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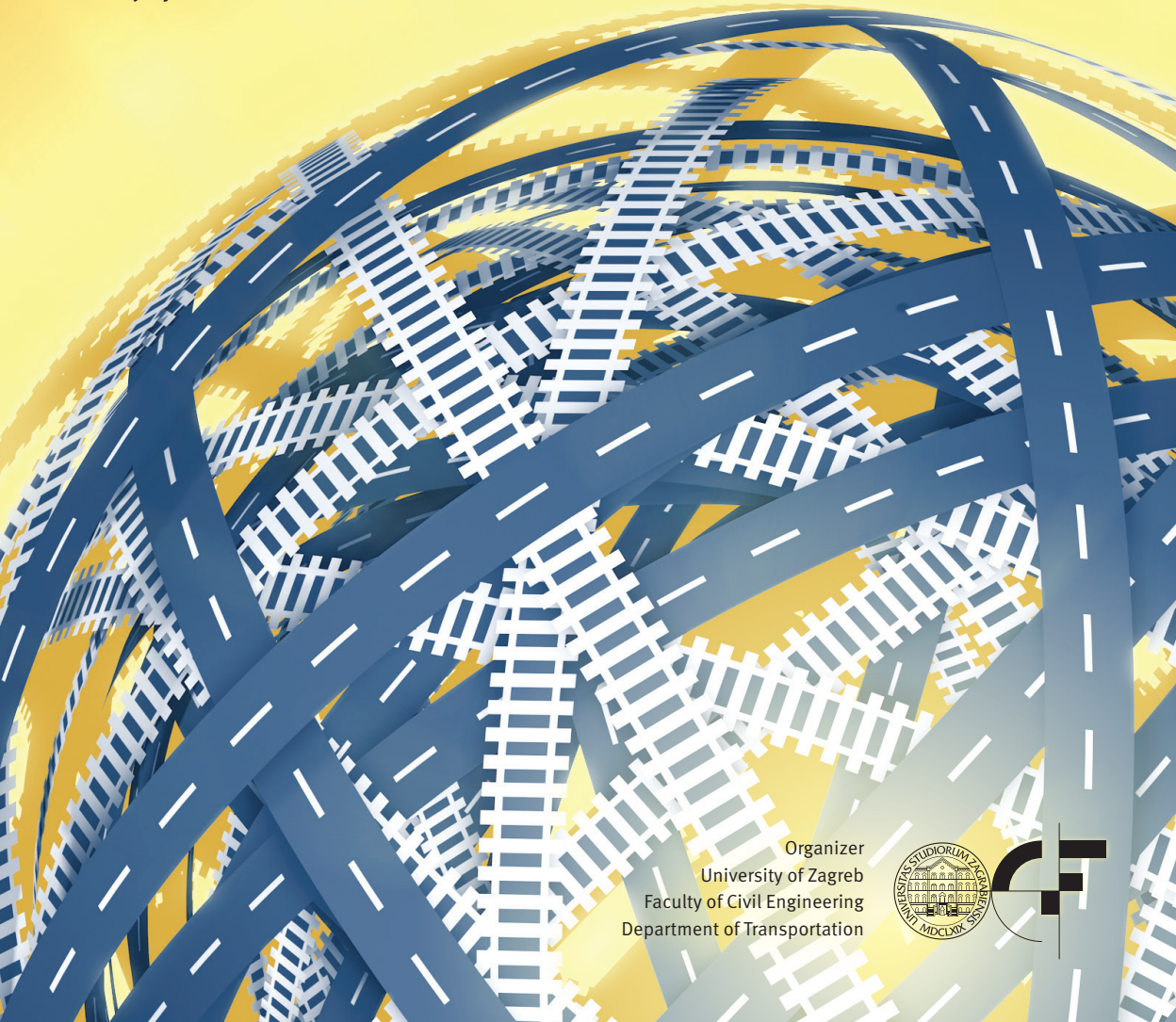**4th International Conference on Road and Rail Infrastructure**
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

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Proceedings of the
4th International Conference on Road and Rail Infrastructures – CETRA 2016
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

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INTELLIGENT INFRASTRUCTURE AND ITS USE IN MONITORING AND REGULATION OF ROAD TRAFFIC

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Abstract

The expression "Intelligent Infrastructure" presents devices and systems which are used with intelligent transport systems and systems for management of traffic. Intelligent Infrastructure presents purposeful organizational and informational – communicative upgrading of classical traffic systems, vehicles and transport entities. Basic role of Intelligent Infrastructure is reflected in information gathering, elaboration and analysis of current status, and on that bases orders are issued in order to provide simple activities flow for all traffic participants in a traffic process. Due to the complexity and the compactness of the term intelligent infrastructure it is necessary to base the division on the devices and objects of Intelligent Infrastructure. The Intelligent Infrastructure devices includes: sensors, detectors and variable traffic signs, while the objects of Intelligent Infrastructure imply the toll booth, intelligent vehicles and intelligent infrastructure in the tunnels. The sensors and detectors are the main technical components of Intelligent Infrastructure that are providing collection of data from "system sources" which includes capability to collect and elaborate data's of Intelligent Infrastructure environment. Variable traffic signs are signs that can change their content due to the different needs, but due to the traffic flow on first place. The application of these complex assets is applicable in the entire transportation system and its application has led to greater safety and security of all traffic participants, a better traffic flow on the roads, reducing congestion and traffic jams, more efficient monitoring and control system.

Keywords: Intelligent infrastructure, monitoring, regulation, road traffic

1 Intelligent Infrastructure communication system in road traffic

Nowadays there are more data transfer technology that is characterized by different parameters such as transmission speed, reliability, flexibility, security and quality of service. Some of these technologies have their place in both fixed as well as mobile and satellite networks. Highways are equipped with information and communication systems. In parallel with the intensive construction of modern, ie, intelligent infrastructure is being built as a information and communication systems which are provided for the control and management on roads [1]. The systems that are used for collecting traffic data, measurements, adaptive control, and traffic signalization are seen as part of intelligent infrastructure on highways. The telecommunications system enables the exchange of data, speech and video between users and centers for traffic management. Globalization and the rapid development of information technology, contributes to the increasing volume and it is needed by the users for broadband data, voice and video services. With advantages such as rapid network construction and fast return on investment, broadband wireless access systems, represent one of the most acceptable solution operators to build a MAN (Metropolitan Area Network). To achieve maximum effect in the monitoring, management and thus improving the overall traffic on the roads it is necessary

to enable communication between vehicles and intelligent infrastrucures. The importance of communication within vehicle-to-infrastrucure is reflected in the fact that the vehicle receiving information about changes in the position of neighboring vehicles (accidents, overtaking and other maneuvers on the road) are able to adequately respond to the same, in terms of avoiding new traffic accidents [2].

1.1 The importance and the role of intelligent infrastructure in the management and safety systems in road traffic environment

Solving the problem of traffic using the information – communication technology has proven to be a very effective way to increase the flow, stabilizing traffic flow, increase safety and driver awareness. Traffic lights with pre-coordinated time for a long period has been a solution that has worked successfully. Enormous increase in motorization and uneven load of road congestion, traffic queue and traffic jams are still present. In the regulation of traffic systems we have involved certain amount of speed and movement detectors of road vehicles, especially sensors, which can analyze the situation on the roads and measure the speed of individual vehicles on the basis to regulate the of speed traffic flows. Traffic flow is displayed in three basic sizes as follows: the flow of vehicles, current density and high space velocity. The values of this parameter indicates what type of traffic flow is in question (free, normal, saturated and forced).The fundamental equations of the theory of traffic flow is:

$$q = g \cdot v_s \ \ (veh/h) \tag{1}$$

Where:
q – the flow of vehicles [veh/h];
g – density flow [train/km];
v_s – average spatial speed [km/h].

The principle operation of detector traffic signalization lights is to electronically register frequencies of traffic and controlled regulation of green light to allow better flow of vehicles. The main advantage of the new management system is the greater flexibility of programmed signal interval, which means less time losses for vehicles waiting for a green signal. There are three types of such traffic lights, which are programmed depending on the type of intersection that is managed. In addition the detectors and sensors without analyzers and process units have no purpose. Processor control is realized through three concepts [4]. The first concept is based on the detection of vehicles to give absolute priority, where the vehicle with priority passage, such as emergency vehicles or trams, gets a solid green light, and the other participants red signal. The second concept is the intersection of the main and sub lines, the main line has a much higher traffic load and if obtained information that there is no vehicle from the side direction of getting the green light. The third concept occurs in the case when both directions around burdened number of vehicles. At these intersections are installed detectors in order to extend the duration of the green light. Work is based on the principle that every three seconds there is a control if a vehicle is arriving. If the camera detects a vehicle from a lateral direction interruption phase intended for the passage of vehicles.The benefit of radar devices is that messages can change the content and warn road users about the weather, the state of road, accidents, road works and the permitted speed of the vehicle.
They are used both in the urban and the rural roads and the roads of the highest rank, ie. highways. The problem of these devices is that the detectors and sensors are sensitive devices that are susceptible to interference and external influences. Additionally still require significant financial resources for the purchase and maintenance. The efficacy, safety, reliability are the keywords today for assessment of traffic transport managment systems. Increasing mobility and the degree of motorization led to imbalances or the state of increasing demands

on network capacites. The result of the congestion in the network to which it is now estimated that the relationship of 2 to 4% of GDP per year in Europe [9]. As a result, one of the imperatives is better, and safer traffic management in the network of existing roads [5].
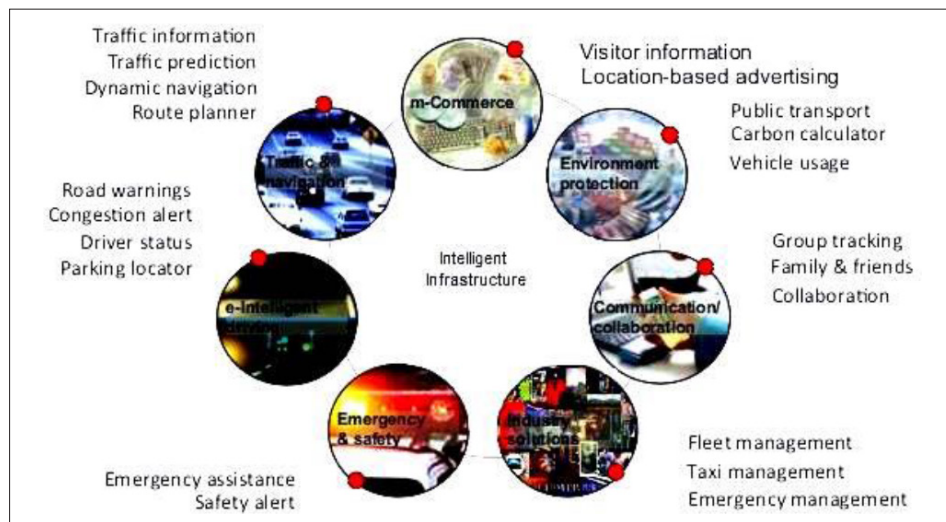

Figure 1   Display of the basic services that ITS provides in the managment of road traffic [4]

The results so far in the application and estimates suggest that intelligent infrastructure will be one of the main tools in achieving better, more efficient, safer traffic conditions on the road networks. Keywords such as efficiency, safety, environment, lower maintenance costs are almost always present in the presentation of certain system of intelligent infrastructure but some doubt remains when one takes into account the structure of algorithms which provide certain management decisions. Progress in terms of utilization of the opportunities provided by Intelligent Infrastructure in practice are very small. Dynamic traffic management is almost not applied in practice. The study of user behavior, accepting or not the information that his offered, acceptable intervals tracking, user behavior in conditions of congestion, travel time-haul flow and others. Research in these areas are very modest and therefore the results. For example relation flow-rate as a function of the characteristics of urban roads are usually taken from existing manuals or instructions that are made in other conditions and in other times. A large degree of safety of road transport today is the goal of many countries. Developed countries are investing heavily in infrastructure and sophisticated equipment. Countries in transition, however, due to lack of investment in existing facilities, and in fact usually clenched increase in the number of vehicles (mostly elderly), complicate the problem of road traffic. The solution probably lies in greater involvement and commitment to traffic not only participants in traffic, but also the whole society. Therefore, road traffic daily corrects and marginalize various regulations and laws. Devices of Intelligent Infrastructure largely correct the use that can affect the change of the safety state of road traffic systems. Although their safety of road transport is not fundamental role in ultimately having a significant contribution to increase the level of safety in road traffic systems. A precondition for this is the connection with the center that aims to rationally manage the traffic and its control. Management of traffic trying to avoid traffic jams, congestion, the appearance of the column of vehicles and other elements that disrupt traffic stability and security. General-known rule says that constant control causes cautionary behavior to drivers and the participants in the traffic so that these appliances such as speed control can contribute to the greater safety of road traffic. An example of application and use of sensors is possible in almost all engineering and many other fields, Figure 2.
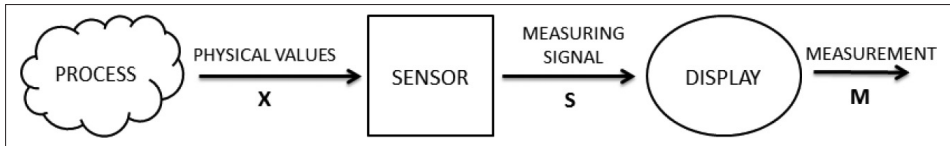
Figure 2   A simple model of instrumentation sensors [4]

Based on the size of the X sensor generates a signal S which can be manipulated in a manner:
1) Display on a visual unit,
2) To carry out treatment,
3) Transfer to certain distance.

Calibration or static characteristics of the sensor is a relation between physical value X and the measurement signal S. The sensor can be calibrated by bringing his input the elements who are a set of known values in the physical value and recording the response to it. In case of additional sensor inputs, interfering input response of the sensor represents a linear combination of the interference input and the measured physical value, shown mathematically and graphically on the chart below, Figure 3.
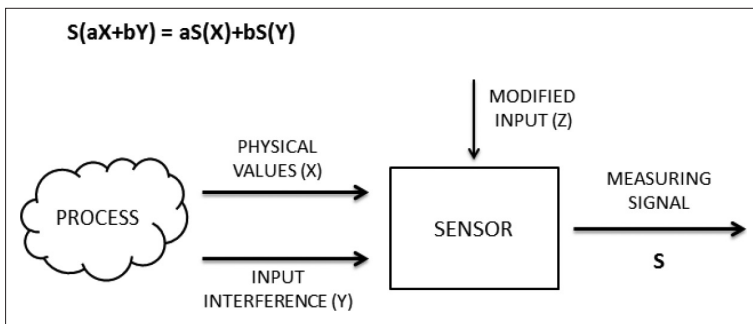

Figure 3   Schematic sensor with modifying entrance [4]

From the point where the sensor is placed it depends his efficiency and maintenance costs. The sensors (the same applies to the detectors) placed on or in the street, are more susceptible to defects than those set above the road. On the choice of where the impact properties of roads, technical limitations and the type of management on the crossroads. There is no country in the world that does not have the problem of traffic safety. But when it comes to our country B&H it should be noted that we are leading in Europe by the number of accidents and fatalities.Despite the planned measures and new stricter legal provisions still did not achieve the desired effect.

2   Application of intelligent infrastructure in the actual surrounding

Intelligent Infrastructure together with ITS is a new discipline that certainly provides a more efficient and safer traffic, and the better use of existing infrastructure, but not always.Today's use of intelligence in road traffic is very tight and difficult to fully digest.

2.1 City traffic control

The population is steadily increasing worldwide resulting in intractable traffic congestion in dense urban areas. Consequently the demand for mobility is increasing, resulting in severe traffic congestion in urban areas. Traffic congestion leads to undesirable impacts on mobility,

accessibility and socio-economic activities, as well as the environment. Another important form of monitoring of traffic is video surveillance. Currently, video surveillance is used manually by the operator in the control center that collects information automatically coming from the detector. There is great interest in automated data collection.

2.2 The system that controls the managment of traffic

Adaptive Traffic Signal Control (ATSC) has the potential to effectively alleviate urban traffic congestion by adjusting the signal timing plans in real time in response to traffic fluctuations to achieve the desired objectives (e.g. minimising delay). For small and medium flows, the system compares the advantages and disadvantages of the change in the next phase and does change when it is needed the most. Reinforcement Learning (RL) has shown promising potential for self-learning ATSC due to its ability to perpetually learn and improve the service (traffic conditions) over time. In RL, a traffic signal represents a control agent that interacts with the traffic environment in a closed-loop system to achieve the optimal mapping between the environment's traffic state and the corresponding optimal control action, offering an optimal control policy. The agent iteratively receives feedback reward for the actions taken and adjusts the policy until it converges to the optimal control policy. Once the optimal policy is learned, the mapping of the observed system states to the optimal control actions is very fast. For a network with multiple signalised intersections, efficient and robust controllers can be designed using a multi-agent reinforcement learning (MARL) approach. This system provides a high degree of flexibility because it is oriented to the group (not on stage), and contains several new features that make heavy traffic safer, reduce congestion and give priority to public transport.
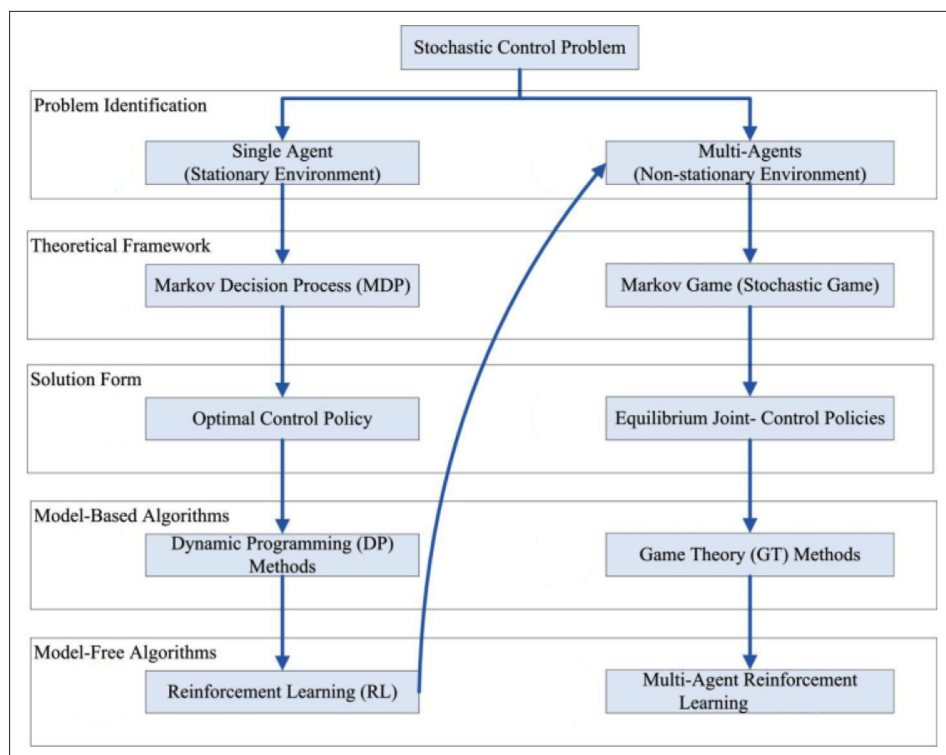

Figure 4   Stochastic control problem [9]

In order to solve the ATSC problem in general, and to particularly facilitate the understanding of the proposed approach in this paper, the problem first has to be properly classified and formulated. Due to the stochastic nature of the traffic environment, ATSC can be classified as a stochastic control problem, Figure 4. This paper provides the relevant theoretical foundation for this type of control problem from single agent and multi-agent perspectives. It also provides a review of RL as a promising solution algorithm for the stochastic control problem. The problem of coordinated ATSC is a challenging due to the exponential growth in the number of joint timing plans to be explored as the network size grows. This thesis focused on the development of self-learning-based approaches to coordinate the behaviour of control agents in a multi-agent traffic control system with an emphasis on decentralised and scalable methods for large-scale urban traffic networks. Achieving coordination between agents in GT is proven to be unfeasible for a large number of players (agents) because the state-action space increases exponentially and the learning speed decreases dramatically with the number of agents in the system, which is known as the curse of dimensionality problem.

2.3 Highways control

This refers to traffic control and tunnels, outside urban areas and includes the detection of accidents, monitoring the load, entry and exit from the highway and follow collective travel guide. The changing display messages "Variable Message Signs' (VMS) can be used to determine the speed and direction (as in" Dutch Motorway Control and Signaling System "(MCSS), so that warns drivers about the state ahead of them or to make recommendations on the selection of direction (as in the Rhein / Main motorway network). It is important to distinguish between "access" control (mandatory access control) and "line" control (required control speed and direction). For sizing station toll is possible to use analytical formula. If these formulas and / or methods do not provide an appropriate solution must not come to a state of supersaturation. Simulation methods are required to analyze the existing station for toll collection (simple and complex – in terms of sizing), in which the combined bidding toll (e + manually) [10]. Classical systems charge fees for the use of road infrastructure are very difficult to apply in countries with a high volume of vehicles, because they require interruption of traffic flow, which results in:
1) Loss of time,
2) Reduced comfort and productivity of transportation,
3) Creating congestion and delays.

To avoid such consequences, the drawing up of the system where the traffic flow is not interrupted, but are billed automated application of the latest achievements of information and telecommunication technologies.

2.4 Detection of accidents and congestion level monitoring

Detection of accidents is very important in tunnels and other high-risk locations. The system of detection of accidents depends on the size of the accident and the level of traffic flow. Car accident detection is based on the measurement of speed and measurement retention, as evidenced by the inductive loop. The early algorithms, such as the California algorithm, they tried to detect the shock wave resulting from an accident by following the spatial and temporal discontinuity of flow and its retention (time for which the loop is occupied and density of the loop). Experience has shown that of all the parameters that are measured at the inductive loops, the change of speed best indicates the presence of an accident. So far, automatic video analysis could find vehicles that are not moving or are slow moving. But in general video surveillance is used manually only as a supplement to other forms of detectors accident.

2.5 Integration with dynamic travel guide

Each intersection controller can basically follow the travel time directly, or indirectly through the detector data in the vehicle. News of the density of traffic on the network can be exchanged allowing it to be made modifications and recommended routes. Driver assistance systems have radar sensors that take into account the traffic from the side and behind the vehicle and constantly inform drivers about potential dangers: when changing lanes, following incoming vehicles that the driver can not see, and warned him not to open the door if you are approaching cyclists. Based on the analysis, the global market for systems that help the driver to the 2015 cost about 1.9 billion euros, for the Member States of the European Union[5]. Since 2010, passengers have access to constant predictions of the traffic situation on their mobile phones, radio and the Internet.

3   Conclusion

Smart infrastructure is a intelligent infrastructure which is fully aware of its functioning and is capable of managing its functioning with a control system. The realization of the need for rational traffic system that is economically efficient and environmentally justified, requires a new way of looking at and solving traffic problems. The implementation of these demands requires a whole new philosophy of formation, functioning and management of all components within the transport system, through the effective application of modern management, computer and communications technology in transport. The development of intelligent infrastructure has to deal with society as a whole, given that the benefits achieved its application of higher social interest. In conclusion, the Intelligent infrastructure framework developed in this papers outperforms prior methods and techniques by introducing a more robust and scalable solution, especially for highly-saturated, diverse, and increasingly larger networks. Therefore, this paper offers a major contribution to the complete management road traffic system. The resulting system is also promising for other control applications beyond ATSC that contributes the most to the Intelligent infrastructure as an adaptive solution. In this context, the Intelligent Infrastructure needs to be developed in an integrated way, in order to provide a significant contribution to the economy, environment, social needs and objectives of social development during the next period.

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