policy and planning considerations. The responses are summarized as follows:

(1) In planning a new ramp control installation, most potential users indicated that their policy would be to maximize the ratio of benefits to cost. A second, but lower, preference was indicated for maximizing total benefits. Very few responses indicated that actual target costs would be set.

(2) The operations and maintenance staffing of a new ramp control project would be planned in advance, under cost constraints, by most potential users. A much smaller, but significant, fraction of potential users would wait until after system installation to determine and budget such staffing.

(3) The type of justification required prior to the installation of a new ramp control system was varied. Most commonly, one or more of the following conditions would have to be satisfied:

- o A recurrent, serious operational problem must be shown to exist.
- o The costs and benefits of the ramp control system would have to be determined, and the benefit-to-cost ratio would have to be greater than 1.
- o Reduced travel time must be demonstrated to satisfy federal policy in PPM 21-21.
- o In somewhat more than half the cases, warrants would be required, although there was no consensus on what the warrants would be.

(4) Valuation of vehicle travel time or delay per vehicle-hour varies considerably among the states. Most states had no dollar figure that had been used in past projects. Those who responded did so with a low value of $1.55 and a high value of $3.60. The average was $2.67 per vehicle-hour.

(5) The service life that would be expected from ramp metering system installations varied considerably. About equal preference was shown for the 5-to-10-year category and for the 10-to-15-year category.

(6) A definite preference was shown for inclusion of geometric improvements (e.g., bottleneck elimination) just before, or concurrent with, installation of ramp control. The most prevalent reason cited for this procedure was that concurrent implementation would prevent the reconstructed area from being overloaded a short time after the improvement was made.

(7) By far, most respondents indicated that high-occupancy vehicles should receive preferential treatment in ramp metering projects. The responses were about equally divided between giving preferential treatment to buses only and to the combination of buses and carpools.

(8) The respondents were requested to select two or three strategies for ramp metering that were most desirable from an operational viewpoint. In addition, a second set of two or three strategies desirable from a socioeconomic viewpoint was to be selected. The operational strategies are listed in descending order of desirability:

- o Maximize the throughput volume of bottlenecks.
- o Minimize accidents by preventing shock waves in traffic flow upstream of bottlenecks.
- o Maximize capacity utilization of each freeway section.
- o Minimize travel time along the freeway.

From a socioeconomic point of view, the following strategies were listed in order of preference:

- o Minimize travel time along the freeway.
- o Equalize queueing delays among the ramps.
- o Minimize accidents by preventing shock waves in traffic flow upstream of bottlenecks.
- o Maximize total input volume to the freeway among all ramps.

APPLICATIONS

The final report provides step-by-step guidance in the development of a ramp metering project. The emphasis is on practical and proven techniques, not on experimental procedures. The closely related topics of merge control, gap acceptance, and the computerized control of traffic signals on surface streets in the freeway corridor were not included in the scope of this project. Also, the project did not address guidelines for extensive freeway surveillance features except where such features relate to the control system. The reader is referred to the report Urban Freeway Surveillance and Control: The State of the Art, Federal Highway Administration, June 1973, which contains closely related information.

To illustrate the areas of potential application of the final report, the following summary of content by chapter is provided.

I. Introduction

A description of the manual and suggestions for its use are provided.

II. Preliminary Engineering

Prior to the design and implementation of a ramp metering system, a number of engineering studies are generally performed to establish an inventory of present conditions. This inventory can be valuable in the identification of existing problems and in the selection of solutions to them. Such an inventory also gives a basis for evaluation of control strategy effectiveness after control has been implemented. Chapter II provides considerable detail on origin-destination data collection and use, safety analysis, public transit studies, as well as congestion, performance, and capacity studies.

Assuming that the preliminary studies have established the existence of a specific problem or set of problems, the feasibility of a ramp metering installation may be determined. Specific guidance in this area is given in terms of delay reduction, adequate ramp storage, and available alternative route(s).

III. Field Configuration Guidelines

Field hardware and typical configurations for detectors, signal heads, and signing are provided.

IV. Selection of Control Policies, Strategies, and Tactics

Chapter IV presents the basic concepts underlying the control methods judged most appropriate for a wide range of installations. The control methods described are predominantly those that have been successfully tested in operational environments.

V. Functional System Design

Guidance in the detailed calculation of actual metering rates is given in Chapter V. The discussion is divided according to control system type and further subdivided into control strategies and override tactics. The computational procedures range from very simple manual computation to relatively complex linear programming methods.

VI. Implementation

The actual implementation of a ramp metering system is considered in detail in Chapter VI. A comprehensive discussion of both detectors and controllers is provided, with the emphasis on successful implementations used by experienced users. Chapter VI addresses the implementation of a centralized/interconnected system in considerable detail.

VII. Operational Requirements

When a system has been installed, operation and maintenance must be provided. Guidance is given in Chapter VII on the major functions required in an operating environment. These functions include system monitoring, hardware maintenance, staffing, and performance evaluation. Detailed consideration is given to adjustments that may be required when the system is operational.

VIII. Representative System Benefits and Costs

To assist the designer in making cost estimates, a final chapter considers representative system costs. The costs shown are for hardware only and specifically exclude those for construction, software, and system operation. The costs for these services are far too varied and dependent on too many indeterminate factors to make generalized estimates meaningful. Cost estimates for a planned installation--a specific location with identifiable operating personnel--are relatively straightforward.

Chapter VIII also briefly deals with benefit-cost analysis as applied to ramp metering systems. Benefits and costs at a number of existing locations are cited, and the techniques for a specific benefit-cost study are described.

FINAL REPORT

The final report submitted by Stanford Research Institute entitled "Guidelines for Design and Operation of Ramp Control Systems" is available at a cost of $8.00. Prepaid requests should be submitted to the Program Director, National Cooperative Highway Research Program, 2101 Constitution Avenue, N.W., Washington, DC 20418. Loan copies may also be requested.

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