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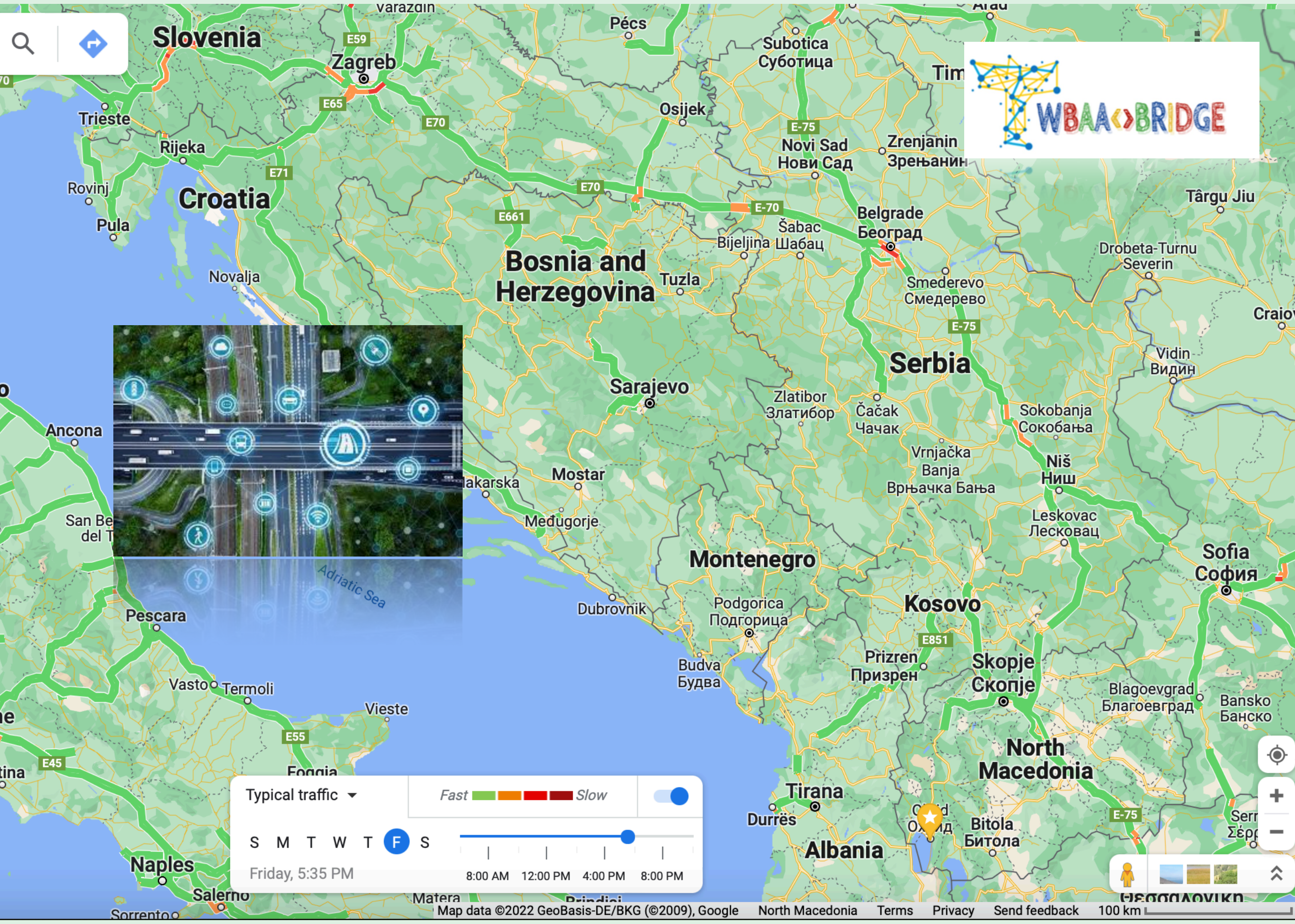

Addressing Trans-Regional Issues in Intelligent Transport Systems from Managerial and Technical Perspective

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EXECUTIVE SUMMARY

Western Balkans countries represent an interrelated region struggling to find answers to the following questions: Can the infrastructure be revitalized? Can the environment be revitalized? Even more importantly – can the economy and society be revitalized? In order to tackle the abovementioned challenges at a regional level, it is important to identify the institutional, economical, technological, infrastructural, and environmental components countries have at their disposal in promoting sustainability of all kinds in the cross-border region.

This book pioneers a comprehensive approach aimed at addressing community problems by facilitating co-creation of diverse stakeholders, and developing a methodology for addressing trans-regional issues with innovative managerial and technical aspects in the domain of Intelligent Transport Systems (ITS). The methodology is based on a MultiCreation approach, combined with PESTLE analysis as a means for identifying the important elements of success. The devised methodology brings together experts, researchers, government, academia, Western Balkan Alumni Association (WBAA) members, students, and civil society to create a vision strategically, with some outlined tactics; identifies the integration between approaches, and provides a framework for making choices where integration is not possible.

The content of the discussions in this text describes the generated approach applied to the construction of open and adaptable ITS in a very wide area of road traffic, transportation, and their application. The book starts with global technologies in communications and computing and well-known implementations of ITS in road transport with special attention on the possibility of using the potential of ITS. The implication of digital transformation, including the Internet of Things (IoT), artificial intelligence (AI), 5G, circular economy principles, SDGs, automation, and electrification of the transport sector and new business models such as Mobility as a Service (MaaS) are covered. The book analyzes the ITS from the point of view of the application of new information and communication technologies whose services and functions represent the backbone of ITS activities. The methodology, long-term goals, short-term goals, initial applications and ways of realization, and a new series of recommendations and measures aligned with international standards are proposed. In the end, a vivid picture of the challenges facing the Western Balkan region as it seeks solutions to transport, economic, and environmental problems is described in the case studies section.

By networking, knowledge, experience and expertise, the authors attempt to provide peers, students and experts, with the basis of understanding the big picture of the Western Balkans, the ITS and the complex approach to it, on the one hand, and with a useful guide in planning the introduction of such complex ITS from the managerial and technical aspects, on the other hand. The book incorporates learnings from the project: *Developing participatory methodology for addressing trans-regional issues bridging science and practice: Use case of Intelligent Transport Systems from managerial and technical perspective,* realized with the support of the Western Balkan Alumni Association (WBAA) and the European Commission.

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[1] http://tactical-management-in-complexity.com/course/view.php?id=27
[2] https://www.western-balkans-alumni.eu/

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CHAPTER I

THEORETICAL FOUNDATIONS AND MAIN CONCEPTS

1.1 Background

Considering the significance of the transport sector, there are two levels of influence that may be identified – one on the quality of living of the population and the other on the overall economic development of a country. There is little doubt that traffic infrastructure directly contributes to the activation of economic potentials, and that transport sector revenues have a significant share in the GDP structure of a country.

A coherent transport policy can also contribute to the reduction of budgetary expenses into the transport sector, either by providing conditions for efficient infrastructure management or by using instruments to reduce external costs (congestion, fatalities and pollution).

Transport occupies a central position in the fabric of any modern-day urbanized nation andthe pervasiveness of transport solutions to transport problems can have major influences on people’s lives. These influences are reflected in the constraints that society currently places on the development and evaluation of various solutions; generally, they must be *economically* sound, *socially* credible, *environmentally* sensitive, and *politically* acceptable.

The need for an efficient transport system is a vital element of modern life and roads are a major national investment.

The key determinant in the transport sector is infrastructure investments. Table 1 shows the total investments (for the year 2020) in road infrastructure, measured as a share of GDP for total investments in euros for EU member countries.

Table 1. Total investment in road infrastructure for EU member countries

Country	Euros
Austria	548 000 000
Belgium	735 000 000
Bulgaria	525 104 816
Croatia	442 003 608
Czech Republic	1 640 906 428
Denmark	1 083 963 935
Estonia	244 000 000
Finland	1 444 000 000
France	9 089 727 000
Germany	16 050 000 000
Greece	797 885 701
Hungary	1 820 222 428
Ireland	837 000 000
Italy	4 310 000 000
Latvia	198 000 000
Lithuania	466 000 000
Luxembourg	246 225 525
Poland	3 207 598 127
Romania	2 181 564 246
Slovak Republic	752 200 000
Slovenia	235 000 000

Spain	3 927 291 764
Sweden	2 941 714 896

Source: OECD data[6]

Balanced regional economic development, new and sustainable employments, promotion of labor mobility, market accessibility, and productivity can be provided by efficient transport infrastructure.

Other costs related to the environment, traffic accidents, and the consumption of energy are not as evident. Road transport contribution to the total air pollution is generally increasing. Transport is responsible for more than half of all NOx emissions and contributes significantly (around 10 % or more) to the total emissions of the other pollutants. Road transport, in particular, continues to make a significant contribution to the emissions of all the main air pollutants (except SOx). While emissions from road transport are mostly exhaust emissions arising from fuel combustion, non-exhaust releases contribute to both NMVOCs (from fuel evaporation) and primary PM (from tyre- and brake-wear, and road abrasion). Emissions of primary PM2.5 from road transport have increased by 19 % since 2000, and the relative importance of non-exhaust emissions has increased as a result of the introduction of vehicle particulate abatement technologies, which have reduced exhaust emissions. In 2016, the non-exhaust emissions of PM2.5 constituted 42 % of emissions from the road transport sector, compared with 17 % in 2000 (for PM10, the contribution increased from 30 % in 2000 to 60 % in 2016)[7].

[6] https://data.oecd.org/transport/infrastructure-investment.htm

[7] https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-6

Viewed from the perspective of sustainability, traffic growth has become a major problem. We came to the point where the question of preserving the environment and natural resources has come to its edge.

As for traffic accidents, road traffic injuries are a major public health problem in the WHO European Region and are the cause ofpremature death of some 120 000 people every year. They are the leading cause of death in children and young adults, aged 5 to 29 years. In addition to this, about 2.4 million people are estimated to be so seriously injured as to require hospital admission each year. This puts a strain on the resources of health systems as they strive to provide quality emergency trauma services, while faced with other competing priorities. Apart from the pain and suffering experienced by the families and the loved ones of traffic victims, road traffic injuries cause a substantial economic loss to society: up to 3% of the gross domestic product of any given country. From these figures, it is clear that traffic safety is both social priority and an economic challenge[8].

As a final point, the use of energy must be taken into consideration. There is a worldwide demand for more efficient products to reduce the consumption of energy and other natural resources in line with improving the overall sustainability. The EU legislation on ecodesign is an effective tool for improving the environmental performance of products by setting mandatory minimum standards for their energy efficiency. This eliminates the least performing products from the market, significantly contributing to the EU's energy and climate targets. Ecodesign also supports industrial competitiveness and innovation by promoting a better environmental performance of products throughout the internal market[9].

[8] https://www.euro.who.int/__data/assets/pdf_file/0015/43314/E92789.pdf

[9] https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/about_en

All data presented above illustrate that the costs associated with road transport in terms of loss of human life, the impact on the environment, and the utilization of non-renewable resources are profound.

That is the background for sharing the common interest in finding means to reduce the high costs. This means that the investments should be made wisely, to ensure that road transport is as safe and environmentally sound as possible. It is, therefore, a common interest for the countries to deal with common problems by working together for their benefit. This is why broad international research and cooperation are recommended.

What follows is a discussion on the need for implementing *new advanced technologies* as an established route to resolving or at least minimizing traffic problems. What follows is a discussion on the new advanced technologies as a modern solution to an old problem. Thus, we come to the question: **What is ITS?**

Advances in technologies have revived the search for “smart”, or “intelligent” highways and vehicles, i.e the search for Intelligent Transport Systems (ITS). *ITS refers to a different, smarter approach to the transport system, including traffic management and control, and road safety; this is not a monolithic system that will be built and is not even a system of systems.*

The development of ITS is a challenging task which requires a multidisciplinary and multi-faced approach for: i) addressing transport, and economic needs; ii) tactical and managerial/governance efforts for a complex system; iii) strong expertise in technologies such as the Internet of Things (IoT) artificial intelligence techniques, computer vision, machine learning (these fields have shown an upward trend of growth in 21st century and they reshaped our lives).

The introduction of ITS can be considered as one of the main steps that will stimulate the application of new information and communication technologies. The conditions of openness, interaction, and flexibility of the system strengthen the role of industry in the construction and operation of the ITS subsystem. However, the main question that arises here is: *How to build a secure and cost-efficient ITS system*?

In this chapter the theoretical foundation of ITS will be described; we will get into more specifics as to how the architecture defines the individual components function and their integration. On the other hand, the state-of-the-art of transportation technologies in the USA and Europe offers a very good sense of comparison between the European and American system approaches and that will be used as a valuable base for Western Balkan countries which are at beginning of this same path. This section will review some of the implemented systems – starting from the simple and going to the more complex ones. The review is not intended to be comprehensive but it will attempt to cover the commonly used systems and services.

1.2 Definitions for Intelligent Transport Systems (ITS)

ITS can be seen as a cybernetic or information and communication upgrade of a transport system. ITS functionalities present upgrades to traditional functions of traffic and transport systems and they create new horizons and possibilities in problem-solving.

ITS enables information transparency, controllability, and improved response of transport system. All these advanced technologies based on sophisticated inventions routinely monitor, communicate and coordinate some of the most critical functions of transportation operations. Changes are coming at us at an ever-faster rate. Advances in technologies have revived the search for “smart”, or “intelligent” transport systems.

The term “intelligent” generally refers to the capability to adapt to environmental changes (variable conditions and other situations). As a term, ITS entered in scientific and professional transport and traffic engineers' vocabulary in the 1990s, after the first ITS world congress was held in Paris in 1994. Before that, similar approaches have been qualified as road transport telematics and intelligent highway systems (ex. Telematics – **tele**communication & auto**matics** (infor**matics**)). The main components of ITS are the following: sensors, ICT, and algorithms.

Some of the ITS definitions derived from relevant literature are:

Definition 1[10]*:*

ITS can be defined as a holistic, control, information, and communication upgrade to a classic transport and traffic system, which enables significant improvements in performance, traffic flow, more efficient transport of passengers and goods, improvement of comfort, and security of passengers in transport, reduced pollution, etc.

Definition 2[11]*:*

ITS is a control and information-communication upgrade of classic traffic, transport, and logistic system with substantial improvements for network operators, service providers, users, and general society.

Definition 3[12]

Intelligent Transport Systems (ITS) are the control and information systems that use integrated communications and data processing technologies for the purposes of:

- *improving the mobility of people and goods;*
- *increasing safety, reducing traffic congestion and managing incidents effectively;*

[10]https://bib.irb.hr/datoteka/801261.ITS_Selected_Lectures_Mandzuka.pdf
[11]Ibid, pp.7
[12] www. https://rno-its.piarc.org/en/intelligent-transport-systems

- *meeting transport policy goals and objectives – such as demand management or public transport priority measures.*

Definition 4[13]:

Intelligent transport systems (ITS) apply well-established technologies of communications, control, electronic and computer hardware and software to the surface transportation system. The main features of ITS are: *adaptability and information in real-time* (Figure 1).

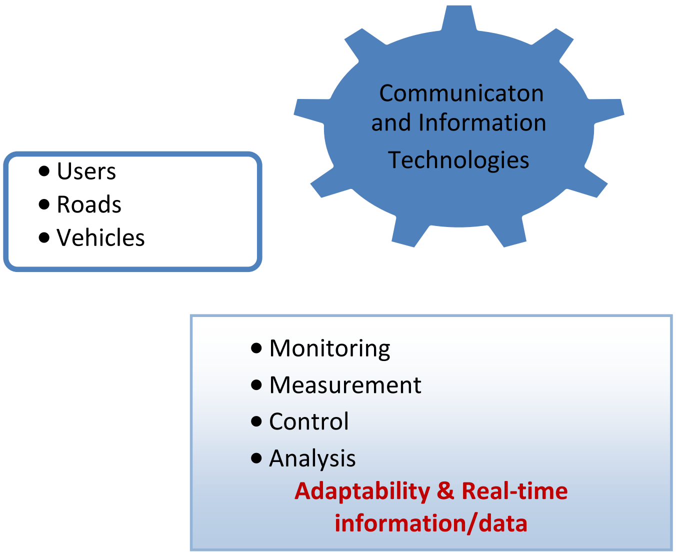


Figure 1. The core of ITS
(Source: The Authors)

Each state uses these technologies to a different degree, and the sophistication of their implementation varies as well. Transportation experts

[13]WBAA bridge – North Macedonia, 2021,project web page

must comprehend the main uses and capabilities of ITS in order to understand prospective benefits, associated costs, and the best way to implement ITS.

1.3 Historical Development of ITS

The first flicker of highway intelligence was patented in 1923 by Garret Augustus Morgan.This invention is to be identified as the traffic light, and even today remains the most critical traffic technology. Charles Adler imagined an intelligent transportation system that was ahead of its time (Figure 2).

Adler had embedded magnetic plates in the road where it led into a precarious curve, and he was now waiting for a specially prepared car to drive over the magnets. The magnets would activate a speed governor connected to the vehicle's engine, slowing it to 24 kilometers per hour.

Figure 2. The men who invented Intelligent traffic control (Source: The Used under creative commons (cc))

Adler had developed this automatic speed-control system for railroad crossings, the scene of many deadly accidents at the time. But he soon came to imagine all sorts of applications for it: "Dangerous Road intersections, streets on which schools are located, bad curves, and even steep downgrades," according to an article in the Baltimore News[14].

The future with technologically sophisticated and advanced traffic and transport solutions has preoccupied the collective American imagination for decades. The ideas behind ITS are not new and the elements have been used for many years. Because of the speedy evolution of the "intelligent" concepts, the organization called Intelligent Vehicle and Highway Society 1990 changed its name to Intelligent Transportation Society in 1994. With transportation projects and experiments in the USA, Europe, and Australasia underway, no one can be far from at least one.

The first ITS studies began in the late 1960s and early 1970s in Japan with CACS (Comprehensive Automobile Traffic Control Systems), and in the USA and Germany with ERGS (Electronic Route Guidance System)[15]. The developments achieved in communication technologies since the mid-1980s accelerated the ITS applications. Large-scale projects were initiated with the partnership of the government and the industry, and ITS, which expanded with applications such as electronic toll collection systems, smart junction control systems, passenger and driver information systems, and traffic control centers, in the 1990s with these projects, began to be recognized as a separate discipline.

Research and development programs in Europe and Japan were launched in the middle of the 1980s, whereas in the US these activities have increased in the past 10 years. There are two reasons for this renewed interest in the US. First of all, many ITS concepts have become technologically feasible as the computer and telecommunications capabilities evolved dramatically in the last 25 years. Furthermore, some traditional approaches to solving

[14] https://spectrum.ieee.org/the-man-who-invented-intelligent-traffic-control-a-century-too-early

[15] https://highways.dot.gov/public-roads/fall-1996/intelligent-transportation-systems-japan

transportation problems are less available today. In particular, the construction of new roads to relieve traffic congestion is facing land use limitations. The ITS alternative could complement the classical approaches.

In the US, ITS research was conducted in numerous independent projects on federal, state, and local level, as well as at universities and industries that have their research programs. As active universities in ITS research, the University of California, Berkeley, Texas A&M University, the University of Michigan, and Massachusetts Institute of Technology have long-standing ITS research programs. At the national level, the ITS coordination was performed with Mobility 2000, in which participants come from governmental institutions, industry, consulting, and the academia.

At the federal level, the US Department of Transport (DOT), the Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (NHTSA), and the Urban Mass Transportation Administration (UMTA) had provided funding for ITS research. In the fiscal year 1991, $20 million were provided in funding for research and operational tests in all four areas of ITS technology.

Much ITS research has been funded by state departments of transportation, most notably, the California Department of Transportation (Caltrans), which has been the biggest state sponsor for ITS research in the USA. Most of the research is conducted under the Program of Advanced Technology for the Highway (PATH), under the direction of Caltrans and the University of California, Berkeley. Caltrans with FHWA, General Motors, and some local agencies in Los Angeles sponsored the Pathfinder experiment (1988) on traveler information technology.

In Florida work has been done on TRAVTEK-a test of traveler information system that provides traffic and tourist information to a fleet of 100 vehicles, equipped with communication and navigation units.

In Chicago, a large-scale field test on Chicago Demonstration Traveler Information Project has been expected to employ a fleet of several thousand vehicles equipped with navigation units that will communicate with an area-wide radio-frequency infrastructure.

In Colorado, a weigh-in-motion scale targets trucks weighing more than 30, 000 pounds on downgrades. Based on weight and previously determined algorithm, the computer calculates a safe speed, then displays a message sign. In New York, tests to detect collisions and automatically order emergencies through cellular phone lines were developed. In Idaho, Wisconsin, and Minnesota, video images from computer databases document out-of-service conditions on individual trucks. In New Mexico, researchers were evaluating a “black box” similar to those in aircraft, to help reconstruct and analyze traffic accidents.

As for the automated vehicle navigation system, a demonstration is made on a 7-mile stretch of I 15 near San Diego. Hundreds of magnets that guide the vehicle are spaced by 3 feet and embedded in the pavement. The vehicles use video, radar, laser, and/or infrared sensors as guidance. They read the distance from vehicles and objects and track lane position. The USA’s initiatives regarding ATT have started to experience some benefits of smart concept applications.

As for trucks, there were two systems in the USA that offer smart movement-Pre Pass in five western and southern states and along Advantage I-75 from Florida to Ontario, Canada. The idea was for the trucks in motion to bypass the weigh stations and state entry inspections by using transponders. There are 1,000 WIM (Weigh-In-Motion) stations around the world, 450 of them in the US. In that period, according to the Colorado food distributor with 300 transponder-equipped tracks, the technology saves anaverage travel time of about 15 to 30 minutes per vehicle for each state at the entry crossing.

The University of California at Davis and Caltrans was using technology to keep maintenance workers inside vehicles and reduce tolls. The technology is designed to improve pedestrian safety by automatic roadway markings application, cone placement, retrieval, and even automated garbage collection by a robotic arm that picks up objects on the road or at the side of the road.

ITS has enhanced emergency response through emergency services provided via satellites and advanced communication systems that notify medical teams. Improved mapping systems aid authorities in locating remote addresses by tracking the caller on a digital map at the dispatch center. In rural areas Mayday (international radiotelephone distress system) transmits a distress signal and vehicle location to a central command center. In this case, the car was equipped with a "panic button" or a cellular phone capable of determining the longitude and latitude. These systems can be used if a car overheats, blows out a tire, hits another car, or is stranded by any severe weather emergency in a rural area. Drivers can immediately notify police or emergency crews of accidents. There is a practical application of these systems in the USA (GM and Ford are two car manufacturers producing Mayday systems).

ITS enhances drivers' safety by issuing a warning about a potential collision and rollover. A system on the ramps warns the driver to slow down when the safe speed is exceeded at exit ramps (Washington); or, a truck speed warning system on a narrow curve; or, collision warning devices in trucks installed by Transport Besner Trucking Co. (on-board computers and sensors that control steering and braking); blind-spot detectors (used on school buses).

ITS was mostly financially supported by the private sector. The federal share was projected to decline. DOT and ITS America are playing active roles in coordinating ITS activities on a national level. Field tests and evaluation of benefits are needed for the real benefits to be publicly known and, consequently, accepted by the users.

European Experiences

Although the US activities started in the 1970s and 1980s, the European activities were faster as a result of the more pressing transportation needs (particularly in the urban areas) as well as government policies. The European experience has helped the American initiative and movement towards ITS. The American community has adopted the desirable characteristics of the European programs.

The most important European ATT programs are: PROMETHEUS (Programme for European Traffic with Highest Efficiency and Unprecedented Safety) and DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe). The former was launched in 1986 by European car companies within the framework of EUREKA (European Research Coordination Agency). It was a 7-year, $700 million program led by Daimler-Benz (privately supported). The research was focused on the vehicle side. By contrast, the DRIVE program established in 1989 by the commission of the EU emphasized the infrastructure side of ITS. The first phase (DRIVE I) was worth $130 million and over $150 million were allocated for its second phase (DRIVE II). It was split up in half between the public and private sector.

Other European projects such as Traffic Master (Traveler Information System and Ali-Scout (route guidance project) have developed outside PROMETHEUS and DRIVE. Traffic Master is a privately owned and operated system for providing real-time traffic information. It operates in the London area since mid-1990.

SOCRATES (System of Cellular Radio for Traffic Efficiency and Safety) as a Traffic Management/Traveler Information System project was the largest DRIVE I project. It used the pan-European radio system known as Global

System for Mobile Communication (GSM), which replaced the cellular radio as an alternative to roadside beacons for intercommunication with vehicles. The test sites were in Sweden and Germany.

POLIS (Promoting Better Urban Operativity Linking Integrated Services) is a Traffic Management/Traveler Information Project.

European vs. USA experiences

As an epilogue, it could be assessed that there is a recent European leadership in specific ITS technologies and projects. There is something that the US could learn from the European experience. An incremental approach has been recognized by both the private and public sector in the US. The private sector needs early economic return as an incentive for ITS investment and the public sector needs an early winner to demonstrate ITS feasibility to taxpayers.

Differences between policy impacts of ITS activities in Europe and the US are few (mainly in privacy areas which is more an issue in Europe, and legal liability, which is more an issue in the US). The US can benefit from public policy debates and actions.

European ITS projects are expected to bring only incremental relief to urban traffic congestion. In Europe, social benefits as a means of relieving traffic congestion and improving traffic safety have been assessed not so much in terms of helping the equipped vehicles to reduce their travel times, but in assessing the total system traffic and safety impacts from the view of traffic management authorities. The issue of a tradeoff between efficiency and safety is very questionable – it may be reduced as drivers are diverted from motorways to urban streets, but a "rat race" may occur.

It is obvious that buses and high occupancy vehicles, through ride-share or car/van pools improve highway capacity. It has been pointed out that public transportation (bus or rail transit) would not be a ready traffic congestion relief solution in the US, given the American traveling habits, individual freedom preference, and suburbanization in metropolitan areas. Conversely, public transportation in Europe has a tradition of being a common mode of travel. The urban population is much more compact and dense. There are many ITS applications to public transportation in Europe such as:

- Fleet management;
- Signal preemption for buses;
- Convenient information for multimodal pre-trip planning;
- The most impressive is the ITS smart bus in Germany with integrated multifaceted functions of fare collection using smart cards, signal preemption (bus priority), station information on bus stops as well as on-board and automatic vehicle location for the dispatcher.

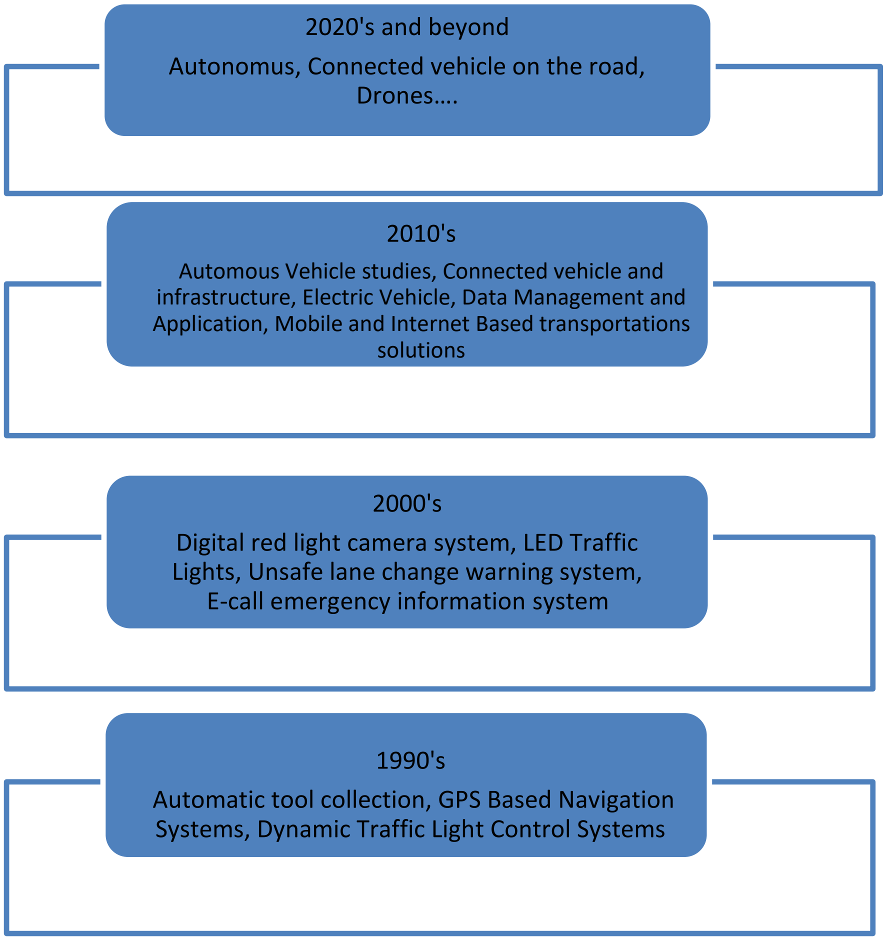
Europe has shown much diversity in its ITS concepts, both technically and institutionally. The US has an excellent top-down engineering approach to the development of ITS architecture. There is much to be gained from trying many options rather than narrowing down too soon or copying from one country to another. This is Lesson No. 1 for developing countries that are at the very beginning of ITS implementation!

The conditions and traditions differ so much and the solutions in the long run are likely to be different in Europe and the US and maybe even different from state to state within the US. The process of continual learning and the goodwill on both sides for international cooperation is very promising. Both can learn so much from each other about ITS. International research has become a strategic element. The preconditions for doing research are the following: solid research programs, up-to-date facilities, and a sound scientific community. Joint research minimizes the risk of overlapping and formulating ineffective or irrelevant conclusions. The members of OECD and EU are making their commitment steps to exchange information with non-member countries. The principal activities address providing technical or policy support.

All these examples point to a revolutionary turn into technological development. But, revolutions could be very messy, even in technology. ITS is no exception. Its concepts are evolving at a very rapid rate, and some demonstration projects could be bypassed by commercial development. For an instance, General Motors will be offering a Global Positioning System and cellular communications device in its cars much like the systems undergoing federally financed tests.

There are some fears that ITS will affect various areas of people's lives and other technologies as well. For instance, satellite-communication standards may be affected by smart highway development. Secondly, individual privacy is going to be unprecedently threatened as well as corporation confidentiality. Sometimes, the technology could be abused by the operators (system operators were using cameras to observe pedestrians instead of monitoring the traffic in one county in Florida). But elements are developing within ITS intelligent vehicles, intelligent highways, wireless smart cards for electronic toll collection, dynamic navigation systems, adaptive intersections control systems, more efficient public transportation, quick Internet-supported dispatch services, automatic notifications by vehicles positioning in incidents, a biometric system for passenger protection, etc.

The essence of ITS is the integration of individual solutions based on common ITS architecture and its very good system specifications. Today, some of the fears have been overcome, and someone are still present but reshaped into new "clothes". In the end, the development of some of the most significant ITS is depicted in Figure 3.


2020's and beyond
Autonomus, Connected vehicle on the road, Drones....
2010's
Automous Vehicle studies, Connected vehicle and infrastructure, Electric Vehicle, Data Management and Application, Mobile and Internet Based transportations solutions
2000's
Digital red light camera system, LED Traffic Lights, Unsafe lane change warning system, E-call emergency information system
1990's
Automatic tool collection, GPS Based Navigation Systems, Dynamic Traffic Light Control Systems

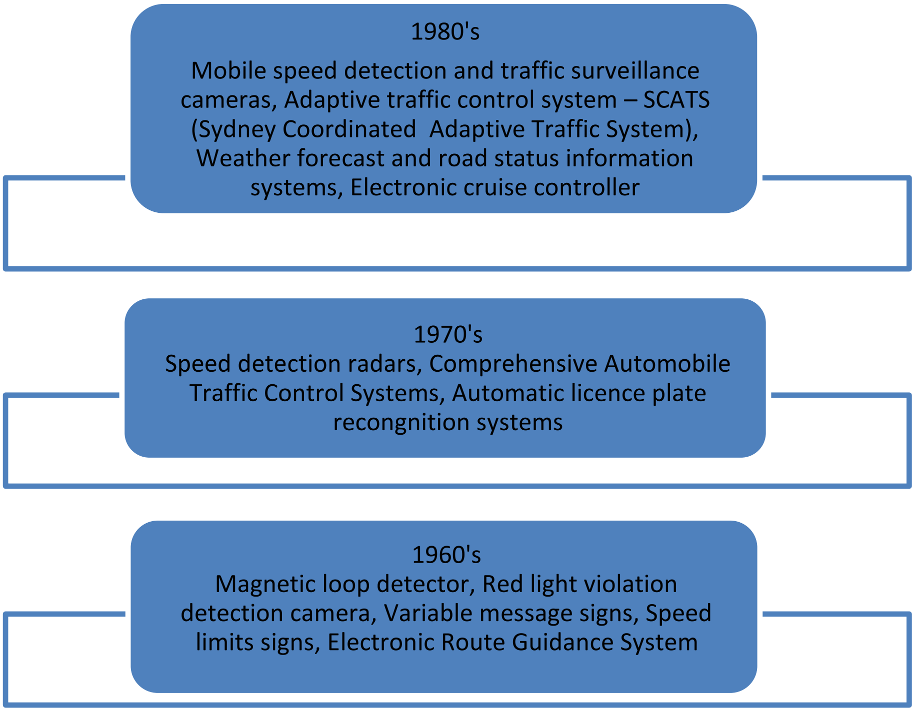


Figure 3. Most significant ITS development
(Source: The Authors)

ITS is an interdisciplinary concept that affects and contributes to a number of industries, including transportation, the automobile industry, health care, the environment, and information technology.

Figure 4 shows a list of sectors which are impacted by the application of ITS.

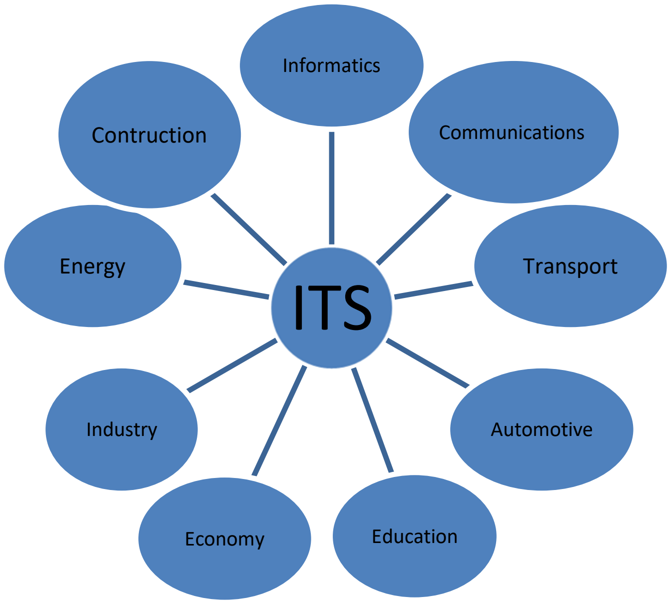


Figure 4. Sectors affected by the ITS application
(Source: The Authors)

1.4 ITS Benefits

The goals of the Intelligent Transport Systems (ITS) are to increase traffic efficiency by minimizing or reducing traffic problems (Figure 6). The expected results are expressed in measures of improvements in the transportation system as defined by the following quantities:

- Percentage of traffic accidents reduction;
- Percentage of the increase in throughput of the transportation system;
- Percentage of travel time reduction with private and commercial vehicles;
- Savings in operational costs for the public sector;
- Customer satisfaction.

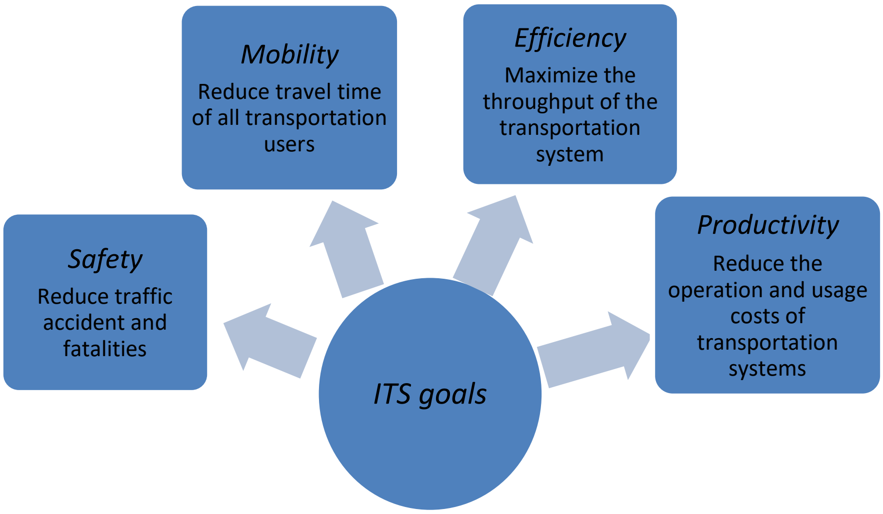


Figure 5. The goals of ITS
(Source: The Authors)

To achieve these goals, the strategic objectives are:

- Integrated deployment of ITS infrastructure;
- Nationwide deployment of commercial vehicle infrastructure;
- ITS rural infrastructure elements deployment.

ITS is not a monolithic system. To the contrary, it is a multi-faceted approach for addressing transport needs. Most of these approaches are already commercially viable and are here today. Others require long-term research. In general, the selection of potential ITS solution rests on the following criteria: flow efficiency, safety efficiency, economical productivity, cost reduction, and environmental benefits.

Early ITS implementation is very advantageous for developing countries and economies, since the rapid increase in the number of motor vehicles on the roads puts additional pressure on the current infrastructure, which, in turn, needs to work more efficiently to handle the increased traffic. We need to *emphasize that every ITS deployment needs to be properly tailored to the local context. In order to ensure the greatest economic advantage and long-term efficiency improvements, it will also take into account the institutional capacity to collaborate across organizations and to install and maintain cutting-edge technology (Lesson No. 2!).*

1.5 ITS Technologies and Services

ITS utilizes a wide range of enabling technologies including:

- Data processing, data management, and archiving technologies;
- Detection technologies (sensors);
- Communication technologies;
- Information dissemination technologies;
- Location referencing and positioning technologies;
- Traffic control and vehicle control technologies;
- Electronic payment technologies;
- Surveillance and enforcement technologies.

At the heart of any ITS are the twin concepts of information and control technologies. Control technologies support many ITS applications and can be divided into two broad categories:

- Infrastructure-based control technologies aimed at controlling and managing traffic such as adaptive signal control systems and ramp metering;
- Vehicle-based control such as Advanced Driver Assistance Systems and Adaptive Cruise Control.

On the information side, technologies are needed to acquire data, process and fuse data, make sense of data, and disseminate information to users – including the traveling public.

The information collected and processed can also be used to implement control and management measures, aimed at improving network performance. ITS enabling technologies also collect real-time traffic and environmental data from the field and transfer the data collected to a central location where it is processed, fused, analysed and used to support decision-making.

As with control technologies, detection technologies fall into two groups:

- Infrastructure-based detection technologies, which include inductive loop detectors, non-intrusive detectors (such as microwave, infrared, ultrasonic, and acoustic sensors), environmental sensors and closed-circuit TV cameras – some with Video Image Processing, etc.;
- Vehicle-based detection technologies, which include vehicle probes, police patrols, mobile safety patrols and citizens' reporting, etc.

The initial standardization of ITS services, which was focused on road transport, was set up by ISO (International Standardization Organization). The first reference model for ITS included 8 functional areas and 32 services (ISO TR 14813-1 – Transport information and control systems – Reference model architecture(s) for the TICS Sector)[16].

The reference models for ITS architecture were improved in 1999 in the way that Part I (1999), describing ITS Fundamental Services, replaced standards presented in Technical Report on Transport Information and Control Systems. The new taxonomy intends to relate similar and complementary ITS services. The taxonomy includes 11 functional areas (Table 2).

[16] https://www.iso.org/obp/ui/#iso:std:iso:14813:-1:ed-1:v1:en

Table 2. ITS functional areas
(Source: The Authors)

Functional areas	Traveler Information
	Traffic Management and Operations
	Vehicles
	Freight Transport
	Public Transport
	Emergency
	Transport Related Electronic Payment
	Road Transport Related Personal Safety
	Weather and Environmental Monitoring
	Disaster Response Management and Coordination
	National Security

The fields of ITS can be identified by user services, which indicate what the system will perform from the perspective of the users. Thirty fundamental services are presented below (Table 3).

Table 3. ITS fundamental services
(Source: The Authors)

Fundamental Services	1. Pre-trip Information
	2. On-trip Driver Information
	3. On-trip Public Transport Information
	4. Personal Information Services
	5. Route Guidance and Navigation
	6. Transport Planning Support
	7. Traffic Control
	8. Incident Management
	9. Demand Management
	10. Policing/Enforcing Traffic Regulations
	11. Infrastructure Maintenance Management

	12. Vision Enhancement
	13. Automated Vehicle Operation
	14. Longitudinal Collision Avoidance
	15. Lateral Collision Avoidance
	16. Safety Readiness
	17. Pre-crash Restraint Deployment
	18. Commercial Vehicle Pre-Clearance
	19. Commercial Vehicle Administrative Processes
	20. Automated Roadside Safety Inspection
	21. Commercial Vehicle Onboard Safety Monitoring
	22. Commercial Fleet Management
	23. Public Transport Management
	24. Demand-Responsive Public Transport
	25. Shared Transport Management
	26. Emergency Notification and Personal Security
	27. Emergency Vehicle Management
	28. Hazardous Materials and Incident Information
	29. Electronic Financial Transactions
	30. Public Travel Security

The idea of user services supports the system design or project definition by outlining the high-level services that will be provided to address identified problems and user needs (Lesson No. 3!).

Most of the ITS solutions are primarily implemented in urban and suburban geographical locations; this does not imply that these systems are not implemented in or do not impact other geographic settings. But they are more often associated with the urban areas and, in general, fall into the following *three broad* categories:

- *Traffic Management Systems (TMS)*;
- *Traveler Information Systems (TIS)*;
- *Vehicle Control Systems (VCS)*.

Traffic Management Systems (TMS)

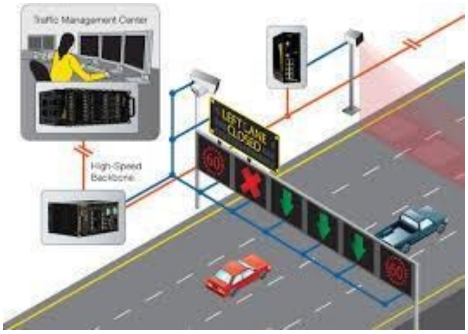


Figure 6: Traffic management system
(Source: Used under creative commons (cc))

They provide:
- Traffic surveillance;
- Optimization of subsystems (e.g., traffic signals);
- Control on highways and local roads (Figure 6).

TMS tends to be highly centralized, although it can be built in both the vehicles and the road system infrastructure. They rely on the flow of information to and from the traffic control center and their main function is to improve the distribution of traffic and the throughput of roadways.

These are the characteristics of control systems:

- Work in real-time, count vehicles, and measure delays;
- Respond to and anticipate traffic flow, and predict congestion;
- Include area-wide surveillance and detection systems and rapid response incident management;
- Integrate demand management, transportation information, ramp metering, and arterial signal control.

Concepts such as Ramp metering and Automatic vehicle identification/toll collection offer the most potential for improving the traffic flow.

1. Ramp metering can relieve accident risks by regulating the access of cars at the on-ramp via automated signals; where implemented the results have shown a 30% decrease in freeway accidents. A strategy very often used with ramp metering is an HOV bypass lane (High-Vehicle Occupancy) that is parallel and bypasses the meter.

2. Automatic vehicle identification/toll collection is a segment of traffic surveillance that probably produces the greatest benefit. This technology uses radio or sensors at a fixed point that recognize the tag mounted on the vehicle. It provides automatic toll collection, road pricing or congestion pricing.

Traveler Information Systems (TIS)

Traveler information systems provide traffic and safety information to users to enhance their traveling efficiency (Figure 7). They help drivers to navigate and make possible just-in-time delivery (for commercial fleet). The information could be stored either in a vehicle or via the traffic center.

Figure 7. Traveler Information System
(Source: Used under creative commons (cc))

In-vehicle information systems (digitized maps) provide drivers with:

- The location on the route;

- "Yellow pages" of shops, parking, restaurants;
- Computerized route planning.

Systems interactive with traffic control center receive from and report to route guidance information.

The advances are characterized by:

- Ability to locate vehicles;
- Doing traffic surveillance;
- Calculating optimum routes for travel.

Automatic vehicle location (AVL) is a technology related to AVI that works with centralized equipment and can detect a tagged vehicle *anywhere* within its range. AVI detects *only at fixed points* where AVI equipment is located.

Basically, there are two types:

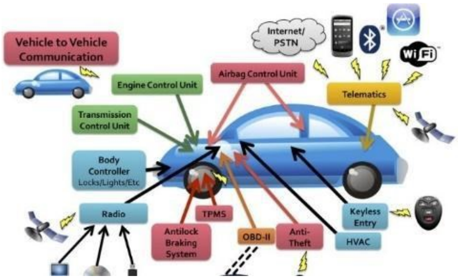
1. Dynamic Route Guidance involves two-way communication between the driver and the traffic control center. Provides optimized routes before the travel starts and en-route. Static route guidance is possible as well from in-vehicle map databases. Systems can be used for route planning, optimizing departure time, estimating an arrival time, avoiding hazards, and intermodal planning with public transportation.

2. Perception enhancement focuses on:

   - "Heads-up displays: provide eye-level displays of dashboard information;
   - "Backseat driver" systems: offer synthesized voice read-outs of dashboard information, and route instructions;
   - Infrared imaging: provides a clearer picture of road conditions at night, at dusk, or in poor visibility; their longer development is expected;

- Headlight glare reduction: uses polarized or ultraviolet headlights combined with appropriate windshield material to reduce glare from oncoming vehicles' headlights.

Vehicle Control Systems (VCS)



They are concerned with the driver (enhancing perception, providing warning about dangerous conditions), the actual vehicle operation (using electronic sensor reactions under computer control that could assist or substitute human reactions), and current conditions in the vehicle's vicinity (Figure 8).

Figure 8: Vehicle control systems driver/automatically
(Source: Used under creative commons (cc))

These systems have two goals: *accident avoidance* and *greater utilization of existing roads* (increasing the capacity by 100% by using the technique sc. "platooning" which involves the coordination of multiple vehicles at 5-25 interspacing with controlled operation on the road).

Regarding the types of vehicle control systems, four categories can be identified: *i) driver warning, perceptual enhancement, assistance/control systems; ii) automated high-occupancy vehicle (HOV) lanes; iii) automated freeway systems: building HOV facilities; iv) autonomous vehicle which offers automated operation on streets/freeways.*

Access to vehicle control systems should be affordable to a wide range of groups:

- Travelers, either on the road or before their journey begins;
- Traffic managers so as to monitor traffic conditions;
- Toll collectors so as to receive toll information;
- Emergency services for warning of the need for their services;
- Regulators so as to monitor adherence to regulations;
- Fleet managers so as to facilitate the management of commercial fleet;
- Large employers so as to provide traffic information to their employees.

Due to its endless potential, ITS has evolved into a multidisciplinary conjunctive field of study and as a result, numerous organizations all over the globe have created solutions for ITS applications to meet their needs.

Today, many ITS applications are available and the most outstanding ones will be briefly addressed in Section 1.6.

1.6 ITS Architecture

Every system initially has an architecture which gives a common starting point and a common language. Before a design is detailed, one has to sit down and decide what the system would do, what its functional components would be, and how they would be interconnected. An architecture provides a framework based on user requirements for a system design. The system architecture is a concept that evolved over many years of developing complex electronic systems. Basic subsystems are being identified, their functions are being defined as well as the data that must be transferred between them.

The term ‘’ITS Architecture’’ refers to a conceptual framework (or structure) that guides the deployment of ITS. It is a detailed formal specification of the following requirements:

- The functions that the ITS deployment will perform (the user services – such as travel planning, traffic, and emergency management…);
- The physical components required to carry out these functions (such as roadside equipment, vehicle-based control systems, and control center workstations);
- The interfaces and communications required to allow data and information exchange between physical components;
- The roles and responsibilities of stakeholders in relation to the deployment of ITS.

In the past, there was little coordination among transportation developers. Everyone's architecture was slightly different, which resulted in preventing interchangeablity among systems. The ITS architecture proposed gives a common framework for discussions with manufacturers and other implementers.

Levels of ITS architecture: the most fundamental level defines a series of ***functions***. Traffic surveillance and operating transit vehicles illustrate some of these functions. High-level functions are broad in scope, so they are normally broken into sub-functions, sub-sub-functions, etc. Lower level functions include the following: monitoring HOV lanes and providing Transit Vehicle Driver Interface. The primary role of ITS architecture is to assign functions to various components or subsystems of the overall ITS. For example, subsystems could be Information Service Providers, Traffic Management, and Transit Management. The various subsystems can not act independently of one another. Therefore, the architecture defines the connections or interfaces between the subsystems.

Each of the lowest level functions is given a precise definition known as Process Specification (P-spec). The *logical* architecture defines the data flow diagrams (DFDs) and P-specs. The *physical* architecture defines subsystems, assigns P-spec functions to them, and documents data flow interfaces between the subsystems. Conformance with the architecture is important for the following reasons: it provides the evolutionary path and common language for deployment and helps the standardization process. The logical and physical architectures describe the transportation functions and data flows are linked together. The architecture allows for any possible information service provider arrangements.

The development of system architecture is iterative. Competing architectures must be analyzed, modeled, produced as prototypes, and tested. The results of these tests must be evaluated and compared in a scientific and unbiased manner. An appropriate test plan must be designed for the tests to ensure that appropriate data are collected and that the results obtained are meaningful.

Comparative assessments are needed. Since the approach adopted is the system approach, the critical systems engineering issues, such as efficiency, life-cycle costs, benefits, compatibility with other systems, safety, and reliability must be considered in order to get the maximum benefit from experiments. The system requirements should be developed by a broadly based group, representing all levels of government, the automotive and electronics industries, research organizations, and the users (both private and commercial).

Most of the efforts are being directed to a technical evaluation of the ability of the alternatives to satisfy the system requirements when developing an architecture for ITS. The evaluations require modeling, simulation, tests of component performance, and validation of concepts via field tests.

A framework ITS architecture serves as a foundation for the creation of stand-alone ITS master plans at the national, regional, or local level. Additionally, it can promote cross-border integration and a free market for ITS products and services.

The European ITS Framework Architecture (also known as “The FRAME Architecture” is the most well-known example of a framework ITS architecture[17]). It was developed initially during the 1990s, but officially the first version was published in 2000. FRAME is analogous, the same as the US ITS Architecture ARC-IT. FRAME has been updated and its tools have been enhanced by different projects such as FRAME-S (2001 – 04), E-FRAME (2008 – 11), and 2017 FRAME NEXT. Today, FRAME is transferred to Enterprise Architect (EA) from SPARX, which also provides additional features[18].

Several countries, including Australia, Austria, Czech Republic, France, Hungary, Italy, and Poland, are developing their own national ITS architectures utilizing the FRAME Architecture as a starting point[19].

The development of an ITS architecture begins with a consensus-building process involving numerous stakeholders focused on the ITS-based services that need to be offered. Thus, the designed architecture is based on a consensus among users, service providers, and transport agencies, expressed in common terms, concepts, boundaries, responsibilities, and expectations among the stakeholders who will later make independent decisions but now are mutually coherent and supportive. The concept of Shared Vision is an important foundation for proactive learning (Lesson No. 3!).

[17] FRAME Architecture, its documentation and tools can be obtained at http://www.frame-online.net/. The FRAME Architecture includes support for Cooperative Systems/Connected Vehicles.

[18] https://frame-next.eu/wp-content/uploads/2020/12/FRAME-Architecture-Tool-User-Guide.pdf

[19] https://trimis.ec.europa.eu/sites/default/files/project/documents/20130515_125913_29633_COMeSafety_DEL_D31_EuropeanITSCommunicationArchitecture_v2.0_01.pdf

The general process that should be followed during the designing and developing of the ITS architecture subset for a specific goal is depicted in Figure 9.

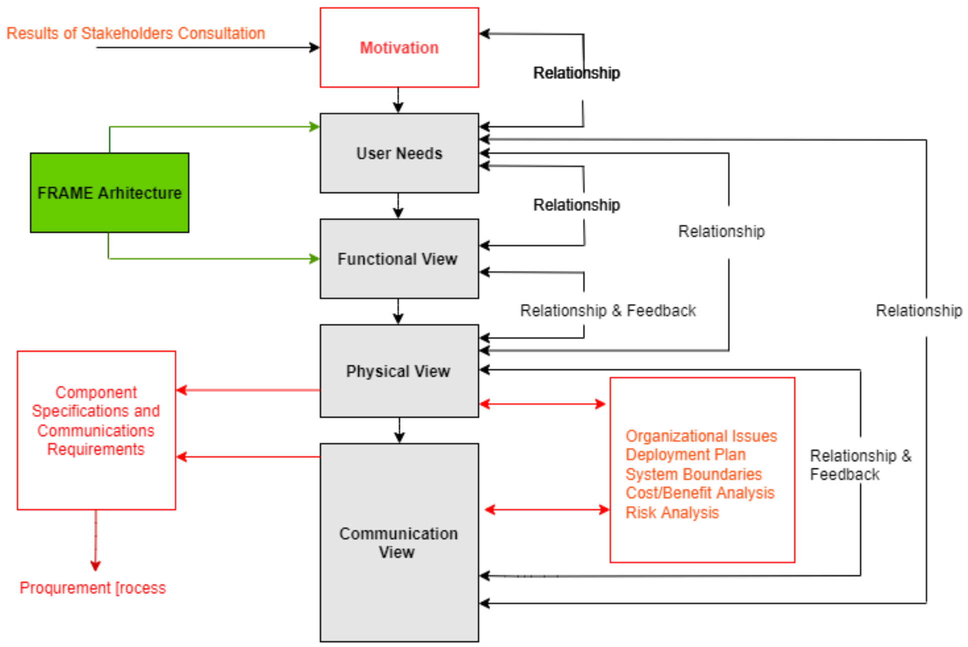


Figure 9. The process of ITS architecture development
(Source: By the authors, adapted according to the FRAME Architecture)

The grey boxes represent the main results obtained by using the EA tool and the white boxes depict the initial process (Motivation) as well as the additional information that can be obtained for the newly created subset for the ITS architecture.

Cooperative ITS & Services (C-ITS)

The new focus brought new ''looks'' to ITS services and applications (Figure 10). Cooperative ITS (C-ITS) have the potential to increase the value of ITS services and applications even further.

Figure 10. Example of a vehicle to vehicle communications (V2V)
(Source: Used under creative commons (cc))

C-ITS is a subset of ITS that communicates and shares information between ITS Stations in order to provide advice or take actions to improve safety, efficiency, and comfort beyond the scope of stand-alone driving sustainability ITS[20].

According to the European Commission's C-ITS Deployment Platform, cooperative Intelligent Transport Systems (C-ITS) shall use mature ad hoc short-range (like ETSI ITS G5) and complementing wide-area communication technologies (like 3G, 4G, future 5G) that allow road vehicles to communicate with other vehicles, traffic signals, roadside infrastructure, and other road users[21].

The cooperative V2X systems are also known as vehicle-to-vehicle communications (V2V), vehicle-to-infrastructure communications (V2I), or vehicle-to-person (V2P) communications. In summary, the wireless data exchange between the different actors and ITS stations and related functions are named cooperative V2X communication. It supports a number of

[20] https://www.itsstandards.eu/25-2/wp-5-3/
[21] https://www.car-2-car.org/about-c-its/

information, warning, and assistance services that will be gradually deployed in coordinated innovation phases during the upcoming years.

1.7 ITS and Innovative Technologies

All devices are being equipped with smart sensors and communication capabilities: smart phones and smart infrastructure.Devices part of a large network, huge amount of data available, data mining methods enable the search for knowledge in various databases, delivery vehicle/Taxi/Public transport GNSS tracks, creation of digital road maps, estimation of speed profiles and travel times for road segments, clustering for estimation of traffic demand repositioning.

Today, all systems are becoming more and more autonomous:

• Operating systems and applications update themselves

• Traffic lights monitor their state and call for repair

– Nearest service vehicle with all needed parts

– New term of autonomicity is introduced

• Origin from self-management function of biological organisms

– Crucial body functions (hearth rate, breading, blinking, blood flow) are self-managed without conscious perception

• Properties of autonomic systems

– Self-optimization, self-awareness, self-healing, self-…

The impact of disruptive and innovative technologies is expected to cause a radical transformation in the transportation industry and people's understanding of the transport modes in the future[22]. It seems inevitable that all aspects of transportation will become entirely user-independent as a result of the influence of artificial intelligence (AI), machine learning (ML), autonomous vehicles (AV), etc. We use the term technologies although some of them may be conjointly viewed as a concept.

CE Delft and TNO conducted a research project on emerging technologies, their impact on the transport sector, and the actions required to prepare transport infrastructure for these changes on behalf of the European Parliament's Committee on Transport and Tourism.

It is expected that a huge amount of data, cloud computing, and MaaS services, as well as modes of transportation will be integrated more quickly, allowing integrated systems to provide services more efficiently, quickly, and easily.

This section briefly touches on the most prominent applications that have the potential to become mainstream in the future, such as *Autonomous Vehicles* (AV), *Internet of Things (IoT)*, *Big Data (BD), Blockchain Technologies (BT), Artificial Intelligence (AI), Machine Learning (ML), Reinforcement Learning (RL), Deep Learning (DL), Drones,* and *Mobility as a Service (MAAS).*

[22]https://www.europarl.europa.eu/RegData/etudes/STUD/2020/652226/IPOL_STU(2020)652226_EN.pdf

Autonomous Vehicles (AVs)

Radar, lidar, GPS odometry, artificial intelligence, sensors, cameras, and other technologies are used by autonomous cars to sense their surroundings. As a result, they are able to move utilizing real-time data without a driver (Figure 11).

Figure 11: Autonomous Vehicle
(Source: Used under creative commons (cc))

Internet of Things (IoT)

It is a network of devices that connect and share information to form an intelligent system by using a variety of communication protocols. In other words, by integrating sensors and data transmission technologies into roads, infrastructures, mobile devices, and similar physical items, objects can be tracked, coordinated, or controlled through data networks or the Internet. Traffic management systems can provide real-time traffic status information by detecting the amount and speed of traffic on urban highways using the IoT (Internet of Things).

Additionally, IoT-based technologies will have the ability to offer a sizable amount of transportation data for use in mobile internet-based travel applications or autonomous vehicles.

Big Data (BD)

The processing and interpreting of data obtained from sensors, cameras, software, traffic management centers, vehicles, and other similar sources are critical in establishing decision-making mechanisms in the context of intelligent transportation.

With the implementation of ITS, large amounts of traffic and transportation data are collected via information and communication technologies from infrastructures, vehicles, and driver behaviors. With rapid and dynamic modeling, better simulation and modeling capabilities for ITS can be provided using big data. Thus, it is anticipated that traffic management will be simplified, as well as the ability to predict and prevent traffic jams, traffic accidents, and other hazardous situations.

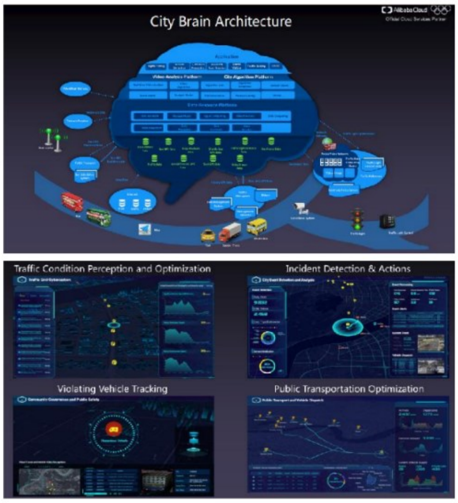
Blockchain Technologies (BT)

Blockchain is a distributed data recording system that enables encrypted process tracking. The reason blockchain is referred to as a data collection system rather than a database is because, once collected, data cannot be altered or deleted.

This function is based on storing data by connecting the data accumulation blocks like a chain via encryption algorithms and sharing this chain with many people in a scattered manner. With this technology, any user can connect to a network, send new operations, verify operations and create new blocks without an agent. It allows the user to perform operations without being connected to a center, so that operations can be carried out safely. Possible areas of application for blockchain technology in the transport sector include the following: MaaS, data exchange, freight and logistics services. Blockchain technology will enable the establishment of MaaS platforms, facilitate data sharing in transportation, make the software running on connected vehicles and updates to that software more secure, and, thus, it will definitely play a central role in the future of autonomous and connected vehicles.

Artificial Intelligence (AI), Machine Learning (ML), Reinforcement Learning (RL), Deep Learning (DL)

Today everything is integrated. To provide safer, more effective, and environmentally-friendly transportation services, developed countries have been researching the use of artificial intelligence in transportation planning, problem resolution, behavior estimation, and management applications. The research on connected vehicles, autonomous vehicles, and intelligent road systems has changed the transportation industry. Due to applications like traffic forecasts, intelligent decision-making using machine learning, deep learning technologies, and big data, the driverless vehicle sector has been advancing quickly. It is anticipated that with the use of all these technologies, traffic accidents can be avoided through the early detection of potential accidents via pre-analysis of possible traffic scenarios.



ET City Brain[23] is an intelligent system that uses rescue teams which can now arrive at their destination 7 minutes earlier. Inefficient urban transportation systems are not uncommon. For example, certain routes are always fully operational, while others have buses and trains that are frequently empty. ET City Brain assisted Suzhou in efficiently managing its bus networks and increasing passenger volumes on pilot bus routes by 17%.

Figure 12. City Brain Architecture
(Source: ET City Brain)

The AI applications in transport have been developed and implemented in a variety of ways from better utilization of accurate prediction and detection models aiming to better forecast traffic volume, traffic conditions, and incidents to the improvement of public transport and the use of a self-driven car.

[23] ET City Brain

An important complementary principle in these approaches is also adaptation to dynamic circumstances and diverse contexts, which help proper management of the higher-level systems as well as on the operational level. A methodology for the implementation of a new way and tool for traffic data collection through the processing of video data into an AI-based software need to be developed. The acquired data from this software is going to be used in creating a traffic simulation model for the purpose of evaluation and analysis of signal-controlled intersections in urban area. The managerial connotation present in this research exists to provide an anchor and a big picture perspective of the approach, channeling the efforts in the proper direction[24].

Reinforcement Learning (RL)

In the recent decades, algorithms from the domain of artificial intelligence and RL techniques are being used for traffic control. They have the ability to accumulate and use knowledge, set a problem, learn, process, conclude, solve the problem, and exchange knowledge with other systems[25]. More

[24] Koltovska Nechoska, D., Petrevka Nechoska, R., Duma, R., Application of Artificial Intelligence for Traffic Data Analysis, Simulations and Adaptation, 2022 57th International Scientific Conference on Information, Communication and Energy Systems and Technologies (ICEST), IEEE, 2022.

[25] Ivanjko, E., Koltovska Nechoska, D., Intelligent Traffic Control in Urban Areas, Horizons Series, B. Vol.3 (2016); pp. 165-176.

detailed analysis and results of RL-based adaptive traffic signal control strategy are discussed in a number of research papers[26][27][28].

We can all agree that today ITS depends heavily on big data, deep learning, artificial intelligence, and other cutting-edge information technology infrastructure and solutions.

AI and machine learning technologies are having a major impact on the automotive and quality industries as they are bringing forth new products and business models instead of solely enhancing productivity.

Drones

Unmanned aerial vehicles (UAVs), commonly referred to as drones, are aircrafts that are piloted remotely and equipped with a GPS module, cameras, and other similar parts. Drones, which have long been utilized for military objectives, are now also employed in a variety of other fields, including precision agriculture, firefighting, product delivery, weather monitoring, search and rescue, security, and surveillance operations.

Mobility as a Service (MAAS)

MaaS (Mobility as a Service) refers to the creation of a single accessible mobility service through the integration of various types of on-demand transportation services. MaaS's major objective is to provide users with

[26] Pavleski, Daniel., Koltovska Nehhoska Daniela., Ivanjko, Edouard. Development of TSCLab: A Tool for Evaluation of the Effectiveness of Adaptive Traffic Control Systems, New Technologies, Development and Application II, Lecture Notes in Networks and Systems Vol. 76, Springer, Karabegović, Isak (ed.). Cham: Bosnia and Hercegovina, 2020. pp. 386-394.

[27] Ivanjko, E., Nečoska, K. Daniela, Gregurić, M., Vujić, M., Jurković, G., Mandžuka, S., Ramp metering control based on the Q-learning algorithm, Cybernetics and Information Technologies, Special Issue on Control in Transportation Systems, Volume 15 (2015), No.15; pp. 88-97.

[28] Koltovska, D., Bombol., Intelligent Agent-Based Traffic Signal Control on Isolated Intersections, TEM Journal, Vol.3 (2014), No.2; pp. 216-222.

more affordable, environmentally friendly, and effective transportation options than utilizing their personal vehicles.

MaaS was first implemented in Finland, where it played an important role in the country's transportation policy. To meet a customer's demand, a MaaS operator may provide public transportation, a vehicle, bike sharing, car rental, or a combination of these options. Instead of multiple toll and payment transactions, MaaS allows users to access an end-to-end travel experience through a single payment channel on an application.

Numerous obstacles must be addressed in order to facilitate and expedite the adoption of Smart Mobility applications in order to reap personal and social benefits. Although each application faces unique difficulties, some universal issues that impede the creation and implementation of smart mobility have been discovered. All of these factors—technical, economic, and social—seem to be of equal importance. Some of the main obstacles to furthering the development and wide-scale implementation of Smart Mobility applications include increasing user and public acceptance, creating workable business cases, ensuring data privacy, providing a unified and secure data sharing infrastructure, and ensuring interoperability between countries/regions and modes.

Current technological advancements are the cornerstone of significant changes in transportation. These are the innovative technologies that are expected to have the most pronounced impact on the transport sector in the period up to 2030[29].

[29] Ibid, p.23

CHAPTER II

ITS AND WESTERN BALKAN COUNTRIES

2.1 Transport Problems and Cross Border Cooperation

Over time many changes occurred in the Western Balkans region. New independent states accompanied by economical, political, and structural changes have emerged. The geopolitical developments in the area affected considerably the area's transport flows and, therefore, the need for infrastructures became more evident.

The Situation in the Republic of North Macedonia

Since its independence, Macedonia has very clearly declared its readiness to become a member of the EU. By intensifying its connections on the basis of its preferable geo-transport position, Macedonia has a possibility to use its spatial and functional position very rationally and effectively with the Mediterranean, Middle East, Central, and Western European countries. Some adverse effects of its central position on the Balkans refer to the following:

- No direct exit to the sea: Macedonia is forced to use port services in Thessalonica (Greece) and Durres (Albania) through rail and road traffic links;
- The dominant role of the Vardar Corridor and its monocentric relevance on the population concentration so far has led to lowering the environmental quality;
- Demographic decrease in the transversal frontier areas and its economic stagnation due to the concentration on the longitudinal axis.

It has been 30 years of Macedonia's independence and the existing transport infrastructure can be characterized as being poorly maintained and in urgent need of rehabilitation.

The **main issues** regarding **the transport corridor bottlenecks** can be summarised as follows:

- **Infrastructure bottlenecks**: delays at road and rail border crossings;
- **Institutional bottlenecks**: border crossing issues in terms of improved training and attitude of customs staff, communications both locally and

nationally, the complexity of transit documentation, the degree of international co-operation;

- **Commercial practices**: outdated railway commercial practices, the degree of co-operation between railways in terms of tariffs and marketing strategy;
- **Legislative framework**: the amount of coordination on road user transit charges, level of a common policy on fuel taxation to help manage the growth in road transport.

The main elements that influence the **transport demand** could be summarized as follows:

- Socio-political environment: defined through market forces that regulate the demand and supply of transport services. Our border regions try hard to "catch up" with this trend due to the local, historical attitudes and the new economic system.
- The system of societal values: there has been a shift towards satisfaction of individual rather than collective needs based on "lifestyle choices".
- Production process: new requirements on the freight transport system are being imposed. Problems with establishing road and rail connections for reliable transport systems have occurred.
- Spatial organization: greater integration among urban and rural areas in the border regions.

On the **supply side**, the main elements can be summarized as:

- Development of coherent transport infrastructure: the notion of a regional transport network as a subsection to the Trans European Transport Networks is a leading effort;
- The process is very slow and requires changes in funding beyond the government's availability. New initiatives such as "private-public" partnerships are most recommended;
- New technological possibilities: the application of ITS (logistic systems, network service providers) is important to facilitate the crossings between the countries in the region.

All of the above identified issues are long-lasting and imply an urgent need for significant changes in transport policy at the national and regional level by the WB candidate countries for EU membership.

EU initiatives, activities & projects toward creating an integrated transport network

Today, more than ever before, the opportunities and necessary conditions are present for an overall plan concerning the development of the transport infrastructure in the whole area of the Balkans, the Adriatic Sea, the Black Sea, and Europe in general. All the projects being carried out so far are leading in this direction. The European Union has given its approval for the creation of a European Transportation Network. It is not accidental that the transport networks have been the main topic of discussions and decisions at all levels of the European "being" for the last few years.

The formation and development of the Trans-European Transport Networks (Ten - T) are mentioned for the first time in the title of the XII Maastricht Treaty 129b, 129c, and 129d. The Trans-European Transport Network (TEN-T) policy addresses the implementation and development of a Europe-wide network of railway lines, roads, inland waterways, maritime shipping routes, ports, airports, and railroad terminals. The ultimate objective is to close gaps, remove bottlenecks and technical barriers, as well as to strengthen social, economic, and territorial cohesion in the EU. The current TEN-T policy is based on regulation (EU) No 1315/2013[30].

The Trans-European Transport Networks (TEN-T) is an ambitious infrastructure program of the European Union launched in 2014 to connect the continent between east and west, north and south. It had a budget of €24.05 billion until 2020. This policy intends to eliminate bottlenecks

[30]https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

currently impeding the internal market's smooth operation, fix gaps in member states' transport networks, and get over technical obstacles such as incompatible rail traffic standards. The TEN-T policy's objectives can only be successfully achieved with the help of ITS.

The “core network corridors” facilitate the development of the core network (Figure 13). Extending the core network corridors to the Western Balkans ensures closer integration with the EU as well as a basis for leveraging investment in infrastructures, such as the EU’s support through the Western Balkans Investment Framework and the Connecting Europe Facility. The core network corridors, once completed, will provide quality transport services for citizens and businesses, with seamless integration within the region as well as with the EU. The priority projects will help remove bottlenecks, promote interoperability, and build missing cross-border connections[31].

[31] WB6_VIE_2015_Annex1.pdf

Figure 13. Core and Comprehensive network of the Western Balkans
(Source: Vukanovic S, et al.[32])

The strengthened collaboration between Berlin Process political leadership and the Western Balkan countries Six (WB6) have fueled the connectivity agenda. Along with this, the nations supported by SEETO and the Energy Community Secretariat have made significant technical efforts.

[32] Vukanovic S, et al., Regional Multimodal Approach for Improving Intelligent Transportation Systems in the Western Balkans, Transportation Research Record: Journal of the Transportation Research Board, No. 2621, 2017, pp. 46–54.

The goal of the regional cooperation, which has been overseen since 2004 by the South-East Europe Transport Observatory (SEETO) and the European Commission, is the integration of the Comprehensive and Core Network to the EU Trans-European Networks in the six countries of the Western Balkans (WB6) region (Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Serbia, Kosovo). The total length of the Comprehensive Road Network is 5.462 km, out of which 2.198 km being on corridors and 3.264 km are routes, while the Core Road Network is a subset of Comprehensive and encompasses 71% of the Comprehensive Network[33].

Global and regional economic, transportation, and environmental systems are inextricably linked. The need to balance economic and environmental activities should be integrated into the government's political and economic programs.

The CROCODILE[34] has moved forward the process of the harmonized exchange of dynamic traffic data and information across borders. Partners have worked together on implementing an infrastructure for providing road traffic information. Efforts are being made in accordance with the EU ITS Directive and its supplementing Delegated Regulations. This encompasses coordination on an organizational level, technical implementation of standards as well as enhancement of management strategies and end-user services. The latter is being improved so that road users can obtain more and better information through channels (e.g. websites, apps) that they are used to, thereby adding to the continuity of services as defined in the EU ITS Directive. This project supports Cross-border traffic management plans (TMPs), along with DATEX II and the exchange of event information for road conditions in other countries. Since critical foundations were established beginning in 2014, a completely new level of coordination was introduced in

[33] https://trid.trb.org/view/1736808

[34] https://www.its-platform.eu/its-corridors/crocodile/

2019: a dedicated TMP-Project with the goal of creating, upgrading, and digitizing international TMPs along five TEN-T corridors[35].

2.2 Environmental Challenges and Sustainability Among Issues of Regional Importance

Transport issues are the first field of cooperation and progress among the countries in the region. But we are witnesses of delicate and very changeable political and social issues occurring in the Balkans. In the current deteriorating economic situation, mostly due to the Covid – 19 pandemic situation, the environmental problems are the lowest priority in Western Balkan countries (Figure 14). Long years of public pressure through various instance and ecological movements have not yet succeeded in changing the government's environmental policy.

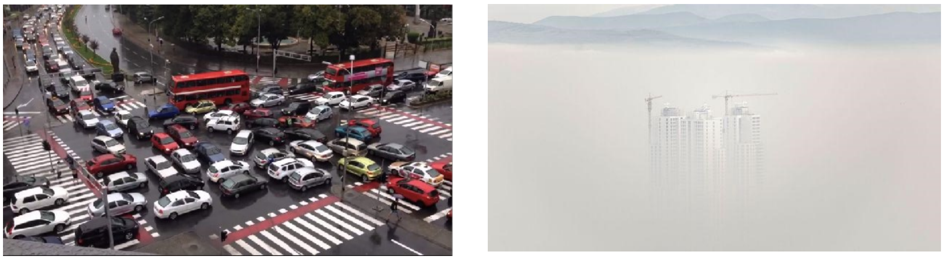


Figure 14. Traffic congestion and environmental problems in Macedonia's capital city – Skopje
(Source: Used under creative commons (cc))

A study published at the beginning of 2017 lists Skopje among the 10 most polluted cities in Europe[36].

[35] Ibid., p.35
[36] World Health Organization, "WHO Global Ambient Air Quality Database." https://www.who.int/airpollution/data/cities/en/, 2018.

The pollution often becomes critical during the winter period, because the concentration of PM10 particles in the air reaches levels up to 20 times higher than the maximum ones measured in the past.

Many sources and causes for the severe air quality problem have already been identified; among them emissions from road transport make a considerable contribution. Road transport emissions depend on multiple factors, including the vehicle category (passenger cars, delivery vehicles for light and heavy goods), vehicle technology (Euro norm of the used engine), the quality of the used fuels, etc[37]. According to the Macedonian Ministry of Interior Affairs, in 2014, there were 161 474 registered vehicles in Skopje[38].

The majority of them (over 40%) are categorized as conventional, with old Euro 1, or Euro 2 norm engines. Such engines have the greatest negative impact on air quality. Also, 31% of delivery vehicles for heavy goods are very old, being categorized as conventional or Euro 1 norm engine vehicles.

In terms of PM10, the oldest classes of vehicles (conventional, Euro 1, and Euro 2) contribute almost 70% to the total emissions from passenger cars.

In addition, data about the fuel type of vehicles in Skopje shows that 53.18% of the vehicles use gasoline fuel, 45.46% use diesel fuel and 0.36% use other types of fuel.

Additionally, most of the passenger vehicles in Skopje (65%) use petrol, and about 30% of them use diesel as fuel[39].

[37] Miletić, M., Kušić, K., Gregurić, M., Koltovska Nečoska, D., Ivanjko, E., Kalinić, H. Creating A Data-Set for Sustainable Urban Mobility Analysis: Lessons Learned, Proceedings of 62nd International Symposium ELMAR-2020, Special session Intelligent Transport Systems, Zadar, Croatia, 14-15.09.2020.

[38] “Ministry of the interior, Republic of North Macedonia.” https://mvr.gov. mk/default. Accessed: 2020-06-08.

[39] Ibid., p. 52

It is obvious that our transportation system is not on a sustainable and ecological path. There is no strategy for maintaining a balance between economic, transport demands and ecological needs. It is necessary to make long-term environmental planning an integrated part of economic and social development strategy in all WB countries. There is no organized information system; data is gathered on an ad hoc basis, without any systematized methodology or procedures. Regulations requiring the creation of environmental databases are not yet defined. Inter-ministerial environmental cooperation is poor.

According to Agenda 21, it is necessary to meet the basic needs of all citizens of the Planet Earth while maintaining the natural resources and ecosystems.

The challenge is how to find ways of meeting our transportation needs that are environmentally sound, socially equitable, and economically viable.

Traffic and transport regulation is a particular element of the ecosystem thinking. The infrastructure network is an element of a dual network approach that is an example of an approach based on the principles of the ecosystem thinking for urban development both at the regional and local level. Stimulating the use of public transport systems, walking and cycling are the basic principles within the ecosystem thinking related to traffic and transport. Within this context, ITS is to move towards sustainability in transport when setting strategic directions that corespond with the principles mentioned above.

As we are living in the 21st century, it is of vital importance for us to discuss the elements influencing the future trends in transport needs in the trans-regional area of interest. To encourage the use and implementation of ITS, we must establish a legal framework that: i) facilitates the use of data generated by ITS, and ii) supports coordinated and interoperable deployment of ITS along TEN-T corridors and in urban and interurban environments.

Sustainable Development and Sustainable Mobility

The strategy for sustainable development is comprised of "*a coordinated set of continuously improving processes of analysis, debate, capacity-strengthening, planning and investment, which integrates the economic, social and environmental objectives of society, seeking trade-offs where this is not possible*".

Sustainability must be understood from the perspective of economic and social well-being for all WB countries.

The set of principles encompasses a set of desirable processes and outcomes to emphasize local ownership, effective participation, and a high-level of commitment. In practice, the strategy should bring together the government, civil society, and the private sector, in order for them to create a vision tactically. It identifies the integration between approaches or provides a framework for making choices where integration is not possible.

Transport issues will be the first field of cooperation and progress among the countries in the region. But we are witnesses of delicate and very changeable political and social issues occurring in the Balkans.

The cross-border cooperation policy should be focused on close work on developing and renovating transport infrastructure, removing administrative and legal obstacles to the movement of people and goods, as well as on implementing ITS and transport systems.

The Western Balkans Green Agenda[40] establishes strategic goals for clean transportation that is fit for a green and digital future, with sustainable mobility and greening infrastructure as critical components[41].

To address the challenges of sustainable mobility, the Western Balkans should take actions aimed at: i) increasing sustainability across all modes of transportation; ii) increasing efforts to make sustainable alternatives available and accessible to all; and iii) ensuring a unified approach to putting the right incentives in place to drive the desired transition. To achieve sustainable seamless travel, the region should prioritize: a) multimodal passenger ticketing, b) digitalized freight transport, c) ITS deployment solutions for all modes, d) digital data exchange at borders, and e) innovation.

One of the "soft measures" identified in the framework of the Connectivity Agenda, which is being implemented jointly by the Western Balkans region and the European Commission, is the deployment of ITS and mobility as a service (MaaS) in accordance with the EU relevant framework.

2.3 Deployment of ITS in Western Balkan Countries

The Western Balkans countries are lagging behind the EU countries when it comes to ITS deployment. So far, ITS has been implemented only in several tunnels in Montenegro and Serbia and on the newly built motorway sections in Bosnia and Herzegovina. In Montenegro, as a part of the Route 4 motorway project, ITS will be introduced in the Smokovac–Matesevo section. Several projects of ITS deployment have been marked as national priorities, especially Corridor 10 in Macedonia and Serbia, Corridor 5c in Bosnia and

[40] https://neighbourhood-enlargement.ec.europa.eu/system/files/202010/green_agenda_for_the_western_balkans_en.pdf

[41] https://www.transport-community.org/wp-content/uploads/2021/06/Strategy-for-Sustainable-and-Smart-Mobility-in-the-Western-Balkans.pdf

Herzegovina, as well as Route 4 in Montenegro. ITS installation is also planned on newly built motorways on Route 6 and Route 7 in Kosovo. ITS applications have been deployed only on 67 km, while on 988 km ITS is currently under construction or planned for the next period.[42][43] Several projects have been planned and were in the phase of realization on different Corridors and Routes, while this book was being written, but there is no ITS implemented in them, to the best of our knowledge.

The analysis has revealed a number of problems, which can be summarized as follows: inadequate standardization of information exchanges, market actors' disparate capabilities in using information and communication technology (ICT), legal requirements impeding ICT use, and data security and privacy issues plague all six countries.

The Macedonian experience with the ITS deployment is presented in a number of research papers as a result of the previous collaboration of the authors of this book[44][45][46]. Deployed solutions in the area of *traveler service information, traffic management and operations,* and *public transport*

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[42] https://trid.trb.org/view/1736808

[43] https://journals.sagepub.com/doi/abs/10.3141/2621-06?journalCode=trra

[44] Mimoza Bogdanoska Jovanovska, Daniela Koltovska Nechoska., Smart Cities: Transport Challenges of the Macedonian Capital City, Journal Holistica, Vol.1 (2017), Issue 1; pp. 45-58.

[45] Koltovska Nechoska, D., Krmac, E., Comparison of Road Traffic Intelligent Transport Systems Application Levels in Republics of Macedonia and Slovenia, Proceedings of Second International Conference "Transport for Today's society", 17-19 May, Bitola, Republic of Macedonia, 2018.

[46] ''Transport Policy Model as a Function of Sustainable Development of the Republic of Slovenia and Republic of Macedonia'', bilateral project, financed by the Ministry of Education and Science of the Republic of Macedonia, 2017–2018. WBAA bridge – North Macedonia, 2021.

services have been mainly implemented in the capital city of Macedonia, Skopje, and on the Skopje – Stip motorway.

Traveler Information Services are a key element of ITS deployment and an essential component for effective and efficient traffic management. They are designed to provide the traveler with comprehensive real-time traffic information allowing for well-informed travel decisions (pre-trip information) and during the journey (on-trip).

One way to promote greater use of public transport is by providing real-time passengers information. The automatic location of the vehicles allows to obtain the time of departure/arrival and transfer from one to another vehicle that stands out at the stops, at home, etc. In Skopje, there are several signs on certain public transport lines at the bus stops, which show real-time bus arrival. Five variable message signs have been implemented providing real-time information concerning traffic conditions on the road network. VMS has been implemented on the new motorway Skopje – Stip. Weigh-in-Motion, Meteorological Stations and automatic traffic counters have been deployed or are planned to be deployed.

A special and crucial element for traffic management and ITS is the Traffic Management and Control Centre (TMCC) (Figure 15). To cope with the increased traffic demand, a TMCC using the UTOPIA (Urban Traffic Optimization by Integrated Automation) adaptive system has been built in Skopje, in 2014, as a result of FP7 project CIVITAS RENAISSANCE and with extra funding from EBRD grant. Currently, it monitors and manages 90 intersections in real time. New parts of the road network are being constantly added.

TMCC is organized based on highest standards and its main functions are: obtaining traffic data in real time, regulating the traffic signal system, traffic monitoring, giving priority to public transport and providing real time information for drivers.

This Centre constitutes a solid base for the introduction of new incoming solutions such as Smart Parking or Smart Free Parking System in the center of Skopje, as well as Shared Transport solutions.

Figure 15. Traffic Management and Control Centre in Skopje
(Source: Used under creative commons (cc))

With a project worth 18.6 million EUR, the highway between Tabanovce and Gevgelija is to be installed with devices for measuring the weight of the vehicles in movement, weather stations – systems for providing information about the weather conditions on the road and systems for measuring greenhouse gasses, surveillance cameras, as well as SOS road telephones and VMS. At the same time, all of these parameters about the road conditions will be monitored by the Public Enterprise for State Roads' Control.

Summary of Key Issues and Objectives

A summary of the analysis of ITS in the Western Balkans, from legislative, strategic, and deployment aspect, regarding the road, rail, maritime, and inland waterways sectors, is depicted in Table 4[47].

[47] Vukanovic S, et al., Regional Multimodal Approach for Improving Intelligent Transportation Systems in the Western Balkans, Transportation Research Record: Journal of the Transportation Research Board, No. 2621, 2017, pp. 46–54.

Table 4. Analysis of ITS in the Western Balkans
(Source: Master thesis[48])

Area	Mode	Focus	ALB	BIH	MK	MNE	SR	Kosovo
Legislative	Roads	Directives & Regulations	1	0	0	0	0	0
		Guidelines and Specifications	0	0	0	0	0	0
		Average	0.5	0	0	0	0	0
	Railways	Directives & Regulations	1	3	3	3	3	3
		Guidelines and Specifications	0	0	1	0	3	0
		Average	1	1.5	2	1.5	3	1.5
	Maritime & inland	Directives & Regulations	1	0	na	2	3	na
	waterways	Guidelines and Specifications	0	0	na	2	3	na
		Average	0.5	0	na	2	3	na
Strategy	National	ITS strategy	2	1	1	0	1	0
		Reference System Architecture	0	0	0	0	0	0
		ITS action plan/implementation program	0	0	0	0	0	0
		Average	0.66	0.33	0.33	0	0.33	0
Deployment	Roads	Infrastructure	1	1	0	0	2	0
		Central	0	1	0	0	1	0
		Control and Management	0	1	0	0	1	0
		Average	0.33	1	0	0	1.33	0
	Railways	Infrastructure	0	0	1	1	0	0
		Stations and yards systems	1	1	1	1	1	1
		Central	0	0	0	0	0	0

[48]Sejdini, Dz., Design of National Arhitecture of Intelligent Transport Systems, Master Thesis, Faculty of Technical Sciences, UKLO, 2022 (In Macedonian).

		Control and Management	0	0	0	0	0	0
		Average	0.25	0.25	0.5	0.5	0.5	0.5
	Maritime & inland waterways	Infrastructure	1	0	na	2	3	na
		Central	0	0	na	3	3	na
		Control and Management	1	0	na	2	3	na
		Average	0.66	0	na	2.33	3	na

Note: na = not applicable.

Summary of key issues and objectives

The newly brought acts have partly taken into consideration the basic guidelines of the relevant international conventions. What is still lacking is the implementation of the international standards, especially the technical and safety standards.

There is a lack of inter-departmental co-ordination and harmonisation of the regulative measures regarding key questions, mainly about the legal, tax and social policies, and the solving of critical problems:

- Restructuring of non-profitable state companies in the transport sector;
- Irrational management of the transport infrastructure;
- Absence of equal market conditions for all the transport branches;
- Failure to implement traffic management principles (mainly urban transport) by inducing the demand for non-road transport modes and public transport;
- Failure to determine external costs of transport (and then also failure to carry out the reduction measures);
- Failure to use scientific resources.

The national ITS architecture will show clearly and unambiguously which processes need to be standardized, especially in communication and data exchange. Based on relevant interfaces and operational needs, user needs and hardware and software specifications, the architecture helps identify the nature of the standards – local, regional or international.

Applying the European architecture of ITS will not only enable the applications to work together, but they can also become interoperable at European level, which is a feature of greater importance. National ITS architecture *provides an open market for services and equipment; allows economies of scale in production and distribution; ensures consistency of information; encourages investment and provides interaction among all.*

The following are some of the identified risks that exist in the absence of ITS architecture:

- ITS will not be able to provide the expected services because the components, both publicly and privately owned, are not fully compatible;
- It is difficult to expand or change in accordance with service requirements;
- ITS will not be able to adapt when new technologies appear.

The lack of non-existent ITS architecture can result in the creation of so-called "Technological islands", which over time will lead to incompatibilities. That is why it is good for each country to design its own ITS architecture, because it helps *to get the best value for the investment and effort you put in, in the long run.* To meet the challenges of setting up a comprehensive ITS, a systematic approach has to be taken (for more details on applied methodology see Chapter 3).

CHAPTER III

DEPLOYED METHODOLOGY

3.1 MultiCreation Approach

MultiCreation approach seeks solutions to real-world problems and challenges, as well as aims to increase the academy's relevance to the real world, by cultivating a research practice with a high potential for meaningful impact. As a result, it frequently adopts an action-research orientation to effectuate changes and, thus, relies on the participation of real-world actors. In any problem-driven research, one of the main theoretical challenges is positioning the multidisciplinary setting of the scientific domains, which are interrelated, so as to address real problems in a conceptual manner. Hence, using our theoretical and professional backgrounds we touched upon management, governance, engineering, traffic, innovation, and higher education – hoping to achieve at least an initial brief portrayal of the incorporated disciplines[49]. The MultiCreation approach was used in developing a participatory methodology for addressing trans-regional issues in ITS from managerial and technical perspective (WBAA – BRIDGE project), and in what follows, the main ideas and project results are discussed[50][51].

The Western Balkan countries are struggling with answers to several key questions: *Can we revitalize our infrastructure; Can we revitalize the environment?*; *Can we revitalize our economy and society overall?* To do so, an efficient methodology for all operators and the deployment of intelligent transport systems (ITS) into the infrastructure of all types are required. Success would enable the economy to take full advantage of the growth potential of sizable infrastructure spending. This would include multiple effects and the stimulation of new, information technology-based

[49] Nechoska Petrevska R., Koltovska Nechoska D., Angeleski M., Engaging Economics and Traffic Engineering Students in Community Issues Using the MultiCreation Approach, September 2021, Naše gospodarstvo/Our economy 67(3):29-37.

[50] http://tactical-management-in-complexity.com/course/view.php?id=27

[51] https://www.western-balkans-alumni.eu/wbaa-project-developing-participatory-methodology-for-addressing-trans-regional-issues-bridging-science-practice/

industries whose products could be incorporated into intelligent infrastructure.

The role of managerial aspects of transport policy, through the application of ITS, has been largely underestimated especially in WB countries. There have been fragmented stories, and improvements in meeting some environmental, social, or economic needs, but often in ways that cause other problems. The understanding of the pressing problems of unsustainable development has improved. More than ever before, the necessary conditions are present for an overall plan concerning the development of the transport infrastructure in the area of the Balkans today. Policy-makers often overlook systematic approaches to sustainable development. Systematic and successful approaches set priorities and establish a long-term vision; promote convergence between existing plans, and ownership and are built on appropriate participation. Many strategies have failed to address the deep economic, social, and institutional changes so far.

An integrated methodology for innovative managerial technical access in ITS is developed and plotted through this project[52]. The methodology is based on a multi-creation approach and PESTLE – Political, Economic, Social, Technological, Legal, and Environmental factors analysis as a means for identifying important elements of success[53]. Systematic and successful approaches set priorities and establish a long-term vision; promote convergence for addressing trans-regional uses for innovative managerial technical access in ITS. The created methodology brings together the WBAA, researchers, government, academia, civil society to create a vision tactically; identifies the integration between approaches, or provides a framework for making choices where integration is not possible.

[52] Ibid. pp. 45.
[53] https://boycewire.com/pestle-analysis-definition-and-template

3.2 PESTLE Analysis

PESTLE analysis is a framework for analyzing key factors (political, economic, sociological, technological, legal, and ecological) and their influence[54]. It offers professionals an insight into the external factors that influence their organization. The analysis is flexible so that organizations can use it in a number of different scenarios. Professionals and senior managers can use the results to guide strategic decision-making.

The PESTLE analysis is a review of six external influences on organizations (Figure 16):

- *Political*: Tax policy; environmental regulations; trade restrictions and reforms; tariffs; political stability.
- *Economic*: Economic growth/decline; interest, exchange, inflation and salary rates; minimum wage; working hours; unemployment (local and national); credit availability; living expenses.
- *Social:* Cultural norms and expectations; health awareness; population growth rates; age distribution; career attitudes; health and safety.
- *Technological*: New technologies are constantly emerging (for example, in the field of robotics and artificial intelligence), and the rate of change is increasing.
- *Legal*: Changes in legislation affecting employment, access to materials, quotas, resources, import/export and taxation.

[54] https://pestleanalysis.com/pestel-framework.

- *Environmental*: Global warming and increased need to switch to sustainable resources; ethical sources (both local and national), including intelligence on supply and other emergencies.

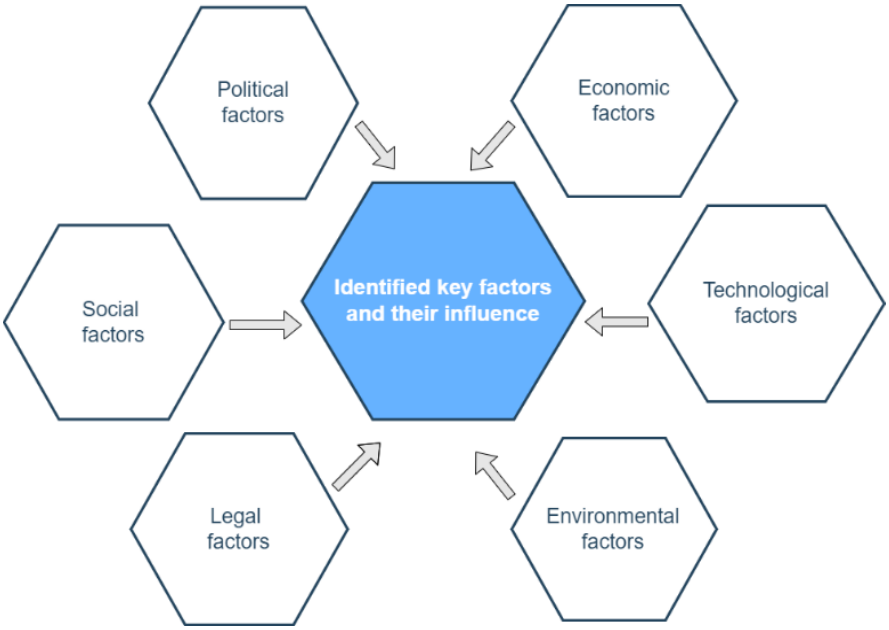


Figure 16. PESTLE analysis framework
(Source: Adapted version of PESTLE by the authors)

The implementation and the use of the PESTLE analysis are part of the basic knowledge on enabling changes in our map of stakeholders (Table 5).

Table 5. *PESTLE analysis*
(Source: Ibid, pp.58)

Political	Economic	Social
- Government support and activities - Institutional support and support for private companies - Political situations in the countries and regions - Lack of defined roles and responsibilities in public administration - Involvements of diverse stakeholders	- Fast and safety movement of traffic and goods - Lack of financial resources at the European level - Discounting on road costs - High costs for updating and inclusion of innovative technologies	- Population migration - Goods, drivers and travelers services approach

3.3 Stakeholder Analysis

Stakeholder analysis entails identifying primary and secondary stakeholders, as well as service users and determines their needs[55]. The level and nature of primary stakeholders' involvement vary:

1. *Primary stakeholders will be those with direct responsibilities for managing, operating, and maintaining the system. Others will be secondary stakeholders, with a lesser impact on business practices and system usage.*

   - The primary stakeholders are: government institutions at the central level, institutions and bodies at the local level and all others that cooperate or are interdependent in the course of their work.

2. *Others will be secondary stakeholders, with a lesser impact on business practices and system usage.*

   - Secondary stakeholders are: citizens, certain target groups, civic organizations and associations, universities and other institutions that are directly or indirectly affected by the transferred programs and/or activities.

The planning, development, operation, and maintenance of ITS projects involve both primary and secondary stakeholders. From the planning to the operations and maintenance stages of a project, all stakeholders with a potential interest in the project must be identified and engaged. Their input and participation are required for an ITS project to be completed successfully.

[55] Nechkoska, Petrevska R., Strategic Foresight & Planning for Dorian Lake, international project, 2020 (in Macedonian).

The analysis of the stakeholder groups shows a significant number of stakeholders in the project for the creation of the ITS architecture that needs to be included (Table 6)[56].

Table 6. Stakeholder groups for ITS design

Stakeholders	Responsibilities	Capacity/ Motivation	Relation with other stakeholders (++/--)	Influence of the project
Ministry of Transport & Communications	Responsible for development and implementation of transport policy	Median capacity Interest for cooperation	++++	Partnership in inspection and implementation of projects
Public enterprise for state roads	Protection and maintenance of the main and regional road network in the country	Median capacity Interest for cooperation	+++	Partnership in the implementation of activities
PE for Railway Infrastructure - Railways of the	Ensuring transparent performance of the activities of	Median capacity Interest for cooperation	++	Support and partnership in implementation

[56] Ibid, pp.58

Republic of Macedonia	the infrastructure manager, railway transport			
Agency for Electronic telecommunications	Providing communication support and integration	Median capacity Interest for cooperation	+++	Support and partnership in implementation
Ministry of Internal Affairs	Increasing the measures and improving the situation	Median capacity Interest for cooperation	+++	Support and partnership in implementation
Municipalities	Coordination of activities and transparency in operations	Median capacity Interest for cooperation	++++	Support and acceptance of part of the projects
Universities and Research Centers	Curriculum improvement Greater involvement of students and high school students New programs	Median capacity Partial interest for cooperation	+++	Support of part of the projects

Civil organizations	Implementation of safety regulatory functions	Median capacity Interest for cooperation	++	Regulation of activities
Students	Education according to needs	Low capacity Interest for cooperation	+-	Beneficiaries of part of the activities of and partnership in the implementation of projects

The clients, professional consultants, suppliers of products and services, contractors, and specialized subcontractors involved in the deployment of ITS can be analogous to those involved in the construction project:

- The client can be a public body or a private operator, or, more often, a multi-agency group led by a lead agency;
- ITS professionals who advise and manage ITS deployment are typically drawn from transport, civil or electrical engineering and transport planning. Their specifications will define the project's needs and expected costs, as well as guide programmers and suppliers, including computer software and hardware, detectors and sensors, communication networks, cameras and infrastructure equipment, fixed and portable devices;
- System integrators may be required for complex ITS projects, particularly if component systems must communicate with one another.

3.4 FRAME Architecture

It is the framework architecture from which logically consistent subsets can be created, which can then be used independently. The methodology is supported by computer-based tools and starts with the wishes or aspirations of various stakeholders for ITS applications and services (Figure 13). The user interface of the FRAME tools, which refers to the display of subsystems from a functional, physical and organizational point of view, is shown in Figure 17. The use of this tool means determining the needs of users that correspond to the aspirations of the concerned party for a specific region or project. Finally, logical errors are displayed that the selection tool finds with the currently selected subset of the ITS architecture.

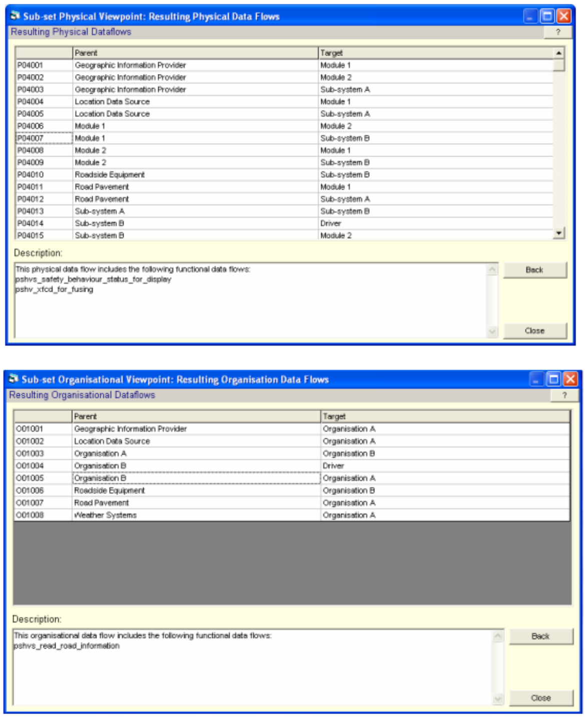


Figure 17. FRAME computer toll interface

(Source: FRAME architecture)

The FRAME architecture is intended to be used within the framework of a top-down approach for planning and deployment of integrated ITS. The entire concept can be presented in a formal (reference) model, because the creation of a reference model requires a large number of decisions or choices to be made by those who implement and/or regulate the ITS architecture.

The entire concept and structure of the system should be described in a technology-independent manner, so that, as technology develops, all high-level requirements remain unchanged.

The information contained in the structure of the system enables the ITS industry to produce equipment and systems that will provide the services required by interested parties, each with its own special characteristics, but in accordance with the goals expressed in the overall concept and structure of the system. Thus, integrated ITS services can be provided to all EU member states. The system structure contains a huge number of components.

What follows is a brief example of ITS architecture for the Variable Message Sign (VMS) system. This subsystem communicates and exchanges data with the road subsystem, which is the other subsystem in the variable speed limit service pack.

The traffic management subsystem (a core subsystem included in a transport facility management system) monitors and controls the traffic on the road networks (Figure 18). The roadway subsystem consists of roadway equipment (e.g., traffic detectors, environmental sensors, and traffic signals), distributed along a corridor for traffic monitoring and management. In this case, the variable speed limit service package supports the use of variable speed limits to promote safety and improve operational and environmental conditions.

The variable speed limits service package performs the following 4 functions: *data collection, data processing, data archiving,* and *information dissemination* (Figure 18). The functions of the different components are depicted as follows:

- Data collection (I);
- Data processing (II);
- Data archiving (III);
- Information dissemination (IV).

The traffic management subsystem receives collected data from the roadway, the roadway environment, and traffic flows. The roadway environment generates information about the physical state and geometry of the road surface. Roadway conditions such as ice, fog, rain, snow, or wind are also included in the data. Traffic data includes real-time traffic flow data as well as traffic images required for surveillance.

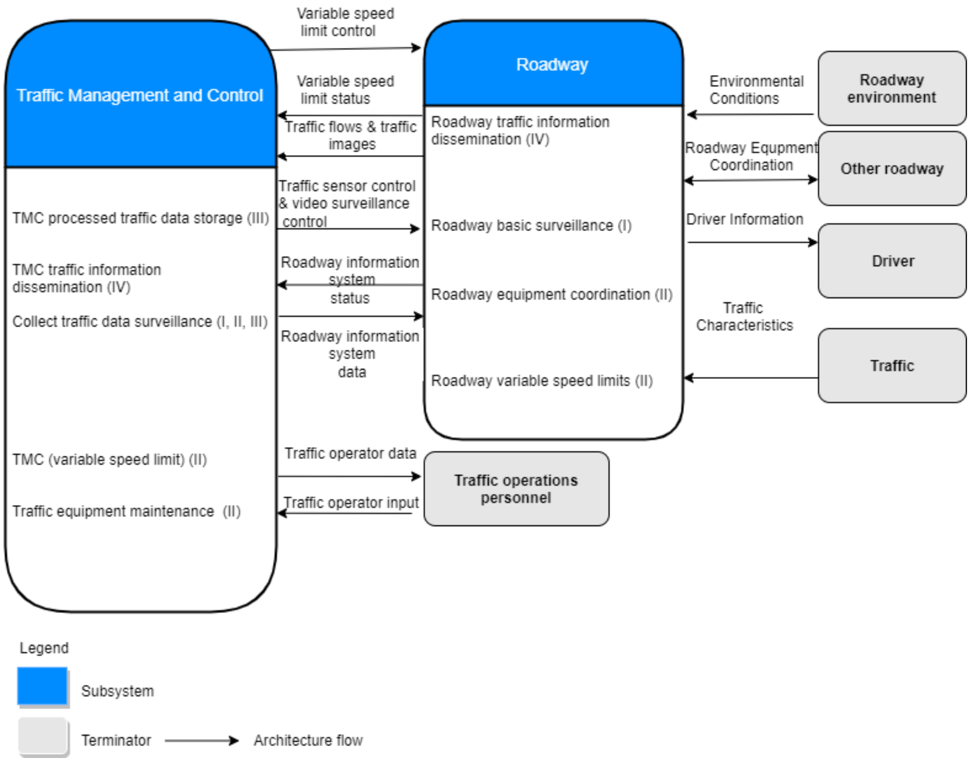


Figure 18: Example of ITS architecture for VMS services (Source: The Authors)

3.5 ITS Action Plan and EU Directive for ITS Deployment

Directive 2010/40/EU is a general document for coordinating the development of ITS in the European Union[57]. The ITS deployment action plan can be viewed as the document that sparked stronger and more focused ITS development in the European Union. Despite the high level of harmonisation in the strategic research, which was supported by the European Technology Platforms ERTRAC and ERTICO-ITS, the framework for ITS deployment in road transport had yet to be designed[58]. The Action plan was developed through stakeholder consultation, workshops, an online survey (public debate), and discussion groups.

In this direction, the following recommendations and guidelines for the Republic of Macedonia are also followed:

1. The adoption of specifications for priority areas is the first step towards a coordinated development. The specifications will be developed individually and, depending on the area covered, they may include different types of provisions:

    a) Functional provisions describing the stakes on the various affected parties and the flow of information between them;

[57] Directive 2010/40/EU, DIRECTIVES OF THE EUROPEAN UNION ON INTELLIGENT traffic.fpz.hr › PROMTT › article

[58] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0886:FIN:EN:PDF

b) Technical provisions that provide technical means for fulfilling the functional provisions;

c) Organizational provisions describing the procedural obligations of the various parties involved;

d) Provisions for services that describe different levels of services and their content for ITS applications and services.

2. Special attention is paid to data protection and the member countries are obliged to ensure the basic rights and freedoms of individuals. The national legislation for ITS must ensure that personal data is protected from misuse, including illegal access, change or loss. For this reason, the use of anonymous data is encouraged.

3. The implementation of the tasks of the Directive will be supported by the European ITS Committee (EIC)[59]. The advisory group includes service providers, users, manufacturers, professional associations, and local authorities.

4. Development of an action plan for the deployment of ITS as a document that initiates a strengthened and focused development of ITS in the Republic of Macedonia. In the preparation of the Action Plan, it will be necessary to include the identified stakeholders in this research,

[59] https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vio3jxa2m8wn

organizing workshops, online polls (public debates) and forming discussion groups.

The introduction of the Action Plan should include three main challenges:

- Measures to reduce traffic congestion and costs;
- Measures to reduce CO2 emissions related to passenger transport;
- Measures to reduce traffic accidents with fatal consequences and death cases.

Politicians' main goals that stem from this challenge are transport and travel to become cleaner, more efficient, safer and more secure. ITS is recognized as a possible solution, and the goal of the Action Plan is to accelerate and coordinate the deployment of ITS in passenger transport, including interfaces with other modes of transport. The potential of ITS could only be realized if its deployment in Europe is transformed from a limited and fragmented implementation to an EU-wide implementation. The role of the EU is to create a framework that will include policy priorities, a choice of generic components of ITS and a clear timetable for specific activities.

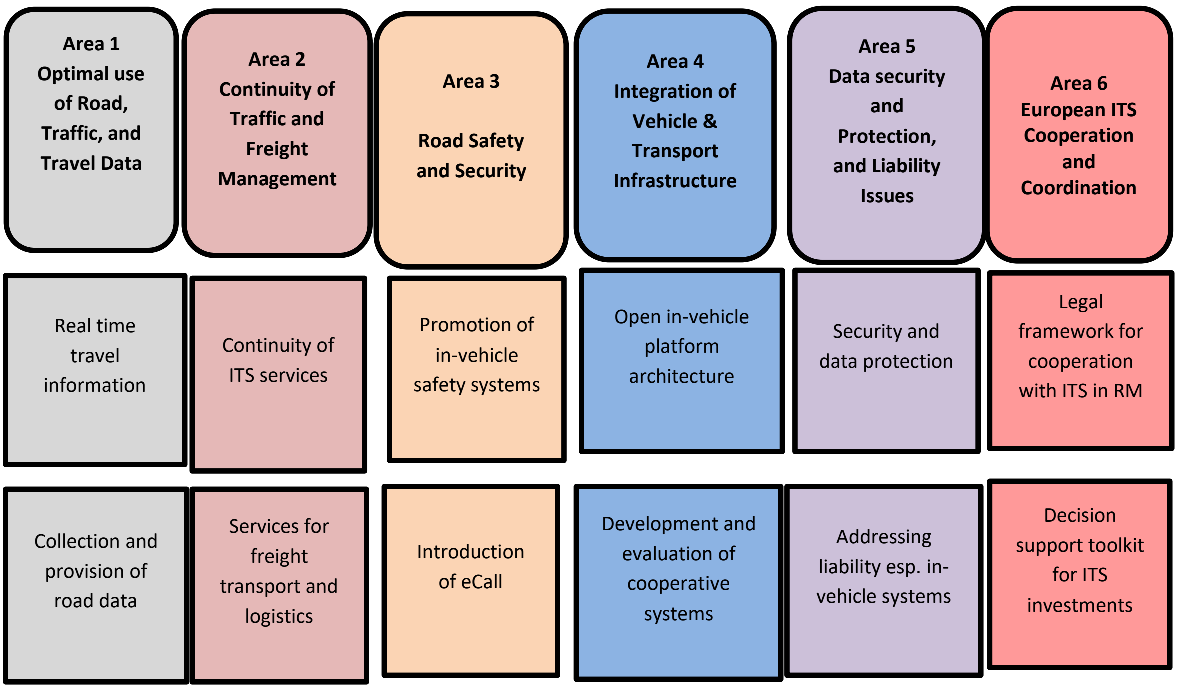
The action plan should focus on six priority areas[60]:

- Optimal use of road, traffic and travel data;

[60] Koltovska Nechoska, D., Krmac, E., Comparison of Road Traffic Intelligent TransportSystems Application Levels in Republics of Macedonia and Slovenia, Proceedings of Second International Conference "Transport for Today's society", 17-19 May, Bitola, Republic of Macedonia, 2018.

- Continuity of traffic and freight management of ITS services on European transport corridors and in urban areas;
- Road safety and security;
- Integration of the vehicle and transport infrastructure;
- Data security and protection and liability issues;
- European ITS cooperation and coordination.

A total of 24 activities are defined in six priority areas according to the Directive 2010/40/EU (Figure 19). Defining and classifying stakeholders that will use the architecture is a crucial element that allows the defining of the responsibilities, and, thus, prevents organizational problems.



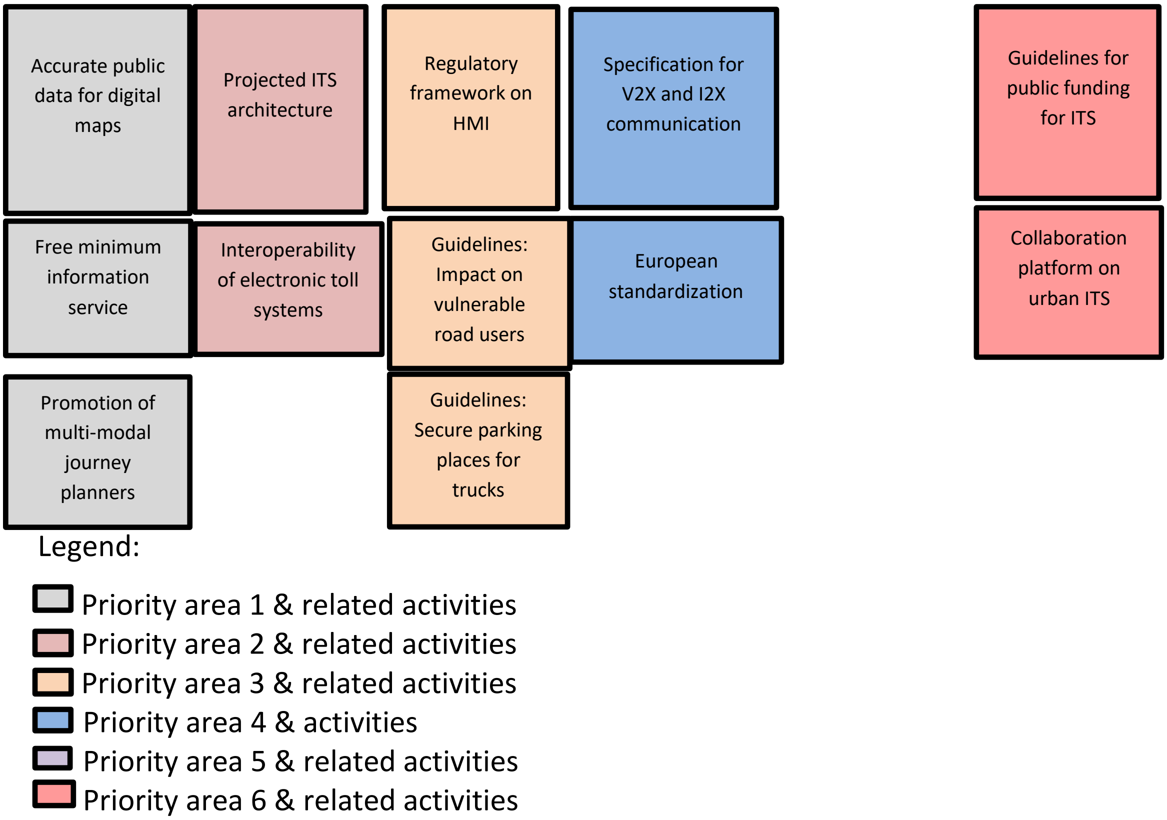
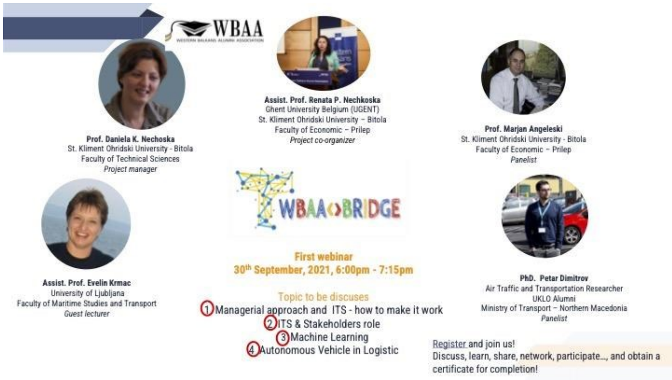


Figure 19. Priority areas and activities for deployment of ITS[61]
(Source: Adapted according to Action Plan for ITS Deployment[62])

[61] Action Plan for the Deployment of Intelligent Transport Systems in Europe COM (2008) 886 final, 2008.

CHAPTER IV

WESTERN BALKANS CASE STUDIES, GLOBAL THEMES and PANEL DISCUSSIONS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Assist. Prof. Renata P. Nechkoska
Ghent University Belgium (UGENT)
St. Kliment Ohridski University – Bitola
Faculty of Economic – Prilep
Project co-organizer
Prof. Marjan Angeleski
St. Kliment Ohridski University - Bitola
Faculty of Economic – Prilep
Panelist
Prof. Daniela K. Nechoska
St. Kliment Ohridski University - Bitola
Faculty of Technical Sciences
Project manager
WBAA BRIDGE
First webinar
30th September, 2021, 6:00pm - 7:15pm
Topic to be discuses
1 Managerial approach and ITS - how to make it work
2 ITS & Stakeholders role
3 Machine Learning
4 Autonomous Vehicle in Logistic
Assist. Prof. Evelin Krmac
University of Ljubljana
Faculty of Maritime Studies and Transport
Guest lecturer
PhD. Petar Dimitrov
Air Traffic and Transportation Researcher
UKLO Alumni
Ministry of Transport – Northern Macedonia
Panelist
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University of Banja Luka
Bosnia and Herzegovina
Project collaborator
Panelist
Prof. Valentina Mirović
Faculty of Technical Sciences
University of Novi Sad
Guest lecturer-Panelist
Assist. Prof. Anita Jurić
University of Mostar
Bosnia and Herzegovina
WBAA member
Panelist
Emina Hadzimuhamedovic
SDGs Roll-out Project Assistant at UNDP
Bosnia and Herzegovina
Panelist
WBAA BRIDGE
Prof. Daniela K. Nechoska
St. Kliment Ohridski University - Bitola
Faculty of Technical Sciences
Project manager and moderator
Second webinar
Bosnia and Herzegovina
28th October, 2021, 6:00pm - 7:00pm
Topic to be discussed:
Internet of Things (IoT) and Transport
Economic, Social and Environmental Dimensions in Smart City
Intelligent Transport Systems in Light of Sustainable Development Goals
Assist. Prof. Renata P. Nechoska
Ghent University Belgium (UGENT)
St. Kliment Ohridski University – Bitola
Faculty of Economic – Prilep
Project co-organizer and moderator
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University of Tirana, Albania
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City University of London
Kosovo
Panelist
WBAA BRIDGE
Prof. Daniela K. Nechoska
St. Kliment Ohridski University - Bitola
Faculty of Technical Sciences
Project manager and Moderator
Third webinar
Albania and Kosovo
30th November 2021, 6:00pm – 7:00 pm
Topic to be discussed:
Smart cities in Western Balkan?
Intelligent Transport Systems in Signal Coordination of Corridors
EVs & Environmentally Friendly Urban Areas
Assist. Prof. Renata P. Nechkoska
Ghent University Belgium (UGENT)
St. Kliment Ohridski University – Bitola
Faculty of Economic – Prilep
Project co-organizer and Moderator
Join us on the WebEx link in the post!
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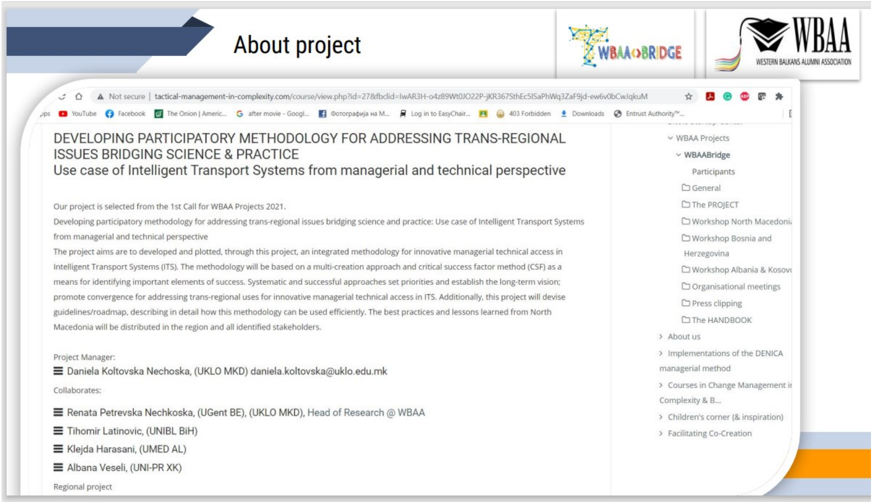
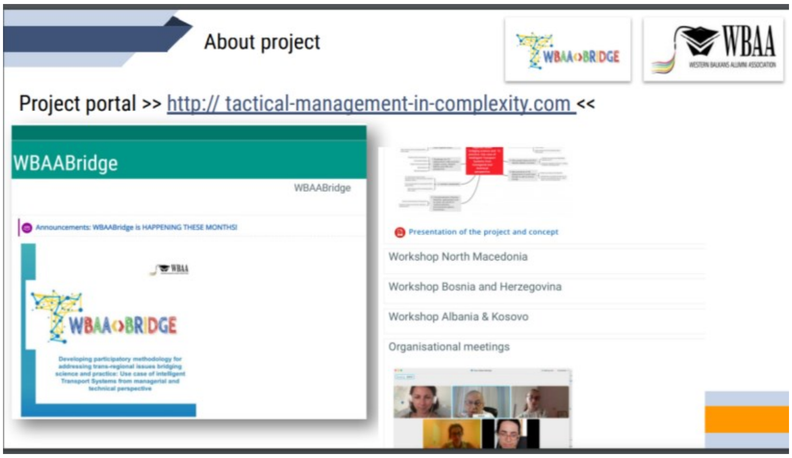




WEB PORTAL [HTTP://TACTICAL-MANAGEMENT-IN-COMPLEXITY.COM/COURSE/VIEW.PHP?ID=27](http://tactical-management-in-complexity.com/course/view.php?id=27)

4.1 Case Study 1: Republic of North Macedonia

Petar Dimitrov – Ministry of Transport of the Republic of North Macedonia, Project WBAA BRIDGE panelist

ITS and Stakeholders' role

General Problem Description

ITS includes various stakeholders in terms of disciplines (engineering, economics, and public policies), busniess sectors (government departments of transport, enforcement agencies, equipment manufacturers and communication service providers) and ownership (public and private entities).

Traditionally, the public sector has been responsible for the ITS operation and highway infrastructure. The Ministry of Transport is practically at the top of the list of main stakeholders in the ITS in North Macedonia. It incorporates the Port Authority which is currently located in Ohrid and deals with the waterway transport; then, comes the rail – the rail infrastructure and transport which consist of two entities and one agency and should be and it is completely independent. The national road network consists of two stakeholders and they have incorporated the following entities: the State Transport Inspectorate (SLI) which should also act as a separate independent body and the Civil Aviation Agency.

In the Republic of North Macedonia there are many obstacles to using the ITS solutions. This is due to several reasons. Firstly, although this country has set the initial national frame of transport policy and strategy, local transport policy framework is lacking. It refers primarily to the design and development of intelligent infrastructure and smart transportation system policy. Secondly, the relation between the public and private sector has not been precisely defined yet. The problem of funding also remains open. The readiness to transfer, to accept and to put into practice some of the modern technologies is very low. The professionals try to stick to their traditional and classical thinking of solving the old problems.

Possible Solutions and Discussions

A total system approach to ITS deployment means paying attention to both technical concepts and institutional measures needed to integrate the key technologies to deliver effective user services.

Successful ITS operations are enabled by a regulatory and institutional framework that is fit for that purpose – with cooperative agreements between stakeholders that define clearly each party's role and responsibilities. An equitable cooperative agreement between stakeholders, guided by suitable risk distribution, cost sharing and revenue or benefit sharing, may solve some of the regulatory and institutional challenges.

According to the Transport Strategy adopted, by 2030, Macedonia's transport system will consist of integrated and interoperable road, rail, air and lake/port urban transport, effectively regulated by a sustainable transport policy.

Infrastructure links between different transport modes will be built and national transport networks will be fully interconnected with urban transport systems, using ITS technologies to provide intermodal system that enables and optimizes the means of transport.

The national and urban networks will be planed, built, managed, operated and maintained in accordance with international standards and best practices and in accordance with national rules and regulations which are fully in line with the EU guidelines and directives.

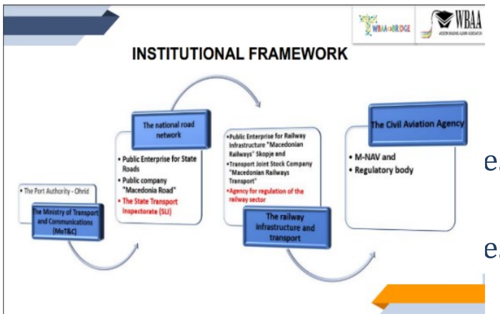
The urban transport will offer efficient and integrated public transport services that are environmentally friendly and will use advanced IT systems such as single tickets, online information, and the planning of traffic routes, which should be fully intermodal and interconnected.

To achieve sustainable mobility for all, the structural framework for effective governance with the sector requires sufficient resources. The government should ensure that the responsible institutions:

- have an available and necessary annual budget for the implementation of the transport policy;
- have an efficient IT communication and exchange system information for collecting, storing and disposing of accurate sector specific information, and
- have sufficient, efficient and well-trained staff to ensure effective management of the sector.

Decisions on the development of transportation systems and transportation activities involve a number of different actors (universities, government, transport planners, business, citizens) and are influenced by factors unrelated to environmental concerns such as prices and quality of services, the availability of modal choices, travel time and the organization of economic and social life. The new transport and ITS research strategy has to meet this vision and to add to it aspects that underscore prospective scientific, technological and societal trends.

The aforementioned topics are presented on the slides below.



Assist. Prof. Dr. Evelin Krmac – the University of Ljubljana, Faculty of Maritime Studies and Transport, Project WBAA BRIDGE Guest lecturer

General Problem Description

Today, we are witnessing the processes of digitalization, robotization, automation, and other industries. Robots like the robotic arm used in manufacturing, and the human-like robots in science fiction movies were the only examples for a long time.

The field of artificial intelligence (AI) research is very broad and it includes many different techniques but not all of them are used and not all of them are suitable for the development of autonomous vehicles.

Most robotic systems are a combination of techniques, and the same applies for autonomous vehicles. For these vehicles, we need techniques that can operate in unpredictable and unusual environments and perform object recognition for real-time obstacle detection and traffic negotiation. All these functionalities are possible with deep learning (DL).

DL belongs to a category of AI software coded machine learning which breaks with tradition by not being developed by a human programmer. In traditional human programming, we usually create a model of the world and approach it using formal logic and rules.

ML software, on the other hand, is trained for its task by being fed huge amounts of training data. In the case of autonomous vehicles, that is gigabytes of raw visual data collected by driving around every day with a camera on board.

ML software learns to recognize patterns by analyzing these huge amounts of data, looks for statistical patterns and builds mathematical models that rank the probability of various possible outcomes, and learns to make predictions and decisions.

The algorithm validates whether predictions are correct or its decisions are appropriate by testing them on new unseen data. If the predictions are wrong then the model is updated. And in this way a machine learning program is fed data to learn from experience, under the supervision of its human programmer whose job is to select the algorithm and provide the data and initial correct or incorrect feedback. These driverless vehicles must deal with infinite states because the vehicle is constantly encountering new situations. That is why machine learning is not an appropriate technique, and deep learning is used instead.

Possible Solutions and Discussions

DL algorithms use neural networks and unlike logic-driven software, neural networks are molded on the nervous system of humans and other animals which are made up of billions of cells called neurons.

Neurons regularly send signals to each other via electrochemical processes and deep learning networks use cascades of many layers of more than 100 artificial neurons to extract features from digital images which are then identified and labeled by software.

To build a deep learning network, the first phase is to feed the network with raw visual data. One of the great strengths of DL networks is that the network develops its ability to recognize objects, when properly arranged and when repeatedly fed with new data. This is a classic example of what programmers call a black box architecture because it is virtually impossible to reverse engineer the steps the software takes in generating the output.

The basic autonomous vehicle equipment consists of three main parts: an on-board computer that takes the data streams from sensors and GPS folds the data onto a high-definition digital map that includes intersections and traffic lights, and, then, processes it all together into a digital model of the world outside the vehicle, which we call occupancy grid.

The other important element – the core software of the autonomous vehicle is its operating system that supports the basic and advanced functions of the vehicle in response to real-time data that is nearly 100% reliable. So, we can say that the operating system is the software that provides reliable artificial perception. A very important component, apart from this equipment, is the set of multiple digital cameras and other sensors which allow data collection.

Autonomous vehicles (AVs) rely on data as much as on fuel and they consume huge amounts of data through its artificial sensors. The more data they collect the better they become as drivers, but they do not only consume data, they also provide data.

A range of hardware devices is needed to make the vehicle operate or to enable the vehicle to see and hear. High-definition digital maps are detailed and accurate regarding surface features containing rich detailed and constantly updated visual maps to enable long-term navigation. These maps are updated by driving around extensively with multiple cameras and reader sensors.

Another important element is digital cameras which simulate human eyes. They are used to capture the visual environment outside the vehicle in a stream of real-time data – fixed values. Therefore, the primary function of a digital camera is to transform the three-dimensional visual world into a two-dimensional matrix of pixels.

Lidar or laser radar is one of the main image sensors that sprays its surroundings with intense beams of light and measures how long it takes for each of those beams to bounce back and then calculates the three-dimensional digital model of the nearby physical environment.

Another element is the radar. The well-known radar – radio detection and ranging used from the vehicle to look in the nearby environment. The radar sensor detects the presence of physical objects in the near environment based on the echo of electromagnetic waves.

Sonar is an ultrasonic sensor which is the equivalent of a human ear. Like the radar, it also emits waves and detects their echoes but it uses sound waves.

Global Positioning System (GPS) is probably the best-known element, or in other words, a device that provides coordinates to pinpoint the exact position of the vehicle on the high-definition digital map.

There is also a set of devices called inertia measurement devices, or the inner ear of the vehicle. This is a multi-purpose device that tracks the position of the vehicle. The modern inertial measurement device is a complex bundle of devices (e.g., odometer, accelerometer, gyroscope, compass etc.) whose data is fused together and it analyzes these sophisticated destination algorithms.

The potential of autonomous robotics is enabled by improving the number of enabling hardware and software technologies, among them, improvement of power storage and efficiency, computational power, sensor technology especially video cameras, data storage and communication bandwidth.

The real potential of all these hardware improvements, is unlocked only while using improved algorithms, the new generation of so-called artificial intelligence software algorithms which enable today’s autonomous driving, the driving as we know it today.

But like any new technology, AI and AVs bring some potential benefits, developments, games, on the one hand, and drawbacks and risks, on the other hand. Among the major benefits is the fact that a new market of production and maintenance of high-definition digital maps will emerge.

The traffic prediction and planning will improve and the traffic will become safer, the traffic flow better, there will be less congestion, less pollution, and all of these are the goals we are trying to achieve with modern ITS systems.

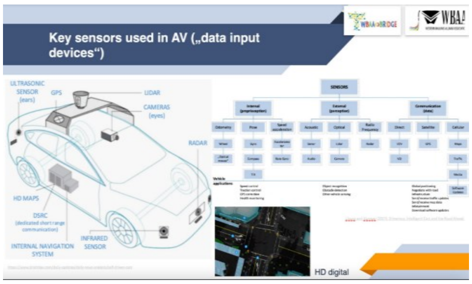
Additionaly, delivery and travel times will be optimized and autonomous vehicles will significantly reduce direct and indirect costs rising from accidents, salaries, and travel time.

However, the possible drawbacks and risks that new technology can bring such as, for instance, that fact that all software is vulnerable; all data transmission channels and data transmission can be compromised; the vehicles response to an emergency may not always be appropriate because this system today does not include the perception of the cost of human life and property, to mention but a few.

This must be determined first, and, then, if possible, the damage would be projected. In the end, our personal privacy, which is already compromised with our mobile devices and phones, will be further compromised.

AVs will change or, better put, are already changing the way we commute to work, how we shop and how we get around. In other words, they are changing our perception of time and space. Some jobs will disappear, some new jobs will be created, new transport policy need to be defined and ITS need to be redefined, or, at least, updated, both from technical and managerial perspective for this new era of transportation.

The slides below depict some of the aforementioned topics.



Prof. Dr. Marjan Angeleski, St. Kliment Ohridski University – Bitola, Faculty of Economics – Prilep, Project WBAA BRIDGE Panelist

Modelling and Simulation of Autonomous Vehicles

General Problem Description

Self-driving cars or autonomous vehicles are one of the most discussed areas of modern researches. Behind the concept of autonomous vehicles is artificial intelligence (AI), that enables computers and systems to derive meaningful information from digital images, videos, and other visual inputs, and, on the basis of on these inputs, to take some actions. A few years ago, to speak about AI seemed like science fiction, but now, as Elon Musk, the founder of Tesla Inc. and SpaceX said, this seems like something that will become increasingly harder to follow and keep pace with in the future.

Formally, AI is a method of making a computer, a computer-controlled robot or a software which can “think intelligently” as the humans do with their minds. Because the humans are considered as the most intelligent species on the Earth, and they can solve problems and analyze big data with their skills (e.g., analytical thinking, logical reasoning, statistical knowledge, and mathematical or computational intelligence), artificial intelligence is the simulation of human intelligence processes by machines. In that respect, self-driving cars or autonomous vehicles are products of artificial intelligent processes, trying to mimic the humans with respect to their ability to drive cars. But what is behind the scene? How does the model for self-driving cars really work?

Methods for Overcoming the Identified Problem

One of the approaches for modeling the self-driving car was proposed in a paper titled “End to End Learning for Self-Driving Cars” prepared by a team of researchers in NVIDIA Corporation using Convolutional Neural Networks (CNN). This paper describes all processes form data collection, network architecture, training details, simulation and evaluation.

Inspired by NVIDIA's model, the simulator was built for Udacity's Self-Driving Car Nanodegree, to teach students how to train cars using deep learning and CNN. This problem represents a ML supervised regression problem that would predict the steering angles for the vehicle based on data collected by manual driving on the simulator.

The data in this simulation is from camera images and steering angles of those images and this problem is well suited for DL, or, more specifically, convolutional neural networks that take in the forward-facing images from the vehicle and output a steering angle. Convolutional neural networks are composed of multiple layers of artificial neurons. Artificial neurons are a mathematical function that calculates the weighted sum of multiple inputs and outputs an activation value.

Possible Solutions and Discussions

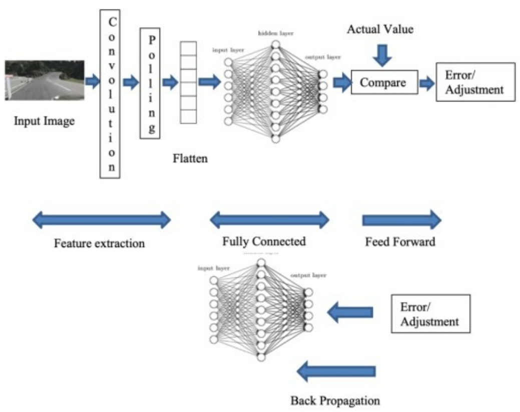
The first step of modeling is gathering data and after that splitting data into a training set and a test set, in between the validation set. It is necessary to collect a lot of data (images) and data from different roads. The next step is data preprocessing and the augmentation of the image frames. Usually, data preprocessing includes cropping the images, RGB to YUV color conversion, normalization of the image's values, etc.

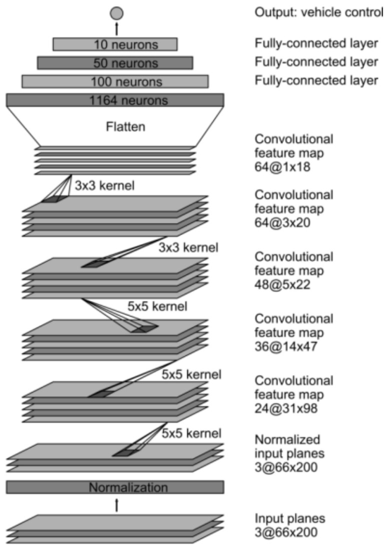
For the training set an augmentation technique is used, usually with some generator to generate a huge number of images. Augmentation techniques include changing the image brightness to simulate day and night conditions, randomly flipping the image left-right, randomly translating the image horizontally or vertically, image blurring, adding shadows to the image, etc.

As part of the modeling different Convolutional Neural Networks (CNN) models with largely varying architectures (for example NVIDIA type model or VGG Type Model Structure) and different types of parameters should be trained. A model's success in this simulation can be measured using the root mean square error (MSE) of the predicted steering versus the actual human steering.

The training, validation, and testing of the model can be performed by using some programming language for example Python programming language.

The slides below depict some of the aforementioned topics.





4.2 Case Study 2: Republic of Serbia

Prof. Dr. Valentina Mirovic – Faculty of Technical Sciences – University of Novi Sad, Project WBAA BRIDGE Guest Lecturer

Sustainable and Smart Mobility

General Problem Description

It is clear that Sustainable and Smart Mobility is based on three priorities: *people, technology,* and *integration*. By 2050, 90 % emissions cut is expected as a result of a smart, competitive, safe, and accessible transport system. One factor that should be taken into consideration in this context is surely the COVID 19 pandemic, as transport has been one the hardest hit sectors by the pandemic.

Possible Solutions and Discussions

The development of the concept of smart city is virtually impossible without the implementation of ITS. ITS is an integral part of the National Transport Strategy in Serbia and the Western Balkans. First of all, given that in the European Union they have standards and procedures for the application of ITS, the next step for us is the harmonization of our standards and procedures with the EU.

At the moment, ITS is defined by “Law on Roads” as systems of information and communication technology in road transport that are related to roads, vehicles, and participants in traffic. Apart from that, there are standards accepted by the Institute of standardization, which is a national body for standards.

Recently, Serbian cities and Serbia have carried out many research studies and projects which include analyses and proposed measures for the development of ITS, such as: Smart Plan Belgrade, Smart Plan Novi Sad, cross border cooperation, etc.

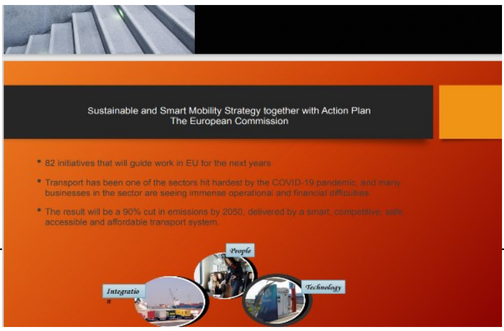
The city authorities have ambitions to harmonize all standards and to become National Management Center which will cultivate different kinds of ITS application in transport not only road, but maritime, rail, etc.

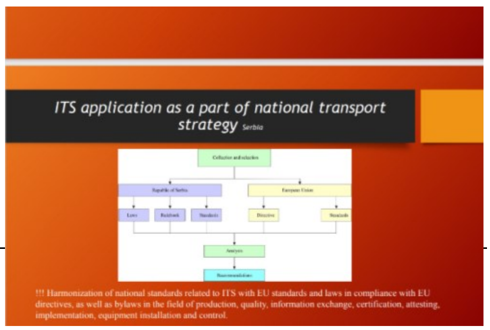
Twenty years ago, efforts to develop bike sharing and to find new ways to introduce bike sharing was established. NS Bike project was launched on July 11 in 2011 within a broader scheme termed "Let’s return Novi Sad back to cyclists”, a joint venture between the City of Novi Sad and Novi Sad Parking Services. The bike-sharing system is planned to comprise 60 stations spaced 400 to 500 meters apart with a fleet of around 600 bicycles. The stations’ distribution and capacity were established based on the distribution of the main activity centres and spatial distribution of trips that was determined by a research conducted by the Novi Sad Transport Model (NOSTRAM).

The system is being introduced through several phases. In terms of its technological features, the goal is to have a fully automated system until the end of the system’s introduction: users pick up and return bicycles using smartcards which enables the system to track bicycles at any moment.

The system is a missing link between the existing public transport facilities and destinations, and offers a new form of mobility to complement the existing public transport. In terms of single trips, bike-sharing system usage fee in Novi Sad is twice lower than a public transport fee and a parking fee per hour. However, future pricing solutions have to be oriented towards attracting trips in which the purpose of travel is work and increased cycling during peak hours. The implementation of such solutions requires integration of urban subsystems and their joint operation with the aim to address the main issue: How to achieve greater transport system sustainability in the city?

Below we provide few slides depicting the aforementioned topics.





4.3 Case Study 3: Republic of Montenegro

General Problem Description

Just like the other Western Balkan countries which have accumulated problems such as: i) a lack of funding for adequate infrastructure maintenance; ii) transportation constraints; iii) traffic accidents; iv) a non-competitive railway system; and v) an insufficient use of sustainable modes of transportation, Montenegro's socio-economic development has suffered too.

Today, Montenegro is planning major overhauls of its road and rail networks, as well as possible expansions of its air transportation system and further valorization of its maritime system, to address this issue.

A modern, functional, and efficient transportation system is a prerequisite for the Republic of Montenegro's faster economic development. Montenegro's Transport Development Strategy (TDS) aims to improve the economic efficiency, safety, accessibility, and environmental sustainability of the country's transport system, while ensuring a seamless integration of the transport sector, as well as a coordination with the national and EU policies.

As the approaches related to transportation mode shift, the implementation of ITS solutions and services, and infrastructure development must be used to distinguish the following goals of Montenegro's transportation system[62]:

1. Increased traffic safety and security;

2. Integration into the European Union via TEN-T connectivity and increased competitiveness of the national transport economy;

3. Improving the quality of transportation services;

[62]Transport Development Strategy 2019-2035 with Action Plan 2019-2020 (www.gov.me)

4. Stimulating economic growth through more efficient and less expensive transportation; and

5. Reducing the negative impacts of transportation development and traffic infrastructure on the environment and society in general.

The main question is how to accomplish all these. The following activities have been proposed:

1. The Ministry of Transport and Maritime Affairs' activities were focused on:

i) adoption of Euro 3 standards as a condition for used vehicles being imported; ii) implementation of a fleet renewal program for Montenegrian carriers with environmentally advanced vehicles; iii) harmonization of regulatory activities with the EU.

In the field of infrastructure, the following activates were undertaken[63]:

- Modernization and reconstruction of the existing road network of up to 5 years – 77 projects;
- Fast roads along the coastline;
- Reconstruction of the Nikšić – Podgorica railway;
- Technology for sustainable and low-carbon transport;
- Biogas buses;
- Electic vehicles for rent a car or taxi services;
- CABLE CAR Kotor – Lovćen – Cetinje;
- Segway.

[63] Sustainable and low-carbon transportation_R_Vujadinovic.pdf

The new Law on Roads introduced the legal basis for ITS implementation, which is a precondition for the implementation of the Directive 2010/40/EU on ITS into the Montenegrin legislation.

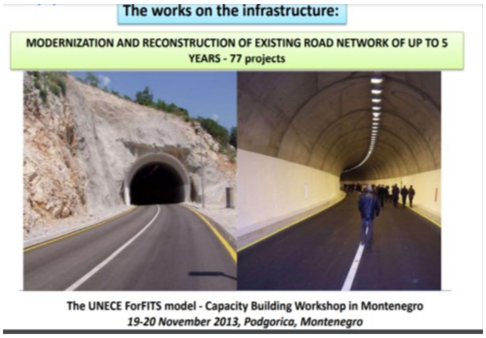
The equipment and functionalities in the Sozina tunnel are in accordance with the relevant EU Directive on tunnels and roads. The tunnel is controlled from the local control centre at Gluhi Do. Installation of ITS equipment for traffic signalization, highway control and management have been planned within the ongoing highway construction of the Smokovac – Matesevo section (Route 4) in total length of 41 km and an estimated cost of €25 million.

Possible Solutions and Discussions

ITS elements that are used in Montenegro as an integral part of the transport system include:

- Surveillance cameras on specific intersections and roads;
- Management of traffic lights and other signalling devices;
- Sensors/Detectors;
- SMS parking payment;
- The monitoring system and transport management of the Sozina tunnel includes: traffic control, vehicle counting with categorization, a contemporary toll payment system, road condition and weather notifications, measuring of smoke concentration in the tunnel and a complete camera surveillance of the tunnel.

Below we provide a few slides depicting the aforementioned topics.



4.4 Case Study 4: Republic of Bosnia and Herzegovina

Emina Hadzimuhamedovic – SDGs roll-out Project Assistant at UNDP, Bosnia and Herzegovina, Project WBAA BRIDGE Panelist

UN SDG's: Intelligent Transport Systems in Light of Sustainable Development Goals

General Problem Description

Transport is not only a matter of developing transport infrastructure and services, but it is rather a matter of the ease of reaching destinations in terms of proximity, convenience, and safety.

Intelligent Transport Systems are not only meant to make cities better places to live in, but better places to enjoy life too. So much of our lives depends on how we shape our cities. It is not just the environmental impact, but our social well-being, our economic vitality, our sense of community and connectedness.

What kind of life we want to bring about has been a question that societies across the globe have been trying to answer, and, at the turn of the millennium, this need for collective vision and collaboration in overcoming the challenges was widely recognized.

The member countries of the UN agreed to set collective global goals which have been the millennium development goals. The seventeen goals present a global agreement for the life we want to bring about. Transport, as we will see, is an important means for achieving all of these goals which address all aspects of social and individual life.

Transport shapes our lifestyles and everything we do depends on it – the way people travel to work or spend their leisure time, how businesses send employees to meet customers and how firms ship products to distribution centers.

Some of the most tangible questions related with ITS and Bosnian expiriences will be presented in this text.

Greenhouse gas emissions from the transport sectors have more than doubled since 1970 globally, and they are increasing at a faster rate than any other energy use sector. Some of the main policies that can reduce air pollution by up to 95% include: *redesigning cities in a way that public transport becomes the main mode of transport; providing cleaner fuels, and implementing vehicle emission standards for light duty and heavy-duty vehicles.*

From an environmental perspective we have an abundance of clear water in the Western Balkans, but the way we approach transport infrastructure affects this, because transport emissions and transport related waste can result in water contamination through metals and minerals impacting water quality and availability.

A range of emission of substances caused by transport may reach the soil, sediments from drainage systems or surface water may reach the water and the air and some of these may reach ground water as well.

Therefore, water contamination can also be sparked by waterborne transport of dangerous goods including chemicals, oil and other hazardous products.

It is not just water ecosystems that are affected. Terrestrial ecosystems are affected as well. Rail and road expansion and constructions have severe impacts on the landscape, and they can result in the destruction of the surrounding ecosystems in land stake or land degradation as well as cultural heritage degradation.

The need for construction materials and the development of land-based transportation has also led to deforestation, degradation of wetlands and reduction of biodiversity as well as the extinction of many animal species as a result of the changes in their natural habitat and the reduction of their movements. However, a well planned infrastructure and corridors or collective means of transport can reduce these negative impacts as well as the infrastructure footprint.

Greenhouse gas emissions and air pollution from transport can also affect crop yields and contribute to climate change, resulting in extreme events such as floods and droughts, impacting food security but also the access to nutritious and affordable food options for citizens. This also, impacts the economic life of citizens because transport offers the means for all of us to reach opportunities while providing job opportunities as well.

It provides accessibility while ensuring inclusiveness and social equality with the cost of transport being the determining factor. Improvement in transport and a decrease in travel costs contribute to household savings, and, therefore, improve food security too. It is important to note that the growth in goods transport and GDP of a country are strongly correlated, and also, that transport itself is a major employment sector offering a diversity of jobs.

Transport also affects livelihood opportunities indirectly by offering more access to formal education; this is, in fact, some sort of cyclical relationship where human resources are also crucial for efficient and high-quality planning and building of ITS.

Transport improves access to opportunities for everyone, however, here, it is important to talk about the context that we live in and to address the problems that we currently face. One of them is the problem of unequal access to opportunities between genders.

Transport is one of the key enablers for women to access opportunities such as health services, education facilities, jobs, participation in politics and social activities. Hence, safe, reliable and sustainable transport interventions can make a big difference in increasing women's education, productivity, health, and promote gender equality as a result.

Basic mobility needs of women and men differ and they are grounded on gender based division of labor within the family and the community. Therefore, it is very important to include women in the planning of Intelligent Transport Systems and this is why there is a specific Sustainable Development Goal dedicated to this gender imbalance. It is important to note that this reflects on all minority groups within a society.

ITS should also contribute to the lessening of crime in transport and also to road safety, particularly given that an estimated 1.24 million people are killed in road traffic accidents globally and the majority of these are young adults who are income earners. There are a number of policies that can prevent this, such as strict implementation of speed limit, traffic calming measures like speed tables, capacity building efforts and road engineering as well as traffic policies and their implementation.

Other health related benefits of sustainable transport refer to active mobility such as walking and cycling as well as noise reduction in the community. Also, affordable, reliable and efficient transportation is a vital precondition for access to healthcare, especially, in the remote areas.

In Bosnia and Herzegovina in the past 7 years there has been a declining trend and transport plays what is often an unaddressed but important role, because it functions as an enabler of economic growth, regional cooperation and economic integration.

Across jurisdictional borders it can help increase economic equality, and, thus, it can also enhance political stability. However, it is important to note that transport corridors can facilitate insecurity and activities of insurgents. Hence, it is vital to consider this in policy planning.

The Council of Ministers of Bosnia and Herzegovina in April 2022 adopted the Sustainable Development Goals framework after it had been adopted by the Entity Governments and the Brcko District Government. This document defines the collective vision at all levels of the country in terms of sustainable development on which the strategic plan for development is going to be based. Actually, this is the only unified vision of development on a national level.

In a document titled "Smart Growth" equal development of transport infrastructure in all parts of the country has been defined as a crucial precondition for strengthening competitiveness, social cohesion and overall sustainable development. The deadlines set for it are 2023 and 2030.

Below we provide a few slides depicting the aforementioned topics.

Assist. Prof. Dr. Anita Jurich (Lalich) – University of Mostar, Bosnia and Herzegovina, Project WBAA BRIDGE panelist[64]

Lessons Learned from the Mountains – Drones and ITS

General Problem Description

Drones, also known as unmanned aerial vehicles (UAVs), have been widely utilized by the army for many years. UAV application in other industries, including precision agriculture, security and surveillance, and the delivery of products and services, has dramatically increased recently. It is not possible to fully automate the transportation system as a whole by just automating the vehicels.

The field support team, traffic police, road surveys, and rescue teams, among other parts of the road and the entire transportation system, all require automation. Those components can be automated by utilizing capable and clever UAVs. In addition to effectively enforcing traffic laws and assisting traffic police on the ground, ITS UAVs may also effectively advise road users about traffic (i.e., intelligent traffic management).

The ITS UAVs can be enabled with a dedicated short-range communication (DSRC) interface, which will be included in future vehicle models providing vehicle-to-vehicle and vehicle-to-infrastructure (V2X) communications.

Some of the applications that may be enabled by ITS UAVs embrace, however are not restricted to flying accident report agents, flying margin units (RSUs), flying speed cameras, flying police eyes, and flying dynamic traffic signals. These examples need multiple UAVs to fly along, collaborate, and coordinate to execute a selected mission.

[64] https://www.western-balkans-alumni.eu

Establishing a link between ITS and mountaineering has turned out to be a very interesting endeavor. In the mountains, people use drones for enjoyment, for taking nice pictures from places[65] they cannot to climb, or for making videos if the weather is nice.

However, drones also play a positive role when it comes to searching and rescuing people who got lost in the mountains.

The mountains in Bosnia are still very wild, which means it is hard to get to some initial spots, from which the hiking can start. For example, driving to a specific starting point can be quite long; it can take up to 2 hours, so not many people go there to hike.

Below we provide a few slides depicting the aforementioned topics.

[65] https://www.youtube.com/watch?v=MnNVcMgMCQs

Prof. Dr. Tihomir Latinovich – Panelist, Faculty of Mechanical Engineering, University of Banja Luka, Bosnia and Herzegovina, Project WBAA BRIDGE panelist

Internet of Things (IoT) and Transport

Problem Description

The term Internet of Things (IoT) refers to physical objects that are embedded with sensors, a processing ability, software and other technology that enables them to connect and share data with other devices.

IoT devices are deployed in a number of areas within the transportation sector, notably in traffic congestion systems, telematics systems within vehicles, tools and ticketing and security and surveillance to name but a few.

IoT for transportation is the networking of objects via embedded sensors, actuators and other devices that gather and transmit data about real-world activities. The use of IoT enabled technology is changing the way in which the transportation sector operates.

What is a smart city? To put it simply, a smart city encompasses: sensing + networking + analysis + control. Looking at it, in the long run, Cisco IBSG predicts there will be twenty-five billion devices connected to the net by 2015 and fifty billion by 2020.

Virtual reality is connected with smartphones, smart homes, smart energy, autonomous and semi-autonomous cars, so there must be connections between cars, drones, and smart grids.

Possible Solutions and Discussions

Possible solutions might include wearable sensors networks to detect brain activity, to control cars, robots or home appliances directly from the brain, and many other wearable sensors to monitor and control our health.

The manufacturing process starts from artisan fabrication to digital manufacturing. This is manufacturing in Bosnia (and in Macedonia also) but this will be the future – the digital manufacturing.

Everything will be on the cloud, on a digital road and all researchers and engineers will be working together in building some new products inside a full digital road. 5G is something that we must establish in Bosnia and Herzegovina and in the Western Balkans and after that we can be thinking about smart cities and other smart things.

Some wider benefits that apply to the use of IoT technology within the transportation sector include the following:

Upgrade Client Experience – IoT technologies offer assistance to supply customers with more exact, up-to-date, real-time data to better plan journeys and improve communication.

Improved Traffic Safety – The ability to track things such as train speeds, aircraft part conditions, roadway temperatures and the number of vehicles at an intersection using IoT enabled technology can help to improve the safety of transit systems worldwide.

Operational Performance Benefits – Transport Agencies adopting IoT technologies are already starting to see benefits in terms of operational performance. Cities can better monitor critical infrastructures and develop efficient processes to minimize operating costs and improve transport system capacity.

Environmental Improvements – By better monitoring congestion in real time, IoT empowered systems can react rapidly to evolving traffic patterns and return real-time data to help people to plan their journeys better.

These benefits of IoT technology in transportation can be applied through a number of applications within the sector.

Applications using IoT technology include:

- Smart parking
- Traffic lights
- Smart accident assistance

Toll and Ticketing – Many of today's modern vehicles are equipped with IoT connectivity. A vehicle can be detected up to a kilometre away from a tolling station, correctly identified and the barrier lifted for the vehicle to pass through.

Connected Vehicle – Vehicles today rely on connectivity and a key part of that is many new cars are now equipped with internet connectivity, sensors and actuators, all monitoring a wide range of applications from brakes and engine to the control of tyre pressure and exhaust gas composition.

Vehicle Tracking Systems

Examples of IoT-powered functionality include: trip scheduling, fleet tracking, driving times and driver rest break scheduling, alerts for speeding, harsh cornering, acceleration or braking, monitoring of vehicle load, distance travelled and fuel consumption.

Public Transport Management

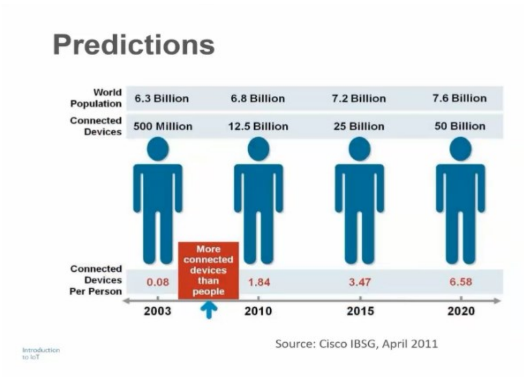
IoT technology for connected public transport systems provides the following benefits:

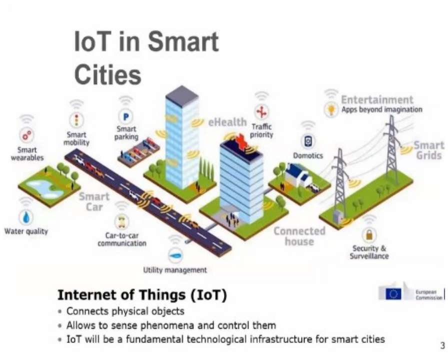
- Real-time vehicle tracking – this helps public transport agencies better communicate with customers and provide accurate arrival times through both mobile devices and passenger information displays at transit stops and stations;
- Data analysis and real-time management **–** the technology allows transit agencies to monitor progress in real-time and to make adjustments for

unpredicted incidents such as accidents, roadworks, emergencies etc., helping to re-route and make travel more efficient;

- Personalised travel information – transport agencies can monitor commuter behaviour and travel patterns, and deliver personalised information directly to their smart phone on key changes such as delays, or re-routing.

Below we provide a few slides depicting the aforementioned topics.





4.5 Case Study 5: Republic of Kosovo

Dr. Albana Veseli – WBAA Board Member, Panelist University of Pristina, Kosovo, Postdoc Researcher, University of Vienna, Project WBAA BRIDGE panelist

The Western Balkans Alumni Association[66] (WBAA hereafter) is a regional association of alumni from Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Kosovo* and Serbia who have spent part of their studies in the EU member states or third countries associated to the Erasmus+ Programme, either as an EU scholar or EU country scholar, or as a self-funded individual. Officially launched in March 2018, WBAA was born from the EU's Western Balkans Platform on Education and Training in 2015, where the Ministers of Education of the 6 Western Balkan countries agreed on the need to establish a regional network of alumni. Since its inception, WBAA has come a long way!

WBAA organised its 1st General Assembly in March 2019 in Tirana, Albania for all WBAA members. In March 2021, the second General Assembly took place. Since 2020, WBAA supports its members to implement WBAA Projects.

Today, the association brings together many relevant actors in the Western Balkans to make sure that the young people's voices in the region are heard loud and clear.

Western Balkans Alumni Association's joint projects of the members of the association are the most measurable results we got in WBAA activities which are developing with a progressing dynamic. The Case studies referred to in this book are being realized in the framework of the projects and are vital in developing participatory methodology for addressing trans regional issues bridging sciences and practicetogether – Use Case of Intelligent Transport Systems from managerial and technical perspective. This is a good example for raising such issues – such as the importance of Intelligent Transport which has been discussed regionally and globally, but not locally.

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66 https://www.western-balkans-alumni.eu/

Professor Assistant Arlinda Alimehaj – University of Pristina, Kosovo, Project WBAA BRIDGE panelist

UK Experiences: Intelligent Transport Systems in Signal Coordination of Corridors

General Problem Description

In Pristina, the capital city of Kosovo, the only or the single technology that make use of ITS is the Urban transport of Pristina – E-bus smart application of bus localization which can find answers to questions such as: *What are the closest stations to Smart Squared – Automation systems? Which bus lines stop near Smart Squared – Automation systems? What is the nearest bus stop to Smart Squared-Automation?*

In Pristina, as far as public transport is concerned, it should be mentioned that there are illegal taxis, which is an obstacle to developing normal traffic and transportation activities. Also there is a lack of information systems and poor access for individuals with disabilities.

And regarding active mobility modes, we can list: parking of vehicles on the sidewalks and in pedestrian areas in general, poor level of pedestrian safety, poor level of service (LOS) of traffic flows.

The roads or the lanes with the heaviest traffic are the Highway M9, which links Pristina with Peja city, and the Highway M2, which links Pristina with Mitrovica in the north and Ferizaj in the south, and the amount of flow or the maximum amount of flow that frequently uses these roads is between 40,000 and 50,000 vehicles per 12 hours and as we can see based on the household survey that we conducted in Pristina, the busiest roads are these roads, and there is an urgent need to do something with respect to construction and signal timing plan organization or traffic control planning and recompilation of these traffic planning of these roads.

There are 10 parking areas and half of the parking users in these parking areas are long time users based on the household surveys that were conducted 2 years ago. So, this is a problem and it seems that these parking areas are exploited in a bad manner – the citizens are not satisfied with the level of the parking service. One of the objectives of the new vision of the mobility plan for Pristina with regard to the poor level of service of motorized traffic is the application of modern information technology to improve the transport system capacity.

Automated Parking Guidance System APGS is technology with which the presence of parked vehicles is monitored in real-time. In addition to that, APGS is a smart parking solution that can help people to find empty parking spaces quickly.

Every parking space is monitored and detected by an ultrasonic sensor and once the car is parked in, the light indicator installed in front of the parking space turns from green to red. By dynamic or variable messages drivers are informed regarding free parking places.

Possible Solutions and Discussion

One of the benefits of ITS is improving the capacity and the level of service with a special emphasis on signal coordination.

Congestion is one of the critical issues that has negative effect on the lives of people. It is a phenomenon which increases with the increased number of people and the increased rate of motorization in the world that has come as a result of people’s need for transport.

Congestion as a phenomenon can be described by the following main indicators: delay, fuel consumption, transportation costs, environmental pollution, etc.

In Pristina, traffic signal control systems are conventional systems that are operating in a fixed time mode.

The fixed mode operates with fixed time or splits that do not change whenever the demand of traffic changes. This means that fixed time splits do not adapt to traffic demand changes but stay fixed all time.

Sensor loops that are mounted on the pavements or the surfaces of streets are expensive-budget costing. Hence, this is not the preferred solution to be used to control traffic at the intersections of our city. An advantage of CVS (Control Vision System) is a type of traffic control which is based on real time control according to current density, and this is less expensive and autonomous.

What is CVS? CVS relies on calculations of traffic density in order to use them or to transmit the traffic density to the controller who is supposed to do the calculations of green times so the vehicles must pursue these plates in order to pass the intersection or to clear the intersections. However, CVS do not use what is relayed in snapshots that come from the cameras at traffic intersections.

Coordination is not beneficial to all systems if the arriving vehicles are random and unrelated to the operation of the upstream intersection. In that case, coordination may provide only limited benefits.

Bandwidth is used as a measure of performance, or better put, a measure of effectiveness of coordinated systems. What is bandwidth? Bandwidth is the number of vehicles or a bunch of vehicles that can go from one intersection to the second intersection, or from the previous to the next intersection. They can pass all the intersections that comprise that segment during the green intervals.

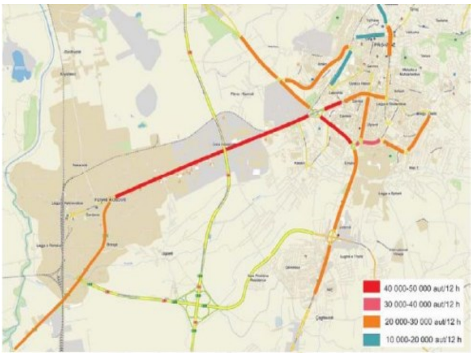
Instead of relying on infrastructure sensors such as loop detectors which are used in most of the cities in the Balkans, the urban traffic signal control can be transformed by connected vehicles or CVS technology.

What are connected vehicles? With this technology, vehicles and infrastructure systems can communicate with each other. In order to coordinate multiple intersections, we need to establish connection corridors in different green times of phase I of each intersection that must be linked, or must be coordinated with the next phase of the next intersection.

Due to the complexity of MINLP which is an abbreviation for Mixed Integer NonLinear Program, we reformulate MINLP as a decentralized two-level problem. In this two-level model, instead of solving the phase durations and offsets optimization for multiple intersections as one mathematical program, we decompose the overall problem into two levels: an intersection level to optimize the phase durations for each single intersection and a corridor level to optimize the offsets.

As a result, the complexity of the original mathematical problem is significantly reduced. The offsets are optimized so the progression of signals to be improved which is a step towards improving the overall level of service of that corridor and the road network in general.

Below we provide a few slides depicting the aforementioned topics.



Mergim Hajrizi – Panelist, MA Global Political Economy, City University of London, Kosovo, Project WBAA BRIDGE panelist

Electric Vehicles (EVs) and environmentally friendly urban areas

Problem Description

The first EVs were first created in 1835 by a professor at the University of Groningen, Mr. Sibrandus, from the Netherlands. At the beginning, it was only considered an innovative thing, it was not scaled up as a mainstream type of transportation. Later on, it was introduced into the mining sector, because it is much easier to go deep into the mines where there is not enough oxygen and it is not very feasible to use an Internal Combustion Engine that also produces CO_2 and reduces the amount of oxygen that actually is used by the miners in the mines.

They used the electric wagons for transport from the mines to the outside and also, later, Thomas Edison created the rechargeable batteries that we use today in the normal Internal Combustion Engines to ignite the car, and these replaced the normal batteries that were used up to that point.

Later on, rechargeable batteries were created, but since this kind of technology was not very well developed and the batteries were not very high tech, the cars could not reach a long distance. Moreover, the mass scale production of the Internal Combustion Engine by Thomas Ford caused the Internal Combustion Engines to become mainstream and the use of electric vehicles was put on hold for a while.

Why are electric vehicles important and what are their advantages compared to the ICE engines?

The pros are that electric cars are very efficient, because they use from 59 % to 62 % of the electricity into vehicle movement. The ICE only uses from 17 % to 21 % of the energy from fuel to make an actual movement.

The motors in the ICE or the normal cars that most of us use today have a lot of processes going on, and a lot of energy is transformed from one form to another, but a lot of energy is also lost in the process before it is transformed into the final movement energy.

The other advantage is that there is no gas emission – since there is no burning of fuel, there are not unhealthy gases like sulfur or CO_2 going out of the gas pipes.

The way the electric motor functions is more efficient. This means that EVs also have a high performance because there is less energy that is lost in the process and the transformation of the energy from electricity to movement is much faster. Also, this gives an instant torque, i.e. pulling power of the vehicles, and this gives the car much better performance and also, for some, that is also a better driving experience.

There are also disadvantages that are worth mentioning. Since the EV technology and the battery have been undergoing a fast developing process in the last 10 or 20 years, the fueling time which is actually charging time is pretty slow.

The other disadvantage is the initial cost because about 20% to 30% of the total vehicle cost goes to the battery cost and the main batteries that are used nowadays are the lithium-ion batteries – the same batteries used in our smartphones because they have more energy density. Hence, they are more suitable to be used in electric vehicles. But thankfully, the cost of those batteries is falling dramatically. Thus, in 1992, the cost of a lithium-ion battery per kW was more than $6000; whereas in 2021, it was drastically reduced to about $100.

The governments give subsidies to EV car owners. Unfortunately, in Kosovo we do nott have this sort of subsidies from the government. In 2019, the Minister of Economic Development came forth with a proposal – to remove customs duties and VHT from importing the EVs in Kosovo. However, because of the change of government, the realization of this proposal has not been pushed forward yet.

The initial cost might be a little bit higher than the ICE vehicles, but one has to consider the saving cost on fuel, because doing the same distance with an electric vehicle means that you will spend less money compared if you fuel your car with petrol or diesel.

Regarding AVs and the Western Balkan countries the lack of the infrastructure is identified as a main problem. That means there are not enough charging stations for charging the vehicles.

Thus, in Kosovo, unfortunately, there are only 3 locations where you can find charging stations and all of them are in the capital, in Pristina. In general, in

Europe, there are around 285,000 charging stations and that includes not only the European Union but the European continent overall, including the European part of Turkey.

Having electric vehicles as new technology creates some challenges that require certain changes to be made. For instance, there is a need for innovation, for policy change and for a new energy strategy.

Why is that so? In 2020 there were 8 million electric vehicles on the market, and, by 2030, according to Deutsche Welle, it is expected their number to rise to 116 million. The sales in 2020 of EVs were 3 million in total, but, by 2040, 66 million electric vehicles are expected to be sold. So, what seems to be the problem with respect to these expectations?

The problem is that the electric vehicle batteries that we currently use today are mainly lithium-ion batteries. The main component is lithium, but also cobalt and nickel or magnesium are needed as well.

Why is cobalt so important? The cobalt is important because it creates stability in the battery. Put differently, if the cobalt is removed the batteries are not stable and during the charging or discharging they can catch fire or explode.

Something like this happened with Galaxy Note 7, in 2015 and 2016, when the company had to pull all their Samsung phones after they released them into the market, because the batteries were catching fire and, in some cases, they were even exploding. That happened because the amount of nickel was higher than it should have been and that, in turn, increased the amount of energy within the battery, and also because there was less cobalt in it, the battery was less stable.

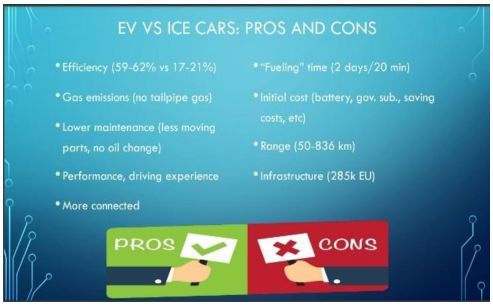
Possible Solutions and Discussions

The European Union in general is working hard toward the green goals and all its members are committed to the goal of selling 100% emission free vehicles by 2035.

That doesn’t mean that there will be only electric vehicles; electric cars that use hydrogen as a source of power are also taken into consideration. Several countries are also bringing the goals much closer, for example, Norway is planning to do that by 2025, and in 2021, 75% of all vehicles that were sold in Norway were electric vehicles.

Today, Norway is having some challenges when in comes to taxing because it has lost about 2.35 billion euros to EVs taxes. In fact, because they have created so many subsidies and so many tax credits and tax cuts to foster the use of electric vehicles, the country has less money to collect, which is a problem that needs to be addressed urgently. Germany has set its own target too – it is planning to produce 10 million EVs and also to have 1 million charging stations by 2030. Netherland is planning to register only free emission vehicles by 2030, and so does Italy, but by 2035.

Below we provide a few slides depicting the aforementioned topics.



4.6 Case study 6: Republic of Albania

Prof. Dr. Klejda Harasani, University of Tirana, Republic of Albania, Project WBAA BRIDGE panelist

Smart Cities in the Western Balkans

General Problem Description

During the past couple of years years, in Albania, this has been one of the “hot“ topics. In fact, 10 years ago this term was not used nor heard of, but now it is a good sign that we are beginning to talk about smart cities and there are many projects that are being implemented, some of which are expected to be fully implemented by 2026.

Are there smart cities in the Western Balkans? Well, searching for the answer to that question, the European Parliament conducted a survey in 2017. According to that survey, unfortunatey, there are no smart cities in the Western Balkans. In 2021 the situation seemed to have changed a little, but almost all cities in the Nordic countries are smart cities and that is also the case with the biggest cities in Italy, Austria and the Netherlands, as well as a half of the British, Spanish and French cities.

In comparison, Germany and Poland are slightly lagging behind, as these two EU members along with the Western Balkans have the lowest number of smart cities. So, to change that, of course, is not a simple task, but things are beginning to move forward.

Smart cities are created, they do not simply exist or emerge, and there is no end point to their development either, as becoming a smart city is a process by means of which cities use smart technologies and innovative approaches to address the challenges they are faced with, which, in turn, helps them to become more resilient and more liveable.

There are many smart actions available to citizens in Albania already present in the infrastructure, in education, etc.

In 2018, a very important conference was held – Tirana smart city conference, and during the conference 112 projects were competing with each other and were designed to make a significant change to Tirana’s current infrastructure by offering sustainable solutions to the city’s urban challenges. However, the problem is how to fund these projects.

This means that there are many projects currently that may be implemented provided there were sufficient financing/funding. The city is looking into innovative financing schemes such as crowd-funding besides public funding, but these are barely enough.

Reward-based crowdfunding models are also being considered, which allow citizens to contribute to certain projects that get private service providers involved as well.

For example, while paying their electricity bill, citizens may have the option to contribute to a social project that aligns with Tirana's smart city goals that are published on the Municipality's web page. However, given that collaboration is the most important point in almost all endeavours, collaborating towards finding smart solutions is vital in this case as well.

Faced with multiple horizontal challenges such as climate change, globalization, digital transformation, demographic change and also the latest global pandemic, municipalities obviously cannot simply "go it alone".

What needs to be done instead is cities have to seek for other collaborations with science, universities, private businesses, NGOs/NPOs as well as national and regional legislatures and governments and other communities to turn themselves into sustainable habitats.

There are some e-services that have made citizens' life easier, such as, for example, the new mobile application – My Tirana. In addition to accessing information on bus stations, taxi companies and real time traffic reports, this application allows citizens to report any neighborhood issues they may be aware of, in order to receive a quick call to action from the municipality, from the police, etc.

Possible Solutions and Discussions

A smart city is one which attracts people and investments, generates business and ideas and gives its citizens fulfilling and productive lives for the citizens are at the center of a smart city. Cities like this hold the potential to generate new industries, green technologies and decent jobs the world needs to sustain inclusive growth and development.

In 2016 a plan was established which was named Go Tirana Smart City 2016-2026. There are a lot of projects that have been competing in this plan: *Mobility* – to move freely, *Society* – directing the energy and talent of citizens, *Living* – a habitable city, *Economy* – moving forward and *Rural life* – the hidden treasure, rural life is an important part of Albania.

Additional CCTV – this is almost fully implemented, so the urban traffic control system of Tirana has been proven to be a very useful instrument in managing Tirana's heavy traffic.

However, for the center to function more efficiently, Tirana's street grid requires a greater number of CCTV in order to allow for better real time management of the traffic lights. And currently there are only 23 equipped with CCTV and this project has added 11 more CCTV on several more intersections.

The dedicated bus lane development has been partially implemented, in other words, some dedicated bus lanes have been constructed but not in the whole city, not in all streets. Integrated public transport systems which are management and passenger information systems, this is in the initial phase, this project.

The Tirana underground parking has been fully implemented in some of the parking lots. Thus, for example, there is a huge underground parking under the Main Square of Tirana.

Pedestrian bridges – the project of pedestrian bridges aims to develop several pedestrian bridges which, if made accessible to disabled people through long ramps, will facilitate the crossing of several crossroads that have become hot spots of problems for citizens and accidents.

In the 2020, very famous architect from Milan, Italy, who is the owner of the studio Stefano Boeri, has designed projects for the Tirana Riverside Neighborhood, which, in addition to other problems, is tackling the post Covid 19 needs.

It is a very recent project, and the architect said that it is no coincidence that Albania and Tirana are the first in Europe to accept the challenge of creating a smart, eco-friendly and self-sufficient energy district in a few months that will be capable of responding not only to post-earthquake emergencies, which was an emergency in 2020 in Tirana, as you may know, but also satisfying post-Covid 19 health requirements and the needs dictated by the climate crisis.

This is a very ambitious project and is a combination of functional and social features for different cultures and social groups.

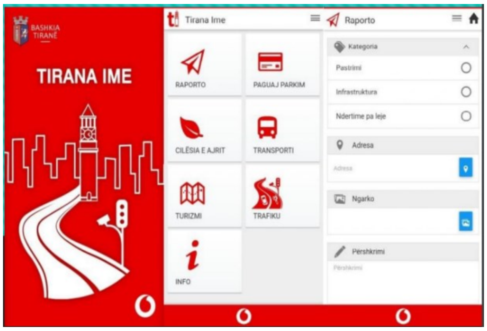
Accessible and self-sufficient in terms of clean energy, water, food and all urban public services and this master plan designed for a publicly owned enterprise located on the Northern border of the municipality and close to the Tirana river allowing new housing solutions to residents, this project will host ground floors allocated to retail and commercial activities with access to residential, sports, work spaces and numerous outdoor areas. And along with the master plan, guidelines for the design of individual building are planned with the aim of working closely with and reactivating small and medium sized Albanian businesses.

There are also essential public services grouped in these locations and the project will also include public and administrative urban factions, and numerous services for the city which is a university center.

On the other hand, public and private greenery and vegetation are distributed throughout communal areas, vertical surface and on roofs; whereas solar panels are used as a source for production and storage of clean energy, creating a local energy network available to all residents.

This offers extremely high performance from a seismic energy and mobility point of view aimed at creating a safe and secure public space.

The aforementioned topics are presented on the slides below.



CHAPTER V

CONCLUSONS

5.1 Recommendations for Western Balkan Countries

The basic economic and social habits, human behaviour and preferences are of great importance in achieving sustainable co-operation. The environment trends has changed into competitive and deregulated one.

Some *key issues* of the cross-border cooperation (CBC) policy are the following:

- Close work on development and renewal of the transport infrastructure;
- Removing administrative and legal obstacles to the movement of people and goods;
- Implementing new technologies and transport systems.

These are the long-term *objectives* that need to be achieved:

- New infrastructure development: creation of complete and functional networks offering efficient transport services;
- Improvement of social infrastructure: to help end-users to become more acquainted with modern technologies;
- Solving institutional and legal aspects: enhanced co-operation between market forces and public bodies;
- Passenger and freight services integration on the geographical, technological, and modal level;
- Permanent market observation mechanisms to gather statistical data and monitoring;

- Social and behavioural issues consideration in order for asymmetrical power relationship to be avoided;
- External effects measurement: the relation between the optimal usage of costs to be paid for the adverse environmental effects.

A sustainable development strategy may be viewed as a system comprising the following components:

- Regular multi-stakeholder for negotiation at a national and decentralised level;
- A shared vision and a set of broad strategic objectives;
- A set of mechanisms that can adapt to change (information system; communication capabilities; analytical processes; international engagement; and co-ordinated means for policy integration, budgeting, monitoring);
- Adoption of principles and standards through legislation, voluntary action, market-based instruments, etc;
- Pilot activities aimed to generate learning and ownership;
- Defining an acceptable level of environmental impact (EI).

The question of EI tolerance is difficult. While the overall environmental objective is "sustainable use", the operational definition is dependant on the project type and the number of social, economic, and environmental factors. Every ecosystem has a threshold for absorbing deterioration and a certain capacity for self-regeneration. The threshold of EI can become more flexible if appropriately implemented mitigation measures can reduce or control the adverse environmental effects.

There is no doubt that incorporating new and advanced information technology into *transport infrastructure* can lead to vast savings in travel time, improved driver safety and convenience, and a significant reduction in energy consumption and pollution.

Success would enable the *economy* to take full advantage of the growth potential of sizable infrastructure spending which will include direct spending and multiple effects, and the future stimulation of *new information technology-based industries*. Taking an approach to infrastructure investment that recognizes long-term opportunities would make a stimulus to our national economy. Infrastructure spending could be a rational means to promote emerging technologies that would be key to developing the economy in the twenty–first century – especially in the case of developing countries such as the Western Balkan countries.

The experience from technologically developed world could serve as a guidance and incentive to the countries in Central and South-Eastern Europe, if they wish to comply with the internationally recognized criteria in dealing with transportation issues.

In the Western Balkan countries, there are many obstacles to using ITS. First of all, the majority of those countries have not yet set the national frames of transportation strategy. Secondly, the relationship between the public and private sectors has not been precisely defined yet. The problem of funding remains open.

The readiness to transfer, accept, and put into practice some of the modern technologies is very low. The professionals try to stick to their traditional and classical thinking of solving the old problem.

The necessity of co-operative work on an international broad level has not been taken as a prerequisite yet. International research programs, transport and traffic data exchange, and technology transfer are at an initial stage. The level of computer network development, telecommunications services, and people's response to highly technological devices are unfortunately very low. Computer literacy is also on a lower level than necessary.

Taking into account all these remarks as well as the willingness and necessity to be a part of a broadened community, the Western Balkan countries have to make a step forward towards participating in the international research plan. This does not necessarily mean that they have to adopt and immediately implement or copy the ITS.

The background is quite different and so are the transportation needs and requirements. But, the evolutionary path will be very similar. That is why the need for an integrated systems approach in transportation, knowledge-based research work, and a shift from traditional to new thinking is being highly recommended.

Hence, when it comes to ITS, it is very difficult to follow the course of one or another country in terms of adopting (copy-pasting) a foreign-developed system. Neither the Japanese nor the Europeans have fully functioning systems that meet the objectives of ITS development.

However, it is very likely that some aspects such as traffic control, traveler information, and vehicle control systems that are readily transferable internationally will be developed in a worldwide context; that is, international standards will emerge so that the best products on the market could be accepted. These readily transferable components will include hardware and some of the software that defines the technique of operation.

The solutions of the institutional and economic problems as well as technological ones will be highly site-dependent- alone from solutions in the US, or Europe or Japan.

International multi – trans – cross - interdisciplinary research has become a strategic element. The preconditions of doing research are to have solid research programs, up-to-date facilities, and a sound, interrelated co-creative scientific community. Joint research minimizes the risk of overlapping and formulating ineffective or irrelevant conclusions.

The members of the OECD and the EU are making their commitment steps to exchange information with non-member countries. The principal activities are directed towards providing technical or policy support.

An unambiguous involvement of all actors: universities, governments, and private and public sectors in comprehensive international research cooperation, thus producing an international transportation database, and the exchange of knowledge and experience, are "condition sine qua non" towards a successful integration of all regions in the unified Europe.

5.2 What the Future Needs – A Step Forward in the Right Direction

Identifying the Need for a Sustainable Concept

In this section we wil highlight some of the key points regarding the need for a sustainable concept.

The technological development, the growth of urban agglomerations, and the globalization are considered as a threat to the natural environment with adverse impacts on the natural resources due to consumption, pollution and other factors.

We have come to the point where the question of preserving the environment and natural resources can no longer be overlookedIn other words, we have to reconsider our way of further development by setting some main principles:

- *Respect and care for each other*: this is the first principle of a sustainable society. A sustainable society places a high priority on the welfare of everyone on the interdependent web of relationships. All people, irrespective of their race, gender, age, and abilities are valued members. Everyone has the same right to a dignified life, which means a safe place to live, employment, access to education and a support system when the things go wrong. This seems to be very nice when put on paper. But, in reality, there are many obstacles, conflicts, prejudices built into the political and economic structure of unsustainable societies that keep them from reaching these goals;

- *Respect and care for the entire community*: this is the second principle of a sustainable society. How can we ensure people's quality of life? Only one part of the picture is to improve our self-made environment. To live a quality life, we have to live within a quality natural environment, which means we have to pay attention to maintaining a high degree of biodiversity of life and ecosystem vitality as well as controlling human population to stay within the earth's carrying capacity.

The concept of sustainability has caused long discussions and reflection on the way of life and economic activities of the developed societies. There are different areas of sustainability that affect society as a whole. These include: sustainable agriculture, sustainable business (sustainable industries), sustainable development (national/global policy), sustainable economics (communications for a sustainable future – ecology, education), sustainable energy systems, sustainable political structures (global network for environmental technology), and sustainable transportation systems.

The idea of sustainability helps to base our standard of living on the carrying capacity of nature. We seek to achieve social justice based on equity and economic sustainability, which require environmental sustainability. Environmental sustainability means maintaining the natural capital, i.e. the biodiversity, which, in turn, means that the rate of emitted pollutants should not exceed the capacity of the air, water and soil to absorb and process them.

Our cities have existed within the course of history and have survived as centres of social life, carriers of economies. Cities have been basic elements of our societies and states. They have been centres of industry, craft, trade, education and government. The European cities are very much diverse. They differ in their geographical circumstances and city administration in terms of sophistication of local responses, processes and techniques. Approaches to sustainable development are likely to differ in different cities. The city is seen as a complex system requiring a set of tools. It is appropriate to seek simple solutions which solve more than one problem at a time.

However, there is a need to set principles towards sustainability in urban areas. These principles are as follows:

- **Urban management**: tools to address environmental, social and economic concerns to provide the basis for integration. A more active view of the role of government is needed. Many of the problems of unsustainability are soluble if people accept limits of their freedom; if they choose or at least consent to them. A civil society in which individuals voluntarily agree to abide by certain collective limitations on their own actions may be the solution for sustainable urban management.

- **Policy integration**: a combination of the subsidiarity principle and the concept of shared responsibility. There is both *horizontal* and *vertical* integration. The *horizontal* integration realises the synergies of integration at all level between and within municipalities, countries, regions. The latter is required across the European Commission as well as within each Directorate General. Well trained and educated people capable of working in an interdisciplinary manner are needed. Professional education and training programmes should be therefore adapted. *Vertical* integration means going across all the levels of the EU Member States and the regional and local government.

- The countries that are to be associative members or about to become associative members of the EU have to start to design frames according to the principles set by the EU. In this part of Europe, we are all faced with choosing the approach of how to bring the process of sustainability closer to that of the EU.

- **Ecosystems thinking**: emphasizes the city as a complex system that is changing and developing. Energy, natural resources and waste production are regarded as chains or flows. Sustainable development subsumes: maintaining, restoring, stimulating and closing the ‘’chains’’. Analysing hydrological and infrastructure networks will result in basic principles for urban sustainability from a physical ecosystems points of view. Ecosystems thinking includes a social dimension which considers each city as a social ecosystem.

- **Co-operation and partnership**: different levels, organisations, and interests are essential parts of sustainability. The importance of “learning by doing” is being emphasised. The are two categories of co-operation. The first one is focused on the operations of local authorities and implies professional education and training: cross-disciplinary working; public-private partnerships, involvement of non-governmental organisations. The second category implies relationships between a local authority and community participation; innovative educational mechanisms and awareness raising.

Our present lifestyle, in particular our patterns of division of labour, land-use, transport, industrial production, consumption and leisure activities, and our standard of living make us essentially responsible for many environmental problems. Eighty percent of Europe’s population live in urban areas. Urban areas face the problem of conflict between human activities and natural processes. The current model of development does not take into account the ecological constraints. There is an increasing environmental decay that compromises the present and future human development. The current demand for sustainable development raises the question of which methodology should be used in order to meet future needs. For instance, the DG XIII within the Value II Programme of CEU launched the sc. “Awareness Methodology” as a method aiming to enhance public debates and to create a balance between society, technology and environment. The central point of this method is the social dialogue, which appears to be a promising instrument for articulation of future visions for implementing sustainable urban development.

Four cities (from the UK, Greece, the Netherlands and France) have been chosen in order to test the feasibility of this method. The method is considered to create societal awareness and participation in technological and environmental development. Regarding the results of implementing the method the need for education of people in the area of environmental issues and a creation of environmental information network. A particular emphasis has been given to local governments and their responsibility for sustainability. Education and information availability on technology accomplishments were considered of great importance.

Also it has been recognised that sustainability is neither a vision nor an unchanging state, but a creative, local, balance-seeking process in the areas of local decision-making. The city is understood to work as an organic whole. The management process rooted in sustainability should represent the interests of the future generations as well.

Reagrding ITS, several key points should be highlighted in order to establish the needs analysis for further research and development:

- System design necessitates a big picture perspective (global, European, regional, national, local level and all relations in between);
- Learning from global best practices, considering local contexts and iterating towards feasible solutions and adaptive management;
- Multi Stakeholders involvement that will bring together all relevant local people and organisations, interested in or related to a chosen policy challenge;
- In the Republic of North Macedonia, a comprehensive and long-term strategic orientation with clearly defined goals for an optimal and sustainable transport is needed;
- The National Action Plan for Environmental Protection and ITS is a particular need. The plan will generate regulations, incentives, and specific instruments to help channel government and private efforts towards sustainable development and environmental protection;
- A transport system design is needed to minimize the harmful impact of transport to the environment. Creating compact cities that reduce distances to public transport can get people switch from private vehicles to mass transit.
- Speeding the process of realisation and implementation of infrastructure projects. Realization of infrastructure projects will provide tangible impacts on growth, quality of life and productivity;
- Regarding traffic problems in urban areas, an integrated approach in carrying out the traffic studies and research is suggested. In this respect,

harmonization with the European regulations and norms in the domain of traffic signs and signals is a prime issue;

- The need for adoption of the possibilities offered by intelligent technologies in traffic management and control is emphasized, having in mind its benefits in the area of traffic safety, environmental protection, energy saving, and mobility;
- The public urban transportation as a mode of transport has to gain its proper role in urban areas;
- In the area of traffic safety the need for national traffic accidents database is emphasized;
- When transporting dangerous goods an integrated approach in respect to environmental protection and safety according to the EU norms and regulations has been proposed;
- There has been a lack of professional approach in performing traffic accidents reconstruction expertise. Hence, a code of ethics for traffic accident reconstructionists has to be designed;
- Since the Republic of North Macedonia is a crossroad between the West and the East, it is necessary to develop a combined transport for better connecting of Macedonia within the unified European transport market;
- Further development of integrated transport and communication system in a way to support modal split and to optimise transport needs and communications is needed;
- Transport intermodal centres design are a prerequisite for efficient, flexible and economic transport system;

- Reconstruction and design of new transport networks should be carried out;
- Dynamic realization of infrastructure upon the defined priorities and economic and transport criteria;
- Access to the whole territory of the country should be provided so that development equity of all regions could be achieved;
- Maximum usage of traditional transport corridors is needed for locating main transport corridors.

The conclusion is that international research has become a strategic element in supporting transport decision makers. The precondition of doing a research is to have solid research programmes, up-to-date facilities and a sound scientific community. Joint research minimizes the risk of overlapping and formulating ineffective or irrelevant conclusions. The members of EU are making their commitment steps to exchange information with non-member countries. The principal activities address to providing technical or policy support.

We have attempted by means of diverse inputs and collaborations to co-create and trace bridges on global, regional, national and domain level. It has been a challenging and hard work, intended to serve as a road map to be followed, instantiated and replicated by various actors in finding solutions to a broad spectrum of trans-regional problems. The authors of this book wish all of them good luck in their endeavours and are always disposed to offer a helping hand.

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APPENDIX

STUDENT EXERCISES AND FOOD FOR THOUGHT ACTIVITIES

- Define ITS in your own words!
- Name some examples of intelligent transportation systems?
- What are the components of intelligent transportation systems?
- How is the intelligent transport system implemented in practice in various cities in the world?
- What is C-ITS?
- Where can you see C-ITS in operation?
- ITS in Action: Case studies of current ITS systems
- Discuss the most important ITS developments!
- How does ITS work?
- What are the benefits of ITS?
- What are the functional areas of ITS and ITS services?
- Research, describe and discuss the most popular ITS solutions!
- What is ITS architecture?
- Case study: Design an ITS architecture with the FRAME tool!
- What is today's most cutting-edge technology, and how does it affect transportation?

- Choose one of the most cutting-edge technologies, study it, and show how it works! Describe your opinions on their usage and implementation in transportation, now and in the future!
- Design and evaluate ITS for urban network by using a microsimulation tool!
- Research and identify the relevant EU initiatives, activities and projects toward creating an integrated transport network!
- Why is sustainable development important?
- Discuss the Smart City concept?
- What is Smart Mobility and what are the main challenges?
- Analyze and discuss the ITS role in developing SUMP-s. For this purpose use the following source: https://www.eltis.org/sites/default/files/the_role_of_intelligent_transport_systems_its_in_sumps.pdf
- Grasp the regional ITS big picture of stakeholders, components and mechanisms!
- Try to grasp the big picture, the local contexts, the regional challenges and the system design of ITS and its management – is it possible? On what level? How can integration occur? How can adaptation take place? How is complexity handled?
- Explore in a multi/trans/cross/interdisciplinary manner the challenges of ITS across the world!
- Investigate the broad range of agents and network relations needed to achieve any conceptual solution in reality!

- Who is accountable for the ITS positive outlook?
- How can we enable self-organization across the broad spectrum of stakeholders in the investigated problems in this book?

ABOUT THE AUTHORS

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Renata Petrevska Nechkoska, after completing double PhD degree in Business Economics from Ghent University Belgium (UGENT) with mentor Prof. Dr. Geert Poels, with PhD in Management at "St. Kliment Ohridski" University - Bitola, North Macedonia (UKLO) with mentor Prof. Dr. Gjorgji Manceski, she currently works as: assistant professor at UKLO and postdoc at UGENT. Since 2015, she is also engaged as European Commission evaluator for projects in Horizon 2020. Before academia, she was a practitioner for almost a decade - a banker in international financial institution ProCredit Bank - with HQ in Frankfurt Germany, mostly on middle management positions - head of HR, branch manager, project coordinator. She is Ghent University alumni ambassador since 2015, Western Balkans Alumni Association Head of research team since 2019, Elsevier Advisory Panel member since 2015, Harvard CID PDIA Community of Practice Alumni since 2017, and during the pandemic, she was EUvsVirus project manager for academia and R&D partners and is now facilitating open innovation in science collaboration under the name of Academia diffusion experiment, with global scholars and practitioners. Her research in 'Tactical management in complexity: managerial and informational aspects' has been her way to build bridges of multiple disciplines (information systems, management, complexity, ...), countries and is being applied in diverse settings.

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