Reducing the urban pollution by integrating weigh-in-motion sensors into intelligent transportation systems. State of the art and future trends

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Abstract. This paper is a short review of Weigh-in-Motion systems used to determine the pollution of the smart cities. The E.U. legislation concerns about the level of pollution in the big cities and how this pollution can be reduced. The main objective of E.U. is to reduce the level of pollution, respectively CO₂ emissions, until 2050 by 60% compared with 1990. Thus, a lot of articles provide new techniques for collecting data info from the WIM systems and use them for reducing the pollution from the cities. The main problem of the transportation is the overloading vehicles, which leads to accelerated wear of road infrastructure (wear increases in proportion to the fourth power ratio of the current load on the axle / standard load, which is 70kN). WIM sensors for interurban traffic are currently performing many other important functions as: estimation of the static load on the wheel, estimation of travel speed, identification of each type of vehicle, providing real-time data needed for intelligent transport systems. This paper presents how the levels of the pollution in some specific areas are influenced by the traffic jams and how we can avoid increasing of pollution.

1. Introduction
The problem of pollution is not new and it has evolved from Middle Ages by developing new industries and by using coal in big cities from UK. In the 20th century, due to the smoke and the pollution of the industry from the cities the governments tried to adopt new rules to reduce smoke emissions from industrial sources. Another big problem in that period was the increasing number of the motor vehicles, which had become the major problem for the pollution in urban areas. The National Air Quality set a new standard for establishing the regulations, and the main objective was to reduce the air pollution from urban zone [1].

More than 17% of greenhouse gases are produced by road transportation. The main problem of the transportation is the overloading of vehicles, which leads to accelerated wear of road infrastructure (wear increases in proportion to the fourth power ratio of the current load on the axle / standard load, which is 70kN). Therefore, an overload of only 10% conduct to an increase in roads wear by 1.1⁴ = 1.464 (or 46.4%) and a reduction in its lifetime by 32%, or 5 years, taking into account that in urban traffic the roadway degrades from excellent to acceptable in approx. 16 years, after which normal degradation is very accelerated [2]. The life of the roads which are developed for interurban traffic must resist approx. 20 years [3].

WIM sensors for interurban traffic are currently performing many other important functions as follows:
2. Current and future uses of WIM sensors
The volume of an engine’s emissions depends on the driving style, the nature of the road wear layer, the speed, the weight of the vehicle, etc. [10]. The European Commission's White Paper forecast for...
road transport a 20% decrease in fossil fuel and CO₂ emissions until 2020, and a 60% reduction in CO₂ emissions until 2050 compared to the year 1990 [11]. The International Energy Agency (IEA) projects that energy use and CO₂ emissions in developed countries will rise by approximately 50% between 2000 and 2030. Worldwide personal transportation is expected to increase 1.7% annually from 2000 to 2050, while worldwide freight transportation is expected to increase by 2.3% annually during the same timeframe. Given these trends, solutions are needed to reduce emissions and energy consumption from the transportation sector, now widely believed to be contributing to climate change [12].

These ambitious targets cannot be achieved without the widespread use of weigh-in-motion sensors (WIM and OBW).

European Commission Directive 96/53/EC establish the weight and dimensions of heavy commercial vehicles. In the EU, one in three heavy vehicles is loaded over the legal limit by 10-20%. In countries with an average number of weigh-in-motion systems (such as France), only 10% of heavy vehicles are overloaded [13]. In countries with few WIM sensors, up to 60% of heavy vehicles are overloaded [14]. Extending the road lifetime by 5 years due to the use of WIM sensors can bring significant savings in funds, materials and energy and a significant reducing of pollutant emissions from concrete and asphalt production. Because of the accelerating wear of the roads, attributed to overloaded heavy trucks, California state pay amount 20-30 million $/year - where, due to the large number of WIM sensors, there are few overloaded trucks circulating [15]. Another problem is the pollution induced by accelerated wear of the roads. In the present day, 8% of global CO₂ emissions come from the cement industry, an important amount being used for the construction of road infrastructure. Similar data is also advanced for asphalt manufacturing [16]. The overload vehicles are also subject to accelerated wear of: tires, brake pads, clutch disc, etc. Roads and vehicles wear results in the production of micro-particles that disperse in air, soil and water, polluting the environment.

The speed of vehicles movement affects the volume of emissions [17]. In congested traffic the vehicles emissions increase by approx. 40% compared to the speed of 45 km/h, usually percentage of travelling in cities. Pollutant emissions are doubled by lowering vehicle speeds from 50 km/h to 25 km/h [18]. When traffic is stopped (engines still runs at idle), pollutant emissions are even higher. Emissions of nitrogen oxides of heavy commercials trucks equipped with Diesel engines are on average 60-70% higher at 104 km/h, compared to the speed of 56 km/h [19].

The tall buildings from cities create a canyon effect, obstruct the vehicles emissions dispersion. Fluid traffic in cities has an important effect on the amount of pollutants.

There are a lot of software for estimating vehicle emissions and their dispersion: COPERT, COPCETE, INTRES, ARTEMIS, EMFAC, MOVES2010, MOBILE6, EMFAC2000, ADVISOR, CMEM, EPA, HIWAY-2, CALINE, CAR-FMI, ADMS, RLINE [20]. These programs need input data like: traffic volume, structure and travel speed (data provided by WIM sensors); weather conditions; altitude, and so on. Such software can be integrated into intelligent transport systems that aim to streamline traffic and reduce pollution. Fluidized traffic can also be done by automatically guiding vehicles on alternative routes based on data from WIM sensors. This kind of system can contribute to a 3% decrease in CO₂ and CO emissions in the Gdynia port area [21].

Vehicle emissions have a greenhouse effect and put a high risk to public health, so the emissions increase the incidence of respiratory, cardiac and cancers diseases [8, 22].

Intelligent transportation system (ITS) technologies include state-of-the-art wireless, electronic, and automated technologies. When ITS is applied to highway and transit system management and vehicle design, it can reduce fuel consumption and emissions by: facilitating optimal route planning and timing, smoothing accelerations/decelerations and stop-and-go driving, reducing congestion and so on. While ITS technologies are still in the early phases of deployment, many have the potential to reduce energy use and CO₂ emissions [23]. Additional research is required comparing the predictions of Average Speed, Traffic Situation and Traffic Variable Ems (Ems likely to be useable within LGA resource constraints) with real-world emissions before the hypothesis can be assessed quantitatively [16].
Overloaded heavy commercial trucks have a higher potential for accidents because they are more unstable, more difficult to manoeuvre, and the braking distance increases. In addition, their involvement in the impact of cars has more serious effects. When bad weather exists, or when transporting dangerous goods, overloaded trucks are even more dangerous [24].

The ITS technologies include Weigh-In-Motion (WIM), License Plate Cameras (LPC), Side View Cameras (SVC), and tracking sensors. In addition to the financial savings realized from longer pavement life and reduced maintenance, there is an additional, less obvious environmental gain due the saving in energy and emissions that would have been required to repair or reconstruct the roadway [25].

Monitoring of traffic with human resources is difficult, expensive and imprecise; also data processing takes a long time [26]. WIM sensors can solve this problem in the real time.

The roads share of freight transport is estimated at 90% while that of railways and air is 8% and 2% respectively. Monitoring was making with two WIM station trucks: Sanghani/3 months (33% of overloaded trucks) and Mullan Mansoor/6 months (48% of overloaded trucks) [27].

In ‘73–’80 in Japan it was used a traffic control centre and radio system information for inform of the highway users. New technology appears among the time like: Vehicle Information and Communication System (VICS - ’96) - which provide new routes for avoid the traffic jams and reduce the CO₂ emissions; Electronic Toll Collection System (ETC - ’97) - which allows the traffic to pass on the toll-gates without stopping; Intelligent Transport System Spot Services (ITS Spot - 2011) - an incorporate car system through the drivers receive real-time traffic data and emergency announcements, whether conditions, suggests which lane it’s better to use and so on. New technology had been developed in 2013 such as Cooperative truck systems or platooning. This system is based on Dedicated Short Range Communication (DSRC) and of Cooperative Adaptive Cruise Control (CACC) and reduces the trucks emissions by maintaining the same distance between the trucks. So it can be use a dedicated lane for platooning trucks system and so will improve the delivery time and will reducing the trucks emissions [28].

In Latvia there are intelligent transport system solutions used for emergency services, parking payment, public transport, fleet management and traffic management. In what concern of management of traffic Latvia adopting the EU directives and has developed traffic information and control centres, traffic restrictions, road weather information system (53 weather stations) and travel information [29]. China has start developed intelligent transport system solutions since 1995 and among to the time they collaborated with big countries like Japan, USA and EU to improve the ITS systems. The ITS development it’s less expensive to start simultaneously with the construction of the road. The new ITS system will take the place of traditional transportation industry and these systems will help to fluidize the traffic jams, reduce the pollutions in areas with high number of vehicles. Each country need to focus on that ITS solutions which satisfied the own needs [30].

3. Conclusions

WIM systems are used now in entire world but the number of WIM stations is not too high because of the costs involved to install the systems. The economical country level and the budged allowed to infrastructure influence the number of WIM stations. The information delivered by this system is used in intelligent transport systems (ITS) and have a lot of advantages like:

- The WIM sensors can be used for estimating the volume, weigh and type of vehicles in the traffic and they can be used for estimating the level of pollution;
- Demonstrated that the cars consume is bigger at lower speeds, so as many traffic jams are, the average speed is decreasing and the consumption of the cars are bigger;
- Monitoring the overloaded trucks conduct to sanctioning the drivers and companies which are damage the road, making waves in asphalt which present a danger for others drivers, making a higher level of pollution by increase the combustible consumptions;
Because of EU regulation, the future will bring drastic restrictions for the levels of emissions vehicles, so integrated WIM sensors in intelligent transport systems will help EU to accomplish the objectives;

All countries are preoccupied to reduce the greenhouse gas emissions and WIM systems can be a good solution to resolve this problem.

4. References

[1] Air pollution 2005 History of air pollution www.enviropedia.org.uk/Air_Quality/History Accessed on: 12.12.2018

[2] Todts W, Oehr B, Haas L and Driel C 2013 Study on heavy vehicle on-board weighing www.transportenvironment.org Accessed on:27.10.2018

[3] Akbari R and Mahmoudabadi A 2016 Developing a cost-effective model for evaluating the efficiency of weigh in motion system Proceedings -International Conference on Industrial Engineering and Operations Management Kuala Lumpur Malaysia pp 3105-13

[4] Hernandez S V2014 Integration of Weigh-In-Motion and Inductive Signature Data for Truck Body Classification (University of California Irvine: PhD Thesis)

[5] Morello R, Mukhopadhyay S, Gaura E, Liu Z, Slomovitz D, Samantaray S R and Onyewuchi U 2017 Guest Editorial Special Issue on Smart Sensors for Smart Grids and Smart Cities IEEE Sensors Journal 17(23) 7594 - 7595

[6] INTERMAT 2012 Volvo’s on-board weighing system Paris, France www.oemoffhighway.com/electronics/smartsystems/automatedsystems/article/10628174 Accessed on: 28.11.2018

[7] Barsanescu P, Carlescu P and Stoian A 2009 Senzori pentru cantarirea autovehiculelor in miscare (Iasi: Tehnopress Publishing House) p 120

[8] Bandowe B A M, Nkansah M A, Leimer S, Fischer D, Lammel G and Han Y 2019 Chemical (C, N, S, black carbon, soot and char) and stable carbon isotope composition of street dusts from a major West African metropolis: Implications for source apportionment and exposure Science of the Total Environment 655 1468–1478

[9] Kanaroglou P, Jerrett M, Morrison J, Beckerman B, Arain M A, Gilbert N Land Brook J R 2005 Establishing an air pollution monitoring network for intraurban population exposure assessment: A location-allocation approach Atmospheric Environment 39 2399–2409

[10] Alwakiel H N 2011 Leveraging Weigh-In-Motion (WIM) Data to Estimate Link-Based Heavy-Vehicle Emissions (Portland State University: MS thesis)

[11] Haugen T, Levy J, Aakra E and Tello M E 2016 Weigh-in-motion equipment – experiences and challenges Transportation Research Procedia 14 1423-1432

[12] Dolcemascolo V, Hornych P, Jacob B, Schmidt F and Klein E 2015 Heavy Vehicle Traffic and Overload Monitoring in France and Applications The XXVth World Road Congress PIARC Seoulpp 1-12

[13] Jacob B and Cerezo V M 2015 Heavy Commercial Vehicle Greening, Safety and Compliance 22nd ITS World Congress Bordeaux France p 14

[14] Markovic N, Schonfeld P and Ryzhov I 2014 Evasive Flow Capture: Optimal Location of Weigh-in-Motion Systems, Tollbooths, and Security Checkpoints NETWORKS 65(1) 22-42

[15] Concrete carbon footprint 2018 Climate change: The massive CO₂ emitter www.bbc.com/news/science-environment-46455844 Accessed on: 23.11.2018

[16] Cadar R D, Iliescu M and Ciont N 2014 Implications of Road Structure Design Using Different Approaches Bulletin UASVM Horticulture 71(2) 428-436

[17] Grote M, Williams I, Preston J and Kemp S 2016 Including congestion effects in urban road traffic CO2 emissions modelling: Do Local Government Authorities have the right options? Transportation Research Part D: Transport and Environment 43 95–106
[18] McDonald B, McBride Z, Martin E and Harley R 2014 High-resolution mapping of motor vehicle carbon dioxide emissions *Journal of Geophysical Research: Atmospheres* **16**(8) 5283-5298

[19] Miller T, Davis W, Reed D, Doraiswamy P and Fu J 2003 Characteristics and Emissions of Heavy-Duty Vehicles in Tennessee Under the MOBILES Model *Transportation Research Record* **1842** 99-108

[20] Patterson R and Harley R 2019 Evaluating near-roadway concentrations of diesel-related air pollution using RLINE *Atmospheric Environment* **199** 244-251

[21] Oskarbski J and Kaszubowski D 2016 Implementation of Weigh-in-Motion system in freight traffic management in urban areas *Transportation Research Procedia* **16** 449-463

[22] Wheeler N and Figliozzi M 2011 Multi-Criteria Trucking Freeway Performance Measures in Congested Corridors *90th Annual Meeting of the Transportation Research Board*

[23] Shaheen S A and Lipman T E 2007 Reducing greenhouse emissions and fuel consumption – Sustainable Approaches for Surface Transportation *IATSS RESEARCH* **31**(1) 6-20

[24] Kulovic M, Injac Z, et al. 2018 Modelling Truck Weigh Stations’ Locations based on Truck Traffic Flow and Overweight Violation: A Case Study in Bosnia and Herzegovina *Transportation Research Procedia* **30**(2) 163-171

[25] Hanson R, Klashinsky R and McGibney S 2010 ITS Technologies for Commercial Vehicle Compliance in the Maritimes *Annual Conference of the Transportation Association of Canada Halifax Nova Scotia*

[26] Dontu A, Maftei A, Barsanescu P D, Sachelarie A and Budeanu B 2016 Method of preventing unwanted traffic in the „Tudor Vladimirescu” University Campus *IOP Conf. Series, Materials Science and Engineering* **147**(1) 012111

[27] Chaudry R and Memon A B 2013 Effects of Variation in Truck Factor on Pavement Performance in Pakistan *Mehran University Research Journal of Engineering & Technology* **32**(1) 19-30

[28] Hayakawa K 2013 Japan: Intelligente Transport Systemen in de logistiek *Innovatie Attaché Tokio* https://www.rvo.nl/sites/default/files/2013/10/Intelligent%20Transport%20Systems%20(ITS)_logistics.pdf Accessed on: 3.12.2018

[29] Yatskiv I, Savrasovsa M, Udreb D and Ruggeric R 2017 Review of intelligent transport solutions in Latvia *Transportation Research Procedia* **24** 33-40

[30] Wang X, Zhang F, Li B and Gao J 2016 Developmental pattern and international cooperation on intelligent transport system in China *Case Studies on Transport Policy* **5**(1) 38–44

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