Integrating ITS Research Project Results into Engineering Curricula

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SECTION 1: INTRODUCTION

A number of factors have recently produced a need for new capabilities in the transportation profession. Increasing travel demands in urban and suburban areas have strained the capacity of existing roadways, while changing land-use patterns have challenged traditional public transportation systems. As traffic congestion has increased, the alleviation of congestion by building new roads has become impractical, due to considerations of cost and crowding in urban areas. Furthermore, energy consumption, noise, and air quality continue to be important factors. Meanwhile, new technologies in real-time communication and computing have made it possible to gather and analyze unprecedented quantities of information to better understand and deal with these factors.

These factors combine to hinder the physical expansion of our transportation systems, while giving us the opportunity to utilize existing networks more efficiently. We can accomplish this by improving our ability to monitor the status of the networks in real time, allowing us to recognize transient variations in congestion levels. Using Advanced Traveler Information Systems (ATIS) technology, we can then disseminate route guidance information to travelers in the network so that they can favor currently underused routes or modes of travel over currently overused or impeded modes of travel. Efforts are also underway to design and implement Advanced Public Transportation Systems (APTS) to improve overall mobility, accessibility, mode choice, and intermodal transfer. An essential complement to ATIS and APTS is Advanced Traffic Management Systems (ATMS), which focuses on real-time control of variable elements of the transportation system itself. Existing applications of ATMS include adaptive traffic signal control and freeway ramp metering, which seek to balance access to a merge or intersection point by its various approaches. Another inherently dynamic aspect of ATMS concerns reducing the severity of non-recurring congestion caused by incidents which may affect the capacity of individual transportation links.

For ATMS and ATIS applications to succeed, we must also study the interaction between the traveler and the transportation system. In order to choose from among alternative ATIS and ATMS policies, we must be able to understand and evaluate their effects. This depends fundamentally on an understanding of how individual travelers choose among their own travel options, with regard to both mode choice (e.g., train vs. car) and route choice (e.g., freeway vs. arterial), and on knowledge of how people will react to new forms of information provision.

In a three-year project initiated in February 1996 under the NSF Combined Research and Curriculum Development (CRCD) program, we are building on the prior and ongoing research of team members in these advanced technology areas, which are generally placed under the rubric of Intelligent Transportation Systems (ITS) research. We are integrating knowledge, concepts, and results from our past and ongoing ITS research into existing and new courses in the University's College of Engineering, primarily in the Transportation Program of the Department of Civil and Environmental Engineering, in order to prepare students at the undergraduate degree level to help plan, design, operate, and evaluate ITS systems, while also teaching students at the graduate level to participate in system development and ITS research. The Transportation Program has been in place for more than 25 years and includes four transportation faculty members and some seven support faculty from other disciplines including electrical engineering, operations research, human factors, computer science, regional planning, and management.

SECTION 2: PROGRAM RESEARCH COMPONENT

Section 2.1: Past and current research supporting the project

Key personnel of the project have participated in past and current research and application projects which provide a knowledge base to be integrated into the University's transportation curriculum. The course descriptions in the Curriculum Development section, below, refer to the research projects from the list given here, to further indicate how these projects support the program.

Past and current ITS research topics and projects of key personnel include:

Large-Scale Implementation and Testing of ATIS

This project developed real-time travel time and incident detection techniques and analyzed route choice and traveler behavior in response to in-vehicle ATIS for the Chicago-area ADVANCE project, the world's largest ATIS field experiment to date.

Travel Behavior Analysis

This study seeks mathematical models which can predict the aggregate behavior of a population of travelers using disaggregate modeling techniques. The models must relate objective measures (e.g., expected travel time, reliability) and possibly subjective measures (e.g., perceived reliability, comfort) of various modes of travel (e.g. car, train, bus) to the share of the population which chooses each mode, in conformance to data obtained from survey and system usage data.

Evaluation of ATIS through GPS/Cellphone Technology

This project, undertaken in cooperation with NYNEX, studies the effect of information dissemination. The study topics include ergonomic issues of traffic management center personnel and traveler perception, behavior analysis of travel decision-making, and institutional factors affecting the information to be provided.

Use of Automatic Vehicle Location (AVL) technology for Paratransit Dispatching

Public and commercial vehicle fleets can be subject to unpredictable demands for travel, as in the case of services like Dial-A-Ride for public transit, which has taken on new importance due to the expansion of special services in accordance with federal regulations concerning the

Americans with Disabilities Act (ADA). AVL technology enables the central system to more efficiently allocate new calls for service among the vehicles already in service in the network. This project includes the evaluation of a paratransit project in Winston-Salem, North Carolina.

Advanced Incident Management Strategies

This USDOT/University Transportation Center Project involves the assessment of mobile telephony and other advanced technologies to assist in the detection, verification, and clearance of incidents and accidents on freeways and other major highways.

Video and Optical Technologies in Traffic Data Acquisition

The aim of this research, funded by USDOT and the Massachusetts Highway Department, has been to assess the use of advanced video and optical equipment in conjunction with image processing techniques to capture, store, and analyze vehicular traffic data.

Electronic Payment Systems

Advanced toll and fare systems with the use of magnetic stripe and smart card applications are being evaluated in five cities (New York, Chicago, San Francisco, Seattle, and Boston). This work is being done in collaboration with the USDOT Volpe Center and will lead to the design of a national workshop.

In-Vehicle Evaluation of Driver Response

Under major support from NSF and industry, Project MIDAS employs a state-of-the-art audiovisual driving simulator to observe driver reactions in an actual automobile. The project will study driver reaction in realistic situations, including eye-tracking and response to acoustic stimuli.

Dynamic Traffic Assignment

Real-time ATIS and ATMS rely on measurements of current conditions and forecasts of future conditions. This study seeks to formulate mathematical models and techniques for assigning to the links of the network the flows resulting from dynamic travel demands and capacities, particularly those caused by unforeseen incidents.

Dynamic Link Travel Time Prediction

Classical traffic science provides models which relate traffic flow rates and link travel times to traffic volumes, under the assumption of static conditions. Under support from the University of Massachusetts, this study seeks to create new inherently dynamic models which will, without resorting to microscopic simulation, predict link travel times from time-varying profiles of recent link usage.

Travel Time Observation via Video Acquisition of License Plate Data

In trials designed by the Volpe National Transportation Systems Center and carried out by metropolitan planning organizations in Boston, Seattle, and Lexington, Kentucky, manual and machine vision methods were evaluated for use in matching license plates from video taken at staggered locations along a route, in order to measure travel times.

Section 2.2: Continuing and future program research

In addition to continuing the research described above, the establishment of this CRCD project facilitates interdisciplinary research among departments on campus in concert with the mission of the University of Massachusetts Transportation Center, a five-campus university system unit. ITS research is inherently interdisciplinary, because of the strong interactions of differing topics on ITS system design, management, and evaluation.

The ITS laboratory facility (described in more detail in another part of this report), while being a vital part of the educational component, will also enable new research applications. The lab will integrate computational and video display capabilities with real traffic and transport data acquired both through previous projects and from connections to be installed to real-time surveillance systems.

It will therefore be possible to test strategies for ITS management and evaluation on-site, contributing a vital practicality to the ITS research field.

SECTION 3: CURRICULUM DEVELOPMENT

Our curriculum plan is intended to prepare students receiving engineering undergraduate degrees, particularly those interested in transportation and ITS systems, to help plan, design, operate, and evaluate ITS systems to be installed or maintained. We further intend to offer civil and other engineering graduate students, as well as graduate students in regional planning, management, and other programs, the opportunity to take courses in system operation and design, to participate actively in our research activities, and to become leaders in the ITS field as operators, evaluators, and educators.

Section 3.1: Place in degree programs

Undergraduates working toward degrees in civil engineering are required to take 132 credits, including four 3-credit technical electives to be chosen from the College of Engineering offerings at large. By choosing from the six courses described below (three to be revised and three to be created), students may acquire basic knowledge in the ITS area and prepare themselves for opportunities in the transportation profession. For example, students interested in day-to-day operations might select CE510, CE511, IE590, and CE590A. Students more interested in public policy and system evaluation might choose CE511, CE516, CE590A, and CE590B.

These courses will also fulfill technical elective requirements for undergraduates in industrial engineering and other College of Engineering departments, and serve as electives for students in other programs, in support of student interests in modern transportation systems.

In addition, the courses will also serve as electives for graduate students, in support of individually designed programs and in accordance with the various departmental graduate program requirements at the M.S. and Ph.D. levels.

Section 3.2: Course revision and creation

We are revising three existing courses taught at the 500 level for senior undergraduates and graduate students in the Department of Civil and Environmental Engineering and for such students in other engineering and non-engineering departments who have an interest in advanced transportation systems. These courses will maintain coverage of fundamental concepts, principles, and topics in transportation science and engineering while incorporating new interdisciplinary material drawn from mathematical modeling, ergonomics, and economics. As stressed in the USDOT IVHS Staffing and Education Study by the Urban Institute, it is extremely important to offer such courses to civil engineering students as well as students in other fields and to emphasize fundamental concepts within the ITS area. The courses are:

CE 516: Transportation Design

A large-scale ITS system with ATIS and ATMS components may substantially alter the travel patterns on a regional basis, tending to create new areas of heavy or highly variable traffic flow. We will take up the new challenges posed as a result in the management of land use, energy consumption, environmental effects, and community impacts, drawing on results from current work in advanced traffic data collection and traffic incident management.

CE 510: Public Transportation Systems

This course will be extended to cover new APTS opportunities presented by real-time data collection in the management of public transport. Topics include dynamic information gathering and dissemination (cf. AVL project) to aid in traveler mode choice and trip scheduling, and flexible scheduling of fixed- and variable-route public transit services and automated fare collection.

CE 511: Transportation Engineering

New material will focus on new methods of planning, design, and operations which may be associated with the implementation of ITS technology and real-time data collection to address recurring and non-recurring congestion (cf. research in travel behavior analysis and discrete event systems).

In addition, we will develop three new courses which deal with the fundamentally novel aspects of ITS:

CE 590A: ITS Technologies

This course will be a foundation to the rest of the educational program, familiarizing students with new technologies which impact the ITS field and preparing them for further studies in use of these technologies. The course will cover past work with NYNEX, the ADVANCE project, the New England Transportation Consortium, and the paratransit AVL project in Winston-Salem, NC.

IE 590: Dynamic Traffic Modeling and Management

We will emphasize forecasting and control of traffic systems which may experience rapidly changing conditions due to variations in travel demands and capacities. The course will be based in methods from industrial engineering and operations research, including mathematical programming models, continuous and discrete optimization methods, and human factors engineering. Ongoing research in dynamic route guidance and traffic assignment will contribute to the course.

CE 590B: Measurement and Evaluation of ITS System Performance

A thorough understanding of the possible interactions between new ITS system components and their environments will facilitate measurement of the effects of existing systems and assessment of potential effects of proposed implementations. The course will combine traditional topics of public-sector analysis and economic decision making from the fields of civil and industrial engineering with ITS-specific material including research on APTS evaluation at the Volpe Center, on ADVANCE, and on FASTTRAC.

SECTION 4: TRAFFIC MANAGEMENT LABORATORY

Perhaps the most significant component of our instructional program is the creation of a computing laboratory in which students would gain hands-on experience in performing tasks of ITS design, management, operations, and evaluation. As reported in the USDOT IVHS Staffing and Education Study produced by the Urban Institute, the U.S. lacks laboratory facilities dedicated to ITS education.

Section 4.1: Laboratory organization

The ITS laboratory will support four main functional areas in ITS. Physically, the laboratory will include four Pentium-class computing workstations. Some workstations will be dedicated to one of the functional areas, while other activities will be supported on all machines when practical, by connections to a central software server.

In addition, the ITS laboratory will operate in concert with a number of external resources for transportation data acquisition and technological contributions from government and industry ITS practitioners. While the inherently interdisciplinary nature of ITS research and practice will blur the distinctions among the four functional areas, we can classify these resources and contributions by the functional area they most strongly support (see Table 1 for a summary):

Advanced Public Transportation Systems (APTS)

This activity will employ Geographic Information Systems (GIS) software and research experience with AVL and GPS technology, in cooperation with the Pioneer Valley Transportation Authority (PVTA) and the University of Massachusetts Transportation System (UMTS).

Automated Vehicle Control Systems (AVCS)

This area will focus on evaluating throttle changes and/or braking either by automatic control or through signals to the driver. Testing of both automatic control algorithms and vehicle control warnings to the driver will employ the Project MIDAS driving simulator, and has interested industrial participants including Peter Pan Bus Lines (testing of AVC safety equipment on passenger buses) and Millitech (design of proximity detectors).

Advanced Traveler Information Systems (ATIS)

This area will investigate travelers' dynamic decision-making process and responses to real-time dynamic route guidance. One form of route guidance to be incorporated for evaluation of message content is an FM subcarrier information system for text messages and digital

Functional Area	Principal Faculty	Principal Field	Associated Resources	Govt./Industrial Participants
APTS	Collura, Shuldiner	Civil Engineering	AVL, GPS, GIS	Pioneer Valley Transp. Authority; UMass Transp. Sys.
AVCS	Fisher	Human Factors Eng.	Promixity sensors, driving simulator	Millitech Corp.; Peter Pan Bus Lines
ATIS	Bhat	Civil Engineering	FM Subcarrier decoder, driving simulator	MITRE Corp.
ATMS	Kaufman, Zazanis	Industrial Engineering/ Operations Research	Fiber-optic data links, video data storage	Mass. Turnpike Auth.; Mass. Hwy. Dept.

Table 1: Functional organization of ITS Laboratory, including external resources and participants

information, under development by MITRE Corporation. ATIS activities will also make extensive use of the Project MIDAS driving simulator.

Advanced Traffic Management Systems (ATMS)

This area includes the synthesis of historical and real-time traffic data to assess current and forecast conditions and generate traffic control policies and route guidance policies. This activity will use data gathered over fiber-optic links carrying data from the Massachusetts Turnpike Authority (I-90) and the Massachusetts Highway Department (Mass. Rte. 9) to the UMass-Amherst campus, and when possible, real-time data sources offering transportation information to the public through national information networks (for example, see the highway congestion data offered by the California Department of Transportation on Internet at World Wide Web address <http://www.scubed.com/caltrans/>. We will employ a magnetic-optical video data storage and retrieval system to support efficient laboratory access to archived traffic video.

Section 4.2: Laboratory exercises

To more fully illustrate the role of the ITS laboratory in this CRCD program, we now describe some sample exercises which students could undertake using ITS laboratory facilities. These exercises demonstrate the integration of recent ITS research into the educational experience. The exercises tend to apply a single functional area to more than one course, or to combine activities from multiple functional areas, illustrating the interdisciplinary nature of the program.

APTS

Exercise: On-time Bus Performance Analysis.

As part of the Public Transportation Systems course, students will examine the on-time performance of selected fixed route-fixed scheduled bus services along major corridors in the five-college area. Route location, clock times and other data will be captured with a land-based AVL system currently being procured by PVTA. The data will be analyzed by students in the ITS laboratory using either PC-based statistical software or AVL proprietary software procured by PVTA. Results will be displayed graphically and tabularly and the operational implications of these results will be discussed.

Exercise: Evaluating Automated Fare Collection (AFC) Systems.

In the course on Measurement and Evaluation of ITS System Performance, students will evaluate the use of AFC systems, considering the fixed and variable costs of AFC alternatives including smart cards, magnetic stripe, and conventional technologies. In addition, consistent with USDOT/FTA guidelines, other quantitative and qualitative criteria and associated data will be utilized to assess other costs and the benefits related to the various AFC alternatives. Life cycle cost analysis will be used to the extent possible. A special effort will be made to impress upon the students the need to examine the institutional, administrative, legal, and privacy issues associated with such AFC applications.

AVCS

Exercise: Effects of Collision Warning Systems.

Students will use our state- of-the-art driving simulator to analyze a number of different aspects of the interface between AVC systems and the driver. These aspects include: (a) the effects of variations in the parameters used to activate collision warning systems on driver acceptance and accident rates; (b) the effects of variations in the parameters used to set system authority limits for intelligent cruise control (ICC) systems (i.e., the limits for acceleration, deceleration, minimum headway and minimum speed for operation) on driver acceptance and throughput; (c) the effects of variations in the level of coupling between subject and lead vehicle on driver acceptance and throughput; (d) the effect of different strategies for entering and exiting automated highway systems on driver acceptance; and (e) the effect of different heads-up displays of the roadway on drivers' ability to maneuver when AVC systems fail. General techniques students will learn include: (a) programming different roadway scenarios; (b) programming different auditory and visual interfaces; and (c) measuring critical driver responses and acceptance.

ATMS

Exercise: Dynamic Travel Time Measurement and Analysis.

As part of the ITS Technologies course, students would employ manual and image recognition methods to recognize license plates from video records of traffic, measuring link travel times under varying conditions by matching license plates passing a series of video recording locations. Students will compare recognition methods on criteria of statistical quality and quantity and computational and labor requirements, taking into account visibility conditions as affected by factors including time of day and weather.

Exercise: Calibration of Dynamic Link Impedance Models.

In the Dynamic Traffic Modeling and Management course, students would construct mathematical models predicting link travel times from time-varying travel demands. The parameters of these models would be calibrated to match the results of video and optical data analysis using statistical methods and numerical optimization techniques. The resulting dynamic link impedance models can be employed in dynamic equilibrium models and macroscopic simulation models of the traffic system.

ATIS

Exercise: Traveler Compliance with Dynamic Route Guidance.

Students will be provided with data from a sample of about 200 drivers each making about 20 runs (including baseline runs where drivers receive no route guidance) in the driving simulator on an encoding of the Amherst area. Data collected will include route guidance provided, route chosen, driver compliance, characteristics of the simulated trip, and socio-demographic data concerning the driver. Students will employ this data to assess the effects of personal, traffic, and system design factors on traveler route choice and diversion choice behavior using methods such as dynamic discrete choice modeling and conjoint analysis. Patterns of changes in behavior across simulation runs for each individual will be carefully examined by the students using contrast analyses to identify differences in traveler behavior resulting from exposure to and use of the ATIS system components.

SECTION 5: PROJECT EVALUATION AND DISSEMINATION

Our CRCD program will maintain reviews of program quality, with attention to making a national impact on ITS education and practice, as we now detail.

Section 5.1: Project evaluation

Our curriculum will be judged by its ability to prepare undergraduate students to participate in the planning, design, and operation of ITS systems and advanced transport management in the public sector. A successful curriculum design will also permit graduate students to participate in ITS operation and traffic management activities, and to contribute to ongoing academic and applied research and perhaps become educators in the field.

Our ongoing evaluation will include the following components:

Standard course evaluations: Students will evaluate each course affected by this program at the time of course completion, on measures of interest, teaching quality, and enhancement of skills.

Post-graduation surveys: Students, and their employers when possible, will be questioned six to twelve months after earning their degrees and taking a position in the transportation profession, to assess the contribution made by the enhanced ITS curriculum as preparation for the U.S. transportation profession.

Professional review committee: We will convene a committee of about six transportation professionals, who will review curriculum and research materials created under the CRCD program for quality and applicability to technical, operational, and institutional issues in ITS. The committee includes the chief ITS engineers from the Department of Transportation of Massachusetts, and of at least one other state. Other committee members will be representatives of industrial firms with expertise in ITS infrastructure, and leading academic members of the ITS committee (not associated with UMass).

Publication: We will publish research results in refereed academic journals. We will also publish articles on ITS practice in refereed publications on transportation practice. The refereeing process will therefore provide us with a broadly-based assessment from our peers in the transportation field.

Section 5.2: Project dissemination

We will also act to ensure that NSF support of ITS activities at UMass enhances national capabilities to meet the vital need for improved transportation capacity and quality, as follows:

Exercise manual: We will compile the laboratory and computational exercises created for the curriculum program into a manual, to be made available publicly to support hands-on ITS education and training at other institutions. The manual would include transportation data sufficient to support a complete application of the exercise, provided either on disk or by Internet.

Professional conferences: Educational materials and research results will be publicized by participation in meetings of professional organizations such as the Transportation Research Board and ITS America.

Journal publication: As discussed under Project Evaluation.

Distance learning: Initiated in 1974, the UMass Video Instructional Program (VIP) expands the membership of full-credit on-campus courses by distributing videotapes of on-campus lectures and facilitating communication between faculty and off-site students. In addition, as a charter member of the National Technological University (NTU) in 1984, VIP broadcasts course video and audio to remote industrial sites live, with real-time audio feedback from off-campus students. In fiscal 1993, VIP broadcast 800 hours and shipped nearly 18,000 videotapes to 1206 students at 240 industrial sites in 40 states.

We will attempt to establish a market for courses affected by the CRCD program among transportation students and professionals throughout the U.S. Should such a market exist, project dissemination via VIP would be self-supporting through enrollment fees. In addition, discussions have been initiated with NTU officials to explore the possibility of including ITS-related courses as part of the NTU program.

BIOGRAPHICAL INFORMATION

JOHN COLLURA, Professor of Civil and Environmental Engineering at the University of Massachusetts, directs the University's Transportation Engineering program. He has served as an ITS America Distinguished Scholar with the Autostrade, Italy's largest toll road agency. His research has been instrumental in the development of evaluation guidelines to assess advanced public transportation operational tests and in the assessment of implementation issues encountered in the design and installation of electronic payments systems on U.S. transit systems.

DAVID E. KAUFMAN, Assistant Professor of Mechanical and Industrial Engineering at the University of Massachusetts, teaches in the Industrial Engineering/Operations Research area. He conducts research into the dynamic aspects of route guidance and traffic modeling and management. He also investigates the theory and application of random search algorithms for global optimization of continuous-parameter productive systems.