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THE ROLE OF BIG DATA IN TRANSPORTATION MANAGEMENT

Azimov K. N., student
Voronova Ye. M., associate professor
Kharkiv National Automobile and Highway University

The big data in transportation sector plays transformative role. It offers countless opportunities to gain the efficiency, save the costs, and improve overall performance that decrease pressure on the environment. This article delves into the pivotal role of big data in enhancing the efficiency of transportation management and investigates the impact of big data on transportation systems that make it transformative, emphasizing its potential to address challenges and enhance overall efficiency, with a focus on real-world implementations in specific countries.

Climate change and energy security stand out as pivotal concerns in the 21st century. Since 2000 over 50% of the world's population is living in cities. 20 % to 35% of greenhouse gasses (GHG) emissions result of transport processes. In residential areas transport is the major GHG emission source with a share of 50%. The main cause for transport demand growth is the interrelation between transport system and long-term adaption of settlement structure [1]. There is 37 megacities on the Earth [2], and the tendency of human development denote that large city bring more challenges. To rule transportation system in them it requires a huge amount of information that is already collected in specified data stores in the most megacities data centers every day. All it's needed to be processed and analyzed.

The field of big data has developed from the discipline of statistical analysis all the way to today's advanced data platform technologies. Through comprehensive data analysis and integration, nations worldwide are leveraging big data to optimize traffic flow, reduce congestion, and improve overall transportation systems [3].

According to current thinking, big data is a large amount of data characterized by three Vs characteristics: variety, volume, and velocity. In the field of transport management and other economic sectors, the properties of big data should also include veracity and value of the gathered data.

There are types of big data sources that are leveraged for demand forecasting and transport planning [4]:

- Data from mobile network operators (MNOs) such as call detail records (CDRs), floating cellular data, and shared smartphone location data;
- Vehicle data from navigation apps (Waze or Google Maps), in-car navigation displays (TomTom), and fleet telematics;
- Public transportation usage data from ticketing systems and smart cards.

The importance of achieved data evaluates by transportation management systems also known as intelligent transportation systems (ITS). Intelligent transportation systems is a critical aspect of transport management, influencing economic productivity, environmental sustainability, and individual well-being [5]. Beyond basic route optimization, it allows for dynamic adjustments in real-time. It suppose that factors like traffic congestion, road closures, or unexpected events are continuously monitored, enabling on-the-fly route changes for maximum efficiency. In addition, intelligent transportation systems may include analyzing emission levels, suggesting eco-friendly routes, and aligning transportation strategies with sustainability goals.

Intelligent transportation systems produce a large amount of data. The produced data have profound impacts on the design and application of intelligent transportation systems, which makes ITS safer, more efficient, and profitable. Studying big data analytics in ITS is a flourishing field.

To assist ITS doing its function exploited a various types of equipment and technologies to track transport activities. The most cutting-edge of them include [6,7,8]:

1. Integration with Internet of Things (IoT) and other smart devices on vehicles . It provides customers and researchers with real-time tracking information for their shipments, and including data such as engine diagnostics, wear and tear on components, and fuel consumption. By the way, integrating data from IoT devices into ITS enhance the precision of predicting maintenance chances. Tracking warranty information through big data analytics ensures that companies capitalize on warranty coverage for components, minimizing out-of-pocket costs for repairs.

2. Advanced traffic cameras equipped with machine vision and artificial intelligence (AI) algorithms. That camera can identify and predict traffic patterns. This information aids in traffic management strategies, such as adjusting signal timings or implementing dynamic lane controls based on real-time conditions.

3. Collaboration with navigation apps and public data sources. It assist ITS to give out real-time traffic information directly to drivers. This cooperative approach contributes to more efficient traffic flow across the entire network. Collaborating with local government traffic databases or event calendars enhances the accuracy of traffic predictions. This integration enables transportation systems to anticipate and mitigate traffic bottlenecks caused by events like concerts, parades, or road closures.

4. The integration with blockchain technology to enhance supply chain visibility. Blockchain provides a secure and transparent ways of recording, transmitting and exchanging data. It enables all stakeholders to track and verify the movement of goods in real-time, and helps identify reliable suppliers, minimize disruptions in the supply chain, and optimize relationships for mutual benefit.

5. Advanced natural language processing techniques, such as sentiment analysis, which can be applied to customer feedback on social media. This allows companies and particularly ITS to gauge customer satisfaction in real-time and make adjustments to improve the overall experience. In addition, leveraging data on past customer preferences allows to offer personalized recommendations. This could include preferred delivery time slots, route preferences, or even personalized promotions, enhancing the overall customer relationship.

After the information gathered, it should be absorbed correctly. In daily routine managers need to analyze big amount of information to make right decision. In order to accelerate it, they can use advanced machine learning algorithms (ML algorithms) that assist to make data-driven decisions. In simple terms, a machine learning algorithm is like a recipe that allows computers to learn and make predictions from data. Instead of explicitly telling the computer what to do, we provide it with a large amount of data and let it discover patterns, relationships, and insights on its own [6].

Thus, ML-algorithms can analyze historical data to predict optimal routes based on time of day, weather conditions, and even special events. It can be done due to predictive analytical model that formed by learning. This learnt predictive model can be used for enhance the adaptability of transportation operations. Apart from it, seamless integration with weather forecasting systems enables to reroute vehicles based on upcoming adverse weather conditions preemptively, reducing the risk of delays and ensuring safety.

In addition to real-time monitoring, predictive analytical models can forecast potential maintenance issues based on the historical performance of vehicles. This proactive approach allows for scheduled maintenance during periods of lower operational demand. Predictive analytical model allows for a thorough cost-benefit analysis of maintenance decisions. By weighing the potential downtime costs against proactive maintenance investments, companies can make informed decisions to maximize operational efficiency and financial savings.

Big data accelerated the digital economy, enabling use cases that had previously been impossible or cost-prohibitive to achieve. With big data financial institutions can use data-driven approach to enable authorities implement targeted measures, such as promoting eco-friendly transportation modes and optimizing traffic signals to reduce carbon emissions. Ukraine is actively using big data in pursuing digital implementations and projects across various sectors.

In essence, big data isn't just about handling large volumes of information. It's about extracting valuable insights for optimizing routes and operations, maintenance prediction of vehicles and equipment, analyzing traffic patterns and historical data, increasing visibility of the supply chains, automate the process of compliance checks, provides the basis for comprehensive audits and enhancing customer experience etc [9].

Big data analytics plays a crucial role in transforming raw transportation data into actionable insights. Countries such as Singapore, the United States, and Finland have successfully implemented innovative solutions to streamline their transportation networks.

Singapore's Intelligent Transport System (ITS) utilizes big data analytics to optimize traffic signal timings based on real-time traffic conditions. This dynamic approach has led to significant reductions in travel time and fuel consumption. But at the heart of all the ITS is the i-Transport. All of ITS data is connected to i-Transport which is an integrated and unified platform, that which makes sense of and disseminates the information for traffic monitoring and incident management in the ITS Operations Control Centre [10].

The Federal Highway Administration's (FHWA) in the USA organized Real-Time Data Capture and Management program that integrates big data from various sources, including GPS and sensors, to monitor and manage traffic patterns. This has resulted in improved route planning, developing new approaches to manage and test highway and vehicle systems, and enhanced their safety [11]

Finland's Smart Mobility Testbed initiative employs big data analytics to enhance public transportation efficiency. By analyzing passenger movement patterns and optimizing routes, Helsinki citizens have seen improved public transportation services, leading to increased ridership. [12]

Among impact of big data listed above, there are a number of fields where it can be used. One of them is parking system. Smart parking systems can use data from sensors and mobile apps to guide drivers to available parking spaces, minimizing the time spent searching for parking and reducing traffic congestion. Also big data offer a great number of solutions for municipality management. By understanding peak commuting times, transit authorities can adjust schedules and routes, reducing congestion and improving the overall commuting experience.

However, while big data is making its mark in various industries, including transportation, it might not be fully mainstream yet for a few reasons. Firstly, implementing big data solutions requires significant investment in technology and infrastructure. Many transportation systems, especially in less developed regions, might not have the resources to adopt these technologies.

In general, extracting and processing transportation big data is complex. Most urban areas lack required number of road sensors for monitoring traffic patterns. Effectively capturing and analyzing video data necessitates a robust and low-latency data governance and management platform. The fusion of diverse data from various sources, presented in different formats, also demands a specified level of technical infrastructure maturity that not all organizations currently possess.

Secondly, there could be resistance to change within traditional transportation systems. People might be hesitant to embrace new data-driven approaches if they've been using more traditional methods for a long time.

Lastly, there could be a far more important questions about personal data privacy and security, especially when dealing with sensitive information related to transportation and logistics. Nobody wants to be captured on camera and subsequently identified by their data science peers as the individual struggling to park on the parking lot. It is essential to cleanse and anonymize all transportation-related data before utilization, followed by the implementation of top-notch security measures. After all, a data lake containing information about the daily movements of an entire population is a valuable tool that can be misused and is susceptible to hacking. These concerns might be slowing down the widespread adoption of big data solutions in the transportation sector.

In summary, the integration of big data in transportation management systems is shaping the future of Internet and communication technologies (ICT). The examples presented from countries like South Korea, the Netherlands, and Sweden underscore the diverse applications of big data in creating more efficient, sustainable, and user-friendly transportation systems. As we continue to harness the power of data analytics, the evolution of transportation management holds the promise of further enhancing the quality of life for individuals and fostering a more sustainable and interconnected society.

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