



Methods and challenges in implementing intelligent transportation system in the United States

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ABSTRACT

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To address congestion, transportation experts agree that Intelligent Transportation Systems (ITS) are the key to urban mobility. In this study, the authors provide a brief overview of ITS technologies currently in use in the United States and the challenges of implementing ITS. Over time and with the development of technology, many solutions integrate into the ITS system and can be grouped into three main groups: Traffic condition monitoring equipment, traffic control systems, and road user information systems. ITS brings many benefits such as safety benefits, environmental and social benefits, security benefits and road network management benefits. However, the implementation of ITS technology in the United States also faces many challenges, the biggest of which are funding for ITS and human resources to operate ITS effectively.

1. INTRODUCTION

Traffic congestion is a major problem that most major cities face. Traffic congestion increases travel time, slows down travel speeds, fatigues and stresses commuters, reduces social productivity and creates invisible costs. In the United States, traffic congestion costed \$74 billion in lost time and productivity by 2024. The average American driver spent 43 hours a year stuck in traffic, equivalent to about a work week. Drivers in the most congested cities like New

York and Chicago lose more than \$1,800 a year in wasted time (INRIX, 2025).

To tackle congestion, transport experts agree that intelligent transport systems (ITS) are the key to urban mobility. Intelligent transport systems are advanced applications that provide services related to different modes of transport and traffic management, helping users to be better informed and use the transport network more safely, more coordinated and smarter (Hesham et al., 2023, ITS Deployment Evaluation, n.d.,

PIARC, n.d., U.S. Government Accountability Office, 2012 & 2023).

2. MATERIALS AND METHODS

In this paper, the use of ITS in the United States for traffic management and control was summarized including commonly deployed technologies and challenges in ITS implementation.

3. RESULTS AND DISCUSSION

3.1 Intelligent transportation system technologies in the USA

Intelligent Transportation System has a long history of development in the United States. Along with advances in science and technology, policies supporting ITS have been approved one after another. Some important milestones were included (Smith, 2017):

+ 1956: Congress passed the Federal-Aid Highway Act and the U.S. interstate network was created.

+ 1966: The U.S. Department of Transportation (USDOT) was established.

+ Late 1960s: The Federal Highway Administration (FHWA) Electronic Route Guidance System was deployed.

+ 1970: The National Highway Traffic Safety Administration (NHTSA) was established.

+ 1990: Intelligent Vehicle Highway Society of America (IHVS America) was incorporated in Washington, DC.

+ 1991: The Intermodal Surface Transportation Efficiency Act (ISTEA) was passed by Congress. Then ISTEA designated IHVS America a Utilized Federal Advisory Committee to the USDOT's IHVS Joint Program Office.

+ 1994: IVHS America became the Intelligent Transportation Society of America (ITS

America). The term "ITS" was official sanctioned by USDOT as a replacement for IVHS.

+ 1996: The USDOT established the ITS Standards Program.

+ 1988: U.S. Congress passed the Transportation Equity Act for the 21's Century (TEA-21).

+ 2002: The USDOT released the National ITS Program Plan: A Ten-Year Vision.

+ 2004: The Research and Innovative Technology Administration was established within the USDOT to support ITS initiatives.

+ 2005: U.S. Congress passed the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).

+ 2012: U.S. Congress passed the Moving Ahead for Progress in the 21st Century Act (MAP-21).

+ 2014: ITS JPO released the ITS Strategic Plan 2015-2019.

+ 2015: President Obama signed the Fixing America's Surface Transportation Act (FAST) into law.

In general, USDOT is a leader in research, development, and evaluation of technologies for transportation and a strong supporter of ITS. USDOT's ITS program includes efforts at FHWA and other administrations within USDOT, as well as the ITS Joint Program Office. The Joint Program Office's mission is to lead collaborative and innovative research, development, and implementation of ITS to improve the safety and mobility of people and goods. USDOT periodically conducts and publishes surveys on ITS deployment, and maintains a database on ITS benefits, costs, and lessons learned.

In the states, ITS implementation is decentralized to state agencies. For example, in California, the Regional Transportation Planning Agency is coordinate with the local agencies, California Department of Transportation (Caltrans) Division of Local Assistance, FHWA Project Engineer and communities during planning and implementation of the ITS project (California Department of Transportation, 2020).

Traffic management system is a context-aware solution based on real-time data from connected road infrastructure and predictive analytics to efficiently coordinate traffic on major roads. The success of such systems depends heavily on the ability of hardware systems such as sensors, cameras and management software systems to coordinate. As shown in Fig.1, data from

deployed ITS technologies is fed into a traffic management center. The center's equipment and computer systems allow traffic managers to receive and analyze information from ITS technologies and, in some cases, remotely control these devices. From the information gathered by the hardware devices, the system will make the most appropriate decisions to reduce congestion, such as automatically changing the timing of traffic signals or providing information to road users, suggesting alternative routes for drivers approaching congested areas. An ITS system in the United States typically consists of three main groups: Traffic Condition Monitoring Devices, Traffic Control Systems, and Road User Information Systems. The details of the operation of each type of device are presented below.

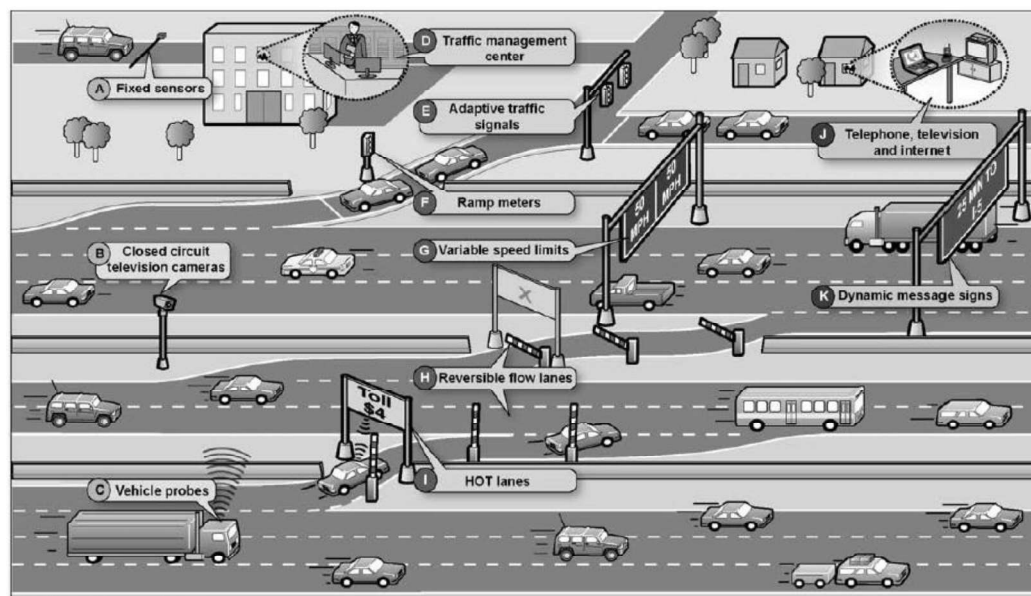


Figure 1. ITS technologies for traffic congestion management in the United States

(Source: United States Government Accountability Office (2012))

3.1.1 Traffic Condition Monitoring Devices:

- *Fixed sensors (Loop detectors)*: A loop detector consists of a loop of wire, embedded in the roadway, connected to a detector unit. The loop forms part of an oscillator circuit, allowing it to generate an electromagnetic field. When a

vehicle—a large metal object—passes over the loop, it disturbs this field, changing the inductance in the loop. This change is detected by the unit, signaling the presence of the vehicle. Loop detector can measure the number and estimate the average speed of vehicle passing.



Figure 2. Loop detector

(Source: Matan (2023))

- *Closed circuit television cameras (CCTV)*: Traffic monitoring cameras are typically deployed at strategic locations along roads and highways to provide a comprehensive view of traffic flow and conditions. These cameras may be mounted on poles, bridges, or other structures and are usually placed at intersections, on-ramps, and other points where traffic is likely to be heavy or congested.



Figure 3. CCTV camera

(Source: Leenanuruksa (2014))

- *Probe Vehicle*: A probe vehicle is a vehicle equipped with on-board electronics, such as a location and a communication device, that is used to determine its position and register experienced traffic conditions. Vehicle probes use roaming vehicles and portable devices, such as cell phones and Global Positioning System devices, to collect data on travel times.

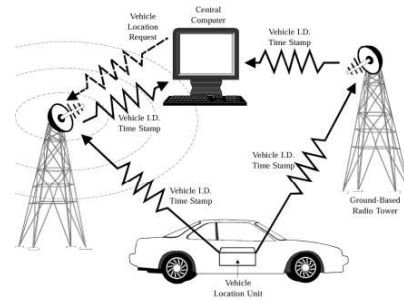


Figure 4. Probe vehicles

(Source: Federal Highway Administration (n.d).

Travel time data collection handbook)

3.1.2 Traffic control systems

- *Traffic management center*: A place where team of engineers and technicians monitor highway conditions around the clock on massive video panels. The team compiles information and coordinates construction activity, roadway advisories and incident management — in real time — to minimize your delays while on the road.



Figure 5. Traffic management center

(Source: Metropolitan Transportation Commission (n.d))

- *Adaptive traffic signals*: Adaptive signals use software to make timing changes to traffic signals in response to traffic conditions. Signal timing is calculated in real-time based on traffic demand and can adjust with each cycle. This software often requires a central system that analyzes traffic data and sends timing instructions to multiple traffic signals. Adaptive is the most advanced signal control technology available and requires reliable vehicle detection and communications equipment.



Figure 6. Adaptive traffic signals

(Source: Daniel Consultants, Inc. (n.d))

- **Ramp meters:** A ramp meter is a device, usually a two-section signal light (red and green only, no yellow) together with a signal controller, that regulates the flow of traffic entering freeways according to current traffic conditions. Ramp meters are used at freeway on-ramps to manage the rate of automobiles entering the freeway. Ramp metering systems have proved to be successful in decreasing traffic congestion and improving driver safety.



Figure 7. Ramp meter

(Source: Wikipedia contributors (n.d). Ramp meter)

- **Variable speed limits:** Speed limits are established with an engineering study based on inputs like traffic volumes, operating speeds, roadway characteristics, and crash history. However, conditions on the roadway are susceptible to change in a short amount of time (e.g., congestion, crashes, weather). Providing variable speeds limits capable of adapting to changing circumstances could reduce crash frequency and severity.



Figure 8. Variable speed limits

(Source: Federal Highway Administration (n.d).

Variable speed limits)

- **Reversible flow lanes:** A reversible lane is a managed lane in which traffic may travel in either direction, depending on certain conditions. Typically, it is meant to improve traffic flow during rush hours, by having overhead traffic lights notifying drivers which lanes are open or closed to driving or turning.



Figure 9. Reversible flow lanes

(Source: Wikipedia contributors (n.d). Reversible lane)

- **High-occupancy Toll lanes (HOT lanes):**

A HOT lane is a type of traffic lane that is available to high occupancy vehicles and other exempt vehicles without charge; other vehicles are required to pay a variable fee that is adjusted in response to demand. Unlike toll roads, drivers have an option to use general purpose lanes, on which a fee is not charged.



Figure 10. HOT lanes

(Source: Wikipedia contributors (n.d). High-occupancy toll lane)

- *Environmental sensor stations (ESS)*: An ESS is a site measuring atmospheric, pavement and/or water level conditions. Many state transportation agencies deploy ESS as field components of Road Weather Information Systems (RWIS).



Figure 11. Environmental sensor stations

(Source: Federal Highway Administration (n.d).
National environmental sensor station map)

- *Transit signal priority (TSP)*: TSP prioritizes transit vehicles at signalized intersections as a method of decreasing transit delay and increasing the person throughput at intersections. This device usually used on bus, sends a signal to a detection device along the roadway. These data feed into a software system that determines whether to extend a green light for the bus to cross the intersection.

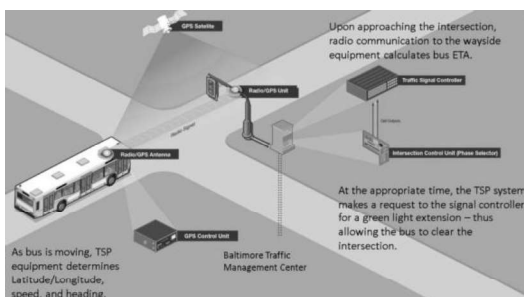


Figure 12. Transit signal priority

(Source: U.S. Department of Transportation (n.d).
Transit signal priority)

- *Emergency vehicle preemption (EVP)*: Similar to TSP but EVP allows fire trucks, ambulances, and police cars to intervene in the

normal operation of traffic control systems using wireless communications installed on traffic intersections and emergency vehicles. It is a dynamic system that ensures traffic lights favor emergency vehicles, minimizing delays at intersections and enabling rapid responses to critical situations.

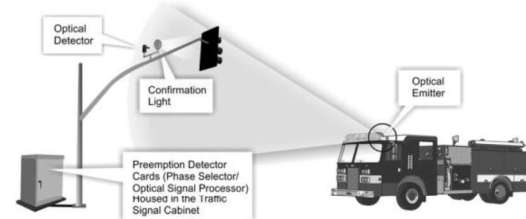


Figure 13. Emergency vehicle preemption

(Source: Wikipedia contributors (n.d). Intelligent transportation system)

3.1.3 Road User Information Systems

- *Dynamic message signs (DMS)*: DMS are signs that are capable of displaying more than one message, changeable manually, by remote control, or by automatic control. They are used for displaying traffic warnings, regulations, routing, and management in the Intelligent Transportation Systems Architecture. These electronic signs are a major component of advanced traveler systems implemented by state departments of transportation.



Figure 14. Dynamic message sign

(Source: SunGuide Transportation Management Center (n.d))

- *Telephone, television and internet:*

Transportation agencies communicate information gathered from traffic monitoring to the traveling public in various ways, including

television, websites, e-mail, telephone, and devices used in vehicles such as cell phones. This information including information about travel times and traffic incidents allows users to make informed decisions regarding trip departures, routes, and modes of travel.

In general, the level of ITS deployment varies by state and locality. Since 1997, USDOT periodically sent the ITS Deployment Tracking Surveys to agencies. In 2020, DOT sent the

surveys to 108 large and medium metropolitan areas nationwide with a focus on agencies that serve populations of 50,000 or more (U.S. GAO Report, 2023). This survey showed that some ITS technologies were widely deployed on arterials or freeways, while others were less widely deployed. Usually, ITS technologies are used more on freeways than on arterial roads. The results are shown in Figure 15 and Figure 16 below.

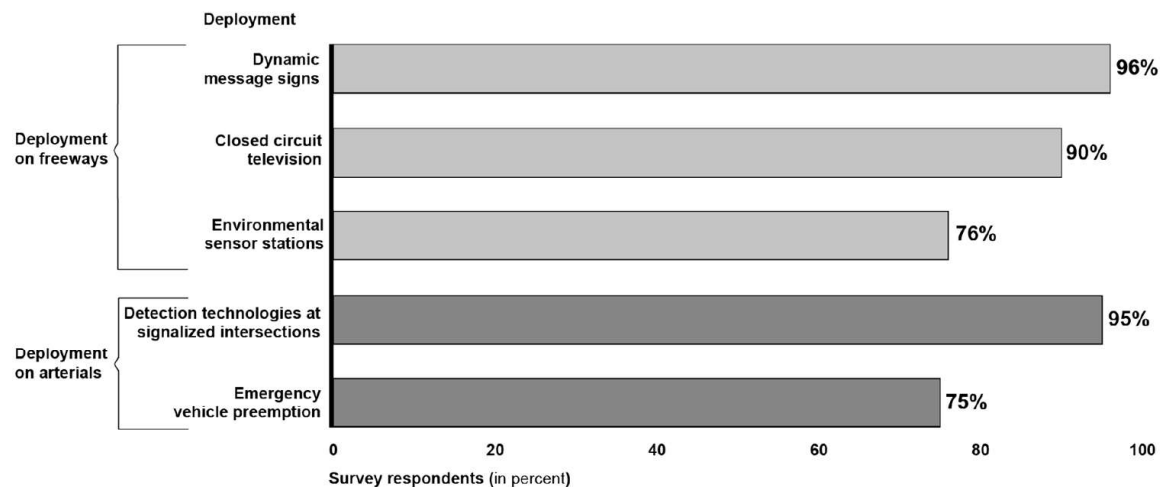


Figure 15. Widely-Deployed ITS technologies in DOT's 2020 ITS survey

(Source: United States Government Accountability Office (2023))

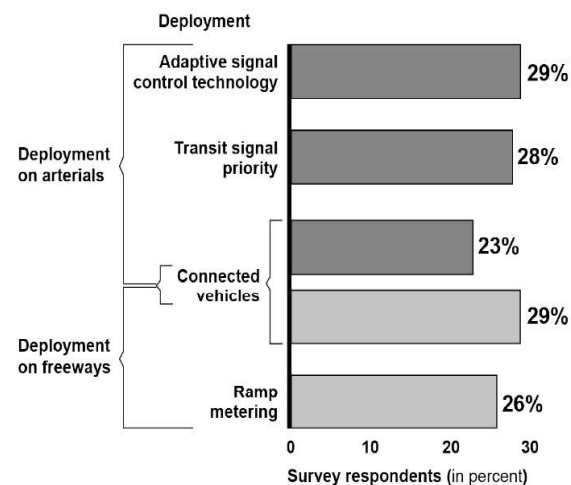


Figure 16. Less Widely-Deployed ITS technologies in DOT's 2020 ITS survey

(Source: United States Government Accountability Office (2023))

3.2 Benefits of ITS and challenges affecting ITS deployment

3.2.1 Benefits of ITS

Many researches (Hesham et al., 2023; ITS Deployment Evaluation, n.d.; PIARC, n.d.; U.S. Government Accountability Office, 2012 &

2023) agreed that ITS brings a lot of benefit to road users and other travelers, public transport users, people with mobility difficulties, local communities, transport policy makers and road network operators. These benefits included safety benefits, environmental and social benefits, security benefits, and road network management benefits.

- *Safety benefits*: The World Bank reports that every year, over 1.7 million people die, over 10 million people are seriously injured ITS reduces road traffic accidents in various ways (PIARC, n.d). ITS reduces the number, frequency and severity of accidents, for example:

- Smooth traffic flow using variable message speed signs,

- Offer intersection signal control and dynamic traffic management,

- Capture data for enforcement purposes: Speed enforcement, red light enforcement,

- Manage the interfaces between pedestrians and traffic, making zone safer and more pleasant.

- *Environmental and social benefits*: Transport is a major source of pollution which has health and quality of life implications. Transportation activities, mostly light-duty vehicles, are the largest source of emissions, accounting for 29 percent of total U.S. greenhouse gas emissions in 2021, according to the Environmental Protection Agency (U.S. GAO Report, 2023). By smoothing traffic flows, reducing energy consumption and vehicle emissions, ITS technologies have the potential to provide environmental benefits.

- *Security benefits*: Road users and transport operators expect roads to be well maintained, in good condition and able to be used in all weather conditions. By ITS installations, transport

operators can monitor the condition of infrastructure and predict more accurately when maintenance is needed. ITS can also support management of infrastructure at times of extreme events (such as flooding, extreme storms), by providing high-performance real-time information to operators and users. In the event of an incident or spill of hazardous materials, the emergency services personnel get information about the vehicle location and nature and contents of consignments, so they can respond appropriately and maintain safety for the public and other road users.

- *Road network management benefits*: There are control centers dedicated to managing the traffic control systems. ITS applications help them to gain some improvement in network efficiency, for example:

- By optimizing road users' use of the network through improved journey planning with real-time information and satellite navigation,

- Through traffic management like speed control, or public transport priority measures that help deliver transport policy goals, such as eco-driving and the safe and efficient use of road space,

- By monitoring the status and condition of the network in real-time for rapid detection of incidents, emergencies and weather events.

3.2.2 Challenges affecting ITS deployment

Although ITS offers many benefits, state and local governments faces many challenges in deploying and effectively using ITS technologies to manage traffic congestion such as strategic planning, investment costs and continuous updates, devices compatibility, skilled human resources, operation and maintenance, and

network security (U.S. GAO Reports, 2012 & 2023).

- *Strategic planning*: Planning for ITS is a critical component of addressing transportation issues and reducing congestion. Many agencies have implemented ITS based on the availability of funding rather than systematic planning. Sometimes ITS implementation is not always well integrated with other transportation strategies and programs.

- *Investment costs and continuous updates*: ITS deployment requires strong financial resources. Transportation officials often consider adding a new lane to a highway more beneficial than ITS when deciding how to spend their limited transportation funds. ITS projects have difficulty competing for funding with other needs, such as road and bridge maintenance projects.

- *ITS funding planning* is also difficult because of the challenges associated with rapid technological change. The life cycle of ITS technology is very short, only 5 to 7 years, meaning that equipment or software will eventually become obsolete or need to be re-equipped. Manufacturers may stop supporting older devices when they release new ones. So when devices break, there may be no replacement parts available.

- *Procurement* is another challenge. For example, the lead time to purchase equipment may be so long that the equipment is obsolete by the time it arrives. Furthermore, it may take the city more than a year to purchase basic items, affecting the city's ability to complete the project on time.

- *Operation and Maintenance*: Furthermore, financing the operation and maintenance of ITS

is more difficult than financing the initial deployment. The operating costs of some systems can exceed the cost of deployment. For example, in 2003, the initial capital cost for signal control hardware was \$21,000 to \$30,000, while annual maintenance costs were \$9,000 to \$10,500 over a five-year period (U.S. GAO Reports, 2012).

- *Skilled human resources*: ITS is a rapidly developing field that requires a specialized workforce familiar with emerging technologies. Staff responsible for managing ITS systems need knowledge in a variety of areas. ITS requires skills that construction engineers at transportation agencies are not specifically trained in, such as an understanding of electrical systems and communications networks, systems integration, and information technology troubleshooting skills.

- *Retaining*: Once ITS professionals have the necessary skills, agencies find it difficult to retain them. Retaining qualified employees is a challenge for agencies. Limitations in salaries and career opportunities can limit the ability of state and local governments to retain employees. Due to budget constraints, they cannot hire ITS employees to replace those who retire.

- *Device integration capabilities*: ITS systems use multiple computer systems to perform their tasks. These systems are not integrated, creating usability issues for them. Similarly, different ITS devices have different software and do not work together. This is a challenge that is increasing, not decreasing, as new technologies develop.

- *Cybersecurity*: Cybersecurity is also a challenge. ITS requires IT systems to communicate, yet nearly 18 percent of highway agencies and 10 percent of arterial agencies

reported experiencing cybersecurity incidents that affected their IT systems and transportation operations. Cybersecurity risks can have a negative impact on critical national infrastructure, including transportation systems.

4. CONCLUSION

ITS deployment in the United States has been going on for more than 35 years if we consider the establishment of Intelligent Vehicle Highway Society of America in 1990 as the starting point. Over time and with the development of technology, many solutions have been integrated into the ITS system and can be grouped into three main groups: Traffic condition monitoring devices, Traffic control systems, and Road user information systems. ITS brings many benefits such as safety benefits, environmental and social benefits, security benefits, and road network management benefits. However, ITS technology deployment in the United States has been inconsistent, depending on the type of road, highway or main road, as well as local capabilities. Despite being a wealthy country, ITS funding remains a major challenge in the United States. In addition, human resources to effectively operate ITS are also a problem.

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