The Cognitive Mobility Concept

Máté Zöldy and Péter Baranyi

Abstract—**Mobility is the engine of our society in the third millennium. Rapid technical development makes it possible to increase cognitive ability in various fields; mobility is one of the most affected. Mobility has become a multidimensional concept in our interpretation; in addition to transportation, it also appears in the digital space, among other dimensions. The 21st century has brought unprecedented challenges, such as the covid-19 virus and the Russian war in Ukraine. These highlight bottlenecks in mobility systems and prompted us to explore the concept of cognitive mobility. This paper intends to refine the CogMob approach, which co-manages human and machine capabilities in mobility. New achievements within CogMob's domain match the new challenges of war and viruses. This article aims to outline the field of cognitive mobility. It presents CogMob's definition and examples that clarify the combinations of cognitive levels of different mobilities.**

Index Terms—**Cognitive Mobility, Vehicles, Infrastructure, Digital mobility**

I. Introduction

Mobility is essential to our lives because we are constantly changing and moving. For many, the word mobility is primarily associated with transport, i.e., a change of location visible to the naked eye, often with the help of some means of transport. However, mobility can be much more diverse: for example, social mobility, which describes a change in the social situation of an individual or family, or labor mobility, which creates a link between a job and a choice of residence.

During the research and conceptualization of cognitive mobility, the focus of our attention is the deeper understanding of mobility with the help of cognitive tools. Transport mobility is a complex process that is preceded by the emergence of a need, the decisions to meet it, and its fulfillment. Essential elements of the used vehicle, the infrastructure, the environmental effects caused; time and energy; and resource demand in both the short term and historical time horizon. The result of mobility is the satisfaction of a trigger need or need and thus the creation of individual and social added value. Analysis of historical mobilities is a tool for a better understanding the present and the future.

Cognition and its mapping have long been a part and foundation of our lives. The rapid digital development of the 21st century allows us to expand our experiential learning with smaller, cheaper, and more sensitive sensors, data fusion, and artificial intelligence, with more and more data available [1]. Among other things, they help to get to know and map the world better and thus mobility. It also opens up new dimensions of understanding and development. Many focus on existing system components, but detailed empirical knowledge of the initial needs or the resulting value is becoming more common. This can lead to new solutions.

[1] Department of of Vehicle Technology, Budapest University of Technology and Economics, Budapest, Hungary (e-mail: zoldy.mate@kjk.bme.hu)
[2] Department of Computer Science, Szechenyi Istvan University, Győr, Hungary (e-mail: baranyi.peter@sze.hu)

Getting better to know our world, our decisions, and our opportunities can, in extreme cases, mean minimizing or even giving up mobility, as we have seen with the Covid waves of the past year and a half or with new compact urban planning goals.

Previous use of cognitive mobility in the thought space has been limited to measuring the transition from one place to another [2, 3]. In our approach, this unique example of mobility is part of cognitive mobility and can be better analyzed and understood with this approach, but it is only a sub-segment.

The challenges of the second decade of the 21st century, which are very different from the trend of the last seventy years, such as the Covid virus and the Russo-Ukrainian war in the EU, also pose a mobility challenge. Not only energy problems, from natural gas to oil to nuclear energy, the collapse of logistics chains, the slowdown in vehicle production, and the production of sensor systems affect new and existing systems.

The evolving artificial knowledge of human cognitive abilities and machines is becoming increasingly fused in mobility. This article seeks to refine further [4] the perspective of a framework in which human and machine capabilities are part of a mobility system.

II. Definition

Cognitive mobility (CogMob) examines the intertwined combination of research areas such as mobility, transport, and its management, vehicle manufacturing, related social sciences, artificial intelligence and its applications, and cognitive info-communications. The main goal of CogMob is to give a holistic picture of mobility and its broad understanding. It thus describes, models, and optimizes as a mixed combination of artificial and natural/human cognitive systems. It sees the whole combination as an inseparable CogMob system and explores what new cognitive abilities come from this CogMob system. One of CogMob's focus areas is, of course, engineering applications in the mobility sector.

Two critical dimensions of cognitive mobility need to be identified: the ranking of mobility and the elements of mobility.

The ranking of mobility is a hierarchy with two purely theoretical endpoints. These refer to the cognitive level of those involved in mobility.

• Intracognitive mobility - participants in mobility have almost similar cognitive abilities (e.g. pedestrians on a pedestrian street or otherwise moving goods in a warehouse)

• Intercognitive mobility - mobility participants have different cognitive abilities (highly automated vehicles and bicycles travel in urban environments).

The elements of mobility are related to the essence of mobility:

• Necessity of initiative: this is the reason behind mobility

• Decision: Influences how mobility occurs, whether it happens at all or not. It can occur more than once during an activity.

• Device / vehicle / quality: different quality parameters that influence the decision, the resource requirement, and the result of the mobility.

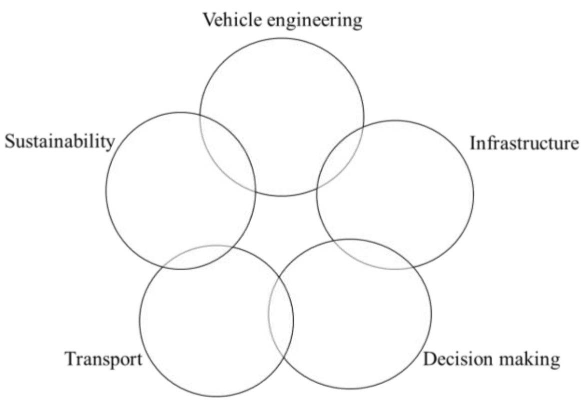
• Infrastructure / Resources: In addition to infrastructure, mobility consumes many resources, such as money, time, energy, etc.

• Human-machine interface: includes a wide range of options, from smartphones, smart maps, web tracking interfaces, simulation software, and more.

III. Key areas of mobility

In the discussion section, we examine the research areas related to CogMob from a historical perspective. This chapter highlights the growing role and influence of natural and artificial cognitive processes in mobility science. It shows that people and the environment are increasingly merging in mobility and offers us a "one-size-fits-all" modeling space that makes it easier to understand mobility.

Historically, research areas related to mobility have been fragmented into silos and run in parallel with a small number of interdependencies. Most of the research focused on their own area of focus and treated the rest as peripherals and endowments. The rate of mobility development has increased in the 20th century, similar to the acceleration of many areas of life. The main areas were automotive, infrastructure, road planning and decision making, transportation science, human-machine communication, and social sciences. This has been complemented by the theme of sustainability in recent decades. The parallel technological development of these sciences has reached the point where more and more synergies have been achieved through in-depth collaboration (Figure 1).



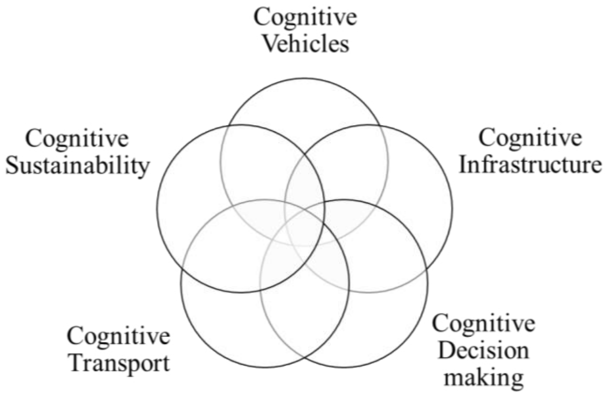


Fig. 1. The key areas of mobility have a higher level of synergy, and the areas come together to develop more effective cooperation.

Interdisciplinary collaboration is growing, as vehicles, for example, used to be mere infrastructure users, but today infrastructure and vehicles work together to provide input for decision-making and route planning.

A. *Cognitive Vehicles*

The growing importance of safety aspects was the first driving force that positively affected the cognitive level of vehicles. Safety devices were mainly mechanical aids for the driver in the beginning. In the last decades, driver assistance devices' role in vehicles has increased [5]. In 2019, a cognitive vehicle engineering workshop was held. The focus was on the human inspiration for perception, learning, and decision-making that could be transferred to increase the intelligence of vehicles and other autonomous systems in the future [6]. They focused on the potential benefits and pitfalls of using artificial and natural approaches in the design of intelligent systems that perceive, interact, learn, and make decisions.

B. *Cognitive Infrastructure*

Historically, the reason for building new transport infrastructure was commercial intent. The ancient Silk Road or the Roman military roads are examples of this, but the Panama Canal or the first railroads were built for a similar purpose. At the beginning of the 20th century, there was a similar motivation behind constructing the electricity network. Although these included complex systems, they are independent tools that facilitate the movement of goods. On the other hand, cognitive transport infrastructure is a meta-infrastructure; it contains many interconnected, and thus continuously interacting, factors. The interconnection aims to increase capacity utilization through several previously unavailable technologies such as 5G or even 6G communications networks, artificial intelligence and big data analytics, social media, Internet-connected devices, or cloud-based storage. The spectrum of users and developers is also complex, as elements of the cognitive infrastructure are developed and used by individuals, companies, and public institutions [7]. The complexity of communication between infrastructure and users is increasingly similar to communication between people. The knowledge accumulated in one area can be transferred to another [8].

C. Cognitive decision making

Decision-making is essential not only for increasingly automated vehicles but also for driver support. Intensive research is also underway in this area. In the field of transport decisions, cognitive memory is of paramount importance. Continuous, dynamic redesign of the route by adding cognitive factors is an excellent example. The goodness of the decision results was greatly improved by reducing the error, indicating that the vehicle was able to learn cognitive variables. It opens up the possibility of unsupervised learning in making sensible transport decisions. Decision-making about vehicles is cognitively similar to the human mind, which also maps the classification of events to processed patterns.

Exploring other features of human cognition, such as emotions and memory structure, offers another exciting way into the future. Unsupervised learning is an essential cornerstone in the development of self-driving vehicles. Data mining can also facilitate routing; however, an optimized mining strategy is required to select selective data [9].

D. Cognitive Transport

Deploying intelligent transport systems is one of the biggest challenges of traffic planning in the 21st century. Developing cooperation between conventional and autonomous vehicles at different levels of the global transport system is a task now and soon. Already in this decade, the proportion of self-driving vehicles, the heterogeneity of traffic, and the distribution of vehicles and transport infrastructure are increasing to ensure their effective control and to improve the quality of the transport services provided. Creating a cognitive multimodal transport system is a complex example of the intellectualization of vehicles, transport infrastructure, and the systems and networks that connect them. The main driver of this process is the artificial intelligence factor in transport systems. A successful system dramatically improves the safety of people and cargo, reduces the average time of passenger and freight transport, improves the efficiency of the use of the capacity resources of the national transport system for a higher level of environmental safety, and has a significant impact on the national economy. Together with the latter result, it can be stated that the development of a cognitive multimodal transport system gives a strong impetus to the general development of the national economy [10].

E. Human-machine communication

The history of the human-machine interface (HMI) is closely linked to the history of driving. The first international conventions on the HMI of vehicles were concluded in the 1949 Geneva Convention on Road Traffic [11]. The Gefi agreement contains, among other things, rules and recommendations for the vehicle's internal HMI. For example, a speedometer and steering wheel must be installed in the vehicle.

A significant step was the emergence of routing assistance systems in the 1970s. Subsequently, the first generation of driver assistance systems and the increasingly complex systems that followed increased communication between the driver and the vehicle. Early driving support systems, such as ABS, ASR, ESP, were already in use at the end of the 20th century, but by the turn of the millennium, a 'cruise control' was introduced to handle tracking distance. There was a significant breakthrough in management support systems in the early 2010s with the advent of complex systems [12]. One sign of this was the growing screens and onboard displays. Communication between the infrastructure elements and the drivers has intensified. In most sub-sectors of traffic, the driver cannot be excluded from mobility, but the functions that partially enable autonomous driving require increasingly complex communication, which encourages the development of communication interfaces.

F. Cognitive Sustainability

Sustainability is a crucial dimension of life at the beginning of the third millennium. Our society transforms and changes even faster and more continuously than any earlier. Mobility is part of the rapid change; sometimes, it is the accelerator. Sustainability aspects are crucial for mobility as society is highly dependent on mobility [13].

Above all, CogMob is a holistic approach that, in addition to examining mobility in the context of artificial and natural cognitive skills, also supports its view of the social sciences, thereby facilitating a deeper, more comprehensive understanding and understanding of mobility. The interaction between mobility and economic processes is a clear link for everyone. Understanding mobility, using the tools of the social sciences, provides an opportunity to learn about and understand the processes behind mobility. A deeper knowledge of the social processes that emerge through mobility can provide an input variable for further mobility development.

The goal and mission of CogMob is a holistic mobility approach that is greatly facilitated by information communication tools. It connects certain aspects of the system, such as decisions, infrastructure, and tools. CogMob provides a shared space for optimization through the conscious and well-chosen use of IT tools, considering system components as part of a cognitive system [4].

IV. Cognitive Mobility in Practice

In this chapter, some examples are provided that clearly show the combination of cognitive levels, mobility modes, and mobility elements.

A. Augmented security of connected vehicles

In the automotive industry, cybersecurity is an emerging area of research in these years that many are approaching from various perspectives [14]. Existing vehicle safety solutions cover a wide area, often with competitors doing the same thing differently. State-of-the-art and future research directions. Based on the results of a wide-ranging analysis covering the topic, the field of artificial intelligence and defense mechanisms was previously underrepresented in research. Therefore, we can expect a wide range of interest in these areas. Another current area is vehicle communication, which dominates most of the developments.

B. Merging of info-communications and mobility

Digitization affects vehicles, drivers and infrastructure, and vehicle occupants. A study has revealed [15] what activities are carried out during non-local journeys, mainly on various means of public transport such as train or city and suburban buses. In summary, it can be emphasized that - based on one of the first travel-based multitasking studies in Hungary - the proportion of activities performed on non-local trips on a smartphone or tablet starts from a low level but is constantly increasing. This process correlates with smartphone ownership and mobile internet access. On the one hand, the main finding is that the use of electronic devices decreases with age [15].

C. Hybrid and electric propulsion systems

In addition to vehicle control, the use of artificial intelligence has also advanced in the driveline. Internal combustion engines are increasingly challenged by more stringent standards [16]. With the development of in-vehicle electronics, components such as brake assist, exhaust gas recirculation, and steering can be controlled so that previously unavailable operating conditions are available. An example of this is the intelligent engine control system [17], which can achieve optimal performance even in extreme conditions. In addition, a supporting vector-machine-based forecasting model has been developed to predict engine performance under varying operating conditions. The developed, supported vector machine model predicted the engine's performance with high accuracy.

The application of statistical regression models has also appeared in vehicle development. A three-step statistical analysis algorithm using vibration and sound pressure data as covariates to predict exhaust gas composition has become demonstrable [18].

Machine learning results can also be applied in vehicle control, especially in the control of self-driving vehicles. The road tracking function is required to guarantee vehicles' safe speed and movement profile with variable tire-road contact. The solution for this case combines Linear Parameter-Varying (LPV) control integration and machine learning-based analysis. The integration takes place in two steps. The result of the estimation method is generated using the coefficient of adhesion decision trees. The estimation result is integrated into the robust LPV controller via a scheduling variable. An error in the machine learning algorithm is built into the design of the control. In a second step, the optimization of longitudinal velocity is proposed over a predicted horizon, with a defined approximation of the accessibility of steering intervention based on machine learning [19].

D. The digitalization of the infrastructure

The cognitive approach is also playing an increasingly important role in water transport. In addition to navigation infrastructure, ports are the ones whose development is tangible. Improving digitization means increasing efficiency, so this can be seen as the main direction of development. Ports have different levels of digitization. Many reasons for this can be, for example, the size of the port, its history and traditions, and the size and type of traffic. A different methodology seeks to bring together the different levels and related developments [20]. Ports were compared within groups of small, medium, and large ports. It is estimated that the level of digitization in small and medium-sized ports is around

30% lower than the level of large seaports. The research results may be of interest to ports seeking to assess the level of their digitization and select the best digital development solutions.

E. Onboard energy management

A complex example of cognitive vehicle technology is vehicle recharge management. The importance of this topic area is growing with the development of self-driving skills of vehicles. It is currently unknown what will be the primary vehicle propulsion in the coming decades. The most complex of the available technologies is plug-in hybrid technology: it combines an electric powertrain and a conventional internal combustion engine, in the latter case with renewable [21-24] or even synthetic [25] propellants. In the case of fossil fuels, communication between filling stations and vehicles is a one-way, narrow channel, providing information on fuel prices only.

In contrast, mutual communication allows joint optimization in terms of route, fuel, charging time, and even price [26, 27]. For example, the longer charging time of electric vehicles, and therefore the waiting time due to the charging needs of others, as a decision criterion, will only be possible with better quality and quantity of communication between systems. Waterborne transport and the use of agrofuels open up further areas for improving the optimal energy management of vehicles with cognitive tools [28].

F. Environment perception

Perceiving and understanding the environment is a central area of automotive development in the 21st century. This solution is of paramount importance not only in self-driving vehicles but also in the driver assistance devices of conventional vehicles. These systems are suitable for processing and managing dynamic relay systems such as controllable signals, adaptive traffic control with traffic lights or even traffic news information. Connecting in-vehicle systems with intelligent infrastructure increases the range of possible decision options. Because the critical input parameter of self-driving and driving support functions is perception, since driving is based on the results of different sensing algorithms, perception can be broken down into subproblems. The most common are lanes, traffic signals, objects, environment, etc. These solutions based on artificial intelligence, primarily neural networks, are already close to applicability today, and we will encounter them more often in the future [29, 30, 31].

G. Digital twin-based research

Intermodal transport infrastructure is a good example of cognitive elements' growing and increasingly important role. An increasingly important element of urban ecosystem models is the design, even optimization, and shaping of mobility. The relationship between urban structure, mobility, and urban development can be identified using cognitive tools. Cognition can be facilitated [32]. Simulation of mobility infrastructure also plays a key role in vehicle development.

This is necessary concerning the development of transport simulations and, on the other hand, for increasing mobility safety. Continuous updating traditional static maps is resource-intensive and opens the door to computer simulations [33]. Due to their technological solutions, self-driving vehicles are almost impossible to integrate into the cumbersome homologation procedures of conventional vehicles [34]. Their long development time can be radically reduced, for example, by using digital-twin solutions [35], in which validation can be performed at any time due to simulation and the parallel running of reality.

H. Intermodality decision making

In mobility, cognitive methods can help make instantaneous decisions. Roundabout has long been used as an intersection solution due to its easy adaptability and high level of safety. In the case of self-driving vehicles, in many cases, one of the main directions of development is the highway scenario; the work in the roundabout requires more time and effort. Research demonstrates the usability of various decision support applications, making it clear that cognitive techniques increase efficiency [36]. Driving wants to avoid collisions and minimize energy consumption. The optimization tasks are interrelated, i.e., quadratic optimization with the vehicle model is used as the environment during training [37]. The application of new cognitive approaches is necessary not only in the ground but also in air mobility. In unmanned aerial vehicles, new applications are very similar to self-driving cars [38].

In intermodal transport, harmonizing sub-sectors can also be interpreted as a complex treatment of the above. These improvements will also increase the level of transport efficiency and sustainability. Research [36] collects and analyzes the factors that have identified ten factors influencing the efficiency and sustainability of intermodal transport.

Conclusions

At the dawn of the 3rd millennium, mobility is one of the foundations of the way of life. The CogMob concept presented in our article consciously focuses on deepening and extending this. The mobility dimensions presented in the article (ranking of mobility and elements of mobility) help to interpret the broad topic of mobility from a cognitive perspective. The examples illustrate the importance of the cognitive approach in many areas and parts of mobility. CogMob explores the similarities between work in each subject area, looking for a holistic framework for managing natural and artificial cognition in one system.

References

[1] P. Baranyi, A. Csapo, "Cognitive Infocommunications: CogInfoCom" Conference Paper · December 2010, · Source: IEEE Xplore DOI: 10.1109/CINTI.2010.5672257

[2] G. J. Borjas, and K. B. Doran, "Cognitive Mobility: Labor Market Responses to Supply Shocks in the Space of Ideas" National Buerau of Economic Research, Working paper 18614, DOI: 10.3386/w18614

[3] R. G. Döbler, "Cognitive Mobility, a Macroscopic Investigation of Migration of Scientists between Research Fields Studied by Example of Mathematics" Journal for General Philosophy of Science · January 1998

[4] M. Zöldy, P. Baranyi, "Cognitive Mobility – CogMob", 12th IEEE conference on Cognitive Infocommunications, 23-25. 09. 2021 Budapest https://www.researchgate.net/publication/361435417_Cognitive_Mobility_-_CogMob

[5] M. Koschuch, W. Sebron, Z. Szalay, Á. Török, H. Tschiürtz and I. Wahl, "Safety & Security in the Context of Autonomous Driving," 2019 IEEE International Conference on Connected Vehicles and Expo (ICCVE), 2019, pp. 1–7, DOI: 10.1109/ICCVE45908.2019.8965092.

[6] Cognitive vehicles/vehicle engineering workshop (https://cogvehicles2019.github.io/)

[7] Allenby B.," 5G, AI, and big data: We're building a new cognitive infrastructure and don't even know it" Bulletin of the Atomic Scientists 75 years and counting, 2019.12.19.

[8] J. De Ruiter, M. Noordzij, S. Newman-Norlund, P. Hagoort, S. Levinson, I. Toni "Exploring the cognitive infrastructure of communication" Interaction Studies, v.11, 51–77 (2010). 11. DOI: 10.1075/is.11.1.05rui.

[9] Y. Saeed, A. Khalil, Z. Mahdi, Z. Asim, C. Vargas-Rosales, and A. Khalid "In-Vehicle Cognitive Route Decision Using Fuzzy Modeling and Artificial Neural Network" IEEE Access. PP. 1-1. DOI: 10.1109/ACCESS.2019.2895832.

[10] V. Komashinskiy, I. Malygin, O. Korolev: Introduction into cognitive multimodal transportation systems, Transportation Research Procedia, Volume 50, 2020, Pages 273–279, ISSN 2352-1465, DOI: 10.1016/j.trpro.2020.10.033.

[11] O. Benderius, C. Berger and V. Malmsten Lundgren, "The Best Rated Human–Machine Interface Design for Autonomous Vehicles in the 2016 Grand Cooperative Driving Challenge," in IEEE Transactions on Intelligent Transportation Systems, vol. 19, no. 4, pp. 1302–1307, April 2018, DOI: 10.1109/TITS.2017.2749970.

[12] Z. Szabó, Á. Török, T. Sipos, (2021) "Order of the Cities: Usage as a Transportation Economic Parameter", Periodica Polytechnica Transportation Engineering, 49(2), pp. 164–169. DOI: 10.3311/PPtr.13786

[13] Zoldy, M., Szalmane Csete, M., Kolozsi, P. P. , Bordas, P., & Torok, A. (2022). Cognitive Sustainability. Cognitive Sustainability, 1(1). DOI: 10.55343/cogsust.7

[14] Pethő Z., Török Á., Szalay Z. A survey of new orientations in the field of vehicular cybersecurity, applying artificial intelligence based methods. Trans Emerg Telecommun Technol. 2021; 32:e4325. DOI: 10.1002/ett.4325

[15] Munkácsy, A., Keserű, I., Siska, M. (2022) "Travel-based Multitasking on Public Transport: An Empirical Research in Hungary", Periodica Polytechnica Transportation Engineering, 50(1), pp. 43–48. DOI: 10.3311/PPtr.15866

[16] Lekić, M., Rogić, K., Boldizsár, A., Zöldy, M., Török, Ádám (2021) "Big Data in Logistics", Periodica Polytechnica Transportation Engineering, 49(1), pp. 60–65. DOI: 10.3311/PPtr.14589

[17] R. Naradasu, J. Srinathu, R. Ramakrishnan "Towards artificial intelligence based diesel engine performance control under varying operating conditions using support vector regression" Thermal Science. 17. 167-178. DOI: 10.2298/TSCI120413218N

[18] T. Žvirblis, D. Vainorius, J. Matijošius, K. Kilikeviciene, A. Rimkus, Á. Bereczky, K. Lukács and A. Kilikevicius "Engine Vibration Data Increases Prognosis Accuracy on Emission Loads: A Novel Statistical Regressions Algorithm Approach for Vibration Analysis in Time Domain" Symmetry 2021, 13, 1234. DOI: 10.3390/sym13071234

[19] D. Fényes, B. Németh and P. Gáspár "Design of LPV control for autonomous vehicles using the contributions of big data analysis" International Journal of Control, DOI: 10.1080/00207179.2021.1876922

[20] Paulauskas, V.; Filina-Dawidowicz, L.; Paulauskas, D. Ports Digitalization Level Evaluation. Sensors 2021, 21, 6134. DOI: 10.3390/s21186134

[21] Emőd István, Füle Miklós, Tánczos Katalin, & Zöldy Máté. (2005). A bioetanol magyarországi bevezetésének műszaki, gazdasági és környezetvédelmi feltételei. Magyar Tudomány, 50., 278–286. http://epa.oszk.hu/00600/00691/00015/03.html

[22] Goldbach, A., Meier, H. F., Wiggers, V. R., Chiarello, . L. M., & Chivanga Barros, A. A. (2022). Combustion performance of bio-gasoline produced by waste fish oil pyrolysis: Scientific paper. Chemical Industry & Chemical Engineering Quarterly, 28(1), 1–8. DOI: 10.2298/CICEQ200810010G

[23] Alahmer, A.; Rezk, H.; Aladayleh, W.; Mostafa, A.O.; Abu-Zaid, M.; Alahmer, H.; Gomaa, M.R.; Alhussan, A.A.; Ghoniem, R.M. Modeling and Optimization of a Compression Ignition Engine Fueled with Biodiesel Blends for Performance Improvement. Mathematics 2022, 10, 420. DOI: 10.3390/math10030420

[24] Annamalai, M., Dhinesh, B., Nanthagopal, K., Sivarama Krishnan, P., Lalvani, J. I. J., Parthasarathy, M., & Annamalai, K. (2016). An assessment on performance, combustion and emission behavior of a diesel engine powered by ceria nanoparticle blended emulsified biofuel. Energy conversion and management, 123, 372-380.

[25] M. Virt, J. Sauer: Investigating the Effects of Oxymethylene Ether in a Commercial Diesel Engine, Cognitive Sustainability, online first, DOI: 10.55343/cogsust.20

[26] M. Mrówczyńska, A. Alsabry, M. Skiba and A. Bazan – Krzywoszańska "Research on energy consumption in the city. A system of modelling potential for energy effectiveness using artificial intelligence" International Journal of Engineering Science and Innovative Technology (IJESIT). Volume 3. 373-384.

[27] M. Zöldy, I. Zsombók "Modelling fuel consumption and refuelling of autonomous vehicles" MATEC Web Conf., 235 (2018) 00037 DOI: 10.1051/matecconf/201823500037

[28] R. Zalacko, M. Zöldy, G. Simongáti, "Comparative study of two simple marine engine BSFC estimation methods" Brodogr. Teor. Praksa Brodogr. Pomor. Teh. 2020, 71, 13–25. DOI: 10.21278/brod71302

[29] Rövid, A., Remeli, V., Paufler, N., Lengyel, H., Zöldy, M., Szalay, Zs. (2020) "Towards Reliable Multisensory Perception and Its Automotive Applications", Periodica Polytechnica Transportation Engineering, DOI: 10.3311/PPtr.15921

[30] B. Varga, T. Tettamanti, Z. Szalay "System Architecture for Scenario-In-The-Loop Automotive Testing" Transport and Telecommunication Journal. 2021;22(2): 141–151. DOI: 10.2478/ttj-2021-0011

[31] I. Varga, J. Bokor "A New Approach in Urban Traffic Control Systems", Periodica Polytechnica Transportation Engineering, 35 (1-2), pp. 3–13.

[32] A Barsi "Performing coordinate transformation by artificial neural network". AVN. 108. 134–137.

[33] Zöldy M. "Investigation of autonomous vehicles fit into traditional type approval process", Proc. Int. Conf. Traffic Transp. Eng. (ICTTE), pp. 428–432, 2018.

[34] Z. Szalay, "Next Generation X-in-the-Loop Validation Methodology for Automated Vehicle Systems," in IEEE Access, vol. 9, pp. 35 616–35 632, 2021, DOI: 10.1109/ACCESS.2021.3061732.

[35] Cao, H., Zöldy, M. (2020) "An Investigation of Autonomous Vehicle Roundabout Situation", Periodica Polytechnica Transportation Engineering, 48(3), pp. 236–241. DOI: 10.3311/PPtr.13762

[36] B. Németh, P. Gáspár "Design of learning-based control with guarantees for autonomous vehicles in intersections "IFAC-PapersOnLine, Volume 54, Issue 2, 2021, Pages 210–215, ISSN 2405-8963, DOI: 10.1016/j.ifacol.2021.06.024.

[37] J. Bokor, B. Vanek "Research directions of unmanned aerial vehicles" In: Finszter, G; Sabjanics, I (szerk.) Security challenges in the 21st century, Budapest, Magyarország : Dialóg Campus Kiadó (2018) 823 p. pp. 411–421., 11 p.

[38] Filina-Dawidowicz, L, Stankiewicz, S., Čižiūnienė, K., and Matijošius, J. (2022). Factors influencing intermodal transport efficiency and sustainability. Cognitive Sustainability, 1(1). DOI: 10.55343/cogsust.9