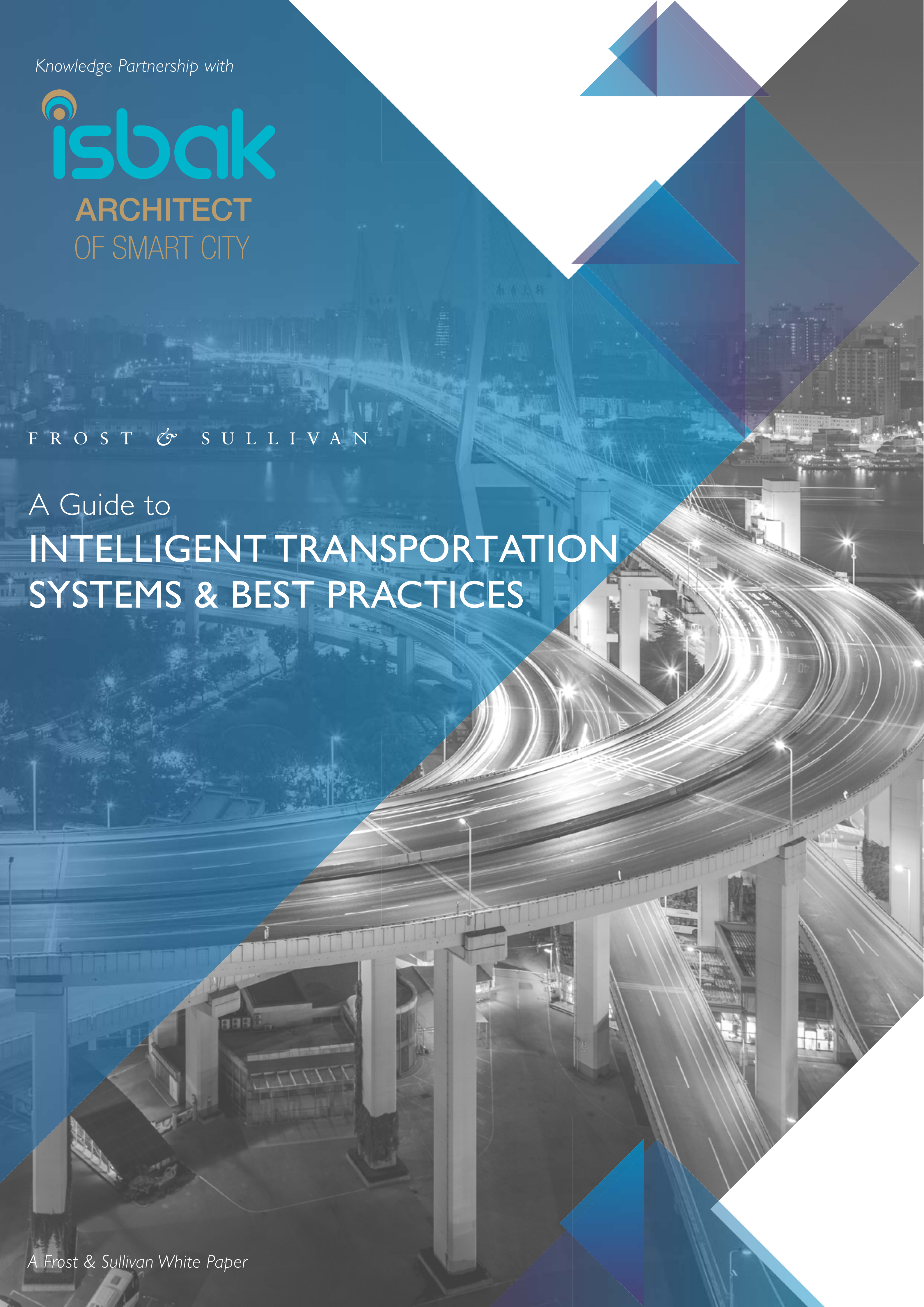

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FROST & SULLIVAN

A Guide to

INTELLIGENT TRANSPORTATION SYSTEMS & BEST PRACTICES

A Frost & Sullivan White Paper

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EXECUTIVE SUMMARY

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INTELLIGENT TRANSPORTATION SYSTEMS
& BEST PRACTICES

The world population is currently hovering at around 7.5 billion and is increasing at a rate of 1.11%. This equates to an addition of 80 million people per year. Frost & Sullivan estimates that by 2020, about 4.5 billion people will live in an urban environment.

The demand on the mobility infrastructure is immense, as people are commuting further every day to work. Although distance remains the same, commuting time has increased significantly due to congestion.

Mobility is transforming due to on-demand, platform-based systems driven by millennials straying away from traditional ownership models.

Future cities are focusing on tackling transportation-related problems using an integrated platform that can centrally manage mobility, safety and the environment.

CHALLENGES IN THE FUTURE CITIES

Future cities aim to increase efficiency by reducing time spent in traffic and lowering emissions by developing a sustainable, affordable transport infrastructure. However, the key challenges that need to be addressed to create a sustainable future transportation network are listed below.

Congestion:
As population increases, urban cities are sprawling toward suburban areas quickly due to limited areas inside the city. However, the infrastructure toward suburban areas is not developing fast enough; therefore, in terms of work and school needs, people are still connected to city centers, which causes daily travel times to increase and creates congestion within the city. For example, according to INRIX traffic statistics in 2016, 104 hours were spent in congestion in Los Angeles, 91.4 hours in Moscow and 89.4 hours in New York.

Energy and Emission:
Emissions are a concern all over the world due to unlimited pollutants and increasing consumption. Vehicle ownership is rising, increasing the emission of pollutant gases that are hazardous to humans. In London, stalled traffic has been found to lead to 8% more CO_2, 6% more PM_{10} and up to 9% more NO_x emissions than free-flowing traffic.

STRATEGIC MANAGEMENT LEVEL

Integrated Traffic Management Platform

OPERATIVE LEVEL

Urban Traffic Control

Freeway Management

Tunnel Management

Parking Guidance

OUTSTATIONS

Traffic Lights

Detection

Automatic Number Plate Recognition

Variable Message Signs

Pay & Display Machines

Safety:

Road safety and vehicle safety have always been crucial in saving lives; however, in 2015, according to the latest WHO statistics, 1.25 million deaths occurred due to traffic accidents. Three-quarters of the fatalities can be avoided by using vehicle-to-everything (V2X) communication technology.

Cybersecurity:

There are about 25 million connected cars on the road today; the number is expected to increase to 70 million by 2022, according to Frost & Sullivan. Cybersecurity is swiftly taking priority over comfort and convenience from both customers' and manufacturers' perspectives. There are currently OEMs forming independent start-ups founded solely to protect against cyber-attacks. Also, Tier 1 automotive suppliers are running V2X field trials to test security.

SOLUTIONS

Intelligent Transportation Systems

The European Commission defines Intelligent Transportation Systems (ITS) as a solution to increase safety and decrease congestion and emissions. It does this by applying information and communication technologies to passenger and freight transport.

Intelligent transportation systems are expected to benefit multiple players; they include faster travel times for commuters, better city management for city councils, a safer commute for citizens, and reduced fuel consumption. Although implementing these systems is extremely expensive, they are amortized over multiple avenues, including reduced fuel imports, reduced accidents and fatalities, and increased efficiency of public service departments such as garbage disposal and police departments.

Application areas of ITS can be grouped under 7 main categories:

- Advanced Traffic Management Systems (ATMS)
- Advanced Public Transportation Systems (APTS)
- Advanced Traveler Information System (ATIS)
- Advanced Transport Pricing Systems (ATPS)
- Commercial Vehicle Operations (CVO)
- Emergency Management (EM)
- Maintenance and Construction Management (MCM)

ITS APPLICATIONS

Advanced Traffic Management Systems (ATMS)

Advanced traffic management systems manage congestion dynamically. They increase the efficiency of utilization of existing infrastructure by using intelligent systems. These systems monitor both recurrent (rush-hour) and non-recurrent (congestion due to accidents, stalled vehicles) traffic conditions, and dynamically control the flow of traffic to reduce congestion.

Advanced Public Transportation Systems (APTS)

APTS is a collection of technologies aimed at improving safety, reliability, and efficiency while reducing commuting time of public transportation systems, thereby reducing congestion and emissions. It offers key advantages to supervisors such as real-time location tracking, accident/event information, and driver and vehicle monitoring.

Advanced Traveler Information System (ATIS)

ATIS is one of the most common ITS services, aiding the transportation of travelers throughout their journey. Information about traffic congestion, delays, accidents, and weather are disseminated through the media, internet, visual messaging, and public announcement systems.

Advanced Transport Pricing Systems (ATPS)

ATPS are used to control congestion by applying charges during certain hours. Electronic road pricing (ERP) uses a pay-as-you-use system that charges motorists for entering certain zones during certain hours denoted as congestion times.

Commercial Vehicle Operations (CVO)

CVO is an ITS solution for commercial vehicles that aids in the efficient management of commercial vehicle operations. It leverages GPS locations along with digital radios and intelligent algorithms to manage commercial vehicles.

Emergency Management (EM)

Emergency management is an ITS application that deals with emergency medical services, large- and small-scale emergency response, routing of emergency vehicles, and informs travelers of disasters.

Maintenance and Construction Management (MCM)

Maintenance and construction management is an ITS application that is used to maintain roadways and manage construction in a region. This includes clearing of snow or road repairs.

BEST PRACTICES OF ITS IN SELECTED MEGA CITIES

ITS applications have been in place in the world's largest Mega Cities since the mid-90s. ITS has been used to tackle the challenges that cities are facing and to ease habitants' daily lives.

Singapore

Singapore has approximately 1 million vehicles; more than 50% are cars. Public transportation plays a key role in ensuring the safe and efficient movement of the nation's population. Singapore has one of the world's most cost-effective public transport networks. Its transportation system includes bus, rail, road, and water taxi. The city employs a variety of ITS systems to tackle congestion and emissions to efficiently use existing roadways.

Electronic Road Pricing (ERP)

ERP uses a short-range communication system called DSRC to collect tolls on certain roadways. This pricing system is levied during peak hours to control the traffic flow in congested areas. In the near future, ERP is going to change from a gantry system to GNSS technology due to better practicality, with an investment of $556 million.

Electronic Parking System (EPS)

EPS was introduced to provide a consistent user experience to motorists. It leverages the hardware that facilitates ERP. It automates parking fees and collection, and can accurately count the number of free spaces available in car parks.

Intelligent Traffic Signals
The traffic signals are network based and responsive to real-time traffic. They allocate green time based on traffic conditions. The network includes functions to extend the pedestrian crossing time for the mobility-challenged and elderly.

Automated Vehicle Operations
In terms of Smart Mobility, Singapore started the world's first autonomous taxi called Robo taxi. It is for a limited region, currently within 2.5 square miles of One North. It is expected to decrease the severity of congestion by reducing the number of vehicles on the road.

London

London's vehicle population at the end of 2016 stood at 3.1 million, of which close to 2.7 million were cars. Congestion costs the economy an estimated £2 billion a year. Public transportation is playing a key role in efficiently moving Londoners today.

London is also a pioneer city in terms of transportation operation data sharing. Transport for London (TfL) has committed to open data to serve the public transparently, and to support the development of start-ups and small-to-medium technology companies.

Smart Ticketing
As the adoption of public transportation increased, the congestion due to purchase and checking of tickets increased. Transport Authority of London TfL (Transport for London) introduced a smart payment card called Oyster in 2003 that allowed public transport users to tap in and out when using transportation services. Over 85% of all tube and bus travel is paid with an Oyster card.

Congestion Zone and Peak Pricing
Congestion charge is a fee imposed on most vehicles for entering a prescribed zone during certain hours of the day. A certain fee is charged for entering the congestion charge zone between 0700–1800 hours Monday to Friday, excluding public holidays.

A fare for travelling on certain public rail lines is applied for peak hours during the workday.

Traveler Information Systems
TfL uses multimedia to disseminate traveler information. For example, it launched a social media TravelBot service in 2017.

New York

New York City has a vehicle population of 2.16 million registered vehicles. Congestion cost the economy $16.9 billion in 2016. The average American commuter spent 42 hours in peak-hour traffic, whereas a New Yorker lost 89 hours. New York City's challenges mainly revolve around congestion, traffic accidents and emissions.

Intelligent Traffic Signals

New York City upgraded its existing intelligent traffic signal infrastructure to a more advanced system. The new system uses RFID readers and cameras that are used to transmit real-time information to the traffic management center, enabling real-time control of traffic. It is the world's largest traffic signal control system.

Transit Signal Priority

Transit Signal Priority (TSP) is a method used to improve bus travel times by prioritizing the traffic signals to reduce the travel time of buses along a corridor.

Istanbul

To overcome Istanbul city traffic challenges, ITS was introduced in the late 90s and has been improved since. ITS applications in Istanbul include nearly all the ITS application areas that are globally available.

As of 2016, Istanbul's vehicle population was 3.54 million vehicles, of which 2.64 million were cars. The number of people with a driver's license reached 5.9 million by the end of 2016.

Traffic Control Center and Fully Adaptive Traffic Management

All signalized intersection points located in the city of Istanbul are kept on the geographic information system and can be monitored and managed online through the intersection control system and the Traffic Control Center (TKM).

Another ATMS example is the fully adaptive traffic management system (ATAK), which was introduced in Istanbul to improve traffic by synchronizing traffic signals dynamically with real-time intervention. Traffic signalization systems are managing highways, connections and tunnels.

Digital Traffic Density Map and Mobile Traffic App

The instant traffic density data obtained from Traffic Control Center, the meteorological data obtained from automated road and meteorology surveillance sensors, and the infrastructure works information obtained from road networks are processed and presented on the Digital Traffic Density Map. Istanbul also has a mobile traffic application that provides traffic information to motorists.

Electronic Toll System and Smart Ticketing

There are two different advanced payment options in Istanbul: Electronic Toll System (ETC) and Smart Ticketing system, called Istanbul Card, which was introduced in 1995 and can be used in all public transportation, parking, taxis and certain social services.

TRANSPORTATION IN FUTURE CITIES

2

INTELLIGENT TRANSPORTATION SYSTEMS & BEST PRACTICES

POPULATION AND INFRASTRUCTURE'S ROLE IN URBANIZATION

Transportation is one of the keystones of the modern world. Today, with growing technology and infrastructure, people can travel further and wider. However, the growth of cities has seen transportation become a challenge rather than a boon. One of the most widely used forms of transportation, road transport, has become heavily regulated to ensure smooth traffic flow. Naturally, cities cannot be extended indefinitely and are constricted by a limited road network; simultaneously, the urban population has grown exponentially over the past few decades.

The population of the world is currently hovering at around 7.5 billion and is increasing at a rate of 1.11%. This equates to an addition of 80 million people per year. Frost & Sullivan estimates that by 2020, about 4.5 billion people will live in an urban environment.

The demand on the infrastructure is immense, as people are commuting further every day to work. Although distance remains the same, commuting time has significantly increased due to congestion. According to Texas A&M Mobility research, the annual delay due to congestion in urban parts of the United States has increased by 25% from 2010 to 2014.

Transportation has evolved from the humble wheel to a complex set of systems that are in place to ensure the efficient movement of people and goods. The transportation conundrum is expected to grow as safer, faster, greener and more efficient modes of transportation are required.

EXISTING MOBILITY SYSTEMS

Current transportation systems are primarily segregated into road, water, rail and air. Road systems include buses, taxis and private cars. While rail systems include trams, underground and overground services, waterway services include ferries. Air transport includes flights, heli-taxis and cable lifts. These systems and vehicles are the most efficient private and public transportation.

Governments are reeling under urbanization and trying to mitigate its effect on transportation by increasing public transportation services as well as imposing congestion charges on private vehicles to counter congestion, reduce travel time, and reduce emissions. Some metropolitan transportation systems have embedded GPS tracking units in buses in order to track in real time and display arrival times at bus stations. However, these are stop-gap measures; a more robust solution needs to be implemented to ensure improved future transportation systems.

Private car usage is one of the most common forms of transport, yet it is under-utilized. Private cars transport fewer occupants and are used only a few hours a day. This, coupled with millennials preferring shared mobility, has given rise to new mobility trends.

NEW MOBILITY TRENDS & INTELLIGENT VEHICLES

Mobility is transforming due to on-demand, platform-based systems driven by millennials straying away from traditional ownership models. They prefer a shared mobility model, driven by the proliferation of smartphones. This is pushing automotive OEMs toward "car as a service" since it is expected to decrease sales. Rising to this challenge, many OEMs have invested in mobility solutions to ensure that they do not lose their presence in the automotive ecosystem.

Future cities are focusing on tackling transportation-related problems using an integrated platform that can centrally manage mobility, safety and the environment. A three-tiered approach shows the strategic management that overlooks the operative and outstation levels.

New mobility trends include carpooling, ride hailing, micromobility and integrated mobility & reporting.

- Carpooling is trendy, especially in Europe, with 23 million registered members making it possible to share long-distance trips.

- Ride hailing enables customers to book a taxi or private vehicle through smartphones, such as Uber and Lyft.

- Micromobility involves eBikes and bicycle incentives, and creating new business models bundled with other lease products or vehicles, such as ALD 6 wheels.

- Integrated Mobility & Reporting is a single platform that benefits customers booking different transport modes via smartphones, such as Moovel.

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Intelligent vehicles also form a part of the future mobility trend, where autonomous taxis will ferry people around. These vehicles leverage a bevy of systems that include artificial intelligence, V2X communication and advanced sensor systems to navigate autonomously.

V2X communication systems allow the vehicle to interact with other vehicles, pedestrians, infrastructure and the network. This enables safe, efficient and greener mobility systems.

Governments want a single platform that tracks and manages all existing transportation systems to better serve their citizens, combining all outstations under different management categories and operating them under an integrated traffic management platform.

One of the most striking examples of futuristic transportation systems is a planned levitated pod that is enclosed in a low-pressure tube and is accelerated and decelerated using electric motors. The pod travels at speeds of about 1125 KPH, covering the distance between Sydney and Melbourne in 55 minutes as opposed to 4.5 hours by air.

Urbanization: It's Impact on Mobility

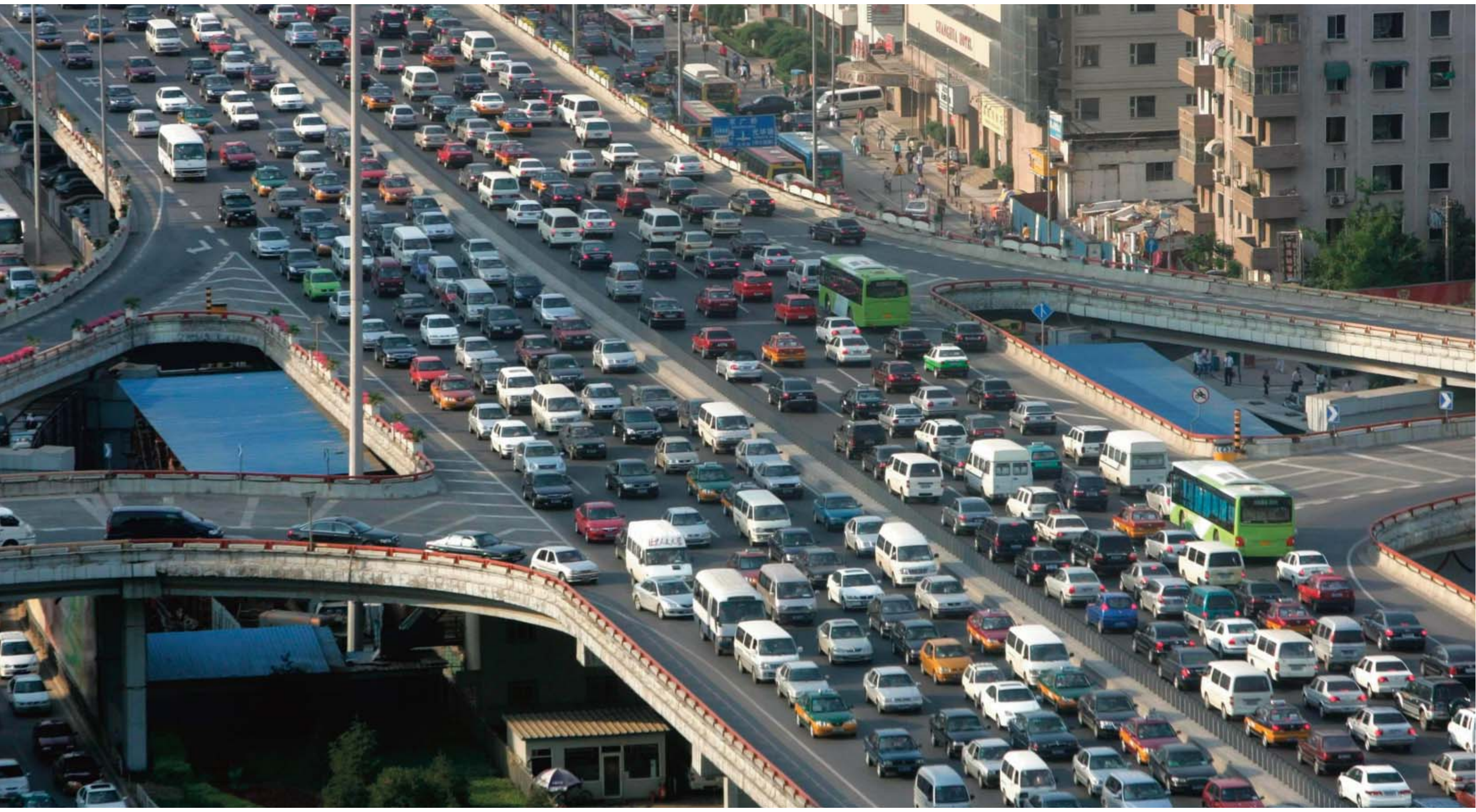
Future smart cities are aiming to increase efficiency by reducing time spent in traffic and emissions through the development of affordable transport infrastructure. To create a sustainable future transportation network, key challenges will need addressing.

Congestion:

As population increases, urban cities are sprawling toward suburban areas quickly due to limited areas inside the city. However, the infrastructure toward suburban areas is not developing fast enough; therefore, in terms of work and school needs, people are still connected to city centers, which causes daily travel times to increase and creates congestion within the city.

Drivers spent the most hours in traffic in Los Angeles, with 104 hours during peak times, according to the INRIX statistics in 2016. The other top cities dealing with long hours spent in congestion after Los Angeles are Moscow, New York, San Francisco and Bogota, with 91.4, 89.4, 82.6, and 79.8 hours, respectively. Except for Moscow and Bogota, the hours spent in congestion increased compared to 2015 results. One of the worst traffic jams in history occurred in China in 2010; a 62-mile long traffic jam on the Beijing-Tibet highway lasted 12 days.

In the US, the average cost of congestion to the average driver is $1,400 per year. The UK department of transportation estimates the average delay is 9 seconds per vehicle per mile (compared to free-flowing traffic) in the year ending March 2017.



Energy and Emission:

Emissions are a concern all over the world due to unlimited pollutants and increasing consumption. Vehicle ownership is rising, increasing the emission of pollutant gases that are hazardous to humans. The US Energy Information Administration (EIA) estimates about 80% of the US energy demand is met by fossil fuels. Consumption of fossil fuels has increased; however, alternative fuel usage might be threatened by resource extinction because the EIA estimates that less than half of the world's fossil fuel reserves would be depleted by 2030.

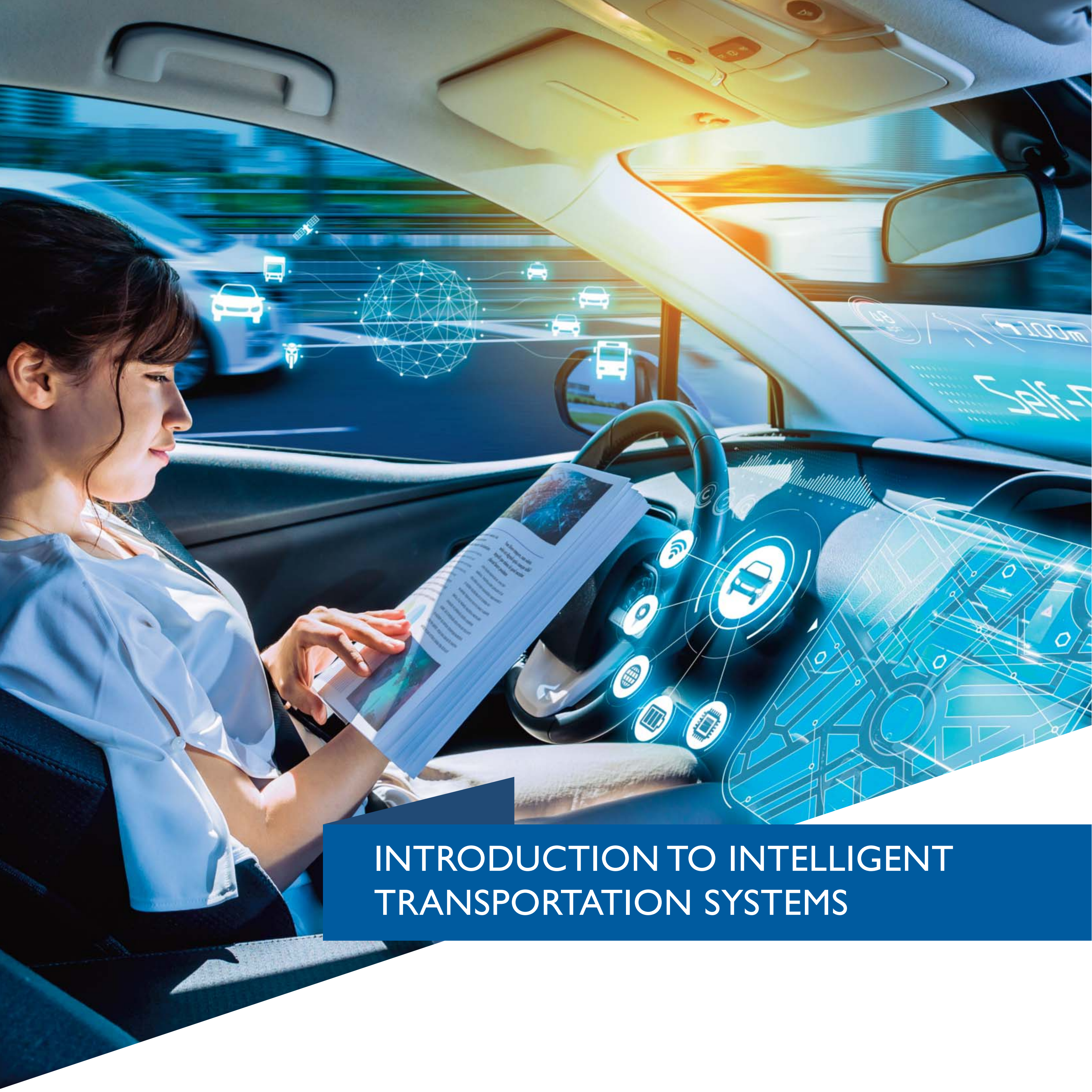
Safety:

Road safety and vehicle safety have always been crucial in saving lives; however, in 2015, according to the latest WHO statistics, 1.25 million deaths occurred due to traffic accidents. According to the EU commission reports in 2016, Europe was considered the safest region in the world with 50 road fatalities compared to 174 fatalities per 1 million people globally; however, in 2010, a goal was set to decrease the total by more than 50% by 2020.

Cybersecurity:

As connectivity combines smartphones, vehicles and infrastructure, there is a higher risk of security in terms of vehicle safety and an increase in vulnerability against outside attacks.

There are about 25 million connected cars on the road today; the number is expected to increase to 70 million by 2022, according to Frost & Sullivan. Cybersecurity plays a key role in ensuring connected cars are not compromised, leading to dire consequences. Cyber-attacks have become commonplace today and pose a great risk to commuters. Cybersecurity is expected to play a key role across the vehicle life cycle, from manufacturing to end of life.



INTRODUCTION TO INTELLIGENT TRANSPORTATION SYSTEMS

3

WHAT ARE INTELLIGENT TRANSPORTATION SYSTEMS?

Definition

The European Commission defines Intelligent Transportation Systems (ITS) as a solution to increase safety and decrease congestion and emissions. It does this by applying information and communication technologies to passenger and freight transport.

Intelligent transportation initiatives are managed by ERTICO in Europe. It is a partnership of public and private companies. It consists of over 100 partners spanning eight sectors. It aims to provide a platform where industry participants can collaborate to develop, deploy, and promote intelligent transportation systems.

In the United States, the Department of Transportation (DOT) has formed the ITS joint program office. It aims to create an intelligent transportation network by integrating intelligent vehicles with intelligent infrastructure. ITS America is its leading authority to research, develop, and deploy an intelligent transportation network. It provides a platform where private, public, research and academia players can collaborate. It also educates the public on ITS technologies.

Japan is one of the most advanced ITS countries. It's ITS organization, ITS Japan, was earlier known as the Vehicle Road and Traffic Intelligence Society (VERTIS). According to Vertis, in the near future, ITS systems will arrive that offer fundamental breakthroughs in safety, congestion reduction, driving comfort, and environmental friendliness, bringing them to levels far higher than those provided by current road transportation systems.

Benefits of ITS

Intelligent transportation systems are expected to benefit multiple players; they include faster travel time for commuters, better city management for city councils, a safer commute for citizens, and reduced fuel consumption.

Although implementing these systems is extremely expensive, they are amortized over multiple avenues, including reduced fuel imports, fewer accidents and fatalities, and increased efficiency of public service departments such as garbage disposal, police departments, and so on. It also increases driver comfort and reduces cost of road maintenance. These benefits are expected to increase the economic attractiveness of the cities because of increased work efficiency*.

What does each application do? What challenges does it help overcome?

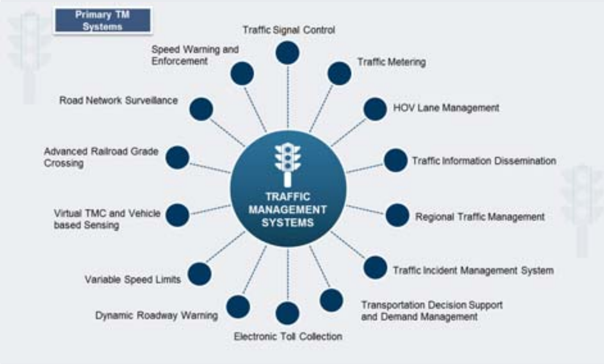
Application areas of ITS can be investigated under seven main categories, including:

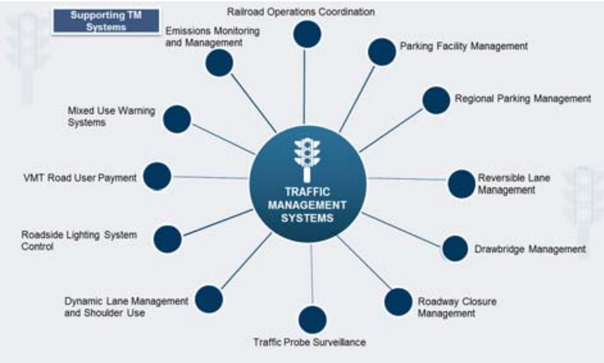
- Advanced Traffic Management Systems (ATMS)
- Advanced Public Transportation Systems (APTS)
- Advanced Traveler Information System (ATIS)
- Advanced Transport Pricing Systems (ATPS)
- Commercial Vehicle Operations (CVO)
- Emergency Management (EM)
- Maintenance and Construction Management (MCM)

Advanced Traffic Management Systems (ATMS)

Advanced traffic management systems manage congestion dynamically. They increase the efficiency of utilization of existing infrastructure by using intelligent systems.

*http://www.wiinom.us.edu.pl/sites/default/files/WSPOLPRACA/Art_2012_02.pdf





These systems monitor both recurrent (rush-hour) and non-recurrent (congestion due to accidents, stalled vehicles) traffic conditions and dynamically control the flow of traffic to reduce congestion. In order to work efficiently, ATMS require a control mechanism, sensors, communication, data collection, manipulation, and algorithms.

- Control mechanisms include traffic metering methods that include traffic lights, lane signals, traffic information and visual message systems.
- Sensors act as the input for the intelligent traffic systems; they include cameras, vehicle probe data and radars.
- Communication systems include vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication systems. These systems enable seamless communication between vehicles and between vehicles and the infrastructure.
- Data collection and manipulation includes collecting data from different sources and fusing them. It also aids in understanding traffic congestion patterns to mitigate traffic congestion.
- Algorithms enable accurate predictions of traffic congestion from the data collected.

The most common applications under ATMS are traffic signal control, traffic incident management systems, traffic metering and variable speed limit panels.

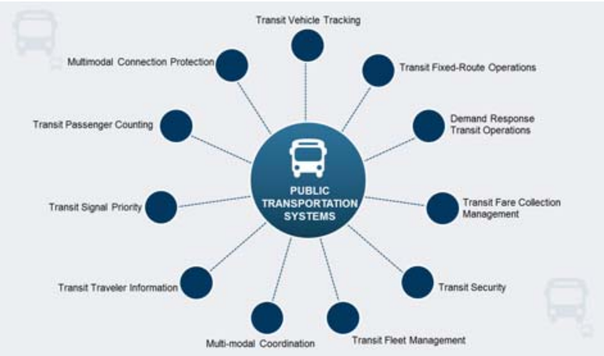
Traffic Metering:

Traffic metering is one of the strategies to control congestion; this is applied in various points in the infrastructure, including highway onramps. The highway onramp metering system uses congestion data collected from highways and uses dynamic traffic signals to meter the flow of traffic into the highway. If the system senses congestion due to a stalled vehicle on the highway, it will automatically activate onramp signals and meter the flow of traffic to reduce congestion.

Variable Speed Limits:

Variable speed limit signs are used as part of the dynamic strategy to adjust speed limits in real time according to prevailing conditions. These conditions include traffic flow, congestion, and weather. Variable speed limits can be enforced on a segment of roadway or individual lanes. This information is transmitted to motorists using visual messaging systems or, with V2I systems, the information can be sent directly to the car.

Advanced Public Transportation Systems (APTS)

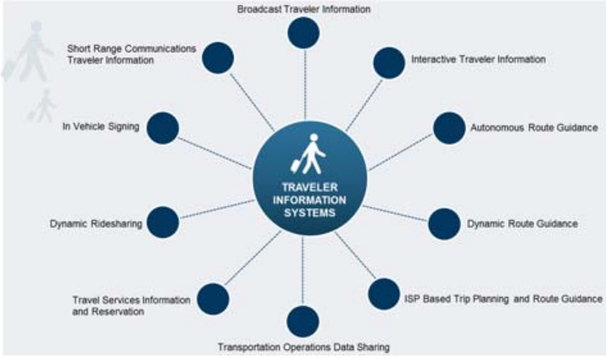


APTS is a collection of technologies aimed at improving safety, reliability, and efficiency while reducing commuting time of public transportation systems, thereby reducing congestion and emissions. It offers key advantages to supervisors such as real-time location tracking, accident/event information, and driver and vehicle monitoring.

Transit Signal Priority:
Transit signal priority systems modify traffic signal phasing/timing to prioritize the movement of in-service transit vehicles, such as buses, trams, and emergency vehicles. This reduces the time spent at intersections, increasing quality of transit services. These benefits are provided with a minimum impact to other road users.

Advanced Traveler Information System (ATIS)

ATIS is one of the most common ITS services, aiding the transportation of travelers from their origin to their destination. Information about weather, traffic congestion, delays, and accidents is disseminated through the media, Internet, visual messaging, and public announcement systems. This allows travelers to plan their journeys and make informed decisions that allow them to reach their destinations more efficiently. This leads to reduced congestion and emissions as travelers use the most efficient route to reach their destinations.



Traditionally, traveler information was sourced from physical maps, print brochures, and call centers. With the advent of ITS, traveler information is gathered from websites, online maps and mobile applications that offer real-time information on traffic, diversions, lane closures, and delays.

Dynamic Ridesharing:
Dynamic ridesharing offers more flexibility than conventional programs. Riders can request a one-time trip on short notice by leveraging GPS and the internet, and social network algorithms are able to match riders with drivers. Dynamic ridesharing reduces congestion and emissions.

Advanced Transport Pricing Systems (ATPS)

ATPS are used to control congestion. Intelligent pricing systems can cover toll collection, congestion pricing, vehicle mile travel, or electronic payment collection.

Electronic road pricing (ERP) uses a pay-as-you-use system that charges motorists for entering certain zones during certain hours denoted as congestion times.

This approach is also applied to public transport, where using trains or buses during peak hours would attract a higher fare. This is used to reduce congestion in public transportation systems. The system tracks the frequency of the ERP road usage and charges accordingly.

The charges can be paid in advance or by using short-range communication systems that deduct charges in real time when entering congestion zones. This reduces vehicle traffic and mitigates congestion. The most common technologies used in ATPS are video tolling (ANPR), dedicated short-range communication (DSRC), radio frequency identification (RFID), and global navigation satellite system (GNSS).

Commercial Vehicle Operations (CVO)

CVO is an ITS solution for commercial vehicles that aids in the efficient management of

commercial vehicle operations. It leverages GPS locations along with digital radios and intelligent algorithms to manage commercial vehicles.

CVO Fleet Maintenance:
Fleet maintenance monitors the vehicle condition using telematics. The vehicle sensors feed information to the onboard telematics unit; once an error code is generated, the driver and the fleet manager are informed.

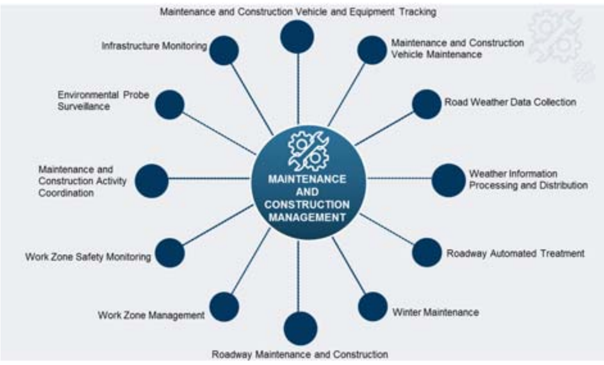
It finds uses in oil and gas, healthcare, transportation, government, energy and manufacturing. The benefits include increased asset life, improved asset visibility, and control and downtime management. It increases the safety and efficiency of operations.

Emergency Management (EM)

Emergency management is an ITS application that deals with emergency medical services, large- and small-scale emergency response, routing of emergency vehicles, and informs travelers of disasters.

Early Warning System:
The sensors deployed in smart cities can be used to provide an early warning of large-scale emergencies, such as natural disasters (earthquakes, tsunamis, etc.) or man-made disasters like terrorist attacks and nuclear power plant accidents. ITS such as cameras and other sensors are used to detect disasters.

Maintenance and Construction Management (MCM)



Maintenance and construction management is an ITS application that is used to maintain roadways and manage construction. This includes clearing of snow or road repairs. This also includes maintenance of the fleet of vehicles. It constantly monitors roadways, walkways and other infrastructure to ensure upkeep. It manages safety and other functions in construction zones.

Work Zone Management

One of the key functions of this subset includes work zone management. The frequency of accidents in work zones is high, so the safety of workers, pedestrians, cyclists and motorist is a priority. Thus, information about construction/road closures is sent in advance, and speed reduction zones and warning boards are installed.

Highway construction projects are some of the most hazardous work environments. The risk of being struck by a vehicle traveling through a work zone increases with higher traffic volumes and speeds. Long delays can sometimes cause motorists to become impatient and act unpredictably. This subset should consider the risks faced by workers when developing a work zone management plan. This subset of ITS also covers the treatment of roadways during adverse weather conditions.

BEST PRACTICES OF ITS IN SELECTED MEGA CITIES

4

INTELLIGENT TRANSPORTATION SYSTEMS
& BEST PRACTICES

The island city-state has a population of 5.35 million as of 2015 (World Bank) and covers a land area of 718 square kilometers. Singapore's total road network spans 3,496 kilometers (as of 2014), including expressways, arterial roads, collector roads and local roads. This occupies up to 12% of the land*.

Singapore's motor vehicle population stands at approximately 1 million vehicles; more than 50% are cars. Public transportation plays a key role in ensuring the safe and efficient movement of the nation's population.

Singapore has one of the world's most cost-effective public transport networks in the world. Its transportation system includes bus, rail, road, and water taxi.

One of the main challenges faced by Singapore is transporting its growing urban population using its existing road network. Lack of physical space restricts expansion.

Intelligent Transportation Solutions:

Singapore employs a variety of ITS systems to tackle congestion and emissions to efficiently use existing roadways.

Advanced Traffic Management Systems: Electronic Road Pricing (ERP)

One of the systems used is electronic road pricing (ERP). It uses a short-range communication system called DSRC to collect toll on certain roadways. This pricing system is levied during peak hours to control traffic flow in congested areas.

In the near future, ERP is going to change from a gantry system to GNSS technology due to better practicality, with an investment of $556 million. Also, the existing inboard units have been improved to on-board units that can be used to pay parking fees and checkpoint tolls.

Advanced Traffic Management Systems: Electronic Parking System (EPS)

EPS was introduced to provide a consistent user experience to motorists. It leverages the hardware that facilitates ERP. It automates parking fees and collection, and can accurately count the number of free spaces available in car parks.

This is paired with the parking guidance system (PGS), a visual messaging service that displays the free parking spaces available in three key zones, including Marina, Orchard, and Harbor.

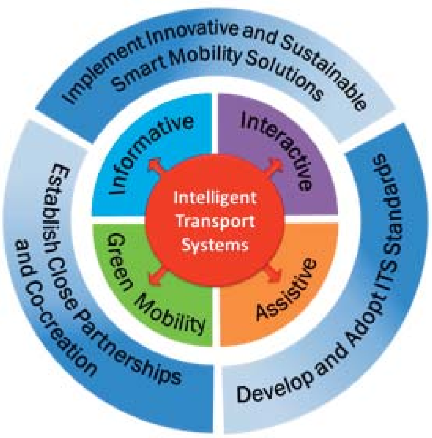
*https://www.lta.gov.sg/content/dam/ltaweb/corp/PublicationsResearch/files/FactsandFigures/Road Length-km.pdf

Advanced Traffic Management Systems : Intelligent Traffic Signals

The traffic signals are network based and responsive to real-time traffic. They allocate green time based on traffic conditions. The network includes functions to extend the pedestrian crossing time for the mobility-challenged and elderly, who receive a card that allows them to extend the time to ensure that they can cross safely.

Implementation of intelligent transportation systems has reduced congestion and increased the average car speed to 27 km/h compared to London (16 km/h), Tokyo (11 km/h) and Jakarta (5 km/h)*.

Singapore's ITS vision is "Moving towards a more connected and interactive land transport community." In order to achieve this vision, it plans to adopt three broad strategies around four key focus areas: informative, interactive, assistive and green mobility*.



What is Next?

In terms of Smart Mobility, Singapore started the world's first autonomous taxi called Robo taxi. It is for a limited region, currently within 2.5 square miles of One North. It is expected to decrease the severity of congestion by reducing the number of vehicles on the road. The taxis are developed by Renault and Mitsubishi EV, and the software is by nuTonomy. It includes six sets of laser radars around the vehicle that allow flexibility to maneuver like a human.

LONDON

The capital city of the United Kingdom and one of the oldest cities in the world, London has a population of 8.78 million and a land area of 1,583 square kilometers. Its road network covers motorways, A roads and B roads that total 14,833 kilometers*.

London's vehicle population at the end of 2016 stood at 3.1 million, of which close to 2.7 million were cars. Congestion costs the economy an estimated £2 billion a year. Public transportation is playing a key role in efficiently moving Londoners today. Compared to the start of the decade, where private and public trips accounted for 47% and 36%, respectively, there is a marked change, despite an increase in population, as private and public trips now account for 36% and 37%, respectively.

*http://www.c40.org/profiles/2013-singapore
*https://www.lta.gov.sg/content/dam/ltaweb/corp/RoadsMotoring/files/SmartMobility2030.pdf
*Department of Transport, London

London's public transportation system is managed by Transport for London (TfL). This includes buses, underground, Docklands Light Railway, London River Services, Tramlink and London Overground. London faces similar challenges to other Mega Cities, including an increasing population and congestion.

However, it is also focusing on reducing emissions and creating a sustainable and affordable transportation network.

Intelligent Transportation Solutions

London employs a variety of ITS solutions to tackle its challenges. They include intelligent traffic signals, traveler information systems, advanced transport pricing systems, and variable speed systems.

Advanced Public Transportation Systems: Smart Ticketing

As the adoption of public transportation increased, the congestion due to purchase and checking of tickets increased. Transport Authority of London TfL (Transport for London) introduced a smart payment card called Oyster in 2003 that allowed public transport users to tap in and out when using transportation services. Over 85% of all tube and bus travel is paid with an Oyster card. Customers can add to their balance in stations, shops, or over the Internet. Through the use of Oyster cards, the TfL has reduced the costs associated with producing tickets by 5%.
In December 2012, TfL announced the acceptance of contactless debit/credit cards across all TfL networks. In 2014, NFC technology by mobile phones was introduced.

Advanced Transport Pricing Systems: Congestion Zone and Peak Pricing

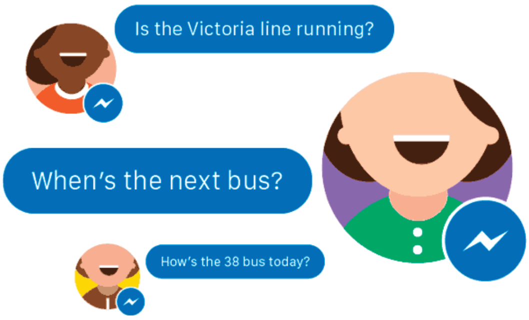
Congestion charge is a fee imposed on most vehicles for entering a prescribed zone during certain hours of the day. A fee is charged for entering the congestion charge zone between 0700–1800 hours Monday to Friday, excluding public holidays. However, a few vehicles are exempt from paying this charge, including two-wheelers, emergency service vehicles, health service vehicles exempt from vehicle tax, vehicles used by the physically challenged, taxis, and private hire vehicles.

TfL charges a peak fare for travelling on Tube, DLR, London Overground, TfL rail and National Rail services in London. This charge applies from 0630–0930 and 1600–1900 hours from Monday to Friday, excluding public holidays. This reduces congestion on these services during peak hours.

Advanced Traffic Management Systems:

Variable speed limits were introduced on roads and motorways to control congestion and increase safety of road users during adverse weather conditions.

Advanced Traveler Information System: Traveler Information Systems
TfL uses multimedia to disseminate traveler information. It recently launched a social media TravelBot service to answer customer questions. The application is powered by artificial intelligence and runs on Facebook Messenger.



TfL also displays real-time bus information at bus stops and on mobile applications. It has trialed a new bus occupancy technology that tells riders the number of free seats available in the upper deck. London's cycle hire scheme "Santander Cycles" has launched a new mobile application that allows cyclists to find which of the 750 docking stations have a free space available.

What's Next?

London Infrastructure Plan 2050 is the first attempt to identify, prioritize and fund London's future infrastructure plan to support growth. The plan outlines challenges and focuses on financial, environmental, social and economic sustainability. The plan covers transport, infrastructure, connectivity, energy, and housing.

London is also a pioneer city in terms of transportation operation data sharing. Tfl has committed to open data to serve the public transparently and to support the development of start-ups and small-to-medium technology companies. It is increasing investment in transportation; for example, providing parking space data and using Google Maps data for tube stations so people can leave cars and use tubes whenever necessary.

NEW YORK CITY

New York City, one of the most populous cities in the United States, was estimated to have a population of 8.54 million in 2016. It has a land area of 788 square kilometers and consists of five boroughs. Its road network is approximated at 10,000 kilometers.

New York City has a vehicle population of about 2.2 million registered vehicles. Congestion cost the economy $16.9 billion in 2016 and it is the second-most congested city in the United States. The average American commuter spent 42 hours in peak-hour traffic, whereas a New Yorker spent 89 hours* in traffic.

Most public transport systems are managed by the Metropolitan Transport Authority (MTA), the largest regional transportation system in the western hemisphere. It manages buses, rail, rapid transit routes, seven toll bridges and two tunnels. It transported, on an average weekday, 5.7 million riders by subway in 2016. New York City's challenges are mainly due to congestion, traffic accidents and emissions. Average bus speeds on arterial roads are 16 kph.

**Department of Transport, New York City*

Intelligent Transportation Solutions

New York City employs a variety of ITS solutions to tackle its challenges. Some key examples of ITS include intelligent traffic signals, traveler information systems, smart ticketing and variable speed systems.

Advanced Traffic Management Systems: Intelligent Traffic Signals

New York City upgraded its existing intelligent traffic signal infrastructure to a more advanced system. The new system uses RFID readers and cameras to transmit real-time information to the traffic management center, enabling real-time control of traffic. It is the world's largest traffic signal control system and boasts over 12,000 advanced solid-state traffic controllers, more than 60 RFID reader sites, 210 remote traffic microwave sensor vehicle detectors, 400 traffic video cameras, and can manage 16,000 intersections.

Advanced Public Transportation Systems: Transit Signal Priority

The New York City Department of Transportation (NYCDOT) implemented TSP in the Staten Island, Victory Boulevard/Bay Avenue Corridor from Saint George Terminal to Forest Avenue—a corridor extending 2.4 kilometers that includes 14 signalized intersections. About 300 MTA buses and 14 intersections were equipped with emitters and detectors, respectively. Time saved during morning and evening peak hours were 17% and 11%, respectively.

In 2016, the NYCDOT prepared the 2016 ITS Strategic Plan. Emerging Technology Readiness is one of six actionable areas identified as part of the plan, which focuses on horizon searching, figuring out how to adopt new technologies, what should change operationally or organizationally, and what level of adaption or adoption is needed.

New technologies that are part of the Emerging Technology Readiness strategic area include:

- Connected Vehicle Technologies
- Integrated Corridor Technologies
- Autonomous Vehicle Technologies

The USDOT is implementing an ITS-connected vehicle pilot across the United States; one of the locations for the trial is New York City. The deployment program is accelerating the adoption of connected vehicles and automation. New York City is also contemplating the implementation of a congestion pricing system to control congestion.

The NYCDOT will deploy CV technology at approximately 250 intersections in Midtown Manhattan, and central Brooklyn will be instrumented with Roadside Equipment (RSE) to communicate with up to 10,000 vehicles with aftermarket safety devices (ASD). The RSE will also be deployed along the FDR Drive. The instrumented vehicles include approximately:

- 6,000 Taxis - Yellow Cabs (Authorized for "hail" fares in lower Manhattan and airports)
- 1,500 MTA buses that frequent lower Manhattan
- 500 Sanitation & DOT vehicles servicing Manhattan
- 500 UPS vehicles servicing Manhattan

Advanced infrastructure that will be useful in enabling the CV pilot in NYC includes:

- 350 signalized intersections with CV technology- already "Advanced Traffic Controllers"
- Megabit Wireless communications backhaul covering all five boroughs
- Extensive fiber network for backhaul at key locations
- Central system that integrates all traffic signals and ITS devices citywide

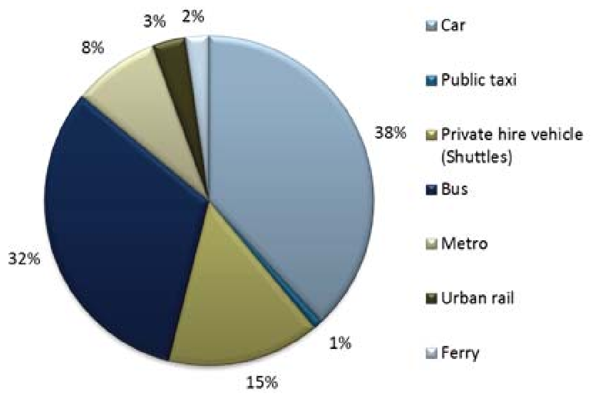
CASE STUDY: ITS IN ISTANBUL

5

INTELLIGENT TRANSPORTATION SYSTEMS
& BEST PRACTICES

MOBILITY OVERVIEW

The population of Istanbul reached 14.8 million in 2016. The city, Europe's only Mega City, has reached a nearly 99% urbanization rate, while Turkey's overall urbanization rate is about 74% according to World Bank Statistics. Urbanization brought commuting alternatives to Istanbul. Road transportation involves BRT, buses, minibuses, taxis and shared taxis, and work and school services.



As of 2016, Istanbul's vehicle population was 3.54 million vehicles, of which 2.64 million were cars. The number of people with a driver's license reached 5.9 million by the end of 2016. Topographically, Istanbul Straits divide Asia and Europe, as well as Istanbul City. The city lies on both continents. With residential, work and school settlements, there are approximately 480,000 vehicles crossing the three bridges connecting the continents daily and 35,000 vehicles crossing via Eurasia Tunnel, which is under water.

The existing transportation infrastructure also involves a 52 km bus rapid transit line built for metrobuses that pass over one of the bridges crossing Bosphorous. Metrobuses carry about 900,000 people daily in Istanbul. They have allowed 21 people out of 100 to give up personal cars. About 86% of passengers are commuted via road transportation.

Another mode of transportation between continents is seaway, with about 566,000 passengers daily. Seaway involves ferries and intercity sea buses.

Rail is also one of the most developing modes of transportation in Istanbul. Roads and seaway are integrated with railway transportation that is 150 km long and expected to reach 449 km by the end of 2019.

These road, rail and sea commuting alternatives are carrying about 12.7 million public transport and 7.8 million private transport passengers daily.

The connection between road, rail, and seaway has been developed tremendously in the past few years due to mega projects.

- ***3rd Bosphorous Bridge*** is the widest suspension bridge in the world at 59 meters. The bridge is now in use and a rail system will be constructed in the near future. The rail system will connect Marmaray, metro, two existing airports, and a third airport that will be built.
- ***Marmaray*** is a 13.6 km long rail line submerged under the Bosphorus, connecting Asia and Europe. This mega project has connections with existing metro infrastructure and bus lines.
- ***Eurasia Tunnel*** is a 14.6 km long road tunnel submerged under the Bosphorus. It shortened the journey between the two continents on the highly travelled D100 Highway connecting roads used by private cars, taxis and minibuses.

CHALLENGES IN INSTANBUL

The population of Istanbul has grown by 8.7% in the past five years. Moreover, the number of vehicles on roads has reached 3.5 million as of 2016 from 2.7 million in 2011.

Congestion: In a city as metropolitan as Istanbul, traffic volumes are increasing, leading to congestion. At peak times, travel times are extended, safety is a concern, and hazardous emissions are heavy.

As a result, authorities search for the best way to enhance traffic flow with solutions to expand the road network. Traffic flow is handled through three main arteries. However, all of these roads are subject to slowdowns and disruptions due to many connections and cannot serve as a transit route. The image below depicts the main highways of Istanbul.

Sprawl toward suburban areas is also an issue for Istanbul; however, workplaces, schools and hospitals are in city centers, which leads to increased travel time and creates congestion during peak hours.

Istanbul drivers spend 58.6 hours in traffic during peak hours, according to 2016 INRIX results; this is the 17th highest average globally. However, Istanbul has improved its rank in the TomTom Traffic Index to sixth in 2016, from first place in 2014, by lowering the congestion level to 49% from 58%.

Topography: Topographically, Istanbul has a unique challenge with uninterrupted traffic flow because it is located between Europe and Asia. The challenge stems from the fact that many people have to cross bridges while commuting to work every day.

Parking: Parking is another challenge in Istanbul. Drivers spend a considerable amount of time searching for parking. According to June 2017 figures, there are 3.6 million registered vehicles in Istanbul City. As a result, available parking spots are hard to find and are expensive is the city center. This is causing the total cost of ownership of vehicles to rise. Since vehicles are parked 90% of the time, the infrastructure and systemized solutions are important for a Mega City like Istanbul.

Construction Sector: In 2016, the Turkish economy grew at a rate of 3.5%, boosting the construction sector, including mega projects, housing and shopping mall projects. An initiative for urban transformation that replaces old buildings was also put in place. However, construction growth causes road blockage and management problems due to a higher amount of heavy commercial vehicles on roads.

Logistics: Mid-and heavy-duty trucks represent 18% of the total number of vehicles per day on roads. There is a regulation prohibiting commercial vehicles from driving on main highways and connecting roads between 6-10 a.m. and 16-22 p.m., except the 3rd bridge and highway, but trucks are still hindering traffic management.

Safety: In 2016, there were 16,000 accidents involving death or personal injury and 32,000 accidents resulting in damaged material, according to Security General Directorate statistics.

Technology Integration & Cybersecurity: The biggest problem is that all aforementioned challenges don't integrate into a single platform to work integrally. Adoption of different technologies and systems that are incapable of cooperating is increasing the magnitude of this problem. The integration of different transport modes, different vehicles, and infrastructure evolved as V2X systems are quite challenging due to arising from several connected problems such as cybersecurity and big data analysis.

To solve some of the above challenges in Istanbul, tracking of existing traffic has evolved fast and created innovative models in the past few years. It is a medium- to long-term process to reach the goal of efficient, safe, and environmentally friendly transportation.

KEY ITS SOLUTIONS IN ISTANBUL

To overcome Istanbul city traffic challenges, the application of ITS was introduced in the late 90s and has been improved since. ITS applications in Istanbul include nearly all the ITS areas that are globally available.

Advanced Traffic Management Systems (ATMS)

Signalization is one of the key elements of advanced traffic management systems. With the growth of intersections over the past 15 years, 2,142 intersections are working via signalization in multi-plan, demand-based reactive, dynamic, flash and adaptive modes. All signalized intersection points located in the city of Istanbul are kept on the geographic information system and can be monitored and managed online through the intersection control system and the Traffic Control Center (TKM) http://tkm.ibb.gov.tr/en.

The functional features of control systems in Istanbul include:

- Monitoring city traffic in real time
- Immediately receiving traffic density information
- Real-time monitoring and management of signalized intersections
- Providing visual and audio information of traffic intensity
- Informing drivers of instantaneous changes
- Providing traffic and road status information to users via web and telephone
- Monitoring of regional traffic conditions
- Conformity to e-transportation concept
- Information on alternative routes

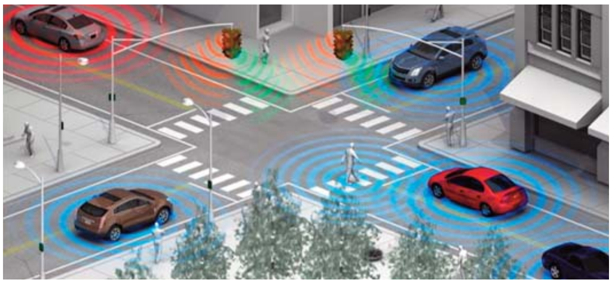
ITS components	Number of ITS components in Istanbul, 2017
Camera	761
Tunnel Camera	455
EDS	439
Detector	433
Sensor	862

Istanbul is using different ITS components such as cameras, traffic enforcement systems (EDS), detectors and bluetooth sensors. In 2010, a full adaptive traffic management system (ATAK) was introduced to improve traffic by controlling traffic signals with real time intervention. Currently, ATAK is providing fuel and time savings equivalent to 37 million USD yearly.

Since ATAK began, improvements include:
In the near term, ATAK is expected to provide:

Improvement Parameter	After ATAK
Travel Time	20% decrease
Delays	30% decrease
CO Emissions	18% decrease
Fuel Consumption	15% decrease
Average Speed (in congested area)	35% increase

- A better integration with Variable Message Systems and city congestion maps, with better directions
- Green light corridor ability for emergency vehicles such as ambulances, police and fire trucks
- Improvement of vehicle-to-vehicle systems by optimizing waiting time and increasing vehicle safety



Traffic detection systems (TEDES) and Tunnel Control Centers are the other key ATMS applications widely used in Istanbul. The traffic enforcement systems (EDS) are installed in 439 points, and their breakdown by different types is as follows:

EDS Type	Number of Points
Red Light Enforcement	155
Hardshoulder Enforcement	97
Parking Enforcement	89
Speed Enforcement (Corridor)	40
Reverse Direction Enforcement	18
Tram Lane Enforcement	16
Mobile Enforcement	11
Offramp Enforcement	6
Pedestrian Crossing Enforcement	3

Advanced Traveler Information Systems (ATIS)

The instant traffic density data obtained from Traffic Control Center, the meteorological data obtained from automated road and meteorology surveillance sensors, and the infrastructure works information obtained from road networks are processed and presented on the Digital Traffic Density Map.

The generated map is published via the web, directing drivers and passengers to alternative routes for economical and comfortable travel. This map is also available on mobile platforms-IBB Mobile Traffic on IOS and Android applications-that provide traffic information at 530 points within Istanbul. This has been downloaded by 9.9 million users as of 2017.

IBB has also developed a mobile navigation application for all transportation modes from private cars to mass transportation, providing information about Istanbul's ITS applications, such as traffic cameras, closed road segments, traffic estimation for the next 60 minutes, and so on. It has been downloaded by approximately 600,000 users following its release in 2017.

To solve parking problems, a mobile application was introduced to show empty parking spots in a pilot region. It is expected to expand into other regions of Istanbul.

Advanced Public Transportation Systems (APTS)

APTS in Istanbul covers multimodal oordination, transit vehicle tracking, and real-time location tracking to inform passengers at stations about vehicle locations. It also covers fare collection through an electronic system.

At bus stations, there are electronic panels showing bus timelines. Expected arrivals of buses for specific stops are tracked, thus making it easier for passengers to plan their routes, even during heavy traffic.

Istanbul Card is an electronic payment system that works with radio signals (RF). Istanbul card can be used in nearly all modes of public transport, such as road, rail and seaway. The first electronic card was used in 2011, and now there are 20 million electronic cardholders. Istanbul Card is used for parking payments, taxis and other social services.

Also for taxis, iTaksi was developed by ISBAK (Istanbul IT and Smart City Technologies Inc.) for the IBB and is operated by ISPARK on behalf of the IBB.

iTaksi membership is mandatory for all Istanbul taxis and taxi drivers. Installation of iTaksi equipment (the iTaksi tablet, security camera and a panic button for the driver) for all Istanbul taxis has begun.

Advanced Transportation Pricing Systems (ATPS)

An Electronic Toll System (ETC) in Istanbul is being used on highways and bridges connecting Bosphorous. The automated toll collection system began 1999. It has been improved to stop disruptions in traffic. As of 2017, multi-lane, free-flow ETC systems are on several points.

Commercial Vehicle Operations (CVO)

Fleet Operations serve Istanbul residents with 5,100 buses and over 40,000 round trips. This bus fleet is controlled over an electronic system from a central location in the Ikitelli Fleet Management Center. Buses are tracked via GSM/GPRS and GPS satellites. Sensors also help distinguish different regions and create alarms and routes according to specific needs.

Another application of CVO is roadside inspection stations that are built to inspect weight, recognize plates, and urge drivers to drive safely under the highway regulations.

This is necessary, especially for school buses and work services. To address and overcome the logistic and construction challenges in the growing Istanbul economy, partnerships with telecommunication companies are made to enable M2M connections all over Turkey.

As of December 2016, there were 4 million M2M members all over the country. An M2M connection connects vehicles with a SIM card and tracks locations through GPS satellites, uses vehicle sensors such as fuel consumption, and sends information to the operating body.

In addition, it helps digital tachographs track working hours and helps drivers check their route via GPRS integration. Since 2007, earthmoving city trucks are required to have telematics devices and are monitored by IBB. There are about 10,000 trucks monitored through this regulation.

CONCLUSION

The world's urban population has increased rapidly in the 21st century, which is projected to reach two-thirds of the total by 2050. This brings numerous challenges for cities to meet the needs of their growing populations. Among them, transportation becomes one of the major topics, as it directly impacts quality of life. City governments have adopted many new solutions, evolving in parallel with technological advancements, and they are continuously seeking innovative improvements to transportation quality. As the transportation problems get more and more complex, the need to implement intelligent solutions becomes inevitable.

Along with construction of new roads, bridges and tunnels, Intelligent Transportation Systems (ITS) are key to address transportation-related challenges all over the world, and from the smallest cities to Mega Cities, new systems are being installed to manage transportation. The use of ITS is not only improving the quality of transportation in cities, but it also contributes to the economic progress.

To show examples of global best practices for intelligent transportation systems, Frost & Sullivan has selected cities from three different continents: London, New York, Singapore and Istanbul. Frost & Sullivan analyzed the transportation policy and practices of these cities in order to understand how they oversee these challenges and what intelligent transportation system best practices they implement. In all of the cities analyzed, ITS is classified under different categories, including traffic management, public transportation, traveler information, pricing systems, commercial vehicle operations, emergency management, maintenance, and construction management. Each category has major benefits for transportation challenges, such as improved safety, better traffic flow, lower transportation cost, better environmental quality, increased business activity, greater user acceptance, better planning information, and better travel information.

Among the cities analyzed within this white paper, Istanbul is one of the most vulnerable cities to transportation and traffic challenges. It is the only Mega City in Europe, with 15 million population and 99% urbanization rate. In the last decade, a vast amount of investment has been made by the city government, not only on the mega projects such as 3rd Boshprous Bridge, Marmaray and Eurasia Tunnel, but also on intelligent transportation systems. This started with signalization in the mid-90s and it is now one of the world's best practices. Istanbul is using a wide range of ITS applications and technologies in the most effective way to improve transportation quality and safety for its citizens.

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ABOUT ISBAK:

ISBAK Istanbul IT and Smart City Technologies Inc. was established by the Istanbul Metropolitan Municipality in 1986 with the purpose of providing project design and implementation services through traffic and system engineering.

ISBAK is one of the leading Smart City solution providers in Turkey. As a subsidiary of Istanbul Municipality, its solutions serve more than 15 million people living in this city. The company now aims to transfer its 30 years of experience in Intelligent Transportation Systems (ITS) to Smart City solutions and become 'Architect of Smart Cities' in Turkey and the world.

ISBAK believes that each city has different problems which require different solutions. In line with this, the company helps cities be smarter and more resilient by providing solutions tailored to their specific needs. ISBAK also offers consultancy services and carryout R&D activities to continuously improve its offerings.

ISBAK offers a broad range of Smart City solutions in Turkey and abroad:

- Intelligent Transportation Systems
- Transportation Planning and GIS
- Safe City Management System
- Smart Lighting System
- Tunnel Management System
- Fleet Management System
- Consultancy for Smart City Transformation
- IoT-based Cloud Traffic Management
- Control and Operations Centers for Metropolitan Areas

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