Strategies for Policy in Science and Education *Volume 31, Number 4s, 2023* *Стратегии на образователната и научната политика*

https://doi.org/10.53656/str2023-4s-13-cha

Education in the Information Society
Образованието в информационното общество

CHALLENGES, REQUIREMENTS, OPPORTUNITIES AND SOLUTIONS FOR THE DIGITAL TRANSFORMATION OF THE TRANSPORT EDUCATION

Prof. Dr. Georgi Hristov,
Assoc. Prof. Dr. Ivan Beloev,
Assoc. Prof. Dr. Plamen Zahariev
"Angel Kanchev" University of Ruse

Abstract. The digital transformation impacted many aspects of the everyday human live. This global phenomenon changed almost all industries and has led to improved working efficiency, overall enhancements of many activities and processes and the establishment of many new professions. The transition into the digital era was fuelled by the vast development, the wide acceptance and the increased use of many new technologies, devices and solutions. Nevertheless, the digital transformation has also resulted in new challenges and has defined new difficulties, which have to be addressed. The transport sector was no exception to the transformation processes and was also significantly impacted by them. Many new technologies for monitoring, control and optimization of the aerial, land and water traffic have been developed and are currently widely used. The paradigms and the leading technologies of the digital transformation, like Big Data, Internet of Things, 5G mobile connectivity, Artificial Intelligence, Information systems and many others have been adapted and integrated in the different transport-related processes and activities. While this transformation resulted in increased income, better traffic management, safer and faster transportation services and reduced workloads for the involved staff, it has also put the transport education sector into a difficult and challenging position – the present-day digital transportation technologies demand the transformation of many traditional educational courses into multidisciplinary IT-oriented subjects. In its own turn, the integration of these new courses requires the purchase and use of specialized equipment and devices, the constant adaptation and improvement of the educational materials and the regular requalification of the teaching staff.

In this article, we present and investigate some of the challenges, requirements, opportunities and solutions for the transition of the education in transport into the digital age. The various modern IT-related technologies and solutions in the transport sector are presented, analysed and discussed in details in the manuscript.

Last, but not least, we have summarized and discussed the present challenges and requirements for the education processes in the area of the transport education.

Keywords: digital technologies; transport education; digitalization of transport; Transport 4.0; autonomous vehicles; smart cars

1. Introduction

The digital transformation is probably the most notable and important event of the 21st century. The scientific advances in different areas, like electronics, micro and nano technologies, computer sciences and information and communication technologies (ICT), have led to the rapid development and integration of numerous systems and technological solutions in many manufacturing and industrial domains. The transport and logistics sectors were also heavily impacted by the digital transformation. Systems for connected and automated mobility, intelligent transportation systems, autonomous vehicles, systems for remote teleoperation of vehicles, transport simulators and emulators, solutions for tracking of shipments and vehicles and others are just examples of digital technologies in the area of the transport and the logistics.

The connection and the dependency between the transport sector and the digital technologies became clearly evident in the last few years. The COVID-19 global pandemic led to a worldwide shortage of semiconductors, which impacted severely not only the ICT sector, but other sectors as well, including the vehicle manufacturing industries, the industries for manufacturing of parts, components and batteries, the transportation companies and others. Regardless of this, the advantages of the digital technologies and their impact on the transport sector are undisputed – the transformation resulted in a more efficient, safer and economically stable and beneficial transport sector.

Unfortunately, the fast rate of adoption of the digital technologies has led to significant new challenges and problems. Apart from the purely technical issues, like the need for integration of the ICT systems in the vehicles, the network and connectivity problems and the partial lack of compatibility between the individual solutions, some more serious and important problems quickly became evident. Some of those issues are not directly connected to the transport sector or to the digital technologies themselves, but to the slow rate of adoption of the new technologies by the education systems and the Higher Educational Institutions (HEIs). To confirm this, several studies (Sitányiová et al. 2018; Duganova et al. 2022; Jovic et al. 2022) have shown that the presently graduating transport engineers are joining the labour market with just basic digital competences, as users of smartphones, computers and online services, and not as experts in the use of the digital technologies for the needs and in the services and the processes from this sector. Unfortunately, other domains are also showing similar signs and symptoms – the agricultural sector, the mechanical engineering sector, the health sector and others are also objects of similar issues (Softic et al. 2022). Even the educational sector itself is producing teachers and educators that are not well prepared or are not fully aware of the potential of the digital technologies and how they are used or can be used in the present-day educational processes. These issues were clearly identified by the governments and by experts from many countries worldwide and in the European Union (EU). To counter this phenomenon, the EU mission 2030[1] is specifically aimed at providing means and solutions to achieve digital literacy of the workforce in all of its member countries. To reach this goal, it is very important to have an improved and up-to-date educational system, at least at the level of the Higher Education Institutions.

2. Present and emerging digital transport technologies

In the present moment of time, there are numerous examples of digital transport technologies, which are in use in the activities and in the processes from the sector. Some of these solutions are implemented using personal or specialized computer systems or using specific information technologies, while others are possible only by the means of the modern communication technologies. Nevertheless, the most popular and widely used digital transport technologies are relying on the simultaneous use of elements and solutions from both technical domains (Fig. 1).

Examples of such digital transport technologies are the intelligent transport systems, the autonomous vehicles, the unmanned aerial, ground or water systems, the transport simulators and emulators, the connected and automated mobility solutions, the different vehicle tracking systems, like AIS and ADS-B, the on-demand ride services and others (Fig. 1). Each of these technologies is unique and is presented in more details in the next sections of this chapter.

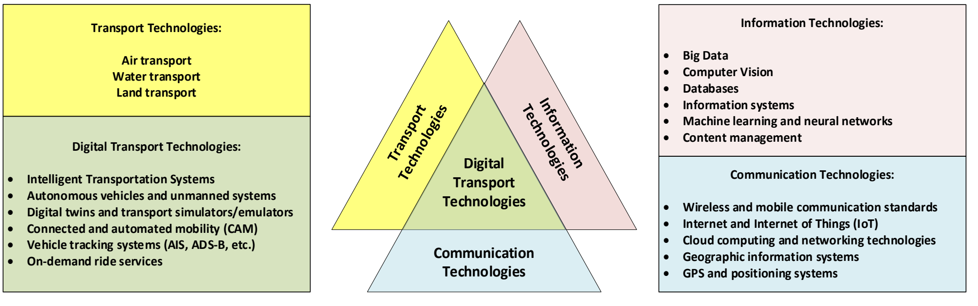

Figure 1. The digital transport technologies are the result from the combination of the traditional transport technologies, the Information technologies and the Communication technologies

2.1. Intelligent Transport Systems (ITS)

The Intelligent Transport Systems are probably the most widely used and well-known digital transport technologies. Usually, these types of systems are used to provide different traffic management services, which can help the companies organize their activities in a better and more efficient way. At the same time, the end-users of the transport services can be better informed about the possible options, so that they can plan for a fast, safe and well-coordinated trip using the available transport networks and solutions. Apart from the services for transportation of people and goods, the Intelligent Transport Systems are also widely used for different governmental purposes, like surveillance of roadways and intersections, recognition of vehicle plates, automated toll systems, speed control, etc. The ITS in the EU are well known and with directive 2010/40/EU they are defined as "systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport"[2]. In many different studies, the Intelligent Transport Systems are categorised based on their applications, functions, capabilities, etc. (Babulak 2008; Duganova et. al. 2022). Nevertheless, a more general categorization of these systems can be made based on the level of involvement of the ICT in their functionality:

– ITS based on different computational technologies – solutions, which are provided thanks to the use of advanced computing systems, like the vehicle systems for automated decision making, which rely heavily on different algorithms from the Artificial Intelligence domain, the systems for process control, the solutions for vehicle ambient intelligence, the infotainment systems, etc.

– ITS that use communication technologies and data exchange mechanisms – the systems for geo-positioning and navigation are probably the most famous representatives of this subcategory of Intelligent Transport Systems. While the majority of these specific solutions rely on satellite communications, others use the triangulation principles to determine the position of the vehicles using the communication signals from the different on-board systems or mobile devices. The ability to transmit the estimated position of the vehicles can also be used for traffic management, optimal route selection, incident notification systems, etc. Other solutions within this category are the systems for telematics, telemetry, vehicle re-identification and others.

– ITS sensing systems – this subcategory can be further divided in two, namely passive and active systems. In the first case, the solutions require the use of improved infrastructure to monitor the traffic, like the inductive vehicle loop detection systems, the vehicle video detection systems, the radar detection systems, etc. In the latter case, modifications to vehicles are also required, so that they can interact in a specific way with the transport infrastructure – by means of RFID tags, Bluetooth, Wi-Fi, etc.

2.2. Autonomous vehicles and unmanned systems

The autonomous vehicles and the unmanned systems have gained a lot of attention in the last two decades. This was caused mainly due to the rapid development and wide use of the unmanned aerial vehicles (UAVs), or drones, which quickly became the sought solution for aerial video and photo shooting. Nevertheless, in the last five years, the unmanned ground and water/underwater systems have also gained significant popularity and have been used for various activities in hard-to-reach or dangerous environments.

The unmanned vehicles have been extremely widely researched in the past few decades – in terms of the possibilities to improve their capabilities and functions and in terms of their use in different application areas and for various activities (Novikov et. al. 2019). In the transport sector, the unmanned systems are nowadays primary used for different activities related to the warehouse automation processes[3] and the transportation of passengers[4]. Nevertheless, with the ongoing research activities in the area of the UAVs, they are now considered as the future of both cargo[5] and passenger transport[6] (Fig. 2).

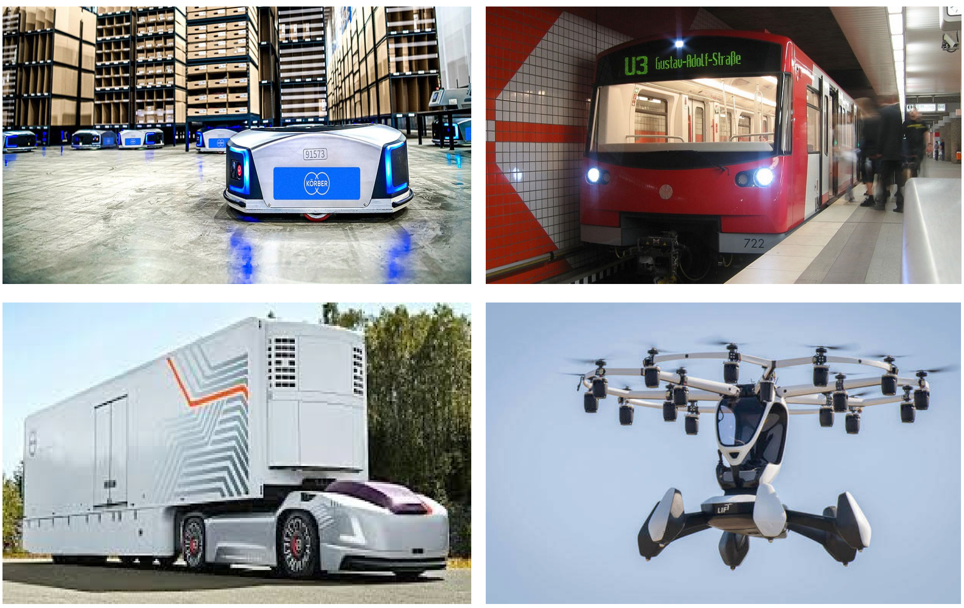

Figure 2. A fleet of autonomous warehouse robots[3] (top left), driverless train in the Nuremberg U-Bahn[4] (top right), autonomous cargo delivery truck prototype by Volvo[5] (bottom left) and the Hexa electrical vertical takeoff and landing single person autonomous UAV prototype[6] (bottom right)

2.3. Digital twins and transport simulators/emulators

The introduction and the use of digital twins in the transport sector is expected to fundamentally change the concepts of the offered services and will further contribute to the integration and the use of autonomous vehicles in the processes for public or private transportation of goods and people.

The digital twins are highly detailed virtual environments, which represent real-world locations, assets and vehicles. Their simplest use in the transport sector is for preliminary surveying and evaluation of transport routes, for simulation and planning of transport, loading and unloading processes and above all – for staff training. The digital twins are usually visualised using multi-screen computer systems, holographic projectors or virtual reality platforms. In many cases, simulators or emulators, which duplicate the control mechanisms of the used vehicles, are used in conjunction with them. These setups make it possible to realistically simulate or emulate complex transport activities, train for multiple operational scenarios in advance and yield significant safety and cost benefits, as no actual vehicles are engaged in any of the processes. In this way, truck drivers, ship operators, airplane pilots and even astronauts can study the upcoming activities and can better prepare themselves for the tasks at hand.


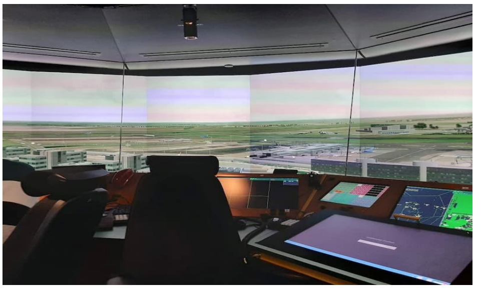

Figure 3. A digital twin of an offshore platform used for educational purposes at the Ship Operation Research Lab[7] at the Norwegian University of Science and Technology[8] (left) and a digital twin of the Schiphol airport used in a 360-degree digital emulator for training of the flight control staff[9] (right)

In the recent years, the use of digital twins is heavily linked with the emerging technologies for autonomous vehicles and the use of Artificial Intelligence in the transport sector. A recent study by Toyota[10] shows that around 14.2 billion km of traveling are needed to make an autonomous vehicle safe for actual deployment and use in the public transportation network. Nevertheless, these kilometres of driving can be achieved in a simulation environment, where digital twins of real cities are used to train and test Artificial Intelligence that operates the vehicle.

Another emerging application for the digital twins is related to their use in combination with various data input devices, like sensors and cameras. In this way, the digital twin model can be used for real time traffic monitoring, traffic planning and reduction of the traffic jams.

2.4. Connected and autonomous mobility

The concept for Connected and Automated Mobility provides a unique opportunity to make the transport systems safer, cleaner, more efficient and more user-friendly. The vehicle-to-vehicle (V2V) communication applications, which are based on different standards for mobile and radio communications, allow the exchange of information between the individual participants in the transport processes and can help avoid crashes, traffic jams and can further contribute to achieve fully autonomous public transport solutions. The technology behind V2V communication allows vehicles to broadcast and receive up to 10 omni-directional messages per second at a distance of up to 300 meters. In this way, all vehicles obtain important information that helps them become aware of the surrounding environment. The V2V communication processes and standards have been subject to numerous studies in the last 15 years. Nevertheless, there are still significant concerns and issues with the available solutions, including concerns related to the road safety, the transmitted information about the vehicles, privacy and security concerns, traffic-related concerns, mobility and reliability concerns, etc.

2.5. Vehicle tracking systems

The vehicle tracking systems, sometimes referred also as fleet tracking systems, are solutions that allow the monitoring of the movement and the actions made by one or more vehicles in real-time or as historical data. These systems can be divided into systems for monitoring of the activities of land, air and water vehicles.

Land vehicle monitoring systems

The main idea of these systems is to enable the businesses to actively track and manage their fleet of vehicles. Numerous different systems are currently available to achieve this goal, but they all operate on a similar principle – they use GPS or Global Navigation Satellite System (GNSS) communication modules to establish the present whereabouts of the vehicles and then transmit the coordinates using the cellular or wireless networks. Several communication standards can be used for the transmission of the data, including EDGE, 4G and 5G cellular networks, Wi-Fi, LoRaWAN and even proprietary wireless standards. The main goal of these systems is to monitor the vehicle usage, the driver behaviour and to detect abnormalities, like accidents, rollovers, rapid braking and acceleration of the vehicle, etc. Some of the discussed systems also support real-time notifications using SMS or specific in-app push notifications.

Aircraft monitoring systems

The Air traffic control radar systems are the primary sensors for detecting and monitoring aircrafts from the civil and commercial aviation. A typical modern radar consists of a primary and a secondary radar. These systems are associated with high costs for purchase, installation and maintenance. The Automatic Dependent Surveillance – Broadcast (ADS-B) system is the next-generation tracking system that complements the existing air traffic control radar systems. The ADS-B systems are autonomous, independent and always on, requiring no operator intervention. The systems depend on information from the GNSS system and provides surveillance services by continuously broadcasting the position of the aircraft.

ADS-B allows pilots and air traffic controllers to monitor and control the aircrafts with greater accuracy and precision from the ground than was previously possible. The accuracy of ADS-B is not seriously affected by the factors that affect radar systems, such as range, atmospheric conditions, altitude, etc. In the present moment, several public ADS-B systems are available for free or commercial use and everyone can become a host of a transceiver for one of them (Fig. 4).

Ship monitoring systems

The system for monitoring the parameters of the sea and river traffic uses a protocol called AIS (Automatic Identification System). In order for the protocol to work, all vessels and stations need to have specialized transceivers that enable the use of the AIS systems to identify and locate vessels through electronic data exchange. The automatic identification system is used for both marine and river systems. The information from the AIS system complements the data from the marine radars, which remain the primary method for monitoring the river and sea transport. AIS and radars are used widely by marine authorities to manage the vessel traffic.

AIS was introduced by the International Maritime Organization (IMO) in order to increase the safety of ships and the environment and to improve the traffic monitoring and the maritime traffic services. The present regulation requires AIS transceivers to be fitted on board of all ships of 300 gross tons and above engaged in international voyages, cargo ships of 500 gross tons and above not engaged in international voyages and all passenger ships, regardless of their size. This requirement is effective since the 31st December 2004 for all ships.

The information provided by the AIS equipment, such as unique identification, position, course and speed, as well as other vehicle parameters, can be displayed on an AIS screen or on an electronic chart display and information system (ECDIS) display. The data is also available on several online platforms for free and for commercial purposes (Fig 4).

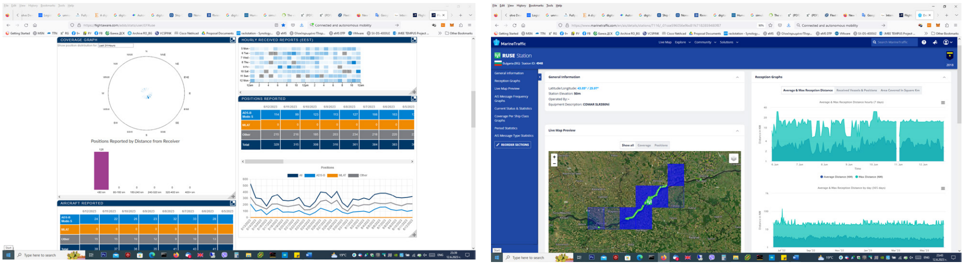

Figure 4. The user interface of an ADS-B aircraft monitoring system (left) and the user interface of an AIS system for observation of the water traffic (right) near the City of Ruse in Bulgaria

2.6. On-demand ride services

On-demand ride services, also referred to as ride-sharing services, have significantly impacted the transport industry since their appearance in 2010. These services quickly evolved and became popular due to their advantages and the flexibility that they offer. In the present-day world, the on-demand ride services are the primary source of traveling in many countries and gaining significant market share in the transport sector. Recent studies (Kushchenko et. al. 2019; Novikov et. al. 2019) have proven that on-demand services can increase the productivity of the vehicles by between 30 and 50% compared to the conventional taxi services. The main factors underlining the advantages of on-demand services include:

– Optimal matching – on-demand services rely on advanced matching systems that try to optimally assign a vehicle to a passenger. These decision-making systems rely on mobile technologies that are able to match geo-located demand and supply in real-time.

– Scale effect – on-demand services usually benefit from a scale effect by being able to offer services over large areas that are covered by more vehicles. In this way, the systems have the ability to match service supply and demand across a city area and have the drivers compete for the customers.

– Regulatory setting - the conventional taxi industry is usually regulated, implying that service areas are defined, the number of vehicles controlled and the fares set. Unlike them, the majority of on-demand ride services are commercial and the standard regulations are not applying to them.

– Supply and fare flexibility - an important advantage of on-demand taxi services is their ability to quickly adapt to changes in demand by increasing the number of vehicles and fares in acute mismatch situations.

The ride-sharing services enable a more flexible workforce allocation, as providers can define their own working hours and can combine this type of work with other working opportunities. The downside of the ride-sharing services is that they are threatening the regular taxi services, which caused legislative actions in some countries (including Bulgaria) and the banning of these services.

3. Present and emerging challenges for the transport education

The aforementioned examples, as well as many other trending or emerging digital transport technologies are presenting significant changes to the employability of the sector. The wide use and the rapid integration of these technologies in the transport sector has caused significant alterations of many jobs - some professions are already endangered by extinction, while other are slowly emerging. The education sector needs to adapt quickly and effectively to these changes, in order to provide educational activities, which are efficient and are corresponding to the needs of the labour market. As a result of this, new education schemes will become increasingly focused, not just on the sector-specific knowledge, but also on strategic and interdisciplinary skills, which the students will need to get a job.

The main challenges for the transport education in the digital age, as well as specific personal, institutional and national solutions for overcoming these challenges, are presented and summarized in the Table 1 below.

Table 1. Main challenges and solutions for the transport education in the digital age

Description of the challenge	Solution at personal level	Solution at institutional level	Solution at national level
Interdisciplinary nature of the modern digital transport technologies	– Participation of the staff in qualification courses, seminars and trainings; – Requalification;	– Involvement of ICT personal or lecturers from ICT departments in the educational activities;	– Adaptation of the learning programs and course contents; – National programs for requalification;
Expensive equipment and devices for the implementation of the educational processes	– Cooperation with the business; – Attraction of sponsors; – Use of open-source products and trials;	– Participation in national and international projects; – Business – Academia cooperation;	– Establishment of national educational and research programs; – Grant programs; – Budget increase;
Lack of educational materials, textbooks, laboratory exercises, training materials	– Development of new textbooks and training materials; – Development of resources;	– Establishment of joint-programs with organizations with know-how on the subject	– Development of expert groups for creation of educational resources; – National programs for development and interchange of know-how and resources;
Lack of skilled and experienced teachers and trainers	– Participation in trainings and courses; – Requalification;	– Organization of courses, training and seminars;	– National qualification programs; – Financial stimulation;

As seen from the table above, the effective transition into the digital age for the transport education will require actions at several different levels. This is due to the various nature of the challenges, as well as due to their complexity and the underlying requirements.

At the personal level, the know-how, the expertise and the attitude of the lecturer (or the trainer) are the primary characteristic, which will guarantee the production of favourable educational outcomes:

– Knowledge (know-how) – this characteristic defines and quantifies the subject-specific content knowledge, subject-specific pedagogical content knowledge and the subject-unspecific psychological–pedagogical knowledge of the lecturer or trainer;

– Skills (practical expertise) – this characteristic is relevant for the teaching profession as pedagogical skill, content-related practical skills, soft skills and digital or ICT skills;

– Attitude – the values, beliefs, commitments, and professional ethics that influence the behaviour of the lecturer or trainer toward the students, trainees, their families, colleagues and the general community.

The readiness for change of the institutions and the flexibility and adaptability of their management teams are among the primary requirements for the transition of the educational processes in the digital age. From one point of view, the educational institutions have to demand from their teachers and lecturers to evolve and to work on the development and integration of new ICT-related, but subject-specific, learning subjects and courses. The institutions are also the sole point for management and control of the processes. From another point of view, the institutions are responsible for the establishment of the right environment and for the financial and technical provisioning of the learning processes. This means, that the educational institutions are put under a lot of pressure, as they need to establish business-academia connections, apply for grants, develop projects and take advantage of all available opportunities for funding and for development and improvement of the facilities and the available equipment, so that they can implement efficient and up-to-date education processes.

The National Institutions also play important role for the transition of the educational processes in the digital age. These institutions have to take care of the general frameworks for the educational programs and are responsible for the accreditation and evaluation of the existing and the newly developed programs. These institutions have to be clearly aware that the transitioning cannot be done by the means of one institution or a team of lecturers, but by national actions for adaptation of the educational programs to the need of the labour markets.

4. Conclusions

The present and emerging digital transport technologies offer significant advantages and provide many new opportunities and possibilities. Nevertheless, the rapid development and the vast adaptation and integration of these technologies presented a new set of challenges for the educational sector.

In the article we presented some of the most widely used digital transport technologies and their main characteristics. Based on that, we have defined and summarized the most common challenges for the transport education in the digital age and we have proposed some solutions at personal, institutional and national level for overcoming these challenges.

Acknowledgments

The work presented in this publication is completed as partial fulfilment of Project BG05M2OP001-1.001-0004 UNITe, funded by the OP "Science and Education for Smart Growth", co-funded by the European Union.

This article was prepared with the support of Project 2023-FEEA-03, financed under the Scientific and Research Fund of the "Angel Kanchev" University of Ruse.

NOTES

1. https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/climate-neutral-and-smart-cities_en.
2. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:207:0001:0013:en:PDF.
3. https://www.koerber.com/en/supply-chain/logistics-highest-potentials-how-amr-help
4. https://www.railtech.com/infrastructure/2019/11/19/fully-automated-metros-run-in-six-eu-countries/.
5. https://www.onthemosway.eu/volvo-develops-autonomous-vehicle-system-for-logistics/?cn-reloaded=1.
6. https://www.military.com/daily-news/2022/07/06/dont-call-it-flying-car-air-force-drone-transport-develops-new-identity.html.
7. https://gunnerus-case.github.io/.
8. https://www.ntnu.edu/ihb/simulator.
9. https://www.nlr.org/article/facing-atm-challenges-with-flexible-atm-simulation-platform/.
10. https://www.forbes.com/sites/alanohnsman/2016/10/03/toyotas-robot-car-line-in-the-sand-8-8-billion-test-miles-to-ensure-safety/?sh=d4c12d216f01.

REFERENCES

BABULAK, E., 2008. Information Technologies in Transportation, *International Conference on Computer Blended Learning ICML*, http://dx.doi.org/10.2139/ssrn.3917991

DUGANOVA, E.; NOVIKOV, I.; NOVIKOV, A.; ZAGORODNII N., 2022. Problems of introduction of digital technologies in the transport industry, *Transportation Research Procedia*, vol. 63, pp. 1024 – 1033. https://doi.org/10.1016/j.trpro.2022.06.102.

JOVIĆ, M.; TIJAN, E.; VIDMAR, D.; PUCIHAR, A., 2022. Factors of Digital Transformation in the Maritime Transport Sector, *Sustainability*, vol.14, DOI: 10.3390/su14159776.

KUSHCHENKO, L., KUSHCHENKO, S., NOVIKOV, A., SHATOVA, J., 2019. Research criteria for assessing the training of drivers of vehicles. *IOP Conference Series: Materials Science and Engineering,* vol. 698, no. 6. DOI:10.1088/1757-899X/698/6/066035.

NOVIKOV, A., GLAGOLEV, S., NOVIKOV, I., SHEVTSOVA, A., 2019. Information technologies and management of transport systems development of the approach to assessing adaptation of the intersection transport model. *IOP Conference Series: Materials Science and Engineering,* vol. 632, no. 1. DOI:10.1088/1757-899X/632/1/012052.

SITÁNYIOVÁ, D., MEUNIER, J.C., MAŠEK, J., 2018. New Training Schemes for the Future Education in Transport Sector, 2018. *Transport technic and technology*, vol. 14, no. 1, pp. 11 – 17. DOI:10.2478/ttt-2018-0003.

SOFTIĆ, S., ODAK, M., LAZIĆ, J.L., 2022. Digital transformation - New Approaches and Challenges in Education, *45th Jubilee International Convention on Information, Communication and Electronic Technology (MIPRO)*, Opatija, Croatia, pp. 749 – 753, DOI: 10.23919/MIPRO55190.2022.9803435.

✉ **Dr. Georgi Hristov, Prof.**
Web of Science Researcher ID: R-7414-2016

Dr. Ivan Beloev, Assoc. Prof.
Web of Science Researcher ID: AAT-7382-2021

Dr. Plamen Zahariev, Assoc. Prof.
Web of Science Researcher ID: B-9260-2016
"Angel Kanchev" University of Ruse
7004 Ruse, Bulgaria
E-mail: ghristov@uni-ruse.bg
E-mail: ibeloev@uni-ruse.bg
E-mail: pzahariev@uni-ruse.bg