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COMMITTEE ACTIVITY
Committee on Traffic Flow Theory
Department of Traffic and Operations
Highway Research Board

REPORT ON RESEARCH NEEDS

Research Problem Statements

Contents

HIGHWAY RESEARCH BOARD • NATIONAL ACADEMY OF SCIENCES - NATIONAL RESEARCH COUNCIL
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INTRODUCTION

In submitting specific problem statements, the subcommittee believes the need for traffic theory is so fundamental that the individual statements attached hereto should be viewed in the context of a preliminary general discussion. This brief background statement is offered to help the Highway Research Board evaluate the importance of supporting such theoretical research. This work is aimed at increasing the knowledge about traffic, which in turn will serve as the basis for designing improvements in traffic facilities and operations.

Why Support Research in Traffic Theory?

Theories about traffic are an integral part of the day-to-day job of traffic engineers, and play an inescapable role in the job of traffic engineering. Existing design standards are based on assumptions regarding drivers, vehicles and roads which are based on experience, but need considerable refinement. Engineers are now applying traffic theories on a limited basis: for example, designers in determining the number of lanes required on a roadway link use a simplified version of traffic theory.

A traffic engineer needs theory so he can have confidence that benefits intended from new construction, new traffic control systems, etc. will actually be obtained. A most important aspect of traffic operations today is their great variability -- in peak volumes, delays, operating speeds, accidents and other aspects of traffic flow. Research is needed to understand more precisely what factors determine observed peak flows, speeds and accidents. This research will consider how much variation can be controlled by application of existing geometric practices and control technology, as well as describe the type of geometrics and devices needed to be developed for improved operations.

In the days when relatively little was spent on facilities to serve road traffic, this lack of basic knowledge was of little practical consequence. But with the money required today for road construction and operation, and with the dependence of a large part of the United States economy on efficient road transportation, the situation has changed. Especially in urban areas, prudent use of public funds requires that there be available to road designers and operators an accurate and detailed body of knowledge with which to assure that expenditures on roads, improvements and controls produce the benefits intended for road users.

What is the Present State of Traffic Theory?

Although there have been a number of publications during recent years, and although there has been some increase in the number of scientists interested in traffic research, the subcommittee believes that considerably more attention is needed if the essential theoretical basis is to be provided for traffic engineering.

Existing traffic theories are not capable of providing traffic engineers with assurance that newly designed geometrics and control devices will actually produce the intended results. There needs to be a greater concentration of effort to achieve meaningful breakthroughs in traffic research. This work is now carried on largely by men scattered throughout the country and the world, who number traffic research as only one of their competing interests. At the same time, costs of experimental facilities needed to develop knowledge has been rising.

The past decision of the sponsors of the National Cooperative Highway Research Program to emphasize research projects which would produce immediate benefits has had an important impact on the present lack of coordinated, sustained and effective theoretical research in traffic, and in the subcommittee's view should be carefully re-examined. It is generally recognized that applied research can be successful only within the limitations of existing basic knowledge. Since in the present case there is relatively little basic knowledge about traffic theory available to be applied, research aimed at producing immediate traffic benefits is handicapped and likely to be wasteful. The need is to emphasize basic research now, to build up the knowledge required for effective applications.

What Work Is Needed in Traffic Theory?

Virtually all elements of vehicle traffic systems require further study to provide traffic engineers with the detailed understanding about traffic flow warranted by the levels of investment being placed in road traffic facilities. The subcommittee proposes that research needed in this field be considered on several levels, beginning with the most fundamental and restricted view and then proceeding to the most comprehensive view. Five levels of necessary research have been defined, and Research Problem Statements are submitted typifying the work needed at each level. It should be noted that the knowledge at each level includes and is dependent on the state of knowledge in each of the preceding levels.

1. Traffic Components: Driver-Vehicle-Road Complex

   Research at this level is concerned with describing the processes which occur as a driver and his vehicle traverse a road. At this level, only the characteristics of the roadside environment and of the vehicle are considered as acting on the driver. Such questions as the effect on driver behavior of abrupt transitions in roadway light levels are of concern here. This research is needed to enable traffic engineers to design all aspects of road geometrics, appurtenances and environment which will best serve individual motorists within funds available for road construction and operation.

2. Elemental Traffic Flow

   At this level, research focuses on the interactions among vehicles traveling in the same direction on a closed roadway. The most elemental situation considers one car following another. Next, additional cars in the same lane are introduced, to explore such matters as wave propagation and stability. Then multilane roadways are considered, adding the influence of moving traffic in adjacent lanes. Finally at this level, the effect of lane changing is studied. Research in this ares is especially important to aid traffic engineers in operating congested roadways for maximum traffic production and safety.

3. Complex Traffic Flow

The phenomena of merging, weaving and diverging are studied at this level. This research provides the foundation for design of acceleration ramps and other geometric and operational features needed for the smoother and safe accomplishment of these maneuvers.

4. Conflicting Traffic

Intersections are the major aspect of traffic behavior studied at this point, but this level would include such conflicting traffic situations as operation of reversible roadways and short radius roundabouts. The design of signalized intersections including consideration of the use of pre-signals and left-turn slots, rests on the understanding of traffic behavior provided by research at this level.

5. Traffic Networks

The distribution of traffic flow on a variety of alternate routes is studied at this level. The traffic engineer needs this research to operate street systems more effectively, and to understand better the effect new construction will have on existing road facilities.

Specific problem statements illustrating the type of research needed in each of these five areas follow:

RESEARCH PROBLEM STATEMENT

Title: 1.1 Driver System Theory

PROBLEM: What information helps a driver, and what information merely distracts him? For better design of signs, signals, markings, lane geometrics, and other driving aids there is needed a comprehensive description of the manner in which a driver receives and processes information. The description must consider:

a. limitations on the driver's information gathering capabilities as a function of environment, speed, motivation, and other factors;

b. conflicts between the driver's information gathering and information processing functions;

c. factors influencing the driver's processing abilities, such as motivation, fatigue, and vehicle characteristics.

PROBLEM AREA: Traffic Components: Driver-Vehicle-Road Complex

OBJECTIVES: Prepare a precise description relating all factors pertaining to the total driver-vehicle-road system, suitable as a framework for subsequent experimental studies aimed at determining quantitative relationships among the various system elements. The description should incorporate knowledge from all pertinent scientific disciplines, including experimental psychology, information theory and systems engineering. When completed, the research should enable tracing the qualitative relationships which will determine such matters as:

a. how inadequate information affects driver reactions and reations times;

b. how much information per time interval a driver can use effectively;

c. the importance of information about relative velocity and how this importance varies with time and distance spacing;

d. the relationship between driver motivation and driver reaction times.

Furthermore, the research will provide the foundation for design of a driving simulator capable of generating and reproducing a variety of controlled informational inputs, as needed for the quantitative studies described below.

RESEARCH PROBLEM STATEMENT

Title: 1.2 Effects of Environmental Features on Driving Performance

PROBLEM: How does speed affect a driver's information reception capabilities? Working with the qualitative system of driver system theory developed in study 1.1, this research would provide quantitative measures of the effect of design speeds on information inputs. These measures would consider:

a. the effect of varying levels and patterns of ambient noise and light;

b. measures of the effectiveness of driver's decisions as a function of the rate at which information is presented;

c. measures of the effectiveness of driver's decision as a function of the rate at which decisions must be made.

PROBLEM AREA: Traffic Components: Driver-Vehicle-Road Complex

OBJECTIVES: Enable more effective design of signs, signals, marking and other driving aids. This research would probably require construction of a driving simulator, and would be carried out by observing the performance of large populations of drivers under exactly the same environmental conditions.

RESEARCH PROBLEM STATEMENT

Title: 1.3 Vehicle Design for Optimal Driving Effectiveness

PROBLEM: How should a vehicle be designed to assist the driver in gathering and acting upon the information he needs for most effective driving performance? What vehicle design features assist the driver in knowing precisely the lateral placement of his vehicle in his lane, and gauging the lateral clearance he will have? What types of engine and car noise help the driver and which mask important information? Similarly, what types of suspension systems provide the sort of "road feels" needed for most effective driving performance? What types of controls will assist the driver, e.g., would a speed control be more helpful than an acceleration control?

PROBLEM AREA: Traffic Components: Driver-Vehicle-Road Complex

OBJECTIVES: Again using the driving simulator, vary the immediate vehicle environment so as to provide automotive designers with information needed to improve driving performance.

RESEARCH PROBLEM STATEMENT

Title: 2.1 Car-Following Behavior

PROBLEM: How are the actions of the vehicle ahead perceived by the driver, and how are his decisions influenced by those actions? Relative to other areas of traffic theory, considerable work has been done on this problem but there are still important questions requiring study. How does relative velocity vary (in determining following-driver decisions) as a function of the speeds at which the pair of vehicles are traveling? As a function of the distance between them? What visual cues provided by the vehicle ahead improve the driving abilities of the following driver? What effect does short radius righthand curve have on car-following behavior? Of a gradual changing from level to a two percent upgrade? Of a fixed roadside obstruction, such as a bridge abutment? Of a transition in ambient light level of a given amount?

PROBLEM AREA: Elemental Traffic Flow

OBJECTIVES: Validate and modify, if necessary, the California "Safe Driving Law" widely used as a guide for the distance drivers should maintain between vehicles at various speeds. Improve the design of visual and electronic displays which assist drivers to measure their velocity, relative to the car ahead. Measure the effect of various types of roadside environment and geometrics of car-following behavior.

RESEARCH PROBLEM STATEMENT

Title: 2.2 Traffic Dynamics in Single Lane Flow

PROBLEM: What is the quantitative relationship between traffic flow and the speed at which changes in density, speed or flow are propagated along the roadway? Describe the time spacings between arriving vehicles which, in a given environment, are likely to result in a cumulative decay in speeds at a given rate. The type of information needed to answer such questions involves extrapolating the car-following behavior of a pair of vehicles in a given environment over many successive pairs of vehicles. It is at this level of research that a road designer can begin to trace the probably effect of various environmental features in generating shock waves, and to consider the types of traffic control operations which might counter the adverse effect of inescapable environmental features.

PROBLEM AREA: Elemental Traffic Flow

OBJECTIVES: Provide road designers and operators with the ability to estimate the probable effects of alternate courses of action available to improve traffic flow by preventing high accident potential and capacity loss inherent in shock waves.

RESEARCH PROBLEM STATEMENT

Title: 2.3 Interactions Among Adjacent Lanes

PROBLEM: With two or more lanes of traffic moving in the same direction, restrictions on lane changes are now usually based on the fixed geometric features, such as curves, grades, intersections, etc. However, there are clearly instances in the moving traffic stream when lane changing should be prohibited, such as when there is high differential in the speeds of two adjacent lanes, or when traffic densities become high. What are the dynamic traffic conditions under which lane changing should be prohibited? Are they the same for changes to the left as for changes to the right?

PROBLEM AREA: Elemental Traffic Flow

OBJECTIVES: Increase the capacity and safety of multilane operations. Provide road designers with more precise information to determine when the net effect of traffic composition and loading in a given environmental situation should require additional lanes, or wider lanes, or wider shoulders, etc.

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