

AN INSTITUTIONAL DEPLOYMENT FRAMEWORK FOR INTELLIGENT TRANSPORTATION SYSTEMS

by

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Bachelor of Science in Civil and Environmental Engineering
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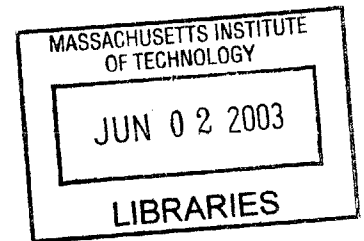
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ABSTRACT

Increasing traffic congestion around the world is limiting urban mobility and contributing to unsustainable environmental, economic, and social conditions. The concept of intelligent transportation systems (ITS), which is defined as the application of computing and electronics technologies to transportation, offers potential for alleviating the negative effects of traffic congestion. These negative effects include impacts on road efficiency, the environment, safety, and cost. Institutional obstacles, however, limit ITS deployment.

This thesis presents a portfolio of ITS technologies that are relevant in combating congestion. Technologies studied include Advanced Traffic Management Systems (ATMS), Advanced Traveler Information Systems (ATIS), Advanced Public Transportation Systems (APTS), Advanced Vehicle Control Systems (AVCS), and many others. Each technology is analyzed on the basis of benefits and costs, real world examples, barriers to implementation, and social implications. From this portfolio, an institutional deployment framework for ITS is developed based on the barriers to implementation shared by many of these technologies. This framework addresses political, economic, organizational, financial, legal, and information issues.

After developing this framework, it is applied to ITS institutions in the cities of Singapore and Kuala Lumpur, Malaysia. Three conclusions can be drawn from this comparison. First, ITS can make significant impacts on congestion, efficiency, safety, and the environment. At the same time, one must consider the social implications and costs of deployment. Second, deploying ITS in urban areas is a complex challenge, requiring the consideration of a wide range of factors. Finally, implementation of ITS must be specific to a particular region; the imitation of other cities without localized planning may result in unsuccessful deployments.

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BIOGRAPHICAL NOTE

Sandi Lin, originally from Vienna, VA, completed her undergraduate studies in civil engineering at MIT in February, 2003. As an undergraduate, she received the Richard Lee Russel Award for academic achievement in civil engineering and the Steinberg Prize in construction management. She was featured in the American Society of Civil Engineers' 150th Anniversary magazine, and was one of four winners in the CE News Star Students competition. Sandi was the president of MIT's Chi Epsilon chapter, and is also a registered Engineer-In-Training (EIT).

While an undergraduate, Sandi competed on the lightweight varsity crew team for four years and was vice president of her sorority, Alpha Phi. She has interned at Lucent Technologies Bell Laboratories, Cambridge Systematics, and Bain & Company. She plans to pursue a career in transportation.

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I would also like to thank the Alliance for Global Sustainability (AGS) for funding my trip to Japan this spring, where I was privileged to attend numerous discussions on sustainability. This trip helped broaden my understanding of sustainability, and gave me the opportunity to meet researchers around the globe interested in the same topics.

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May 9, 2003

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CHAPTER ONE: ORGANIZATION

This thesis aims to accomplish four objectives related to intelligent transportation systems (ITS) and the institutional structures necessary to support ITS deployments. The four objectives are:

- To introduce a portfolio of ITS technologies, and analyze their impacts
- To propose a framework that can assess a region's institutional readiness for ITS deployment
- To apply this deployment framework in two urban contexts
- To develop recommendations, based on this framework, for institutional transformation in the city of Kuala Lumpur.

The following sections describe the organization of the thesis and summarize the contents of each chapter.

Chapter Two: Context

The institutional analysis carried forth in this study is conducted in the context of a broad range of issues relating to mobility and sustainable development. This chapter introduces the concepts of sustainability, urban mobility, and transportation management. Within this context, ITS is discussed as a tool to alleviate urban congestion. At the same time, it is institutional barriers, not technology, that commonly prevent ITS from being deployed as extensively as it might be.

Chapters Three and Four: ITS Portfolio

One of the institutional barriers for ITS implementation is a lack of knowledge about the available technologies and their applications. The purpose of these two chapters is to introduce a portfolio of ITS technologies useful for managing congestion in urban areas. These chapters attempt to demonstrate how these technologies can positively affect safety, infrastructure efficiency, financing, and the environment. The benefits and costs, barriers to implementation, and social implications for each technology are discussed. In addition, an example implementation for each system is presented.

Chapter Three focuses on ITS technologies that require shared public infrastructure. For example, the use of an incident management system requires equipping public roadways with intelligent sensors and cameras. This chapter covers advanced traffic management systems, advanced traveler information systems, electronic payment systems, and advanced public transportation systems.

Chapter Four focuses on ITS technologies that are primarily based within or inside vehicles. For example, intelligent cruise control is a technology embedded within a

vehicle's structure. This chapter covers advanced vehicle control systems, drive-by-wire, navigation assistance, mayday systems, and mobile computing.

Chapter Five: Proposed Deployment Framework

The primary barrier to deployment of ITS technologies remains institutional, not technological. To that end, Chapter Five proposes a deployment framework that assesses a region's institutional readiness to deploy ITS. The basis for developing this framework was the research conducted while assembling the portfolio presented in Chapters Three and Four. The main categories of institutional analysis are organization, finance, legal & regulatory, and information, along with the overarching issues of political environment and economic development. This framework is meant as a planning guide for regions seeking to use ITS tools in managing urban congestion.

Chapter Six: ITS Deployment in Singapore

Singapore is often used as a positive example of ITS deployment. The island country's roads are equipped with extensive networks of sensors and cameras that support its deployments of electronic road pricing, incident management, and other technologies. In Chapter Six, the framework developed in the previous chapter is applied to Singapore's institutional structure. The analysis shows that Singapore has addressed nearly all of the points highlighted in the framework. At the same time, their institutional structure is likely to be unique to their political system and culture.

Chapter Seven: ITS Deployment in Kuala Lumpur

The city of Kuala Lumpur, Malaysia, is facing severe urban congestion. A high rate of motorization, along with poorly managed public transit, has led to clogged streets and frequent accidents. Rather than addressing the problem through road building alone, Chapter Seven suggests that ITS can be used to increase the effective capacity of the existing road network.

To successfully deploy ITS, however, Kuala Lumpur (KL) must have the institutional capability necessary to support the implementation effort. In this chapter, the framework developed in Chapter Five is applied to the existing institutional setup of KL. The analysis shows several institutional gaps that may hinder the success of ITS deployments. To close these gaps, several recommendations are made for KL, and methods are suggested to implement these strategies.

Chapter Eight: Lessons Learned

The final chapter summarizes the lessons learned from developing the ITS portfolio, institutional development framework, and performing the case studies.

CHAPTER TWO: CONTEXT

This chapter introduces the broad context behind the institutional deployment framework developed in this thesis. Sustainability and urban mobility are key issues when considering the deployment of ITS. Among others, there are often tradeoffs between road efficiency, the environment, economic growth, and social equity. The themes introduced in this chapter should be kept in mind when considering the impacts of ITS projects.

2.1 SUSTAINABLE DEVELOPMENT

Sustainable development encompasses a wide range of issues. Early concerns about sustainability focused on the depletion of natural resources such as land area and minerals. More recently, the concept of sustainability has broadened to include the preservation of biodiversity, maintenance of well-functioning ecosystems, and protection of global climate¹. Current understanding also accounts for economic, financial, and social sustainability, in addition to environmental sustainability. This holistic view is summarized by the World Commission on Environment and Development's definition of sustainability:

“A sustainable condition for this planet is one in which there is stability for both social and physical systems, achieved through meeting the needs of the present without compromising the ability of future generations to meet their own needs”².

Part of this thesis attempts to assess the impacts of intelligent transportation systems (ITS) on sustainability. While certain policies may encourage environmental sustainability, it is important to recognize their potential tradeoffs with economic, social, and financial sustainability. Some technologies with environmental benefits, for example, may only be affordable to the more affluent in society. Likewise, the implementation of ITS might be used as an alternative to road construction, a traditional driver of economic growth. Sustainable development, therefore, is a complex concept when viewed from a holistic perspective.

2.2 URBAN MOBILITY

Urban mobility refers to the ease by which people and goods move from one place to another in cities. In the context of this thesis, urban mobility refers specifically to vehicle traffic in the city environment. Urban areas pose a unique challenge due to a combination of physical space constraints and a strong emphasis on economic activity.

¹ Transportation Research Board. Special Report 251: Toward a Sustainable Future. Washington, D.C.: National Academy Press, 1997.

² World Commission on Environment and Development. Our Common Future. Oxford, England: Oxford University Press, 1987.

At the same time, cities frequently offer public transit systems that may be able to provide alternative service to the central business district (CBD). While many of the technologies and institutions discussed in this study focus on the CBD, one cannot ignore the effects of ITS designed for expressways carrying traffic into the cities. Since much of city traffic originates from outlying areas, improvements outside the city limits also have the potential to alleviate congestion inside the CBD.

The state of urban mobility around the world is currently very poor. Rates of automobile ownership, and vehicle miles traveled, are rising quickly without corresponding increases in road capacity. This problem is especially severe in developing countries. As a result, cities are now suffering from heavy downtown congestion, highly reduced travel speeds, and extended rush hour periods. This congestion creates unsustainable environmental impacts, in addition to negatively affecting economic activity and social welfare.

Environmental unsustainability can be primarily attributed to the air pollution caused by traffic congestion. Vehicle exhaust contains carbon dioxide, carbon monoxide, hydrocarbons, particulate matter, nitrous oxides, and other emissions that contribute to global climate change, human disease, acid rain, and smog. The situation is often worse in developing cities where large percentages of the driving population use motorcycles or vehicles with inadequate pollution controls. Alleviating traffic congestion through ITS could significantly reduce the environmental harm caused by vehicle use.

Figure 1 shows the estimated annual cost of congestion for five Asian cities, where the cost of congestion includes the cost of delay and the cost of wasted fuel. Per capita, the cost seems small because of the relatively low motorization rate in these cities and the relatively low cost of time. However, the environmental cost of air pollution per capita is an order of magnitude larger, indicating the environmental unsustainability of traffic congestion.

Table 1. Cost of Congestion in Five Asian Cities

City	Population Estimate (millions)	Annual Cost of Congestion		Annual Cost of Air Pollution	
		Total (US \$M)	Per Capita (US \$)	Total (US \$M)	Per Capita (US \$)
Delhi	12.1			400	33
Bangkok*	10.0	400	40	1300-3100	130-310
Seoul	10.3	154	15	6154	600
Manila	10.9	51	5	1800	165
Jakarta*	11.0	68	6	400-800	36-73

*includes metropolitan regions

Source: Jitendra Shah, et al., World Bank³

³ Shah, Jitendra, N. Harshadeep, Jian Xie, Victor Loksha, Carter Brandon, Paul Martin, and Priya Mathur. World Bank. "Urban Pollution from Two Stroke Engines in Asia: Technical and Policy Options." Presented at World Bank Transportation Forum. 1997.

Congestion also contributes to economic unsustainability because of lost productivity and wasted fuel. The Texas Transportation Institute estimates that in the year 2000, congestion caused 3.6 million vehicle-hours of delay, 5.7 billion gallons of wasted fuel, and \$67.5 billion in lost productivity among the 75 largest U.S. metropolitan areas, representing 46% of the U.S. population⁴. Besides the extra time and fuel used for travel, the economic cost of traffic delays is also passed on to consumers through the form of higher prices. These prices reflect increased shipping costs, higher man-hours for labor, and extra fuel. Economic unsustainability is also caused because congestion limits growth in the city centers. If congestion could be reduced, businesses might be more likely to choose office space downtown, rather than the suburbs.

Unsustainable social conditions are caused by traffic congestion through its effects on public health and social equity. Vehicles cause deaths among other drivers, passengers, and pedestrians. The World Bank reports that traffic crashes are the leading cause of death for young males. The air pollution caused by automobiles is also harmful, especially for young children. In Central Europe alone, the World Health Organization estimates 21,000 annual deaths from road traffic air pollution⁵. Socially, the effects of increased road building also include mass relocation, lower quality of life, and adverse effects from noise.

2.3 TRANSPORTATION MANAGEMENT STRATEGIES

The current condition of urban mobility appears to be unsustainable from a variety of perspectives. At the same time, cities are beginning to employ a range of transportation strategies to manage the demand for road infrastructure, not merely the supply. Three of the most important strategies are transportation demand management, transit-oriented development, and intelligent transportation systems. The first two are discussed here, while ITS is discussed separately in Section 2.4.

Cities have historically employed measures to increase effective road supply to drivers. Such policies include building more roads and supplying public transit systems. Transportation demand management, in contrast, focuses on changing the demand for road infrastructure through a variety of market-based initiatives and command & control policies. Examples include road pricing, vehicle & fuel taxes, no car days, and vehicle location restrictions. These policies attempt to change driver behavior by making alternative commutes, including carpooling and public transit, more attractive. Cities are beginning to realize that managing the supply side of the equation is not enough to address urban mobility problems; they must look at transportation demand as well.

Transit-oriented development is another transportation management tool currently under study by city planners. TOD is a method of locating residences and other destinations, such as employment and shopping areas, near public transportation in order to reduce

⁴ US DOT. Federal Highway Administration. "Congestion Mitigation." 5 Mar 2003
<<http://www.fhwa.dot.gov/congestion/congest2.htm>>.

⁵ Intergovernmental Panel on Climate Change. Climate Change 2001: Mitigation – Contribution of Working Group III to the Third Assessment Report of IPCC. 2001. 5 Mar 2003
<http://www.grida.no/climate/ipcc_tar/wg3/index.htm>.

people's dependence on the automobile. Elements of TOD include enhanced mobility, pedestrian friendliness, mixed-use development, and ample provision for public spaces. The concept has significant implications for regional sustainability, since the proper linkage between land use and transportation can have a dramatic effect on total energy consumption. Densely populated transportation corridors and efficient rapid transit systems will not only reduce the demand for the automobile, but they also reduce the need for infrastructure, and reduce the effects of urban sprawl.

The TOD model includes both regional and local planning. The backbone of the TOD is the regional Trunk Line that can be either heavy rail, light rail, or express bus. Along the Trunk Line are a series of Urban TODs, which are developed at high commercial and residential densities. Neighborhood TODs are composed of residential uses and local shopping, and linked to the urban transit stations via feeder bus lines. It is not enough for a development to be adjacent to transit; it must be shaped by transit, in terms of parking, density, and building orientation. The concepts of land use, economics, and transportation must all be considered in creating an integrated development strategy.

2.4 INTELLIGENT TRANSPORTATION SYSTEMS

The United States Federal Highway Administration defines ITS as systems that “apply well-established technologies in communications, control, electronics, and computer hardware and software to improve surface transportation performance”⁶. ITS can increase effective road capacity, improve vehicle safety, increase the efficiency of public transit, and reduce environmental impacts, all without conventional infrastructure building. Advances in technology have led to the exploration of applications of electronics to transportation. As a result, there is a broad range of ITS technologies available, though many of these are not widely implemented. Chapters Three and Four discuss ITS based in public infrastructure and vehicles, respectively.

While many transportation professionals support increased research and development into ITS, certain environmentalists oppose the concept. Although ITS can have significant benefits on reducing congestion and air pollution, some argue that ITS contributes to an unsustainable lifestyle by making driving more attractive. At least in the short term, however, it is clear that ITS can have measurable impacts by improving urban mobility. In the long term, this thesis should be taken in context with other transportation management strategies such as TDM and TOD.

Numerous ITS technologies have been developed in the last several decades, yet it remains difficult for regions to implement these congestion-reducing measures. The problem appears to be institutional rather than technological. The MIT Laboratory for Energy and the Environment reports that:

⁶ US DOT. Federal Highway Administration. “What Have We Learned About Intelligent Transportation Systems?” Washington, DC: Federal Highway Administration, 2000.

“Political and social institutions influence whether transportation infrastructure can be built, where it can be built, how long it takes, and what it costs. Economic institutions can either take the lead in encouraging change or drag their feet and make change more difficult and expensive. Assuming the institutional capabilities that exist today, both developed and developing countries will find it nearly impossible to reach a consensus about what needs to be done (sic) to make mobility sustainable and then to design, implement, and then monitor the necessary plans for change. Thus, institutional capability rather than technological capability may well determine the pace and direction of change in mobility systems”⁷.

Institutional capability is a crucial component for success in using ITS to manage urban transportation systems. In addition to organizing public institutions, planners must consider the roles of the private sector, individual citizens, legal issues, and financial considerations. This thesis attempts to formulate a deployment framework for agencies to use when planning the deployment of ITS for their regions. Before developing this framework, however, it is first important to understand the range of available technologies and their barriers to implementation. Chapters Three and Four build a portfolio of ITS technologies, as a base from which to formulate a framework for deployment.

⁷ MIT Laboratory for Energy and the Environment. “Worldwide Mobility: A Status Report and Challenges to Sustainability.” e-lab Research Reports. Cambridge, MA: Massachusetts Institute of Technology, Jan-Mar 2002.

CHAPTER THREE: INTELLIGENT INFRASTRUCTURE TECHNOLOGIES

Intelligent infrastructure technologies require geographically widespread networks for information processing and sensing. Unlike intelligent vehicle technologies, the hardware is largely based within road or transportation infrastructure itself. Examples include sensors imbedded in the roadway or receivers placed at the sides of roads.

Many intelligent infrastructure technologies are comprised of the same hardware components. Among these are variable message signs, video imaging technology, and central control centers. While the technologies in this chapter are treated separately, they have commonalities that can be leveraged during actual implementation. The incident management control center, for instance, could be used to manage advanced traveler information systems as well.

Federal, state, and local governments, not the private sector, are typically the champions for intelligent infrastructure investment. There are several reasons for this. First, ITS often carries high capital costs that may not be economically attractive for private ventures, but are socially attractive for the public at large. Second, infrastructure technologies require the use of equipment owned by the public sector, with which private companies may not have access. For example, a private sector initiative into electronic fare payment requires an overhaul of public fare collection equipment. Finally, intelligent infrastructure technologies should be managed in the public's best interest, and the government is the logical stakeholder to perform this role.

It should be noted, however, that while the government normally champions ITS infrastructure, it often does so through private sector channels. One example is the government granting electronic toll road concessions to private operators. In this case, the private sector is responsible for the deployment of electronic toll collection technology. However, the government is still needed to organize the effort and ensure the technical interoperability of the various concessionaires.

The first set of intelligent infrastructure technologies in this chapter relates to Advanced Traffic Management Systems (ATMS). These computer systems help manage arterial and freeway traffic by adjusting the flow of vehicles on roadways through traffic signals and fast response to blockages. Examples of ATMS presented in this chapter are:

- Smart traffic signal control
- Ramp metering
- Automated red light enforcement
- Incident management

A second set of intelligent infrastructure technologies is Advanced Traveler Information Systems (ATIS). ATIS provide current and accurate traffic information to help drivers choose better routes. The information can be disseminated through a variety of media, including television, the Internet, and cellular phones.

Electronic payment systems are another group within infrastructure-based technologies. Unlike the systems presented above, this ITS category groups together similar technology rather than its applications. As a result, similar electronic payment system concepts are found in several infrastructure technologies. The two systems discussed in this chapter are electronic toll collection, with relatively fixed charges, and electronic road pricing (congestion pricing), with varied charges according to congestion.

The final set of intelligent infrastructure technologies is Advanced Public Transportation Systems (APTS). These technologies apply general ITS concepts to the specific area of public transportation. For example, the concept of electronic payment applied to public transit is electronic fare payment. Similarly, the concept of ATIS applied to public transit is automated passenger information. A third technology utilized by APTS, automated vehicle location, is also discussed in this chapter.

A subset of ITS technologies omitted from this discussion covers systems specifically for commercial vehicle operations (CVO). CVO systems are largely information technology applications ranging from electronic screening programs to electronic credentialing clearinghouses. While loosely classified as ITS, the author considers many CVO-specific technologies to be administrative in nature, and therefore fundamentally different from the other systems discussed in this chapter. However, almost all of the technologies covered in this thesis can be applied to commercial vehicles as well as private vehicles, with few distinctions. For example, electronic toll collection is applicable to all types of vehicles including trucks, not just cars and motorcycles.

Intelligent infrastructure technologies aim to control traffic congestion through both demand and supply side management. On the demand side, congestion pricing and APTS are examples of how ITS can be used to influence private vehicle use and provide attractive alternatives. On the supply side, ATMS is an example of how ITS can increase effective road capacity. In addition to efficiency benefits, intelligent infrastructure technologies can also increase safety, decrease operating costs, and lower air pollution.

The value of each technology in this chapter is described. Benefits and costs are presented. Typically, benefits and costs are either based on efficiency, safety, the environment, or finances. Where possible, actual cost data from various deployments is included. Finally, an example of each technology is given, along with a discussion of the barriers to implementation and the social implications.

3.1 ADVANCED TRAFFIC MANAGEMENT SYSTEMS (ATMS)

Advanced traffic management systems help control traffic. The first two technologies discussed in this section, smart traffic signal control and ramp metering, accomplish this by using signals to limit the number of vehicles passing through in a single light cycle. In addition, these signals may be coordinated so that cars going at a certain speed do not need to stop. They use sophisticated computer algorithms to determine the optimum cycle times for maximum road efficiency. The third technology, automated red light enforcement, reduces accidents by catching all drivers who violate the red light signal at intersections. Since accidents can be the cause of much congestion, reducing accidents also eases the traffic congestion problem. The final technology discussed in this section is incident management. Incident management systems detect flow problems, such as vehicle breakdowns, and notify the appropriate personnel to clear the blockage as rapidly as possible. Detecting problems early can help control non-recurring congestion.

3.1.1 SMART TRAFFIC SIGNAL CONTROL

Broadly, smart traffic signals respond to changing traffic conditions by adjusting a signal's length and offset through automated control algorithms. The sophistication of the control systems range from simple timing plans to fully adaptive traffic signal control. Algorithms can be static, based on time of day, follow predefined plans, or be dynamic and optimized over a large traffic signal network⁸. In the last case, the synchronized signals are usually deployed over a large number of intersections to produce the maximum benefit. Components of the system typically include local controllers at each intersection, customized software, detector loops, and communications equipment.

3.1.1.1 Benefits and Costs

The purpose of smart traffic signal control is to increase throughput by minimizing delays and number of stops. In turn, pollution and travel times are reduced as well. The following table summarizes the range of benefits realized in several performance metrics, as reported by the U.S. Department of Transportation.

Table 2. Benefits of Smart Traffic Signal Control

Metric	Benefit
Travel Time	Decreased by 8%-25%
Travel Speed	Increased by 14%-22%
Vehicle Stops	Decreased by up to 41%
Delay	Decreased by 17%-44%
Fuel Consumption	Decreased by 6%-13%
Hydrocarbon Emissions	Decreased by 4-10%
Carbon Monoxide Emissions	Decreased by 5%-15%

Source: US DOT⁹

⁸ Sussman, Joseph. *Introduction to Transportation Systems*. Boston, MA: Artech House, 2000.

⁹ US DOT. Federal Highway Administration. "Developing Traffic Signal Control Systems Using the National ITS Architecture." Washington, DC: Federal Highway Administration, 1998.

Implementing smart traffic signal control, however, can be expensive for small municipalities. Both capital and maintenance costs must be considered. The following table summarizes these costs.

Table 3. Estimated Capital Costs of Smart Traffic Signal System Components

System	Central Hardware (\$)	Central Software (\$)	Local Controllers* (\$)	Detectors * (\$)
SCATS**	30,000	40,000-70,000	4,000-6,000	5,000-7,000
SCOOT	30,000	unknown	Unknown	5,000-7,000
OPAC	20,000-50,000	100,000-200,000	4,000-6,000	Unknown
RHODES	50,000	500	Unknown	Unknown
ATCS	40,000-50,000	1,000+license	8,000-10,000	5,000-10,000

*per intersection

**SCATS requires additional regional hardware and software that interfaces between the central computer and the local computers

Source: US DOT¹⁰

Two subgroups of smart traffic signal control system are discussed below – adaptive signaling systems and vehicle priority or preemption signals.

3.1.1.2 Adaptive Signaling Systems

Adaptive signaling systems change timing plans depending on current traffic conditions. Instead of following a fixed time-of-day plan, for example, adaptive systems measure current traffic patterns and adjust signals accordingly. They use inductive loop vehicle sensors imbedded in the roadway to collect and respond to information on traffic flows. Many are also programmed to automatically notify maintenance staff in the case of equipment failures.

Because adaptive systems respond to traffic conditions, computer programs control the timing plans. There are several adaptive algorithms available. The two traditional ones are Australia’s SCATS (Sydney Coordinated Adaptive Traffic System) and the United Kingdom’s SCOOT (Split, Cycle, Offset Optimization Technique). SCOOT has been deployed at more than 100 sites worldwide, and SCATS is in use in nine different countries. While many of the adaptive signaling deployments in the United States use one of these two algorithms, there have also been several newer ones developed for more specific applications, such as arterial streets and grid networks. These algorithms include OPAC (Optimized Policies for Adaptive Control, RHODES (Real-Time Hierarchical Optimized Distributed Effective System, RTACL (Real-Time Traffic Adaptive Control Logic), and ATSC (Automated Traffic Surveillance and Control)¹¹. The following table shows benefits from of these U.S. deployments.

¹⁰ US DOT. Federal Highway Administration. “What Have We Learned About Intelligent Transportation Systems?” Washington, DC: Federal Highway Administration, 2000.

¹¹ Ibid.

Table 4. Benefits of Adaptive Signaling Systems

Location	System	Benefits Realized
Broward County, FL*	SCATS	Delay reduced by up to 42%, travel time reduced by up to 20%
Oakland County, MI	SCATS	Delay reduced by 6.6% to 32%, with an average of 7.8%
Newark, DE area	SCATS	Travel time reduced by up to 25%
Los Angeles, CA	ATSC	Delay reduced by 44%, travel time reduced by 13%
Minneapolis, MN	SCOOT	Delay reduced by up to 19% during special events

*The system in Broward County was installed as a demonstration and has since been turned off due to lack of funds.

Source: US DOT¹²

3.1.1.2.1 Example: Toronto, Canada

In September 1990, Toronto conducted a demonstration project of SCOOT that covered three signal networks and included 75 intersections. The purpose was to measure the difference between SCOOT and their existing time-of-day plan. The results were impressive. SCOOT produced a reduction of 6%-11% in vehicle travel time, a reduction of 24% in rear-end collisions, a reduction of 3%-6% in pollutant emissions, and an increase of 3%-16% in traffic flow speeds¹³.

Based on the successful demonstration, Toronto proceeded to expand SCOOT to approximately another 250 intersections. The new control system responded better than the old one to changing travel patterns, special events, and day of week fluctuations¹⁴. The following table summarizes the average benefits from the full deployment.

Table 5. Average Benefits from Toronto SCOOT Deployment

Metric	Benefit
Travel time	Reduced by 8%
Delay time	Reduced by 17%
Number of stops	Reduced by 22%
Fuel consumption	Reduced by 5.7%
Hydrocarbon emissions	Reduced by 3.7%
Carbon monoxide emissions	Reduced by 5%

Source: SCOOT Urban Traffic Control Website¹⁵

¹² Ibid.

¹³ Greenough, J. and W. Kelman. "ITS Technology Meeting Municipal Needs – The Toronto Experience."

6th World Congress Conference on ITS. Toronto, Canada: Nov 1999.

¹⁴ Kelman, L. and S. Kemp. "Operational Experience with Adaptive Control Systems." Toronto, Canada.

¹⁵ SCOOT Urban Traffic Control Home Page. "Results - Toronto 1993." 2002. 1 Apr 2003

<<http://www.scoot-utc.com/Results/tor.htm>>.

3.1.1.3 Vehicle Priority and Preemption Signals

Vehicles can be equipped with transmitters to grant either traffic signal priority or preemption at intersections. The most common application of traffic signal priority signals is with public transit vehicles. Emergency vehicles, such as ambulances and fire trucks, are the most common application for traffic signal preemption.

Allowing buses to extend green times, or to truncate red cycles, reduces the total trip time for passengers. The reduction in bus schedule variability also improves the level of service for bus passengers. There are several different control logics used in various areas. In addition to simple red and green light manipulation, conditional priority is used to grant priority to buses behind schedule, and to delay buses ahead of schedule. However, transit vehicle priority often negatively impacts non-transit vehicles¹⁶. The benefits of improving public transit level-of-service must be weighed against the added delays for private vehicle operators.

Emergency vehicles can be equipped with emitters to activate or extend green time when approaching intersections. This system stops cross traffic, making it much easier for an emergency vehicle to proceed along its route. This time savings has enormous impact when human lives are at stake. In Houston, TX, the average emergency vehicle travel time decreased by 16% in one district, and 23% in another, after a signal preemption system was installed¹⁷.

3.1.1.3.1 Example: Eindhoven, The Netherlands

In Eindhoven, an extensive study was conducted to evaluate the effectiveness of conditional priority signals for bus public transit. On these buses, an on-board computer determined the vehicle location and communicated with the local traffic signal about the buses' early or late status. The study found that the average deviation time for buses under conditional priority decreased by 17 seconds compared to the no priority case.¹⁸ In addition, 74% of the late buses experienced zero-delay service at a particular intersection¹⁹.

3.1.1.4 Barriers to Implementation

The deployment of smart traffic signal control systems is still limited. Causes include cost, system complexity, and uncertainty in benefits.

Cost remains a barrier in terms of both capital and O&M expenses. The capital cost for smart systems is much higher than compared to the base case of standard timing systems. The difference in O&M cost is unclear – although smart signals need manual re-timing less often than standard systems, they do require significantly more maintenance on the

¹⁶ Chada, S. and R. Newland. "Effectiveness of Bus Signal Priority, Final Report." Florida: University of South Florida, Jan 2002.

¹⁷ Traffic Engineers, Inc. "Emergency Response Management System Study." Houston, TX: Apr 1991.

¹⁸ Muller, T. and P. Furth. "Integrating Bus Service Planning with Analysis, Operational Control and Performance Monitoring." Presented at 2000 ITS America Meeting. Boston, MA: May 2000.

¹⁹ Furth, P. and T. Muller. "Conditional Bus Priority at Signalized Intersections." Presented at 79th Transportation Research Board Meeting. Washington, DC: Jan 2000.

detector loops. Even if cost savings in O&M can be achieved, many municipalities are unable to support the large one-time capital outlay for deploying the system.

The complexity of the system is also a barrier to implementation. The system requires extensive operations training for effective deployment. The system is heavily reliant on accurate detection – as a result, the detector loops must be scrupulously maintained. The complexity of regional coordination is also difficult to solve. Smart traffic signal control is most effective when optimized over a large number of intersections, meaning that systems should often be deployed over jurisdictional boundaries. The coordination between agencies is difficult to achieve. However, coordination across jurisdictions can yield great benefits by creating a continuously timed travel corridor.

Finally, implementation of smart traffic signal control systems is hindered by an uncertainty about its actual benefits. The success of each system depends highly on the base case conditions and the manner in which it is implemented. During peak hours, the benefits may be minimal and unnoticed by most drivers. Systems may be successful in one situation but not another, depending on how the detectors are placed. For example, a SCOOT installation in Anaheim, CA reduced delay during nonpeak periods, but actually increased delays during peak traffic periods.²⁰ Malfunctioning equipment also tends to cause large delays in the system. These problems contribute to general uncertainty about benefits of smart traffic control systems.

3.1.1.5 Social Implications

Smart traffic signal control systems are typically government initiatives. As such, they do not intentionally favor particular classes of income, ethnicity, or gender. The technology adds social benefit by improving throughput, reducing pollution, and minimizing traffic delays as described above.

However, there may be unintentional social side effects. For example, smart traffic signal control could favor certain roads and directions over others, which has important revenue implications for commercial businesses through induced demand. Political lobbying groups of higher-income residents could also push for smart traffic signals to be installed in their home areas first. By prioritizing different intersections and redirecting traffic flow, smart traffic signal control systems could favor certain groups of citizens over others.

3.1.2 RAMP METERING

Ramp metering controls the amount of traffic flowing onto freeways from arterial roads. It uses traffic signals located on the on-ramps that respond to freeway conditions. The signals adjust their light cycles to maintain a threshold level of service on the expressway. To collect traffic data, the system uses measurements from freeway detector stations and senses the number of vehicles waiting on the ramp. The following table lists elements of a ramp metering station, as organized by the Ontario Ministry of Transportation.

²⁰ Ibid.

Table 6. Components of Ramp Metering Station

Component	Purpose
Stop bar	To show vehicles where to stop
Passage loop	To monitor vehicles released from queue
Demand loop	To measure vehicle demand
Ramp control signals	To signal red, yellow, and green to the vehicle queue
Storage area	To ensure the queue does not interfere with arterial traffic
Queue loop	To override the stop signal if the queue is too long
Mainline detector	To provide freeway data to determine ramp meter timing
Equipment cabinet	To house control equipment for signals and loops
Warning sign	To warn drivers of ramp metering

Source: Ontario Ministry of Transportation²¹

There are three types of metering – fully restrictive, partially restrictive, and non-restrictive²². Fully restrictive metering is used when there is ample storage space to accommodate a vehicle queue. The traffic signals are metered such that maximum level of service is achieved on the freeway. Consequently, some vehicles choose alternate routes since the queue may grow to be inconveniently long. Partially restrictive metering is used when there is not enough storage to handle peak period vehicle demand. Either vehicles are constantly admitted to the freeway at a higher rate to prevent storage overload, or the signal is overridden when the queue reaches capacity. Non-restrictive metering does not take current freeway conditions into account when timing the ramp signal. The benefit is only in breaking up clumps of vehicles before merging.

3.1.2.1 Benefits and Costs

During periods of congestion, staggering vehicle inflow has positive benefits on road efficiency and safety. Travelers are delayed at the meter, but overall travel time is reduced. Average vehicle speed is increased, vehicle throughput is increased, travel time is reduced, congestion is reduced, and accidents (especially from merging) are reduced. The following two figures show flow rate and vehicle speed, before and after ramp metering, for a highway in San Diego, California. They clearly demonstrate the benefits in vehicle speed, and therefore result in faster travel time.

²¹ Ontario Ministry of Transportation. "Ramp Metering Stations (RMS)." 5 Mar 1999. 4 Dec 2002 <<http://www.mto.gov.on.ca/english/traveller/compass/compass/rms.htm>>.

²² New York State Department of Transportation. "Ramp Metering." 4 Dec 2002 <<http://www.dot.state.ny.us/reg/r10/ramp.html>>.

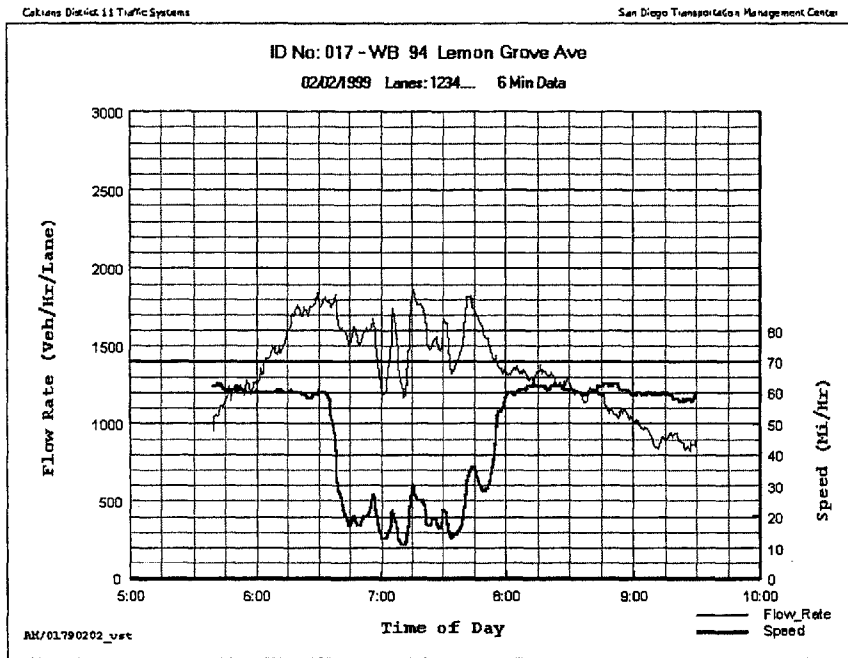


Figure 1. Speed and Flow Rate Without Ramp Metering

Source: San Diego TMC²³

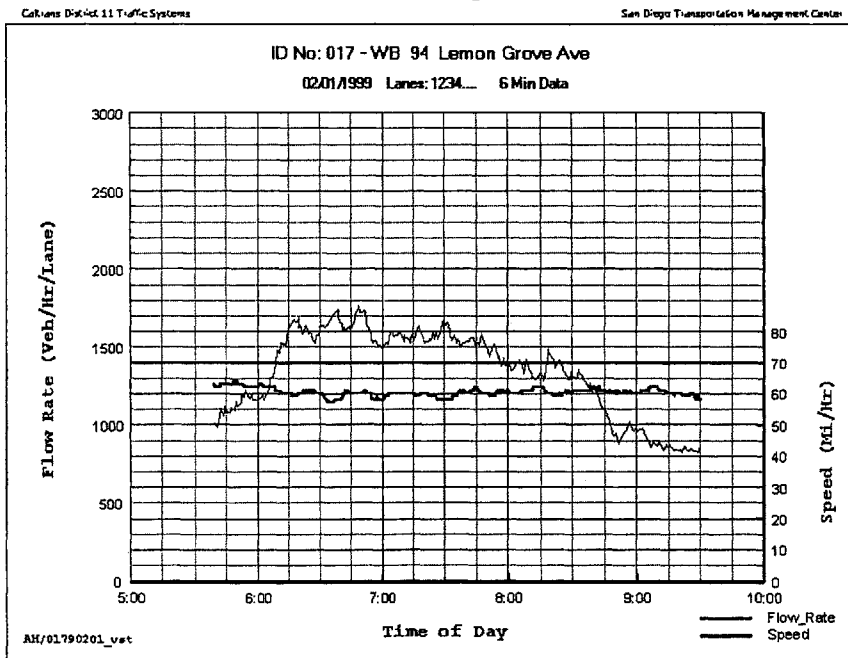


Figure 2. Speed and Flow Rate With Ramp Metering

Source: San Diego TMC²⁴

²³ San Diego Transportation Management Center. "Why We Meter the Freeways." 2000. 4 Dec 2002 <<http://www.dot.ca.gov/dist11/d11tmc/sdmap/direct/rampinfo.html>>.

However, ramp metering has an environmental cost in terms of resource usage. Faster highway speeds in the meters-on condition actually increase overall fuel consumption. But even though overall fuel consumption increases, tailpipe emissions still decrease due to better efficiency on the freeway. As such, ramp metering is one of the few ITS technologies that actually has one negative consequence – the increased consumption of fossil fuels.

Ramp metering also has a significant capital and maintenance costs. It is difficult to assign costs to ramp metering because much of the detector equipment has a dual purpose in incident management. For example, the mainline detector cost could also be assigned to an incident management system discussed below. Commercial vendors claim the average cost for a single ramp meter and installation is \$50,000²⁵. Costs for one example are detailed below.

3.1.2.2 Example: Minneapolis, Minnesota

The Minnesota Department of Transportation (Mn/DOT) uses approximately 430 ramp meters to control access to around 210 miles of freeways in the Minneapolis-St. Paul region. In 2000, the state legislature passed a bill requiring a strict evaluation of the effectiveness of the ramp meters. The ramp meters were shut down for six weeks to measure the effect. The following table summarizes findings after the ramp meters were shut down. Clearly, the freeway level of service suffered dramatically without the ramp meters (with the exception of fuel consumption).

Table 7. Mn/DOT Results from Ramp Meter Shutdown

Metric	Result
Volume	Without metering, decreased by 9%*
Peak period throughput	Without metering, decreased by 14%
Freeway travel time	Without metering, increased by 22%
Speeds	Without metering, decreased by 7%
Peak period crashes	Without metering, increased by 24%
Emissions	Without metering, increased by 1,160 tons per year
Fuel consumption	Without metering, decreased by 22,246 gallons per year**

*Growth statistics show volume increases of 3-4% per year

**This is the only category where ramp metering had a negative impact. Allowing faster highway speeds increases the consumption of fuel.

Source: Cambridge Systematics²⁶

²⁴ Ibid.

²⁵ IST International, Ltd. Home Page. "Ramp Meter Traffic Light (RMTL)." 2 Jul 2002. 4 Dec 2002 <<http://www.onlinetrain.com/ist/RMTL.asp>>.

²⁶ Cambridge Systematics, Inc. "Mn/DOT Ramp Meter Evaluation – Phase II Evaluation Report." Prepared for Minnesota DOT. Oakland, CA: 10 May 2002.

3.1.2.3 Barriers to Implementation

Ramp metering faces a set of institutional barriers to implementation. These problems are primarily organizational and financial. Public acceptance is sometimes an issue, but generally does not pose a grave threat to deployment. In the Minneapolis case, for example, public acceptance for ramp metering is over 80%²⁷.

There are significant institutional problems associated with administrative organization. Ramp metering involves many vertical layers of government since it affects several jurisdictions. Arterial roads may be under a city's jurisdiction, while the state government may operate the freeway. In the United States, the federal government also often provides part of the funding for ITS initiatives. These vertical layers create a problem where no authority has ultimate control. Project management and general decision-making can be delayed and lead to inefficient processes.

Financially, there are several issues that need to be resolved. One is the simple problem of capital budgeting and operations funding. Systems relying on imbedded loop detectors, including ramp meters, require a good deal of maintenance to remain useful. This leads to the second problem of allocation of costs. Components of ramp metering systems often serve dual purposes for freeway management and incident management uses. The costs could therefore be assigned to different systems. The costs also need to be allocated among the different agencies involved. Therefore, there are two problems – finding the budget, and then dividing it between separate agencies.

A final barrier to deployment is training. When several organizations manage the deployment, it is difficult to coordinate a single training agenda among all staff. Often the wrong people are trained, or each agency learns a different method of operations. With technically sophisticated systems like ramp metering, coordinating the training process is very important for the success of the program.

3.1.2.4 Social Implications

Ramp metering has interesting social implications. On one hand, it has proven to reduce travel time and increase vehicle speeds on freeways. On the other, motorists must wait in a queue to enter the freeway. Many motorists value the freedom they feel while driving. To these people, government intervention into traffic regulation may seem invasive. There are also people who prefer to drive potentially longer routes simply to avoid stopping at red lights or other signals. They will also not support the use of ramp metering, and may simply transfer the congestion problem off the freeway onto secondary roads.

One important benefit that ramp metering provides is a reduction in variability of travel time. This provides social benefit because departure and arrival times can be more accurately predicted. Departure time to an airport, for example, can be later if one knows that there is little variability in travel time on the freeway.

²⁷ Ibid.

3.1.3 AUTOMATED RED LIGHT ENFORCEMENT

Vehicles speeding through intersections as they violate red lights often cause traffic accidents in urban areas. The Federal Highway Administration (FHWA) estimates that 50% of urban crashes in the U.S. are caused by intersection violations²⁸. The Texas Transportation Institute estimates that there are more than 100,000 red light running crashes annually in the U.S., resulting in 90,000 injured and 1,000 people killed²⁹. More than half these fatalities are pedestrians or occupants of the other vehicle. In addition to the loss of life, the congestion from these crashes can be particularly troublesome because traffic in multiple directions is blocked.

The purpose of automated red light enforcement is to deter violations by rigorously assessing fines for all violators. Photo or video imaging is used to capture the pictures of vehicles entering the intersection during the red light cycle. The violator is later sent a bill with the picture through the postal mail. Additional information, such as the date, time, vehicle speed, and number of seconds elapsed since the start of the red cycle can also be sent.

Basic components of the technology include a camera, loop detectors, mounting pole, and equipment cabinet. Installation and maintenance costs can be significant. In the United States, the private sector often operates the system in exchange for a percentage of the fine revenues.

The value from using automated red light enforcement is that the technology can catch more offenders, with higher efficiency, than the police force. Motorists never know exactly where the police will be, but with a fixed red light enforcement infrastructure, motorists know in advance to drive safely through particular intersections.

Automated red light enforcement can also be applied to intersections between road and railroad crossings at grade. In conventional crossing, warning signal alerts often begin before a train is in sight. As a result, drivers have adapted by sometimes speeding across the intersection to avoid a relatively lengthy delay. This is very dangerous because cars can stall on the tracks, high-speed trains can appear quickly, and accidents are usually fatal.

At road/rail crossings, red light enforcement has reduced the number of violations drastically. To track the reductions, municipalities used the equipment to measure the number of violations at an intersection, before the camera began operating. In this respect, violations are defined as the number of vehicles that ignore the red light, not just the vehicles that are caught. In Los Angeles, CA, two separate deployments produced reductions of 92% and 78% in the number of violations. A Fort Mead, Florida

²⁸ US DOT. Federal Highway Administration. "Overview of Current Intersection Safety Conditions." 7 Mar 2002. 4 Dec 2002 <<http://www.fhwa.dot.gov/safety/fourthlevel/07/mgriffith.htm>>.

²⁹ Quiroga, Cesar, Edgar Kraus, Ida van Schalkwyk, and James Bonneson. Texas Transportation Institute. "Red Light Running – A Policy Review." College Station, Texas: Texas A&M University, March 2003.

deployment reduced violations by 50% and a Jackson, MI installation reduced violations by 60%³⁰.

3.1.3.1 Benefits and Costs

The use of automated red light cameras has reduced the number of violations at intersections dramatically. It also partially moves the enforcement burden off the police force and shifts it onto the technology. Automated cameras are robust in that they can catch all of the offenders through a particular intersection. The technology is not limited by the capacity of human officers to manually pull over drivers and take time to write them tickets. Finally, the government also receives a revenue stream from collecting the fines.

Although deploying the technology reduces the number of red light violations, there are only a few independent studies conducted as to the impact on safety. The percentage reduction in violations ranges from 20% to 87%³¹. Some studies indicate no significant effect on crash behavior, while others show that there is an effect. One of the earliest evaluations in Melbourne, Australia reported an approximate decrease of 30% in accidents and 10% in fatalities³². The city of Charlotte, NC reported an approximate decrease of 9% in accidents³³.

A report issued by the Transportation Research Board separates red light crashes into three types: angle crash, left-turn crash, and rear-end crash. Angle crashes involve hitting "a vehicle proceeding through an intersection legally on a green signal display"³⁴. Left-turn crashes involve hitting a vehicle turning left from the opposite approach direction. Rear-end crashes involve hitting a vehicle immediately in front. The TRB report explored the possibility of an increased number of rear-end crashes with automated red light enforcement, since the lead motorists are likely to be more cautious entering intersections on a yellow signal. The report found that angle crashes are usually reduced, while rear-end crashes did increase in some situations. However, since angle crashes are typically much more severe, the net benefit appeared to be positive.

The capital and maintenance costs for automated red light enforcement are relatively high. The system requires many hardware components that must be precisely installed and calibrated. As a result, many jurisdictions contract out the installation and maintenance to the private sector and only run the back-end billing system in-house. The cost of the hardware runs from \$75-\$136K per camera, of which approximately \$25K is the installation cost. Annual O&M cost is approximately \$60K³⁵. Ticket revenue defrays

³⁰ "Photo Enforcement Proves Very Effective." *The Urban Transportation Monitor* 17 Mar 1995.

³¹ Maccubbin, Rob, Barbara Staples, and Dr. Arthur Salwin. Mitretek Systems. "Automated Enforcement of Traffic Signals: A Literature Review." Prepared for US DOT. McLean, VA: 13 Aug 2001.

³² Passetti, K. "Use of Automated Enforcement for Red Light Violations." College Station, Texas: Texas A&M University Department of Civil Engineering, Aug 1997.

³³ "Branding is the name of the game in enforcement." *ITS International* May/June 2000.

³⁴ Transportation Research Board. *Impact of Red Light Camera Enforcement on Crash Experience: A Synthesis of Highway Practice*. National Cooperative Highway Research Program, Synthesis 310. 2003.

³⁵ US DOT. "Traffic Camera for Red Light Running Enforcement Costs." ITS Benefits and Unit Costs Database 2000. 4 Dec 2002 <<http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/ID/>>

some of this cost. However, using the system leads to greater compliance and decreased ticket revenue in the long run. The best case for the public interest is when no violations occur. Therefore, municipalities should not grow to depend on ticket revenue as a funding source, otherwise they may find themselves in an ethical conflict of interest.

3.1.3.2 Example: San Francisco, CA³⁶

Between 1996 and 1998, the city of San Francisco, CA deployed automated red light cameras at five intersections. The equipment was owned by private companies, who received \$17.50 of each \$104.00 collected fine. The camera was triggered when a vehicle traveling at least 15 mph entered the intersection 0.3 seconds or more after the start of the red cycle. The city launched a public awareness campaign about the red light running problem at the same time that it installed the cameras, and posted warning signs at the approach to each intersection.

Both the San Francisco Department of Parking and Traffic and an independent study conducted by the Insurance Institute for Highway Safety found that the number of red light violations decreased by 42%. The success can be attributed to the technology, successful public/private partnerships, and a focused public awareness campaign.

3.1.3.3 Barriers to Implementation

The deployment of automated red light enforcement cameras faces a host of organizational, financial, legal, and information problems. As a result, implementing the technology requires careful consideration of many issues.

As stated above, the cost for deploying red light cameras is very high for most municipalities. To address this problem, many cities have chosen to partner with the private sector, allowing companies to install and maintain the equipment in exchange for a percentage of revenues collected. The cities themselves normally handle the billing and payment side. This organizational relationship requires a high level of communication and cooperation between the public agency and the private companies.

Legally, the video evidence may not be admissible in court should motorists choose to contest the ticket. In some regions, even though deployment reduces the number of accidents, there is no viable way to install the cameras since there is no way to finance the system without the revenue stream from violations. Concerns have also been raised about privacy, since the government can track people's movements if enough cameras are deployed. The courts have not supported the claim that red light cameras violate a person's privacy.

Finally, there are information problems with public education and billing systems. First, automated red light enforcement only becomes effective if citizens know of the consequences for running lights at particular intersections. Therefore, a successful deployment must include warning signs and some sort of public education campaign.

B474887398CC1DED85256B970052FD21>.

³⁶ Fleck, J. and B. Smith. "Red Light Photo Enforcement Program." San Francisco, CA: San Francisco Department of Parking and Traffic, Mar 1999.

Second, enforcement is feasible only when the government can match license plate numbers with the names and addresses of the car owners. This requires a complete, up-to-date motor vehicle database, which some countries do not maintain.

3.1.3.4 Social Implications

Automated red light cameras have both positive and negative social implications. By reducing the number of red light violations, the technology has the positive effects of lowering the citation and accident rate. However, there are negative issues related to public acceptance of the technology. Citizens in some countries view the cameras as just an easy way for the police force to make money. They are also concerned about their privacy as mentioned above.

One solution to the problem is to launch a public awareness campaign that emphasizes the safety benefits of automated red light enforcement. The safety aspects need to be demonstrated in order to gain public acceptance. Municipalities should also carefully consider how they use the revenues generated from the red light violations.

3.1.4 INCIDENT MANAGEMENT

Incident management refers to the system by which blockages on roads are identified, cleared, and by which throughput is restored. These blockages can be caused by crashes, disabled vehicles, natural debris, and other factors. The steps of incident management are detection, verification, response, clearance, scene management, and traffic management and operations. The system is often linked to advanced traveler information systems.

There are several key components to incident management systems. Closed Circuit Television (CCTV) allows personnel to quickly identify the location of incidents and to observe traffic flow. The images from CCTV can also be disseminated to news stations and ATIS channels. Loop vehicle detectors imbedded into roads can also warn traffic personnel of flow problems. These detectors count the number of vehicles passing by; a low count indicates reduced throughput and a possible blockage. Variable Message Signs (VMS) are changeable information boards, located primarily on highways, whose displays are remotely controlled by traffic management centers. VMS can route motorists around an incident or warn them of congested conditions ahead. Emergency phones or callboxes are also essential pieces of an incident management system, particularly for smaller incidents such as flat tires, road debris, or a vehicle running out of gas. Service patrol teams, who are dispatched to clear up incidents, are the last piece of the system but are not considered an ITS component.

Incident management can be very effective in clearing away blockages and restoring traffic more quickly. It is particularly useful in hazardous materials incidents. HAZMAT incident management decreases the time necessary to identify and contain the cargo, thus reducing the amount of material leaked and minimizing the negative environmental effect.

The advent of E-911 in the United States has led to another interesting development with incident management. Traditionally, calls to the 911 emergency line could only be traced

to land phone lines, not cellular calls. Recent Federal Communications Commissions (FCC) mandates have led to the development of wireless tracking devices to enable E-911 tracking on cellular phones. To track the phones, most technologies merely require the phone to be turned on (IntelliOne, TruePosition, Cell-Loc), while some actually require the phone to be in use (US Wireless)³⁷. At Motorola Labs, in addition, researchers have been able to track vehicles using a GPS card attached to the phone³⁸. These tracking devices can determine both vehicle speed and position.

Tracking cellular phones has several implications for both navigation assistance (discussed in Section 4.3) and incident management. By using cellular phones as a proxy for vehicles, control centers can more easily determine vehicle flows and blockages. As a result, centralized navigation assistance devices can better optimize vehicle routes on the network.

The use of cellular phones as traffic probes also has its associated problems. Privacy issues are significant because the location of each user's cell phone is known, except for the technology where the phone is tracked only when it is in use, not merely turned on. The solution to the privacy problem may be to enable legislation and technology protecting the identity of individual users. Organizationally, the concept requires a close collaboration between the public and private sectors. At the same time, the technology is attractive to public agencies, because cell phone companies are likely to bear most of the infrastructure cost in order to comply with the FCC mandate³⁹.

3.1.4.1 Benefits and Costs

The Federal Highway Administration estimates that incidents account for 25% of vehicle-hours lost to congestion⁴⁰. Incident management therefore has benefits in road efficiency, cost, and environmental effects. Clearing away blockages faster, and notifying motorists through VMS, reduces vehicle delay and improves efficiency on the network. Drivers can reroute around the incident and save time. Finally, improving throughput and reducing delay also mean fuel savings and lower tailpipe emissions, in addition to the special environmental case of hazardous materials mentioned above. For example, Atlanta's NaviGator incident management system, implemented for the 1996 summer Olympic Games, reduced average incident verification time by 74%, average response time by 50%, and average clearance time by 38%.⁴¹ Pittsburgh's

³⁷ Ciccarelli, Armand. PBS&J. "Innovative Traffic Data Collection: An Analysis of Potential Uses in Florida." Prepared for Florida DOT. Tallahassee, FL: 6 Dec 2001.

³⁸ Chen, Stephen. "Reply from Dr. Terry Heng." E-mail to the author. 22 Nov 2002.

³⁹ Ciccarelli, Armand. "An Analysis of the Impact of Wireless Technology on Public vs. Private Traffic Data Collection, Dissemination, and Use." Master's Thesis. Cambridge, MA: Massachusetts Institute of Technology, 2001.

⁴⁰ US DOT. Federal Highway Administration. "Congestion Mitigation." 5 Mar 2003
<<http://www.fhwa.dot.gov/congestion/congest2.htm>>.

⁴¹ Booz-Allen and Hamilton. "1996 Olympic and Paraolympic Games Event Study." Prepared for the US DOT. McLean, VA: 2 May 1997.

system has reduced about 547,000 hours of delay annually, which is valued at \$6.5 million⁴².

There are significant capital and operations costs for deploying incident management systems. The capital costs include hardware (video cameras, callboxes, VMS, loop detectors, computers for the traffic center) and software. Operations costs include maintenance and labor for both the traffic center and the incident teams. Actual cost figures are difficult to find, since each incident management system is different. However, capital costs appear to be around \$1 million per mile, and operations costs close to a million annually for a mid-sized deployment⁴³.

3.1.4.2 Example: Maryland Coordinated Highways Action Response Team (CHART)

Maryland State's CHART program began in the mid-1980's as a local initiative and has since expanded to statewide control, creating greater efficiency and time savings. CHART covers 375 miles of freeways and 170 miles of highway arterials. Components of the system are CCTV, VMS, loop detectors, speed detectors, pavement weather sensors, highway advisory radio, and highway advisory telephone.

CHART is significant for its interregional nature; it integrates incident management systems over a broad geographic region. Although it began in Maryland's eastern shore as a "Reach the Beach" traffic initiative, CHART is now administered cooperatively by the Maryland State Highway Administration, Maryland Transportation Authority, Maryland State Police, the Federal Highway Administration, the University of Maryland, and various local governments. Operations are centralized in a state operations center, with satellite traffic centers throughout the state⁴⁴. CHART is coordinated with traveler information systems and emergency services. Real-time information is distributed through radio, telephone, and the CHART website.

The system has been successful in reducing vehicle delays. Studies have shown an approximate 5% decrease (2 million vehicle-hours per year) in delay from incident-related congestion. The average incident duration decreased by 35%. Estimated fuel reduction was 5.85 million gallons per year, a huge resources and emissions benefit⁴⁵.

3.1.4.3 Barriers to Implementation

Incident management systems face barriers to implementation in organization, financing, legal issues, and information. Organizationally, the system requires coordination between several different agencies within one region. The traffic authority is most likely

⁴² US DOT. Federal Highway Administration. "What Have We Learned About Intelligent Transportation Systems?" Washington, DC: Federal Highway Administration, 2000.

⁴³ US DOT. "Equipment Costs for Transportation Management Center." ITS Benefits and Unit Costs Database 2000. 4 Dec 2002 <[http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/SubsystemCosts?OpenForm&Subsystem=Transportation+Management+Center+\(TM\)](http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/SubsystemCosts?OpenForm&Subsystem=Transportation+Management+Center+(TM))>.

⁴⁴ CHART Home Page. 2001. Maryland State Highway Administration. 4 Dec 2002 <<http://www.chart.state.md.us/default.asp>>.

⁴⁵ University of Maryland College Park and Maryland State Highway Administration. "Performance Evaluation of CHART – An Incident Management Program in 1997." College Park, Maryland: May 2000.

in charge of the system, but must have relationships with the police and emergency services to bring information from the system to action. There must also be regional coordination across jurisdictions. Since an incident in one region can cause congestion in another, agencies must build relationships with each group of police and emergency services personnel, in order to deploy the system most effectively. There may need to be coordination vertically as well. If a municipality wishes to implement an incident management system on a state or federal highway, then there are issues of ownership and operations that need to be resolved.

Financially, the capital and operations costs may cost millions, with little to no revenue streams to offset them. As with many ITS applications, even if a region can allocate the capital budget, it is difficult to find operations funding every year. Until incident management systems are mainstreamed into the planning process, operations funding will remain scarce.

Procurement of incident management systems brings up some legal and regulatory issues. Most governments are required to use a model of procurement that includes open bidding and automatic award to the lowest price bidder. For incident management systems, however, price cannot be the only factor. Governments need to consider the quality of the vendor, and how effectively they can design systems and software. Standard procurement regulations are too inflexible for ITS.

Finally, there is an information issue with incident detection. There is a tradeoff between detection sensitivity and false positives readings, where an incident team is dispatched but the blockage is relatively minor. The detection algorithms are continually improving, but use of artificial intelligence and neural networks have yet to solve this problem.

3.1.4.4 Social Implications

The use of incident management systems raises a few social questions. The first relates to privacy. CCTV captures images of vehicles and sends them to television news stations and the Internet. Citizens in certain countries view this as an invasion of their privacy. Legal opinions in the United States have not supported this claim. In some areas, however, it may be appropriate to enact legislation prohibiting certain uses of the images.

The other issue is that the rise of technology in society may eventually render some components of incident management unnecessary. Cellular phones have penetrated widely in the market and there is a strong initiative for cellular e-911 location. Because of this technological development, call boxes are becoming unnecessary. Similarly, the increasing popularity of mayday systems (see Section 4.4) reduces the need for public sector incident management. Since mayday systems alert authorities to traffic accidents and problems, they duplicate certain incident management functions. In the future, these two technologies may lead to changes in the way incident management is deployed.

3.2 ADVANCED TRAVELER INFORMATION SYSTEMS (ATIS)

The purpose of traveler information systems is to provide accurate knowledge of current traffic situations to drivers, and to instruct them of changes or detours. This allows motorists to make educated decisions about their routes. The concept ties closely with networked in-vehicle navigation assistance devices as discussed in Section 4.3. However, ATIS uses far more distribution channels.

Because ATIS relies on accurate and reliable traffic data, agencies must first deploy ATMS technologies before implementing ATIS. Information collected through the ATMS network is then disseminated through ATIS channels. The data is often processed by third parties, typically private companies, to make the information useful to drivers.

Traveler information can be distributed not only in-vehicle, but also through the Internet, cell phones, and other channels. The following table shows the U.S. level of deployment of traveler information systems for arterial roads through different channels (excluding variable message signs). These signs are used primarily on freeways to alert drivers of congestion or dangerous weather conditions.

Table 8. U.S. Arterial ATIS Deployment Levels

Technology*	Percent Agencies Using Technology in 1999**
Internet websites	7.8%
Telephone system	5.8%
Dedicated cable TV	5.0%
Facsimile	5.0%
E-mail or other direct PC communication	4.4%
Kiosks	3.0%
Pagers/personal digital assistants	2.8%
Cell phone/voice	1.1%
Cell phone/data	0.6%
Interactive TV	0.3%
In-vehicle navigation systems	0.3%
Other	1.9%

*Broadcast media (television and radio) is the primary method currently used to disseminate arterial information. However, these media are not considered ITS.

**Percentage calculated from 361 agencies nationwide responding to survey

Source: Reissnecker⁴⁶

A subset of advanced traveler information systems is parking guidance systems. Parking guidance systems reduce congestion by helping drivers find open parking spaces. In Cologne, Germany, a central computing system counts the number of cars entering and

⁴⁶ Reissnecker, A. "Equipment Requirements for Adaptive Traffic Control." Transportation Research Board Workshop. Washington, DC: 9 Jan 2000.

leaving each parking zone. The information is displayed real-time on variable message signs located on major roads into the city, as well as on the Internet⁴⁷.

3.2.1 BENEFITS AND COSTS

The majority of ATIS users in the U.S. are employed commuters that use the information to decide among alternate routes, estimate trip durations, assess congestion, and time their departures. The primary benefits are increased travel time reliability, reduced travel time, and improved road efficiency, although these benefits are typically small on a normal basis. In the event of a major accident, however, VMS and distributed information can avert significant congestion around the accident site. While normally the measurable improvement is small, drivers place high value on additional knowledge about their travel routes. These customers seek the following benefits from ATIS.

- Camera views that portray road conditions
- Detailed information on incidents
- Direct measures of speed for each highway segment
- Travel time between user-selected origins and destinations
- Coverage of all major freeways and arterials
- En route access to good traffic information⁴⁸

Deploying ATIS can be very costly. The financing can sometimes be planned in conjunction with ATMS. Nevertheless, it requires a large capital outlay to install the hardware and sensors necessary to collect the relevant traffic data. There must also be significant operations and maintenance to ensure reliable data. As a result, ATIS is a project that requires significant government initiative and a dedicated budget.

3.2.2 EXAMPLE: METROPOLITAN MODEL DEPLOYMENT INITIATIVE (MMDI) – SEATTLE, WASHINGTON

The Metropolitan Model Deployment Initiative program was sponsored by the U.S. DOT ITS Joint Project Office. The program is described as an “aggressive deployment of ITS at four urban sites: New York/New Jersey/Connecticut, Phoenix, San Antonio, and Seattle.⁴⁹” Out of twenty-three metropolitan applications, these particular sites were chosen on the basis of high pre-existing levels of ITS, systems capable of supporting the new ITS initiatives, and a record of cooperation with the private sector.

For Seattle, \$13.7 million was allocated to support the MMDI program. Under the initiative, the Washington State DOT implemented an ATIS program that distributed traffic information and visual displays over the Internet, telephone, cable television, PDA’s, kiosks, and other channels. This ATIS deployment was compared to the base

⁴⁷ Chen, Kan and John C. Miles, ed. *ITS Handbook 2000: Recommendations from the World Road Association (PIARC)*. Boston, MA: Artech House, 1999.

⁴⁸ US DOT. Federal Highway Administration. “What Have We Learned About Intelligent Transportation Systems?” Washington, DC: Federal Highway Administration, 2000.

⁴⁹ Science Applications International Corporation. “Metropolitan Model Deployment Initiative National Evaluation Strategy.” Prepared for US DOT, ITS Joint Program Office. McLean, VA: Nov 1998.

case of using highway advisory radio and variable message signs. The following table summarizes the benefits of the Seattle ATIS deployment.

Table 9. Results of MMDI Seattle Deployment

Metric	Benefit
AM peak total system delay	Reduced by 1.5%
Travel time variation	Reduced by 2.5%
Emissions	Statistically insignificant impact
Number of crashes	Reduced by 0.6%

Source: Mitretek Systems⁵⁰

3.2.3 BARRIERS TO IMPLEMENTATION

Despite its relative technical simplicity, ATIS technologies face a number of barriers to implementation. There are significant organizational and information issues.

From an organizational standpoint, ATIS deployments require the involvement of a large number of partners. Public agencies typically collect the traffic data, but numerous private companies are the ones who distribute it to the public through certain channels, such as cell phones and pagers. These companies must negotiate with each individual state or city transportation authority to gain access to the traffic data. To complicate the situation, there may be several public agencies working together on the same ATIS system. For example, information on arterial roads under a city traffic agency's jurisdiction may need to be displayed on the state turnpike's variable message signs. For implementation to succeed, there must be a regional architecture of agreements between each partner.

In addition, there is some debate on whether private companies should have to pay for traffic data obtained by the transportation agencies. One argument is that the data is in the public domain and therefore accessible to everyone. On the other hand, some argue that private companies are using the data for profit and should have to contribute to the cost of deploying the system.

There are technical information issues that also need to be addressed. Currently, there is no common method for describing traffic conditions to the public. Qualitative terms such as heavy, moderate, and light may hold different meanings for different regions. Quantitative measures are more precise, but need to be conveyed quickly and accurately to the general public.

Questions remain on the best way to get traffic data. Proposals have included a wide range of technologies, from road-imbedded induction loops to tracking devices in cellular

⁵⁰ Wunderlich, Dr. Karl E., James Brunch, and James Larkin. Mitretek Systems. "ITS Impacts Assessment for Seattle MMDI Evaluation: Modeling Methodology and Results." Prepared for US DOT, Federal Highway Administration. McLean, VA: Sept 1999.

phones. Camera pictures, while helpful, do not provide a complete description of a particular traffic situation that is robust enough for a model.

Technically, a standard for receiver technologies may also have to be developed. ATIS should be tightly integrated with in-vehicle navigation assistance devices, but there is currently no standard between manufacturers of these devices. Their technologies must be compatible in order to achieve the goal of real-time information sent by ATIS systems.

3.2.4 SOCIAL IMPLICATIONS

ATIS has social benefit in providing traffic information to motorists. However, there are several difficult social issues. One is that institutional focus is shifting towards electronic devices such as cellular phones and personal digital assistants that may not be affordable for some people. Although traditional channels such as radio and television are still available, improving these services may lose priority to developing more innovative and expensive channels.

The other issue is of privacy. As discussed above with incident management, some proposals call for using tracking devices in vehicles, particularly cellular phones. People are concerned that the government will be able to track their movements. Similarly, others may object to traffic images displayed on television and the Internet.

3.3 ELECTRONIC PAYMENT SYSTEMS

On toll roads, congestion often backs up for miles before a toll plaza, as cars queue for manual payment. Using electronic payment systems increases throughput significantly, because vehicles no longer have to come to a complete stop to offer payment. In addition, electronic payment eliminates the need for human operators to make change and collect tickets, which are both time-intensive processes.

Two applications of electronic payment technology are smart cards and wireless transmitters. Smart cards can have either contactless or contact interfaces. They function as debit cards and can be “refilled” at physical stations or sometimes online. Some examples of physical stations are ATM’s, convenience stores, and post offices. Wireless transmitters are usually affixed to the windshield of a vehicle. These communicate with roadside receivers, which then access a central computer for charging and billing.

Two important uses of the technology are electronic toll collection and electronic road pricing.

3.3.1 ELECTRONIC TOLL COLLECTION (ETC)

ETC systems support automated payment at tollbooths and other collection areas at near-highway speeds. The purpose of the system is to speed vehicles through the tollbooth bottlenecks, thus increasing effective road capacity as well as driver level of service.

Payment is collected using Automatic Vehicle Identification or Automatic Vehicle Classification technology. Typically, payment is debited through use of a contactless smart card or a vehicle-mounted transponder. The devices communicate through

dedicated short-range communications systems (DSRC). A toll lane antenna captures a vehicle's identification and sends it to a roadside reader unit. This unit accesses a central computer to locate the record from which to deduct the toll⁵¹.

Because automated payment is computer-based, a variable pricing scheme can be introduced depending on time-of-day, class of vehicle, and other factors. Some regions charge a fee for the transponder, but offer a discount on tolls for ETC users. Depending on the sophistication of the system, confirmation of toll charges may also appear on message signs or on in-vehicle devices. Violators are caught using license plate recognition technology (video enforcement system) that consequently bills the offender from existing records.

3.3.1.2 Benefits and Costs

Using ETC, drivers no longer have to stop, roll down the window, and manually pay with cash or tickets. Since time delays on toll roads are often spent waiting in a queue for the tollbooth, ETC can greatly decrease total travel time and increase driver convenience. At Japan's Odawara Toll Gate, for example, toll collection time was reduced from 14 seconds per car to 3 seconds per car after ETC was installed⁵². Beyond the transaction time, the waiting time for each car was also reduced.

Other benefits include reduced operating costs and environmental benefits. Operating costs are reduced since fewer tollbooth operators are needed at each toll plaza. In the United States, operating costs for an automated lane have been reduced by 90% compared with an attended lane⁵³. ETC options require only maintenance and account support. There are also environmental benefits from using ETC. Since fewer vehicles idle at toll plazas, emissions and fuel consumption are reduced and the air becomes cleaner.

The costs for ETC can be very high. In addition to the physical infrastructure, there must also be the purchase cost for appropriate software and linkages to payment systems. The operations and maintenance costs, however, can be close to zero if one excludes the overhead costs of enforcing payment. Apart from the infrastructure, motorists are often required to pay a small fee for acquiring the transponder. A discount on tolls is sometimes offered as an incentive to purchase the transponder. The following table summarizes some of the costs.

⁵¹ Smith, Lauren. "Electronic Toll Collection." *ITS Decision*. Berkeley, CA: 1 Mar 2002.

⁵² Highway Industry Development Organization, Ministry of Construction. "Intelligent Transport Systems Handbook in Japan." Odawara, Japan: 1 Oct 1997.

⁵³ MITRE Corp. "Intelligent Transportation Infrastructure Benefits: Expected and Experienced." Prepared for US DOT, Federal Highway Administration. Washington, D.C: Jan 1996.

Table 10. Estimated Costs for U.S. Electronic Toll Plaza

Element	Lifetime (years)	Capital cost (\$K)	O&M cost (\$K)	Notes
Electronic toll reader	10	2-5	0.2-0.5	One reader per lane
High-speed camera	10	5-10	0.5-1	One camera per two lanes
ETC software	10	5-10	--	
ETC hardware	20	10-15	--	

Source: US DOT⁵⁴

3.3.1.3 Example: New Jersey Turnpike

The New Jersey Turnpike Authority implemented an ETC system called E-ZPass on its turnpike system in September 2000. E-ZPass covers many of the northeastern states in the United States. A single transponder can communicate with toll collection booths over all of the E-ZPass areas, despite crossing numerous political and jurisdictional boundaries. A study conducted by Wilbur Smith Associates revealed the following results. They show that ETC dramatically reduces delay at toll plazas and provides other benefits as well.

Table 11. E-ZPass Study Results

Metric	Benefit
Delay at toll plazas	Reduced by 2.1 million hours/year
Fuel consumption	Reduced by 1.2 million gallons/year
VOC emissions	Reduced by 0.35 tons/day
Nox emissions	Reduced by 0.056 tons/day

Source: Wilbur Smith Associates⁵⁵

3.3.1.4 Barriers to Implementation

ETC systems are fairly common around the globe. In addition to several systems within the United States, there have also been successful installations in Japan, Hong Kong, the Philippines, Argentina, Turkey, Hungary, India, Singapore, China, and Australia, to name a few. Nevertheless, there are several barriers to implementing the technology.

Payment enforcement can be a challenging task. Although video image processing is commonly employed, the process is often manual and also relies on accurate records maintained by the toll agency or the department of vehicle registration. The payment system also faces legal issues. In case tickets are contested in court, all legal

⁵⁴ US DOT. "Equipment Costs for Toll Plaza." ITS Benefits and Unit Costs Database 2000. 4 Dec 2002 <[http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/SubsystemCosts?OpenForm&Subsystem=Toll+Plaza+\(TP\)](http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/SubsystemCosts?OpenForm&Subsystem=Toll+Plaza+(TP))>.

⁵⁵ Wilbur Smith Associates. "Operational and Traffic Benefits of E-ZPass to the New Jersey Turnpike." 20 Aug 2001.

requirements for record keeping must be met. The toll agency must be able to defend the accuracy of the violation detection and notice issuance system.

Another implementation hurdle in more developed countries is the issue of user privacy. This is one of the most frequently cited concerns over ETC implementation. Besides the obvious data encryption concerns surrounding any electronic payments, some people believe that the government may try to track their movements or use their private account information. This concern can potentially be addressed through legislation prohibiting certain uses of the information.

Implementing ETC on new toll roads is much easier than upgrading an existing freeway system. To retrofit existing attended lanes, the toll agency must be able to manage traffic disruptions during the installation. The loss of toll attendant jobs is often an issue with labor unions, or politicians who use the jobs for patronage. These conversion problems must all be addressed when upgrading to ETC.

Finally, a major barrier to ETC implementation is technical and administrative interoperability. The goal of technical interoperability is for all transponders to be able to communicate with all roadside readers, and for all readers to be able to identify any kind of transponder. This will allow vehicles to travel on multiple toll roads without possessing a separate transponder for each one. In areas that use smart cards for payment, technical interoperability means that the same card could be used for parking fees, public transit, and a variety of other applications on top of electronic toll collection.

Administrative cooperation is needed if technical interoperability is ever to exist. There must be integration between toll agencies, transit operators, different regional authorities, and between the public and private sectors. Several coalitions have already been formed to address this issue; one of the most successful has been the E-ZPass implementation in the United States across nine different states. In Malaysia, the need for integration has only emerged after over a dozen toll concessionaries realized the inefficiencies of each requiring a different transponder.

3.3.1.5 Social Implications

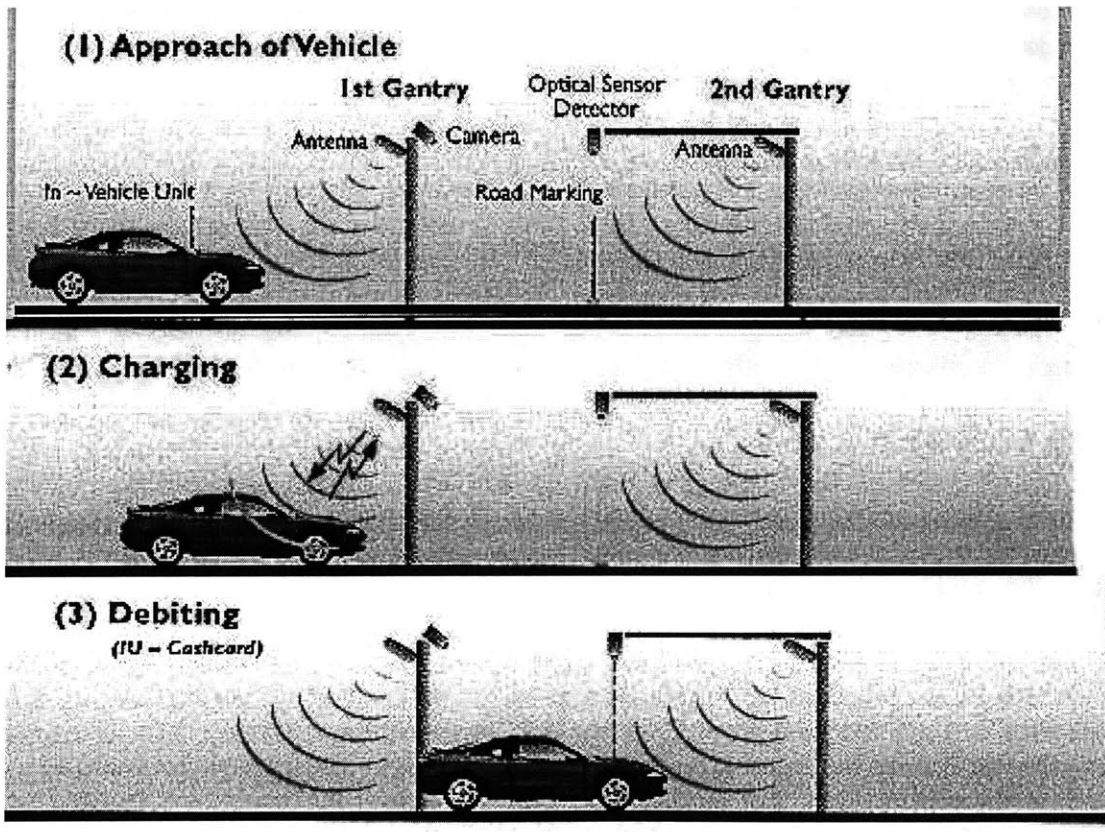
The use of electronic toll collection systems renders the payment process partially invisible. It is somewhat analogous to the use of credit cards in place of cash. Continuing with the analogy, it is conceivable that drivers will be more likely to use toll roads since ETC makes it more convenient. The growth of toll roads as an alternative to traditional road building could increase as a result.

The other social implication relates to the issue of privacy. As discussed earlier, motorists in many countries are concerned about the government tracking their movements through information collected by the tollbooths. The information could be used in many other ways. For example, a vehicle's average speed could be calculated by comparing the time and distance between each tollbooth checkpoints. Can the police force access this data to catch speeders? Using electronic toll collection brings the government closer into people's lives, and the issue of "Big Brother" must be handled carefully.

3.3.2 ELECTRONIC ROAD PRICING

Electronic road pricing, also known as congestion pricing, is an extension of ETC concepts to urban areas rather than along toll roads. The concepts are similar, but ERP charges fares based on congestion, rather than tolls based on recovering infrastructure costs. Like ETC, congestion pricing is an electronic system that automatically deducts fees from vehicles within a restricted zone, often in congested city centers.

There are two types of ERP technologies – vehicle positioning systems (VPS) and dedicated short-range communications (DSRC). VPS systems use GPS technology to determine a vehicle's location and charge the appropriate amount. The advantage of VPS is that the restricted area is flexible without the need for changing physical infrastructure. However, the technology is relatively new for ERP applications, and GPS signals can sometimes be lost in densely built cities. In contrast, DSRC systems are run locally with a vehicle identification unit, some form of smart card or automated payment, a central computer, roadside antennas, and a video enforcement system similar to ETC systems. Rather than GPS identification, vehicles traveling into the ERP area pass underneath an overhead gantry that provides coverage to all of the lanes. A second gantry is often used to verify the charge.⁵⁶ The following figure illustrates a DSRC system.



⁵⁶ Clark, Julie. "Sky-High Tolling." *ITS International* Feb 2000.

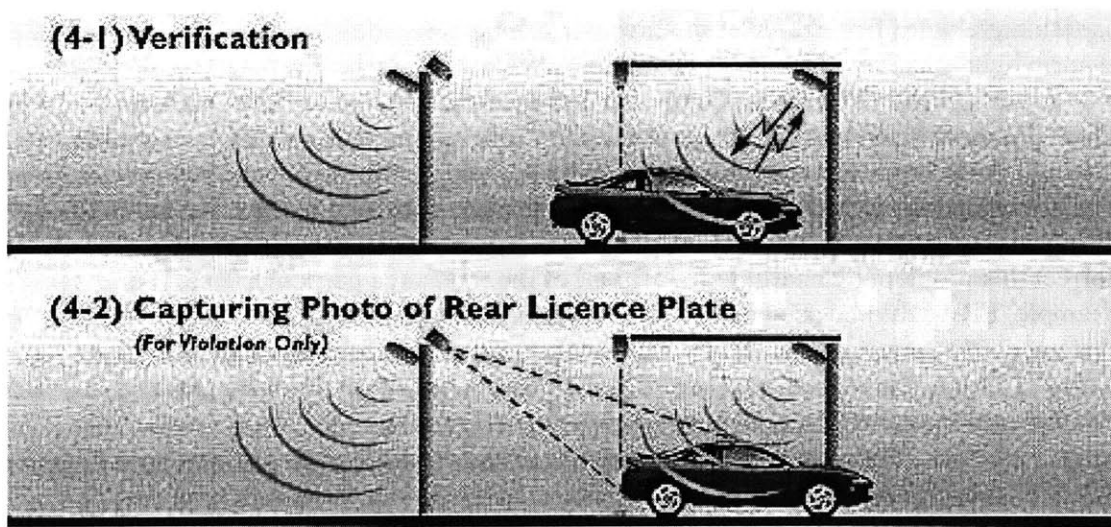


Figure 3. ERP DSRC System

Source: ITS Hong Kong⁵⁷

In London, the city is using 816 video cameras around the zone boundaries to record license plate numbers using infrared technology. These numbers are then compared against a list of drivers that have paid the universal daily fee. Drivers can pay in advance or the same day to avoid a large fine. However, London's system does not use gantries or physical barriers to deduct fees in real-time or prevent infractions⁵⁸.

While tolls are most often used to cover the cost of building and maintaining a road, ERP charges are aimed at controlling congestion, hence the name of congestion pricing. The premise is to charge drivers for the additional congestion for which they are responsible. The charge theoretically covers the costs of the time delay, deterioration of the road, environmental emissions, increased likelihood of accidents, and other social costs. Under the current system, motorists are not charged for their contribution to the congestion problem. In an article for the *OECD Observer*, Anthony Ockwell writes:

“When it comes to transport, most authorities supply roads to ‘meet’ the demand for road space. Users are not really faced with the actual price of using that road. Rather, motorists see road infrastructure as a public good, whose provision is financed from taxation.”⁵⁹

The advantage to using ERP is that pricing can vary with demand. As traffic increases on the network, the price can automatically increase as well. Prices can vary at different entry points to the ERP zone. In addition, different types of vehicle identification units can be issued depending on the vehicle type and emissions profile. The different identification units communicate with the central computer to charge a particular fee for a

⁵⁷ Zen, Tony. “Hints to Successful Implementation of Electronic Road Pricing System.” Hong Kong, China: ITS Hong Kong, 2000.

⁵⁸ Frankel, Glenn. “Toll Zone Put to Test in Divided London.” *The Washington Post* 17 Feb 2002: A22.

⁵⁹ Ockwell, Anthony. “Road Pricing – What’s the Deal?” *The OECD Observer* 1 Mar 2002.

particular vehicle. For example, motorcycles can be charged differently from a gasoline-electric hybrid car according to their particular vehicle identification transponders.

There are three types of ERP schemes – facility pricing, network pricing, and cordon pricing. Facility pricing is similar to a toll road except that fees are based on congestion. The advantage to facility pricing is that there are clear entry and exit points, but the disadvantage is that drivers can find alternative roads to use. Network pricing attempts to correct this problem by charging fees for all of the roads in a particular area. For example, ERP could be used on all of the highways leading into a major city. The last system, cordon pricing, is currently the most popular form of deployment around the world. Cordon pricing sets a restricted zone around a city’s central business district. Examples of cordon pricing include Singapore and London.

3.3.2.1 Benefits and Costs

ERP effectively manages congestion in downtown urban areas by decreasing vehicle demand for road space. The primary benefit is efficiency, as traffic volume in the ERP area decreases. ERP can also produce a rush hour spreading effect to lessen peak period congestion. Pricing can be adjusted to encourage certain types of driver behavior.

Decreasing congestion in central businesses districts has other positive effects. Pollution and emissions are reduced. Businesses in the ERP zone benefit from increased throughput and faster speeds. Fewer vehicles also mean a better environment for pedestrians and bicyclists. Finally, revenue from the ERP charges is a financial benefit to the government. This revenue is often reinvested in improving public transportation.

From a systems perspective, however, some of these benefits are reduced when one considers that traffic outside the ERP zone may become worse, particularly on orbital routes. There may be environmental and efficiency costs as drivers circumvent the ERP area. Agencies must also consider the availability of parking spaces to ensure that commuters deciding to use public transit have space to put their car. In a study for the 2003 deployment of ERP, London’s transport agency predicted the following results:

Table 12. Predictions for London Electronic Road Pricing Scheme

Performance measure	Expected result
Inside the zone – traffic volume	Reduce by 10-15%
Inside the zone – traffic queues	Reduce by 20-30%
Inside the zone – traffic speeds	Increase by 10-15%
Outside the zone – orbital traffic volume	Increase up to 5%
Outside the zone – radial traffic volume	Reduce by 5-10%
Outside the zone – overall traffic volume	Reduce by 1-2%

Source: Transport for London⁶⁰

⁶⁰ Transport for London. “Congestion Charging Benefits.” 2002. 5 Dec 2002 <http://www.londontransport.co.uk/tfl/cc_fact_sheet_other_schemes.shtml>.

ERP is costly to implement and operate. However, the operations cost is less than using transit personnel to manually check and charge vehicles entering the ERP area. In Hong Kong, a proposed ERP system is estimated to have a capital cost of \$1 billion, with a recurring cost of \$200 million per year. The Hong Kong example also anticipates yearly revenues of \$0.4-1.3 billion to be returned for transport infrastructure investment⁶¹. London's camera system cost \$145 million to set up, with annual anticipated profit of \$210 million, again earmarked for transportation improvements and busing⁶².

3.3.2.2 Example: Singapore

The world's first ERP system was started in 1998 in Singapore. Since 1975, Singapore was using a road pricing system called the Area Licensing Scheme. Under the ALS, motorists pre-purchased colored entry licenses, which were manually checked by transit personnel monitoring the restricted zone in the central business district⁶³.

Singapore realized that their manual system was inflexible to changing traffic conditions, required extensive manpower, and created traffic bottlenecks at ALS entry points. Consequently, they implemented a dedicated short-range communications ERP system using smart cards that are refillable at ATM's, gas stations, post offices, and other convenient locations. The Singapore system uses a double gantry verification process. However, the government has plans to upgrade to vehicle positioning systems technology. This switch would reduce the need for infrastructure maintenance and also address the problem of physical inflexibility with modifying the restricted zone.

Singapore has quickly seen the benefits of switching to an ERP system. There was a 13% total reduction of traffic volume during all charging hours, and a 22% rise in traffic speed⁶⁴. The number of solo drivers was reduced, and many vehicles switched from peak to non-peak hours. The government also benefited from a far less paper-heavy, manual system.

3.3.2.3 Barriers to Implementation

The main barriers to implementation of ERP are informational and financial. Informing the public about ERP is very sensitive process. Many drivers do not understand why they must begin to pay charges for roads for which they were not charged before. In Singapore, ERP is very unpopular, but the political process is such that the government can implement the system regardless of public opinion. In more democratic countries, public acceptance will be a more significant information challenge.

⁶¹ Hong Kong Special Administrative Region of the People's Republic of China. Government Information Centre. "Electronic Road Pricing Feasibility Study Executive Summary, April 2001." Apr 2001. 6 Dec 2002 <<http://www.info.gov.hk/td/eng/publication/images/erp.pdf>>.

⁶² Frankel, Glenn. "Toll Zone Put to Test in Divided London." *The Washington Post* 17 Feb 2002: A22.

⁶³ Cheatham, Benjamin. "Sustainable Urban Transportation in Developing Mega-Cities: A Review of Policies, Regulations, and Technologies." Master's Thesis. Cambridge, MA: Massachusetts Institute of Technology, Feb 2002.

⁶⁴ Transport for London. "Congestion Charging Fact Sheets - Singapore." 2002. 5 Dec 2002 <http://www.londontransport.co.uk/tfl/cc_fact_sheet_other_schemes.shtml>.

Financially, it is difficult for the transport agency to set the right ERP price. Many people have no choice about whether they travel within the ERP zone, and these people may not have the income to pay for new charges. It is also important for the transport agency to allocate revenues appropriately in order to win the public's acceptance. Most proposed ERP schemes are revenue neutral; that is, the money generated in the ERP zone is used for transportation purposes. For example, by committing ERP dollars into public transportation for the next ten years, London has tried to address the critics who say that ERP unfairly burdens poor drivers.

In many areas, the political will for implementing congestion pricing is lacking as well. Citizens are simply unwilling to accept the government's authority to control their driving behavior. In an essay discussing transportation policy and air quality, Arnold Howitt and Alan Altshuler discuss the lack of political will to implement economic incentive policies, including congestion pricing:

“Elected officials and other policymakers strongly regard the imposition of direct auto-use charges on individuals as politically infeasible . . . From the perspective of any particular citizen or firm, these policies promise few perceptible positive effects, at best a hypothetical (and marginal) improvement in air quality or travel time; but they do impose significant individual costs in inconvenience or dollars.”⁶⁵

Legally, there have also been issues raised about privacy. By electronically deducting payments, the government can determine a vehicle's approximate whereabouts during certain times of the day. Objections over privacy were a significant obstacle in Hong Kong's attempt to deploy ERP, because citizens were suspicious of electronic records generated on their movements, particularly in the evening hours.

3.3.2.4 Social Implications

One of the reasons that ERP is often controversial is that it appears to hurt lower-income drivers the most. Wealthy drivers can easily afford the charges, but poorer ones cannot. This also exacerbates the image problem that many public transportation systems across the world face, when competing with relatively luxurious private automobiles. There are two strategies for dealing with this problem.

The first is to reinvest revenues from ERP back into public transportation. Thus, the charges flow back to improving transit for people who cannot afford to, or choose not to, drive into the ERP area. It is very important that the revenue generated through ERP be used in a socially beneficial manner, to avoid the appearance of another tax. As a transportation demand management policy, the purpose of ERP is to control traffic congestion, not to raise money.

⁶⁵ Howitt, Arnold M. and Alan Altshuler. “The Politics of Controlling Auto Air Pollution.” *Essays in Transportation Economics and Policy*. Ed. Jose Gomez-Ibanez,, William Tye, and Clifford Winston. Washington, DC: Brookings Institute Press, 1999. 246.

The second strategy is to charge different prices for different users. While most regions consider it discriminatory to charge people differently based on their income, agencies can use other factors to determine the ERP fare. For example, vehicles could be classified by weight or by emissions profile. Under this scheme, drivers of sport utility vehicles could be charged more for their emissions than the drivers of gasoline-electric hybrids. By charging expensive vehicles more for using the ERP area, agencies can try to shift charges away from lower-income commuters.

3.4 ADVANCED PUBLIC TRANSPORTATION SYSTEMS (APTS)

APTS is a broad range of ITS applications that are specifically used in public transportation. They do not control vehicle traffic congestion directly. However, by making public transportation more attractive, APTS may draw drivers to use public transit, thus reducing congestion on the roads.

Some APTS technologies, such as traffic signal preemption, have been discussed above. Many of the principles covered in this section may already seem familiar through their applications in intelligent infrastructure technologies (for instance, the ATIS concept). This section discusses automatic vehicle location, automated passenger information, and electronic fare payment as applied to public transportation.

3.4.1 AUTOMATIC VEHICLE LOCATION (AVL)

AVL is the technology by which the location of each transit vehicle is relayed to a central control center. It has four main uses - passenger information, driver/dispatcher information, vehicle schedule adherence, and timing of transfers. There are three methods to determine vehicle position. They are signposts, dead reckoning, and GPS⁶⁶.

The signpost system consists of a series of radio signposts located along each route. The vehicles are equipped with devices that receive the radio signals from the signposts. When AVL vehicles pass a signpost, that information is relayed to the central control center. Between signposts, the position of vehicles is estimated. However, the system is limited because the signposts are fixed and they cannot track vehicles that do not pass them.

The dead reckoning system uses the vehicle odometer and a compass to determine vehicle position from a known starting point. This method is the most imprecise of the three, as error accumulates with distance traveled. Dead reckoning is generally supplemented with a few signposts or GPS.

GPS uses a receiver attached to the vehicle to calculate position from satellites orbiting the earth. It requires signals from at least three satellites. GPS is used in most new AVL systems, but the signals may be lost between tall buildings or underground.

⁶⁶ US DOT. Federal Highway Administration. "What Have We Learned About Intelligent Transportation Systems?" Washington, DC: Federal Highway Administration, 2000.

3.4.1.1 Benefits and Costs

By providing accurate vehicle location data, AVL has a benefit on passenger information, dispatching, vehicle schedule adherence, and transfer timing. AVL can tie into the passenger information systems discussed in the next section to give real-time information updates. Dispatchers use the data to quickly send the nearest personnel to the exact location of an incident. Transit vehicle drivers can use AVL to follow their schedules more closely, and create more uniform headway intervals. For example, if a vehicle is a few minutes ahead of schedule, then it can wait longer at stops and travel slower in order to reconcile with the schedule. Transfers also receive a benefit because passengers can immediately tell if they have missed a transfer or how far away it is from the transfer point. The following table summarizes results in schedule adherence from AVL in North America.

Table 13. Schedule Adherence from AVL

Location	Change in Schedule Adherence
Kansas City, Missouri	Improved by 12.5%, from 80% to 90%
Denver, Colorado	Improved by 12%-21% on various routes
Baltimore, Maryland	Improved by 23%
Hamilton, Ontario	Improved by 8.5%

Source: US DOT⁶⁷

There is a small cost benefit from using AVL. Many transit agencies employ manual service adherence checkers, whose jobs could be eliminated from AVL technology. Headcount of information agents and street supervisory personnel may also be reduced. If schedule adherence can be improved to a certain threshold, then transit agencies may even be able to reduce their fleets while maintaining the same level of service for their passengers.

AVL-equipped vehicles can also act as traffic probes in general traffic conditions. The speed of the roadway is inferred from the speed of the AVL vehicles. Similarly, drivers who witness traffic incidents can report to the control center, which then uses the AVL vehicle location to direct emergency personnel to the scene of the accident. This may reduce the assigned cost of incident management systems described earlier.

The capital cost of an AVL system varies widely depending on the size of the system and its technical sophistication. In a study conducted by the US DOT in the public transportation area, researchers found that the average cost per bus was around \$15,500 with a range from \$6,800 to \$30,500⁶⁸. Costs include the equipment and software at the central facility, plus the hardware on each individual vehicle.

⁶⁷ US DOT. Federal Highway Administration and Federal Transit Administration. "Automatic Vehicle Location Successful Transit Applications: A Cross-Cutting Study." Washington, DC: ITS Joint Program Office, Aug 2000.

⁶⁸ Ibid.

3.4.1.2 Example: Milwaukee, Wisconsin⁶⁹

The Milwaukee County Transit System (MCTS) first issued an RFP for AVL technology in 1991. The next year, they approved the installation of a Westinghouse Smarttrack System for the Milwaukee bus fleet. Their system uses differential GPS for an accuracy of between ten and twenty meters. MCTS installed the system on around 535 buses and uses computer aided dispatching through 8 dispatch stations. The hardware included location equipment as well as some surveillance cameras and silent alarms.

The results were promising. MCTS reported an increase of 4.4% in schedule adherence, from 90% to 94%. In addition, the playback feature showed that 50% of customer complaints were invalid. Results also showed that 28% fewer buses were more than one minute behind schedule, as compared to the data obtained before AVL deployment⁷⁰.

3.4.1.3 Barriers to Implementation

AVL technology has existed for over a decade; yet its deployment remains relatively limited. The main barrier to implementation is financial, although there are also legal and organizational problems to be overcome.

The public transit authority in a particular region is largely responsible for capital budgeting and maintenance expenditures. The largest issue for AVL has been convincing the right people to budget the necessary money for installing the system. While AVL is a large capital outlay, one possible solution is including it in a systems-wide communications upgrade to defray some of the cost.

Legally, a significant issue for AVL has been procurement. Lack of significant vendor competition has led to delays from multiple solicitations for bids, contractor nonperformance, unavailability of software development and upgrades, bids above budgeted funding levels, and faulty installation. Some of these problems cannot be solved easily, but a revision of the procurement code for public agencies can help. With the current array of AVL vendors, low-price bidding does not appear to be working well.

There are several problems with information. First, the enormous amount of data provided by AVL can overwhelm the analysis capabilities of some transit agencies. Second, a data standard needs to be developed for agencies sharing the information (for example, transit agencies relaying location data to emergency services personnel). Finally, the staff must be trained in the new system, and additional technically qualified employees may need to be hired.

Organizationally, there are fewer problems than most ITS applications because AVL tends to be owned and operated by the public transit authority. However, this agency must be prepared to cooperate with other agencies, such as emergency services, that may benefit from the use of the location data.

⁶⁹ Ibid.

⁷⁰ Giugno, M. "Milwaukee County Transit System, Status Report." Milwaukee, WI: July 1995.

3.4.1.4 Social Implications

Providing vehicle location data to passengers and transit agencies is a benefit for society at large. Public transit becomes more efficient and passengers no longer have to wonder if they have missed their ride or when the next vehicle will arrive. Since vehicles, not individual people, are tracked, there are few of the privacy issues associated with other ITS initiatives like electronic toll collection and automated red light enforcement. However, AVL is sometimes implemented alongside technologies like surveillance cameras and electronic payment, which may be perceived as more invasive.

3.4.2 AUTOMATED PASSENGER INFORMATION

Automated passenger information can be divided into two types, pre-trip and en route. Pre-trip information systems are widely deployed, but en route systems are not.

Pre-trip information includes routes, maps, schedules, fares, and other useful trip information. It is disseminated through a variety of media, including telephone, Internet, pagers, personal digital assistants, kiosks, and television.

En route information includes real-time vehicle arrival information and time estimates to the next arrival. It is displayed either at transit stops or on electronic signs in transit vehicles. Kiosks are sometimes used at major transit hubs. Light emitting diode (LED) displays and digital voice announcements are the most common⁷¹. En route information relies on location data provided by AVL technology.

The INFOPOLIS-2 project supported by the European Commissions' Telematic Application Program (Transport Sector) summarized the scope of passenger information to include the following⁷².

- Public interactive terminals located near transport facilities to help passengers plan journeys and look up arrival and departure times
- Dynamic bus stop displays disseminating real-time next arrival information
- On-board information announcing the next stop and possible connections
- Information at home/office providing pre-trip information
- Portable information equipment such as cellular phones to give information before and during the journey

3.4.2.1 Benefits and Costs

Providing automated pre-trip information has cost and efficiency benefits. In terms of cost, automated information reduces the need for customer information staff. This is because passengers can access the data through many channels, so fewer passengers will call the telephone help line. For example, New Jersey Transit's automated system reduced caller wait time from 85 seconds to 27 seconds, and lowered the hang up rate

⁷¹ Transportation Research Board National Research Council. "Electronic On-Vehicle Passenger Information Displays (Visual and Audible)." *Research Results Digest*. Number 5, Jun 1995.

⁷² INFOPOLIS-2 Home Page. 13 Jun 2000. European Commission Telematics Application Programme (Transport Sector). 4 Dec 2002 <<http://www.ul.ie/~infopolis/>>.

from 10% to 3%. Rochester-Genesee (New York) Regional Transportation Authority's new information system answered 70% of calls and allowed four information staffers to be reassigned⁷³.

En route information benefits the transit passengers. By eliminating uncertainty about the time of the next vehicle arrival, the passenger level of service is improved. Transit agencies hope this will increase ridership and revenues, but there is no solid evidence of this link as yet⁷⁴. In-vehicle passengers also benefit from having stops announced clearly and reliably, which does not often happen when the vehicle operator is responsible for announcing stops. By shifting this information burden away from the operator, he or she is able to better concentrate on driving.

Costs of the system are capital and maintenance expenditures. Automated telephone information systems cost approximately \$75,000-\$100,000, and Internet websites cost up to four thousand dollars⁷⁵. The average kiosk costs about \$8750.

3.4.2.2 Example: 423 Public Transport Telematic System - Helsinki, Finland⁷⁶

The 423 Public Transport Telematic System became operational in Helsinki in 1999. The system originally covered tram line #4 and bus route #23, leading to the name 423. Helsinki's system uses GPS-based AVL to track the transit vehicles.

The bus stop displays show the route number, the destination of the arriving vehicle, and the waiting time in minutes. On-board displays announce the name of the next stop. The real-time information is also available via telephone and Internet. Since Finnish and Swedish are both spoken widely, both languages are cycled through in visual and auditory announcements.

Personal interviews conducted found that 71% of tram passengers and 83% of bus passengers noticed the new displays. The displays were considered useful by 66% of the tram passengers and 78% of the bus passengers. The characteristics valued were information on the remaining wait time, the option to choose another line, the understandability of the display, and knowing if the expected vehicle had already passed so the rider could make use of the remaining wait time⁷⁷.

⁷³ US DOT. Federal Transit Administration. "Operation Timesaver - ITI Transit Components." 4 Dec 2002 <<http://www.fta.dot.gov/library/technology/APTS/iti/iti.htm>>.

⁷⁴ US DOT. Federal Highway Administration. "What Have We Learned About Intelligent Transportation Systems?" Washington, DC: Federal Highway Administration, 2000.

⁷⁵ Ibid.

⁷⁶ Sane, Kari and Erkki Nickul. "Real-time Passenger Information - A New Way to Promote Public Transport." City of Helsinki, Traffic Planning Division, and Helsinki City Transport. 20 Dec 1999. 4 Dec 2002 <<http://www.hel.fi/ksv/entire/repPassengerInformation.htm>>.

⁷⁷ Lehtonen, M. and R. Kulmala. "The Benefits of a Pilot Implementation of Public Transit Signal Priorities and Real-Time Passenger Information." Presented at the 81st Transportation Research Board Annual Meeting. Washington, DC: Jan 2002.



Figure 4. Real-Time Bus Stop Display in Helsinki

Source: Sane and Nickul⁷⁸

3.4.2.3 Barriers to Implementation

Assuming that AVL technology is already in place, the barriers to implementation for automated passenger information systems are primarily financial and informational. Financially, public transit authorities often consider passenger information systems to be non-essential extra cost items. There is no evidence that they increase ridership, though existing riders are more satisfied with the transit service. It is therefore difficult to budget for the purchase of these items.

From an information point of view, there must be qualified staff to operate and maintain the information systems technology. The hardware, most notably kiosks, is often slow or out of service. Transit agencies must be able to train or hire the appropriate personnel to ensure that the system remains accurate and reliable.

3.4.2.4 Social Implications

Automated passenger information systems benefit society by distributing real-time knowledge about vehicle locations. It is particularly beneficial for those passengers who do not use the system everyday. One example is tourists, who can be easily bewildered in an unfamiliar city with no knowledge about the public transit system.

Providing real-time information also allows travelers to time their arrivals such as to minimize wait time at the transit station. Especially in areas with severe weather or high crime, riders benefit from a reduced wait time. The on-board information systems, when available, are a great help to the disabled community that often cannot hear the operator announcing the next stop. Using on-board displays and audio announcements help the disabled be ready to disembark at the appropriate transit stop.

⁷⁸ Ibid.

3.4.3 ELECTRONIC FARE PAYMENT

Electronic fare payment (EFP) replaces traditional cash and tokens systems with electronic fare media. There are two types of electronic fare media - magnetic stripe cards and smart cards containing microprocessors. Smart cards can be divided into two categories as well - contact smart cards and proximity (contactless) smart cards. While their initial application is in public transit, a single smart card can provide payment for parking, electronic tolls, electronic road pricing, public transit, and other charges. For example, people "could eventually use such devices not only to buy coffee and newspapers, but also to store bus transfers, hold medical records and drug prescriptions, download coupons, and redeem tickets to museums and sporting events"⁷⁹. These cards can be refillable at a variety of locations, including ATM's, grocery stores, gas stations, and even online.

One example of the expanding domain of smart cards is ExxonMobil's SpeedPass. SpeedPass was originally intended for electronic payment at Exxon and Mobil gasoline service stations. ExxonMobil is now working with McDonald's and Stop and Shop supermarkets to use SpeedPass for their checkout payment systems as well⁸⁰.

Magnetic stripe cards consist of a "mag stripe" imprinted on heavy paper or thin plastic. These cards require a contact between the magnetic stripe and a fixed reader that either validates the card (i.e. a fixed price monthly pass) or deducts the fare from the stored value. Magnetic stripe cards have limited data storage compared to smart cards⁸¹.

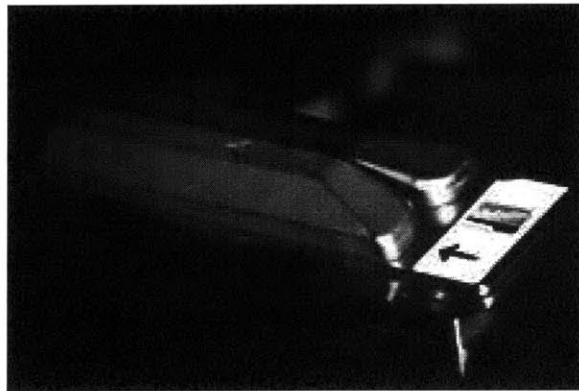


Figure 5. Magnetic stripe card in New York City

Source: US DOT⁸²

⁷⁹ "How You'll Pay." *Technology Review* Dec 2002/Jan 2003 p. 50.

⁸⁰ Ibid.

⁸¹ US DOT. Federal Transit Administration. National Associations Working Group for ITS. "Electronic Fare Payment Systems - Smart, Convenient, Cost-Effective." Washington, DC. 4 Dec 2002 <<http://www.nawgits.com/fhwa/sheet8.pdf>>.

⁸² US DOT. Federal Transit Administration. "Transit Intelligent Transportation Systems Electronic Fare Payment Systems." 4 Dec 2002 <<http://www.fta.dot.gov/research/fleet/its/efp.htm>>.

Contact smart cards have an array of small metal contacts in one part of the card. They contain both programmable memory and read-only memory. The programmable memory stores changeable data such as the cash balance and use history. The read-only memory stores the microprocessor operating program and identification information for encryption.

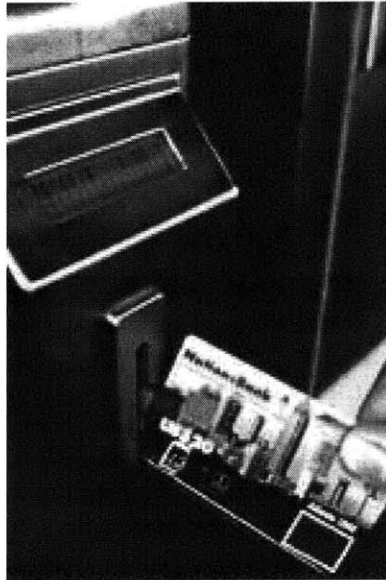


Figure 6. Contact Smart Card in Atlanta, Georgia

Source: US DOT⁸³

Proximity smart cards use radio frequency or infrared signals to transmit signals. The distance required for transmission varies from a foot down to about an inch. The advantage to users is that one need not remove the card from a wallet for validation. As a result, passenger throughput in transit stations and on vehicles can be greatly increased. This technology is also being used for identification cards in keyless security systems.



Figure 7. Contactless Smart Card in Washington, D.C.

Source: US DOT⁸⁴

⁸³ Ibid.

Both types of smart cards have greater security, reliability, and resistance to fraud than magnetic stripe cards. However, they are also more costly⁸⁵.

3.4.3.1 Benefits and Costs

Electronic fare payment has cost and efficiency benefits. For transit agencies, using EFP reduces operating costs by decreasing the need for labor-intensive cash and token handling, though payment by cash can probably never be completely eliminated. With fewer tokens and cash, the risk of theft is also greatly reduced. EFP lowers the maintenance costs for fare boxes since there are less moving equipment parts as compared to a mechanical token collector. In addition, finance and accounting functions can be automated and more accurate since data is stored electronically.

Transit agencies benefit not only from reduced costs, but also increased revenues. Using EFP reduces fare evasion and possibly increases ridership. An electronic system also allows the agency to use a pricing system that varies by distance traveled, time of day, and type of user. This system of differential pricing can lead to greater revenue and ridership (i.e. discounts for senior citizens). The data collected by the system also provides detailed ridership statistics for the agency to use.

From an efficiency standpoint, EFP results in faster throughput of riders in stations. Passengers no longer need exact change, nor must they queue frequently to buy tokens. This benefit becomes more pronounced as smart cards are regionally integrated onto multimodal and multiprovider transit networks. Instead of purchasing several different tokens, a single smart card can pay for travel on a variety of routes. EFP reduces public transit travel time and increases the efficiency of the system.

Upgrading an existing fare collection system to an electronic system can be very costly. The cost depends on the type of infrastructure – heavy rail systems, for example, require turnstile overhauls at a fixed number of stations, whereas buses require installation of special equipment on each vehicle. In a survey conducted by the Volpe Center, the median capital cost was over \$8,500 per vehicle in a bus system⁸⁶. For a large city such as Boston, Massachusetts, the overhaul of the rail system is expected to cost a total of \$120 million⁸⁷. Costs include an extensive equipment overhaul, implementation of a communications infrastructure, a data processing center, and software. To upgrade from magnetic stripe cards to smart card infrastructure, Visa USA estimates a total cost of \$11 billion nationwide⁸⁸. However, as mentioned earlier, operating costs of the transit system may decrease due to reduced maintenance and labor needs.

⁸⁴ Ibid.

⁸⁵ US DOT. Federal Highway Administration. "What Have We Learned About Intelligent Transportation Systems?" Washington, DC: Federal Highway Administration, 2000.

⁸⁶ Ibid.

⁸⁷ Newcombe, Tod. "A Smart Way to Pay." *Government Technology* July 2002.

⁸⁸ "How You'll Pay." *Technology Review* Dec 2002/Jan 2003 p. 50.

3.4.3.2 Example: Washington, D.C. – SmarTrip

In 1999, the Washington Metropolitan Area Transit Authority (WMATA) implemented the first contactless smart card public transit system in the United States. The system covers the District of Columbia as well as the Washington metropolitan area in both Maryland and Virginia.

The passes function as stored value debit cards, which can be bought and recharged online, at Metro offices, or at hundreds of participating retail stores. Employers offering transit benefits can also load the value onto the SmarTrip card automatically⁸⁹.

The SmarTrip card pays for the Metro subway system and parking fees at Metro stations. More than 30% of subway trips are taken using SmarTrip. There are plans to expand the card to include buses, commuter rail, and eventually the public transit systems in Baltimore. The WMATA is currently retrofitting buses to accept the technology. The original capital cost was estimated at \$30-\$35 million. For the bus expansion, the cost is estimated to be an additional \$24 million⁹⁰.

The WMATA charges a \$5 fee for the SmarTrip card. However, it offers a 10% discount on fare purchases above \$20. Each card has a unique, unalterable serial number. If the card is registered with the WMATA, the authority can issue a replacement card for the same \$5 fee in case of theft or loss. The replacement card will contain the same unused balance as the card that was lost.

The system has been very successful in increasing throughput in stations. Public acceptance is evident by the rapid growth and wide market penetration of the technology. In a region heavily congested with automobiles, SmarTrip is making an impact by increasing the level of service on public transportation routes.

3.4.3.3 Barriers to Implementation

Despite its convenience, smart card technology remains in limited deployment for public transportation systems applications, particularly in the United States. Although 685 million smart cards were shipped in the year 2001, 60% of these went to Europe and 30% to Asia⁹¹. The SmarTrip example described above is the only large-scale successful implementation in the U.S. The problems for deployment are largely organizational and financial.

To implement EFP over several transit operators or modes, there needs to be horizontal integration between the separate transit agencies. They must be willing to share data and agree to use the same technical standard for smart card technology. This requirement sometimes forces a link between agencies that do not historically work closely with each other.

⁸⁹ SmarTrip Home Page. 2002. Washington Metropolitan Area Transit Authority. 4 Dec 2002 <<http://www.wmata.com/riding/smartrip.cfm>>.

⁹⁰ Layton, Lyndsey. "Many Don't Notice New SmarTrip Bus Farebox." *The Washington Post* 12 Nov 2002.

⁹¹ "How You'll Pay." *Technology Review* Dec 2002/Jan 2003 p. 50.

Perhaps the largest barrier to implementation is simply financial. Even the smallest EFP deployments are likely to cost several million dollars to be effective, since they are so large in scope. EFP initiatives need a champion to lobby for funding and to oversee the planning, installation, and operation of the system.

3.4.3.4 Social Implications

Electronic fare payment has several positive implications for society. First, the vision of a single payment system across all modes and operators greatly increases the ease of transferring within public transit. Second, EFP is useful for children and other citizens who are either not able or not willing to carry cash while traveling alone. Finally, increasing the ridership on public transit will decrease congestion and its corresponding pollution on the roads.

However, EFP also has negative implications. The parallel to EFP in the private sector is congestion pricing. Not surprisingly, EFP has many of the same problems. The electronic system is conducive to more sophisticated pricing, where travelers can be charged according to different factors. While this could ostensibly be used to offer discounts to lower-income users, the resulting debate on the exact nature of the pricing system is sure to generate controversy. Although privacy concerns have not been an issue so far, citizens may eventually question the government's right to track their movements through the smart cards.

This chapter explored infrastructure-based technologies. The next chapter, Chapter Four, looks at intelligent transportation systems that are based within vehicles. Similar analysis into benefits and costs, examples, barriers to implementation, and social implications is carried out for each technology in the next chapter as well.

CHAPTER FOUR: INTELLIGENT VEHICLE TECHNOLOGIES

This chapter discusses ITS technologies that are primarily located within, or as part of, individual vehicles. Intelligent vehicle technologies can be included within vehicles such as a car, motorcycle, or truck. They are largely one of two types – technologies integrated into the vehicle itself, and external technologies mounted onto a vehicle. Several of the key components to many intelligent vehicle technologies are Global Positioning Systems (GPS), electronic sensors, wireless communications, and sophisticated computer control algorithms.

Unlike the infrastructure-based technologies discussed in the previous chapter, vehicle-based technologies are most often developed and marketed by the private sector, primarily the automobile industry. Many of these technologies are sold as separately priced options on cars, depending on consumer purchase choices for their deployment. There may conceivably be areas of overlap with infrastructure-based technologies; for example, electronic toll collection infrastructure requires vehicle-based transponders. For the purposes of this paper, vehicle-based technologies are those that are focused on devices placed on a driver or on a vehicle. In the example of electronic toll collection, the system is based on the toll road infrastructure, not on the individual vehicle transponders.

One set of vehicle-based technologies is sometimes referred to as Advanced Vehicle Control Systems (AVCS). These systems improve driver behavior in risky situations by changing vehicle speed and direction, either automatically or through visual and auditory warnings. Examples of AVCS presented in this chapter are intelligent cruise control, vision enhancement systems, collision avoidance technology, intelligent stability and handling systems, and drowsy driver sensors.

There is also an entirely new approach to vehicle control systems called drive-by-wire. Drive-by-wire replaces the hydraulics and mechanics of traditional automobiles with an advanced electronic control system. As a complete overhaul of automotive mechanical limitations, drive-by-wire has many implications for changing vehicle form and function.

While AVCS and drive-by-wire do not directly affect traffic congestion from a systems perspective, they can make an impact by reducing the number of accidents and by mitigating some of the negative effects of congestion. For example, many AVCS technologies improve vehicle safety, thus lowering accident risk and reducing the congestion associated with vehicle accidents. Similarly, these technologies can reduce tailpipe emissions through greater efficiency, which lower the negative environmental impact of congestion without necessarily reducing the congestion itself.

The remaining technologies addressed in this chapter are information-based systems. Navigation assistance devices are currently in the marketplace. These devices reduce travel time by helping drivers plan faster routes. The technology uses GPS positioning and map databases to guide vehicles. Mayday systems are another vehicle information system described in this chapter. Mayday-equipped vehicles automatically notify a call center in the event of a crash. Many private mayday services also offer traveler information services on top of the basic crash notification service.

Finally, vehicle mobile computing is growing in popularity as a method by which drivers can better use the time that they are normally caught in traffic congestion. If delays can be used productively, then the negative efficiency effects of traffic congestion can be lessened, though the environmental effects remain. This concept is already being developed through providing e-mail and Internet access to special in-vehicle receptors or cellular phones.

The technologies presented in this chapter are not meant to be a complete list. It is difficult to describe all vehicle-based ITS at any given moment, since automobile manufacturers are continually trying to anticipate the next wave of ITS features that consumers will actually value. The value of each technology in this chapter is described. Benefits and costs are also presented. Typically, benefits and costs are either based on efficiency, safety, the environment, or finances. Where possible, actual cost data from various deployments is included. Finally, an example of each technology is given, along with a discussion of the barriers to implementation and the social implications.

4.1 ADVANCED VEHICLE CONTROL SYSTEMS (AVCS)

Advanced Vehicle Control Systems do not control traffic congestion directly. Rather, they aim to indirectly control congestion by reducing the number of accidents caused by vehicles on the road. This is accomplished with smart safety systems that detect and warn of dangerous situations. These situations can be single-vehicle (i.e. driving in icy road conditions) or multiple-vehicle (i.e. an imminent collision). Accidents can create large amounts of congestion, whose aftereffects last long after the accident itself has been cleared. This section describes five AVCS technologies – intelligent cruise control, vision enhancement, collision avoidance, intelligent stability and handling, and drowsy driver sensors.

4.1.1 INTELLIGENT CRUISE CONTROL (ICC)

Intelligent cruise control technology, also known as adaptive cruise control, is a system that extends conventional cruise control (CCC) by adding the ability to maintain safe following distances to a vehicle in front.

Most new cars today have a conventional cruise control option. Under a CCC system, drivers set a cruising speed that is maintained until braking or acceleration is manually applied. As a result, CCC vehicle speed is independent of the lead vehicle's velocity changes. If the lead vehicle were to brake suddenly, the responding driver may be unable to react quickly enough to avoid a rear-end collision. Under an ICC system, the ICC vehicle will sense lead vehicle speed changes, and will automatically adjust the ICC

velocity to maintain a safe distance between cars. This feature is especially useful in heavy traffic where vehicle speeds often change rapidly.

Vehicles equipped with ICC use either radar, infrared, or laser sensors to determine the distance to the lead vehicle. Daimler Chrysler, an automobile manufacturer, describes the system as follows:

“A radar sensor determines the distance and relative speed compared with the car in front. If the distance goes below the set limit, then the system reduces the engine output and, if necessary, activates the brakes. In this way, the system reduces the speed until the distance from the vehicle in front is once again sufficient. If the distance grows, the system accelerates the car to a speed set in the cruise control.”⁹²

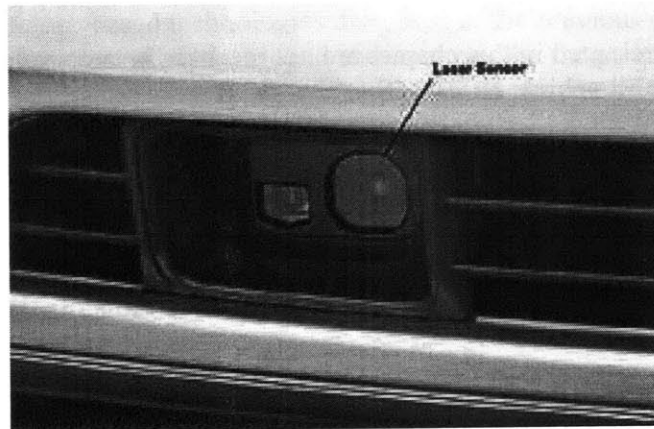


Figure 8. Lexus LS 430 Laser Sensor

Source: Memmer⁹³

4.1.1.1 Benefits and Costs

Using intelligent cruise control has several benefits over conventional cruise control. The first is driver convenience. ICC allows the driver more comfort by automating speed control. ICC systems show an advantage in safety as well, since the car itself will avoid coming too close to other vehicles.⁹⁴ The actual effects, however, are difficult to measure since it is impossible to completely isolate the influence of ICC. Aside from driver convenience, the throttle reductions and velocity smoothing produced by the system also result in reduced fuel consumption and emissions, especially in congested conditions. ICC systems also carry several costs. The expense for auto manufacturers is higher, which is then passed on to the consumer. The ICC option is expected to cost around

⁹² Daimler Chrysler. “Innovation Award 1998: The Winning Theme – Distronic.” Press Release. 3 Dec 1998.

⁹³ Memmer, Scott. “Cruise Control With A Brain.” *Edmunds Car Buying Guide* 14 Mar 2001. 2 Dec 2002. <<http://www.edmunds.com/news/innovations/articles/43022/article.html>>.

⁹⁴ Nelson, Peter. “The Effect of Intelligent Cruise Control Vehicles in Mixed Traffic on the Environment and Flow Characteristics.” University of Minnesota ITS Institute: 9 Oct 2001. 25 Oct 2002 <<http://www.its.umn.edu/seminars/2001/fall/02ioannou.html>>.

\$300-\$350, or about \$100 more than conventional cruise control⁹⁵. Another cost is that drivers using ICC may be lulled into a false sense of security. While ICC helps drivers navigate more safely, it does not replace human alertness and judgment. If drivers trust ICC to prevent all rear-end collisions, it may cause more accidents than conventional cruise control. In addition, any type of cruise control is inherently more risky than complete manual control. Finally, separating speed control from driver control can cause passenger discomfort. ICC changes velocity automatically; as a result, passengers do not actually anticipate and adjust for the acceleration and deceleration of the vehicle.

4.1.1.2 Example: Michigan Field Operational Test⁹⁶

In 1996 and 1997, the National Highway Traffic Safety Administration and the University of Michigan Transportation Research Institute conducted a field test of intelligent cruise control technology. Test drives were conducted on vehicles equipped with intelligent cruise control, conventional cruise control, and manual –only control.

The test revealed that drivers used ICC about 50% more of the time than CCC, on both freeway and arterial routes. ICC was qualitatively ranked safer than CCC, although still considered less safe than manual control. In fact, the vehicle test data showed response time for both types of cruise control to be around 0.3 seconds slower than manual control. However, the use of ICC also resulted in a lower percentage of risky lane changes. The following table summarizes some of these findings.

Table 14. Findings from Michigan Field Operational Test

Type	Lane changes per 100 km	% lane changes resulting in close situation	Average vehicle headway (sec)	Average speed (km/hr)	Average standard deviation in speed (km/hr)
ICC	8	2%	1.9	106	4.4
CCC	7	7%	2.2	110	2.8
Manual	19	8%	1.7	96	11.1

Source: Volpe Center⁹⁷

4.1.1.3 Barriers to Implementation

ICC development has been pioneered by the private sector. ICC systems are already available from several automobile manufacturers, including Toyota, Mercedes and Lexus. However, there are several barriers to widespread deployment of the technology.

The first is driver acceptance. Under an ICC system, passengers may be disoriented by unanticipated changes in velocity over which they have little control. This can result in

⁹⁵ ITS America. "International ITS Information Clearinghouse Fact Sheet #4." Washington, DC: 17 Feb 1995.

⁹⁶ Volpe National Transportation Systems Center. "Evaluation of Intelligent Cruise Control System. Volume 1 – Study Results." Prepared for US DOT, NHTSA. Cambridge, MA: Oct 1999.

⁹⁷ Ibid.

human discomfort, or vehicle error if drivers are startled and overcompensate. Drivers need to be trained in ICC to gain the maximum benefit from the technology.

The second is safety. Although ICC systems seem to have a safety advantage over CCC systems, the use of cruise control itself carries greater accident risk than manual control. Increasing driver reliance on an automated system may exaggerate this effect. Drivers may become inattentive or take unnecessary risks, under the belief that ICC will prevent accidents. Although some versions of the technology have built-in cabin warnings, these alarms may be too late to prevent a collision.

Finally, legal liability is a critical area that has significantly slowed deployment in the United States. Automotive suppliers such as TRW, Raytheon, and Delco Electronics are more eager to introduce the technology in Europe, where they face less product liability⁹⁸. ICC cannot avoid all rear-end collisions; it is meant to reduce the likelihood of accidents and increase driver comfort. The legal implications of accidents caused while using ICC must be investigated. Until then, manufacturers are afraid that they will be held liable for accidents that occur while ICC is in use.

4.1.1.4 Social Implications

The use of ICC with limited market penetration may not have a significant social impact. As the system becomes more common, however, several emergent network effects could result. In one scenario, the number of accidents could decrease. This would not only save lives, but also reduce the traffic congestion associated with vehicle accidents. However, another possible outcome of widespread ICC use is the cascade effect of accidents. When an accident occurs up ahead, the ICC vehicles following behind may not be able to stop quickly enough. If drivers far in the rear are not vigilant, the effect could ripple through and create a far more serious accident than originally occurred. The emergent behavior of numerous ICC vehicles remains unclear.

In addition, the broadest use of ICC may lead eventually to Automated Highway Systems (AHS). AHS refers to vehicles traveling under fully external automated operations and control, similar to autopilot systems in aircraft. AHS technology has been successfully tested in San Diego, but research has since slowed due to a number of difficult transitional, funding, and institutional issues⁹⁹. Concerns on emergent network behavior, as described briefly above, are also preventing AHS deployment. The wide market penetration of ICC and other AVCS technologies may serve as an intermediate step in enabling the future implementation of AHS. However, it is unclear whether ICC will be successful, or if the concerns about safety and liability are so great as to prevent widespread deployment.

⁹⁸ Content, Thomas. "Radar-aided Cruise Control: Avenue to Safer Roads." *USA Today*. 23 Nov 1999.

⁹⁹ Bishop, Richard. "Whatever Happened to Automated Highway Systems (AHS)?" *Traffic Technology International* Aug/Sept 2001.

4.1.2 VISION ENHANCEMENT

The National Highway Traffic Safety Administration (NHTSA) estimates that reduced visibility is a significant factor in 44% of all vehicle crashes and 60% of fatal crashes¹⁰⁰. Visibility can be limited for a number of reasons, including glare, night driving, fog, rain, and other conditions. The purpose of vision enhancement systems is to supplement visual information provided to the driver by these road conditions.

A number of different vision enhancement technologies are under development by both the public and private sectors. The most common are polarized headlights and windshields, infrared imaging, radar detection, rear-view monitors, ultraviolet headlights. The imaging systems can use a head-up display (HUD) inside the vehicle to alert the driver to pedestrians, bicyclists, approaching curves in the road, and other obstacles, as well as to comply with traffic signs.

Some night vision systems are already available commercially, such as the Cadillac DeVille's infrared night vision enhancement technology. The effectiveness of infrared technology is partially dependent on the willingness of public agencies to install infrared reflective lane markings on roads.

4.1.2.1 Benefits and Costs

Enhancing visibility in limited driving conditions has great potential for reducing crashes and saving lives. The system may be most beneficial in reducing vehicle-pedestrian and vehicle-object collisions. These collisions are often the most serious in terms of human injuries and deaths. In addition to crash avoidance, vision enhancement systems provide information to the driver in limited visibility conditions. Since the technology is largely still in the development phase, however, the measurable benefits remain to be seen.

The costs of vision enhancement systems are primarily financial. There is also the possibility of driver distraction due to the head-up display. One would expect, however, that using the head-up display would provide enough vision enhancements to outweigh the effects of driver distraction.

The following table summarizes the range of estimated costs for vision enhancement systems. The costs include a camera, software, processors, head-up display, and infrared sensors with a lifetime of seven years.

Table 15. Estimated costs for vision enhancement systems

	Capital Cost (\$K)	O&M Cost (\$K/year)
Low estimate	1.2	0.06
High estimate	2.2	0.11

Source: US DOT¹⁰¹

¹⁰⁰ Li, Bryon. "Collision Avoidance through Vision Enhancement." *ITS Decision* 26 Jun 2000.

¹⁰¹ US DOT. "Vision Enhancement System Costs." ITS Benefits and Unit Costs Database 2000. 3 Dec 2002 <<http://www.benefitcost.its.dot.gov/ITS/benecost.nsf/ID/>>

4.1.2.2 Barriers to Implementation

Vision enhancement systems are largely still in the testing phase. There are still real questions as to the best way to display information on head-up displays. For example, people disagree on whether the presentation of solid versus dashed lines is more informative for drivers. As part of the U.S. Intelligent Vehicle Initiative, the Minnesota DOT is currently conducting tests and surveys to determine user preferences and needs.

Implementation of vision enhancement systems will likely be through auto manufacturers providing the technology as a priced option¹⁰². As a result, there must be customer demand, and willingness to pay, in order for the deployment to succeed. In addition, systems training will need to be provided depending on the usability of the system.

4.1.2.3 Social Implications

The reduction of vehicle crashes has positive social impacts. Fewer crashes lead to fewer injuries and fatalities. This is especially true for vision enhancement systems, since the technology aids drivers in difficult driving situations. Since many of these accidents involve full-speed collisions into stationary objects, the resulting serious damage can be drastically reduced. Similarly, many lives can be saved by avoiding vehicle collisions with pedestrians and bicyclists, which tend to be more serious than collisions between vehicles only.

4.1.3 COLLISION AVOIDANCE

The purpose of collision avoidance systems is to reduce the likelihood of rear-end, road departure, intersection, and lane change crashes. The underlying principle governing the technology behind each type of collision avoidance is the same. When a potentially dangerous situation occurs (for example, if a vehicle in front stops suddenly), the driver is notified through a warning signal. This signal can be auditory, visual, or both.

Rear-end collisions account for 25% of crashes every year, and affect both passenger vehicles and public transit buses. The NHTSA estimates that half of these crashes can be avoided using rear-end collision avoidance¹⁰³. The systems share some elements of the intelligent cruise control technology as discussed earlier. Under ICC alone, human operator intervention is sometimes necessary to apply the brakes quickly enough to prevent a rear-end collision. Under a rear-end collision avoidance system, an auditory or visual warning is issued to alert the driver to a dangerous situation ahead. As algorithms become more sophisticated, the computer may eventually be able to apply braking automatically in the event of an imminent crash.

Road departure crashes occur when a vehicle runs off the roadway, accounting for about 20% of annual crashes¹⁰⁴. No other vehicles are usually directly involved. The most

F602B0CFD73116FB85256B970052FC9B>.

¹⁰² US DOT. ITS Joint Program Office. "Intelligent Vehicle Initiative Business Plan." Washington DC: ITS Joint Program Office, Nov 1997.

¹⁰³ Intelligent Vehicle Initiative Home Page. 13 May 2002. US DOT. 3 Dec 2002

<<http://www.its.dot.gov/ivi/ivi.htm>>.

¹⁰⁴ Ibid.

common physical avoidance systems currently in use are highway rumble strips. These strips are installed on the highway shoulder and cause significant vibrations inside a vehicle that is drifting off the road.

Road departure collision avoidance systems replace physical avoidance with intelligent sensing to perform this function. The systems use road edge tracking sensors to determine the maximum safe speed for the road ahead and to relay the information to the driver. By monitoring lane position relative to the road edge, road geometry, and road conditions, the collision avoidance system warns the driver of imminent road departures. This warning can be auditory, visual, and tactile. For example, a tactile warning system simulates the feel of a rumble strip by vibrating the steering wheel before the vehicle actually drifts off the road.

The intersection collision avoidance problem is more complex, as it requires monitoring the status of an entire intersection area. The goal of these systems is to sense the intersection geometry, as well as the positions and velocities of other vehicles. The system then informs the driver of an impending traffic violation or collision. Although the initial delivery of the system is likely to be through in-vehicle displays¹⁰⁵, there may be sophisticated roadside sensing infrastructure support in the future. These roadside sensors can provide additional warnings, but there is no guarantee that the visual signs will reach the driver's eyes. A cooperative road infrastructure and in-vehicle combination will be the most effective combination. Eventual assistance services may include impending intersection signal violation warnings, stop sign violation warnings, traffic signal left turn assistance, and stop sign movement assistance.¹⁰⁶

Lane change avoidance systems monitor the positions and velocities of vehicles beside and behind the system-equipped car. The system can notify the driver of the potential for collision both before and during the lane change. This technology is especially useful in regions with a high number of motorcycles, as motorcycle movements and positioning are normally difficult for drivers to track. It can also be used for collision avoidance while merging. One example is a system in development by TRW Inc. that uses GPS to track vehicle positions. The system warns drivers of adjacent vehicles by displaying a red triangle in the rearview and side mirrors¹⁰⁷.

4.1.3.1 Benefits and Costs

The main benefit from using the collision avoidance systems described above is safety. By alerting the driver to potentially hazardous situations, these systems decrease the likelihood of accidents. By reducing the number of crashes, the traffic congestion due to the accidents also decreases, which is an efficiency benefit. The following table presents safety benefits from a modeling simulation run by the NHTSA in 1997.

¹⁰⁵ Ibid.

¹⁰⁶ US DOT. Federal Highway Administration. "Infrastructure Intersection Collision Avoidance." 6 Mar 2002. 3 Dec 2002 <<http://safety.fhwa.dot.gov/fourthlevel/19/ivi.htm>>.

¹⁰⁷ Trimble, Paula Shaki. "Smart roads and smarter vehicles." Federal Computer Week 7 Aug 2000.

Table 16. Simulation results of collision avoidance systems

Type of crash	Percent of crashes affected
Rear end, lead vehicle decelerating	42%
Rear end, lead vehicle stationary	75%
Rear end, total	51%
Lane change/merge	37%
Road departure	24%

Source: NHTSA¹⁰⁸

There are also costs associated with the implementation of collision avoidance systems. As with most vehicle control technologies, the auto manufacturer must pay an initial development cost for the system. This cost is passed on to the consumer through a priced option or through increased sticker price. Like ICC, collision avoidance systems may also lead the driver into a feeling of security that may produce riskier driving behavior.

4.1.3.2 Barriers to Implementation

Collision avoidance systems are largely in the development or testing phase, although rear-end avoidance systems can potentially be evolved from ICC technology. Once developed, these systems will face certain barriers to implementation. The largest hurdle is legal liability. Like ICC, collision avoidance systems are designed to warn drivers of dangerous situations, not to prevent accidents completely. The possibility of legal liability can significantly slow the deployment process.

Training might also be required to educate the public on the proper use of the system. Since the system relies on visual, auditory, and tactile cues, the public should be informed as to the meaning of each warning signal. These signals may also need to be standardized so that each driver can understand the information provided by systems manufactured by different companies.

4.1.3.4 Social Implications

The implementation of collision avoidance systems has social benefits. As mentioned earlier, reducing the number of accidents translates to fewer injuries and fatalities. The effectiveness shown in Table 16. Simulation results of collision avoidance systems demonstrates the high potential of the system to warn drivers of dangerous situations. If even half of these warnings are successful in averting an accident, then the number of traffic fatalities and traffic congestion due to accidents will drop significantly. However, it is also possible that collision avoidance will lead to a false sense of security, which may cause accidents that would not happen with normal vigilance.

¹⁰⁸ National Highway Traffic Safety Administration. "Opportunities for Collision Countermeasures Using Intelligent Technologies." 1997.

4.1.4 INTELLIGENT STABILITY AND HANDLING SYSTEMS

Many accidents are caused by steering errors around curves. Excessive speed, oversteering, and understeering can cause vehicles to roll over or run off the road. These situations might happen due to weather, speed, road surface, or swerving around obstacles such as potholes, or in emergency maneuvers. In the case of commercial vehicles, this situation is especially problematic because of spills. The clean up of oil, hazardous materials, and other cargo can cause enormous delays. To make matters worse, the high centers of gravity in commercial vehicles make them more prone to roll over¹⁰⁹.

Intelligent stability and handling systems deal with this problem by matching the vehicle's true direction with the driver's intended direction as inferred from the movement of the steering wheel. It is not to be confused with antilock braking systems (ABS). An intelligent stability system uses wheel speed sensors, steering angle sensors, lateral acceleration sensors, and vehicle yaw rate sensors as inputs¹¹⁰. When the system detects a mismatch, it applies selective braking to specific wheels before control is lost. For instance, when the sensors detect that oversteer is imminent, the system will automatically brake the outside front wheel to bring the vehicle back in line. This allows the driver to retain steering control.

Although the system engages automatically, drivers are alerted to the dangerous situation through a lit dashboard icon or auditory warning signals. Some products include a display of vehicle rollover threshold and the current safety margin to reach the threshold.

The technology is currently available under a variety of names, including Active Handling, AdvanceTrac, Dynamic Stability Control, Electronic Stability Program, StabiliTrak, and Traxxar¹¹¹. The feature is mostly found in high-end sport utility vehicles, luxury sports cars, and rental cars. Suppliers predict that in Europe, one out of every three new cars will be equipped with intelligent stability by the year 2004¹¹².

4.1.4.1 Benefits and Costs

Intelligent stability and handling systems yield large benefits for vehicles equipped with the technology. Since the system actively corrects dangerous situations, it can prevent accidents and rollovers. In commercial vehicle operations, the technology can provide significant savings from cargo and hazardous materials clean up.

However, intelligent stability and handling systems are currently offered as an expensive option on automobiles. The system is costly due to the number of required sensors and

¹⁰⁹ Intelligent Vehicle Initiative Home Page. 13 May 2002. US DOT. 3 Dec 2002 <<http://www.its.dot.gov/ivi/ivi.htm>>.

¹¹⁰ ABS Education Alliance. "Everything You Ever Wanted To Know About Intelligent Stability and Handling Systems Including 'What are They?'" 5 Nov 2002 <<http://www.carcarecouncil.org/fw01-stab.htm>>.

¹¹¹ Car Care Council. "Newer Automotive Safety Systems Work Without Drivers' Help." The Fulton Daily News 20 May 2001.

¹¹² "Continental Providing Intelligent Stability and Handling System." ITS America News 1 Sept 2000.

sensitive hardware. For example, Ford's AdvanceTrac option costs around \$1,225 and GM's Stabilitrak around \$880¹¹³. In some models, the intelligent stability system is already included in the sticker price. Nevertheless, this cost may prove to be less than the repair charge for a few fender benders or accidents. If this is the case, then consumers will be unwilling to pay for the intelligent system.

4.1.4.2 Barriers to Implementation

Like ICC, intelligent stability and handling systems are consumer-driven purchases that require demand and affordable prices. If customers do not desire the system, or if costs remain high, then widespread deployment might be very limited.

There are also legal liability issues. The vehicle equipped with an intelligent stability system, while more effective in handling curves, must still obey the laws of physics. Use of the system can promote riskier driving behavior and will not be able to prevent all the accidents that might follow. In countries with highly litigious judicial systems like the United States, motorists may blame the manufacturer for failing to prevent rollover accidents.

4.1.4.3 Social Implications

Intelligent stability and handling systems allow standard vehicles to drive like high-end sports cars around curvy roads. This brings a luxury car feature to a larger fraction of the population. However, it may also promote riskier driving behavior. One would expect, nonetheless, that the total social cost of accidents would decrease with high market penetration of the technology.

The technology may be especially useful in reducing accidents among teenage drivers, who may not have enough experience in handling difficult turns or driving through icy conditions. Intelligent stability and handling systems therefore have the potential to make driving much safer.

4.1.5 DROWSY DRIVER SENSORS

The final AVCS technology presented in this chapter is drowsy driver sensors. The National Highway Traffic Safety Administration estimates that annually, at least 100,000 crashes, 1,500 fatalities, and 71,000 injuries are directly attributable to driver fatigue¹¹⁴. These numbers are likely too low, since they do not account for crashes where driver tiredness was a significant factor but not the direct cause of the accident. The problem is especially severe in commercial vehicle applications. Truck drivers must often drive during the night, keep irregular schedules, and stay on the road for long periods of time.

The purpose of drowsy driver sensors is to audibly and visually alert the vehicle operator of dangerous levels of fatigue. The most common form of implementation is in

¹¹³ Romans, Brent. "Road Test Follow Up: 2001 Ford Focus." *Edmunds Car Buying Guide* 30 May 2002. 12 Nov 2002 <<http://www.edmunds.com/reviews/roadtests/spin/45501/article.html>>.

¹¹⁴ Everding, Gerry. "Warning System for Fatigued Drivers Nearing Reality with New Eye Data." *ScienceDaily Magazine* 27 Jul 1999.

measuring and analyzing the driver's eye movements. This non-invasive system requires a sensor, a general processing unit, and a real-time image processing component.

Using algorithms, the system can locate the driver's eyes and analyze his or her blinking patterns and percent eyelid closure. The normal human eyelid blink lasts two to three tenths of a second, while simulators show that the majority of driver fatigue accidents are preceded by eyelid closures lasting from half a second to as long as two or three seconds¹¹⁵. These patterns, however, often occur too late in the fatigue cycle when the driver is already drowsy. Research continues in simulators to develop better algorithms for detecting early ocular signs of driver impairment.

4.1.5.1 Benefits and Costs

The potential benefits of this technology are enormous. As cited above, a conservative estimate is that 100,000 crashes, 1,500 fatalities, and 71,000 injuries are directly attributable to driver fatigue annually (about 1.5% of all crashes). If these fatigued drivers can be taken off the road, then the reduction in accidents and traffic congestion due to these accidents is significant. In commercial vehicle applications, the prevention of truck accidents also saves money in cargo and hazardous materials clean up. Estimates are that thirty to forty percent of trucking accidents are due to fatigue¹¹⁶. Even if these drivers continue traveling on the road, the warning may be enough to make them more alert or warn them to use other methods of stimuli (i.e. coffee, radio).

Most research into costs has focused on the trucking industry since commercial vehicle operators will gain the most benefit from the system. The device is estimated to cost several thousand dollars initially, but will decrease in price as passenger vehicles begin to use the technology as well.

4.1.5.2 Barriers to Implementation

Drowsy driver sensors are still in the development and testing phase. One main barrier is simply technological. Although several studies have been conducted analyzing eye movements before falling asleep, it is still difficult to develop algorithms that accurately predict dangerous levels of fatigues. The system may even need to be calibrated to each particular driver. These are technical challenges related to human behavior that need to be overcome before drowsy driver sensors are fully effective.

The other main barrier is driver acceptance. Even the most technically accurate drowsy driver warning system is ineffective if it does not change driver behavior. Commercial vehicle operators, and eventually private vehicle owners, must be willing to accept the benefits of the technology over personal judgment of their own fatigue. If they do not, then even a widespread deployment of drowsy driver sensors will not produce the intended result of a reduction of traffic accidents.

¹¹⁵ Salleh, Anna. "A Warning System for Fatigued Drivers." News in Science 27 Jul 1999. 16 Nov 2002 <<http://www.abc.net.au/science/news/stories/s39159.htm>>.

¹¹⁶ Louisiana Department of Public Safety. "Facts about Drowsy Driving." Traffic Issues: A Guide to Enforcement Resources. 24 Oct 2002 <<http://www.dps.state.la.us/tiger/drowsy.html>>.

4.1.5.3 Social Implications

Fatigue related crashes are most common among young drivers, workers that have irregular shifts, and operators of commercial vehicles¹¹⁷. These groups of people stand to benefit the most from drowsy driver technology. Implementing the system can reduce the accident and fatality rates for these groups. Particularly for teenage drivers, the technology can also reduce insurance rates and help people make better decisions about driving.

4.2 DRIVE-BY-WIRE

Drive-by-wire is a relatively new vehicle concept that replaces mechanical systems in vehicles with highly advanced electronic controls. The term is derived from the “fly-by-wire” systems long used in the aviation industry. Under fly-by-wire, an airplane pilot uses computer controls and software, instead of steel cables and hydraulics, to control the turning, braking, and throttling functions of the airplane. Drive-by-wire is the same idea extended to the steering, braking, and acceleration of motor vehicles¹¹⁸.

Without the complex mechanics normally included in motor vehicles, drive-by-wire cars can have fundamentally redesigned interiors. In current prototypes, most of the panoramic interior space is dedicated to passengers and cargo, and seating can be rearranged into several configurations. Without the need for foot pedals and traditional steering wheels, several car manufacturers have chosen to develop a joystick or video game-style controller with handgrips. For the video game-style controller, squeezing the grips slows the vehicle and rotating the grips adds speed.

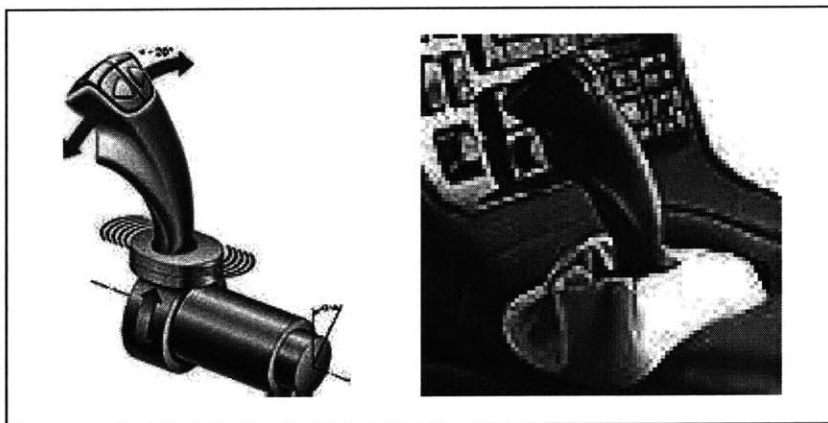


Figure 9. Daimler-Chrysler joystick controllers

Source: Daimler-Chrysler¹¹⁹

¹¹⁷ Ibid.

¹¹⁸ Brauer, Karl. “Why Drive-By-Wire?” *Edmunds Car Buying Guide* 25 Jan 2001. 15 Nov 2002 <<http://www.edmunds.com/news/innovations/articles/43033/article.html>>.

¹¹⁹ Daimler Chrysler. “Drive-by-Wire.” *Special Reports* 2002. 1 Nov 2002 <http://www.daimlerchrysler.com/index_e.htm?/specials/sidestick/sidestick3_e.htm>.



Figure 10. GM Hy-Wire video game controller

Source: Popular Mechanics¹²⁰

Current drive-by-wire technology in the marketplace replaces only the cable-operated vehicle throttle systems with electronic sensors and controls. The technology is already available on cars including the C5 Corvette, Mercedes E-class sedan, Acura NSX, Toyota Tundra, and is planned for the 2004 Ford Explorer¹²¹. Although the systems rely on electronic instead of mechanical links, current models still include the conventional foot pedals for convenience. The designs of more futuristic advanced prototype vehicles, such as the Bertone Filo, have fully eliminated the steering column, all pedals, and the gearshift¹²². Eventually, drive-by-wire systems may be used for all four systems - braking, steering, accelerating, and gear shifting.

4.2.1 BENEFITS AND COSTS

There are several advantages to using drive-by-wire technology over traditional mechanics. The first is environmental impact. Drive-by-wire was first developed as a response to tightening regulations on fuel emissions. By drastically reducing the number of moving parts, drive-by-wire translates into reduced vehicle weight and greater engine efficiency. In addition, the electronic signals can be integrated with information about fuel pressure, engine temperature, exhaust gas re-circulation, antilock brakes, gear selection, and traction control to improve the vehicle's fuel economy, power delivery,

¹²⁰ Eisenstein, Paul. "Hy-Wire Act." *Popular Mechanics* Aug 2002.

¹²¹ Brauer, Karl. "Why Drive-By-Wire?" *Edmunds Car Buying Guide* 25 Jan 2001. 15 Nov 2002 <<http://www.edmunds.com/news/innovations/articles/43033/article.html>>.

¹²² McElroy, John. "Bertone Uses Drive-by-Wire Technology to Fundamentally Change Vehicle Design." *Autoline Detroit* 28 Nov 2001.

and emissions¹²³. The electronic system also eliminates the need for hydraulic and brake fluids, which reduces leaks into the environment.

Drive-by-wire also has important safety advantages. For example, drive-by-wire brakes in Mercedes vehicles “are smart enough to recognize when a driver is in a panic stop and automatically increase braking force.”¹²⁴ Drive-by-wire systems can also correct the situation when a driver is taking a corner too fast and is about to spin out of control, or decrease the throttle as a vehicle is about to lose traction with the road. The computer can correct for slippery pavement. The systems can even compensate for strong lateral wind gusts and prevent accidental driver-induced vehicle rollovers.

There are several physical safety advantages as well. In collisions, the lack of a steering column or foot pedals can prevent chest and foot injuries respectively. Because there is no need to switch foot pedals, braking time is also reduced. Daimler Chrysler, an automobile manufacturer describes the benefits from reduced braking time as follows:

“In order to brake, drivers of conventional vehicles require an average 0.2 seconds to move their foot from the gas to the brake pedal. At a speed of 30 miles per hour, this translates into an additional braking distance of roughly nine and a half feet. The quicker reaction time of the ... system could therefore prevent many collisions.”¹²⁵

Finally, drive-by-wire is comparable to traditional mechanical systems in cost. One might expect drive-by-wire to be more expensive, but because hydraulic components in traditional steering and braking can be eliminated, the assembly in manufacturing plants is much easier, thus reducing installation cost. In addition, the design of a drive-by-wire vehicle is more open, requiring fewer costly structural details to fit a steering column, for instance. The electronics also need less maintenance than a mechanical system. It is estimated that in bulk production, drive-by-wire systems have roughly the same cost as today’s hydro-mechanical systems.

4.2.2 EXAMPLE: BERTONE FILO

Engineered by Sweden’s SKF AB and created by Italy’s automotive designer Bertone, the Filo concept car is a drive-by-wire vehicle that combines state of the art technology with a completely redesigned interior. The magazine Industry Week describes the Filo as follows:

“With the Filo, driver input (steering, acceleration, braking and gear shifting) is translated into electrical signals that go by wire to electromechanical control units. Electric motors take over the conventional mechanical or hydraulic functions with

¹²³ Brauer, Karl. “Why Drive-By-Wire?” Edmunds Car Buying Guide 25 Jan 2001. 15 Nov 2002 <<http://www.edmunds.com/news/innovations/articles/43033/article.html>>.

¹²⁴ Eisenstein, Paul. “Hy-Wire Act.” Popular Mechanics August 2002.

¹²⁵ Daimler-Chrysler. “Drive-by-Wire.” Special Reports 2002. 1 Nov 2002 <http://www.daimlerchrysler.com/index_e.htm?/specials/sidestick/sidestick3_e.htm>.

integrated sensors and measurement systems determining position, force, and displacement.”¹²⁶

The Filo is run with a video-game style controller mounted in the front center armrest, allowing easy portability between right and left hand drive. Instead of turning one-and-a-half revolutions to put a full lock on the wheels, the Filo controller requires only twenty degrees of movement. The controller is speed sensitive - at lower speeds, a small rotation results in a larger turn than at higher speeds. Twist grips control the accelerator, thumb buttons activate the clutch, and squeezing the grips applies the brakes.

The interior is also completely redesigned. Without pedals or a steering column, the floor and dashboard are free of obstructions and provide a panoramic view to passengers seated in the lounge style chairs¹²⁷.



Figure 11. Bertone Filo controller and interior

Source: Automotive Intelligence¹²⁸

¹²⁶ Teresko, John. “Filo Concept Car Demonstrates By-Wire.” *Industry Week* 1 Dec 2001.

¹²⁷ Ibid.

¹²⁸ “Bertone: Bertone-SKF Filo ‘drive-by-wire’.” *Automotive Intelligence* 2001. 15 Nov 2002
<http://www.autointell.com/supplier/engineering_supplier/bertone/bertone-skf-filo/bertone-filo-01.htm>.

4.2.3 BARRIERS TO IMPLEMENTATION

As mentioned earlier, there are several drive-by-wire throttle systems currently on the market. However, several issues need to be confronted before widespread deployment can be attained.

One of these is the perception of safety. Drive-by-wire could be perceived as risky since it has only recently been implemented in cars. In this case, however, the same technology has been used for decades in both military and commercial aircraft. The issues of reliability and failure have been worked out. The safety issue, therefore, is mostly one of perception. In fact, drive-by-wire cars operate more safely than conventional cars. Public education will be helpful, but it is possible that only time will convince people of the technology's reliability.

Related to the safety issue are legal and regulatory barriers. Partially in response to the safety concerns, drive-by-wire systems are currently required to have hydraulic backup in addition to the normal built-in redundancy and backup power supplies. This is inefficient and not cost-effective, because the weight reduction and fuel consumption benefits associated with drive-by-wire are lost. Eventually, legislation may allow electronic backup and redundancy instead of hydraulic backup.

As drive-by-wire is phased in, there may be a difficult transition period for drivers on the road. The system responds very differently than traditional vehicles. The steering is very quick and there will eventually be no pedals to control speed. Although the response to test-drives of the Filo have been positive, some feel that it may still be too different for the average driver¹²⁹. The private sector is taking the right approach by slowly phasing in different aspects of a complete drive-by-wire vehicle.

Finally, there are issues of technical standards and protocols. The reliance on electronics in a complete (braking, steering, accelerating, gear shifting) drive-by-wire system requires a 42-volt energy source, while most cars are equipped with 12-volt sources that are only capable of supporting a single by-wire system. Experts do not expect 42-volt systems to be available until the year 2010¹³⁰.

The issue of protocol is also difficult. Before drive-by-wire development moved to advanced stages, the automotive industry adopted a privately-owned safety protocol called Time Triggered Protocol (TTP) as its standard. However, the industry quickly realized that changes to the rigid TTP guidelines needed to be made in order to commercialize the technology. Unsatisfied with the owner's reluctance to change the protocol, Daimler-Chrysler and BMW are leading a coalition to develop a new safety protocol. The search for a consensus international standard may slow the deployment process¹³¹.

¹²⁹ McElroy, John. "Bertone Uses Drive-by-Wire Technology to Fundamentally Change Vehicle Design." *Autoline Detroit* 28 Nov 2001.

¹³⁰ Teresko, John. "Filo Concept Car Demonstrates By-Wire." *Industry Week*. 1 Dec 2001.

¹³¹ Clarke, Peter. "Protocol Fight Could Stall Drive-by-Wire Rollout." *The EETimes* 7 Jul 2000.

4.2.4 SOCIAL IMPLICATIONS

Drive-by-wire has the potential to fundamentally change the way motor vehicle travel is perceived. Elimination of the mechanics and interior components allows a new degree of architectural freedom. While there must still be a human driver, the rest of the interior space and exterior shell could be completely redesigned. The exterior may look completely different and the interior could include far more amenities that run on electric power. The public could use travel time more productively under the new design.

Many developing and developed economies, however, depend on the automobile manufacturing industry for a significant portion of domestic jobs and productivity. The transition from mechanical to electrical automobiles could mean the loss of many workers' assembly and manufacturing jobs. At the same time, drive-by-wire vehicles will need maintenance and repair from a new specialty work force of qualified people who understand both electrical and mechanical engineering. These human resources requirements will create jobs to partially balance the jobs lost from manufacturing. In certain regions, it may be difficult to find people with this training. Although it is clear that moving to drive-by-wire creates a social shift to more highly qualified jobs, the net balance between elimination and creation of jobs is difficult to predict.

4.3 NAVIGATION ASSISTANCE

In-vehicle navigation devices are designed to aid drivers in selecting and navigating travel paths. These systems are called "telematics" systems because they blend telecommunications with informatics, the science of sending information.

The purpose of in-vehicle navigation devices is to help drivers optimize their travel paths by providing detailed information about routes. Some products also provide dynamic route guidance once a route has been selected. Most units use GPS technology for vehicle location. GPS requires signals from four satellites; therefore signals can be lost around tall buildings or under a bridge. The GPS is backed up by dead reckoning, which uses a gyroscope to calculate vehicle position from a known reference point¹³². The cumulative error with dead reckoning is occasionally corrected through radio beacons at known locations.

Navigation assistance devices can be stand-alone units or networked together to a central computer. Stand-alone units cannot receive real-time information about traffic conditions, accidents, and weather problems. Centralized units can optimize routes to avoid existing traffic congestion. However, stand-alone units currently have greater market penetration due to the institutional issues associated with traffic data collection and distribution¹³³.

¹³² Miller, Brian. "Finding the Way: Navigation Devices and Public Safety." Government Technology Mar 1995.

¹³³ Chen, Kan and John Miles, ed. ITS Handbook 2000: Recommendations from the World Road Association (PIARC). Boston, MA: Artech House, 1999.

The technology is primarily available in rental cars and high-end luxury vehicles. The hardware typically consists of a GPS receiver, vehicle-mounted gyroscope, and display unit. Control may be text-based or voice-based. To select routes, the system relies on digital map databases loaded through wireless connections or disks. For example, a private U.S. company called DENSO supplies DVD U.S. maps for navigation systems in Lexus, Cadillac, and Jaguar vehicles¹³⁴.

Navigation assistance devices can also be integrated with other services. There is a move to integrating the technology with wireless Internet, entertainment, and cell phone service for a complete computing environment within a single vehicle. Another extension of navigation assistance is speed limit detection. In a test conducted by the Swedish National Road Administration, map databases included the speed limit information for roads in several cities. When drivers exceeded the local limit, the navigation device flashed a light and emitted a warning noise¹³⁵. In the future, more services may continue to be added to basic navigation assistance.

4.3.1 BENEFITS AND COSTS

The primary benefit to driver navigation assistance technology is reduced travel time through optimized route planning. In Turin, Italy, the implementation of in-vehicle navigation devices reduced travel time by more than 10%¹³⁶. The time savings also eases congestion and the corresponding air pollution. Reduced travel time has an especially large impact on public safety applications (see Section 4.3.2 below).

It is unclear whether the risk of accidents is greater or smaller with vehicles equipped with navigation assistance. There is evidence that dynamic route guidance decreases the crash rate for equipped vehicles by about 4%, through reduction of wrong turns, increased throughput, and the tendency of the system to prefer safer roads¹³⁷. There is also evidence that driver anxiety and stress are reduced.

However, there are people who argue that the risk of accidents is increased, due to driver distraction from use of the navigation device. Similar to the argument against use of cellular phones while driving, the evidence of this cost is largely anecdotal. To address this concern, however, navigation product design has moved towards hands-free use. In addition, several products have “lock-out” options that prevent new routes from being programmed while driving¹³⁸.

¹³⁴ Benson, Jay. “LBS Technology Delivers Information Where and When It’s Needed.” Business Geographics Feb 2001.

¹³⁵ Diop, Julie Claire. “Sensing Speed Limits.” Technology Review Dec 2002/Jan 2003: 29.

¹³⁶ Cordis Transport Sector of the Telematics Applications Programme. “Telematics Applications Programme – Transport Areas’ Results (4th Funding Programme).” 1 Jul 2000.

¹³⁷ Science Applications International Corporation. “TravTek Evaluation Orlando Test Network Study.” Prepared for US DOT, Federal Highway Administration. McLean, VA: Federal Highway Administration, Jan 1996.

¹³⁸ Epstein, Jonathan. “Driver Distraction and the Use of Wireless Phones and Other In-Vehicle Technologies.” Telecommunications Law 4th Quarter 2000: Vol 2, Issue 1.

The purchase price of navigation devices is also relatively high. The average factory-installed price is currently around \$2,000¹³⁹. Until this cost can be lowered, average drivers will choose not to implement the system and its benefits.

4.3.2 EXAMPLE: ALBUQUERQUE, NEW MEXICO¹⁴⁰

In-vehicle navigation systems have immediate impact on emergency service vehicles, which need to travel to unknown addresses with maximum speed. The Albuquerque Ambulance Company installed a navigation assistance system in 1993. Under the system, a central dispatcher used automatic vehicle location to notify the nearest ambulance to a call. The new address and route appeared on the ambulance's display unit. As the ambulance got closer to the destination, the electronic map display decreased down to increments of one-tenth of a mile to show route details. As a result, ambulance response time changed from 89% of calls answered within ten minutes to 94% of calls. The company also saved \$500,000 in personnel and equipment costs.

4.3.3 BARRIERS TO IMPLEMENTATION

The main barrier to widespread deployment of in-vehicle navigation devices is lack of customer demand due to the high purchase price. The technology is being introduced by the private sector, and is therefore subject to market forces. As cited above, the average factory-installed price is currently around \$2,000. This price is about triple of what customers are willing to pay. As a result, J.D. Power and Associates predicts that while 30% of cars will offer a navigation assistance option by 2006, only 6% of consumers will actually purchase the technology¹⁴¹. As the price falls, or the technology becomes more integrated with entertainment and communications systems, customers may be more willing to pay for the additional service.

For networked navigation assistance devices receiving real-time traffic information, there is also a set of institutional issues to be addressed. To integrate data collected by a public agency with a system delivered by the private sector, there needs to be communication between the two parties. There are also questions of whether the private companies should have to purchase the traffic data from the public agency. On one hand, public data is free and accessible to everyone. On the other, the tax money is used to collect the data, and the private companies will profit from its use. Finally, since vehicle travel frequently crosses jurisdictional boundaries, private companies must either negotiate agreements with all of the relevant public agencies, or conform to a currently unspecified data standard.

4.3.4 SOCIAL IMPLICATIONS

The relatively high purchase cost of navigation devices could produce social inequalities in traffic congestion. Since motorists with higher incomes can afford the units, they can essentially pay their way out of congestion by following the recommended optimized

¹³⁹ J.D. Power and Associates. "In-Vehicle Navigation Systems Poised for Significant Growth." Press Release. 11 Oct 2001.

¹⁴⁰ Miller, Brian. "Finding the Way: Navigation Devices and Public Safety." Government Technology. Mar 1995.

¹⁴¹ Ibid.

routes. Motorists with lower incomes who cannot afford the units are more likely to remain in the more highly congested areas.

It is important to note, however, that the people who buy the devices and navigate away from congested areas also provide a benefit to the people who do not buy the devices. The diverted traffic reduces congestion for those drivers who remain on the main routes.

4.4 MAYDAY SYSTEMS (AUTOMATIC CRASH NOTIFICATION)

Mayday devices, or SOS systems, enable direct verbal or data communication with emergency personnel. Their primary function is to automatically notify the call center in the event of a crash. This feature, which transmits the GPS location of the vehicle to the response center, is typically activated by airbag deployment or by a driver panic button. In the event of serious injuries, the intervention of the mayday device can reduce the critical response time necessary for medical help to arrive, since the devices are already integrated into the emergency response system.

Some versions of mayday devices have additional features on top of accident notification. Their capabilities include asking the call center for directions or mechanical assistance. Three popular systems currently on the market are OnStar by General Motors, RESCU by Ford, and RESPONSE by AAA¹⁴².

4.4.1 BENEFITS AND COSTS

In serious accidents, the chances of survival is tightly linked to the number of minutes it takes for the victim to get appropriate help. Even a few minutes may mean the difference between life and death. Mayday systems provide assurance to users that medical help will be on the way as soon as possible, regardless of where they are or if they have any assistance at hand. The technology can save lives, prevent more serious medical complications, and give motorists peace of mind.

Private automobile companies currently operate mayday systems on a monthly subscriber basis similar to cellular phone service. After purchasing the in-vehicle hardware, users pay a monthly fee for the mayday coverage. Plans for the General Motor OnStar service range from \$16.95 to \$69.95 per month¹⁴³.

4.4.2 EXAMPLE: GENERAL MOTORS ONSTAR¹⁴⁴

General Motors' OnStar system was the first mayday system to be implemented in the world. Its voice-activated cellular phone is equipped with GPS and automatically notifies the call center when the vehicle's airbag is deployed. The operator then calls the car and dispatches emergency services as necessary.

¹⁴² Mulholland, David. "Intelligent Transportation Systems: A Traffic Incident Management Tool." Tech Talk. International Association of Chiefs of Police Technology Clearinghouse: Mar 2001.

¹⁴³ General Motors OnStar Home Page. 2002. General Motors Corporation. 3 Dec 2002

<<http://www.onstar.com>>.

¹⁴⁴ Ibid.

OnStar provides many more features than crash notification, however. In addition to the accident help and emergency services, OnStar is a 24-hour, 365-days vehicle assistance program. Capabilities include remote vehicle door unlock, remote engine and brake diagnostics, stolen vehicle tracking through the GPS receiver, turn-by-turn route support, taxi hiring, ticket and restaurant reservations, trip planning, and general information listings (for example, the location of the nearest open gas station). The operators at the OnStar call centers assist motorists in hundreds of ways. In addition, subscribers feel reassured by talking to a human being instead of a computer-controlled menu.

Drivers can choose between three plans ranging in price and features. The simplest plan, Safe and Sound, begins at \$16.95 per month and includes the basic services. The deluxe plan, Luxury and Leisure, costs \$69.95 per month and provides assistance with everything relating to vehicle trips. For the approximate monthly price of a cellular phone plan, motorists using OnStar gain the peace of mind with knowing that they will receive the fastest help in the event of a crash.

4.4.3 BARRIERS TO IMPLEMENTATION

The technologies of mayday devices present an integration challenge both technically and institutionally. There are technical issues with making the systems effective over large geographic areas, as different regions use different emergency response systems. Institutionally, there are issues with cooperation between the public and private sectors with communication between private call centers and public emergency services.

The National Mayday Readiness Initiative (NMRI) was launched in the U.S. in 2000 to identify and address these issues. NMRI is a public-private partnership between over twenty national organizations. The following summarizes the key barriers to implementation¹⁴⁵.

- **Lack of private-public communication** – To ensure fast, accurate, and reliable emergency responses, there must be effective communication between the motorists, the private call centers, and the public emergency response agencies.
- **Lack of training** – Private call center operators must be trained in the same operating procedures for emergency services as public operators. The public must also be educated about how mayday devices work.
- **Lack of comprehensive database** – On the local, regional and national scale, voice and data communications from mayday devices must be conveyed to the relevant emergency services, 911 centers, hospitals, and law enforcement agencies. There is no consolidated national database to alert the necessary emergency agencies.
- **Lack of up-to-date emergency services equipment** – Many emergency response agencies lack computers and high speed Internet access.

¹⁴⁵ Communications for Coordinated Assistance and Response to Emergencies (ComCARE). “National Mayday Readiness Initiative.” 2001. 3 Dec 2002 <<http://www.comcare.org/projects/nmri.html>>.

- **Lack of wireless coverage** – The mayday devices sometimes require a wireless connection to communicate with the emergency response community.
- **Lack of data standards** – Vehicles are increasingly capable of capturing advanced crash data and predicting the severity of injuries. There is no process for deciding what data should be captured and communicated, nor a technical standard for collecting the data.
- **Lack of national communication** – There is no national forum besides NMRI for interested organizations to discuss the relevant issues.

4.4.4 SOCIAL IMPLICATIONS

Mayday systems provide a social benefit by bringing medical help more quickly to the scene of an accident. Since the systems can alert the police force and other traffic authorities, the congestion resulting from traffic accidents can also be alleviated faster.

The extra features included in some plans like the GM OnStar also provide a social benefit by making in-vehicle travel time more productive. The system links motorists with information sources that can save time searching for locations or making plans. The basic plans are comparable to cell phone service that has attained widespread market penetration across all income levels. As a result, mayday service plans are largely affordable and can provide a valuable service to most people who own cars.

4.5 VEHICLE MOBILE COMPUTING

The concept of a “virtual office” is not new. Estimates of the annual growth rate for the number of workers telecommuting in the U.S. range from 2.1% to 8.4%, and about 55% of the nation’s corporate workforce has remote and/or mobile access to their offices¹⁴⁶. Recent advances in technology are bringing this technology to in-vehicle applications.

According to a Goldman Sachs automotive research report, North Americans spend a combined 26 billion passenger-hours in their vehicles annually, or 500 million passenger-hours per week¹⁴⁷. This time could be less stressful and more productive if mobile computing was brought to private vehicles. Cellular phones are a logical channel for computing, because of their wide market penetration, and the fact that up to 80% of cellular calls are made from within automobiles.

To this end, cellular phone companies are creating new products that enable an office on the road. These phones include features such as data capability, interfaces with personal digital assistants, and compatibility with computers, printers, and fax machines. Wireless phone makers such as Nokia and Motorola hope that the widespread use of cellular phones can facilitate the introduction of office capabilities into the private vehicle.

¹⁴⁶ Kistner, Toni. “Reports: Growth in Telecommuting Slows.” *Network World* 11 Feb 2002.

¹⁴⁷ Mobile Advisor. “Mobile Computing – On Wheels.” *News* 12 Oct 2000. 3 Dec 2002 <<http://www.advisor.com/doc/07277>>.

There are also initiatives into laptop computing built into automobiles. However, there are difficulties in finding an appropriate display area without creating excessive driver distraction.

Regardless of the channel, vehicle mobile computing has the goal of bringing relevant information to motorists and making their travel time more productive. Examples of information linkages are e-mail, news, stock quotes, family-related tasks, and entertainment.

4.5.1 BENEFITS AND COSTS

Using vehicle travel time more productively has a large benefit for worker output. However, there are no real traffic efficiency, safety, environmental, or cost benefits to be gained. In fact, it is possible that increasing the usefulness of travel time will encourage more people to use their private vehicles, which actually increases congestion and reduces road efficiency.

The cost of the technology can be high. Like other in-vehicle electronic devices, the cost is borne by the consumer and runs several hundred dollars.

There is also a safety cost. Vehicle mobile computing devices must be controlled by either speech or touch. Either of these control mechanisms causes driver distraction and may increase the risk of accidents. This problem is similar to the cell phone safety issue. Research has shown that both hand-held and hands-free cell phone users have significantly longer reaction times than non-users¹⁴⁸. Most studies support the assertion that any distractions, including cell phone use, talking with passengers, and tuning the radio, increase the likelihood of accidents. For more information, the National Highway Traffic Safety Administration recently released a report detailing the types and extent of distracted driving behavior¹⁴⁹. Although the technology for vehicle mobile computing is still too new to evaluate risks empirically, all devices that require actions unrelated to driving are somewhat distracting and are likely to decrease vehicle safety.

4.5.2 EXAMPLE: MOBILEARIA¹⁵⁰

MobileAria is a company that develops fleet and automotive telematics applications. Their technology delivers voice-automated wireless Internet content and applications through cellular phones. Services include automated dialing, voicemail, email, news, personal information such as notes or calendar, traffic, directions, business finder, weather and stocks. The service is linked to Microsoft Outlook to access mail and personal information.

¹⁴⁸ Strayer, David, and Frank Drews, et al. "Does Cell Phone Conversation Impair Driving Performance?" *Psychological Science* Nov 2001.

¹⁴⁹ Royal, Dawn. The Gallup Organization. "National Survey of Distracted and Drowsy Driving Attitudes and Behaviors: 2002. Volume 1 – Findings Report." Submitted to the National Highway Traffic Safety Administration. Washington, D.C.: April, 2003.

¹⁵⁰ MobileAria Home Page. 2002. MobileAria, Inc. 3 Dec 2002 <<http://www.mobilearia.com>>.

MobileAria works on multiple hardware platforms and uses the latest wireless technology. It incorporates speech recognition, text-to-speech, GPS, and wireless connectivity. The company emphasizes the safety of its software through use of voice applications. The following diagram is a schematic of the system architecture.

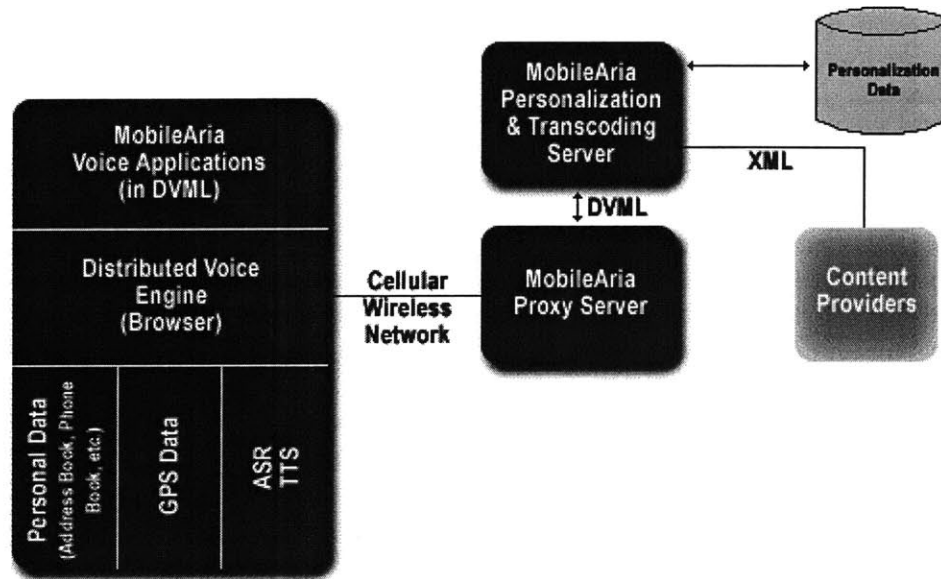


Figure 12. MobileAria Platform Architecture

Source: MobileAria¹⁵¹

4.5.3 BARRIERS TO IMPLEMENTATION

Vehicle mobile computing is undergoing development and implementation in the private sector. There is an organizational issue that should be addressed, however. It is possible that these mobile computing initiatives will have overlapping functionalities with both mayday systems and incident management systems. These overlaps could result in duplicated, conflicting, or confusing messages. To ensure a single line of command to emergency services, for example, there needs to be organization and coordination between each initiative. This is more difficult to do in the private sector because companies are sometimes unwilling to disclose information.

4.5.4 SOCIAL IMPLICATIONS

Vehicle mobile computing has the potential to change how some workers view their commutes. Turning frustrating travel time into productive work time has large worker efficiency benefits for countries. Even if workers cannot telecommute, they can use part of their travel time to accomplish work normally done in the office.

¹⁵¹ Ibid.

Although the technology does not directly affect congestion, it could smooth out peak period traffic patterns. If commuters can perform work while driving, they can conceivably arrive at work later and leave earlier and still accomplish the same amount of work. This can reduce the heavy traffic congestion normally associated with rush hour.

Changing the use of travel time also has other positive benefits. It reduces much of the stress and frustration caused by traffic congestion. This may eventually lower the amount of government intervention necessary to achieve the same level of public satisfaction.

Having explored both intelligent infrastructure and vehicle technologies in Chapters Three and Four, it is evident that there are several institutional obstacles to deployment common to more than one. This portfolio of technologies leads to a set of institutional issues that can be organized and analyzed on their own. The development of this framework is discussed in Chapter Five.

CHAPTER FIVE: PROPOSED FRAMEWORK FOR ITS DEPLOYMENT

The deployment of ITS technology faces a number of institutional barriers to implementation. From studying a wide range of infrastructure-based and vehicle-based technologies presented in Chapters Three and Four, the following framework was developed around which institutions can base their planning. No single issue may necessarily derail a proposed ITS project; however, the accumulation of many small problems can lead to project delays, cost overruns, ineffective deployment, or user dissatisfaction.

Four main categories are proposed for consideration - organization, finance, legal & regulatory, and information. Within each are examples of sub-categories that are relevant to ITS deployment. The importance of each issue should be taken in context of two overarching issues - a region's political environment and its stage of economic development.

This framework is meant as a general reference for planning purposes. While this framework attempts to capture the main institutional barriers to ITS deployment, the particulars for each specific project will be different. Privacy issues, for example, could be very significant in an automated red light enforcement project, but may not be as important in a smart traffic signal initiative. Nevertheless, from the snapshot presented by this framework, one can better identify potential gaps in planning.

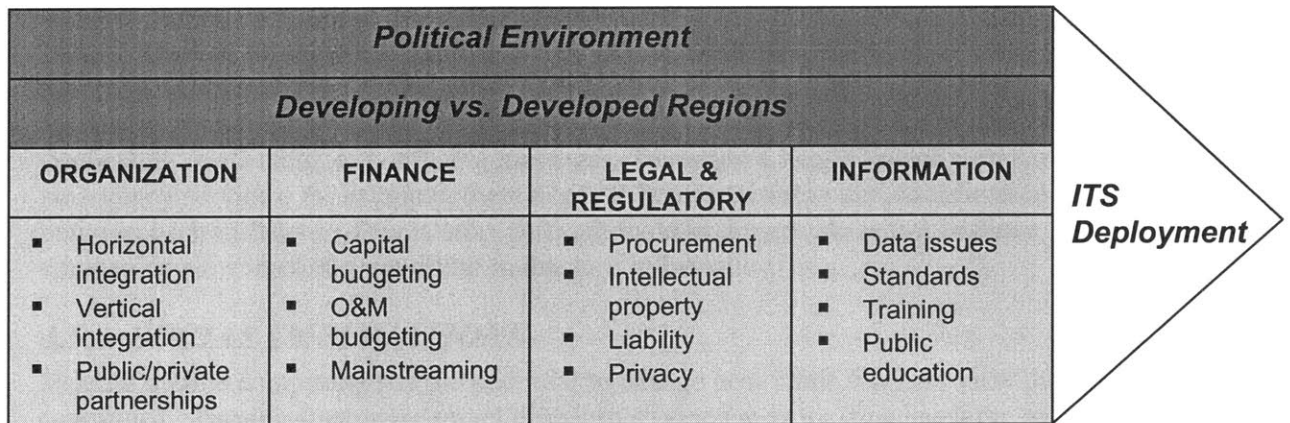


Figure 13. ITS Deployment Framework

5.1 POLITICAL ENVIRONMENT

Before discussing the four main categories, the two overarching issues are first considered. The first of these is the political environment for ITS. A region's political environment has considerable effect on the institutional arrangement necessary for ITS to be deployed. The political environment refers to both the form of government and its political goals. It encompasses aspects of the political process including the power of public opinion and political will.

The political environment is an overarching issue because it affects each of the four categories – organization, finance, legal & regulatory, and information. In organization, for example, strongly centralized governments may not need to address problems of vertical integration as extensively as governments that are decentralized over local, state, and federal levels. In finance, political will may encourage mainstreaming of ITS funding into the regular planning process, instead of as a separate R&D program. In the area of legal & regulatory issues, the rigidity of a region's judicial system affects the liability concerns of the automobile industry. In information, regions with high professional turnover rates must treat retention of human resources more importantly than regions with low turnover.

5.1.1 PUBLIC OPINION

ITS initiatives, especially those involving revenue collections, are often unpopular with the general public. Examples of these initiatives include automated red light enforcement and electronic road pricing. Ramp metering, while not a revenue-generating technology, is often unpopular as well. Whether these technologies can be successfully deployed often depends on the power of public opinion.

Public opinion manifests itself in several ways. The most fundamental of these is votes. In democratic societies, the public can express its dissatisfaction by voting their elected officials out of office. More subtly, wealthier citizens can facilitate change by donating to certain campaigns, political parties, and political action committees. Citizens also form community groups to organize events and lobby lawmakers for their cause. In more autocratic societies, people may not always have these political channels through which to express their opinions.

With ITS, the question is not whether the public can express its views, but whether the public has the power to change policy. When public opinion and lawmakers are linked through voting and campaign funding, officials have an interest in keeping their constituents content. When these links are weak or nonexistent, the power of public opinion is weaker. Unpopular ITS initiatives can be implemented in either case, but the institutional strategy to do so will be different.

Where the power of public opinion is strong, the intervention of other stakeholders such as the private sector may be necessary for deployment. One example of this is in the United States, where automated red light enforcement is often contracted out to private companies. Among other reasons for using private companies, it addresses the privacy concerns that many citizens have about government cameras tracking their movements.

Where the power of public is weak, even unpopular ITS initiatives can be implemented as long as there is strong government leadership behind the idea. One example is Singapore's electronic road pricing, where most of the population is against the system. Because citizens in Singapore accept the government's authority to regulate their behavior, the autocratic leadership was able to implement ERP. In contrast, Hong Kong's attempt to expand ERP from a pilot program to full deployment was dropped due to lack of public support, both in the mid-1980's and more recently in April 2001¹⁵².

5.1.2 TURNOVER RATE

Public opinion is linked to the turnover rate among elected officials and the bureaucracy. Ultimately, public opinion has power when officials need votes to stay in office. In regions where turnover rate is high, one would expect officials to be more sensitive to public opinion. In regions where turnover rate is low, officials may be more insulated.

Continuity in leadership is important to ITS. In the future, ITS may become a sufficiently visible issue that lasting bipartisan coalitions can be formed. Until this point, a political champion is often necessary to lobby for capital and operations funding until the program is mainstreamed (see Section 5.4.3)¹⁵³. The champion is also needed to create awareness among transport agencies and the public. When the champion is lost through a change in elected officials, the ITS program may also lose its funding.

Using the ERP example above, it is difficult for legislators and executives to champion unpopular ITS initiatives when their political seat may be in jeopardy. Hong Kong's legislature is elected to four-year terms and is comprised of five competitive political parties¹⁵⁴. Singapore, on the other hand, elects officials to five year terms. More importantly, their one major political party, the People's Action Party, has been in power since the country's inception, and currently holds 97% of the parliamentary seats¹⁵⁵. Since there is a reasonable assurance of reelection in Singapore, officials are more insulated from public opinion and are better able to take risks by supporting unpopular ITS initiatives like ERP.

5.1.3 POLITICAL WILL

Political will refers here to the government's goals and commitments to sustainability. Regions around the world face varying degrees of severity in problems of pollution, congestion, and transportation. As a result, their governments also have different levels of concern about sustainable development.

The goals of the government affect ITS implementation. If the primary goal is economic growth, then ITS might not be as attractive compared to physical infrastructure

¹⁵² Intelligent Transport Systems Hong Kong. "Electronic Road Pricing and Smart Cards." 15 Oct 2002. 6 Dec 2002 <<http://www.its-hk.org/octopus.htm>>.

¹⁵³ US DOT. Federal Highway Administration. "What Have We Learned About Intelligent Transportation Systems?" Washington, DC: Federal Highway Administration, 2000.

¹⁵⁴ "Elections in China." [Electionworld.org](http://www.electionworld.org) 17 Nov 2002. 6 Dec 2002 <<http://www.electionworld.org/election/china.htm>>.

¹⁵⁵ Central Intelligence Agency. [The World Factbook 2001](http://www.cia.gov). Washington, D.C.: 2001.

investments (i.e. road-building). In this case, the throughput and economic gains of infrastructure may outweigh the environmental and efficiency benefits of ITS. The government may also be committed to developing the fossil fuel and/or automobile industries. While air quality and traffic congestion are still a concern, they may not be as important as creating jobs and growing these economic sectors.

If the government is more committed to sustainable development, then ITS may be a more attractive alternative to infrastructure expansion. Through air quality, environmental protection, and natural resource conservation regulations, regions can demonstrate their dedication to sustainability. These regions are sometimes limited by their geography, which force them to make more efficient use of their space. Mexico City, for example, must deal with severe air pollution issues due to its location in a mountainous basin.

From the perspective of the private sector, uncertainty about future political will affects the deployment of ITS. The private sector is a key component for ITS, both in intelligent vehicle technologies and in public/private partnerships. The example of Minnesota ramp metering illustrates how the legislature ultimately controls whether projects are started, continue to receive funding, or are shut down. The case of Autoguide in the United Kingdom is another example. Because the government insisted on an intermediary report and debate before granting a fully commercial license, the private sector was unwilling to risk the result of Parliament's subjective evaluation of its pilot project¹⁵⁶. Uncertainty about political will can make ITS too risky for private companies to undertake.

5.2 DEVELOPING VS. DEVELOPED REGIONS

The second overarching issue to be considered is a region's stage of economic development. The distinction between developed and developing (transitional) regions is an important one to make when thinking about ITS deployment. Demand for transportation services is rapidly growing in transitional countries as they race to boost economic development. Knowing that transportation budgets are limited, ITS could play a significant role in increasing the productivity of existing infrastructure, in conjunction with road building.

Development is an overarching theme because it affects all four of the categories in the framework. In organization, the bureaucratic agencies in developing regions may be more malleable than in developed areas where the boundaries between institutions are more sharply drawn. In finance, developed regions have more resources to devote to ITS since their infrastructure and economies have already developed, and they are simply richer. In the legal & regulatory area, transitional regions may not have created a framework for intellectual property, liability, and other concerns, which could suppress ITS deployment. In information, developed regions are more likely to have technical sophistication, a trained workforce, effective organization, and complete databases of information.

¹⁵⁶ Chen, Kan and John C. Miles, ed. ITS Handbook 2000: Recommendations from the World Road Association (PIARC). Boston, MA: Artech House, 1999.

There are several differences between the developed and developing countries in the context of the framework presented above. Among these are the existing infrastructure base, degree of technical sophistication, resource availability, rate of motorization, and the role of public transportation.

The size of a region's existing transportation infrastructure affects the resources available for ITS. Developing regions must balance new construction with ITS deployments, while developed regions have fewer immediate infrastructure needs. Because developed countries are likely to have more roads per capita (or roads per square kilometer) than developing countries, they may also have more transportation resources available to devote to ITS. Under limited budgets, transitional countries may mistakenly believe that ITS can be used to replace traditional road building¹⁵⁷. In fact, ITS is only part of a regional transportation plan that, for most transitional countries, should include continued infrastructure investments in both roads, ITS, and public transportation. ITS can be used strategically for sustainable growth, but not as the only solution.

Besides road infrastructure, developing countries must also consider their telecommunications infrastructure. ITS requires comprehensive wireless and wire-line communication networks. These networks should be able to carry voice, data, image, and multimedia communications. They should also provide the required bandwidth, cover a wide geographic area, and have high quality of service (reliability and efficiency). For transitional countries, this telecommunications infrastructure must first be installed before certain ITS deployments can proceed.

Technology transfer from developed to developing countries is more difficult than between two developed regions. The lessons from an industrially advanced region may not apply to a transitional country. Among other factors, cultural differences, human resources, and technical sophistication make the situation more complicated. When transitional regions buy ITS electronics and equipment from developed nations, they must be prepared to operate and maintain the devices for their lifetimes. Many developing areas lack enough people with the necessary skills and knowledge to support ITS deployment. To address this problem, developing countries including Malaysia and Thailand are establishing universities that emphasize technology in order to train the next generation of college graduates.

One possible solution is to create an intermediate technology transfer. Instead of jumping to the high-tech industrialized version of ITS, transitional countries may instead choose to implement lower-cost, locally provided services. It may not be possible for the full capabilities of an ITS concept to be implemented at this intermediate stage, but this approach also provides a progressive step in developing intellectual and technological capital for the future. It is important to ensure a growth path from the intermediate stage to the advanced stage. For example, instead of purchasing the most advanced sensing and camera equipment from abroad for use in an incident management system, developing countries may want to pursue domestic loop detectors and simple cameras to

¹⁵⁷ Ibid.

deploy the same system at a lower cost. As the country's electronics industry matures, these components can be upgraded while enhancing the performance of the system.

Developed and developing countries also face stark differences in financial resource availability. While ITS deployment can be costly, its capital and operations budget is relatively small for developed countries compared to other transportation investments. Transitional countries, however, face high demand for capital in all areas, as well as receiving smaller tax revenue. The transportation needs alone, including highways, rail, airports, and shipping, cannot be met immediately. As a result, ITS budgeting is much more competitive in developing regions.

At the same time, ITS in developing areas has the potential for a higher benefit/cost ratio than in developed areas. Since capital is so scarce, ITS can be a cost-effective alternative to building more conventional capacity. Technologies like smart traffic signaling and electronic toll collection can have large benefits for congested regions. At the same time, technologies such as navigation assistance may have less value in developing areas, since fewer drivers will be able to afford it.

The fact that developing areas face fast growing rates of motorization is also important. As income per capita and standards of living increase, citizens seek to own private vehicles. High growth in the number of vehicles also means rapidly worsening traffic congestion and traffic safety. In many transitional areas, particularly in Asia, motorcycles are extremely popular among citizens who are unable to afford a car. The mix of motorcycles and vehicles indicate that technologies with safety benefits could be a higher priority than in developed countries.

A byproduct of high motorization rates is inexpensive cars with higher incidences of mechanical problems, whose breakdowns lead to traffic congestion on the road. High motorization rates in transitional countries are often composed of a large percentage of motorcycles, which amplify the negative effects of congestion by emitting higher levels of pollution. As a result, ITS technologies such as incident management could have higher benefit/cost ratios in transitional countries than in developed ones.

Finally, the differing role of public transportation in developed and developing regions affects the ITS framework presented above. Public transport, including buses and rail, typically plays a more important role in transitional countries because a higher percentage of citizens do not own cars. As a result, advanced public transportation technologies have the potential to benefit a great number of people. Financially, funding for public transportation ITS applications may be a higher priority since public transit is so important in developing regions.

Both transitional countries and developed countries can greatly benefit from ITS. Depending on the stage of development, the areas of organization, finance, regulation, and information can be addressed differently. Certain ITS technologies may also have higher benefit/cost ratios in developing regions than in developed ones. Developing areas offer a good opportunity to implement ITS and infrastructure investment together

according to a master transportation plan, instead of retrofitting infrastructure after it has been built (as often happens in developed countries).

Having addressed the cross-cutting issues of political and economic environments, the following sections address specific institutional barriers to ITS deployment. The first set of these barriers focuses on organizational issues.

5.3 ORGANIZATION

Deploying ITS requires a supportive organizational structure. The purpose of the organization area within the ITS deployment framework is to produce an effective institutional arrangement that promotes collaboration. This collaboration must work in three dimensions - horizontally, vertically, and between the public and private sectors. Organizational issues are often the hardest implementation barriers to overcome. At the same time, they are only self-imposed by bureaucratic boundaries.

5.3.1 HORIZONTAL INTEGRATION

Horizontal integration refers to the cooperation between agencies at a single organizational level, whether it is local, regional, or national. The agencies within a city or metropolitan area must work together for successful deployment. Because transportation infrastructure crosses municipal boundaries, this cooperation must often also be interregional between different political jurisdictions.

Horizontal means that the agencies are independent from one another and that they have relatively similar influence. While there may be an internal hierarchy (for example, different departments within the same agency), the term horizontal as applied here refers to political entities that differ in sector more than power. Integration means that there is a dialogue between all parties to most effectively implement ITS in the region. Since communication is often limited between different agencies, horizontal integration brings together expertise from the relevant areas of government. It is often necessary for this collaboration to exist for all phases of the implementation cycle, from planning to operations.

Within the scope of an ITS project, there are typically elements relating to the environment, land use planning, traffic, transportation, and law enforcement departments, to name a few. Historically, these agencies often do not interact closely with one other, and certainly not all together. Horizontal integration is necessary when deploying ITS in order to coordinate these disparate agencies.

Horizontal integration is especially important when deploying technologies that cross geographical borders, such as systems affecting major highways. Since most ITS systems generate the greatest benefit when deployed on a regional basis¹⁵⁸, there must be communication between agencies of neighboring municipalities. Horizontal integration enables this communication.

¹⁵⁸ US DOT. "What Have We Learned About Intelligent Transportation Systems?" Washington DC: 2000.

The implementation of horizontal integration is not a simple task. To begin with, agencies may not wish to collaborate with one another, due to factors ranging from institutional culture to competition for funding. To further complicate the situation, the nature of ITS suggests a central command over facilities and services that are typically managed by separate institutional entities¹⁵⁹. This creates turf issues that must be addressed in order to work cooperatively. Because of this, transitional countries may find it easier to integrate horizontally than developed countries, simply because agencies have had less time to stake out their bureaucratic turf.

One strategy in enabling horizontal integration is to create an entirely new organization to handle ITS deployment. The new organization may be comprised of members of each of the relevant departments, and in practice is often funded by statute. New organizations are often most successful in pioneering large-scale projects that require a strong management structure and a wide regional focus. In certain applications, public agencies can contract a private sector company to fill this role.

This strategy is particularly important for developing economies. Many of these areas undergo relatively frequent institutional change, as leadership changes hands and bureaucracies are more malleable than in developed nations. A separate ITS organization is more insulated from these institutional changes, and is only subject to the same risk of dissolution as with any other agency. There is less danger that membership will change rapidly, which may dilute the new organization's mission and undermine ITS projects.

The other strategy in enabling horizontal integration is to utilize an existing partnership in a new way. Some coalitions of agencies already exist for purposes such as managing construction or regional incident management. If the mission of such an agency is readily adaptable to include ITS, and if the partnership is strong enough to coordinate deployment efforts, then these coalitions could be used for ITS implementation. These coalitions are more likely to be found in developed economies than developing ones, since they imply a preexisting concern over regional sustainability.

An example of successful horizontal integration for ITS deployment is the E-ZPass Interagency Group along the east coast of the United States. E-ZPass is an electronic toll collection technology that is now used in Delaware, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, and West Virginia¹⁶⁰. Comprised of transportation agencies and toll authorities, the Group was originally formed in 1991 to bring a single-tag ETC system to the east coast¹⁶¹. The Group has since worked together successfully to implement a uniform technology along the corridor, which enables drivers to use the same vehicle transponder when traveling through multiple states. This initiative required a new organization to lead the project and resolve regional issues.

¹⁵⁹ Deakin, Elizabeth. "Mainstreaming Intelligent Transportation Systems: Findings from a Survey of California Leaders." Berkeley, CA: 31 July 2002.

¹⁶⁰ E-ZPass Network Home Page. 2002. <http://www.ezpass.com>

¹⁶¹ New York State Thruway Authority. "E-ZPass Receives Federal Highway Administration Honor." 13 Apr 1999.

Another common approach to facilitating horizontal integration is the creation of a regional architecture. A regional architecture defines a set of user services, how these user services fit together, and how information is shared. It is important to include the relationship between regional institutions that are responsible for information sharing and control. Creating a regional architecture can be very beneficial because it requires planners to address the questions of interoperability and institutional cooperation¹⁶². It should be noted that regional architectures must take different vertical institutions (see Section 5.3.2 below) into account as well.

Horizontal integration is crucial to the success of ITS operations. In public sector applications, agencies may choose between forming a new administrative entity and utilizing an existing partnership between entities. Agencies must also consider the regional implications of ITS projects, since highways and vehicles frequently cross political boundaries. To facilitate this process, the creation of a regional architecture can be helpful in defining institutional roles and mapping the flows of information.

5.3.2 VERTICAL INTEGRATION

Besides horizontal integration, vertical integration is another form of collaboration that should be considered when deploying ITS. Vertical integration refers to the cooperation between agencies at different government levels, such as local, regional, and national. A single ITS project can often involve agencies from all three levels, for example federal financing, state or regional administration, and local operations and implementation. The three efforts must be coordinated in order for the deployment to achieve maximum benefits, or even occur.

In developed regions, the problem with vertical integration is sometimes one of leadership. When agencies from separate levels work together, projects are often split into modules with little communication between the different parties. Depending on the project, it may be appropriate for even a local agency to lead the ITS initiative. In these cases, the “higher” levels involved in the project must be willing to follow the leadership of the local agency.

The official body in charge of ITS deployment must also have substantial influence over all the other agencies. As a result, this ITS committee is often incorporated into high levels of government. Two examples are the ITS Joint Program Office within the US DOT, and the Public Authorities Coordinating Committee for the Greater Paris Region. However, the committee is not required to be incorporated at the national level. For example, ITS deployments in Australia are planned, implemented, and managed at the state level.

In developing regions, the problem is sometimes one of communication. National governments tend to set sweeping economic goals and policies without input from the

¹⁶² For a complete discussion of regional architectures, please see: Pendleton, Todd Andrew. “Regional Architectures: Definition and Integration into the Strategic Transportation Planning Process.” Master’s Thesis. Cambridge, MA: Massachusetts Institute of Technology, May 1998.

lower levels of government. Municipal goals may be very different from national goals. For successful ITS implementation, the goals of all levels of government should be aligned.

An example of an ITS application requiring strong vertical integration is incident management. Incident management is most often implemented along freeways. When these freeways are owned by the state, the state manages the construction and operations of the system. However, the state must also coordinate with local emergency services and law enforcement to respond to incidents. Since incident management is a capital-intensive ITS project, the state is also likely to need funding from the national government. As a result, the national government will be involved to ensure that the deployment is meeting federal standards and regulations.

Like the case of horizontal integration, vertical integration can necessitate the creation of a new managing group, or the utilization of an existing partnership. Because of sensitivity to different levels of authority, creating a new group may be a more attractive option when managing vertical integration. In either case, successful integration requires harmonizing the terminology, training programs, and cultures of different agencies if they are to work together on a long-term basis.

To facilitate this process, many countries have developed, or are in the process of developing, national ITS architectures to guide ITS implementation. These architectures define standards, terminology, physical architectures, and information flows. When deploying ITS using federal funds, countries can require the projects to comply with the national ITS architecture, providing a framework for vertical integration. Countries taking this approach include Australia, Canada, Japan, Taiwan, and the United States¹⁶³.

In the future, it will be necessary to coordinate ITS efforts internationally. At this stage, there is potential for vertical integration from the local to international levels. An example of international cooperation thus far is the High-Level Group on Road Transport Telematics, consisting of representatives from each country in the European Union. The High-Level Group has worked on achieving consensus standards.

In applications involving multiple layers of government, vertical integration is crucial to the success of the project. Leadership and communication are challenges to achieving vertical integration. Many of the same strategies to achieve horizontal integration can be used to achieve vertical integration. In addition, the creation of a national ITS architecture is helpful in developing a top-down coordinated strategy.

5.3.3 PUBLIC/PRIVATE PARTNERSHIPS

Many ITS technologies involve public/private partnerships. The public sector has traditionally managed infrastructure systems such as traffic signals and toll collection. The private sector has provided telecommunications networks and in-vehicle equipment.

¹⁶³ System Architecture Committee Library of Architectures Home Page. 25 Sep 2001. ITS America. 19 Dec 2002 <<http://www.itsa.org/committe.nsf/14584d850ba3b706852565d7006a5516/eaac2bae66ce8bc48525686c007867e0?OpenDocument>>.

Because ITS often involves both types of components, it is necessary for both parties to work together to achieve success. For example, the data collection infrastructure for traveler information systems can be installed by the public sector, but the information is often disseminated through private sector channels such as television and cellular phones. Likewise, mayday systems are in-vehicle devices provided by the automobile industry and purchased by the consumer, but the private call centers must interface with public emergency services and law enforcement agencies.

Besides the technical requirements, there are several other justifications for public/private partnerships for ITS projects. ITS deployment can be very costly for the public sector to finance alone, and bringing a private sector partner on board can significantly defray this cost. There are also lucrative profit opportunities for the private sector in partnerships because they can be the first to take advantage of new products and services.

According to the World Road Association, public/private partnerships for ITS fall largely into one of four types. In decreasing control for the public sector as shown in Figure 2, they are public-centered operations, contracted operations, franchise operations, and private competitive operations¹⁶⁴. Each of these is discussed briefly below.

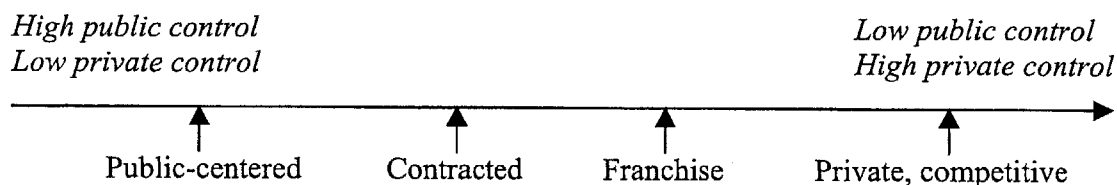


Figure 14. Public/private partnership models

As the name implies, public-centered operations are the type with the greatest public control and the least private control. Public-centered operations are characterized by public responsibility for financing, control, and operations. The role of the private sector is small and usually in the form of specialist support contracts. An example is traffic signal maintenance support.

In contracted operations, the private sector takes on a larger role. The public agency retains control, but awards an operations and management contract to a private company. It is important in contracted operations to consider both price and quality when selecting a private sector partner. These issues are discussed in further detail in Section 5.5.1.

The franchise operations model gives the private sector complete authority over the day-to-day operations of the ITS project. The role of the public sector "is mainly to see that service standards are maintained and service users are not subjected to unfair pricing."¹⁶⁵ The franchise holder is often responsible for financing as well. A common application under this model is concessions for privately operated toll roads.

¹⁶⁴ Ibid.

¹⁶⁵ Ibid.

The final public/private partnership model is private, competitive operations. This model has the least public control. It allows for competition and market forces to work in equilibrium. For example, the public agency in Paris collects traffic data but provides it to multiple information services companies in order to encourage competition. These companies compete by processing and distributing traffic data to the general public.

The public and private sectors bring different strengths to the partnership. The public sector strengths are in its service culture, infrastructure management skills, funding for unprofitable but publicly beneficial projects, and ability to create a legal & regulatory framework governing safety and the environment. However, it is financially limited and is sensitive to social issues. The private sector strengths are in possessing skilled human resources, flexibility, entrepreneurial culture, and market funding. When working together, the two sectors must find a joint interest in the project. For the public sector, this means providing quality service for the public interest. For the private sector, this means profitability.

To facilitate public/private partnerships, many nations have created partnership organizations that often act in an advisory capacity to local, state, and national governments. Examples of these are ITS America in the US, ERTICO in the European Union, and VERTIS in Japan. These organizations are very influential and encourage communication between the public and private sectors.

Public/private partnerships are a necessary component of many ITS applications. Agencies should choose the partnership model that is most appropriate to the particular project. In addition, the partnership should be structured in such a way that both parties benefit from the relationship. National ITS organizations like ITS America and ITS Australia can be helpful in facilitating this communication.

5.4 FINANCE

Like any other new initiatives, ITS projects require funding. Funding can come in many forms, including federal/state/local financing, loans, and bonds. The private sector and individual consumers also often bear part of the cost for ITS initiatives, particularly for intelligent vehicle technologies. When deploying ITS, both capital and operations and maintenance (O&M) funding should be considered. Eventually, public agencies should strive to mainstream ITS into the regular transportation planning process. Mainstreaming allows ITS to be considered as a viable alternative to traditional infrastructure investments.

5.4.1 CAPITAL BUDGETING

The initial deployment of ITS requires an upfront capital cost. This cost includes command and field hardware, software, installation, and other necessary components. When included as part of a new infrastructure investment, the capital cost for ITS is typically around 2-3% of the cost of the entire project¹⁶⁶.

¹⁶⁶ US DOT. Federal Highway Administration. "What Have We Learned About Intelligent Transportation Systems?" Washington, DC: Federal Highway Administration, 2000.

Not all costs are necessarily borne by the government. In certain applications, the automobile industry and/or the end user pays for part or all of the capital cost. For example, the automobile industry initially pays for the development of AVCS technology, the cost for which is partially passed on to the purchaser. The end user also usually bears the cost for driving conveniences such as mayday systems and navigation assistance devices. For collection of traffic data, Apogee Research predicts that 80% of the cost will be borne by consumers and private companies by the year 2015¹⁶⁷.

In applications where the primary cost is borne by the government, particularly intelligent infrastructure technologies, finding financial resources can be difficult. Policymakers must balance transportation budgets with competing demands from other sectors like education and national defense. Within the transportation budget itself, ITS competes heavily with physical infrastructure investments for very limited resources. For example, China estimates that it can only provide 75% of the capital necessary for highway development domestically, requiring at least \$1.5 billion in annual foreign investment¹⁶⁸. In such an environment, justifying an additional 2-3% for ITS projects may be difficult.

One method of obtaining capital financing is through the use of a political champion. This person or group of people may be necessary in certain applications to fight for and secure capital. Champions can be transportation professionals, elected officials, industry experts, and academics. The champion faces the challenge of generating awareness about the benefits of ITS.

Many countries have also created programs charged with providing financing for ITS initiatives. Though some come in the form of federal capital commitments, many utilize other financial mechanisms such as flexible credit and loan guarantees¹⁶⁹. Many ITS projects are therefore funded through a mix of local, state, and federal funds, with a combination of loans, grants, and bonds.

Increased awareness of terrorist threats may also provide an avenue for securing ITS funding. The United States interstate highway system was originally funded during the Cold War as the National System of Interstate and Defense Highways. In a similar vein, ITS could be funded by arguing that these technologies can increase effective road capacity in the event of emergencies. For example, incident management and ATIS systems could reroute critical traffic onto alternative roads in the event that a major interstate is destroyed. A nation's transportation infrastructure, instead of being paralyzed in an emergency, could remain functional by using ITS. However, this exposes infrastructure to a different type of risk from cyber-attacks.

¹⁶⁷ Apogee Research, Inc. "Intelligent Transportation Systems - National Investment and Market Analysis." Prepared for ITS America and US DOT. 1997.

¹⁶⁸ SinoProjects Forum. "Highway Development & Intelligent Transportation Systems in China." Feb 2001. 17 Dec 2002 <<http://www.sinoprojects.com/English/newforum/Forumarticle-1-rev.doc>>.

¹⁶⁹ US DOT. Federal Highway Administration. "Financing Federal-Aid Highways." Washington, DC: Federal Highway Administration, 13 Sep 1999.

The United States, however, does not appear to be adopting this approach for deploying ITS. Rather, it is implementing a policy of controlling entries and exits onto transportation infrastructure¹⁷⁰. The most prominent example of this is the new federally controlled airport passenger screening system. This approach is fundamentally different from the ITS approach, which manages risks and impacts rather than system inputs (passengers).

Increasingly, public agencies are turning to the private sector for financial assistance. The private sector can be involved as a concessionaire or inside a partnership. Under the concessionaire model, the government essentially contracts out the entire service (and associated revenues, if any) to the winning bidder. This is often used for toll roads where the public agency requires the use of electronic toll collection. Under a partnership model, the government works with the private sector to jointly deploy the ITS technology. For example, the private sector purchases and operates the hardware for automated red light enforcement systems in exchange for a percentage of the fines collected. The public sector can also shift R&D responsibility to the private sector by issuing stricter regulations and standards. In order to comply with these regulations, the private sector (and ultimately consumers) ends up funding the development and deployment of ITS projects.

The problem with involving the private sector is that not all ITS applications can provide profitability, a necessary condition for private companies. Although benefit/cost ratios for ITS are typically very favorable, not all of these benefits can be captured in the form of money. Societal impacts like cleaner air, fewer vehicle accidents, and increased road efficiency do not translate directly into profits for the private firm. Public agencies should therefore carefully consider the business model under which they bring on a private sector partner, if they hope for the partnership to succeed in the long run.

Capital financing in a limited budgetary environment can be very difficult for public agencies. Frequently, ITS projects require a champion or other form of national commitment to set aside money for these initiatives. Another approach has been to turn to the private sector. These partnerships should be planned so that all parties can benefit from a sustainable relationship.

5.4.2 O&M BUDGETING

Operations and maintenance funding can be closely tied to capital funding if the budgets are allocated simultaneously. They face many of the same problems, including the need for a champion, federal commitments, or private sector assistance. O&M funding includes facility costs, staff training and salaries, office support, integration with other

¹⁷⁰ Dillingham, Gerald L. Director, Physical Infrastructure Issues. United States General Accounting Office. "Transportation Security: Post-September 11th Initiatives and Long-Term Challenges." Testimony before the National Commission on Terrorist Attacks Upon the United States. New York, NY: General Accounting Office, 1 Apr 2003.

systems, power for field devices, inventory supplies, periodic diagnostic testing, and other supporting costs¹⁷¹.

Since operations and maintenance costs are recurring, they are typically classified together for budgeting purposes. Their specific processes can be defined separately, however. For ATMS, Ginger Daniels and Tim Starr define operations to include¹⁷²:

- Overseeing the day-to-day function of control and management equipment
- Collecting real-time traffic flow data and reacting with traffic flow and incident management technologies
- Communicating and coordinating with related transportation and emergency response agencies
- Disseminating information to the media and public
- Monitoring system performance criteria
- Updating system databases
- Notifying maintenance personnel of system malfunctions, and coordinating them with related transportation and emergency response agencies
- Administering operations contracts and monitoring the performance of operations contractors

Likewise, Daniels and Starr define maintenance as¹⁷³:

- Performing preventive maintenance
- Monitoring hardware and software components for required performance levels
- Repairing or replacing equipment, components, and modules
- Diagnosing and resolving software inconsistencies
- Administering maintenance contracts and monitoring the performance of maintenance contracts

O&M funding can be even more difficult to obtain than capital funding. This is because, unlike road building, ITS projects have high maintenance costs compared to their construction costs¹⁷⁴. As a result, transportation professionals need to consider the impact of O&M costs early on in the project, and create awareness of the need for continued funding.

Without proper maintenance and repair, the performance of ITS systems can degrade rapidly. This may compromise both potential benefits of the deployment as well as

¹⁷¹ Western Transportation Institute. "California-Oregon Advanced Transportation Systems ITS Strategic Deployment Plan." May 2001. 17 Dec 2002 <http://www.coe.montana.edu/wti/wwwshare/COATS/sdp_toc.htm>.

¹⁷² Daniels, Ginger and Tim Starr. "Guidelines for Funding Operations and Maintenance of Intelligent Transportation Systems/Advanced Traffic Management Systems." Transportation Research Record 1588 No. 971390.

¹⁷³ Ibid.

¹⁷⁴ US DOT. Federal Highway Administration. "What Have We Learned About Intelligent Transportation Systems?" Washington, DC: Federal Highway Administration, 2000.

public acceptance of ITS in general. For example, improperly maintained smart traffic signaling systems can actually cause more congestion than before the technology was installed. Since the benefits of smart traffic signal control are ambiguous to the public already, this negative result could lead to increased skepticism of all ITS technologies. Maintenance can be easily deferred during financially difficult years, which further increases the risk that ITS systems may not perform to their full potential.

Fortunately, some ITS projects also have the potential for generating revenue that offsets some of these O&M costs. Applications such as automated red light enforcement and electronic toll collection create a revenue stream that can be partially used for operations and maintenance. Public agencies also may have the option of selling collected data or allowing marketers to target drivers through ITS channels, though this raises issues of privacy. When deploying ITS, public agencies should consider possible methods by which the technology can generate a revenue stream on its own, or be prepared to provide annual O&M funding for the lifetime of the project.

5.4.3 MAINSTREAMING

Rather than trying to obtain funding for individual ITS projects as they arise, a different approach is to consider ITS projects within the regular transportation planning process. This approach is called mainstreaming. The Multi-state Operation Research and Implementation Program (MORIP), a collaboration between the states of California, Minnesota, Texas, and Washington, defines the term “mainstreaming ITS” in three related ways. The first definition is when ITS projects compete head-to-head with similar projects without ITS, for example a highway equipped with incident management systems versus the same highway without the technology. The second definition is when ITS funding is mainstreamed, that is, when ITS projects have access to the same funding pool as traditional highway projects. The final definition is when ITS is integrated into routine planning activities¹⁷⁵.

Mainstreaming ITS is preferable to ad hoc funding for several reasons. When ITS is incorporated into the planning process, transportation professionals develop an awareness for the potential benefits of ITS projects. The process of mainstreaming also circumvents the need for a strong champion or legislative commitment in order to finance any particular ITS initiative. As a result, operations and maintenance funding may also be easier to obtain once ITS has already been deployed.

Mainstreaming ITS is a shift from the traditional transportation planning process. For mainstreaming to occur, there must first be an established planning process. In transitional countries, the transportation planning process can be anywhere from nonexistent, to rudimentary, to well developed. Provided that an effective planning process is in place, agencies can then develop strategies to successfully integrate ITS. Since transportation planning involves numerous institutions and intermediary steps, mainstreaming will require “the identification of which partnerships are necessary to

¹⁷⁵ Multi-state Operation Research and Implementation Program. “Intelligent Transportation Systems Mainstreaming Initiative.” 5 Sep 1998. 18 Dec 2002 <<http://morip.tamu.edu/Documents/Irvine98/Handouts/ITSMainstreamingInitiative.PDF>>.

facilitate such a mainstreaming activity; who has lead responsibility for the products and processes under discussion, and what institutional arrangements and understandings are recommended to accomplish the work.”¹⁷⁶ ITS will also need to be integrated into all levels of decision-making.

The U.S. is an example of a federal government that has taken steps to mainstream ITS. The Transportation Equity Act for the 21st Century (TEA-21) encourages mainstreaming in two ways. First, TEA-21 provides \$1.282 billion in funds for ITS research and implementation through the year 2003. To qualify for funding, one of the requirements is that states and municipalities must show that ITS projects are included in statewide or metropolitan transportation plans, and have ensured continued long-term operations and maintenance activities¹⁷⁷. Besides the grant incentives, TEA-21 also encourages mainstreaming by incorporating the grant application process into regular federal aid planning. TEA-21 mainstreams federal ITS funding, thereby setting an example for state and local agencies to follow likewise.

Funding for roadway infrastructure and ITS projects may always be scarce. However, ITS has a better chance at deployment if it can be mainstreamed into the regular transportation planning process. Mainstreaming ITS also creates awareness of ITS benefits among public agencies and provides a viable alternative to traditional infrastructure investments.

5.5 LEGAL AND REGULATORY

Successful ITS deployment requires a supportive legal and regulatory structure. Without such a framework, consequences may include long project delays, financial problems, and/or lack of user acceptance. It is necessary for regions to consider how they handle questions of procurement, intellectual property, liability, and privacy.

Though this section focuses on a legal and regulatory structure for ITS deployment, other regulations can provide incentives for ITS innovation. For example, tightening emissions standards have forced automobile manufacturers to develop technologies that increase vehicle efficiency and reduce tailpipe emissions. Regulations can also shift the financial burden from the public to the private sector. By regulating emissions, accident rates, and other negative effects of congestion, the government can allocate responsibility for congestion to the automobile industry. While regulations of all types can affect ITS research, the focus here is on the necessary conditions for implementation.

5.5.1 PROCUREMENT

The issue of procurement is important when deploying ITS technologies. Its importance differs depending on a country’s political structure. Democratic societies tend to have stricter procurement rules in order to ensure competitive bidding and best use of public

¹⁷⁶ Ibid.

¹⁷⁷ US DOT. Federal Highway Administration. “Intelligent Transportation Systems in the Transportation Equity Act for the 21st Century.” Washington, DC: Federal Highway Administration.

funds. Other societies may have more flexibility in using innovative procurement methods for public construction.

Procurement for ITS technology is complicated due to a number of factors. The requirements for projects often cannot be completely specified at the outset, which makes bidding difficult. If sophisticated technology is bundled into the infrastructure construction contract, the general contractor may not have the expertise to implement the systems. The technology itself is changing rapidly. These factors all contribute to a system where bidders are not well informed of costs and product quality when submitting their bids.

The traditional form of construction procurement in restrictive legal environments is design-bid-build. Under this system, two independent entities are responsible for separate design and construction contracts. This system is used because it creates a competitive and open bidding process where construction is based on lowest price. The public is also assured that government funds are being used in the most economical manner.

However, design-bid-build is often not suitable for ITS for two reasons. First, the steps of design and implementation are often tightly integrated in software development and computer engineering. By separating the two, a deployment of lesser quality may be produced. Second, low-bid contracting does not ensure the best system design or product quality. Since the quality, accuracy, and reliability of ITS technology is so crucial to its success, awarding contracts on price alone may not be recommended¹⁷⁸.

It should be noted that design-bid-build is only required for construction projects, not for design projects. As a result, ITS applications that do not require infrastructure construction can be procured through other methods of project delivery. Unfortunately, ITS is often procured through the same contract as the entire construction project, since the technology component may only be a small percentage of the entire cost. However, even when ITS is classified as construction, there are still alternatives available¹⁷⁹. Depending on the legal environment, public agencies do have other options that maximize project quality and cost while still complying with federal, state, and local procurement regulations.

The first of these is prequalification. Agencies using prequalification first screen a pool of potential candidates. Firms that pass this qualification screen are allowed to move onto the competitive low-bid round. The advantage of this system is that public agencies can satisfy themselves that the contract winner has the expertise and capabilities to execute the contract to completion. However, this still does not address the problem of integrated design and implementation with ITS technology.

¹⁷⁸ US DOT. Federal Highway Administration. "FHWA Federal-Aid ITS Procurement Regulations and Contracting Options. McLean, VA: Federal Highway Administration, 20 Sept 1999.

¹⁷⁹ US DOT. ITS Joint Program Office. "Procurement Options for ITS Federal-Aid Projects." 12 Dec 2002 <<http://www.its.dot.gov/Technical/procop.htm>>.

Another strategy for public agencies is to hire a procurement agent. This strategy is common in transitional countries that lack well-developed model procurement codes¹⁸⁰. Under this model, the procurement agent develops and manages the procurement process. It is the responsibility of the procurement agent to produce the best candidate for the contract award.

Still another approach is the use of a system manager. System managers provide the entire spectrum of design, procurement, and installation services, and may therefore be procured through engineering and design guidelines¹⁸¹. These guidelines are typically far more lenient than construction project guidelines. In the U.S., for example, engineering and design services can be procured through competitive or noncompetitive negotiations, in contrast to low-price bidding¹⁸². When using system managers, the actual construction is typically contracted to another entity.

The final strategy presented here is design-build. This method of project delivery awards both design and construction responsibilities to a single contractual entity. Design-build awards must consider cost as either the sole factor, or as one of multiple factors. While design-build addresses the design and implementation integration problem associated with ITS, it also requires a detailed set of specifications before bidding in order to provide enough information to potential bidders.

Procurement issues may be problematic in developed countries that have statutory procurement codes. In these cases, other forms of project delivery should be considered to support ITS deployment. Some alternatives presented here are prequalification, procurement agents, system managers, and design-build. These alternatives are not mutually exclusive (for example, prequalification can be used in design-build projects). Public agencies should choose the method that produces a high quality product while adhering to the regulatory framework of its particular region.

5.5.2 INTELLECTUAL PROPERTY

Intellectual property (IP) rights are an issue of concern when implementing ITS. IP refers to inventions, copyrights, trade secrets, and data that is patentable or considered proprietary technology. According to the US DOT, intellectual property issues “are some of the most pervasive and frequently cited obstacles to ITS. Although expending the time and effort required to resolve these issues is not the path of least resistance, making this effort is the path to success for ITS.”¹⁸³

¹⁸⁰ Chen, Kan and John C. Miles, ed. “ITS Handbook 2000: Recommendations from the World Road Association (PIARC).” Boston, MA: Artech House, 1999.

¹⁸¹ US DOT. ITS Joint Program Office. “Procurement Options for ITS Federal-Aid Projects.” 12 Dec 2002 <<http://www.its.dot.gov/Technical/procop.htm>>.

¹⁸² US DOT. Federal Highway Administration. “FHWA Federal-Aid ITS Procurement Regulations and Contracting Options. McLean, VA: Federal Highway Administration, 20 Sept 1999.

¹⁸³ US DOT. Federal Highway Administration and Federal Transit Administration. “What’s Yours, Mine, and Ours: Overcoming Intellectual Property Rights Issues, A Cross-Cutting Study.” Washington, DC: FHWA and FTA, Aug 2000.

Intellectual property problems typically arise in public/private partnerships. There is an inherent tension between the public and private sectors because they have conflicting interests concerning IP. The public sector is generally interested in promoting competition and protecting the use of public funds through broadly interpreted IP regulations. In contrast, the private sector is interested in retaining IP rights in order to make profits and to reap the benefits from investing in research and development. As a result, the private sector is often unwilling to bid on contracts that require public sector licensing and/or public disclosure¹⁸⁴.

IP can also be an issue between private sector companies. In the effort to create standards, automobile companies must work together to reach a consensus standard on many issues, one of which is high-speed electrical buses. The Automotive Multimedia Interface Consortium (AMIC) calls for open specifications so that the industry can build upon the adopted specifications. However, the developers of ITS technology standards frequently sign nondisclosure clauses, which prevent the sharing of proprietary information. As a result, other companies are forced to pay licensing fees and sign agreements in order to use the technology. While companies do have the right to keep their technology private, choosing to follow this practice adds another barrier to ITS implementation¹⁸⁵.

When working with the public sector for ITS deployment, private companies bring to the table preexisting technology, as well as technology developed during the course of the project. This raises two IP concerns – licensing rights for the preexisting technology, and ownership rights of the enhanced technology. Both issues should be addressed when negotiating contract agreements between the public and private sectors.

Public agencies have approached the problem in several ways. In a San Diego, California deployment of smart call boxes, the implementation team “purposely did not acquire intellectual property rights in order to give the vendors more freedom in developing their systems and to encourage them to continue marketing and development.”¹⁸⁶ Other approaches for public agencies are to solicit federal government input, develop licensing agreements, create an intellectual property manual for private sector reference, and create flexible IP programs¹⁸⁷. These approaches can be applied alone or in combination with one another. The key component of any of these IP policies is to draft contract language clarifying all uncertainties and limitations at the outset of the project.

The problem of intellectual property rights can significantly stall projects by shifting focus from technical to procedural issues. However, there are also many possible solutions to the problem of intellectual property rights. Public agencies should choose

¹⁸⁴ L.S. Gallegos and Associates. “Innovative Contracting Practices for ITS.” Prepared for US DOT, Federal Highway Administration. April 1997. 13 Dec 2002 <http://www.fhwa.dot.gov/resourcecenters/eastern/operatn/inncontracting_practices.htm#Intellectual%20Property>.

¹⁸⁵ Murray, Charles J. “Day of reckoning nears for automotive buses.” *EE Times* 26 May 2000.

¹⁸⁶ TranSafety, Inc. “Institutional Lessons Learned from Examining a California Smart Call Box Study.”

¹⁸⁷ US DOT. Federal Highway Administration and Federal Transit Administration. “What’s Yours, Mine, and Ours: Overcoming Intellectual Property Rights Issues, A Cross-Cutting Study.” Washington, DC: FHWA and FTA, Aug 2000.

the approach that best suits their specific project and region. As long as the issue is addressed, the allocation of intellectual property rights does not need to derail an ITS deployment.

5.5.3 *LIABILITY*

Both the public and private sectors must address the issue of legal liability when implementing ITS. Liability has serious financial implications and comes in several forms, including product liability, tort liability (negligence), breach of warranty, and false advertising. The problem is particularly severe in the United States, which generally has a more litigious political system than Europe or Asia.

Liability is a serious consideration, especially with AVCS technology. Automobile manufacturers are concerned that liability for accidents will shift from the driver to the technology. While communications and entertainment services are commercializing quickly, safety devices like intelligent cruise control and vision enhancement systems are much slower to deployment, primarily because of liability issues. As a result, North America is far behind Europe and Japan in implementing AVCS and reaping its benefits. The United States must also deal with recent findings linking accidents with the use of cellular phones, another electronic device. An anonymous engineer for one of the big US automobile manufacturers pessimistically described the situation as:

“These days if you hang anything on a car that requires a driver to do something he normally would not do, you automatically become liable. If cruise control had been developed today, no US car manufacturer would be willing to be the first to field it. New technology or applications of this type goes to Europe or Japan first, get[s] tested [and] developed, and it becomes their market.”¹⁸⁸

While AVCS is the likely target for legal action, it is not the only ITS technology threatened by the risk of liability. Any technology that affects how people drive also carries the potential for lawsuits. For example, a study released by the University of Michigan Transportation Research Institute (UMTRI) listed the following potential lawsuits associated with navigation assistance devices:

- A route guidance systems tells the user to turn left into a lake. Who pays for the damage/injuries?
- A driver using an in-vehicle map system unknowingly turns the wrong way down a one-way street and gets into an accident. Can he sue for damages?
- The database displays a speed limit of 65 miles/hour. The speed limit is actually 55 miles/hour and the user gets a speeding ticket. Who should be held responsible?
- A vehicle is routed through a dangerous area that would otherwise be avoided. Who should be blamed if a mugging or car jacking results?

¹⁸⁸ Braun, Alexander E. “Intelligent Transportation Systems: Mirage or Reality?” *Microwave Journal*. 16 Dec 2002 <<http://stewks.ece.stevens-tech.edu/EE685/TechArticles/mwjjournal/article12/ITS.html>>.

- An emergency response vehicle carrying a heart attack victim gets to a hospital ten minutes late because of inaccurate map data. The patient dies. Is the navigation system at fault?¹⁸⁹

In regions where the threat of liability is high, the public and private sectors must take steps to address potential lawsuits. There are three strategies – build the expected cost of litigation into the business plan (i.e. pass the cost to the user), engage in activities to minimize liability (i.e. purchase insurance), and/or delay the introduction of technology until lawsuits are minimized through legislation or other means¹⁹⁰. While the private sector has several mechanisms for managing risk, such as insurance and legal disclaimers of liability, the public sector does not have the same access to these mechanisms. ITS technologies deployed by the public sector are therefore more likely to be stalled by the issue of liability. In these cases, it may be prudent for the public agency to partner with the private sector so that liability is allocated to parties that can manage the risk.

There are several approaches to dealing with the liability problem. The automobile industry's approach to AVCS liability is to market the technology as driving aids, not as safety benefits. While this may or may not limit liability claims, it also detracts from public education about the safety benefits of ITS. Without the public recognizing these benefits, the market penetration of AVCS may suffer as a result.

Another approach is to exchange legislative liability protection with the development of standards for the automobile industry. In recommending this approach, John Collins, then president of ITS America, wrote "it would be unconscionable if massive safety benefits to U.S. society as a whole were delayed because we are unable to develop a scheme for fairly compensating the few who will inevitably be injured in the use of such systems."¹⁹¹ Liability protection can be in many forms, including statutes of limitations and caps on punitive damages and "pain and suffering" awards. In exchange, the automobile industry must establish rigorous performance standards and show that their technology adheres to these standards.

Public and private sector participants can also allocate liability risk through standard contract clauses (indemnity, releases, waivers) to which all parties agree in advance¹⁹². Liability costs can thus be borne by the most appropriate party. The role of insurance companies should also be defined. Either insurance companies or automobile manufacturers could require drivers to sign informed consent and/or waiver of liability forms as a condition for using AVCS.

¹⁸⁹ Richardson, Barbara C. and Paul A. Green. "Trends in North American Intelligent Transportation Systems: A Year 2000 Appraisal." Ann Arbor, MI: University of Michigan Transportation Research Institute, April 2000.

¹⁹⁰ Ibid.

¹⁹¹ Collins, John. President, ITS America. "Priorities for Federal Innovation Reform." Submitted to National Science and Technology Council, Committee on Technology. Washington, DC: 17 Sep 1999.

¹⁹² L.S. Gallegos and Associates. "Innovative Contracting Practices for ITS." Prepared for US DOT, Federal Highway Administration. April 1997. 13 Dec 2002 <http://www.fhwa.dot.gov/resourcecenters/eastern/operatn/inncontracting_practices.htm#Intellectual%20Property>.

Liability can be a major barrier to deployment, particularly for AVCS technology. Especially in litigious regions, the public and private sectors need to address how they will handle potential lawsuits and liability issues. There are a variety of approaches that agencies and companies can use to allocate risk to the appropriate parties. Without proper liability management, ITS deployment could be delayed significantly, and the project stakeholders could suffer large financial losses from liability claims.

5.5.4 PRIVACY

Questions relating to privacy issues abound in the deployment of many ITS technologies, including incident management, automated red light enforcement, electronic toll collection, and even drowsy driver sensors. While citizens in different regions around the globe value privacy to varying degrees, people are generally uncomfortable with the idea of government collecting data about their movements and using video surveillance as a means to law enforcement. This can be a large barrier to implementation in open political systems that place high value on individual freedoms and rights.

ITS can infringe on personal privacy in a variety of ways. Though information can be used to great benefit, it can also be abused. With incident management systems, for example, there are concerns about the ability to record a particular vehicle at a given time without the consent of the operator. Red light enforcement technology is highly susceptible to privacy issues, because computers collect driver information and pass violations on to law enforcement agencies. Electronic toll collection raises questions about vehicle location tracking and transaction records hidden within a database. Even potential users of drowsy driver sensors are wary of constant surveillance and a record of driver behavior¹⁹³.

There are many facets of privacy to be considered when constructing a legal framework for ITS deployment. The following list of issues is adapted from a paper written by Phil Agre, researcher on privacy and ITS at the University of California, San Diego. Agre argues that agencies need to construct rules for the collection, dissemination, and protection of the information gathered through ITS technologies. His concern is that without considering the issues outlined below, this “information obviously invites a wide range of secondary issues, from law enforcement to targeted marketing to political repression”¹⁹⁴.

- **Individually identifiable information** – Many believe that using ITS requires individual identification of people or their vehicles. To solve this problem, anonymous methods should be explored to their full potential.

¹⁹³ Worrall, Dr. Richard. “Privacy Issues and Intelligent Transportation Systems.” PowerPoint presentation given at the National Association of Counties (NACo) Information Technology Summit III – The Priority of Privacy. Seattle, WA: 2001.

¹⁹⁴ Agre, Phil. “Technology and Privacy in Intelligent Transportation Systems.” Presented at the Conference on Computers, Freedom, and Privacy. San Francisco, CA: University of California San Diego, Mar 1995.

- **Security** – Wireless interception, external attacks, and insider leakage are potential security problems. In addition to using encryption technology, agencies can increase system privacy by decreasing the sensitivity of information being transmitted.
- **Standards** – Technical data standards can be established in such a way that they inherently protect privacy.
- **Secondary use** – To protect privacy, drivers should be able to opt out of secondary uses of their information, namely for marketing purposes. Marketers have the potential to target drivers based on where they drive or the real-time location of their vehicle.
- **Law enforcement** – The privacy concern is that drivers may be ambushed for other infractions through data collected via ITS (for example, speeding tickets issued by calculating speeds from toll collection data). To address this issue, public input is required during planning to establish the degree to which law enforcement agencies can track citizens' movements.
- **Commercial applications** – ITS applications with the fewest privacy protections are those for commercial vehicles. Trucking companies now monitor their vehicles and drivers through GPS and other surveillance technology. The privacy concern is that this might set a precedent for consumer applications as well.
- **Choice** – There are privacy arguments on whether ITS should be voluntary or mandatory. Even when ITS is not mandatory by law, it may be mandatory in practice due to lack of alternatives.
- **Participation** – To protect privacy, the public should be able to participate in discussions on ITS with the industry and the government.
- **Strategies** – There are multiple strategies for protecting privacy. Among these are legislation, system design, and standards.

There are several ways to address the issue of privacy in ITS. To allay concerns about the collection of information, one approach is to strip personal information from data. In Seattle, WA, for example, the bus driver identification is stripped from vehicle identification data before it is relayed to the control center¹⁹⁵. Another approach is purely legislative. Regions can pass laws governing and restricting the use of information gathered through ITS. In the US for example, the states of New Jersey and New York limit the use of images captured through video enforcement systems on electronic toll roads¹⁹⁶.

¹⁹⁵ US DOT. Federal Highway Administration. "What Have We Learned About Intelligent Transportation Systems?" Washington, DC: Federal Highway Administration, 2000.

¹⁹⁶ Ibid.

When drafting legislation, it is important to consider both the privacy of users and the needs of the public agencies. These considerations must be carefully balanced. The wording of legislation passed by the Washington State Legislature in 1999 is careful to protect commercial vehicles while allowing information to reach the appropriate agencies. It states:

“Any information obtained by governmental agencies that is collected by the use of a motor carrier intelligent transportation system or any comparable information equipment attached to a truck, tractor, or trailer is confidential and not subject to public disclosure under this chapter. However, the information may be given to other governmental agencies or the owners of the truck, tractor, or trailer from which the information is obtained.”¹⁹⁷

Government agencies and industry partners can also develop a set of privacy principles to guide them in deploying ITS. In the United States, ITS America (a collaboration of public and private entities) have adopted “Fair Information and Privacy Principles” to be used as reference. A summary of the main points are that ITS should be:

- **INDIVIDUAL CENTERED.** Intelligent Transportation Systems must recognize and respect the individual's interests in privacy and information use.
- **VISIBLE.** Intelligent Transportation Information Systems will be built in a manner "visible" to individuals.
- **COMPLIANT.** Intelligent Transportation Systems will comply with applicable state and federal laws governing privacy and information use.
- **SECURE.** Data collected or distributed using Intelligent Transportation Systems will be secure.
- **PROTECTED FROM LAW ENFORCEMENT.** Intelligent Transportation Systems have an appropriate role in enhancing travelers' safety and security interests, but absent consent, statutory authority, appropriate legal process, or emergency circumstances as defined by law, information identifying individuals will not be disclosed to law enforcement.
- **RELEVANT.** Intelligent Transportation Systems will only collect personal information that is relevant for ITS purposes.
- **ANONYMOUS.** Where practicable, individuals should have the ability to utilize Intelligent Transportation Systems on an anonymous basis.

¹⁹⁷ As cited in Goehring, Janet B. and Melissa A. Savage. “Intelligent Transportation Systems Update.” National Conference of State Legislatures Transportation Series Mar 2001, No. 16.

- **SUITABLE FOR COMMERCIAL OR OTHER SECONDARY USE.** Intelligent Transportation Systems information stripped of personal identifiers may be used for non-ITS applications.
- **AWARE OF FOIA.** Federal and State Freedom of Information Act (FOIA) obligations require disclosure of information from government maintained databases. Database arrangements should balance the individual's interest in privacy and the public's right to know.
- **SUBJECT TO OVERSIGHT.** Jurisdictions and companies deploying and operating Intelligent Transportation Systems should have an oversight mechanism to ensure that such deployment and operation complies with their Fair Information and Privacy Principles.¹⁹⁸

Protecting the privacy of users is a concern that has varying degrees of importance depending on a region's political environment. Strategies for dealing with privacy are to solicit public discussion, enact protective legislation, design systems with privacy in mind, and develop a set of principles. The widespread collection of vehicle and driver information may always raise privacy questions, but with careful planning these questions do not need to slow the deployment of ITS technologies.

5.6 INFORMATION

ITS technologies use information to improve traffic congestion, safety, efficiency, and the environment. They must necessarily deal with large quantities of data as a result. Since the role of public transportation agencies has historically been in the realm of infrastructure and operations, many agencies are ill equipped to manage ITS information. Almost always these are not purely technical problems, but rather difficulties associated with the institutional capacity to handle such data.

This section discusses some of the problems public agencies may face with regard to ITS information. Data issues arise through all stages of the process – collecting, processing, and distributing. Agencies must also consider standards for the information that they use. A big challenge for many regions with information is attracting and retaining skilled employees to handle the systems. Finally, agencies may need to implement informational public education campaigns to increase ITS awareness and improve user acceptance.

5.6.1 DATA ISSUES

Obtaining and using data in ITS applications can be difficult. Many intelligent infrastructure technologies collect large amounts of information that is not useful unless it is processed and distributed appropriately. The two institutional challenges that ITS deployment faces are obtaining complete accurate data and processing it in a useful way.

¹⁹⁸ ITS America. "ITS Privacy Principles." Washington, DC: 15 Jan 2001 <<http://www.itsa.org/resources.nsf/24aebd36f046a5a58525658d00644198/bad372b260280b3385256818004fe7e3?OpenDocument>>.

The problems in collecting complete and accurate data are twofold - one, the data may not exist, and two, the stakeholders possessing the data may not share it. Certain technologies depend on obtaining such a database, particularly those where enforcement is important. Electronic toll collection, for example, relies on using vehicle registration and driver information databases to identify offenders from images of their license plates. Once the offender has been identified, the system also needs to send a bill to his current address. ETC technology sometimes also links transponder charges directly to billing through automatic credit or debit deductions. Many regions, especially in transitional countries, do not have complete motor vehicle registry information. Even if the information exists, it may not be updated regularly. This limits enforcement and the successful deployment of electronic toll collection.

Assuming that complete and accurate information exists, deployment may still be limited if it is not shared with the appropriate agencies. This problem is similar to the horizontal integration and public/private partnership challenges discussed above. Using the ETC example presented above, a region's Department of Motor Vehicles may be unwilling to share data with private toll road concessionaires. There are many legitimate reasons for the DMV to limit cooperation - customer privacy, concern about data integrity/abuse, coordination among multiple concessionaires, and lack of human resources, to name a few. Even when administered by a public agency, these issues must still be overcome.

Processing collected data in a useful way is also a challenge. Many technologies, including incident management and automatic vehicle location, provide large amounts of information to agencies. This information is not useful unless it is analyzed and acted upon accordingly. To address this problem, agencies often send information gathered by ITS technologies to central control centers. However, they must be prepared to invest in computer equipment and trained personnel to use the information productively.

Certain technologies, particularly ATIS, require agencies to distribute some of the information they collect to both private companies and the public at large. However, the two may have differing interests in the quality and type of data to be collected. The public sector is concerned with traffic management, while the private sector is concerned with satisfying demand from its customers.

In 2000, ITS America and the US DOT issued a report on data for ATIS. The following table lists the priorities for the public and private sectors in data collection. Clearly, the two have contrasting interests in collecting different types of information.

Table 17. Public and Private Priorities in Traffic Data Collection

Private Sector Priorities	Public Sector Priorities
1. Traffic Speeds and Travel Times	1. Current and Scheduled Work Zones
2. Incidents	2. Incidents
3. Road Conditions	3. Road Conditions
4. Current and Scheduled Work Zones	4. Emergency Routes and Procedures
5. Weather Conditions	5. Weather Conditions

Note: Priorities range from 1 - most important, to 5 - least important.

Source: ITS America and US DOT¹⁹⁹

The same report issued by ITS America and the U.S. DOT also generated the following list of questions when considering traffic data sharing between the public and private sectors.

- Which data are to be made available (e.g., raw/processed, fine grain/aggregated, some/all, etc.)?
- How will the data be accessed (e.g., process and technology)?
- To whom will the data be made available (e.g., general public, registered ISPs/media, etc.)?
- How often will the data be accessed (e.g., continuous feed, periodic “subscription,” etc.)?
- Is there a cost to provide access, and is there an appropriate cost recovery mechanism (if required)?
- Are there any system or privacy security issues?
- How will they be handled?
- Are there to be assurances (or caveats) to users regarding accuracy, reliability or availability?
- Should there be “performance” or data integrity requirements to ensure that the data are “properly” used?
- Is there any liability for use of the data, or relief from such liability?
- How would archived data be made available to interested public and private parties?²⁰⁰

When deploying ITS, there are clearly issues to be addressed in both obtaining and using the necessary data. While the specific questions will be different for each type of technology, they all require planning for securing, processing, and distributing data. Without planning, there may be problems achieving the desired benefits and working cooperatively within the established regional architecture.

¹⁹⁹ ITS America and the US DOT. "Closing the Data Gap: Guidelines for Quality ATIS Data." Sept 2000.

²⁰⁰ Ibid.

5.6.2 STANDARDS

Without standards, every appliance would have a different electric plug, every recording would require a different player, and every camera would use a different type of film. Standards have an important role in intelligent transportation systems just like other types of technology. ITS standards provide a guideline for how components interconnect and communicate with one another. They also define reliability and performance characteristics. These standards apply to all phases of ITS deployment, including design, interface, frameworks, performance, testing methodology, and terminology.

Richard Weiland, a consultant on ITS standards, states that standards can arise one of three ways – through de facto, regulatory, and consensus means. De facto standards arise from market forces and dominating firms, such as Microsoft's Windows operating system dominating UNIX and other operating systems, and VHS recordings dominating Beta. Regulatory standards arise from public agencies, such as regulations governing emissions and food handling. Consensus standards are voluntary agreements formed by industry, government, users, and Standards Development Organizations (SDOs). The emerging ITS standards are largely of the consensus type²⁰¹.

Examples of technology aspects that require standards include map databases, ATIS, electronic toll collection, and Dedicated Short Range Communications (DSRC). Map databases, for example, should be standardized so that every kind of navigation assistance device can access all types of databases. The terminology (data dictionary) in ATIS should be standardized so that people understand the measurements and directions that the information system provides. Electronic toll collection transponders should be standardized, or else drivers need to have a different transponder for different toll roads. This has occurred in many regions, particularly transitional countries, and requires a costly retrofit of existing systems.

Regions need to consider standards when deploying ITS. Without standards, the transportation technology system will be a conglomeration of components designed for different applications and with different specifications. This reduces the potential benefits of the deployment, since users are less inclined to adopt inconsistent and/or confusing technology. The lack of standards also hurts the development of a coherent and large user market.

In the United States, Congress has allocated responsibility for setting national standards to the US DOT through the Transportation Equity Act for the 21st Century (TEA-21) legislation. It is expected that over 100 standards will need to be defined²⁰².

Organizations participating in the process include AASHTO (American Association of State Highway and Transportation Officials), ANSI (American National Standards Institute), ASTM (American Society for Testing and Materials), IEEE (Institute of Electrical and Electronics Engineers), ITE (Institute of Transportation Engineers),

²⁰¹ Weiland, Richard. "ITS Standards – An Overview." PowerPoint presentation prepared for HRI/ITS Standards Workshop. 22-23 Jul 1999.

²⁰² US DOT. Federal Highway Administration. "Intelligent Transportation Systems – Critical Standards." Jun 1999. 11 Dec 2002 <http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_pr/49701!.pdf>.

NEMA (National Electrical Manufacturers Association), and SAE (Society of Automotive Engineers).

ITS standards are not to be confused with the National ITS Architecture created by the US DOT and ITS America. The National ITS Architecture describes the interfaces between ITS systems and subsystems, and does not specify technology. In contrast, consensus standards fit into the architecture by ensuring the interoperability of ITS components that together comprise the master plan²⁰³.

Internationally, countries are working together under the umbrella of the International Organization for Standardization (ISO). The two most relevant Technical Committees for ITS are ISO/TC 22 (in-vehicle transport information and control systems) and ISO/TC 204 (transport information and control systems). While the focus for standards has so far been national, the issue of international standardization will become more relevant as ITS becomes more widely deployed.

5.6.3 TRAINING

Intelligent transportation systems are technologically advanced networks of hardware and software. Both the users and the people responsible for ITS maintenance must be properly trained in order to keep the systems operational.

As early as 1993, the lack of technical expertise was seen as a key barrier to ITS implementation at the local level²⁰⁴. Professor Joseph Sussman at the Massachusetts Institute of Technology argued in 1996 that even technical expertise is not enough to achieve organizational readiness. To achieve organizational readiness for ITS, agencies must develop and acquire staff trained in communications and information systems, as well as traditional knowledge of infrastructure maintenance²⁰⁵. Organizational readiness requires an intermodal, integrated, and customer-centered approach to ITS deployment.

Governments and public agencies have taken a number of steps to address this problem. For transitional countries in particular, the demand for citizens with technical training extends far beyond ITS. One approach has therefore been to establish technical universities and information-based training programs for students still in school. Malaysia, for example, has established the Malaysia University of Science and Technology to develop a generation of technically skilled citizens in order to achieve their goal of a knowledge-based economy.

Many governments have also initiated training programs to educate and promote ITS to transportation professionals. The ITS Joint Program Office in the U.S. offers extensive distance learning courses, as well as provides comprehensive catalogs for courses taught

²⁰³ US DOT ITS Standards Home Page. 2002. US DOT. 11 Dec 2002 <<http://www.its-standards.net/>>.

²⁰⁴ Rowe, Edwin, "Operations and Maintenance: Achilles Heel of IVHS?" *IVHS Review* Fall 1993.

²⁰⁵ Sussman, Joseph. "Beyond Technology - Local Organizational Readiness for ITS." *ITS Quarterly* Summer 1996.

by universities and private sector firms²⁰⁶. A number of non-profit professional societies, such as ITS America and ITS Canada, have been formed to promote ITS. ITS Canada also offers training and links to educational ITS programs²⁰⁷.

Users of ITS technologies sometimes need to be trained as well. Many technologies, particularly intelligent vehicle applications, require a manner of operation that is substantially different from conventional technology. Users of drive-by-wire systems, for example, may eventually have to adapt to video game style controllers and squeeze grips instead of pedals. Drivers of vehicles equipped with collision avoidance systems must be able to understand and react to the signals they provide. Similarly, Minnesota state troopers field-testing a vision enhancement system stated that training would be necessary in order to use the technology²⁰⁸.

Issues of training and organizational readiness are crucial to the prolonged success of ITS deployment. Without the proper usage and maintenance, systems can be unsuccessful or even exacerbate traffic congestion. The maintenance of loop detectors in smart traffic signaling, for example, is key to the success of the system. Agencies wishing to deploy ITS should carefully consider how they plan to acquire and retain talented employees with the technical skills to manage the technology.

5.6.4 PUBLIC EDUCATION

The success or failure of ITS deployment is dependent on the ability of the public to understand and operate within the system. For many technologies, particularly unpopular ones, a public marketing campaign addressing benefits and costs is often necessary. The power of public opinion as discussed above affects the importance of public education as a factor. Where public opinion is important, agencies are more likely to launch education initiatives in order to convince the public of potential benefits.

Automated red light enforcement is one example of ITS that may require a public education effort. Public knowledge of costs and benefits is essential to successful deployment, as well as for the system to work effectively. For these systems, "favorable public opinion and public acceptance have been named most often as the aspect that can 'make or break' an automated enforcement program."²⁰⁹ If the public perceives red light cameras as invasive and/or as revenue machines for the government, then the technology may not be implemented in regions where the power of public opinion is high. If the public understands the safety benefits of enforcement, however, the resistance will be much lower.

²⁰⁶ Professional Capacity Building Program Home Page. US DOT. ITS Joint Program Office. 7 Dec 2002 <<http://www.pcb.its.dot.gov/>>.

²⁰⁷ ITS Canada. "Education/Training." 6 Dec 2002 <<http://www.itscanada.ca/>>.

²⁰⁸ University of Minnesota ITS Institute. "Troopers say new vision technology could make for safer driving." *Sensor* Fall 2001. 7 Dec 2002 <<http://www.its.umn.edu/sensor/2001/fall/ves.html>>.

²⁰⁹ Turner, Shawn and Amy Polk. "Overview of Automated Enforcement in Transportation." *Institute of Transportation Engineers Journal*. Washington, D.C.: Jun 1998.

There are many steps in the planning process where lack of public education can derail the implementation of ITS technology. Without involving the local judiciary in the system design, the courts can strike down enforcement programs. Without involving city councils or state legislators, the enabling legislation may never be passed.

A public education campaign must be designed with the entire ITS system in mind. For red light enforcement, several issues must be addressed. Turner and Polk write:

"Public safety campaigns explain why the state or local government is implementing the program, the traffic safety issues being addressed . . . what advantages automated enforcement has over conventional law enforcement methods, and how ticket revenue will be used. These programs also inform people who receive notices by mail of their options, such as paying the fine by mail, contesting the ticket in court, or identifying another driver who committed the alleged violation."²¹⁰

Increasing public awareness of ITS in general is also important. Since the cost of many intelligent vehicle technologies is borne by the automobile industry and passed on to buyers, the public needs to understand the benefits in order to be willing to pay for ITS features in their vehicles. The same argument is true for costly infrastructure technologies such as an electronic fare payment overhaul for an existing public transportation system. Without awareness of ITS, the public may find it difficult to justify these large public expenditures.

Having developed this framework for ITS deployment, the next two chapters apply the framework to two actual cities – Singapore and Kuala Lumpur. Singapore is studied because of its advanced and extensive ITS deployments. The nation is often cited as the paradigm for ITS. Kuala Lumpur, another Asian city, is in the beginning stages of deploying ITS. These two cities create an interesting contrast and illustrate how the framework can be applied to different situations.

²¹⁰ Ibid.

CHAPTER SIX: ITS DEPLOYMENT IN SINGAPORE

Singapore is an interesting case study for ITS because it has a large number of technologies already in place. The country's electronic road pricing system is one of the few successful ERP projects in the world. This chapter explores Singapore's institutional processes for deploying intelligent transportation systems, within the context of the framework described in Chapter Five and repeated here below.

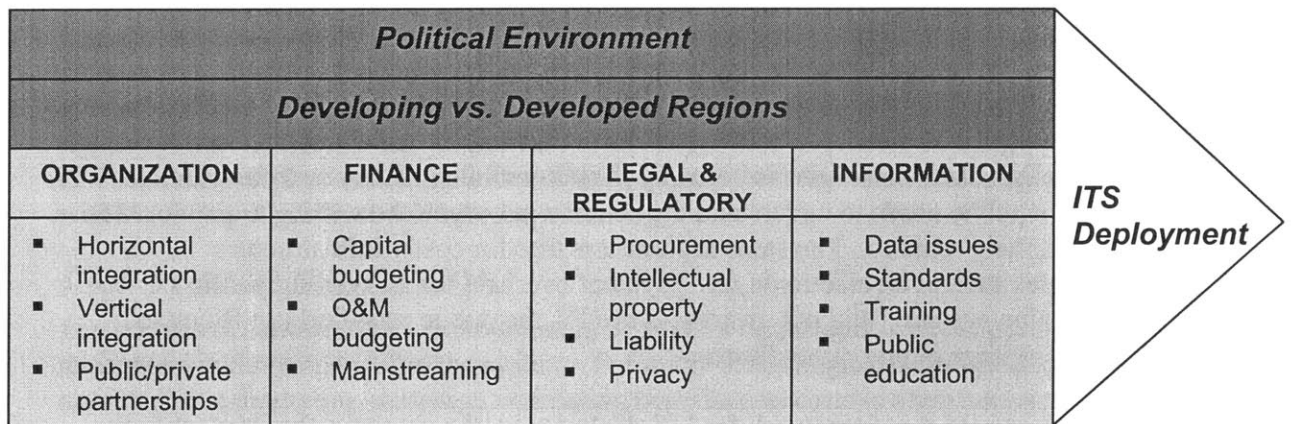


Figure 15. Framework for Analysis

6.1 BACKGROUND

The country of Singapore is comprised of the main island of Singapore and around sixty smaller islands at the southern end of Asia as shown in Figure 16. Map of Singapore Its position just south of Malaysia and adjacent to Indonesia gives the small country a strategic position on major trade routes. Though only 266 square miles in area, and possessing no natural resources except for a deep harbor, Singapore's strategic geographic location has enabled it to become one of the world's busiest ports.



Figure 16. Map of Singapore

Source: Lonely Planet²¹¹

The population of Singapore (as of July 2002) is approximately 4.45 million people. Of these, roughly three-quarters are ethnic Chinese, with the remainder composed of Malays and Indians²¹². Singapore existed as a British trading colony until 1959. It joined Malaysia in 1963, but withdrew again in 1965. Despite these origins as a Third World country, Singapore's economy has grown approximately 8% annually since 1960, except during the Asian financial crisis of the late 1990's²¹³. As a result, Singapore in 2001 had a GDP per capita of \$24,700 USD, one of the highest in the world. The economy is heavily dependent on exports, particularly electronics and manufacturing, and relies primarily on its seaport.

In 1975, Singapore found itself facing enormous problems of traffic congestion, air pollution, and land availability. Over half of workers were commuting by car, about 10% of the country was already paved over, and traffic speeds were unacceptably slow²¹⁴. The government's solution was three-fold: building more road capacity, instituting strict environmental standards, and implementing transportation policies. In the context of this

²¹¹ LonelyPlanet.com. Singapore Map. 20 Feb 2003

<http://www.lonelyplanet.com/mapshells/south_east_asia/singapore/singapore.htm>.

²¹² Central Intelligence Agency. *The World Factbook 2002: Singapore*. 9 Dec 2002. 20 Feb 2003

<<http://www.cia.gov/cia/publications/factbook/geos/sn.html>>.

²¹³ As cited in Cheatham, Benjamin. "Sustainable Urban Transportation in Developing Mega-Cities: A Review of Policies, Regulations, and Technologies." Master's Thesis. Cambridge, MA: Massachusetts Institute of Technology, Feb 2002.

²¹⁴ Baum, Dan. "The ultimate jam session." *Wired* 8 Feb 2002. 24 Jan 2003 <<http://www.drivers.com/cgi-bin/go.cgi?type=ART&id=000000503&static=1>>.

chapter, only the transportation policies will be discussed in light of their impacts on ITS in Singapore.

To manage the number of cars, Singapore instituted the Vehicle Quota System (VQS), which limits the number of vehicles sold each year. The annual quota is determined by road capacity, traffic conditions, and the rate which old vehicles are taken off the roads. Buyers are selected through a public bidding system. Though not an ITS scheme, the Vehicle Quota System is an important transportation policy in controlling congestion.

To further discourage driving, Singapore implemented the Area Licensing Scheme (ALS). In 1975, Singapore defined a restricted area within its central business district (CBD) in which drivers would be charged for entering. All vehicles were required to display a valid license. The system was enforced by traffic personnel stationed at the entrances to the restricted area, which would record the identifying information of vehicles without the ALS license. Violators would then be sent a ticket in the mail²¹⁵. The ALS was designed to discourage unnecessary trips, increase carpooling, and promote public transportation. These objectives were largely successful; from 1975 to 1989, the number of vehicles in Singapore increased by 77%, but traffic within the CBD decreased by 70%. During this time, the percentage of Singaporeans commuting by public transit increased from 33% to 69%²¹⁶.

The ALS was the basis for one of Singapore's most notable ITS deployments: the electronic road pricing (ERP) system. The problem with the ALS was that it required hundreds of human inspectors to manually enforce the restriction zone. Since April 1998, Singapore has begun automating the system using ERP. Payment is deducted from refillable smart cards, inserted into dashboard units, when vehicles pass underneath an overhead gantry. The actual charge is based on the time of day and the vehicle's emissions profile.

Providing feasible alternatives to private vehicles was crucial in deploying ALS and ERP. Singapore's public transportation system is efficient, comfortable, and accessible. Both heavy rail (referred to in Singapore as mass rail) and light rail systems exist throughout the island. These are operated by the Singapore Mass Rail Transit Corporation and its wholly owned subsidiary, the Singapore Light Rail Transit Corporation. The rapid transit systems are fed by three private bus operators, Singapore Bus Services (SBS), Trans-Island Bus Services (TIBS), and Singapore Shuttle Services (SSS). The integration of routes and fares is handled by the government and TransitLink, a private sector partnership described in Section 6.4.1 below.

Besides ERP, Singapore has instituted a wide range of ITS technologies. Many share the same sensing infrastructure embedded into all of Singapore's expressways. In Singapore,

²¹⁵ Zen, Tony. "Hints to Successful Implementation of Electronic Road Pricing System." Hong Kong: ITS Hong Kong, 2000.

²¹⁶ Gomez-Ibanez, Jose A. and Kenneth A. Small. "Road Pricing for Congestion Management: a Survey of International Practice. NCHRP Synthesis of Highway Practice 210." Washington, DC: National Academy Press, 1994.

optical sensors are mounted on lampposts every 500 meters, and a video camera records images every kilometer. The following lists Singapore's major ITS deployments.

- **Electronic Road Pricing** (detailed above)
- **Incident Management:** Singapore's system is called the Expressway Monitoring and Advisory System (EMAS). Besides the sensors and cameras, EMAS uses variable message signs, traffic directing signs, and estimated time travel displays to manage the expressways. There is also an internal recovery crew that can be dispatched to handle incidents. EMAS communicates with the police, media, and towing services as well.
- **Smart Traffic Signal Control:** Since 1988, all of Singapore's traffic signals on arterials roads have been controlled by a SCATS-based system called Green Link DEtermining (GLIDE). Traffic data is measured by magnetic loops in the roadway. A central computer optimizes the signal timing. GLIDE also allows for emergency vehicle signal priority.
- **Junction Electronic Eyes (J-Eyes):** The counterpart of EMAS on non-expressways, J-Eyes consists of surveillance cameras mounted at major intersections. Operators watching the video images can intervene to avoid congestion-causing situations such as illegal parking.
- **Automatic Vehicle Location/Traffic Probes:** Singapore's TrafficScan system probes the country's taxi fleet for vehicle speeds and locations using the fleet's existing GPS system. The GPS was originally used for booking and dispatching services. Traffic conditions are then estimated from the speeds of the taxis and given to the public. Prior to Singapore's traffic.smart system (see below), TrafficScan also integrated and disseminated information from EMAS, the Road Information Management System (RIMS), and J-Eyes. RIMS is an information management system used internally at Singapore's Land Transport Authority.
- **Advanced Traveler Information Systems:** Singapore has linked all of its ITS systems into traffic.smart, a one-stop web page designed to deliver all relevant traffic information to travelers. The site features real-time camera images, estimated travel times, lists of construction areas, road projects, and current incidents. Traffic.smart includes information from the ERP, EMAS, GLIDE, TrafficScan, and RIMS systems.
- **Electronic Fare Payment:** Fares for heavy rail, light rail, and the buses can now be paid using ez-link, Singapore's new contact-less smart card. Using ez-link offers a discount over the cash system, and fully replaced the magnetic swipe system in December, 2002. The ez-link card also offers seamless transfers between public transit services.

- **Automated Passenger Pre-Trip Information:** Similar to traffic.smart, Singapore's transit.smart web page is a one-stop resource for public transit information. In addition to providing travel information, the site can also suggest public transit routes given origin and destination addresses.

Singapore has clearly deployed a wide array of advanced ITS technologies. The rest of this chapter looks at the institutional arrangement supporting these deployments.

6.2 POLITICAL ENVIRONMENT

Singapore was originally a British trading colony and became independent in 1959. The small country joined the Federation of Malaysia in 1963, but withdrew in August 1965 to become independent once again. Since then, the government has exerted strong control over its citizens. Formally, the government is structured as a parliamentary republic system, though political dissent in the media and judicial systems is not allowed.

Elected officials are insulated from public opinion by a variety of factors, including lengthy terms, low turnover, and public acceptance of government behavior regulations. The president of Singapore is elected to a six-year term and members of the unicameral Parliament are elected to five-year terms, both of which are lengthy enough to bring about real legislative change. The parliament is dominated by the People's Action Party (PAP), which enjoys tremendous popularity and currently holds 82 of the 84 elected seats. This single-party dominance provides reasonable assurance to PAP legislators that they can act more independently from their constituents, since their chances for reelection are safer than they would be under a competitive party model. Finally, citizens in Singapore are accustomed to having their behavior regulated by the government. Since Singaporeans are used to tolerating unpopular programs, elected officials have freer rein to deploy ITS projects. These factors result in weak power for public opinion.

The Singapore government, in addition to implementing socially beneficial policies without regard to popularity, has a tradition of regulating the behavior of its citizens. This tradition is the vision of Lee Kuan Yew, the man who led Singapore to independence and served as prime minister for thirty years. In exchange for becoming an economic powerhouse, Lee demanded law and order from Singaporeans in all aspects of daily life. For example, chewing gum is banned, and there are massive fines for littering, graffiti, and jaywalking. The restriction on smoking in public places is strictly enforced, and the government imposes the death penalty on those convicted of drug trafficking. In a similar manner, citizens are accustomed to severe government regulations on driving. The vehicle quota and road pricing systems are merely extensions of the government's policies on controlling the behavior of its citizens. Political dissent is not tolerated.

ITS deployments in Singapore are further aided by a strong political commitment to both information technology and managed development. IT is emphasized throughout the schooling process in order to produce skilled workers that are capable of supporting Singapore's strong electronics industry. Since 1980, the government has championed computerization and information technology. A series of IT plans, starting with the 1980

National Computerisation Plan, is shown below in Figure 17. Singapore IT Plans since 1980

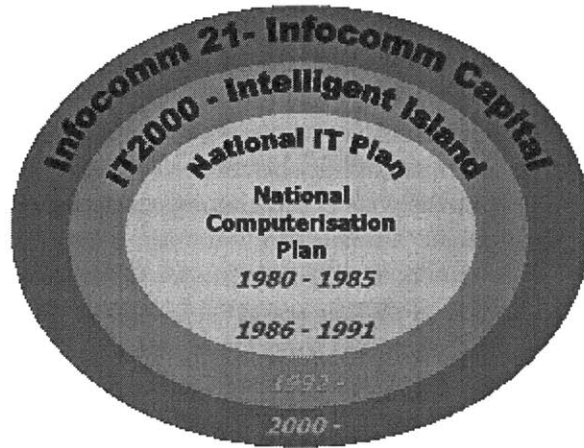


Figure 17. Singapore IT Plans since 1980

Source: Singapore Government²¹⁷

In one of the more recent initiatives, the government aims to become an “e-Government” to better support citizens and businesses in a digital economy. One result has been the creation of an “e-Citizen” portal through which Singaporeans can easily access government services online. Through IT, the government is discovering new tools to enable more efficient processes, using the strategic framework presented in Figure 18.

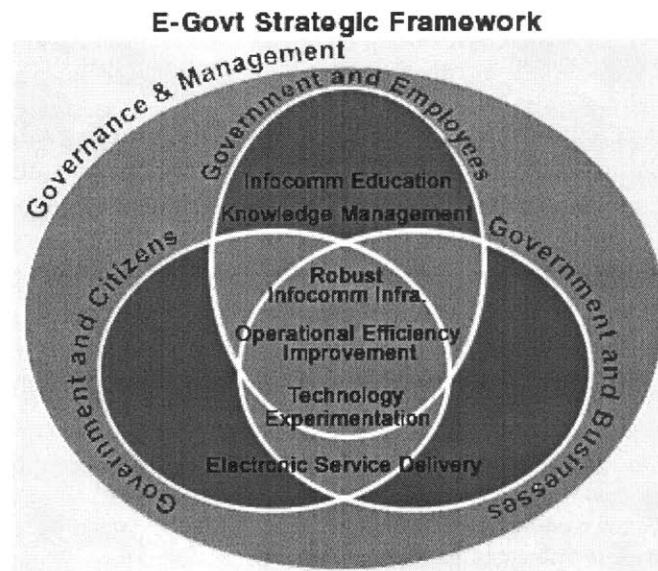


Figure 18. Singapore E-Government Framework

²¹⁷ e-Government Home Page. Government of Singapore. Ministry of Finance and InfoComm Development Authority. 24 Jan 2003 <<http://www.egov.gov.sg/>>.

Source: Singapore Government²¹⁸

Because of Singapore's extremely limited land availability, the country has faced the necessity of managed development for several decades. As a result, the government is highly committed to sustainable growth coupled with careful land use planning. In the government's view, ITS has been an effective strategy to generate maximum road capacity with limited expansion of road infrastructure. Today, the government has wired all freeways and many arterial roads with ITS technologies, to create a single networked system that controls congestion and limits traffic volume.

6.3 DEVELOPING VS. DEVELOPED REGIONS

Singapore's meteoric rise from poverty to wealth in forty years has resulted in a highly developed economy and infrastructure. ITS deployments have been aided by an extensive physical infrastructure base, as well as a highly skilled workforce. At the same time, Singapore has managed to avoid many of the transportation problems common to developed regions.

In addition to the country's extensive road, rail, and public transit infrastructure, Singapore also has a strong telecommunications infrastructure. Singapore Telecom, the nation's leading communications company, has developed an advanced telecommunications infrastructure for voice, data, and wireless applications. Besides physical and telecommunications infrastructure, ITS deployments are aided by a large electronics industry that accounts for over half of Singapore's manufacturing output²¹⁹. This electronics industry helps produce the extensive sensing and communications equipment necessary for many ITS technologies. To support this industry, Singapore also has the benefit of a highly skilled workforce capable of installing and maintaining intelligent transportation systems.

Unlike other developed nations, Singapore has avoided the problem of high motorization among its population. In 2002, for example, there was only one private car or motorcycle per 8 people²²⁰. This situation is the result of strict government management for both the supply and demand of private vehicles. On the supply side, Singapore requires citizens to bid for a limited number of license plate numbers under the Vehicle Quota System. Prices for these numbers, or "certificates of entitlements," are expensive because of the scarcity of COEs. In the February 2003 bidding, COEs for the smallest vehicles sold for approximately \$17,750 USD²²¹. On the demand side, Singapore has implemented road

²¹⁸ Ibid.

²¹⁹ Government of Singapore. Employment Town. "Industry Spotlight: Electronics." 10 Feb 2003 <<http://www.employmenttown.gov.sg/ecareer/solutioncontent/1,1380,15,00.html>>.

²²⁰ Population data from: Government of Singapore. Department of Statistics. "Population (Mid-Year Estimates)." 23 Dec 2002. 10 Feb 2003 <<http://www.singstat.gov.sg/keystats/hist/population.html>>. Vehicle data from: Singapore Ministry of Transport. Land Transport Authority, Vehicle Registration and Licensing. "Annual Vehicle Statistics 2002." 10 Feb 2003 <http://www.lta.gov.sg/3_Vehicles/9_Facts.htm>.

²²¹ Singapore Ministry of Transport. Land Transport Authority. "Results of February 2003 First Open Bidding Exercise for Certificates of Entitlement." 6 Feb 2003. 10 Feb 2003 <http://app.internet.gov.sg/scripts/lta/3_press_content.asp?start=672>.

taxes and road pricing to raise the cost of driving significantly. No cars are manufactured on the island; drivers must pay a 140% registration fee plus 31% import duty on the price of the car. Total fees nearly quadruple the market price of vehicles.

Singapore's population, as a result, has become dependent on public transit. The nation's clean, efficient, and accessible public transportation infrastructure provides mobility without the private automobile. By making investments in their heavy rail, light rail, and bus systems, Singapore has also seen no need to develop a national automobile industry. In fact, avoiding the automobile industry has perhaps allowed the growth of Singapore's high-tech industry by channeling capital and human resources to another path, electronics and manufacturing. Without falling back on a domestic automobile industry, Singapore has chosen the technology industry as a means to becoming a developed nation.

Singapore, as a developed nation, has every economic advantage in deploying ITS. The country has a workforce capable of supporting their enormous electronics industry, and there is already extensive transportation and telecommunications infrastructure in place. Citizens of Singapore also have strong incentives to use public transportation instead of private vehicles, which is anomalous among most developed regions.

6.4 ORGANIZATION

This section examines the institutional issues of organization for ITS deployments in Singapore.

6.4.1 HORIZONTAL INTEGRATION

Singapore has addressed its problems of horizontal integration by simply merging all the relevant agencies into one entity, the Land Transport Authority (LTA). In September, 1995, the LTA was established through the merger of the Registry of Vehicles, the Mass Rapid Transit Corporation, the former Roads & Transportation Division of the Department of Public Works, and the former Land Transport Division of the Ministry of Communications²²². This new agency has control over all land transport initiatives and developments, including ITS deployments.

The LTA has been very successful in the integration of previously separate functions. Their strategies take a systems view of the relationship between public transport, private transport, land use planning, the environment, and technology. Offering public transport allows the LTA to limit automobile use because they can provide a truly feasible alternative. By merging different agencies into one, Singapore has overcome the problems of bureaucracy and fragmentation that occur when implementing interdisciplinary policies like ITS. The LTA's five-point strategy demonstrates their integrated approach to land transport development:

²²² Singapore Ministry of Transport Land Transport Authority Home Page. 10 Feb 2003
<<http://www.lta.gov.sg/>>.

“We have adopted a multi-pronged strategy, comprising:

- Integrated planning
- Expanding the road network
- Harnessing advanced technology
- Demand management
- Improving public transport”²²³

While most transportation issues can be addressed internally within the LTA, it is also necessary for the LTA to interact with other governmental agencies such as the Ministry of the Environment. When this occurs, Singapore has also succeeded in creating a cooperative and integrated relationship. The prime example is the relationship between the LTA and the Public Transport Council (PTC), both housed under the Ministry of Transport. The PTC has regulative authority over bus services and public transit fares. In other countries, this institutional arrangement could create many problems with integrating the bus and rail systems. In Singapore, the LTA and PTC have worked to carefully define each of their roles and responsibilities, as shown in Figure XXX. This has resulted in a collaborative working relationship between the two agencies.

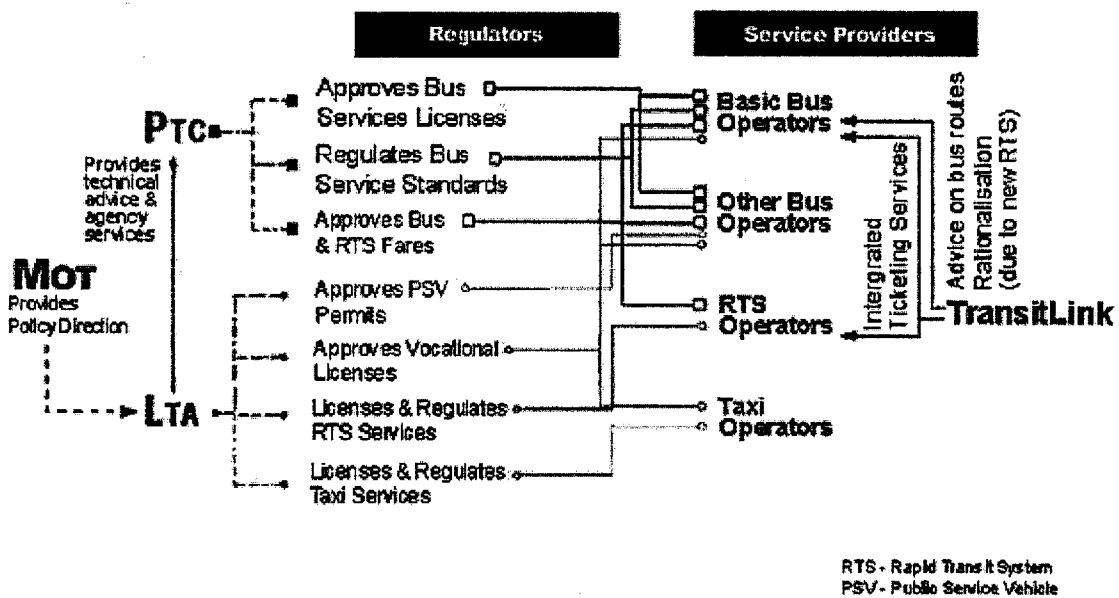


Figure 19. LTA and PTC: Roles and Responsibilities

Source: Public Transport Council²²⁴

²²³ Ibid.

²²⁴ Singapore Ministry of Transport. Public Transport Council. “How We Work.” 10 Feb 2003 <<http://www.ptc.gov.sg/howwework.html>>.

With respect to problems with regional integration, Singapore has benefited from being an island. Although it is connected by a causeway to Malaysia, Singapore has largely been spared from integrating its transit infrastructure into neighboring jurisdictions.

The horizontal integration exhibited by the government has also extended into the private sector. The three major bus and rail operators (SMRT, SBS Transit, and TIBS) have set up a service company called TransitLink to integrate public transport. TransitLink's mission is to achieve integrated ticketing, information, and route networks²²⁵. The company has been successful by implementing the ez-link smart card, publishing an annual integrated information booklet, and taking charge of route planning and coordination. TransitLink is the private sector counterpart of the LTA by merging transportation functions into one entity, thus overcoming issues of horizontal integration.

6.4.2 VERTICAL INTEGRATION

The problems of vertical integration are not applicable to Singapore because the country is essentially a city-state with only one layer of government. Because the functions of local, state, and national governments are collapsed into a single entity, Singapore has avoided the organizational issues associated with vertical integration.

6.4.3 PUBLIC/PRIVATE PARTNERSHIPS

Singapore's use of public/private partnerships has been successful. For transportation, the government has retained tight control while allowing private companies to operate taxi, bus, light rail, and heavy rail lines. With ITS deployments, the government has largely paid all of the capital costs. Though Singapore uses the contracted operations model for many of its transportation privatizations, it has managed to reserve much of its authority by working closely with its partners.

For example, the Singapore government maintains a close relationship with the heavy rail operator, the Singapore Mass Rail Transit Corporation (SMRT). The LTA retains regulatory control, while leasing the system under a License and Operating Agreement (LOA) to SMRT. The current LOA took effect in 1998 and is valid for thirty years²²⁶. The LTA and PTC retain control over pricing, routes, and other components of the system. For example, SMRT is required to meet the following list of performance standards set forth by the LTA in 1997.

- At least 94% of trains arrive within 2 minutes of schedule
- At least 96% of trains depart within 2 minutes of schedule
- Train service availability will be at least 98%
- No more than 6.7 failures for every 100,000 uses of ticket vending machines
- No more than 5 failures for every 100,000 uses of ticket gates
- No more than 200 hours downtime for every 100,000 hours of escalator operation

²²⁵ TransitLink Home Page. 10 Feb 2003 <<http://202.40.224.178/>>.

²²⁶ Singapore Mass Rail Transit Corporation Home Page. 2002. 11 Feb 2003 <<http://www.smrtcorp.com/smrt/>>.

- No more than 1 failure for every 1,500 station stops for the train signaling system (51 stations total)²²⁷

At the same time, SMRT's mission statement includes securing "reasonable returns for its shareholders"²²⁸. The most recent publicly available financial statements show SMRT earning an annual profit of \$50 million USD, as well as distributing a generous 8% dividend²²⁹.

Singapore's contracted operations model has been beneficial for both parties due to the government's support of the private companies. Thanks to government policies discouraging vehicle use and promoting public transportation, private companies like SMRT have been able to turn profits. At the same time, the government does not need to oversee the day-to-day operations of its transportation operators. The public/private partnership is valuable to both.

6.5 FINANCE

Singapore's institutional process for financing ITS projects is analyzed in this section. Capital budgeting, O&M budgeting, and mainstreaming is examined within the framework developed in Chapter Five.

6.5.1 CAPITAL BUDGETING

The Singapore government most often pays the capital cost for ITS and transportation projects around the country. In their strictly regulated form of government, it makes sense for the government to retain control of systems financing. If the private sector were to pay for transportation systems, then the government would lose some of its authority over the infrastructure. This could hinder the integrated land-use, transportation, and environmental planning currently practiced by the LTA.

Singapore's financial situation is supportive of transportation and ITS projects. In the fiscal year 2002 (ending March 31st, 2003), the government allocated \$929 million USD for transportation, or 5.76% of Singapore's total budget. Of this, \$696 million USD was earmarked for capital development projects²³⁰. The allocation for capital projects provides dedicated funds for possible ITS deployments. As a result, the LTA was able to spend \$140M USD in the late 1990's to implement ERP, and \$11.6M USD in the late 1980's for GLIDE, in addition to developing extensive rail and road networks for public transit.

Since ITS projects are dependent on government financing, it is also important to look at Singapore's financial history. Figure 20 depicts the government's deficits and surpluses

²²⁷ Ibid.

²²⁸ Ibid.

²²⁹ Singapore Mass Rail Transit Corporation. "Financial Report 1999." 8 Jul 1999. 11 Feb 2003 <http://www.smrtcorp.com/smrt/index_financial.htm>.

²³⁰ Singapore Ministry of Finance. "Summary of FY2002 Budget: Total Expenditure." 2003. 12 Feb 2003 <http://www.mof.gov.sg/budget/budget_2002/gov_exp/gov_exp_ex_tot.html>.

since FY1996. The many surpluses show Singapore’s financial strength, and provide assurance of available resources for transportation.

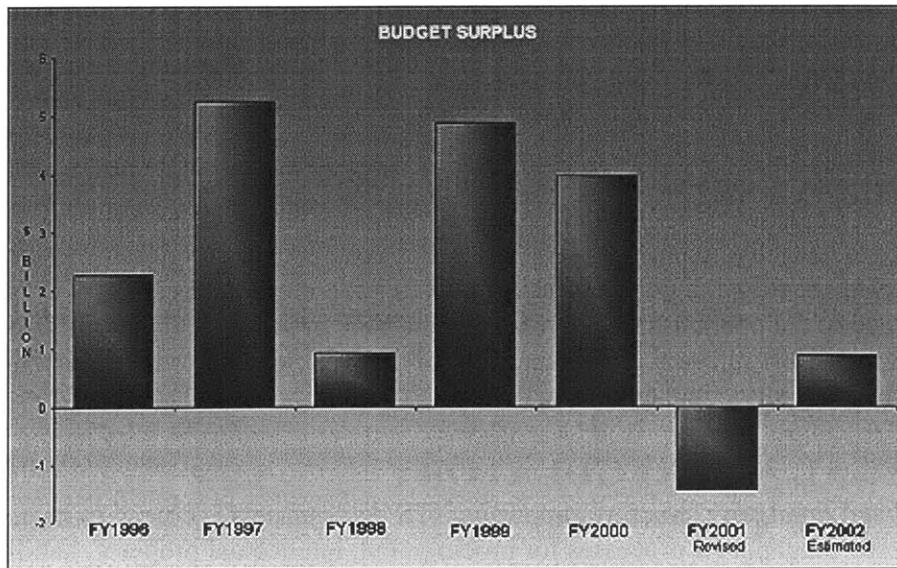


Figure 20. Singapore Budget Surpluses, FY1996-2002

Source: Singapore Ministry of Finance²³¹

6.5.2 O&M BUDGETING

Unlike capital budgeting, Singapore uses a variety of methods to finance the operations and maintenance of its ITS and transportation systems. The government does maintain many of its own systems. For example, \$234 million USD in FY2002 was allocated for operations and maintenance in transport²³². However, the government also allows the private sector to maintain systems through licensing operations as described in Section 6.4.3. In the cases of the public heavy rail and light rail systems, the SMRT Corporation is responsible for O&M funding.

Financially, Singapore is also aided by its use of revenue-generating transportation policies. Both ERP and ETC are ITS deployments that result in the collection of fees from the public. These fees are reinvested in the transportation sector. In addition, the government receives funds from the auction of COEs and charges taxes on all vehicles. While this makes driving very expensive, citizens have not complained to the government, perhaps because of both the political structure and the policies’ beneficial effect on traffic congestion.

²³¹ Singapore Ministry of Finance. “Summary of FY2002 Budget: Budget Surplus.” 2003. 12 Feb 2003 <http://www.mof.gov.sg/budget/budget_2002/gov_exp/gov_exp_bud_sur.html>.

²³² Singapore Ministry of Finance. “Summary of FY2002 Budget: Total Expenditure.” 2003. 12 Feb 2003 <http://www.mof.gov.sg/budget/budget_2002/gov_exp/gov_exp_ex_tot.html>.

6.5.3 MAINSTREAMING

Because of Singapore's limited land space, the government years ago recognized the need for ITS as an alternative to building physical road capacity. ITS is now fully mainstreamed into the LTA's planning process as demonstrated in their five-prong approach to planning: integrated planning, expanding the road network, harnessing advanced technology, demand management, and improving public transport.

An example was Singapore's decision to convert from the ALS system to ERP technology. Aside from the labor issue, the government believed that ERP could improve road capacity, due to its better reliability and operational effectiveness compared to the ALS. In reality, the government decided to issue more COEs in 2001 as "a direct consequence of the operation effectiveness of the ERP system."²³³ The switch to the ERP system in 2001 allowed a 1% expansion of the vehicle population while maintaining the same level of service on the roads.

6.6 LEGAL AND REGULATORY

The legal and regulatory structure supporting ITS deployments is crucial to its acceptance and success. Singapore's processes for procurement, intellectual property, liability, and privacy are examined in this section.

6.6.1 PROCUREMENT

Singapore's government procurement policies are flexible and account for the specific needs of ITS projects. On a general level, Singapore awards "the bid that brings best value for money for the public sector, taking a holistic approach," and claims to remain committed to the "fundamental principles of fairness, openness, and competitiveness"²³⁴. This holistic approach is very important for ITS deployments, since it takes into account the quality of vendors.

Recognizing that procurement needs vary across the government, Singapore has decentralized procurement to individual departments while meeting central guidelines set by the Ministry of Finance. For contracts above \$50,000 in price, the guidelines allow three types of tenders: open, selected, and limited. These options provide flexibility in procuring ITS services.

- **Open tenders** - Any company may participate.
- **Selected tenders** - Any companies passing a prequalification screen may participate.

²³³ Cheatham, Benjamin. "Sustainable Urban Transportation in Developing Mega-Cities: A Review of Policies, Regulations, and Technologies." Master's Thesis. Cambridge, MA: Massachusetts Institute of Technology, Feb 2002.

²³⁴ Singapore Ministry of Finance. "Singapore Summary Information on Government Procurement." 13 Feb 2003 <<http://160.96.179.95/gitis/regime.html>>.

- **Limited tenders** - Only invited companies may submit bids. Limited tenders must be approved by the Secretary of the Ministry or CEO of the statutory board²³⁵.

To further address the specific needs of construction-related procurement, Singapore has separated construction goods and services from general procurement. While most procurement activities are handled through the Expenditure and Procurement Policies Unit (EPPU) of the Ministry of Finance, construction procurement is addressed by the separate Building and Construction Authority (BCA). The BCA only handles construction-related tenders, allowing it to better apply procurement policies to a particular project.

Finally, Singapore promotes openness in procurement by conducting all procurement activities through the Internet. The Singapore Government Internet Tendering Information System (GITIS) posts information, tender notices, awards, qualification, and registration procedures. As a central repository, GITIS allows businesses to bid in an easy, efficient process. For projects of all types, GITIS ensures a fair and open competition.

The Singapore government's methods of procurement support ITS and transportation projects. By permitting use of both prequalification and limited tenders, officials can be satisfied as to the quality of their contractors. The separate BCA, handling all construction-related procurement, allows for even more flexibility in meeting the specifications of ITS deployments. Through GITIS, the government makes the bidding process accessible to all who are interested.

6.6.2 INTELLECTUAL PROPERTY

Singapore has created a strong regulatory framework governing copyrights, trademarks, and patents. Especially with regard to the technologically advanced sectors of its economy, the country has gone to great lengths to protect IP rights in order to attract foreign investment and trade. IP has been a significant issue for many years; as a result, Singapore has already created an extensive legal structure for dealing with intellectual property. Today, the nation has the best level of IP protection in Asia, according to the Political and Economic Risk Consultancy (PERC)²³⁶.

Specifically for the high-tech industry, Singapore has created an IP structure for the layout designs of integrated circuits (IC). Integrated circuits are electronics built into semiconductors, such as silicon wafers. They are found in most electronic products, including those for ITS such as computers and traffic signals. Since 1998, Singapore has allowed circuit designs to be automatically protected for up to 15 years²³⁷. This

²³⁵ Ibid.

²³⁶ Singapore Economic Development Board. "Protecting Intellectual Property Rights in Singapore." 2002. 17 Feb 2003 <<http://www.sedb.com/edbcorp/bizresourceintellectual.jsp>>.

²³⁷ Intellectual Property Office of Singapore. "Information on Intellectual Property: Integrated Circuits." 2001. 17 Feb 2003 <<http://www.ipos.gov.sg/intell/ic.html>>.

framework encourages the private sector in developing and deploying advanced technology.

Finally, Singapore has largely avoided IP disputes with ITS through the structure of its public/private partnerships. By retaining ownership and using licensing to involve the private sector, the government keeps control over the intellectual property associated with the project. However, even if the government decided to use an alternative public/private partnership model, the country's strong IP framework ensures that intellectual property is carefully considered during ITS deployments.

6.6.3 LIABILITY

Unlike highly litigious societies like the United States, Singapore's issues with ITS liability are not as urgent. Although the automobile industry could theoretically face the same lawsuits in Singapore as anywhere else, the structure of Singapore's judicial system discourages liability claims that might arise when accidents occur involving AVCS or other technologies.

Trials in Singapore are decided by a single judge, not by jury. Since the judge is presumably more knowledgeable in law, this system reduces the possibility that persuasive lawyers could engineer an unfair result. Singapore's court system is also considered to have high "credibility and efficiency," with highly expert judges²³⁸. As a result, only legitimate lawsuits are brought to trial. Singapore also offers an alternative Court Dispute Resolution Scheme to help litigants settle their cases outside of the courtroom. This procedure reduces liability claims as well²³⁹. Though the system is often accused of favoring government officials over their political critics in defamation suits, the rest of the court system is considered fair and impartial.

The other strategy that Singapore employs to avoid liability claims is to ensure extremely high reliability of its transportation technology systems. The ERP system used in Singapore has a measured reliability of 99.999%²⁴⁰. This reliability, coupled with a knowledgeable and impartial court system, allows only legitimate liability claimants to emerge.

6.6.4 PRIVACY

With Singapore's extensive network of traffic sensors, payment zones, and video cameras, government officials admit "one could in theory track an individual car as it wanders around Singapore."²⁴¹ Except for data encryption of electronic transmissions, there are few measures to protect the privacy of drivers and pedestrians in Singapore.

²³⁸ International Centre for Commercial Law. "Legal System – Singapore." 18 Feb 2003 <<http://www.legal500.com/as500/edit/si3.htm>>.

²³⁹ Singapore Ministry of Information, Communication, and the Arts. "Singapore Fact Sheet: Law." 18 Feb 2003 <<http://www.mita.gov.sg/bkslaw.htm>>.

²⁴⁰ Zen, Tony. "Hints to Successful Implementation of Electronic Road Pricing System." Hong Kong: ITS Hong Kong, 2000.

²⁴¹ Baum, Dan. "The ultimate jam session." *Wired* 8 Feb 2002. 24 Jan 2003 <<http://www.drivers.com/cgi-bin/go.cgi?type=ART&id=000000503&static=1>>.

This results from a cultural acceptance of the government's authority to interfere in its citizens' personal lives. Government surveillance is commonly used in Singapore to "promote social control and limit domestic opposition."²⁴² In regard to ITS, the government's method of dealing with privacy concerns is to simply ignore them. In 1986, then-Prime Minister Lee Kuan Yew described his privacy policy as:

"I am often accused of interfering in the private lives of citizens. Yet, if I did not, had I not done that, we wouldn't be here today. And I say without the slightest remorse, that we wouldn't be here, we would not have made economic progress, if we had not intervened on very personal matters – who your neighbor is, how you live, the noise you make, how you spit, or what language you use. We decide what is right, never mind what the people think. That's another problem."²⁴³

The legal framework surrounding privacy is ambiguous. While some statutes appear to protect citizens' privacy, others grant the government broad powers of investigation into people's lives, particularly under the Internal Security Act. This Act allows the government to monitor any activities connected to threats to national security. The government has the legal right to search computers without a warrant, seize data and encrypted material, monitor telephone conversations, and police the Internet²⁴⁴. Though citizens in Singapore are accustomed to less privacy than in most other nations, the government has still explicitly addressed the issue from a legal and regulatory standpoint.

Singapore's privacy policy hinges on the fact that citizens accept the government's intentions when monitoring their movements. The ERP system tracks vehicles through video surveillance cameras and SmartTag transmitters. The government claims this data is only kept for 24 hours. Similarly, the EMAS cameras produce video images of major intersections. The government again claims that "we don't abuse the system that way"²⁴⁵ with respect to unauthorized police access and vehicle tracking.

The government has addressed privacy concerns by explicitly dismissing them and trusting that citizens will accept this policy of government intrusion. Singapore has not ignored the issue. It has set up a legal framework to support its actions. Though there appears to be little public outcry over the government's policy, it is conceivable that privacy will become more important in the future. Until then, Singapore's privacy policy is well-planned for the nation and helps support the ITS deployments.

²⁴² Privacy International. "Privacy Report: Republic of Singapore." 1999. 19 Feb 2003 <<http://www.privacyinternational.org/survey/countries-p-end.html#Heading8>>.

²⁴³ As cited in Tremewan, Christopher. *The Political Economy of Social Control in Singapore*. Oxford: St. Martin's Press, 1994.

²⁴⁴ Privacy International. "Privacy Report: Republic of Singapore." 1999. 19 Feb 2003 <<http://www.privacyinternational.org/survey/countries-p-end.html#Heading8>>.

²⁴⁵ Baum, Dan. "The ultimate jam session." *Wired* 8 Feb 2002. 24 Jan 2003 <<http://www.drivers.com/cgi-bin/go.cgi?type=ART&id=000000503&static=1>>.

6.7 INFORMATION

The final step of the institutional analysis is to look at information issues with ITS deployments in Singapore. In this section, the structure around managing data, standards, training, and public education is explored.

6.7.1 DATA ISSUES

Because of Singapore's existing telecommunications infrastructure, the country is physically capable of handling data-intensive ITS applications. Its institutions related to land transport have also been structured so that they are able to process data. In addition, Singapore has maintained complete databases of information necessary for certain ITS deployments.

The LTA, the agency in charge of ITS and transport projects, devotes one of seven divisions entirely to information technology. Data management is an important responsibility of this division²⁴⁶. Both the LTA and the Department of Statistics keep accurate databases of vehicle facts and figures. This information is necessary in determining the proper number of COEs to offer in every bidding cycle, among other purposes. The extensive vehicle registration and licensing procedures ensure that these databases are up-to-date and complete. As a result, they can be used reliably for license plate enforcement purposes.

Singapore has resolved any possible data issues by creating an extensive telecommunications infrastructure, in conjunction with instituting data management processes within the LTA and other relevant agencies. This data is efficiently shared with the proper stakeholders; for example, EMAS video feeds are piped into television and radio stations²⁴⁷. The information contained in Singapore's databases is accurate and can be used for ITS projects. Finally, the institutional structure of the LTA allows the information technology division to handle new data issues as they may arise.

6.7.2 STANDARDS

Singapore, as with most other developed nations, has addressed the issue of standards for ITS and other technologies. The most relevant agency is SPRING Singapore, an acronym for the Standards, Productivity, and Innovation Board. SPRING Singapore is in control of all standards; within the board, however, is a standards body specific to information technology. This body, the Information Technology Standards Committee (ITSC), was formed in 1990 and is comprised of industry partners as well as government officials. By separating out IT and allowing businesses to participate, Singapore has facilitated a standards process that meets specific IT needs and accounts for private sector input. These consensus standards are voluntary, but the government can make them mandatory requirements²⁴⁸.

²⁴⁶ Singapore Ministry of Transport. Land Transport Authority. "Organization Chart." 19 Feb 2003 <<http://www.lta.gov.sg/newsletter/org.pdf>>.

²⁴⁷ Baum, Dan. "The ultimate jam session." *Wired* 8 Feb 2002. 24 Jan 2003 <<http://www.drivers.com/cgi-bin/go.cgi?type=ART&id=000000503&static=1>>.

²⁴⁸ Information Technology Standards Committee Home Page. 8 Jan 2003. 19 Feb 2003 <<http://www.itsc.org.sg/index.htm>>.

For example, the ITSC has developed a smart card standard that can be applied to the LTA's ez-link, Singapore's CashCards, and even security access control cards²⁴⁹. The standards include specifications for both the card readers and the operating protocol embedded in the smart cards. The ITSC's standards keep in consideration the guidelines set by the ISO and other international standards bodies. In the future, Singapore's smart cards can be used in countries adhering to ISO standards.

By deploying many ITS technologies themselves, the government has also maintained a de facto technical standard. The standardization process has been simplified because the private sector is rarely involved in capital decisions and general planning. Since the government has retained broad control of ITS developments, it has been able to implement a cohesive, interoperable, and standardized system.

Singapore's strong electronics and high-tech industries have long necessitated the need for standards. With ITS, the standardization process has been aided by both the separate ITSC standards body as well as the government's top-down deployment model. The ez-link implementation is just one example illustrating how Singapore is capable of handling standards issues.

6.7.3 TRAINING

To support its high-tech manufacturing and services sectors, Singapore requires a steady supply of skilled labor. As such, the government has realized the need to invest in human resources in order to produce generations of technically capable citizens. Even with its heavy investment in training programs and education, Singapore still faces an acute skilled labor shortage.

On the domestic side, Singapore has tried to increase its skilled labor supply through academic support and government programs. Policies over the years include government-subsidized job training, raising the retirement age, and encouraging women to work part-time through flexible employer schedules. The nation also has a wealth of universities devoted to technical subjects, including:

- Nanyang Technological University (Singapore-MIT Alliance)
- National University of Singapore (Singapore-MIT Alliance)
- Singapore Polytechnic
- Nanyang Polytechnic
- Temasek Polytechnic
- Institute of Technical Education

On the foreign side, Singapore has tried to attract skilled labor from other Asian countries like China, Taiwan, and Japan. It is common for foreign engineers to work in Singapore in order to receive more advanced training. However, Singapore's high wages and offers of permanent residency are not enough to retain these foreign workers, who frequently

²⁴⁹ Chua, Hian Hou. "One Card Fits All." *Computer Times* 24 Apr 2002. 19 Feb 2003
<http://www.itsc.org/standards_news/2002-04/2002-04-24-one-card-fits-all.html>.

return to their native countries after a few years. This problem is exacerbated by the growing strength of high-tech industries in other Asian countries besides Singapore²⁵⁰. In addition to creating more difficulty in retaining foreign workers, this situation also makes relocation more attractive for native skilled labor.

The shortage of skilled labor in Singapore is not an easy problem to solve. Though the government has invested heavily in domestic training and tried to attract foreign workers, the skilled labor shortage is pervasive throughout Asia. Workers appear to arrive in Singapore seeking better job opportunities and advanced training, then return to their home countries or go somewhere else. In addition, Singapore faces competition from the government-sponsored recruitment programs in China and other Asian countries.

6.7.4 PUBLIC EDUCATION

As has been emphasized throughout this chapter, public acceptance is not necessary to deploy ITS in Singapore's political environment. The government has flexibility in implementing unpopular programs that it believes to be socially beneficial. The need to win public approval for ITS is therefore much less urgent than in more politically constrained societies like the United States.

At the same time, the Singapore government has taken care to win public approval whenever possible. With public approval, it is much easier to achieve compliance. To increase public support for ERP, for example, the LTA reduced tolls to 30% below the existing ALS fees. This action resulted in a compliance rate of 97% within a year²⁵¹.

6.8 SYNTHESIS

The following table summarizes the analysis conducted above on Singapore's institutional readiness to deploy ITS. It should be noted that the designation of "Adequately planned" indicates that Singapore has considered and addressed the issue, irrelevant of democratic values or principles. For example, Singapore's exclusion of privacy concerns from their deployments is part of a planned strategy, not an accidental omission.

²⁵⁰ Santiago, Tony. "Singapore fabs serve as EE training ground." Electronic Engineering Times 1 Aug 2002.

²⁵¹ Zen, Tony. "Hints to Successful Implementation of Electronic Road Pricing System." Hong Kong: ITS Hong Kong, 2000.

Table 18. Singapore Readiness for ITS Deployment

Category	Subcategory	Adequately planned	Somewhat planned	Unknown/Not planned/NA
<i>Organization</i>	Horizontal Integration	X		
	Vertical Integration			X*
	Public/private partnerships	X		
<i>Finance</i>	Capital budgeting	X		
	O&M budgeting	X		
	Mainstreaming	X		
<i>Legal and Regulatory</i>	Procurement	X		
	Intellectual property	X		
	Liability	X		
	Privacy	X		
<i>Information</i>	Data issues	X		
	Standards	X		
	Training		X	
	Public education	X		

*Not applicable because Singapore does not have state or local governments.

Table 18 clearly demonstrates that Singapore has planned well for institutional readiness in deploying ITS. The only exception, training, is largely due to the heavy competitive forces for skilled labor in Asia. The government, in this case, has tried to address the issue; however, their efforts have been only marginally successful.

Singapore has a number of factors working in its favor for ITS deployment. First, the country is economically advanced despite only a half-century of independence. This factor means that Singapore already has an extensive telecommunications infrastructure, a strong high-tech industry, a supportive legal framework, and a skilled base of human resources. Second, the country is very small. This factor eliminates the need for vertical integration and forces the consideration of land-use planning, transportation, and ITS together in the planning process. Finally, Singapore's culture allows for significant government regulation of citizen behavior. This factor results in political freedom to institute unpopular policies, and ensures citizen compliance.

As a result, the institutional lessons from Singapore's ITS deployments may not be readily transferable to other nations and cities like Kuala Lumpur. Developing countries do not have the same resources as Singapore, larger countries must deal with additional

levels of bureaucracy (and therefore complexity), and countries with greater political freedom have to contend with public acceptance and privacy concerns. Singapore is often referred to as a paradigm for ITS success. However, the analysis presented in this chapter shows that much of this success can be attributed to a combination of factors unique only to Singapore. Though universal lessons can certainly be drawn from the Singapore case study, other countries should be wary of implementing the same strategies ad hoc, without considering the overall framework as applied specifically to their region.

CHAPTER SEVEN: ITS DEPLOYMENT IN KUALA LUMPUR

The purpose of this chapter is to explore Kuala Lumpur’s institutional readiness for deployment of intelligent transportation systems (ITS). KL provides an interesting contrast because unlike Singapore, it has begun ITS deployments but remains a developing country. Using the framework developed in Chapter Five, this chapter assesses the areas of organization, finance, legal & regulatory concerns, and information through the overarching themes of the political environment and stage of economic development. After completing this assessment, several recommendations are made for institutional transformation.

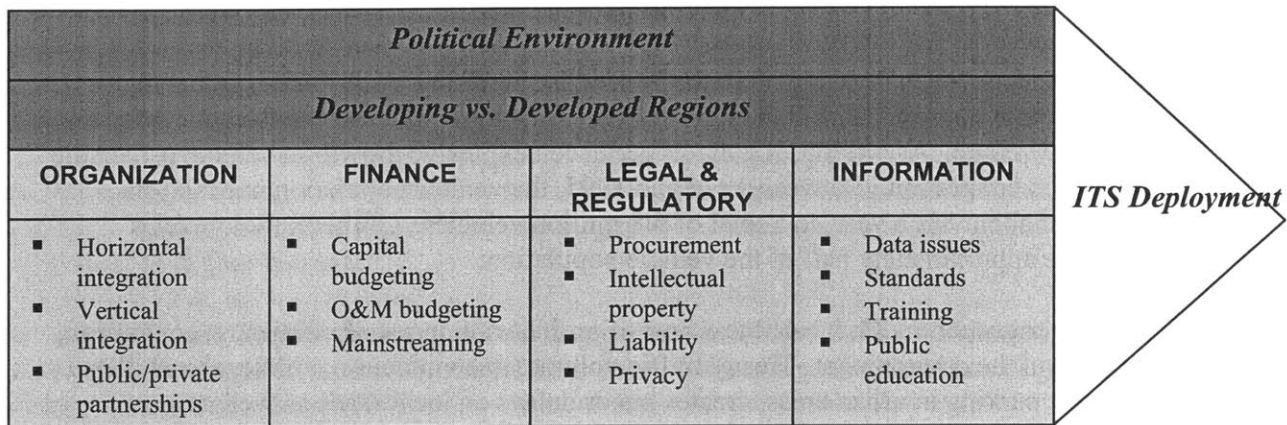


Figure 21. Framework for Analysis

7.1 BACKGROUND

The country of Malaysia is separated by the South China Sea into two parts - West Malaysia, also known as Peninsular Malaysia, and East Malaysia on the island of Borneo as shown below. The total population is 23 million, with 80% of the population on the peninsula. Of the population, about half are Malay and 30% are Chinese, with the remainder composed of Indians and natives.

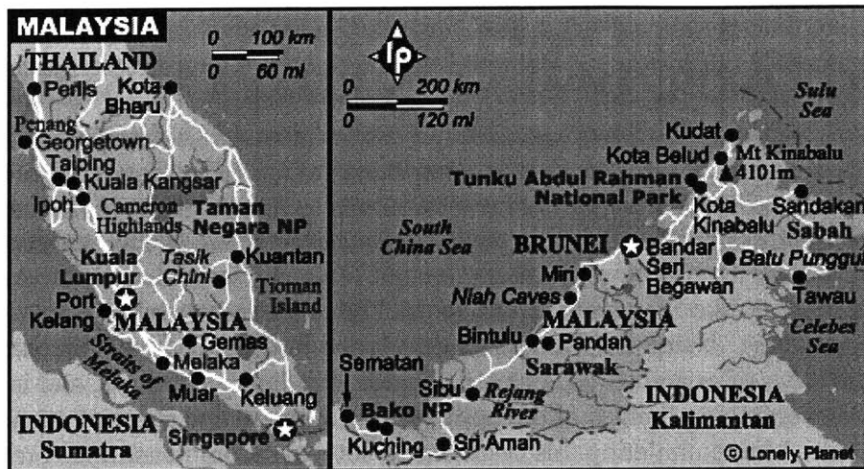


Figure 22. Map of Malaysia

Source: Lonely Planet²⁵²

Kuala Lumpur (KL), the capital city, is located in the Klang Valley and is home to a population of approximately 1.3 million people. Its household income is about twice the national average. As a result, KL has experienced explosive growth in vehicle ownership and traffic congestion. Between 1976 and 1995, the vehicle population in Malaysia increased about 8% a year, to a total of 6.8 million vehicles. Of these, motorcycles comprise approximately half of the vehicle population.

Traffic congestion in KL has led to a host of problems in terms of efficiency, congestion, safety, and the environment. Heavy traffic volume, in conjunction with legal and illegal on-street parking in urban areas, creates major delays on local roads as well as expressways. The mixture of cars, motorcycles, public transport, and commercial vehicles leads to inefficient use of available lanes. In terms of safety, the high number of motorcycles contributes to an annual accident growth rate of 9.5%²⁵³. Because KL has few pedestrian facilities and walkways, pedestrian and motorcyclists comprise about 70% of total accident casualties, though more cars are involved in accidents. Environmentally, vehicle congestion and motorcycles in particular greatly exacerbate the amount of carbon monoxide, hydrocarbon, nitrous oxides, sulfur oxides, and particulate pollution in the air.

An alternative for Malaysians is public transport. Within the last decade, two light rail lines have begun operations in Kuala Lumpur – STAR and Putra. The STAR operating company is backed by a consortium headed by British construction company Taylor Woodrow. Putra is the second longest fully automated (driverless) line and is wholly owned by the Malaysian conglomerate Renong Berhad²⁵⁴. A third rail line, the KL Monorail, is under construction. There is also a high-speed Express Rail Link connecting

²⁵² LonelyPlanet.com. Malaysia Map. 28 Dec 2002

<http://www.lonelyplanet.com/mapshells/south_east_asia/malaysia/malaysia.htm>.

²⁵³ Road Engineering Association of Malaysia. Technical Committee on Intelligent Transportation Systems. "ITS Strategic Plan for Malaysia." Dec 1999.

²⁵⁴ Putra Home Page. 2002. 22 Dec 2002 <<http://www.putralrt.com.my>>.

KL with the new KL International Airport (KLIA) to the south. In addition, there are several bus companies offering local public transport, though these are unreliable due to congestion and poor operating practices. In total, public transport serves only about 20% of all person-trips made in KL and the Klang Valley²⁵⁵. However, the government has been forced to take over STAR, Putra, and the bus companies of Park May and Intrakota due to financial difficulties.

Limited funds for road construction, combined with rapidly growing transportation demand, have led KL and Malaysia to consider ITS solutions. Kuala Lumpur has implemented several ITS technologies. These include:

- **ETC (Electronic Toll Collection System)** - Full-scale operation of ETC began in December 1995. There are several systems in use, but these were supposed to be standardized by Jan 1, 2003 to the Touch'n'Go infrared smart card and the in-vehicle SmartTag transponder. However, this deadline has been deferred, due to operator complaints about the terms and conditions offered by Touch'n'Go.
- **Traffic Information System On Expressways / Highways** - The Malaysian Highway Authority (MHA) has installed rudimentary traffic control and surveillance systems. Components include emergency phones, closed circuit televisions, and a control center. A few of the expressways have variable message signs to disseminate the information. This system is now linked into ITIS (see below).
- **Smart Traffic Control** - Kuala Lumpur has used the SCATS system (originally developed in Australia) since 1993. Some form of signal control has been used since the mid-1970's.
- **City Traffic Information System** - Traffic information is collected by closed circuit TV at several sites in Kuala Lumpur, and disseminated through radio and the Internet. The information is used for surveillance and for the SCATS system. This system is now linked into ITIS (see below).
- **Bus Information Kiosks** - KL implemented six interactive public transport information kiosks in Kuala Lumpur to provide bus information to the public
- **Red Light Enforcement** - Throughout Malaysia, several red light traffic cameras were installed to assist enforcement and reduce accidents.
- **Automatic Vehicle Location** - AVL has been introduced in the private sector, specifically the taxi service at the Kuala Lumpur International Airport (KLIA). By tracking taxis, the operator can dispatch the closest vehicle to a particular

²⁵⁵ Cruickshank, Roger. Senior Transport Consultant, Symonds Group. "Policy Towards Sustainable Transportation." Presented at Malaysia University of Science and Technology Seminar Series on Transportation and Logistics. Petaling Jaya, Malaysia: 26 Mar 2003.

location. However, this system is no longer operational due to operator bankruptcy.

- **Electronic Fare Payment** – Putra light rail and some of the buses accept the Touch'n'Go smart card. These cards can be easily refilled at ATM's, gas stations, and other locations. Touch'n'Go is also accepted in other applications, including parking.

One recent ITS initiative for Kuala Lumpur is the Integrated Transport Information System (ITIS), launched in March 2003. Planned since 1999, ITIS is an advanced traveler information system application that integrates the KL city system with the expressway information system. It brings together KL's previously separate ATMS and ATIS systems, with the federal government bearing all of the cost. The first phase is the creation of an online portal for disseminating travel information relating to expressways and public transit. Automatic Vehicle Location and Automated Incident Management systems are included to gather traffic data. Installation of closed circuit TV and variable message signs will also occur along all major roads in KL. Phase 2 is testing and data gathering. The final phase is centralizing all of these applications in a Transport Management Center that will receive ATMS data and distribute it through ATIS channels including the Internet portal and variable message signs. Wireless capabilities will be added by the middle of 2005²⁵⁶. With this information, drivers can make more informed decisions and avoid heavily congested roads.

A widely discussed possible initiative for Kuala Lumpur is the Public Transport Integration Program, meant to coordinate the complicated routes and fares offered by the KL rail and bus companies. The consolidation of STAR, Putra, Park May, and Intrakota into the government should facilitate this process. Current privatization mechanisms have generated incompatible fare systems, lack of efficient feeder systems, buses competing for the same routes, and uncoordinated service. The Integration Program has the potential to include Advanced Public Transportation Systems in the reorganization of KL public transportation.

This chapter examines Kuala Lumpur's institutional readiness for deploying ITS under the framework presented in Figure 21.

7.2 POLITICAL ENVIRONMENT

Since its independence from Great Britain in 1957, Malaysia's government has been a constitutional monarchy with a parliamentary system. Executive power is vested in the prime minister as head of government. Kuala Lumpur, as a federal territory, is governed by a mayor who is appointed by the prime minister. The current prime minister, Mahathir bin Mohamad, has been in office since 1981, but plans to step down next year. His departure may signal the beginning of a time of political uncertainty.

²⁵⁶ City Hall Kuala Lumpur Integrated Transport Information System Home Page. 2003. 31 Mar 2003 <<http://www.itis.com.my/>>.

The parliament is divided into a House of Representatives and Senate. The 193-member House is elected from single member districts and terms can last up to five years. The 69-member Senate is comprised of 26 state-elected legislators and 43 appointed by the king and prime minister. Senate members serve six-year terms. Because the Senate is at least one step removed from the general public, and both houses have long terms of office, the parliament is somewhat insulated from the power of public opinion. This could encourage politicians to support potentially unpopular ITS initiatives without constantly worrying about their reelection chances. On the other hand, some officials will continue to resist ITS in favor of conventional infrastructure.

Though there are more than 30 registered political parties, the United Malays National Organization (UMNO) has been dominant since independence, in coalition with other parties. The current coalition is called Barisan Nasional and holds three-fourths of the parliamentary seats. However, the leader of the opposing coalition, the Islamic Party of Malaysia (PAS), has been gaining strength in recent elections. Nevertheless, Barisan Nasional coalition members have reasonable assurance of their party's continuity of leadership.

Besides a political environment marked by long tenure and continuity of leadership, ITS projects in Malaysia greatly benefit from a strong national commitment to information technology development. Since 1991, Malaysia has been working to achieve its "Vision 2020" of developed-nation status. The Eighth Malaysian Plan 2001-2005 (the most recent of Malaysia's five-year national plans) is the first phase of the broader Third Outline Perspective Plan 2001-2010 (OPP3) to implement Vision 2020. Both the Eighth Plan and OPP3 emphasize the shift from a manufacturing-based economy to a knowledge-based economy with higher value-added activities. At the same time, it recognizes the importance of environmentally sustainable development. To achieve these two policy goals, ITS is a logical tool for managing transportation growth.

To support the move to a knowledge-based economy, much of the necessary infrastructure installation for ITS will already be occurring. Fiber optics, wireless communications, and high-speed data access will be used to upgrade networks in the Klang Valley region. This shift presents a good opportunity for Malaysia to implement ITS projects.

There is much promise for ITS in the new Multimedia Super Corridor (MSC), a 9 by 30 mile area of land set aside for information technology and located between Kuala Lumpur and the new airport. The MSC will be home to new multimedia universities, information technology companies, and engineering centers. In addition, Malaysia is creating two new cities within the MSC, Cyberjaya and Putrajaya, the latter of which is the new administrative seat for a paperless, electronic government. To address the transportation needs for the MSC, Malaysia can use ITS to showcase information technology while building an efficient and sustainable transportation system.

The political environment in Malaysia is ripe for ITS deployment. There is strong national and public commitment to technology in general, and increasing frustration with

current traffic congestion in Kuala Lumpur. Malaysia could take advantage of the creation of the MSC and its associated telecommunications infrastructure to support ITS deployments.

7.3 DEVELOPING VS. DEVELOPED REGIONS

Although Malaysia hopes to achieve developed nation status by 2020, it is currently still a nation in transition. As such, it faces economic and social issues unique to developing countries. For example, Malaysia has a shortage of technically trained citizens to manage the vast investments in telecommunications infrastructure it is making. As a result, human resources development is an issue of significant concern.

A major issue for Malaysia is the relationship between the national car and the government's commitment to public transportation and sustainable development. Malaysia's two national car companies, Proton and Perodua, are partially owned by the government (32% and 6.8% respectively). Prime Minister Mahathir Mohamad is a supporter of the steel plants, factories, and petrochemical industries necessary to stimulate a domestic automobile industry. As citizens in a developing nation, many Malaysians want private vehicles and purchase them as soon as they are able. In China, for example, workers have been willing to pay even 90% of their salary for car payments²⁵⁷. These forces work against the government's other commitments to encouraging use of public transportation and decreasing reliance on the automobile. Improving public transit with ITS, for example, may have no effect if the government simultaneously promotes the national car. This internal conflict is yet to be resolved.

The situation is exacerbated by the impending loss of tariff protections against foreign imports. When the ASEAN Free Trade Rules come into effect in 2005, Proton will no longer be protected by 42%-70% duties on imported car components and 300% taxes on imported complete cars²⁵⁸. Though Malaysia has pledged to protect its national car against the cheap imports through other price barriers, the increased competition and lowered prices, combined with rising per capita incomes, will likely enable more Malaysians to purchase their own automobiles or motorcycles, contributing further to the problems of congestion and pollution.

At the same time, the development of a national automobile industry and the development of ITS technology need not be mutually exclusive. Several intelligent vehicle technologies, including adaptive cruise control, collision avoidance, and vision enhancement systems, could be researched in Malaysia and included as features in the national car. While not directly reducing traffic congestion, ITS applied in this manner can improve safety, reduce pollution, and reduce accidents, thereby mitigating some of the negative effects of urban congestion.

²⁵⁷ Goodman, Peter S. "Polishing Its New Industry." *The Washington Post* 17 Dec 2002, E1.

²⁵⁸ Ranawana, Arjuna. "Local Win, Global Worries." *Asiaweek.com* 26 May 2000. 28 Dec 2002 <<http://www.asiaweek.com/asiaweek/magazine/2000/0526/biz.auto.html>>.

7.4 ORGANIZATION

Having addressed the overarching issues of political environment and economic development, this section discusses the organizational issues for ITS deployment in Kuala Lumpur.

7.4.1 HORIZONTAL INTEGRATION

Public agencies in Malaysia have developed in a compartmentalized manner. It may be difficult to implement ITS in such an environment, since the functions of land use planning, infrastructure, the environment, human resources, and other departments are wholly separated. ITS is often interdisciplinary and intermodal, requiring close collaboration between different functions. The decentralized bureaucracy in Malaysia is not conducive to such an effort.

One of the key agencies for ITS is the Road Transport agency in the Land Transportation Department (see Figure 3 below). For effective implementation, however, the Road Transport agency must work with the Legal Adviser, the public transport operators, Public Relations, Human Resources, Finance, Information Technology, and other departments within the Ministry of Transport alone. Several organizational steps separate the Road Transport agency and the others with which it needs to work.

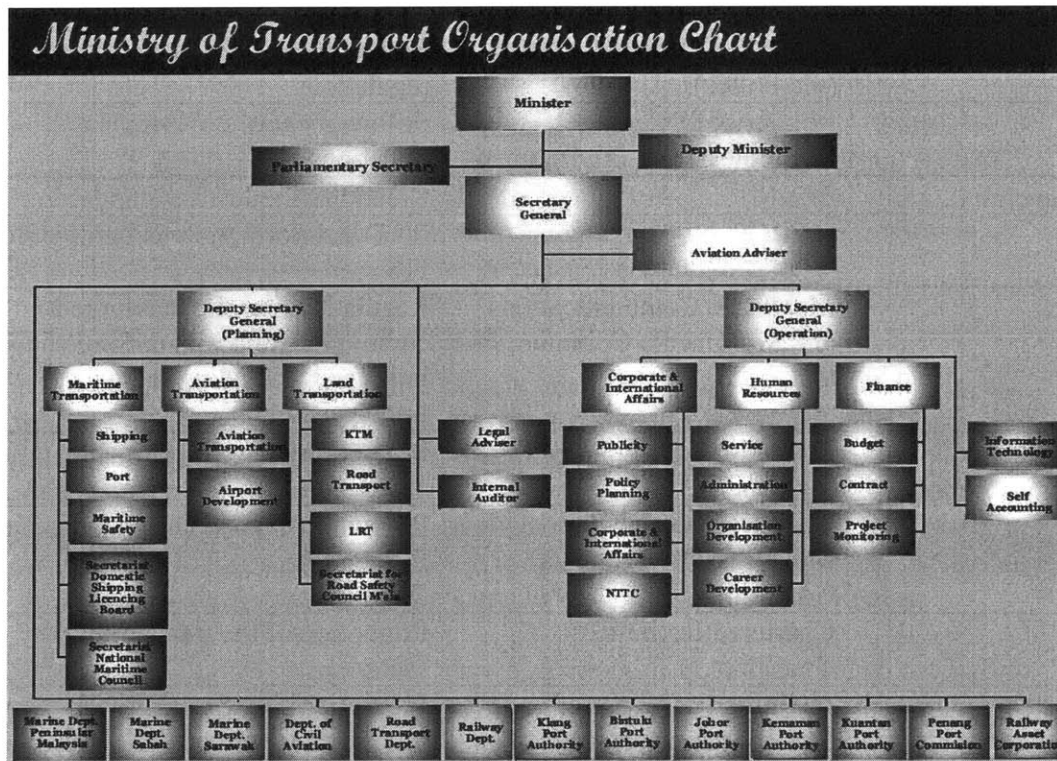


Figure 23. Ministry of Transport Malaysia Organization Chart

Source: Ministry of Transport Malaysia²⁵⁹

²⁵⁹ Ministry of Transport Malaysia Home Page. 2001. 26 Dec 2002 <<http://www.mot.gov.my/english/>>.

Institutions involved in ITS deployment, however, are not limited to the Ministry of Transport. The situation is complex because it involves a wide range of ministries, agencies, professional organizations, and private companies. In the 1999 ITS Strategic Plan for Malaysia, researchers attempted to document the existing institutional set-up for Malaysia. The following table is adapted from the plan.

Table 19. ITS-Related Institutions in Malaysia

Type	Name	ITS Responsibilities
<i>Ministries</i>	Ministry of Works	Road infrastructure and road network design
	Ministry of Energy, Communication, and Multimedia	Policies and regulations for the networked communications and multimedia industries
	Ministry of Information	Traffic information dissemination through Radio and TV Malaysia
	Ministry of Transport	Transportation policies and planning
	Ministry of Local Government and Housing (via local authorities)	Local area road networks and urban traffic management
	Ministry of Internal Affairs (via Police)	Enforcement of laws and regulations
	Ministry of Science, Technology and Environment	Enforcement of environmental violations
	<i>Agencies</i>	SIRIM
MIMOS		R&D in information technology for ITS
Malaysian Communications and Multimedia Commission (MCMC)		Regulations for the networked communications and multimedia industries, including radio frequencies
<i>Professional Organizations</i>	Institution of Engineers	Promotion of the engineering profession
	Road Engineering Association Malaysia, ITS Technical Committee	Promotion of road engineering and ITS
	Chartered Institute of Transport	Promotion of the transportation sector
	Institution of Highways and Transportation	Promotion of the road & transportation sectors
	PIKOM	Promotion of computer industries
<i>Public transport</i>	Bus companies	Ownership of bus services
	Light rail companies, inc. STAR, Putra	Ownership of LRT services

	Rail companies, inc. KTMB	Ownership of rail services
<i>Concessionaires</i>	PLUS	Ownership of North-South Highway
	KESAS	Ownership of Shah Alam Express
	ELITE	Ownership of Klang Valley Central Link
	Penang Bridge	Ownership of Penang Bridge
	LITRAK	Ownership of Damansara-Puchong Highway
	LINKEDUA	Ownership of Singapore Second Crossing
	Other concessionaires	

Source: Road Engineering Association of Malaysia²⁶⁰

Not surprisingly, ITS deployment in Malaysia thus far has been uncoordinated among the ministries, agencies, public transport operators, and concessionaires. Incompatible versions of electronic toll collection, traffic management, electronic fare payment, and other technologies are being implemented. As the Road Engineering Association of Malaysia (REAM) points out, “none of the ITS deployments are being planned to enable information sharing and exchange and common operation.”²⁶¹ Without a common ITS architecture, implementation is proceeding ad hoc based on the local needs of a particular organization.

Malaysia clearly must take action to horizontally integrate its agencies in order to facilitate ITS development and implementation. In the ITS Strategic Plan, REAM recommends a public-private ITS Strategic Council to be incorporated within the Ministry of Works. The formation of such a council would be an important step in creating the necessary collaboration for successful deployment.

7.4.2 VERTICAL INTEGRATION

The ITS initiatives in Malaysia have largely been championed at the national level. Goals for information technology development, including the Multimedia Supercorridor and its associated telecommunications infrastructure, are promoted through Vision 2020. Since the national government is strongly committed to developing IT, transportation applications in ITS are a logical way to encourage the shift to a knowledge-based economy. The ITS committee of REAM is also a body of national scope, though many of its initiatives are focused on Kuala Lumpur and the Klang Valley Region.

Malaysia’s national government has shown a commitment to ITS through the Eighth National Plan, 2001-2005. In the Infrastructure and Utilities chapter, the development goals include “encouraging the use of public transport as well as intelligent transportation

²⁶⁰ Road Engineering Association of Malaysia. Technical Committee on Intelligent Transportation Systems. “ITS Strategic Plan for Malaysia.” Dec 1999.

²⁶¹ Ibid.

systems, particularly in urban areas to reduce congestion.”²⁶² Calling ITS “an imperative tool in the strategy to alleviate traffic congestion,”²⁶³ the government is providing approximately \$110 million USD under the Plan to improve transportation systems, with a heavy emphasis on ITS²⁶⁴.

Local governments have also taken the lead in ITS where appropriate. Kuala Lumpur’s local government has implemented the smart traffic signal control system, Web-based real-time traffic information, and interactive public transport information kiosks. While national agencies typically handle the interregional applications such as toll roads, the local governments are able to deploy ITS projects that are smaller in scope.

The local and national governments have also demonstrated an ability to work together on ITS implementation. Touch’n’Go, the electronic payment system, is interoperable for some toll roads as well as applications internal to Kuala Lumpur, such as the Putra light rail system. This smart card will eventually be the standard for all toll roads around KL. The private sector is largely responsible for the implementation of Touch’n’Go integration, however, the local and national governments set standards and communicated to ensure interoperability and ease of use.

Thus far, Malaysia has allocated ITS responsibilities well between the local and national level. The national government has set policy goals and provided funding for ITS development. However, the local government has also taken the initiative to plan and deploy several ITS projects. The relationship is collaborative, as demonstrated by the success of the Touch’n’Go smart card system.

7.4.3 PUBLIC/PRIVATE PARTNERSHIPS

Kuala Lumpur has tried numerous public/private partnerships in transportation, primarily in the areas of public transportation and toll roads. These partnerships have had mixed results – many public transit operators have been unable to turn a profit, but some toll road concessionaries are now profitable. It is unclear as to what degree the public transit failures can be attributed to the 1997 financial crisis of Southeast Asia, and how much can be attributed to mismanagement. Regardless of the cause, the Malaysian government has been forced to bail out the debts of these companies in order to sustain operations, indicating a need to reengineer public/private relationships for ITS.

The two light rail systems in Kuala Lumpur, STAR and Putra, have both been bailed out by the government. The concession company Sistem Transit Aliran Ringan (STAR) first began construction in late 1993 and went online with passenger service in three phases from 1996-1998²⁶⁵. Similarly, the company Projek Usahasama Transit Ringan Automatik (Putra) went fully online between September 1998 and June 1999. The

²⁶² Malaysia Prime Minister’s Department. Malaysia Economic Planning Unit. “Eighth Malaysia Plan, 2001-2005.” Chapter 8. 23 Apr 2001.

²⁶³ Ibid.

²⁶⁴ Sayeg, Phil. “Malaysian stopover.” Traffic Technology International. Jun/Jul 2001.

²⁶⁵ MetroPlanet. “Kuala Lumpur Malaysia.” 2001. 22 Dec 2002 <<http://www.metropla.net/as/kual/kuala-lumpur.htm>>.

commercial debts of both STAR and Putra were backed by the government under the terms of the concession agreements.

As early as the third quarter of 1999, however, both STAR and Putra were in serious financial trouble. Ridership was 20% and 40% of predicted volumes respectively, and the companies were defaulting on interest payments totaling millions of dollars²⁶⁶. Putra lowered its fares in an attempt to lure more riders to its system. By 2001, the Malaysian government, through a Ministry of Finance subsidiary, was forced to assume the commercial debt for both companies for a combined amount of RM 5.5 billion, or around 1.63 billion USD²⁶⁷.

The public bus system also shows some negative effects from privatization. There is little coordination among the multiple bus providers in terms of routes, fares, and transfers. The feeder systems provided by independent bus companies into STAR and Putra are inefficient. Bus companies find themselves competing for the same passengers by operating the same routes, as a result of privatization.

However, concessionaires for toll roads have fared better. Profits from the subsidiary operator running the 870 km PLUS toll road, for example, are so great that they are being used to rescue their parent companies Renong and United Engineers Malaysia in a government-engineered debt restructuring²⁶⁸. However, PLUS is also tax-sheltered until the year 2007 and has permission to raise tolls by 10% every three years, or receive guaranteed government compensation for the same amount²⁶⁹. The latter has occurred in practice, resulting in a total payment to PLUS of \$113.9 million USD between 1996 and 1998 alone. Under this concession agreement, the government benefits from savings on the capital construction, and PLUS is also able to turn a profit.

Malaysia's strong preference towards privatization is due to the firm support of Prime Minister Mahathir Mohamad. Since 1983, Malaysia has privatized over 400 projects ranging from utilities to television to trash disposal. However, critics point out that the government has been forced to buy back or "de-privatize" numerous operating companies including those in charge of the national sewer system (\$52.6 million) and the Bakun Dam hydroelectric project (\$250 million)²⁷⁰. The situation is further complicated by Mohamad's imminent departure from public office. Nevertheless, optimism for privatization remains strong among the operating companies, perhaps because there is strong precedent for government bailouts. For example, Kuala Lumpur's new airport

²⁶⁶ "Getting Back on Track." [Asiafeatures.com](http://www.asiafeatures.com) 15 May 2002. 22 Dec 2002 <http://www.asiafeatures.com/current_affairs/0004,0130,03.html>.

²⁶⁷ "Fresh Start for Light-Rail Transit Operators." [Asiafeatures.com](http://www.asiafeatures.com) 8 Dec 2001. 22 Dec 2002 <<http://www.asiafeatures.com/business/0112,3008,04.html>>.

²⁶⁸ Ranawana, Arjuna. "Rescue Mission." [Asiaweek](http://www.asiaweek.com) 30 Oct 1998. 22 Dec 2002 <<http://www.asiaweek.com/asiaweek/98/1030/biz1.html>>.

²⁶⁹ Home, Jackie. "PLUS drives through the finish line." [FinanceAsia.com](http://www.financeasia.com) 27 Jun 2002. 22 Dec 2002 <<http://www.financeasia.com/Articles/3CC0F747-84A8-11D6-81E00090277E174B.cfm>>.

²⁷⁰ Keong, Lee Min. "Malaysia's privatization at crossroads." [Asiafeatures.com](http://www.asiafeatures.com) 15 May 2000. 22 Dec 2002 <http://www.asiafeatures.com/current_affairs/0004,0130,01.html>.

express line operator, Express Rail Link, is eager to take on new projects despite only six months of operation with ridership 30% below forecasted levels²⁷¹.

The examples of STAR, Putra, and PLUS illustrate how public/private partnerships can both fail and succeed in transit applications. PLUS was profitable because the government structured the relationship such that the private sector would receive enough revenue. In contrast, STAR and Putra were not protected in this manner. It should be noted that government protection need not only be in the form of revenue guarantees. For Star and Putra, the government could have offered incentives to public transit riders, raised parking fees, or revamped the public bus routes to better integrate with the light rail lines.

In light of the failure of other privatization projects, Malaysia has not demonstrated a consistent ability to structure a mutually beneficial relationship with the private sector. For ITS, the government should consider alternative forms of partnerships besides the franchise (concession) model. Since many ITS projects do not generate a revenue stream, the contracted operations model may be more appropriate. In addition, the Malaysian government should be careful to consider the profitability risks associated with their public/private partnerships, since ultimately the government will be forced to assume the debt should the partnership fail.

7.5 FINANCE

7.5.1 CAPITAL BUDGETING

Malaysia's privatization model creates problems for capital budgeting in ITS applications. The government boasts a nationwide \$34 billion in capital savings due to privatization; however, this model may not work for ITS capital funding²⁷². Many ITS benefits are in the areas of safety and the environment, and leave no direct financial impacts. As a result, the private sector often does not have incentive to implement ITS because it will not be financially profitable. Yet the majority of Malaysian ITS projects have continued to follow the privatization model. Not surprisingly, these projects have only succeeded where the government has provided additional financial incentives.

The privatization model also exposes transportation projects to economic and financial risk. When the Southeast Asian financial crisis occurred in 1997, many of these projects were shelved indefinitely, some already in the middle of construction²⁷³. While the government is not completely insulated from the same economic risks, internal capital budgeting can shield transportation projects, a public good, from certain market uncertainties.

²⁷¹ How, Hong Boon. "ERL set for more fast train concession jobs." *The Star* 9 Dec 2002. 22 Dec 2002 <<http://biz.thestar.com.my/news/story.asp?file=/2002/12/9/business/bherl&sec=business>>.

²⁷² Keong, Lee Min. "Malaysia's privatization at crossroads." *Asiafeatures.com* 15 May 2000. 22 Dec 2002 <http://www.asiafeatures.com/current_affairs/0004,0130,01.html>.

²⁷³ "Privatization Hot List: Who gets what, who gets grounded." *Asiafeatures.com* 15 May 2000. 28 Dec 2002 <http://www.asiafeatures.com/current_affairs/0004,0130,04.html>.

The ITS Strategic Plan recommends that the national government establish a special fund for ITS projects. This fund would enable socially beneficial but unprofitable ITS deployments to proceed. Under the Eighth Malaysia Plan, the government has taken the first step by creating a \$110 million fund for transportation and ITS in particular. However, competition for these funds is likely to be intense.

7.5.2 O&M BUDGETING

Like capital budgeting, Malaysia's privatization strategy has greatly reduced the problem of operations and maintenance funding for the public sector. The terms of concession agreements, however, often guarantee a certain toll rate or amount of revenue generation backed by the government. In a sense, these expenses could be considered O&M costs for the government.

Private companies, however, still retain the day-to-day burden of keeping their ITS deployments functioning properly. As discussed in the Public/Private Partnerships section above, STAR and Putra are only two examples of companies unable to finance their operations on a long-term basis. If the government had backed these concessions with guaranteed revenue, then the government's "O&M" expenditure would also be greatly increased. Without this guarantee, the government still had no choice but to assume the expenses of the failing companies.

Under Malaysia's privatization model, the private sector should be covering operations and maintenance costs. In practice, however, the government has been forced to provide financial guarantees in order to make ITS investments attractive. As a result, the government has assumed some of the O&M costs for which the private sector was originally responsible. In planning future deployments, Malaysia needs to add this cost to financial projections.

7.5.3 MAINSTREAMING

The broadest definition of mainstreaming is when ITS is integrated into routine planning activities concerning land-use and transportation. This integration can be through competition for funding or consideration of ITS as a regular alternative. Malaysia cannot consider mainstreaming, however, until a clearly defined planning process is implemented.

As a developing country, Malaysia's land-use planning process is still in the early stages of formation. Links between transportation and land-use are weak, as evidenced by the common occurrence of commercial vehicles traveling through residential communities²⁷⁴. The land-use planning process is very decentralized among local, state, and federal authorities. There are duplication of planning responsibilities and sometimes-inappropriate allocation of roles. Land-use planning functions are primarily housed within the Economic Planning Units at each level of government. As such, the EPU has little interaction or coordination with the relevant transportation agencies.

²⁷⁴ Road Engineering Association of Malaysia. Technical Committee on Intelligent Transportation Systems. "ITS Strategic Plan for Malaysia." Dec 1999.

At the same time, mainstreaming is especially important in transitional regions so that ITS is deployed alongside road infrastructure expansion, not in hindsight. Without a clear decision-making process, however, it will be difficult for Malaysia to present ITS as a regular alternative to all of the stakeholders involved. Mainstreaming should become a higher priority in the future once transportation planning has been firmly established.

7.6 LEGAL AND REGULATORY

It appears that Malaysia has only begun to address the legal issues associated with ITS. In the area of procurement, Malaysia's privatization model has allowed for alternative methods of delivery besides design-bid-build. Many of the toll road concessions, for example, were granted under a build-operate-transfer (BOT) model. Issues of intellectual property (as pertains to ITS), liability, and privacy, however, have not yet become major problems with the public. As a result, there has been little concern among policymakers to create a supporting legal structure.

Malaysia has addressed some of the issues in the realm of information technology, though these apply to electronic transmissions in general and are not entirely applicable to ITS. While not tailored to ITS specifically, this legislation encourages the development of information technology industries in general, which may eventually carry over into ITS. The following list summarizes the recent cyber legislation for information technology²⁷⁵:

- **Digital Signature Act 1997** - enables the implementation of electronic signatures instead of their handwritten counterparts in legal and business transactions
- **1997 Amendments to the 1987 Copyright Act** - guarantees full copyright protection for multimedia works
- **Computer Crimes Act 1997** - defines illegal access, interception and use of computers and stored data. Outlines potential penalties for infringements
- **Multimedia and Communication Act 1998** - promotes the national objectives of the industry including information reliability and security

Similar to the above legislation, Malaysia needs to consider the privacy, liability, and intellectual property concerns that will eventually arise from ITS deployments.

7.6 INFORMATION

7.6.1 DATA ISSUES

Kuala Lumpur has demonstrated its capacity for handling data issues. These issues include data completeness, transmission, and processing. As transmission costs are a substantial percentage of ITS investments, the current upgrades of KL's communications

²⁷⁵ Ibid.

systems complement its goals to implement ITS. Through creation of the MSC and the paperless government, Malaysia recognizes the telecommunications infrastructure requirements for handling ITS applications, and is taking action to upgrade accordingly.

Malaysia has also developed a vehicle registration information database called SALAM in anticipation of ITS enforcement needs²⁷⁶. SALAM is within Malaysia's Road Transport Department, which is completely separate from the Road Transport agency within the Land Transportation unit (see Figure 3). The Road Transport Department is responsible for enforcement of vehicle and driver licensing.

Current electronic toll collection lanes still use manual barrier gates to deter violators, which prevents the system from reaching maximum efficiency²⁷⁷. Eventually, SALAM can be linked with electronic toll collection and other ITS enforcement applications to automatically bill offenders. By removing the physical barriers, vehicles will be able to move through ETC lanes without coming to a complete stop, thus increasing efficiency.

7.6.2 STANDARDS

Malaysia has already begun to address the issue of technical and performance standards. There are four standardization and regulation bodies related to ITS deployments. The following table summarizes the roles and responsibilities of these committees.

Table 20. Malaysian Standards and Regulation Bodies

Name	Purpose
Standards and Industrial Research Institute of Malaysia (SIRIM) Industrial Standards Committee	SIRIM is the Malaysian standards organization. The Industrial Standards Committee is responsible for establishing local standards for industrial products.
National Committee of ISO-TC 204	Official link between SIRIM and the International Standardization Organization, representing Malaysia's interests.
Ministry of Energy, Communication, and Multimedia	The Ministry ensures the proper usage of radio frequencies through regulations.
National Information Technology Council	Serves in an advisory capacity to the development of Malaysian IT industries

Source: Sayeg²⁷⁸, Leong²⁷⁹

Although these bodies are charged with setting standards, there is still a lack of ITS-specific standards. This is partly due to a lack of Malaysian expertise in information technology, telecommunications, and electronic applications. As Malaysia shifts to an

²⁷⁶ Sidek, Dr. Mohamad Shahar Bin. Director General, Malaysia Road Transport Department. "Message from the Director General." 28 Dec 2002 <<http://www.jpj.gov.my/kps.htm>>.

²⁷⁷ Touch. 'n' Go Home Page. 2002. 28 Dec 2002 <<http://www.touchngo.com.my/>>.

²⁷⁸ Sayeg, Phil. "Malaysian stopover." *Traffic Technology International*. Jun/Jul 2001.

²⁷⁹ Leong, Dr. Siew Mun. Road Engineering Association of Malaysia. Chairman, Technical Committee on ITS. "The Profile of Intelligent Transportation Systems (ITS) Development in Malaysia." 4 Aug 1998.

information-based economy, however, we would expect this expertise, and therefore standards, to develop.

In the meantime, however, Dr. Siew Mun Leong, chairman of REAM's ITS Technical Committee, states that "most of the available 'Malaysian' standards are basically direct adoption of the globally accepted standards such as the ISO, British, American, etc."²⁸⁰ Because the standards and specifications do not take Malaysian characteristics into account, public agencies and private companies are limited to ITS systems that may be incompatible or fail to meet Malaysian needs. Leong believes this "deficiency" in standards has led to undue supplier influence on ITS system selection. With this deficiency, the public and private sectors cannot make the best choice for a particular ITS application.

Another problem is that ITS implementation has sometimes proceeded without first establishing standards. As many regions have discovered, it is better to establish a standard before deployment, instead of dealing with incompatible legacy systems and investments several years later. Malaysia's privatization policy also exacerbates the problem of creating several competing systems. In Malaysia, the most prominent example of a standardization problem has arisen in the area of electronic toll collection.

Kuala Lumpur has about 24 separate toll road concessionaires, 15 of which are in operation. The first of these were established in the mid-1990's using a wide variety of toll collection systems by each concessionaire company, requiring several different transponders. Malaysia's ITS Strategic Plan recognizes this difficulty, stating that "the main problem is that they have been installed as separate systems and are not interoperable. This greatly reduces their value to both users and operators."²⁸¹

To address this problem, the Malaysian government announced in 2000 that the Touch'n'Go infrared smart card, using the SmartTAG transponder, would be the single national electronic toll collection system. Originally, the government gave all toll road concessionaires until 2006 to convert, in order for concessionaires to recover the costs of their legacy equipment²⁸². However, the government shortened the deadline to Jan 1, 2003, resulting in lower rates of return for the eight concessionaires that currently do not use Touch'n'Go²⁸³. This deadline has been extended because of disputes about the terms and conditions between Touch'n'Go and the concessionaires.

Malaysia has taken steps to address standardization issues for ITS deployments. However, these standards do not always take into account specific Malaysian needs. In addition, implementation sometimes proceeds ad hoc without first establishing standards. This creates problems when legacy systems are installed that later require extensive retrofits.

²⁸⁰ Ibid.

²⁸¹ Road Engineering Association of Malaysia. Technical Committee on Intelligent Transportation Systems. "ITS Strategic Plan for Malaysia." Dec 1999.

²⁸² "Malaysia to Move to Touch 'n' Go Infrared Technology by 2006." The Intelligent Highway 15 Sep 2000. 27 Dec 2002 <<http://www.efkon.com/newsmalnov.html>>.

²⁸³ Letchumanan, A. "Touch 'n' Go for all highways." The Star 1 Nov 2002. 27 Dec 2002 <<http://thestar.com.my/news/story.asp?file=/2002/11/1/nation/ncard>>.

7.6.3 TRAINING

To support ITS deployment, as well as the general shift to a knowledge-based economy, Malaysia must produce a skilled workforce trained in electronics, communications, and information technology. Human resource development is also necessary in order to take full advantage of technology transfer from more developed countries.

The Eighth Malaysia Plan predicts enormous growth in demand for engineering, professional, and technical workers. It provides an extensive list of policies designed to encourage human resource development in science and technology. These include the establishment of polytechnic branch campuses, expanding the METEOR (Multimedia Technology Enhancement Operations) distance learning program, offering incentives for universities offering technology courses, and supplementing the Skills Development Fund for supplementary private sector training²⁸⁴. The Plan also more than doubles the funding allocation for industrial training to 3.76 billion RM, or about \$990 million USD.

The ITS Strategic Plan also recommends partnerships between universities and professional organizations such as REAM, the Institute of Engineers Malaysia, and the Chartered Institute of Transport Malaysia. By planning and implementing ITS projects together, graduates can become knowledgeable about ITS. One such university, the Malaysia University of Science and Technology (MUST), now offers a master's degree in transportation that prepares students to become future leaders in the field.

Malaysia recognizes its shortage and need for workers skilled in technology, for ITS and other applications. It is taking action in both developing young talent and providing ongoing education for professionals. This strategy should facilitate Malaysia's deployment of ITS, as well as its shift to a knowledge-based economy.

7.6.4 PUBLIC EDUCATION

Malaysia recognizes the importance of public education and perception in the success of ITS deployment. The ITS Strategic Plan suggests a series of seminars, workshops, forums, newsletters, and articles in order to inform the public and the government of the benefits of ITS technologies. Certain applications appear to have achieved wide market penetration. Over 1.1 million Touch'n'Go smart cards, for example, were in circulation by April 2001. Since most of the Touch'n'Go application areas are within the KL and its immediate vicinity, this is an astonishing figure in light of a Kuala Lumpur population at the same time of approximately 1.3 million people²⁸⁵.

Public education is particularly important for Malaysia since many of its ITS projects are privatized. Dr. Ahmad Sadullah of Universiti Sains Malaysia writes "the degree of acceptability among users and potential beneficiaries need also be considered. The users will usually influence the level of demand that may exist and *this is usually the major*

²⁸⁴ Malaysia Prime Minister's Department. Malaysia Economic Planning Unit. "Eighth Malaysia Plan, 2001-2005." Chapter 4. 23 Apr 2001.

²⁸⁵ Sayeg, Phil. "Malaysian stopover." Traffic Technology International. Jun/Jul 2001.

*determinant for the success of any ITS-based systems (emphasis added).*²⁸⁶ Without user demand, ITS projects will not be financially attractive for private operators.

As recommended by the ITS Strategic Plan, REAM has taken an active role in promoting out-reach programs. REAM has partnerships with ITS Canada, ITS Australia, ITS United Kingdom, and VERTIS to share information and experience. These organizations should be able to help REAM with its own public education program.

7.7 SYNTHESIS AND RECOMMENDATIONS

The following table summarizes the analysis conducted above on Kuala Lumpur's readiness to deploy ITS.

Table 21. Kuala Lumpur Readiness for ITS Deployment

Category	Subcategory	Adequately planned	Somewhat planned	Unknown/Not planned/NA
<i>Organization</i>	Horizontal Integration			X
	Vertical Integration	X		
	Public/private partnerships		X	
<i>Finance</i>	Capital budgeting		X	
	O&M budgeting		X	
	Mainstreaming			X
<i>Legal & Regulatory</i>	Procurement		X	
	Intellectual property			X
	Liability			X
	Privacy			X
<i>Information</i>	Data issues	X		
	Standards		X	
	Training	X		
	Public education	X		

From the table above, several key recommendations can be made for Kuala Lumpur in facilitating ITS implementation. These recommendations will be the focus for further research.

²⁸⁶ Sadullah, Dr. Ahmad Farhan Mohd. Universiti Sains Malaysia, Perak Branch Campus. "Intelligent Transport Systems (ITS) in Malaysia: Challenges Ahead." 4 Aug 1998.

- **Creation of a national-level ITS strategic office** – Design and development of an administrative entity that has funding and oversight over ITS projects. Along the lines of the US DOT’s ITS Joint Program Office, this office should represent both the public and private sectors, and serve as a resource for state and local governments.
- **Creation of a national ITS architecture** – It is imperative that a national ITS architecture is formed to coordinate ITS efforts in Malaysia. The national architecture is essential in order to facilitate the standardization process and to aid in system selection. Large regions such as Kuala Lumpur should also construct regional-level ITS architectures.
- **Exploration of alternative forms of ITS public/private partnerships** – Malaysia’s plan for transition to a knowledge-based economy emphasizes privatization as the model for the future. ITS applications, however, may be unsuitable for privatization since socially beneficial ITS projects are often unprofitable. Kuala Lumpur should consider exceptions for ITS in its privatization policy. At the same time, the private sector can stay involved and retain technology transfer by acting as contractors rather than operators.
- **Research into legal issues** - Though legal issues including intellectual property, liability, and privacy are not become public problems yet, they are likely to arise in the future. The new regulatory framework appears to address only basic copyright issues, while omitting consumer-side concerns related to ITS and other data-gathering information technologies.
- **Reorganization of standards process** - The current process for setting ITS standards is weak. Four different institutions are involved, and there is a general lack of expertise on technology and ITS issues. When standards can be agreed upon, they are often taken from the ISO or other countries, instead of being adapted for Malaysia specifically. Often, these standards are also decided after legacy systems are already in place.

7.8 IMPLEMENTATION STRATEGY

The implementation strategy for the recommendations above will be complex. This section explores methods for the Malaysian government to begin addressing these issues.

The first recommendation is to create a national-level ITS office to coordinate responsibilities currently fragmented across numerous ministries and agencies. Short of simply merging transportation functions into a single entity like Singapore’s LTA, a national ITS office provides single-source support and planning for the complex issues surrounding ITS. One potential model is the United States’ ITS Joint Program Office (JPO).

Set up within the Federal Highway Administration in the US DOT, the ITS Joint Program Office was created out of organizational problems similar to those currently facing

Malaysia. Before the office was established in 1994, ITS responsibilities were decentralized across the Federal Highway Administration, the National Highway Traffic Safety Administration, the Federal Transit Administration, and the Federal Motor Carrier Safety Administration²⁸⁷. Though implementation remains with these agencies, overall policy is set by the ITS JPO, whose objectives include:

- Providing strategic leadership for ITS research, development, testing, and deployment
- Guiding policy coordination
- Ensuring resource accountability²⁸⁸

Malaysia will need to adapt the U.S. example to fit its own requirements; however, the ITS JPO serves as a good model for a national-level strategic office that can coordinate a number of government agencies. Malaysia's infrastructure and existing ITS deployments are far less sophisticated than in the developing world, so Malaysia's ITS strategic office might incorporate more financial and implementation functions than in the U.S. In addition, Malaysia's office also needs to cope with human resource shortages by working more closely with international organizations in order to develop expertise.

A potential example for Malaysia to follow in developing a national ITS office is its own Inter-Agency Planning Group (IAPG) within the national Economic Planning Unit. The IAPG is responsible for certain land-use planning functions, and is comprised of representatives from all levels of government, as well as the private sector. The IAPG shows how a Malaysian national office can assist in coordinating efforts across multiple layers of bureaucracy.

The second recommendation is to develop a national ITS architecture. If a national-level strategic office is established as suggested above, it will be this office's responsibility to organize an ITS architecture. The purpose of this procedure is to reduce inefficiencies in ITS deployments; for example, duplication of similar services or installation of equipment that is incompatible. Creating a national ITS architecture also encourages Malaysia to consider the technical and institutional relationships between system components, which helps to integrate ITS functions both horizontally, vertically, and with the private sector.

The third recommendation is to revise the current public/private partnership system. Models for restructuring these relationships exist both inside and outside Malaysia. In addition to improving its current privatization structures, the government should consider alternative forms for involving the private sector. As emphasized throughout this chapter, privatization may not be profitable for ITS deployment, since many of the benefits are difficult to capture as dollars. Rather, the benefits of greater efficiency, better air quality, and improved road safety are social benefits that accrue to the general public.

²⁸⁷ US DOT. ITS Joint Program Office. "ITS Program Coordination." 25 Feb 2003
<<http://www.its.dot.gov/jpostaff/backgrd.htm>>.

²⁸⁸ Ibid.

The Singapore case study provides an example of an alternative model for involving the private sector. As described in Chapter Six, Singapore owns its road and public transit infrastructure while granting long-term licenses to private operators. Singapore's model shifts the burden of recovering large capital costs away from companies. At the same time, it allows for private sector partnerships and reserves some control within the government.

Even under Malaysia's privatization model, improvements can be made to avoid the financial difficulties illustrated by STAR and Putra. The example of the PLUS toll road within Malaysia shows that government support can result in profits for private operators. However, the challenge for the Malaysia government is to determine the appropriate level of public support to maintain profitability without overpaying. Comprehensive economic and financial studies, with the relevant risk analysis, should be completed before structuring the financial relationship within Malaysia's privatization model.

The fourth recommendation is to research legal issues surrounding ITS; namely, the problems of procurement, intellectual property, liability, and privacy. The purpose of this research is to produce a statutory and/or regulatory framework that supports ITS deployments. It is difficult to suggest a clear strategy for implementation since legal issues are highly specific to a region's political culture and judicial system. The Malaysian government can look to Singapore for examples of legislation addressing the specific needs of high-tech systems. Other relevant examples can be found in U.S. and Japan. Again, it is important to adapt these examples to meet Malaysian requirements, avoiding the adoption of measures meant for a different culture or political system.

The final recommendation is to reorganize the process of setting standards for ITS. The first step in this reorganization is developing expertise about ITS and specific Malaysian needs. To this end, a committee could be set up within SIRIM or its Industrial Standards Committee to deal specifically with transportation or technological standards. This committee should include members knowledgeable about ITS. They will also need to decide on policies to avoid implementing ITS without first deciding upon a standard. As such, the committee will need to work closely with the many institutions listed in Figure 4. If a national-level ITS strategic office is established as recommended in this study, however, then the committee may be able to interface with just this ITS office alone.

These suggestions are meant as a guide for implementing the recommendations that emerged from the institutional analysis of this chapter. Using the framework in Figure 21, certain gaps in ITS deployment readiness were identified. It is hoped that the implementation strategies set forth in this section may be able to better direct the Malaysian government in methods to close the gaps in their institutional arrangements.

CHAPTER EIGHT: LESSONS LEARNED

As stated in Chapter One, the goals of this study were fourfold:

- To introduce a portfolio of ITS technologies, and analyze their impacts
- To propose a framework that can assess a region's institutional readiness for ITS deployment
- To apply this deployment framework in two urban contexts
- To develop recommendations, based on this framework, for institutional transformation in the city of Kuala Lumpur.

These four objectives were addressed during the course of this study. There are also several overarching lessons that can be drawn from the development of the ITS framework presented in this thesis. These conclusions summarize the lessons learned that may be beneficial to cities interested in deploying ITS.

Intelligent transportation systems can make significant impacts on congestion, efficiency, safety, and the environment. At the same time, one must consider the social implications and costs of deployment.

Chapters Three and Four detailed the benefits and costs of a variety of ITS technologies. Some of these reduce congestion directly, like electronic road pricing. Others rely on decreasing congestion associated with traffic accidents, like mayday systems, AVCS, and incident management. Still others attempt to control congestion by providing information about alternative routes, like navigation assistance and ATIS. Regardless of the mechanism, ITS does have a measurable impact on congestion, and therefore affects the negative efficiency, safety, and environmental issues caused by congestion as well. Using a combination of ITS technologies in a particular city has the potential to significantly reduce problems of urban mobility and sustainability.

At the same time, ITS can be seen as costly to implement because these social benefits often cannot be captured as profits. The benefits of ITS have to be weighed against the capital and maintenance costs of the system. Other options include partnering with the private sector or using a revenue-generating technology. For example, many countries are turning to private developers to build and operate toll roads with electronic toll collection. Agencies could also charge for the use of ITS by asking users to buy in-vehicle transponders, or pay electronic road pricing fees. These options attempt to capture some of the social benefits of ITS. However, care should be taken to structure the relationships so that fees are charged equitably and that revenues are returned to those whom the charges hurt the most.

Socially, ITS has the potential to help people across all levels of income. However, certain technologies, or their benefits in reducing congestion, may only be affordable to wealthier motorists, who can either purchase the technologies or pay the electronic charges. At the same time, different technologies may help poorer citizens who can benefit from improved public transit or reduced fuel costs. ITS technologies have social implications that cannot be ignored during the planning process, since it is likely that they will have varying impacts on different people in a city's social organization.

Deploying intelligent transportation systems in urban areas is a complex challenge, requiring the consideration of a wide range of factors.

The framework presented in Chapter Five illustrates that deploying ITS is a complicated process of planning and implementation. Numerous stakeholders must be involved. These include multiple levels of government, the private sector, financial institutions, the judiciary system, universities, and the general public. Not surprisingly, a high degree of coordination is required between all of these different parties.

Overarching issues in ITS deployment are the political environment and stage of economic development. A region's political environment affects the power of public opinion and the political will to improve sustainability. Economic development is a significant factor because ITS must be balanced against continued investment in road building and the national economy. In addition, developing countries may lack human resources and technical capabilities to maintain ITS systems. Sustainability is also a challenge because developing countries often believe that developing a domestic automobile industry is crucial to economic growth, and that economic considerations should dominate environmental factors.

Other factors contributing to the complexity of ITS deployment are organizational problems, financial constraints, legal & regulatory concerns, and information issues. Organizationally, public institutions require integration both horizontally and vertically. Since ITS involves transportation, the environment, and land-use, this integration is difficult when bureaucracies are firmly entrenched and protective of their own turf.

Many ITS deployments also must be coordinated with the private sector, because public agencies often lack the capital or technical capability to deploy ITS. Financially, ITS projects are often the first to be cut when agencies are faced with cost overruns or tightening budgets. While not as capital-intensive as traditional infrastructure building projects, ITS deployments frequently require high levels of maintenance. Even when ITS projects do get funded, their yearly operating budgets seem to always be in jeopardy. One possible solution is mainstreaming, where ITS projects are regularly considered as an alternative in the transportation planning process. Few regions, however, have mainstreamed ITS.

From a legal and regulatory viewpoint, cities need to consider issues of procurement, intellectual property, liability, and privacy. These issues are more pressing in developed countries, but a supportive legal framework in developing regions can also prevent poor

project quality or a large number of lawsuits. Finally, problems with information include data capabilities, technical standards, training, and public education. Cities may simply not have the information processing capabilities or the human resources necessary to deploy and maintain ITS systems.

Implementation of ITS must be specific to a particular region; the imitation of other cities without localized planning may result in unsuccessful deployments.

The conclusion drawn from the case studies in Chapters Six and Seven is that the institutional structure behind ITS deployment is specific to a particular region. Lessons drawn from the Singapore example are not directly transferable to an analysis of Kuala Lumpur. The ITS experiences of different countries can serve as good models, but agencies should be careful to tailor implementation strategies to meet the needs of their own areas.

The Singapore case study shows that part of the island nation's ITS success comes from its small land area, lack of vertical government layers, sophisticated IT equipment, and cultural view of government authority. Kuala Lumpur, by contrast, must also address regional issues, decentralized government, the role of privatization, and a less highly skilled workforce. These differing parameters are captured in the overall deployment framework developed in Chapter Five.

The deployment framework presented in this thesis does not mandate one specific solution to implementation issues; rather, it provides a structure around which these problems should be addressed. The range of possible solutions depends on a region's characteristics, and these solutions need to consider local details. For example, the approaches of Singapore and Kuala Lumpur to the legal issue of privacy must necessarily be different. Privacy needs to be addressed in some way, however, for ITS deployment to fully succeed.

The deployment of intelligent transportation systems is a complex process, but the technology has the potential to produce significant benefits in reducing congestion and its associated negative effects. Institutional obstacles are often the main barriers to implementation. As such, careful planning is necessary to ensure successful deployment in the long run. It is not enough to address organizational issues; problems of finance, regulation, and information must also be included. The author hopes that the framework developed in this thesis can eventually aid people who hope to bring ITS technologies to their own cities.

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