
CHAPTER 21

Intelligent Transport Systems

In recent years there have been major efforts throughout the developed world to apply our new technological capabilities in computing, sensing, and communication to improve road transport. The effort in the United States has been dubbed the intelligent transportation system program.

—WILLIAM L. GARRISON AND JERRY D. WARD (2000)

Initially there was an Intelligent Vehicle Highway Systems (IVHS) program, but that gave way to intelligent transport systems with the recognition that perhaps ITS technology might be applicable also to transport modes other than highways and motor vehicles. We now have clusters of technology that focus on selected problem areas. This chapter reviews some of the technology developed in this area within the context of sustainable transport.

The Transportation Research Board defines Intelligent Vehicle Highway Systems as “the application of advanced information processing and communications, sensing, and control technologies to surface transportation,” noting that the objective is “to promote more efficient use of the existing highway and transportation network, increase safety and mobility, and decrease the environmental costs of travel” (TRB, 1993, p. 5). Several of the problems with sustainable transport are problems that can be resolved by IVHS or, more recently, ITS. This chapter surveys the broad areas where ITS is being applied, provides illustrations of these applications, and then evaluates its relative success in solving some of the problems of transport sustainability.

Reasons for moving in this technological direction rest on the belief that the current transport system is about as large as it is going to get, particularly in urban areas. If you accept that premise then in order to improve the flow of traffic, reduce

congestion, and increase safety we must be able to communicate more with the driver than is possible with the occasional passive road sign. In other words, we need to increase efficiency.

ITS TECHNOLOGIES

In general there are six recognized areas of ITS activity. The first set of three is primarily technology-oriented, while the second set is applications-oriented. The technology areas are examined first below.

Advanced Traffic Management Systems (ATMS)

The ATMS area includes technologies designed to monitor, control, and manage traffic flow on streets and highways. Examples of such systems include centralized traffic control facilities that monitor traffic at critical sites throughout the urban area and control congestion using ramps, signals, and other devices to these ends; message boards that convey information to drivers regarding traffic conditions and alternate routing; priority routing for emergency vehicles; programmable directional traffic control systems; and automatic systems for dispatching tow, service, and emergency vehicles to crash sites. These are already well established in certain urban areas, featuring interactive traffic signals that can change in response to the specific levels of traffic or even individual disabled vehicles in an intersection, as opposed to a signal on a timer.

Advanced Traveler Information Systems (ATIS)

ATIS includes technologies that are useful to travelers in planning as well as related to improving the convenience and efficiency of travel. Examples of this technology within the vehicle might include onboard map displays that feature roadway signs intended to communicate information to the driver, systems to interpret digital traffic data, and driving hazard systems that report on road conditions. Outside the vehicle, trip planning services and route and headway information for public transit services are the most common functions provided.

Advanced Vehicle Control Systems (AVCS)

AVC systems are intended to assist drivers in controlling their vehicles, relieving them of certain tasks through use of various electronic, mechanical, or communication devices. These may be in the vehicle or on the roadway.

This area is perhaps more advanced in people's minds than it is in real operations. Included here would be systems referred to as adaptive cruise control, which slows cruise-controlled vehicles if they get too close to other vehicles; systems to enhance viewer vision at night or during storm events; systems that warn the driver

when the vehicle has left its lane; systems (often called collision avoidance systems) that prevent vehicles from running into one another; and automated highway systems that control vehicle movement in certain lanes thus increasing highway capacity and safety.

ITS APPLICATION AREAS

The specific application areas for ITS are generally organized around three activities or types of systems, namely, advanced public transportation systems, commercial vehicle operations, and advanced rural transportation systems.

Advanced Public Transportation Systems (APTS)

The APTS area uses advanced technologies to improve the attractiveness and economics of public transit operations. These technologies, which affect both vehicles and drivers, aid in coordinating operations and making better information available to system users. Examples of this technology include fleet monitoring systems, dispatching systems, onboard displays, real-time displays at transit stops, intelligent fare collection systems, and ride share and high-occupancy-vehicle databases and information systems.

Commercial Vehicle Operations (CVO)

CVO applications are intended to assist the operations of commercial vehicles, whether on land or sea (e.g., motor carriers, buses, or ships). Applications in these areas generally replace activities that may interfere with the flow of commercial vehicles through the reduction of administrative barriers. Among the functions served are toll collections, vehicle weighing, permit acquisition, and the like. Notable activities in these areas include weigh-in-motion systems, electronic placards and bills of lading, automatic vehicle location systems (most of which use global positioning systems), and communications systems installed vehicles that enable them to communicate directly with central dispatchers.

Advanced Rural Transportation Systems (ARTS)

These systems are generally implemented in rural areas, which because of their lower population densities and lesser transport demand, are sometimes overlooked or neglected. The principal ARTS applications at present are systems that assist with route guidance, communications, emergency signaling, incident detection, as well as automatic vehicle location systems and road warning systems.

These six enumerated areas, are not so much targeted areas for future development of these applications but rather a classification of the work already being done by them. The lines demarcating certain areas are sometimes tenuous, but the

distinctions offered are instructive. However, the established categories are not necessarily a function of need—except insofar as one views the activities of inventors and entrepreneurs as responding to need.

A different approach to this classification of ITS would have been obtained had we gone to governmental organizations and simply asked the question, Which of your current problems can technology have the greatest impact in resolving? This was essentially the approach employed by the Finnish National Road Administration, or Finnra (Kulmala & Noukka, 1998), which in assessing Finland's long-term transport plan for 2010 determined that ITS could play a pivotal role in helping that nation reach its objectives. Looking at the six major objectives and the capabilities of ITS, it was determined that the latter could help with all of the objectives but certain objectives were more important than others (see Table 21.1). Table 21.1 reflects the perception that ITS can definitely make traffic and transport more efficient and safer. It can also help with managing transport demand and the efficient use of the transport infrastructure, but increasing cooperation between modes or ensuring mobility and accessibility are less relevant to its particular strengths.

Finnra followed the prioritization of its objectives for ITS by sending a list of specific potential ITS functions to numerous experts in the field. The experts were to score (from -1 to 3) each potential ITS function in terms of the perceived capability of ITS to successfully address each of the six objectives; the median score (usually rounded) on each assessment appears in Table 21.2. Functions are ranked in order by the overall scores they received. Incident management was viewed as the most accomplishable ITS function, especially as it relates to efficiency and safety. Several functions are important in the safety area. Broadly speaking, these either relate to weather information or, in what we typically call "smart cars," consists in modifying the vehicle's actions (e.g., speeding up or slowing down) to avoid potential hazards or incidents. Often these functions are important *only* in the safety area. Few ITS capabilities can do much for intermodal cooperation except to make information more widely available about options. Similarly, there isn't much that ITS capabilities can do for mobility and accessibility as well. The one item that stands out is demand-responsive public transit. Although this mode uses ITS in many cases, it is probably incorrect to include it here.

TABLE 21.1. The Weights of Finnra's Objectives for ITS

| | |
|---|-----|
| 1. Ensure efficiency of traffic and transport | 30% |
| 2. Improve traffic safety | 30% |
| 3. Manage demand more efficiently | 15% |
| 4. Use infrastructure more efficiently | 15% |
| 5. Improve cooperation between modes | 5% |
| 6. Ensure mobility and accessibility | 5% |

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TABLE 21.2. Potential of ITS Functions to Fulfill Finnra's Objectives (Median Scores)

| ITS function | Efficiency | Safety | Demand management | Efficient use of infrastructure | Modal cooperation | Mobility and accessibility |
|--|------------|--------|-------------------|---------------------------------|-------------------|----------------------------|
| Incident management | 2 | 2 | 0.5 | 1 | 0 | 0 |
| Pretrip information on other modes | 1 | 1 | 1 | 1 | 2 | 1 |
| Park-and-ride facilities | 1 | 1 | 1 | 1 | 2 | 1 |
| Guidance to alternative routes | 1 | 1 | 1 | 2 | 0 | 0 |
| Pretrip weather information | 1 | 2 | 0.5 | 0 | 1 | 0 |
| Pretrip info on incidents, congestion | 1 | 1 | 1 | 1 | 1 | 0 |
| Roadside information about weather | 1 | 2 | 0 | 0 | 0 | 0 |
| Local warnings about weather | 1 | 2 | 0 | 0 | 0 | 0 |
| Weather-controlled speed limits | 1 | 2 | 0 | 0 | 0 | 0 |
| Congestion/area tolls for motor vehicles | 1 | 0 | 1 | 2 | 1 | 0 |
| Information about congested locations | 1 | 1 | 0 | 1 | 0 | 0 |
| Roadside info on incidents, congestion | 1 | 1 | 0 | 1 | 0 | 0 |
| Demand-responsive public transit | 1 | 0 | 1 | 1 | 1 | 2 |
| Signal control at junctions | 1 | 1 | 0 | 1 | 0 | 0 |
| Network signal control | 1 | 1 | 0 | 1 | 0 | 0 |
| Lane control at special locations | 1 | 1 | 0 | 1 | 0 | 0 |
| Lane control in tunnels | 1 | 1 | 0 | 1 | 0 | 0 |
| Lane control on motorways | 1 | 1 | 0 | 1 | 0 | 0 |
| Terminal/stop timetable information | 1 | 0 | 1 | 1 | 1 | 1 |
| Alternative mode information | 1 | 0 | 1 | 1 | 1 | 0 |
| Roadside dynamic parking information | 1 | 0 | 1 | 1 | 1 | 0 |
| Dynamic speed adaptation | 0 | 2 | 0 | 0 | 0 | 0 |
| Intelligent headway control | 0 | 2 | 0 | 0 | 0 | 0 |
| Collision warning systems | 0 | 2 | 0 | 0 | 0 | 0 |
| Collision avoidance systems | 0 | 2 | 0 | 0 | 0 | 0 |
| Vision enhancement | 0 | 2 | 0 | 0 | 0 | 0 |
| Driver state monitoring | 0 | 2 | 0 | 0 | 0 | 0 |
| Automatic speed enforcement | 0 | 2 | 0 | 0 | 0 | 0 |

ITS AND SUSTAINABLE TRANSPORT

It is not immediately apparent how ITS has a role to play with regard to sustainable transport as defined here. Recall once again that our current systems are considered nonsustainable because they deplete finite petroleum reserves, pollute both the local and global environments, result in excessive human fatalities and injuries, and encourage too much traffic congestion.

ITS is unlikely to have much of an impact on the finite nature of petroleum reserves. On the other hand, there are aspects of ITS that increase the efficiency with which fuel is used, including navigational systems that avoid needless “searching” behavior by drivers, systems that provide drivers with information regarding the availability of parking, and various route-finding technologies. The overall impact of these on extending the life of petroleum is probably minor but nonetheless real.

Of course, any ITS system that saves on fuel use by its very nature also decreases local air pollutants and global greenhouse gases. Again, we may not be talking significant amounts, but ITS will help to some extent.

However, the main contribution of ITS to sustainable transport, as defined here, is in the area of motor vehicle crashes and the resulting fatalities and injuries. We have already seen major ITS developments in these areas, with the introduction of various automatic restraint systems for passengers and air bags that instantly inflate on impact, which help minimize injuries from such crashes. But by far the most exciting technologies are those that prevent accidents from occurring in the first place—for example, ITS systems that can adjust the speed of your vehicle to existing traffic conditions or keep your vehicle at a safe distance from other vehicles. If your vehicle is about to collide with another vehicle, there is technology that can forewarn you of that and even technology that enables your vehicle to take over and avoid such collisions. Other systems can monitor your body and wake you if you doze off at the wheel. Or, if night weather conditions are bad, there is technology that effectively improves your vision. Finally, there are systems of automatic speed enforcement that can prevent excessive speeding, which is known to account for many crashes.

Various weather information services made possible by ITS are available, and, to the extent that this information leads people to cancel trips when learning of poor driving conditions, this may result in the saving of lives and reductions in injuries. In other cases state highway weather information systems may lead those on the highways to change their routes because conditions are bad on the route they are using. In still other cases highway departments that monitor speed levels closely and count vehicles remotely may also have sensors in the pavement that can detect hazardous pavement conditions, for example, snow or ice. Through advanced ITC this information could be communicated to vehicles on the highway and the vehicles could adjust their speed to these conditions and so inform the driver. These advanced systems, many just on the drawing boards, are intended to prevent crashes, and this prospect must surely be a fundamental part of a sustainable transport system.

There has been no discussion here of the growing number of baby boom drivers who will soon be reaching old age. For a while there was a general consensus that we would see a resurgence of public transit ridership as this age group reached its "golden years." This belief has since been weakened somewhat by a number of points. First, this age group, at least in the United States, is one that has grown up and grown old with the automobile. They are unlikely to be willing to hang up their car keys and switch to a new mode just because of their age. Second, public transit appears to be losing elements of prior support, so that it is unlikely that this mode will provide anything near the level of mobility or accessibility that it did previously. Clearly, if we are unable to get people out of their cars and into public transit, the reality is that they are going to be driving their automobiles.

Statistics on automobile crashes show that motor vehicle crash rates are highest for both the young and the elderly. We may be able to control fatalities of the former group through such regulatory measures, as stronger drunk driving laws or increasing the age for beginning drivers, but these measures are less applicable to the aged. Consequently, we must do more to increase the safety of the vehicles they use. This appears to be an area where ITS can usefully contribute to improvements in the future.

With regard to congestion, there are a number of ways in which ITS can be helpful. There are roadside or radio systems that inform drivers of congested situations and recommend alternative routes to avoid these. In the event of highway crashes there are systems that can detect these and inform drivers "upstream" that they may want to consider alternative routes under these circumstances as well.

Of course, one of the ITS areas of growing importance in relation to congestion is congestion pricing or tolls. There are basically two types of such facilities. The first charges drivers to use an alternative (frequently parallel) route that has much less traffic because of the fee. This enables one to travel at higher speeds, and the value drivers place on their travel time may make this a reasonable expenditure. The second sets fees for use of a facility simply to increase the cost of transport, to increase transport funds for a state or city, and as a result decrease the volume of traffic on it. It is difficult to say how widespread congestion pricing will become as a way of decreasing traffic volumes. Wachs has argued there are political risks associated with congestion pricing and that no political constituency will consistently fight to increase it. "Advocates of congestion pricing will have to settle for smaller victories during the foreseeable future. Eventually many small victories could add up to a new approach to highway management and finance, but don't count on it happening any time soon" (Wachs, 1994, p. 19).

Some ITS Cases

It may be worthwhile simply to illustrate some of the ITS products that have already been introduced. Examples from the areas of AVCS (automated vehicle control), ATMS (congestion pricing), and ATIS (weather warning systems and navigation systems) will be reviewed here.

The San Diego Automated Highway

There is a 7.6-mile section of Interstate 15 north of San Diego in California that has been made into an automated highway (see Kasindorf, 1997). This system was first demonstrated successfully in August 1997. In rural areas it requires automated vehicles that include onboard cameras and sensors that keep the vehicle within the lane markings and warn of drivers passing or following too closely. In urban areas the vehicle switches to an under-the-bumper sensor system that tracks magnets embedded in the roadway, approximately one every 4 feet and costing \$1 each. This system was developed by American Honda Motor Company. An alternative guiding system has been developed by Ohio State University that involves the use of radar and magnetic strips in the road. The cost of the system is one of the attributes that many highway officials find especially appealing: It would cost less than \$10,000 a mile, as compared to a new highway, which would cost \$1–\$10 million a mile.

Developers of the system argue that it has the potential to significantly increase safety since the crash avoidance systems should eliminate the 90% of the crashes that result from human error. Drive times would also be more predictable. Vehicles on these systems would also likely use less fuel and pollute less, and what is most important is that vehicle spacing could be precisely controlled, which would enable much higher densities and volumes on the systems without the attendant risks that these phenomena currently entail. Similar systems are under development elsewhere; Japan first tested such a system in 1995.

Congestion Pricing

Certainly there is nothing new about collecting money from the users of highway transportation facilities. This was common on early private roads as well as on the national road of the United States during the early 19th century. The difference between the charges then and the charges now is that nowadays people can be charged to travel variable amounts on facilities that have less traffic. Still, this *could* be done even without ITS. However, today this process of charging and collecting fees is very much influenced by ITS. Let us look briefly at southern California's State Route 91 (SR-91) in Orange County.

The SR-91 project involved the construction of four new express lanes in the median strip of an existing freeway. ITS was implemented in this project in several ways. First, the toll charged is intended to provide users with a free flow of traffic, and the rate charged varies depending on the rate of the flow (which ranged from \$0.25 to \$2.50 during the spring following the lanes' opening on December 27, 1995). Second, vehicles using the facility must first secure a transponder, which is placed near the center of the front windshield of the vehicle. As the vehicle passes under overhead receivers, the driver's account is charged for the trip. Third, if the vehicle includes three or more passengers, it is allowed to pull into a special lane that credits any charges back to the account; this lane may also be used by buses.

State troopers patrol the special lanes, just to assure against cheating to avoid the charges.

The facility revealed was built by the California Private Transportation Company, a private corporation that now operates the express lanes. The fees collected go toward retiring the company's debt and covering its operating costs, which includes among other things contractual payments made to the California Highway Patrol to police the facility. The state retains ownership of the underlying rights-of-way.

A similar facility exists south of San Diego, California, on Interstate 15. The so-called FasTrak system there also uses lanes constructed on the median, transponders, and variable tolls that are based on traffic volumes at the time of use.

Weather Information Systems

When the state highway department sends out trucks to put down chemicals in response to a snowfall, the typical cost is \$100,000. Obviously there is a need for accurate decision making regarding the use of snow removal equipment. For many years the highway departments and departments of transportation used local weather forecasts to determine what actions they should take with regard to snow and specifically when they should take them. For areas of northern North America as well as Europe, this is potentially a multimillion-dollar problem.

For the past several years we have been seeing an increase in road weather information systems (RWISs). These systems enable highway maintenance units to have far more information available to them. An RWIS may include accurate sensors embedded in the pavement to sense surface and subsurface temperatures, dew point, and the percentage of ice versus snow. These systems may also include wind speed and direction, barometric pressure, and the type of precipitation falling. Some enhanced sites may include video cameras for verification of weather conditions suggested by the data, which is usually sent to a central facility for analysis. If the system detects dangerous conditions, it automatically activates the highway advisory radio.

As of 1998, 44 states in the United States have RWIS systems. Colorado has 150 RWIS sites alone, which it finds necessary for traveler safety in the event of sudden changes in weather conditions. The system also helps with general routing decisions during adverse weather (Hansen, 1998). It also helps to decrease vehicular crashes, as weather conditions play a role in an estimated two-thirds of all highway crashes!

In-Car Navigation Systems

In-car navigation systems come in many varieties. The earliest of these consisted of a CD-ROM that included a digital map of the city of interest. More recent systems have digital information that may be updated from the Internet and have a voice-directed in-car navigation system developed by Pioneer. Their Raku-Navi

unit is activated by the vehicle's ignition being turned on. The system will first ask for the driver's destination. Once the driver gives this information, the system will offer graphic information on a 5.6-inch television screen as to the best route, or it will issue voice commands that relay the same information (*Traffic Technology International*, 1998b). Technology is moving rapidly in this area—so much so that investments in systems installed by the vehicle manufacturer may be an unwise choice.

Usually these devices include in-car navigation systems or GPS gear for determining the vehicle's location. It should be obvious that, unless it is immediately disabled, this could also be an excellent antitheft device. It has frequently been used in this manner, according to various news reports. In cases where the driver loses track of his or her parked vehicle, some manufacturers have produced portable car-and-pocket systems.

Some major automobile manufacturers in the United States have developed systems that include cell phones and GPS. The driver simply "phones home" to the manufacturer, which in turn locates the "lost" vehicle and informs the driver where to find it. This system also uses a geographic information system (GIS) on the manufacturer's end along with the GPS readings. Other systems that employ GIS devices paired with a facilities database can readily supply the user information on nearby restaurants and shopping facilities. Information specific to each locality, for example, local weather conditions or traffic information, can also be passed along via such a system.

There are other systems that inform the manufacturer whenever a vehicle's air bags have been deployed. In this case, the manufacturer can contact the vehicle occupants to see whether emergency vehicles need to be dispatched, a measure that can obviously assist in reducing injured fatalities from accidents, particularly in remote areas.

As for the other navigation-based systems, if they significantly decrease the amount of driver "search behavior," then they will result in less fuel being wasted and fewer pollutants being emitted. On the other hand, in a partial offset, it might also encourage drivers to go into more distant areas unfamiliar to them and in the end generate incrementally more travel.

CONCLUSIONS

There is far more going on in ITS than one can hope to cover here (see Stough, 2001), but most of it appears to have only minor impacts on sustainable transport. The greatest contribution is from those systems that lessen motor vehicle fatalities and injuries. Second are systems that reduce congestion in some corridors. Third are those systems that increase the efficiency of certain transport systems and their operation.

While all of these technological changes will facilitate traffic flow and make it safer, there is some question as to whether this is what we really want to do. Put

another way, every major transport improvement over the past 200 years ended up resulting in an increase in the total amount of travel taking place. Is it likely that ITS when implemented will result in this same type of impact? Will it in the end generate additional travel? It may, but that travel should be safer and more efficient than it has ever been before, so perhaps the negative impacts of additional travel will not be as great as they are now.

PART III

SUMMARY AND CONCLUSIONS