Introduction

In the last decade, research in Intelligent Transportation Systems (ITS) has led to the development of various tools for the optimization of transportation systems. ITS has concentrated some of its efforts on the study of road traffic. Currently, several ITS technologies intended to achieve efficiency in the management of traffic operations are being developed. These technologies are based on complex software systems implemented in the Traffic Management Centers (TMCs). Advanced Traffic Management Systems (ATMSs) and Advanced Traveler Information Systems (ATISs) are the two main ITS technologies currently being developed. The use of both technologies in TMCs will lead to advanced traffic management with dynamic route guidance and traffic control in the future. However, the introduction of such diverse software systems poses difficult problems for issues of system integration, data communication, interfacing , and synchronization, among others. The study of these difficulties and the possible solutions is the basis of this work.

1.1 Dynamic Traffic Management Systems

Dynamic Traffic Management Systems (DTMSs) are designed to support the operations of TMCs. They are the latest generation of support systems and all internal operations are generally performed in a completely automated way. DTMS are dynamic: the management of the traffic network is based on proactive strategiesas opposed to reactive strategies. Predicted conditions constitute the basis upon which these proactive systems generate strategies. Predicted conditions are used to generate route guidance and traffic control.

There is a very strong coupling between traffic control and route guidance, both in the modeling level as well as the physical level. The modeling issues are partially reviewed in 1.4. The physical issues include communication networks, system interfaces, database management, etc.

1.2 TMC overview

A TMC consists of multiple ITS systems: some core systems (e.g. the Surveillance System), and some interfaced systems (e.g. a Route Guidance System). The core systems provide the basic set of functionality needed to operate a TMC (collecting surveillance data, controlling signals, and coordinating incident response). The core systems are usually legacy1 systems designed for a custom TMC. The TMC basic functionality is enhanced with the addition of interfaced systems (e.g. real-time adaptive traffic control, route guidance, etc.) The TMC must provide the necessary interfacing capabilities. Namely, the TMC must provide:

A system architecture that allows the integration of all systems. The architecture must encapsulate the custom nature of the TMC's core systems, so that any additional system can be easily plugged in.

1.2.1 Surveillance Systems

Traffic surveillance is an essential TMC system. Traffic information is collected using a variety of technologies: loop detectors, video detection, infrared sensors, vehicle probes, aerial surveillance, etc. The information is captured by the sensors, processed locally, and aggregated for transmission to the TMC. Regular scanning frequencies are 1/240s and broadcasting frequencies are in the order of 1 or 2 seconds.

1.2.2 Control Systems

One of the fundamental properties of a TMC is the capability for controlling a traffic network. Control may be centralized, distributed, or hierarchical. In a centralized environment, a central facility collects traffic status data and makes traffic control decisions. In a distributed environment, control is performed locally, generally at the intersection level. A hierarchical control configuration is a hybrid between central and distributed control. In this architecture, control is generally performed locally; control decisions are monitored by a central facility that may override local control to achieve optimized traffic flow on a sub-region basis.

Regardless of the specific architecture, the vision is for integrated, proactive control rather than reactive control. Proactive control requires the support of a prediction system. A wide range of options is available for the control, including realtime tr
adaptive signal control, adaptive freeway control including ramp metering, transit and emergency vehicle preferential treatment, and lane usage control.

1.2.3 Incident Management Systems

One of the primary goals of ITS is to reduce congestion. Since a significant portion of traffic congestion is due to traffic accidents and other incidents, a primary functional requirement of a TMC is the detection and management of incidents. Because of the importance of this function, it is generally treated separately, although it involves elements of surveillance, monitoring, control, and decision support.

Certain information processing capabilities are required for the TMC to provide incident management. These include: integrated data management, real-time traffic model execution, image processing for area-wide surveillance and incident detection, and man/machine interfaces providing transparent access to needed information.

1.2.4 Decision Support Systems

Decision Support Systems extend the TMC's traffic control capabilities to support the decisions operators at TMCs have to make. All of the traffic models and simulations used in the TMC reside in the Decision Support System. Online models are used for developing response strategies. They must execute faster than real-time so that their results can affect decision-making processes occurring in real-time.

FHWA (1993) interviewed the managers from the most important TMCs in the U.S. The requirements for Decision Support Systems that the managers suggested included the following:

" Expert systems to aid in incident detection and management.

" Access to traffic simulation models.

* Evaluation models to support route diversion and route guidance.

Thus, existing traffic simulation models are not used online for three.

1.2.5 Other Systems

ATMS is the core of ITS. As such, it is the integrating agent for both ITS and non-ITS systems. Within the TMC, interfaces are required to all other ITS systems including ATIS, APTS (Advanced Public Transportation Systems), CVO (Commercial Vehicle Operations) and AVCS (Automatic Vehicle Control Systems). Of these, the strongest coupling is between ATMS and ATIS. Centralized route guidance will require high

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1.2.6 Computing Environments

The typical TMC configuration uses a mini-computer (e.g., Concurrent, PerkinElmer, Modcomp) to operate the control system software, and a networked group of PCs to provide all other TMC functions. The dominance of PCs in the TMC primarily reflects the fact that historically PCs were cheaper than workstations. Additionally, much of the traffic engineering sofware was originally written under Microsoft's DOS. The prevalence of personal computers has created a de facto standard operating system in TMCs: MS-DOS. Many of the managers interviewed by FHWA (1993) expressed an interest in moving towards UNIX environments. Due to the date of this report, it is likely that the operating system conditions have changed. In fact, many TMCs are now updating their systems to UNIX platforms.