Abstract — Emission charging is a new phenomenon in transportation research. Whilst fuel taxation and road tolling are common ways of income raising in many countries, these initiatives are primarily aimed at road infrastructure financing. Worldwide, there has been growing interest in pricing structures designed to manage the growing levels of traffic congestion and, in recent times, an increasing focus on generating reductions in carbon emissions from vehicle ownership and usage. In this research model for vehicle emission charging using cooperative intelligent transport systems (ITS) has been made. With the use of proposed model, traffic management would be more accurate and efficient using the data provided by the Traffic Cooperative Center for Emission Charging. At the end, significant reduction of environmental pollution produced from road traffic would be achieved.

Keywords — cooperative systems, emission charging, intelligent transport systems, vehicle emission

I. INTRODUCTION

The emission charging is an important role in environmental protection. It reflects the efficiency of the environmental supervision and law enforcement. Tightly with the project examination and approval, environmental supervision, monitoring and legislation, the emission charging has a sophisticated information structure. In road transport emission charging hasn’t yet been implemented on a cooperative system basis. Through this research paper, model for vehicle emission charging using cooperative intelligent transport systems is presented.

In the second chapter basic concept of cooperative ITS with communication technology is described. Also, main cooperative ITS solutions and possible implementation scenarios are presented, where communication between vehicles and infrastructure is essential. Third chapter defines basic principles and models of emission charging with comparison with congestion charging is made. Several emission charging methods are described regarding of placement and defined scenarios. In the fourth chapter the model for vehicle emission charging using cooperative ITS is presented with essential need of Traffic Cooperative Center for Emission Charging implementation. Fifth chapter defines the architecture of defined model of cooperative ITS for emission charging.

II. COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS

The concept of cooperative intelligent transport system in terms of communication includes gradual increment of commercial solutions and systems in automotive industry on the market such as [1]:

- safe distance control systems
- speed maintaining systems
- autonomous management of vehicles within the traffic lanes
- avoidance of overtaking in unsafe places
- safe passage through the intersection, etc.

These systems, with the benefits and their advantages that they provide to users of the transport system could further increase the superstructure of the existing system functionality in which individual vehicles could constantly communicate with each other or communicate with the transport infrastructure [2].

From Fig. 1, the establishment of an extended communication between the main traffic center, vehicles and drivers is visible. An expanded set of data includes the location and speed of the vehicle, the current number of

Fig. 1. The ITS communication system [3].
passengers, possible delay to a defined timetable, etc. [4]. In this way, the urban transport system can be viewed as a single system with real-time information exchange between vehicles, infrastructure and the driver.

Functionally, ITS system could be divided into 4 subsystems. These subsystems are [5]:

- personal ITS system or personal ITS station that is most often performed as a handheld device
- Central ITS subsystem, which is usually part of a larger ITS system
- ITS subsystem in a vehicle, for example, personal, cargo vehicle which is being driven or parked
- road ITS subsystem in tunnels, bridges, parts of roads, portals etc.

ITS communication system that supports networking towards the topology, as shown in Fig. 2.

![Fig. 2. Concept of cooperative ITS communication](image)

Shown topology very clearly illustrates the full range of existing information sources whose principle development and constraints achieves a higher degree of interoperability described in the next section.

III. PRINCIPLES OF EMISSIONS CHARGING

Principles of emissions charging can be applied analogously to the principles of congestion charging [7]. First theory of traffic congestion charge was presented in scientific circles in 1920 by Pigou. Four years later, Knight presented his theory that was developed by Waters & Vickery in 60 years of the 20th century. Developing that theory, pricing principle was put forward with base on marginal cost from an economical angle, giving importance to negative externality produced by congestion. Because of the negative externality, marginal cost of transportation journey (cost, oil consumption, vehicles lose, service upkeep, parking fee) was smaller than society’s marginal cost (personal marginal cost and other people’s time loss, fuel consumption, pollution and traffic accident caused by traffic congestion).

Analog to this principles, emissions charging can be carried out according to the following principles.

Vehicle Types - For the personal vehicle, traveler’s pollution charge should be much higher than for vehicles of public transit with a high loan capacity for encouraging higher usage of public transport. Also, pollution charge would depend on vehicles ECO-norm standard, defined by the car manufacturer (higher ECO norm, less pollution charging).

Pollution Degree - Depending on the pollution degree, travelers should be forced to change their route of journey by choosing a cheaper route (road sections with smaller pollution degree and shorter duration pollution time), or changing the time of going on a trip, if it’s possible. Those chosen routes, should be free of charge or charged low.

Road Network Situation - While executing traffic pollution charge, travelers are being forced to change their route of trip by choosing non-charging paths in road networks. Before deciding of changing the route, travelers are taking into account travelling time, traffic flow, straight line coefficient, views, points of personal interest on the path and so on to make their choice. Sometimes, the road pollution pricing must be much higher for drivers to choose different route that’s free of charge or very low charged.

Traveler’s Bearing Ability - Charge standard should be very well analyzed for a successful implementation on a longer period of time, from the view of the traveler and his possibilities. Travelers sometimes would choose a pollution charged area, but they can’t pay it. If this important factor would be forgotten, the traffic pollution charge would be unable to implement.

Making the decision of size of the area of charging the pollution is an important link. City encircling route, city bottleneck road and city region boundary can be taken for charging pollution fare.

Encircling Route Emission Charge - Encircling route emission charge means charging to all vehicles which enter into encircling route. Emission charging standard is decided by the vehicle type. This kind of emission charging, also takes into account, time of travelling on encircling route. For problem solving of traffic emission in central areas of cities, this function of emission charge won’t be successful. Urban living communities concentrate on the suburb, while working in areas of the city, journey elasticity is very low.

Bottleneck Road Emission Charge - Bottleneck road emission charging means charging to vehicles which run on the bottleneck road by setting toll station at the main street intersection. Charging amount for a traveler will depend with amount of the emission at bottleneck toll station that varies also with time of the day, volume of traffic and etc. The theory of this method is the bottleneck model of path congestion charge system that was proposed in 1969 year by Vickery. Vickery pointed out that collecting congestion charge may eliminate queuing phenomenon, but also if not dealt properly it could cause new congestion. In our case more emission.

Region Emission Charge - The principle of region emission charge is charging to the vehicles that enter the certain area. Area is defined according to the city district...
division putting toll stations, charge monitoring stations etc. Only vehicles entering charging area in a specific time will be charged with positive result, reducing traffic flow and traffic emission. The goal of this method is bigger growth of public transport.

IV. MODEL FOR CHARGING VEHICLE EMISSION USING COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS

There are two methods to charge vehicle emission: manual charge and cooperative charge. Manual charge works on following principle: vehicle enters area of charging vehicle emission through the tollbooth for taking a ticket that is used for paying the vehicle emission leaving at the exit tollbooth. At the exit tollbooth, vehicles information (ECO-norm standard, type of engine, etc.) is used to charge the driver. That information is gathered with license plate camera reader that is connected to the data base on back-end server of Traffic Cooperative Center for Emission Charging mounted on the tollbooth.

Cooperative charging of vehicle emission shown on Fig.3 works on following principle: while the vehicle is approaching the emission charging area it sends its information to the Traffic Cooperative Center for Emission Charging through the road side units for calculating the charge of using the emission charged area. On that information driver decides to use it, or not. If the driver decides to use the emission charging area, paying is processed when leaving the area. Paying process can be done on two ways, paying based on monthly usage report for that vehicle, and paying immediately through personal device connected with vehicle (smartphone, on-board diagnostics (OBD) dongle, etc.).

If the vehicle is not technically in order and the MIL (Malfunction Indicator Lamp) indication is on, while approaching the emission charging area, driver gets information from the Traffic Cooperative Center for Emission Charging to choose an alternative non-charging route and visit the vehicle service. Drivers are not allowed to enter that area, because their vehicle is producing more emission than it is allowed by the Law on Road Traffic Safety.

![Fig. 3. Model for emission charging with use of Cooperative ITS](image)

V. ARCHITECTURE OF COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS IN USE FOR VEHICLE EMISSION CHARGING

This kind of architecture is created for allowing all vehicles and infrastructure elements to communicate with each other in a continuous and transparent way using a variety of media with enhanced localization and in vehicle communication capabilities, for fast and reliably emission charging [8]. Architecture of emission charging system supports cooperation models in real-life applications and services for drivers, operators, industry and other
stakeholders. This kind of architecture provides the processing and communication feature that is located in each vehicle and it provides the application to show position of vehicle, communication functions and interfaces to other vehicles and other entities, Fig. 4. Those entities, can be central servers used by service providers that communicate with the Vehicle Data Acquisition Systems using cellular technologies, OBD dongles, etc., for acquisition of vehicle data like ECO-norm standard, etc. [9]. Road side units function is to provide communication support to Vehicle Data Acquisition Systems via the 5.8 GHZ DRSC radio communication link and to communicate with other network entities like; in vehicle systems (Comfort module, Engine Control Unit, etc.) used by the service provider and by emission charging administrators, located far away and are using Internet infrastructure [10].

Fig. 4. System architecture for emission charging with use of Cooperative Intelligent Transport Systems

VI. CONCLUSION

The definition of system architecture for emission charging with use of cooperative intelligent transport systems is of particular importance, because it reflects the efficiency of the environmental supervision and law enforcement. Without defining the architecture, it is difficult to charge vehicle road emissions for better traffic planning and solving problem of traffic congestions. Using this model of system architecture with V2I communication, it is possible to track vehicles and charge drivers for their real road emission produced by their own vehicle. However, realizing benefits of emission charging requires very precise designing, planning and it must be made for local circumstances of a specific area. Future research would be focused on real implementation possibilities with restraints and challenges. Also, the impact on traffic and transport planning will be considered.

ACKNOWLEDGEMENTS

The research presented in this paper supported with University of Zagreb funds through the project: "Cooperative System Application for Urban Traffic Energy Optimization".

LITERATURE