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Big Data in Transport Modelling and Planning

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Abstract

This article is built on the exploration of the possibilities of using Big Data, Machine Learning and the Internet of Things technologies for the needs of transport planning and modeling. The authors analyze the problems arising in the transport infrastructure because of the growing urbanization of cities and propose a solution to the problems based on the use of processing large amounts of data. As a result of the study, a comparative table was created showing the possible application of Big Data technologies in integration with other modern technologies and what problems of transport planning they will solve.

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1. Introduction

In today's world, we are facing rapidly growing urbanization resulting in increasing stress on transportation infrastructure. The population growth as well as increased quantity of vehicles brings us to the problems of air pollution, road accidents and traffic congestions (Zannat and Choudhury, 2019). Moreover, passengers demand decreased travel time, predictable schedule and tracking ability, which result in overall comfortability of public transport usage. At the same time, public transportation faces several challenges due to financial support, adequate economic efficiency and limited investments.

On the other hand, in recent years the advances of information technology were undisputable. Big Data is one of the most popular topics in both industry and researches, and public transport is one of the many fields where it can be used (Zhu et al., 2018). The amount of data generated, processed and used in transportation is enormous and can be handled with the use of Big Data analytics bringing insights to the stakeholders such as management or government.

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The relevance of the study is due to the exponential growth of data and the demand for Big Data technology, which can be successfully applied in transport planning and modeling both to ensure the economic efficiency of transport infrastructure and to increase passenger satisfaction from using public transport.

On the other hand, in the field of transport, many problems of a global and private nature affect both passengers and citizens. Many countries are interested in improving the management of transport infrastructure and are positive about the introduction of the latest technologies in public transport services.

2. Transport Planning and Modelling Needs

Rapid growth of urbanization has made researches on public transportation and transport infrastructure essential for urban planners. Globally, more people are living in cities than in rural area, according to the United Nations, in 2018, 55% of world's population lives in urban area and it is expected to increase to 68% by 2050 (United Nations, 2018). It creates an unprecedented demand for transportation resources and raises serious concerns for city governments. Moreover, cities face a variety of challenges such as air pollution, road accidents and congestion. In response to these challenges, increased usage of public transport rather than personal can help reduce air pollution, traffic congestion and travel time, and can provide reliance on renewable energy sources more easily than personal transport. As a result, many decision makers are facing questions linked to the development of best strategies to improve transport infrastructure to make it comfortable for citizens and effective for the government and society.

Along with the urbanization, there have been significant changes in how people use mobile devices and social media sites, plan to travel and agree to provide personal data on their movements for commercial, registration and government use (Ilin et al., 2019). This brings us to the rapid growth of big amounts of data that were or were not specially collected for transport applications, but could be used for further analysis and service improvements.

Traditionally, the field of transport researches has relied on manual travel research conducted on board, at stops or stations, or at the household level. These methods are useful for describing socio-demographic characteristics of respondents, along with detailed information about the trip (purpose of the trip, choice of mode, etc.). However, these methods are labor intensive, leading to higher costs, therefore, provide smaller sample sizes, and lower update rates. This is especially problematic in the context of developing countries, where resources are limited. In addition, the data may contain errors in reporting and is usually prone to statistical errors (Milne and Watling, 2018).

The data revolution has made it possible to generate, collect, store and analyze Big Data automatically. It has opened new opportunities for the development of smart cities and improvement of transport infrastructure. However, we are still facing many troubles in transportation due to the constantly growing number of cars in use, newly built areas with undeveloped transport infrastructure and increased use of central city districts that are not intended for traffic. This leads us to the conclusion that the development of urban infrastructure is currently not coordinated with the development of transport infrastructure (Toole et al., 2015). The transport system of many modern cities is not able to provide timely and comfortable services for an ever-growing number of citizens.

Digitalization and new technologies could be used to solve the problems arising from urbanization. The emergence of new elements of the transport system, the development of an automated road network should soon be applied in many countries and supported by the use of new technologies, advanced data analytics and the use of predictive models.

3. Problems in Transport Modeling and Planning

As the urban development is accompanied by problems needing to be solved, transport infrastructure also can not use its potential to progress. Functioning and development of transportation industry is not possible unless the solution to the key problems of this field are found resulting in the decrease of its negative effects for the society. The key problems of the public transport could be divided into two groups: the ones of general origin and the specific ones. The problems of global origin are the following:

- Significant impact of automotive transport on environmental pollution. The residents of both megalopolises and rural settlements located along highways feel this influence. At the same time, the volume of emissions and the amount of cars involved in pollution has only increased in recent years. The main activities taken to solve this

problem are to improve the design of vehicles and tighten environmental standards, but also to improve the organization of traffic in order to reduce delays, increase the smoothness of traffic, improve the maintenance and repair processes of the vehicles.

- Insufficient development of the process of accounting passenger traffic. Passenger traffic management is an activity of practical importance: flexible route planning and reallocation of vehicles should change depending on day of the week and time. It should be based on real-time collected passenger data to ensure that the distribution of passengers is comfortable and correct. If the distribution is not flexible, it affects both transport infrastructure and the well-being of passengers. Thus, the solution of the problem will lead to the optimization of the route schedule, the extension of the service life of vehicles and improving the quality of transport services.
- Insufficient development of the city's road traffic network. As gained experience shows, one of the most effective ways to improve the efficiency of urban transport systems is the introduction of various measures aimed at limiting the use of road transport at the same time developing of the public passenger transport system (Kuzmich and Fedina, 2015). The focus is to reduce the number of cars to a level that does not exceed the road capacity and the capacity of parking lots in the city. Thus, the managed road traffic network will free up sections of road for public transport priority, decrease traffic congestions and improve the overall road user's experience.

The specific problems of transport industry are not identified globally; however, they are found in many countries and need to be addressed for further development of transport infrastructure. Among such problems are the following:

- Insufficient development and quality of the road network. In Russia, for example, the density of highways is 0.044 km / km^2, while in Finland this figure is 1 km / km^2, and in Japan - 3 km / km^2. In addition, the need to modernize the existing road network in order to increase its traffic safety is no less urgent.
- Increased costs of road accidents for the society. Road accidents cause significant damage to the economies of countries. The solution to the problem of reducing accidents should be based on a systematic approach: it is necessary to change the traffic supervision system, improve the safety of transport systems, create modern highways with efficient traffic management, and develop and popularize public transport.
- Features of urban planning policy associated with the lack of mechanisms for reserving sufficient space for the development of transport infrastructure. This problem is most noticeable in areas of new construction, although central districts and areas of old construction also suffer from high traffic flows and unorganized parking. As a result, the transport system cannot develop in cities, which leads to a deterioration in the life of the population (Gorev et al., 2015).

The solution of these problems is of a practical nature for the development of comfortable infrastructure in modern cities. It is not possible to solve these problems without the use of digital technologies. New technologies, including Big Data, can provide tools that can help find the solution to these problems and open up new opportunities for its further development of transport infrastructure: city infrastructure, seaport infrastructure (Maydanova et al., 2020) etc.

4. Big Data

The term Big Data is a trendy one; however, it should be defined precisely in order to avoid misusage. According to De Mauro A., Greco M., Grimaldi M., 2014, the definitions of Big Data can be divided into four groups:

- The first group points at the characteristics of Big Data, usually known as "the 6 V's" – the main criteria differing Big Data and usual data: Volume, Velocity, Variety, Variability, Veracity (Thakuriah et al., 2016).
- The second group of definitions states the technological needs behind the Big Data, such as computing power, scalable infrastructure, efficient storage etc.
- The third group of definitions emphasizes that Big Data is crossing some sort of threshold as it requires alternative ways to collect, store and process it.

- The last group of definitions is linked with the impact Big Data brings to the society as it changes the way we analyze data and transforms the way we make decisions.

However, in terms of our research we will refer to Big Data as structured and unstructured data generated naturally as a result of activities in transportation usage such as transactional, operational, planning and social activities. According to the literature review, the sources of Big Data in transportation can be identified as traditional or new ones (Torre-Bastida et al., 2018). Traditionally used sources include structured and semi-structured data, collected by Intelligent Transportation Systems (ITS): smart cards data, GPS data, videos and images. New potential data sources include such sources of non-structured or semi-structured data as:

- Data collected from Social Media. Social Media has become a powerful tool for Big Data analysis. The main features of using Social Media for transportation advances linked to the vast number of users, timely updates, user's engagement and geo-tagged content (Bregman, 2012).
- Open Data. The concept of Open Data is relatively ambiguous, however the UK has been successfully working on Open Data approach since 2012. The purpose of the concept is to make public service data open and accessible to everyone in order to promote its use without restrictions or other mechanisms of control. The repository of transportation routes and existing trips from 2004 to 2011 was recorded and presented for free access. This step is meant to encourage development of innovative solutions including Road Safety or Integrated Transport applications (Kerr and Somerville).
- Data collected by roadside or car sensors. Sensors are used to collect data of many types, for example, vehicle's speed, trip timing, traffic congestions, passenger traffic etc.

However, our focus in this research is to assess the possibilities, prospects and limitations of using Big Data in transport modeling and planning; to analyze trends of using Big Data in conjunction with other technologies, such as machine learning, IoT, V2X, RFID, cloud computing.

5. «Smart Roads» Concept

Let us go back to the days of mobile phones. This revolutionary device provided the population with wireless communications, made it possible to make calls and send SMS messages. Over time, the transformation of mobile phones took place: the size, design changed, the functionality expanded. A modern smartphone is almost a mobile office that allows you to implement the functionality of various devices fully or partially: a computer, audio player, TV, alarm clock, camera, video camera, navigator, etc. The list goes on. The smartphone is a shining example that reflects one of the main trends of our time - the trend of technology amalgamation. This process covered many areas, including transport infrastructure.

By the transport network, we mean the transport infrastructure and all road users. The faster the technological progress, the more the ways of their interaction change.

A system of requirements is imposed on modern transport networks:

- The quality of the road surface;
- Convenience of navigation;
- High level of security;
- High level of roadside service;
- The most comfortable speed mode;
- No traffic jams;
- Ability to quickly solve problems related to changing traffic situations.

These requirements are important for both free and alternative toll roads.

What will be the future of the entire transport infrastructure and the interaction of Smart Roads participants? Smart roads of the future can be characterized by the following main features:

- high-tech: unification of all road users and infrastructure facilities with a dynamic communication and information system;
- environmental friendliness: the use of qualitatively new road surfaces, reduction of road congestion by improving the transport planning and modeling system based on Big Data analysis;
- safety: large-scale integration of technologies will reduce the role of the human factor in ensuring road safety;
- express roads;
- cost-effectiveness: dynamic pricing will allow you to adapt the cost to specific situations;
- a high level of comfort due to the automation of processes (the use of artificial intelligence technologies will reduce the human factor and reengineering processes).

As part of the strategy for the development of the concept of smart roads, it is planned to use innovative technologies in various aspects:

- monitoring of environmental pollution;
- creation of an innovative road surface;
- organization of interaction between road users;
- use of modern technologies for monitoring traffic flows and detecting violations;
- introduction of the concept of using unmanned vehicles;
- formation of a flexible tariff system.

Let us consider in detail some of these aspects, as well as the possibilities of using Big Data to implement these innovations.

The modern organization of interaction between the participants of the "Smart Road" is implemented within the framework of the V2X (Vehicle-To-Everything) concept. V2X is a system of communication between the car and everything that surrounds it while driving. It includes several types of communication - V2V, V2I, V2P. This system involves vehicles, road signs, traffic lights, pedestrians, roadways. V2X allows for more efficient interaction between vehicles and existing infrastructure. Realizing the V2X concept involves the use of flexible transport planning and modeling techniques. To organize traffic in accordance with the V2X concept, it is necessary to monitor all participants in traffic. This means that it is necessary to collect information (using IoT, machine vision technologies, etc.), process the received BIG DATA, make decisions based on the analysis of the results. The combination of these technologies will allow for high-quality planning and modeling of traffic flows, improve the quality of interaction of all road users, and create more flexible and comfortable models of interaction between road users.

When designing roads, modeling traffic flows can significantly increase the efficiency of managerial decision-making (Wu et al., 2020). Such systems provide the ability to collect, track, analyze and visualize the most significant data, including in real time. At the same time, technologies for collecting, processing, and analyzing Big Data in combination with IoT, V2X, RFID, cloud computing technologies are critically important as technologies.

To optimize the work of the road, first, it is necessary to introduce two main systems: for strategic planning of flows and for operational management of the transport situation. Modern transport modeling allows integrating all traffic participants into a single mathematical transport model. There are systems that make it possible, on the basis of a full-fledged multimodal 4-step transport model, to predict the traffic intensity on any part of the network, including taking into account toll charges, for a long time (10-30 years) and to take into account changes in the road network, population mobility, and socio-economic development of the territory. Experiments with tariffs allow you to test the elasticity of demand, to select and identify the optimal tariff. Accordingly, such systems can be applied at the stage of feasibility study (feasibility study), design and operation for more effective financial planning.

Modern engineering science in planning and analysis cannot do without simulation. On toll roads, it allows you to recreate situations at the toll station in real time. This, in turn, makes it possible to optimize the operation of the checkpoint. Such systems can reproduce not only traffic, but the movements of aircraft, ships, and pedestrian flows.

Speaking about toll roads, it is worth noting that the use of transport modeling methods makes it possible to calculate hundreds of scenarios for different forecasting horizons, taking into account options for economic and

transport development, systems and methods of collecting tolls, fare, modes of transport. At the same time, both the tasks of strategic planning for an investor or designer and the operational tasks of managing a toll road are solved.

To predict the intensity of traffic on toll roads and income from their operation, transport models are being developed. At the same time, traffic intensity forecasting is carried out based on macroscopic transport models using a bicriterion approach to considering the willingness to pay for travel. The use of algorithms that consider the continuous distribution of the willingness to pay for tolls makes it possible to forecast traffic intensity on toll roads and revenue from toll collection with high confidence.

6. Key Problems of the Transport Area Solved Using Big Data Technology

Big Data technologies are becoming the engines for the development of modern infrastructure the creation of "smart cities" and "smart transport infrastructure". The capabilities of Big Data are indispensable in the effective management of city traffic in real time.

There are several main problems in the transport industry, which are solved based on the use of Big Data processing technologies:

- geolocation analytics (flexible analysis and testing of a wide range of hypotheses for the development of individual territories in terms of logistical accessibility, coverage with a transport network);
- optimization of transport logistics (reduction of idle mileage for freight transport, identification of additional windows in routes for passing loading of partially filled trucks, etc.);
- informing about the need to perform vehicle maintenance (wear analysis);
- combating fraud (blocking the ability of drivers to assign time on flights, control of travel payments by passengers, etc.);
- collection of data for optimization of tariffs of insurance companies (formation of a system of flexible discounts for carriers based on statistical data on insurance cases of vehicles) (Iliashenko et al., 2019).

Today, it is possible to divide transport big data into two classes - according to the form of their collection, which decisively affects the format of the information received.

The first class of big data is static. In this case, information is recorded, processed, and transmitted further for processing and interpretation by static, immovable sensors. These are, first, all types of cameras - both pre-installed and portable mobiles, which capture only what falls into their directional focus. Information in this class is extremely local. Its meaning and potential are manifested only when it is assembled in a long chain (Verendel and Yeh, 2019).

For example, law enforcement agencies are actively using data from cameras installed on the roads to track the trajectory of wanted vehicles. But this analysis is possible only when combining data obtained simultaneously from a certain number of cameras. The desired car must fall into several cameras so that you can plot an accurate trajectory or even predict its further development. But data from one single camera will not be able to tell analysts something fundamentally important.

Big data of the second class - dynamic - offers much more extensive possibilities. This is data obtained from various sensors and devices that are not tied to a specific place and are constantly in motion, often in the immediate vicinity or even inside the object under study (we can say that these are classic IoT sensors, recall the example of Tesla from Fremont). The advantage here lies in the fractality of the data, in their self-sufficiency. One separate stream of information can give enough information about the object under study to form various hypotheses. The presence of a chain of devices is not critical to the operation. The main player in this class of big data, no matter how trite it sounds, is a mobile device - a phone or tablet that a driver carries with him in a car or truck.

Transport companies primarily work with dynamic data. Based on only one GPS-GLONASS sensor, today it is possible to identify and analyze the following parameters:

- road congestion (analysis of traffic jams, causes and trends of traffic congestion);
- typical trajectories of bypassing traffic jams in separate sectors of the city, identifying new emergency sections, poorly regulated intersections;

- identification based on typical trajectories of bypassing problem situations with the very infrastructure of the city;
- seasonality, dependence of the volume of orders of the transport company on yield, good weather, quality of roads in certain settlements;
- technical condition of units, consumable parts in vehicles (Ilyashenko and Ilyashenko, 2018).

When analyzing all these parameters, it is important to consider the reaction rate. In the city, the flow density is higher, and the length of sections is shorter. As a result, a greater responsiveness to certain events is required. And traffic control is not limited to speed alone: there are traffic lights, a transition to one-way traffic, and even completely closed sections for certain types of transport. So, a system designed for use in a city will be much more complex. Today Rosavtodor and several other state and private companies are developing applications that allow drivers to send data about new pits on the sections to the road management companies in one click. Such mini services are the basis for improving the quality of the entire industry infrastructure.

7. Analysis of the Big Data Integration with Other Modern Technologies

The table presents the integration of modern information technologies with an indication of the problems that they can solve.

Table 1. Integration of modern information technologies to solve the problems of the transport sector.

Technologies	Problem description (idea)	Problem solution (result of implementation)
Big Data + IoT	Problems with road irregularities and sewer hatches strongly pressed into the asphalt (Boston, USA)	Mobile application development. Residents report deficiencies in the road surface using their smartphones. Photo and video materials are automatically sent to the server of utilities. Result: problems are corrected at an early stage thanks to the prompt collection of data on road problems; saving money to the city budget.
Big Data + IoT + Machine Learning	Traffic analysis to identify road sections with a high risk of road transport accident (Moscow)	Automatic data collection from video cameras installed at intersections, as well as external factors (precipitation, fog, lighting and temperature). Machine learning algorithms analyze weather and road conditions (width and change in the capacity of a road section, average congestion score in a city and traffic speed). If, taking into account the current traffic situation and the weather, some section is critical (an accident in this place will lead to severe congestion), then the situation center assigns it the highest priority in case of calling the traffic police. Overlapping even one lane in the event of an accident reduces bandwidth by 20%, which leads to delays in personal and public transport. Prompt elimination of accidents significantly saves time for drivers and passengers.
Big Data + IoT + Machine Learning	Analysis of the traffic situation taking into account the use of urban traffic lights combined into a self-regulating system (Los Angeles, USA)	IoT sensors and cameras transmit information to a single computing center, where machine learning algorithms analyze the traffic situation. Thus, traffic signals at major intersections are dynamically adjusted, depending on the traffic congestion. As a result of the implementation of this system based on Big Data and Machine Learning, the average speed in the city increased by 16%, and the waiting time in traffic jams decreased by 12%.
Big Data + IoT	Using electronic boards to show the time of arrival of public transport (Seoul, Moscow)	At public transport stops, electronic boards are used to indicate the arrival of buses. The buses themselves are equipped with displays, internet modems and GPS receivers. Thanks to this, each passenger on a large monitor or the screen of his mobile sees the location of the transport on the route and current accidents.
Big Data + IoT + Machine Learning	Optimization of transport routes (Moscow)	From IoT sensors installed on personal and public transport, the data is sent to the City Information Center every day. Experts monitor and analyze information about traffic flows using Machine Learning algorithms, and then send updates to passengers' smartphones. In this way, transport routes are optimized without building new roads - thanks to the even distribution of traffic, large congestions are avoided.
Big Data + IoT	Collection of information from traffic flows (Moscow)	Collecting information about traffic flows due to the installation of sensors on vehicles.
Big Data + IoT + Machine Learning	Collecting information on passenger movements (Moscow)	The technology of chipping travel tickets is used, each of the tickets has a unique identification code that is read during validation. This data is anonymous, but accurately shows the picture of the movement of passengers.
Big Data + RFID + Cloud computing	Monitoring of traffic flows and detection of violations (Kazan)	The use of RFID tags for license plate recognition to identify drivers who violate parking and speed regulations, and remotely check drivers' documents (RFID Industry 2020). A radio frequency tag is integrated into the plastic number. The RFID sensor is placed on the elements of the transport network. When a vehicle approaches, information about the vehicle is read and the data is transmitted to the data processing center (DPC). During the experiment, 98% of the numbers were identified at a distance of about 40 meters. Photo and video fixing cameras recognize license plates at a distance of 10-20 meters.

Thus, we can conclude that the rapid development of the use of modern IT solutions in integration with each other will help to perform difficult tasks for further analysis of traffic situations.

8. Discussion

We can say that the further development of systems for collecting, storing and processing data will allow tracking long-term trends and planning the development of megacities. Considering that by 2050, about 70 percent of people will live in cities, and every seventh in metropolitan areas, the most comfortable living conditions will provide the cities that will quickly respond to the changes in the environment and human needs.

9. Conclusion

Analysis of Big Data technology in the transport sector made it possible to identify the main goals of a transport company that need to be achieved to improve its efficiency:

- increased use of vehicles,
- reducing the company's operating costs or the cost of fulfilling a transportation order,
- reduced fuel consumption,
- avoiding delays in the execution of orders for transportation.

Moreover, depending on the purpose of the company, it is necessary to collect and analyze the relevant data:

- the nature of the routes along which the goods are transported,
- driving style of drivers,
- operation of vehicles, deterioration of individual sub-assemblies, such as brake pads, suspension.
- use of the loading space.

Obtaining and comparing data related to these issues can become the basis for analyzing the existing situation and modifying the elements that reduce the efficiency of the enterprise.

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