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ON THE ROADS OF SMART CITY: DATA MINING ALGORITHM FOR ADAS

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Abstract

If we speak about the Smart City's transport system, autonomous vehicles idea is the first thing that comes in mind. Today, it is strongly believed that the autonomous vehicles' introduction into the traffic will increase the road safety. However, driverless cars are not the solution by themselves. The road safety and, accordingly, sustainability will strongly depend on decision making algorithms inbuilt into the control module. The Intelligent System for fully- or semi- autonomous vehicle that we suggest consists of 3 modules: (1) an Object detection module; (2) a Data analysis module; (3) a Knowledge database built on decision rules generated with the help of our data mining algorithm. Despite there are a lot of Advanced Driver Assistance Systems, the question is how to derive knowledge from the data possessed and how to use modern technologies to make driving safer. That's why the main influence on any Driver Assistant system is done by the artificial intelligence algorithm (AI) used. Since an AI algorithm is a set of decision rules that target a specific problem to solve, the novelty of our proposed Intelligent System for fully- or semi- autonomous vehicle is concluded in our EAV (Entity–Attribute–Value) model based decision making algorithm. The created system was tested on a simple collection of photos from a Polish two-lane road.

Keywords: autonomous driving; unmanned vehicle; machine vision; decision rules; Decision Table

1. Introduction

The term "Smart City" today is extremely trendy for everyone involved in city governance, but it is still relatively unclear not well-defined, despite there are a lot of different definitions in the literature. For example, first time this concept was described in 1992 as the development of the city towards technology, innovation and globalization [10]. Kustra and Brodowicz in their article [16] even have created a consolidated table where they have listed main existing descriptions of Smart Cities. And summarizing, they have defined a Smart City as a city concept based on information and communications technologies (ICT), open Big Data systems and other intelligent solutions that become a crucial driver for enabling sustainability of urban areas. Application of this concept requires a lot of advanced technologies, such as Big Data [3, 4], the Internet of Things (IoT) [14, 25], artificial intelligence (AI) [1, 18], Cyber security [20], or Blockchain technology [27].

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Currently, Smart Cities are defined as "systems of people that interact and use the flows of energy, materials, services and financing to catalyze a sustainable economy, development, resilience and high quality of life" [30]. Thus, Smart Cities cover six important sectors that need to work in unison to achieve a common goal of making a city more livable, sustainable and efficient for its residents. These sectors are smart energy, smart integration, smart public services, smart mobility, smart buildings, and smart water. All these subsystems are connected to each other and within the framework of a common goal provide a qualitatively new level of operation. However, smart mobility is one of the main issues here, since it provides people with access to both: working places and recreation zones, and it is also a part of the production and other subsystems in the city's economy [15]. Therefore, transport system is one of the main intelligent systems in Smart City. To ensure its sustainability and safety, three directions are realized: smart infrastructure, smart vehicles and smart citizens (Figure 1). Intelligent Transport System (ITS) of the Smart City due to this integrated approach provides the opportunity to implement interactive services, which leads to a decrease in traffic congestion and makes the traffic convenient and safe for all its participants.

The development of "unmanned vehicles" or "autonomous vehicles" has become a logical trend on the way of ITS implementation as a systemic strategy. ITS, according to [26], can create clear benefits in terms of efficiency, safety and security of transport, while at the same time contributing to the development of the European Union internal market and increasing competitiveness. However, Park et al. [19] consider autonomous vehicles as one of the most disruptive technology innovations due to issues of customers' acceptance based on safety, ethics, etc.

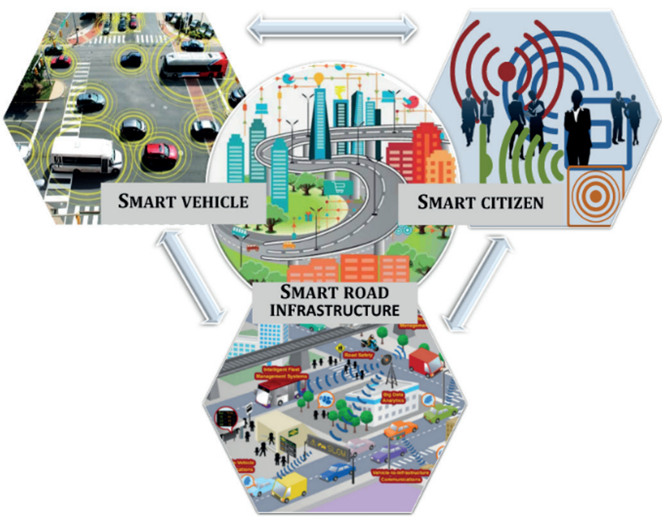

Fig. 1. Main directions of the transport system's development in Smart City

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SAE prognoses that by 2045, more than 70% of all sold vehicles will integrate autonomous capabilities from "first level of automation" to "full automation" [2]. Wherein, the automation levels from 1 to 4 refer to the driver assistance systems, combination of driver assistance systems, or fully automated driving systems. Transition from Advanced Driver Assistance Systems (ADAS) to semi-autonomous and fully autonomous vehicles is a global trend that is explained by the desire of developers to ensure sustainability and safety of the transport system. Safety driver assistance systems play a critical role both in averting crashes and reducing the likelihood of serious injury in the event of a crash. For example, according to statistics published already in 2015 [13], the use of Automated Emergency Braking System can reduce the number of collisions caused by too close approach of the car to the car in front. This is confirmed by statistics published in the Road safety annual report 2020 [23]: over the past 5 years, the number of passenger injuries has been reduced by almost 40%.

Such Safety Driver Assistance Systems include, for example, an electronic engine management system, a remote vehicle diagnostics system, safety systems, vehicles' positioning and a number of others [8]. One of the important areas of vehicle intellectualization is accident prevention systems based on "machine vision". For example, Mobileye [17] is being developed today, which is used in BMW and Tesla cars. As the leader in automotive safety, Volvo also couldn't avoid developing its own technology City Safety [6]. The first generation of standard brake support Volvo has introduced in 2006. Now, City Safety takes on an extended, all-new role in car brake solution: it is efficient at all speeds including slow-speeds from 4 km/h. Subaru also has its own Driver Assist Technology: EyeSight. When equipped with EyeSight, the 2019 Ascent, Crosstrek, Forester, Impreza, Legacy, Outback, and WRX received the highest possible rating for front crash prevention from IIHS highest rated claim from 2019 to 2020 [11].

Cross Traffic Alert Systems [21] also help to prevent many accidents when the driver does not notice traffic moving in a cross direction. Such systems are usually based on high frequency radars (20 GHz and higher). However, they are quite expensive and can be installed in high-end vehicles as an additional option [9]. Machine vision can greatly simplify such systems and make them widely available. One more type of Driver Assistant System's function that should be mentioned among those based on machine vision is Driver Fatigue Monitoring Systems [29].

In the machine vision systems, the design of AI algorithms is an important part of the decision making based on real-time information. It requires to be efficient in terms of time required to process the algorithm for a large number of input data. That is why, despite a lot of different researches are made on the development of different AI decision making algorithms, there are still a lot of work to be done in order to make these algorithms work faster and more accurate.

The goal of this article is to check the possibility of using our data mining algorithm based on Entity–Attribute–Value (EAV) model for decision making in the Intelligent System in the fully- or semi- autonomous vehicles.

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2. Research methods

Digitalization and intellectualization of all economic sectors and fields of activity give new possibilities to improve decision-making processes in the complex systems management. This provides increased efficiency, safety and sustainability of such systems. For these purposes, intelligent information systems are created. This is especially true for the autonomous vehicles, where artificial intelligence algorithms should be created in a way to replace the human in making decisions. Such intelligent systems can be clustered according to various types of AI algorithms. One of the big clusters are the systems based on machine vision.

The machine vision is very often mistakenly confused with image recognition. However, machine vision is not only the image recognition, it is mostly about automation of understanding of what machine "sees" in this world and making decisions basing on it. That is why there have to be created an intelligent system based on image recognition as well as on decision taking algorithm. We suggest that this Intelligent System in the fully- or semi- autonomous vehicles should have 3 modules:

1. Object detection module;
2. Data analysis module;
3. Knowledge database founded on the algorithm for decision rules generation.

2.1. Methodology to create Object detection module

The process of image recognition is based on the RetinaNet model. This model was chosen because according to the researches made by Saini et al. [24], Fan et al. [12], Carranza-García et al. [5], RetinaNet is highly accurate, especially for unmanned aerial vehicle (UAV) technologies. Our object recognition model has been trained with the help of the COCO collection [7].

The created Object detection module is implemented in Python and it allows detecting 80 different objects from everyday life in the images in jpg format. The outcome of the module are the photos with information about the detected object and the probability with which this object was detected. Additionally, the detection result is displayed in the console from which the script is run. It is a single script application which code is presented in Figure 2.

2.2. Methodology to create Data analysis module

To create this module, the field expert is responsible for building a Decision Table based on previously received information on objects detection. This Decision Table should contain criteria to classify the objects detected on the images into suggested groups (in our case – to specify the number and probability level of recognised cars and trucks). Probabilities of belonging to a particular group must be discretized (it is necessary to generate decision rules in the next step). Role of the field expert is to define actions (based on a given photo) that autonomous vehicle can perform in a given situation for

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road traffic safety. Thanks to this, it is possible to perform a supervised learning of the model, which, in principle, will assist in driving an autonomous vehicle.

```
from imageai.Detection import ObjectDetection
import os
import time
import glob

execution_path = os.getcwd()

detector = ObjectDetection()
detector.setModelTypeAsRetinaNet()
detector.setModelPath( os.path.join(execution_path , "res-
net50_coco_best_v2.0.1.h5"))
detector.loadModel()
for file in glob.glob("input/*.jpg"):
    filename = file.split("/")[1]
    detections = detector.detectObjectsFromImage(input_image=os.path.join(execu-
tion_path , file), output_image_path=os.path.join(execution_path , "out-
put/", filename))
    print(filename)
    for eachObject in detections:
            print(eachObject["name"] , " : " , eachObject["percentage_probabil-
ity"] )
```

Fig. 2. Snippet of the Object detection module's libraries

2.3. EAV based decision making algorithm to create Knowledge database

On the base of the Decision Table from the Data analysis module, the Knowledge base was generated automatically. This module is processing according to the EAV model based algorithm that belongs to the group of heuristics as it constitutes approximate decision rules. We have developed this algorithm to reduce the number of attributes under consideration while getting the same level of accuracy. In our previous article [28], we have compared results of our algorithm with the results provided by the use of dynamic programming approach.

To ensure road traffic safety in the future, when autonomous vehicles will become usual road users, it is extremely important that they make decisions as quickly and correctly as possible. This will highly depend on the quality of the decision taking algorithms. That's why we suggest to use our EAV model based algorithm that, while providing the same level of accuracy, works faster by reducing the number of analyzed attributes.

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The algorithm consists of the following steps:

1. Selection of the best attributes from the Decision Table based on their distribution (standard deviation) in relation to the decision class.
2. Generation of the decision rules consisting of the best attributes that have been chosen in the selection step (the generated rules are optimal in terms of length).

We have created the state transition diagram (STD) to show our algorithm (Figure 3). We believe that this algorithm still can be developed, and we will continue working on it in our future researches.

One more advantage of our suggested algorithm is that the Knowledge database generated in this way can be easily enlarged with new rules. Moreover, the set of rules can be not only infinitely extended, but it also can be updated. This helps to avoid the Knowledge base becoming too large, so that it is able to be used in real time and is easily maintainable. This means that it will be a Self-Learning System that can be used in an autonomous vehicles.

3. Results and discussion

To check the proposed approach and to start building the Decision Table on the base of the real data, we have carried out experiments based on a series of frames collected from a fragment of a dashboard camera's recording from the Polish two-lane road.

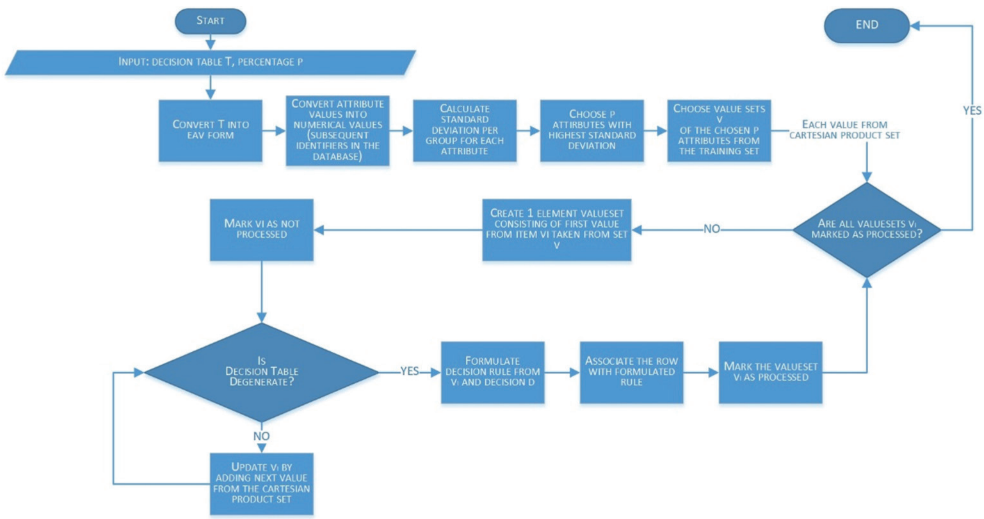

Fig. 3. STD of the decision algorithm based on EAV model

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The first step is the image recognition using the proposed Intelligent System. We have taken as an example only 9 photos, however, the system will be able to extract 30 frames per one second of the video. In the Figures 4-7, objects were identified and classified. It means that each object marked by a rectangular shape has been detected by the system as a car or a truck with the probability expressed as a percentage that is written in the images near every identified object. The higher the probability is, the bigger chance that the detection is correct. Of course, it is directly proportional to the decision the intelligent system takes. It is important from the point of view of creating Knowledge Database.

(a) (b)

Fig. 4. Identified objects; (a) in the 1st photo, (b) in the 2nd photo

(a) (b)

Fig. 5. Identified objects; (a) in the 3rd photo, (b) in the 4th photo

(a) (b)

Fig. 6. Identified objects; (a) in the 5th photo, (b) in the 6th photo

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(a) (b)

Fig. 7. Identified objects; (a) in the 7th photo, (b) in the 8th photo

Of course, there are problems with identifying, for example, on the 3rd photo (Figure 5a) there is a wheel of the truck mistakenly detected as a car with a 53.799% probability. However, it doesn't decrease the value of the suggested system as a whole thanks to our decision making algorithm. Due to its self-learning abilities and embedded feature selection step, misdetections do not have impact on the overall correctness of operation. The algorithm does not have tendencies to overlearn to the given datasets. The problem of decision rules construction is NP-hard and that's why it is not recommended to use all the input attributes (in this case all object detection results) – otherwise the algorithm would be too slow to operate in real-world traffic. Moreover, it can be treated as algorithm's advantage as it can minimize the influence of Object Detection System's mistakes on the final system's performance.

Based on the results of the objects detection, an exemplary Decision Table was created (Figure 8). It has been built manually basing on opinion and experience of the expert who knows which factors are influencing the decision taking while driving. In our further researches we will enlarge, correct and verify this Decision Table by opinions of other experts in order to build the Intelligent Self-Learning Expert System later.

Number of cars (no_of_cars)	Number of trucks (no_of_trucks)	Maximum probability for the car (max_car_propability)	Maximum probability for the truck (max_truck_probability)	Proposed action (action)
1	1	70-80	70-80	accelerate
4	1	80-90	90-100	neutral
3	1	90-100	70-80	neutral
2	2	90-100	60-70	neutral
3	1	90-100	50-60	brake
2	0	90-100	0	brake
2	0	90-100	0	brake
2	0	90-100	0	brake
1	0	80-90	0	stop

Fig. 8. Exemplary Decision Table for the set of identified objects

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Taking into account the results of object detection, it is possible to distinguish several attributes that can affect driving the vehicle. They are:

- Number of identified cars,
- Number of identified trucks,
- Maximum probability for this object that it is a car,
- Maximum probability for this object that it is a truck.

To apply our decision rule generation algorithm, these probabilities had to be discretized (they have been grouped into 10 intervals consisting of 10 percentages each: 0 to 10, 10 to 20, 20 to 30, 30 to 40, 40 to 50, 50 to 60, 60 to 70, 70 to 80, 80 to 90 and 90 to 100).

The Decision Table is used to create a Knowledge Database consisting of decision making rules constructed using our EAV model based algorithm. The set of decision rules is presented in Figure 9.

Decision rules of the form (attribute=value) -> decision
(no_of_trucks = 1)(max_truck_probability = 70-80)(no_of_cars = 1) -> accelerate
(no_of_trucks = 1)(max_truck_probability = 90-100) -> neutral
(no_of_trucks = 1)(max_truck_probability = 70-80)(no_of_cars = 3) -> neutral
(no_of_trucks = 2) -> neutral
(no_of_trucks = 1)(max_truck_probability = 50-60) -> brake
(no_of_trucks = 0)(max_truck_probability = 0)(no_of_cars = 2) -> brake
(no_of_trucks = 0)(max_truck_probability = 0)(no_of_cars = 1) -> stop

Fig. 9. The set of generated decision rules

On the base of experiments made, we can say that the proposed decision rules are optimal with respect to the length (in relation to the Decision Table row for which they have been generated). Since the algorithm can generate same rules for different Decision Table rows, we have removed duplicated ones. A Knowledge Database constructed in such a way can be directly integrated into an autonomous vehicle control module and additionally freely expanded according to changing needs.

Today it is strongly believed that the great number of road accidents are connected with the violation of traffic rules and slow or incorrect drivers' reaction to some dangerous situations, i.e., due to "human factor". Therefore, there is a widespread opinion [22] that introduction of fully- or semi- autonomous vehicles into the road traffic will improve road safety and, as a result, sustainability of the whole transport system in the Smart City. However, appearance of autonomous vehicles by itself is not a panacea for traffic accidents. New types of vehicles with fundamentally new control systems can cause new, not existing now, safety problems. The main function of the autonomous control system is the ability to analyse the road surface and objects that are located nearby. Thus, road safety will depend on intelligent algorithms for decision making: on their correctness, speed, completeness of the knowledge database and the possibility of self-learning.

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4. Conclusions

In this article, we have made the first step in creation of the Intelligent System for the fully- or semi- autonomous vehicles based on machine vision. Therefore, we have presented here only an exemplary Decision Table and Decision Rules. The next steps of our research are to develop the decision taking algorithm so that it worked even faster and to create the Intelligent Self-Learning Expert System based on several high quality field experts' opinions.

Of course, there already exist different similar systems that are based on different types of decision making algorithms. However, the novelty of the suggested Intelligent System is concluded in our data mining algorithm that by excluding the mistakes made on the object detection stage, works faster than existing ones with the same level of correctness.

5. Nomenclature

ADAS Advanced Driver Assistance Systems
AI Artificial Intelligence
EAV Entity–Attribute–Value
ICT Information and Communications Technologies
IoT Internet of Things
ITS Intelligent Transport System
UAV Unmanned Aerial Vehicle

6. References

[1] Allam Z., Dhunny Z.A.: On big data, artificial intelligence and smart cities. Cities. 2019, 89, 80–91, DOI: 10.1016/j.cities.2019.01.032.

[2] Ataya A., Kim W., Elsharkawy A., Kim S.: How to Interact with a Fully Autonomous Vehicle: Naturalistic Ways for Drivers to Intervene in the Vehicle System While Performing Non-Driving Related Tasks. Sensors. 2021, 21, 2206, DOI: 10.3390/s21062206.

[3] Bibri S.E.: The IoT for smart sustainable cities of the future: An analytical framework for sensor-based big data applications for environmental sustainability. Sustainable Cities and Society. 2018, 38, 230–253, DOI: 10.1016/j.scs.2017.12.034.

[4] Braun T., Fung B.C.H., Iqbal F., Shah B.: Security and privacy challenges in smart cities. Sustainable Cities and Society. 2018, 39, 499–507, DOI: 10.1016/j.scs.2018.02.039.

[5] Carranza-García M., Torres-Mateo J., Lara-Benítez P., García-Gutiérrez J.: On the performance of one-stage and two-stage object detectors in autonomous vehicles using camera data. Remote Sensing. 2021, 13(1), 1–23, DOI: 10.3390/rs13010089.

[6] City Safety by Volvo Cars – outstanding crash prevention that is standard in the all-new XC90: https://www.media.volvocars.com/global/en-gb/media/pressreleases/154717/city-safety-by-volvo-cars-outstanding-crash-prevention-that-is-standard-in-the-all-new-xc90 (accessed on 28.09.2021).

[7] Common Objects in Context: https://cocodataset.org (accessed on 28.09.2021).

[8] Coskun S.: Autonomous overtaking in highways: A receding horizon trajectory generator with embedded safety feature. Engineering Science and Technology, an International Journal. 2021, 24(5), 1049–1058, DOI: 10.1016/j.jestch.2021.02.005.

DOI: https://doi.org/10.14669/AM.VOL94.ART3

[9] Cross Traffic Alert: https://www.cogentembedded.com/automotive-computer-vision/cross-traffic-alert/ (accessed on 28.09.2021).

[10] Delsing J.: Smart City Solution Engineering. Smart Cities. 2021, 4(2), 643–661, DOI: 10.3390/smartcities4020033.

[11] EyeSight Driver Assist Technology: https://www.subaru.com/engineering/safety.html (accessed on 28.09.2021).

[12] Fan J., Huo T., Li X.: A review of one-stage detection algorithms in autonomous driving. 4th CAA International Conference on Vehicular Control and Intelligence. 2020, 9338663, 210–214, DOI: 10.1109/CVCI51460.2020.9338663.

[13] Global status report on road safety 2015: https://www.afro.who.int/publications/global-status-report-road-safety-2015 (accessed on 28.09.2021).

[14] Hammi M.T., Hammi B., Bellot P., Serhrouchni A.: Bubbles of Trust: A decentralized blockchain-based authentication system for IOT. Computers and Security. 2018, 78, 126–142, DOI: 10.1016/j.cose.2018.06.004.

[15] Kalašová A., Harantová V., Čulík K.: Public transport as a part of shared economy. The Archives of Automotive Engineering – Archiwum Motoryzacji. 2019, 85(3), 49–56, DOI: 10.14669/AM.VOL85.ART4.

[16] Kustra M., Brodowicz D.: Implementing smart city concept in the strategic urban operations - the case of Warsaw. 11th International Forum of Knowledge Assets Dynamics 2016. Dresden, Germany, 2016, DOI: 10.13140/RG.2.1.4675.9925.

[17] Mobileye An Intel Company: https://www.mobileye.com/ (accessed on 28.09.2021).

[18] Mora L., Deakin M.: Untangling Smart Cities: From Utopian Dreams to Innovation Systems for a Technology-Enabled Urban Sustainability. Elsevier: Amsterdam, The Netherlands; Cambridge, MA, USA, 2019.

[19] Park J., Hong E., Le H.T.: Adopting autonomous vehicles: The moderating effects of demographic variables. Journal of Retailing and Consumer Services. 2021, 63, 102687, DOI: 10.1016/j.jretconser.2021.102687.

[20] Ramírez-Moreno M.A., Keshtkar S., Padilla-Reyes D.A., Ramos-López E., García-Martínez M., Hernández-Luna M.C. et al.: Sensors for sustainable smart cities: A review. Applied Sciences-Basel. 2021, 11(17), 8198, DOI: 10.3390/app11178198.

[21] Rear Cross Traffic Alert: https://mycardoeswhat.org/safety-features/rear-cross-traffic-alert/ (accessed on 28.09.2021).

[22] Richardson N., Doubek F., Kuhn K., Stumpf A.: Assessing Truck Drivers' and Fleet Managers' Opinions Towards Highly Automated Driving. Advances in Intelligent Systems and Computing. 2017, 484, 473–484, DOI: 10.1007/978-3-319-41682-3_40.

[23] Road safety annual report 2020: https://www.itf-oecd.org/road-safety-annual-report-2020 (accessed on 28.09.2021).

[24] Saini D., Thakur N., Jain R., Nagrath P., Jude H., Sharma N.: Object Detection in Surveillance Using Deep Learning Methods: A Comparative Analysis. Lecture Notes in Networks and Systems. 2021, 173 LNNS, 677–689, DOI: 10.1007/978-981-33-4305-4_49.

[25] Sharifi A.: A typology of smart city assessment tools and indicator sets. Sustainable Cities and Society. 2020, 53, 101936, DOI: 10.1016/j.scs.2019.101936.

[26] Transport in the European Union. Current Trends and Issues: https://ec.europa.eu/transport/sites/default/files/2019-transport-in-the-eu-current-trends-and-issues.pdf (accessed on 28.09.2021).

[27] Venkadeshan R., Jegatha M.: Blockchain-Based Fog Computing Model (BFCM) for IoT Smart Cities. EAI/Springer Innovations in Communication and Computing. 2022, 978-3-030-76215-5, 77–92, DOI: 10.1007/978-3-030-76216-2_5.

[28] Zabinski K., Zielosko B.: Decision Rules Construction: Algorithm Based on EAV Model. Entropy. 2021, 23(1), 1–18, DOI: 10.3390/e23010014.

[29] Zhang S., Liu F., Li Z.: An effective driver fatigue monitoring system. International Conference on Machine Vision and Human-Machine Interface, MVHI 2010. Kaifeng, China, 2010, 279–282, DOI: 10.1109/MVHI.2010.153.

[30] Zywiołek J., Schiavone F.: Perception of the Quality of Smart City Solutions as a Sense of Residents' Safety. Energies. 2021, 14(17), 5511, DOI: 10.3390/en14175511.