Applications of Advanced Technologies in Transportation Engineering

Chris T. Hendrickson, M.ASCE

Abstract: Since the initial “Applications of Advanced Technologies in Transportation Engineering” conference in 1989, numerous examples of advanced technology applications have appeared. The need for such applications has grown, especially with continuing economic development and new social goals such as sustainability. Fortunately, a variety of new and promising technologies are available for application.

DOI: 10.1061/(ASCE)0733-947X(2004)130:3(272)

CE Database subject headings: Transportation; Technology; Infrastructure; Transportation engineering.

Introduction

It is a pleasure to present this Twelfth Francis C. Turner Lecture at the Seventh International Symposium on the Application of Advanced Technologies in Transportation Engineering. I would like to take the opportunity to reflect on this conference series, as well as on the general question of the importance of new technologies in the transportation engineering field.

Applications of “Advanced Technologies in Transportation Engineering” Conference Series

The “Applications of Advanced Technologies in Transportation Engineering” (AATTE) conference series originated at Harbor Island, San Diego, in 1989 with Kumares Sinha as the conference chair. This was an opportune time to consider new technologies for transportation engineering. A variety of new technologies were becoming sufficiently mature to allow some significant new initiatives for transportation engineering.

Most of the basic technologies applied for transportation had been developed in the first half of the twentieth century if not earlier (Hendrickson 1996). Electric street cars had only incremental evolution to become the light rail transit systems of the late twentieth century. Subway systems are still in use from the earlier twentieth century in areas such as Boston and New York City, while new systems as in San Francisco or Washington are immediately recognizable as close cousins. The internal combustion engine became the norm for motor vehicles in this period, while diesel locomotives replaced the venerable steam locomotives for trains. Walking and bicycling continue to be the preferred means of nonmotorized transportation. Freight containers were invented in the 1930s.

By 1989, some promising new technologies were becoming available. Global positioning systems for location provided a new means for much better management of vehicles in transit as part of automatic vehicle location and control systems. Computers had become much more prevalent, especially with the advent of the IBM personal computer (IBM 5150) in 1981 (IBM 2003). Software systems were improving rapidly to take advantage of the new computer hardware. Alternative propulsion systems were under active investigation, including electric vehicles and magnetic levitation.

The transportation engineering community was eager to investigate these new technologies. The first AATTE conference was cosponsored by ASCE, CALTRANS, Transportation Research Board, and the U.S. Department of Transportation. The initial plan was to solicit 50 presentations. The response to the call for papers was so large that 132 presentations were scheduled, including six tutorial sessions reflecting the need for retraining and continuing education.

Topics in the 1989 conference included (Hendrickson and Sinha 1989):

- Knowledge-based expert systems (software emulating human decision making). Typical applications were for work zone design, traffic control, and project scheduling.
- Vehicular navigation, control, and location, including use of global position system (GPS), in-vehicle information systems, and automatic vehicle identification.
- Computer-aided planning and design, including weigh-in-motion systems and evacuation planning due to catastrophes such as hurricanes.
- Robotic system and automation, including applications to subway car cleaning and automated highways.
- Real-time traffic systems for traffic signals and motor vehicles.
- Artificial vision and image processing. Typical applications

1This paper is derived from the Twelfth Francis C. Turner Lecture presented at the 7th International Conference on the Applications of Advanced Technologies in Transportation Engineering, August 8, 2002, Cambridge, Mass.

2Duquesne Light Professor of Engineering and Head, Dept. of Civil and Environmental Engineering, Carnegie Mellon Univ., Pittsburgh, PA 15213. E-mail: cth@cmu.edu

3Note. Discussion open until October 1, 2004. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on February 5, 2004; approved on February 5, 2004. This paper is part of the Journal of Transportation Engineering, Vol. 130, No. 3, May 1, 2004. ©ASCE, ISSN 0733-947X/2004/3-272–273/$18.00.
included pavement distress assessment, traffic volume estimation, motor vehicle type identification, wheel wear, and video photologging.

This set of topics ranges widely over the transportation engineering field, involving multiple modes, fixed infrastructure, and moving vehicles. Proceedings for the other conferences are also available (Stephanedes and Sinha 1991; Hendrickson and Sinha 1993; Stephanides and Filippi 1996; Hendrickson and Ritchie 1998; Cheu et al. 2000; Wang 2002). The Eighth International AATT conference will be held in Beijing in 2004.

### Challenges and Opportunities

Since 1989 and the initiation of the AATT conference series, there has been a continuing introduction of new technology for transportation. The effect of Moore’s Law of increasing chip complexity and reduced cost has led to more powerful and smaller computers, enabling more extensive modeling, control, and automation. Table 1 shows the growth in the numbers of transistors on selected processors from 1971 to 2000. Networking has been enabled within motor vehicles and at the global level, leading to much improved information exchange, sensing, and dispersed teams. Vehicles have seen dramatic changes, with rapidly increasing numbers of on-board microprocessors, better reliability, improved safety, and reduced emissions. New technologies in bioengineering and nano-scale devices are emerging and may become important for transportation applications.

During the same period, the need for innovation has increased. World population is expected to grow substantially in the next 50 years, with fundamental needs for more infrastructure. Huge conurbations are emerging around the globe. Terrorist activity and extreme weather events have focused attention on infrastructure vulnerabilities and security needs, leading to new objectives for survivability and self-repair.

Sustainability has also emerged as a major social goal for transportation (Sinha 2003). Many argue that consumption exceeds replenishment throughout the global environment, with our stocks of natural resources such as fisheries and petroleum diminishing. We need to find ways for cost effective reuse of materials and new technologies for energy and manufacturing. We are in a race among limited resources, expanding needs, and technology development.

To achieve these goals, transportation must change. We need more service with less resource use. Some new technologies provide possibilities for such improvements:

- Hybrid gas-electric and diesel-electric vehicles are an example of the possibility for substantial gains in energy efficiency, albeit with a substantial cost in additional batteries and control equipment. We need new technology to improve this type of vehicle.
- Alternative fuels such as ethanol from poplar trees or switch grass may become attractive with new processing technologies.
- Ubiquitous computing and sensing provides an opportunity for major changes in the efficiency of traffic management and vehicle control. Microelectronic-mechanical systems (MEMS) provide an opportunity for low-cost instrumentation and improved control for infrastructure and vehicles.
- Wireless networking can be cheaper and less energy intensive than conventional network communications. With large amounts of transportation infrastructure to manage, wireless communications can be attractive.
- Designing systems to be more robust or easier to repair can have ancillary benefits. For example, energy efficient light emitting diode (LED) traffic signals with battery backup could be cheaper over their life cycle and avoid power outage problems.

Implementing new technologies continues to be a major challenge in transportation. Organizational changes are needed. Some transport agencies do not have direct incentives or an appropriate culture to seek more cost-effective alternatives. Design/build/operate and public/private partnering should become more widespread in the next decades. A consistent life-cycle viewpoint for design and decision making would be helpful, especially in choosing options that are more technologically advanced, which will have life-cycle payoffs.

### Conclusions

Considering the history of the “Applications of Advanced Technology in Transportation” conference, new technologies can have transformational effects on the transportation field. Drivers for such changes are goals for mobility, accommodating population changes, efficiency, sustainability, and global competitiveness. The scope for application of advanced technologies is increasing over time.

### References


<table>
<thead>
<tr>
<th>Intel processor</th>
<th>Year of introduction</th>
<th>Transistors</th>
<th>Log transistors</th>
</tr>
</thead>
<tbody>
<tr>
<td>4004</td>
<td>1971</td>
<td>2,250</td>
<td>3.35</td>
</tr>
<tr>
<td>8008</td>
<td>1972</td>
<td>2,500</td>
<td>3.40</td>
</tr>
<tr>
<td>8080</td>
<td>1974</td>
<td>5,000</td>
<td>3.70</td>
</tr>
<tr>
<td>8086</td>
<td>1978</td>
<td>29,000</td>
<td>4.46</td>
</tr>
<tr>
<td>286</td>
<td>1982</td>
<td>120,000</td>
<td>5.08</td>
</tr>
<tr>
<td>386</td>
<td>1985</td>
<td>275,000</td>
<td>5.44</td>
</tr>
<tr>
<td>486</td>
<td>1989</td>
<td>1,180,000</td>
<td>6.07</td>
</tr>
<tr>
<td>Pentium I</td>
<td>1993</td>
<td>3,100,000</td>
<td>6.49</td>
</tr>
<tr>
<td>Pentium II</td>
<td>1997</td>
<td>7,500,000</td>
<td>6.88</td>
</tr>
<tr>
<td>Pentium III</td>
<td>1999</td>
<td>24,000,000</td>
<td>7.38</td>
</tr>
<tr>
<td>Pentium 4</td>
<td>2000</td>
<td>42,000,000</td>
<td>7.62</td>
</tr>
</tbody>
</table>