National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

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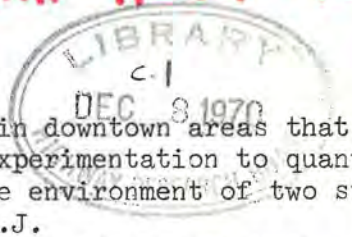
Optimizing Flow on Existing Street Networks

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 3-14, "Optimizing Flow on Existing Street Networks," by Edwards and Kelcey, Engineers and Consultants, Newark, N. J.



THE PROBLEM AND ITS SOLUTION

This project investigated the benefits to traffic flow in downtown areas that can be achieved by application of traffic engineering measures. Experimentation to quantify the effect of road improvements was carried on in the real-life environment of two study areas--the downtown portions of Louisville, Ky.; and Newark, N.J.

Operational studies, conducted as one of the first elements of project work, investigated the potential for traffic engineering improvements to the street systems of these study areas. These investigations included study of traffic operations, mass transit operations, and accident records. The operational studies produced reports describing deficiencies in the existing system and proposed remedial measures based on these observations.

Meetings were held with the city traffic engineers of both study areas to review these reports and to receive comments and criticism of the measures proposed. The project regulations required that the local governments having jurisdiction over the roads involved in the proposed experimentation pay for construction of permanent improvements; however, engineering costs were to be supported by the project. Many of the improvements that involved considerable cost, such as major channelizations or replacement of signal equipment, were rejected because of budgetary considerations. The final program of experimentation for each city was controlled by these considerations: (1) the opportunities offered by each study area for improvements of the type specified to be of interest to this project; (2) approval of the improvement by the public officials, including acceptance of the costs of permanent improvements; (3) time and budget limitations of the project itself.

Concurrently with the traffic operations studies, inventories of street and transit facilities were compiled; and files of existing traffic engineering data were reviewed to obtain background information for the project.

Traffic counting stations were established at key points in each study area to

provide a continuing record of traffic volume data for experimental control and for detection of possible changes in traffic flow due to the experimentation. A continuing travel-time study also was developed to yield information describing trip time, amount of delay time, number and cause of delays, average speed, and the number and severity of accelerations. These data were used during the development of the trip assignment model of the Newark downtown area and for analysis of network effects of experimentation in both study areas. Volume and travel-time measurements were also made both before and after most experimentation, concentrating measurements on and near the experimental site.

Project experimentation included an analysis of the local effects of the improvement, which has been generally referred to as the First Level Analysis. The Second Level Analysis included consideration of the network effect of experimental improvements on roads of the study areas and a generalized analysis to develop methods for application of this information to other areas. The applications, as presented in the agency's report, develop a methodical approach to analysis of traffic flows in a congested urban environment, which is intended to develop the framework for functional and operational studies of the traffic problems in a downtown area.

The results of experimentation and analysis performed on this project demonstrate to public officials the benefits of similar programs in their cities. To rely entirely on the published material to develop this awareness was not considered realistic. The technical nature of most publications, the time required to read them, and their limited distribution all indicated the need for a more acceptable medium to demonstrate the results of this project. To fulfill this need, a 25-minute color motion picture (with sound) was produced. This film, "Relief for Tired Streets," may be obtained from Coleman Productions, Inc., 45 West 45th Street, New York, N.Y. 10036, for $75 or borrowed on a short-term loan basis from NCHRP.

FINDINGS

In general, it has been found that significant benefits to traffic flow may result from relatively minor operational improvements to the downtown street network. In most cases, the benefits to the traveling public obviously far outweigh the costs of analysis, engineering, and construction of the improvement.

In prescribing an order for the implementation of improvements in a downtown area, those elements that involve the functional use of streets (such as one-way patterns, reversible-lane operations, major parking prohibitions) should be developed first. This should be followed by analysis and correction of all the minor influences that create frictions in the traffic stream, such as turning movements, truck loading, pedestrian interference, proper allocation of signal time to the various approaches of an intersection, and other traffic problems of the area. When local frictions have been reduced sufficiently, proper platooning of traffic for implementation of signal progressions may be possible. When this has been successfully accomplished, the optimum location of bus stops may be considered and bus movement in the progressive system developed.

As a result of the analysis of travel time, it has been found that a level-of-service definition describing quality of flow on downtown streets is possible. This level-of-service definition should be based on the delay ratio measured by travel-time surveys.

A review of the results attained by project experimentation for the improvement of traffic flow indicates that large improvements may be associated with poor "before" levels of service, whereas minimal improvements may be associated with high "before" levels of service. It has been found that a level-of-service definition is a reliable indicator on which to base the priorities for traffic improvements.

As a result of investigations for use of various models in the analysis of downtown network problems, it is concluded that the Network Assignment Model, Newell's Intersection Model, and the Analog Traffic Signal Model are all useful tools in their respective fields of application for these analyses.

Based on experience of this research, it is concluded that strict enforcement of

necessary traffic regulations is an essential component of traffic engineering in the downtown area. In several experiments, improvements designed to optimize road capacity resulted in hazardous situations and inefficient road use because of violations. Under these conditions the value of an improvement may not be realized unless enforcement sufficient to educate the public to correct driving habits is available.

APPLICATIONS

This research project, unlike many others, has been involved in the study of many subjects. Methods of optimizing flow have been investigated in 37 experiments. Statistical analysis of flow data has described the variance and distributions of these data and developed information for control of surveys in the downtown area. Study of models for use in the analysis of downtown problems has resulted in the use of several models for these purposes. A method for describing a level of service for downtown roadways has been developed from the study of travel time. Problems of mass transit, enforcement, safety, public convenience, and many other aspects of traffic engineering in the downtown area have all entered into some phase of this project. Therefore, it is not the purpose of this digest to recapitulate the details of every application of every investigation that was performed, but rather to describe the application of these elements in a broader sense to develop a systematic approach to analysis of the traffic problems of a downtown area. As such, it is directly oriented to the fourth objective of the project statement, which required the project studies to "outline a procedure for the practical application of the results of this research to street networks in general."

Relationship to the Urban Area Transportation Study

The study of the problems of a downtown area should proceed logically from the base that has been established in the urban area transportation study. This study, required for all urban areas of more than 50,000 population, will provide the basic information with which to begin analysis. The urban area transportation study should be able to provide a description of origins and destinations of travelers to and through the downtown area, records of counting stations in the area, and description of trips by purpose, time period, and mode of travel. The transportation study should also define the area to be given further study as the "downtown area." Projections of future needs will also be developed as part of the transportation study, as well as a description of community goals related to land-use planning, redevelopment programs, and other similar developments. All these aspects of urban area transportation planning that emanate from the transportation study will form the base on which the study of the downtown area is built.

Functional Analysis

The functional classification of streets for a downtown area can be a fairly complex subject, because it must recognize the many uses of the downtown street system and the changing patterns of traffic by time of day. The major problem is to develop sufficient arterial capacity to meet the changing traffic needs of each time period of the day. Because of the heavy directional movements of peak periods, a street that is not required for arterial purposes during periods of light traffic may be impressed into use as an arterial to meet the needs of peak traffic flow. To maintain this flexibility, it is suggested that downtown streets be classified into four functional categories, as follows: (1) arterial streets, (2) limited arterial streets, (3) circulating roadways, and (4) land service roadways.

The arterial and limited arterial roadways are of major interest to the traffic study of the downtown area. Traffic signals for intersections of arterial and limited arterial streets should, at a minimum, be totally interconnected, fixed-time with sufficient dials to accommodate the changing traffic patterns by time period (usually three). In planning the use of arterial streets by time period, the Network Assignment Model will be a useful tool for testing the effect of various patterns of street use. The

Signal Analog Model also will be useful for developing signal offset relationships of signals of the arterial street system. This knowledge may then assist in the selection of limited arterial streets that best fit the pattern set by traffic progressions for the arterial streets.

The functional classification of streets should produce a complete description of desired street use in the downtown area by time period, with particular consideration of curb-lane use, detailing the traffic regulations that are necessary to implement the desired changes in street use during various time periods. The functional analysis will establish a basis for evaluation of the operation of the arterial system.

Operational Analysis

After selection of the arterial and limited arterial streets of the downtown street system, surveys should be conducted to describe, in detail, the traffic-volume fluctuations by time of day and the travel time for each arterial and limited arterial street. Upon completion of the travel-time surveys, a level-of-service definition may be developed for each street surveyed. Deficiencies then may be identified in general form by those areas having a low level of service. Study priorities may also be established in relation to this definition. Inspection of the results of the travel-time surveys will make possible identification of those locations where repeated delays have occurred. These locations may then be subjected to field reconnaissance to determine the cause of congestion, the need for additional surveys, and the appropriate analysis. In the study of intersections, the analysis should include the surveying of vehicles stopped on red, vehicles through, and number of saturated cycles. Newell's Intersection Model may then be used to estimate the delays at each intersection approach. The need for additional lane capacity, turning lanes, separate signal phases, etc., may then be assessed and the appropriate action taken.

In performing the operational improvements, it would be logical to implement analysis and improvements in the following order:

1. Effect major changes in road use resulting from the functional analysis, such as one-way streets, reversible lanes, and reversible roadways.
2. Assess local conditions that require channelization, elimination of parking, provision of turning lanes, guide and directional signing, lane striping, parking prohibitions, control of truck-loading operations, and all other such elements designed to eliminate frictions in local areas.
3. Develop signal phasing, cycle length, and offset relationships of adjacent signals.
4. Finally, the study should progress to consideration of transit movement in the system.

For purposes of transit analysis, surveys should be conducted to assess the average number of passengers loaded and discharged at each stop location by time periods of the day and these data used to predict passenger service time. Because a major element in this consideration is the incidence of signal delay, studies should be made of the optimum bus position with respect to the signal progression. The coordinated signal system acts as a huge clock by which bus movement is controlled and which the bus operator should be instructed to recognize in his passage through the downtown area.

Upon completion of the physical improvements, "after" travel-time surveys and field reconnaissance should confirm that the anticipated flow improvement has actually been realized. This is necessary, because in many cases changes to traffic flow may produce unexpected results. As an example, violations by drivers and pedestrians may nullify the intended improvement. Efficient pavement use requires efficient enforcement of the regulations. As the operational analysis and the implementation of improvements proceed, it is necessary to develop the body of traffic regulations that will protect the value of the engineering efforts and financial investment in the improvements. It is essential that the proper ordinances be enacted to provide the basis for effective administration and enforcement.

Continuing Review

The need for a continuing review of the traffic operations in the downtown area is similar to the need for updating of a transportation study. Redevelopment programs, highway construction, changing land uses, and other elements of urban growth and change will undoubtedly be reflected in the traffic flows of the downtown area. As these changes occur, it will be necessary to make appropriate adjustments. Counting stations should be established for systematic assessment of the growth of traffic and change of patterns by time periods of the day. A travel-time survey should be implemented periodically and compared to the historical record of travel time to pinpoint developing situations. Field reconnaissance by competent traffic engineers is an important part of a continuing review to recognize and define the need for further traffic engineering action.

Movie

A professionally produced 25-minute, color motion picture (with sound) suitable for television audiences is available for use by state highway departments. The film, "Relief for Tired Streets," demonstrates for lay audiences the results that can be obtained by applying sound traffic engineering practices to urban traffic problems. "Relief for Tired Streets" is offered as a tool that can be used by highway departments to help explain the value of good traffic engineering to others.