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Performance Evaluation of Signalized Network Control Strategies

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 3-18(4), "Performance Evaluation of Signalized Network Control Strategies," by H. N. Yagoda and D. J. Parietti, Computran Systems Corporation, Hackensack, NJ.

THE PROBLEM AND ITS SOLUTION

Over the past 10 years, NCHRP has conducted four separate, but related, research efforts as part of Project 3-18. The overall objective was to provide improved traffic operations and control techniques having applicability to signalized street networks. The first three projects addressed: (1) improved computer-control logic for signal systems, (2) special traffic control techniques for dealing with networks having saturated conditions, and (3) a methodology to compare alternative network traffic surveillance and control systems. The reader is referred to the latest NCHRP Summary of Progress for more detailed descriptions of these projects and for the availability of their final reports.

While the first three projects were specifically directed to the development of techniques for improving traffic operations, the fourth project had a different emphasis in that its objective was to provide information related to how a significant improvement in traffic performance can be accurately measured. After a signal control change has been made in a street network, the traffic engineer has the sometimes difficult task of identifying the exact effects of that change. Often, the magnitude of difference in traffic performance (i.e., between two alternative control strategies) is relatively small and, therefore, difficult to measure. The ability to detect small changes in system performance is important because even a minor improvement of say 5 percent in average speed can be very significant in terms of actual costs to the motorist.

Project 3-18(4) had the objective of developing a methodology that would enable traffic engineers to select the most appropriate network performance measure of effectiveness (MOE) and to quantify that MOE using efficient, simple, and inexpensive data collection techniques. Equally important, the methodology was to ensure that measured performance differences were, in fact, statistically significant. The methodology was intended for use in the evaluation of timing plans, alternative control methods, and overall network control strategies.

The research was conducted by Computran Systems Corporation in two phases. Phase I consisted of a conceptual study to develop a preliminary network performance evaluation methodology with emphasis on the identification of the most appropriate MOE's. Field tests were accomplished in Phase II to examine the theoretical concepts of Phase I and to assess the relative merits of alternative data collection techniques.

FINDINGS

In Phase I, an approach for selecting MOE's suitable for performance evaluation of alternative traffic control strategies was developed. Travel time was selected as the principal attribute for examining network effectiveness, and energy consumption and pollution were also considered as relevant network attributes. The evaluation approach developed in Phase I was designed to discriminate a 5 percent change in traffic performance. Although a 5 percent reduction in travel time may go unnoticed by the driver, previous research has shown that such an improvement can result in an annual savings of several million dollars in a middle-size city.

The researchers proposed a conceptual technique for judging network effectiveness in which both the quality and quantity of service provided were considered. The findings indicated that when travel time was the selected attribute for judging performance, vehicle-miles per hour and vehicle-miles were the most appropriate measures of the quality and quantity of service provided, respectively. This technique relates a link level MOE (vehicle-miles of travel per hour) to the service provided (vehicle-miles of travel) on the link using a linear regression analysis. Difference in performance, if any, is represented by a vector whose components are given by the difference between sample means of the link level MOE (dependent variable), and the difference between the sample means of the service provided (independent variable). Such a vector is associated with each link, and the difference between two strategies on a network basis is represented as the sum of the individual link vectors.

Although the conceptual techniques proposed in Phase I were considered applicable to extensive street networks, a relatively simple test site consisting of 10 signalized intersections on an arterial street was used in Phase II to facilitate the experiment by minimizing the number of control variables.

The research approach consisted of altering the signal timing plans and measuring the resulting changes in traffic flow. The field study compared three data collection methods -- floating car, aerial photography, and license matching.

The actual findings are quite limited because considerable difficulties were encountered in using two of the data collection techniques (aerial photography and license matching). Because of these difficulties, the researchers concluded that the floating car technique was most efficient and appropriate for use in general practice. However, some of the problems encountered with the other two data collection techniques were attributable to the type of test equipment used in the research; therefore, the findings regarding the potential applicability of these techniques are not conclusive. A brief summary of the difficulties encountered during this research is provided next for those who may be considering the use of similar techniques.

The license-plate-matching approach was predicated on capturing numerical license plate data by photographic procedures; recording these data as a function of time at selected sampling points; matching the data at input and output locations along the arterial; and computing travel time samples based on these matches. Prior to the initiation of the field tests, the researchers discovered that using an 8-mm camera resulted in a legibility problem due to the combined effect of varying light levels, moving vehicles, image vibrations, and the angle at which license plates are mounted. The research team was unable to find a reasonable combination of camera parameters with which to reliably acquire data for the intended purpose. Detailed studies were made at camera speeds of 24 frames per second, and suitable resolution could not be achieved. The researchers concluded that acquisition of license plate data by use of 8-mm cameras and commercially available color film was impractical. Therefore, the planned use of this technique was abandoned before the actual field tests were initiated.

The aerial photography approach for travel time data collection utilized a fixed wing aircraft and 35-mm camera. The camera was capable of holding 250 frames, and interframe timing was accomplished with a 10-sec repetition rate. The camera system provided adequate image resolution to count cars in most picture frames; however, as a result of ceiling and visibility limitations, only 40 percent of the study area could be covered during each data collection period. This limitation significantly reduced the total sample size for each link below that originally planned. A second factor which reduced the sample size was the difficulty experienced in trying to maintain a prescribed flight pattern in a fixed wing aircraft. Although these two factors affected the test results, the data collected were considered adequate to draw some general comparisons to the data collected by the floating car technique.

The floating car technique was successfully executed and the researchers were able to obtain an adequate sample size for purposes of statistical testing. This approach was facilitated through the use of a digital data collection system, the Traffic Analysis (TA-1) System developed by Microtrans Associates, Inc., to collect the raw travel time data. This system enabled the researchers to obtain approximately 5 samples per link per day during each data collection period.

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The field data were evaluated to determine if signal control changes designed to provide a 5 percent change in traffic performance actually produced the desired effect and could be measured with acceptable accuracy. Tests conducted during the morning peak period showed a statistically significant increase of 5.6% in vehicle-miles per hour, as was expected. However, similar tests during the evening peak period showed an unexpected decrease of 3.5% in vehicle-miles per hour. This decrease was attributed to the traffic's inability, due to saturation flows, to keep pace with the progression speed resulting in increased stops and delay. These findings suggest that the data collection and analysis techniques are capable of measuring performance changes to the desired accuracy, but that extreme care must be exercised in determining whether the change is due to the signal control strategy being tested or to other factors.

The researchers found the vector analysis technique developed in Phase I to be straightforward to apply and easy to interpret through the use of relatively simple graphics which compare the "quality" and "quantity" of service as a number pair (i.e., vector). The vector analysis of the floating car field data indicated a statistically significant improvement in system performance in both the morning and evening periods as a result of increasing the progression speed by 5 percent.

APPLICATIONS

The use of vehicle-miles and vehicle-miles per hour as performance measures is fairly commonplace among traffic engineers, as is the use of the floating-car technique. Hence, the findings of this project do not suggest a major change from current practice. The research has confirmed that relatively small changes in traffic performance can be measured with reasonable accuracy and, therefore, greater reliance can be placed on comparisons of traffic control strategies having minor differences.

The research findings will have limited usefulness until the techniques are developed further. The description of the techniques and the results of the field studies presented in the final report provide a good basis for future work. To increase the usefulness of the findings of this research, the data collection and vector-analysis techniques should be applied to a more extensive street network. Also, gas consumption should be included as an additional MOE. The researchers recommended that a standard software package be developed to facilitate data analysis.

FINAL REPORT

The final report of this project will not be published in the regular NCHRP series. A microfiche copy of the agency's final report may be purchased from the TRB Publications Office, 2101 Constitution Avenue, N.W., Washington, D.C., 20418, for $3.50 prepaid; or a paper copy may be obtained, on a loan basis, by request to Mr. K. W. Henderson, Jr., Director, Cooperative Research Programs.