Tech Brief

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Evaluation of Adaptive Control Strategies for New Jersey Highways

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BACKGROUND

- The traffic engineering community has more than 30 years of experience with computer-controlled traffic signals. Many researchers addressed different aspects of these traffic adaptive signal control systems. The main driving force behind these efforts in the U.S. was the research sponsored by FHWA.
- The performance of various adaptive control strategies including SCOOT, SCATS, RHODES, OPAC, can widely vary depending on the location, traffic conditions, and network characteristics.
- Thus, Location, traffic conditions, and control strategy can all play a very important role in determining the success or failure of adaptive signal systems.
- NJDOT, and various other transportation agencies In New Jersey have been considering implementing traffic adaptive signal systems. Newark and Trenton are considering the installation of adaptive signal systems. Atlantic City and New Brunswick have already installed a system.

HERE'S THE PROBLEM

- It is clear that the Department of Transportation (DOT), counties and municipalities will continue to install traffic adaptive signal systems to alleviate some of the worsening traffic congestion problems in the State.
- However, it is not clear that these adaptive signal systems will provide extensive benefits that can justify the cost of installation and operations. There are four main factors that should be considered in assessing the effects of implementing adaptive signals namely:
  - Geometric Configuration of Signalized Intersections(s): It is now a well recognized fact that the benefits of upgrading an individual or series of signals can be different depending on the location of the individual signal in the network, as well as the location of adjacent signals with respect to that individual signal. Moreover, geometric characteristics such as lane configuration, lane widths, and approach angles play an important role in affecting the benefits of adaptive signal systems.

- Current and Projected Traffic Conditions: Current and projected traffic demand, the time-dependent fluctuations in traffic demand, saturation flows, current and projected levels of service, and other traffic related factors have a major effect on the performance of “adaptive signals”
- Transportation Corridor in which Traffic Signals are Located: Arterial roads work in tandem with freeways and other roads as part of a larger transportation corridor. In fact, the effect of an upgraded signal within a transportation corridor, where other traffic management infrastructure, such as, Variable Message Signs (VMS), Closed Circuit Television (CCTV), and Highway Advisory Radio (HAR) exist, has to be assessed to make an optimal selection regarding which intersections must be upgraded.
- Control Strategy: Another very important factor that directly affects the performance of the adaptive signals is the type of signal control algorithm used to change signal timing plans on-line in real-time. There are several adaptive signal control strategies that are in use today. OPAC, RT-TRACS, RHODES, SCOOT, and SCATS are some of the most widely used ones. Operational field studies showed that each of these control strategies work varyingly under various conditions and it is important to understand the root cause of these performance differences to be able to select the most suitable strategy

OBJECTIVES…

- Develop a computer-based decision support system (DSS) that takes into account the heuristic nature and inherent uncertainties associated with the above factors directly affecting the performance of these systems. This DSS is an integrated knowledge-based expert system, which combines expert system rules with simulation. The general functioning of the proposed approach for developing the DSS for evaluating adaptive traffic signal control systems is shown in Figure 1.

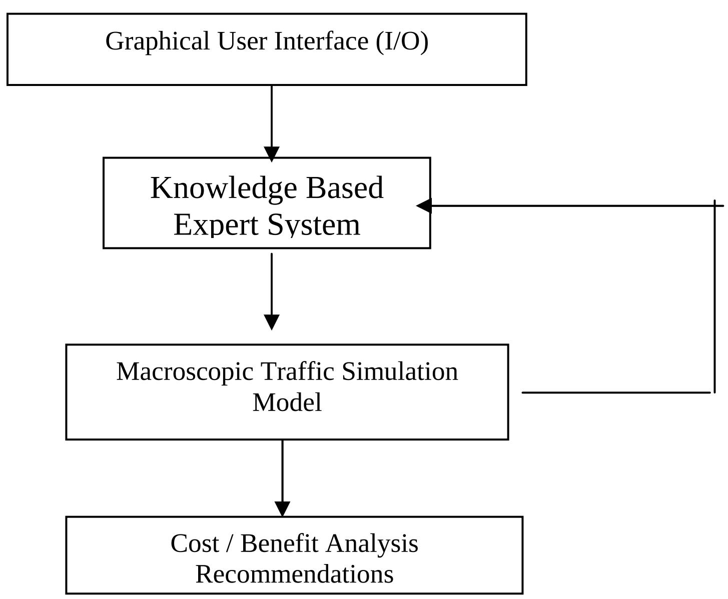


Figure 1 Implementation Architecture of the Proposed Decision Support System

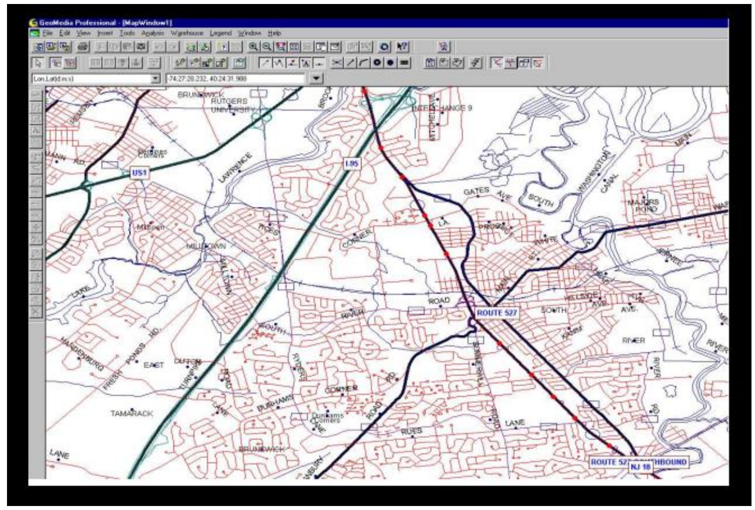
- Implement a computerized prototype DSS to be employed by NJDOT to prioritize this selection of best upgrade candidates in an efficient and methodical way. The efficient development and usage of the developed prototype DSS shall be ensured by:
  - Identifying the input needs of the developed DSS tool.
  - Assessing the availability of the input needs of this DSS tool in the NJDOT traffic signal inventory.
  - Developing a plan to update the current NJDOT signal inventory according to needs of the DSS tool.
  - Identifying most user-friendly graphical user interface, especially regarding input and output functions of the developed system.
  - Identifying the best outputs for the developed system i.e., providing the most informative yet well-organized output to the users. A plain list of selected intersections can be too simplistic. On the other hand, we propose a flexible output system that can create assessment reports of different complexity based on the requests of the user.

HERE IS WHAT WE DID…

- A comprehensive literature search of the papers and reports describing the effectiveness and impact of adaptive traffic signal control systems were conducted. This literature research was the first step in identifying the impact of different factors in the effectiveness of “adaptive traffic signal control systems”. Major attention was devoted to completed or on-going ITS field operational tests focused on adaptive signal systems. This is, in fact, a very important part of this research because there is a wealth of data and information available to better understand the operational aspects of adaptive traffic control systems. This literature search is not limited to the operational aspects of adaptive control strategies only, but it is also a review of the literature as related to expert systems, decision support systems, and traffic simulation.

- Then, using portions of the three arterials selected by NJDOT, namely, Route 10, Route 23, and Route 18, the attributes and contents of the current NJDOT traffic signal inventory is studied as applied to the development of the prototype DSS proposed for this project. After familiarization with this traffic database and signal inventory of NJDOT, a more general database model needed for this project is developed and implemented using GeoMedia Geographical Information System tool. This combined database contains Intersection infrastructure data such as intersection geometry and signal timings Static traffic data for the roads and intersection.

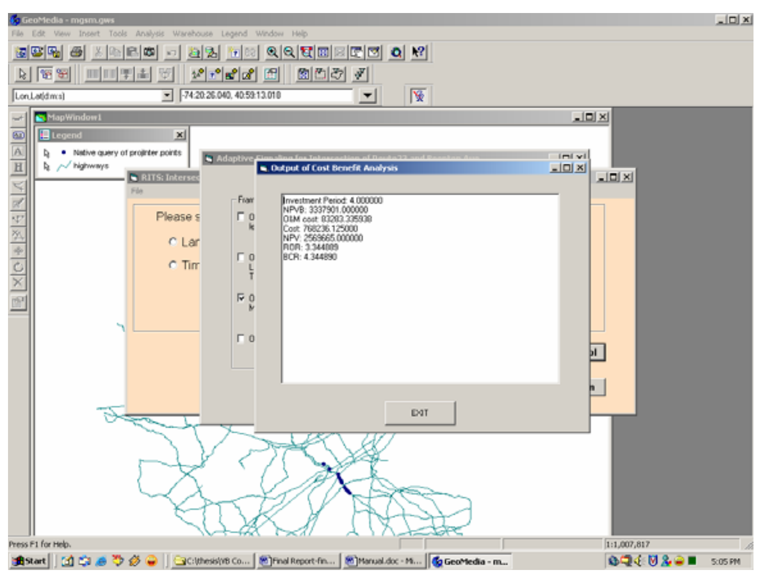
- Naturally, all this data is location based, i.e. geographical. Thus, the development of the database is done in the form of a GIS, which relates the traffic signal data with geographical information. The integration of a traditional traffic flow and signal database with GIS enables NJDOT to take full advantage of GIS functions such as advanced visualization tools, location-based search, efficient representation of the transportation network, integration of other infrastructure data such location of power and communication lines, right-of-way information with traffic signal data, and the ease of large data set manipulation in real-time including on-line traffic data. As part of this task, this database was implemented using GeoMedia Pro.



- After several meetings with NJDOT and as a result of an extensive literature review, the research team decided to focus on three of the most widely used and accepted control strategies, namely, OPAC, SCOOT, and SCATS.

- The integrated DSS model consists of 4 major modules :

  1. **Input–Output Module:** A GIS module allows the decision maker to focus on a certain area and select the study area from a detailed map. This module is fully integrated with SYNCHRO software package by allowing two data exchange.
  2. **Knowledge Based Expert Systems (KBES):** The DSS required in this project should be able to use both analytical and heuristic knowledge. The quite complex nature of deciding on the best individual or series of traffic intersections for the implementation of adaptive traffic control requires the use of a knowledge-based system that is different from a *traditional algorithmic approach*, which consists of “simple rules”. In fact an expert system is quite different from algorithmic approaches due to the fact that it uses the expert knowledge the way human experts make decisions.
  3. **Macroscopic Simulation Module:** KBES selects the best candidates for implementing one of the adaptive control strategies. However, the rules are often generic and more detailed analysis is always needed. To conduct this detailed analysis, a macroscopic simulation program that allows for the incorporation of adaptive signal control strategies such as OPAC, SCOOT, and SCATS. The macroscopic simulation module is basically used to determine the effectiveness of the adaptive control at a very detailed level. To ensure an interactive evaluation process, a macroscopic simulation approach to the modeling of three major adaptive control strategies studied in this



project was developed.

4. **Benefit-Cost Analysis:** A benefit-cost analysis module that determines costs and benefits of implementing the selected adaptive control strategy for the selected intersection is developed.

- Finally, a series of case studies for selected intersections from the database are conducted to evaluate the developed tool and to better understand various factors that affect the effectiveness of adaptive signal strategies for various traffic and network conditions. The report is concluded with a series of lessons learned and recommendations regarding the implementation of adaptive signal strategies and possible use of the developed prototype DSS tool.

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