OPERATION ISSUES OF PASSENGER INFORMATION SYSTEMS

Łukasz WOLNIEWICZ, Franciszek J. RESTEL

Wroclaw University of Science and Technology, Faculty of Mechanical Engineering, Wroclaw, Poland, EU,
lukasz.wolniewicz@pwr.edu.pl, franciszek.restel@pwr.edu.pl

Abstract

Modern agglomerations are interested in the development of public transport and the use of advanced technical and organizational solutions in this area. One of the elements is passenger information. Good passenger information reduces travel time and increases the competitiveness of public transport. It is therefore an element that encourages the use of public transport, improves the comfort of travel and improves the image of the city and the carrier. The question rises, how is the efficiency of the presented information in terms of passenger readability. Therefore, the aim of the paper is to identify the information system components which gives important information to the passenger, and which are threatened by misreading. Afterwards, the main goal of this work is to give answer about correctness of gathered information. There is lack of regulation on the visibility distance of displayed text in boards is not in line with the current disability friendly policy. An attempt has been made to determine the minimum visibility limits depending on the type of board and the type of text. The manufacturer of display boards also does not declare the visibility distance of the displayed text on the boards. It was found that boards of smaller size, commonly used in new vehicles, adversely affect the visibility of text. The worst results of visibility distance measurements were recorded on small LEDs boards with a contrasting line number installed in new trams in Wroclaw. The best readable are the messages on large LEDs boards with a contrasting line number commonly used in many cities.

Keywords: Public transport, display board, passenger information systems

1. PASSENGER INFORMATION SYSTEMS

Passenger information systems are one of the most important elements of modern public transport. They significantly increase the comfort of passengers when travelling. They enable to obtain information necessary for travel comfort. They allow the carrier to communicate quickly with passengers. Modern trends concern ecological means of transport, accessible for people with reduced mobility and transparent information [1,2,3,4]. The basic functions of dynamic passenger information are:

- assisting in the selection of the place to wait for the vehicle,
- calculation of the waiting time,
- supporting the decision on changing the planned travel method to alternative [5].

These systems are most commonly used in vehicles, stations, communication nodes, platforms and stops [6,7,8]. The main elements are electronic information boards and audio information devices. In a vehicle, visual information is provided by electronic boards. Depending on the demand, the boards are of different sizes and the matrices they are made of have different resolutions and different production technologies. They are installed at the front, sides and rear and in the interior of the vehicle. Additionally, a voice announcement system is installed, which increases the effectiveness of information provided to passengers. All the devices mentioned above are controlled by the on-board computer. Passengers inside the vehicle obtain complete information about the vehicle (line, mileage, stops, communication nodes, etc.), and those waiting at stops know how many minutes they will be able to continue their journey. At stations and airports, visual information is provided by means of electronic arrival and departure boards placed in halls, waiting rooms, on platforms, and voice announcements ensure its comprehensiveness [9,10]. At airports, the flow of passengers is analyzed on the basis of the information used [11,12,13]. Specialized software presents the content

automatically, providing predefined content to be displayed on all system boards. It is possible to modify the information on an ad hoc basis (e.g. due to a change in departure time), and to change the data permanently. The control system for display boards and voice announcements is compatible with the timetabling software. The system has the ability to provide passengers with scheduled information only, without automatic consideration of changes (e.g. delays). In real time mode (on-line), the timetable is displayed on the boards, but it is dynamically corrected for deviations during the ride. Modifications take place automatically. A passenger waiting at a bus stop always sees the actual time of departure of the vehicle from the bus stop, in which possible deviations from the timetable have been taken into account. These systems can be easily extended with additional elements. In this way, they can be activated in stages, depending on the customer's needs.

The aim of the paper is to identify the information system components which gives important information to the passenger, and which are threatened by misreading. Afterwards, the main goal of this work is to give answer about correctness of gathered information.

2. DEPARTURE BOARDS AT THE STOPS

One of the most important functions of the modern urban public transport system is the information of passengers about the current, real time arrivals and departures of vehicles from stops and to present interchanges at selected stopping points. Dynamic Information Systems provide passengers with such information on electronic boards. The display boards in stops, which are part of the passenger information system, present current departure times to passengers [14,15]. They also enable the transmission of messages about traffic difficulties and changes in the course of the journey. Display boards usually consist of orange diodes and automatically adjust the brightness of light to the lighting conditions. This system enhances the comfort of travel by making up-to-date information quickly available. Passengers can quickly decide to interchanges within a node by comparing the actual departure times [16,17].

Data from on-board vehicle systems shall be used by a Central System to keep passengers informed so that arrival and departure times of vehicles can be displayed in real time according to their current deviation from the scheduled timetable. It is important because in case of high saturation of urban traffic, especially during peak hours, timetables placed at bus stops usually do not reflect the actual situation and will not be consistent with the moment of arrival of the vehicle at the bus stop.

A dynamic passenger information system consists of the following interacting elements:

- controller placed in public transport vehicles (analyses punctuality on the basis of data on the GPS location of the vehicle),
- infrastructure for the exchange of short-range data (update of the timetable and directional tables in the depot),
- long-range data exchange infrastructure (transmission of data to the server from vehicles and from the server to bus stops and mobile applications),
- central server (processing of data received from vehicles and calculation of expected departure times),
- dynamic passenger information in stops (display of actual departure times for passengers) [18].

The system can also be adapted to people with reduced mobility. At departure times it is possible to display information on whether the course is supported by low-floor rolling stock. The second facilitation is a built-in speaker, which reads all the information contained on the display board.

A pilot solution is to replace the traditional timetables at bus stops with displays made in e-ink technology, commonly used in ebook readers. This solution has many advantages. First of all, there is no need to print and exchange cards with the timetable. Secondly, energy efficiency. The screen illumination can be powered by

photovoltaic panels. Thirdly, the flexibility of the solution. On such an e-ink display we can show real-time information about traffic difficulties.

Nowadays, every passenger using mobile devices has access to a range of applications that allow to track difficulties and changes in running, plan a trip, or monitor punctuality. Until a few years ago, we used a timetable application, and now we can check the actual departure times of buses, trams and even trains. Depending on the city, the passenger can choose to check the live departures from his stop, the travel planner, information about the low floor or air conditioning. The authors [19,20] evaluated the application features of various carriers using a form. The need for integration of the programs with social media was demonstrated and the possibility of making proposals for changes in public transport was also demonstrated [21,22,23].

We can also use mobile apps during rail travel. As an example, you can give KDGo! which allows you to monitor the movement of Lower Silesian Railways, check the nearest departures from a given station, and even see the current speed of the vehicle. In aviation, we also use applications showing the actual departure times and delays of plane [24]. MPK Wroclaw as the first of the large transport companies in Poland decided to make the location of its vehicles publicly available. Each vehicle of the city carrier and its subcontractor is equipped with a GPS transmitter. The iMPK application has been running in Wroclaw since 2013. It provides:

- actual departure times from the stop,
- locate a vehicle with a particular rolling stock number,
- check if the vehicle is adapted to the needs of people with disabilities,
- check that the vehicle is air conditioned,
- actual messages about traffics difficulties with the indication of the stops they concern.

3. PASSENGER INFORMATION ON THE VEHICLE

The displays of the internal passenger information system are on board the vehicles. They are used to provide various types of information to travelers. The basic functions are the presentation of the route, direction of travel, time, date, date and information about the next stop. In addition to these basic functions, you can also see: information about traffics difficulties and proposed interchanges. Informing passengers about traffics difficulties and route changes is carried out through a special HOT bar on multimedia displays.

In vehicles there are the following types of internal displays:

- XTL-type LED boards,
- 23" TFT LCD monitors (can display: part of the route, line number, driving direction, possible interchanges, date and time, information about the lockout of cashiers and activated air conditioning of the passenger area, active button on request stop, service number of the driver, can also be used to broadcast advertising materials while maintaining a passenger information strip of approximately 30 % of the monitor area).
- 38" TFT LCD monitors (designed to present the route in the form of the so-called "beads", contains all the names of stops with the distinction between the serviced and future, travel, times between the stops, names of the streets on which they are located, names of city districts, possible interchanges, information and tourist attractions, the number of the line and its category, date and time, contact details of the unit responsible for the organization of transport).

3.1. PASSENGER INFORMATION OUTSIDE THE VEHICLE

Outside passenger information is designed to provide information to a potential passenger by means of light boards. It should be brief so that the passenger can quickly identify the vehicle. In the event of a mistake, there is a risk of misuse by a passenger. Risk issues are important in transport systems [25,26]. The outside line

boards are characterized by a bright light color for visually impaired people. Increasingly, vehicles are also equipped with an external voice line and directional announcement system.

Basic types of light boards used in Poland:

- XTD-type of boards,
- FLIP-DOT-type of boards.

On XTD boards, the text is created by means of a LED matrix. In these boards, a high readability of the text is ensured due to the high brightness of the LEDs and the large angle of light. The LEDs used are white, blue, orange and red. In Wroclaw, the orange applause boards have been combined with a contrasting blue line board visible to the visually impaired. The display boards automatically adjust the brightness depending on the prevailing conditions so that it is suitable in all conditions. In the evening they shine darker, and when the sun is shining brighter. This ensures optimum contrast. XTD LED panels are equipped with a battery saving mechanism in the vehicle in which they are installed. When the vehicle engine is switched off, the LED brightness is automatically set to a minimum and after 20 minutes the LEDs are switched off. If the engine is restarted, the displayed content is restored. In LED boards are used classic diode (round) and surface mounted diode (SMD) with a wider angle of light and greater durability.

On electromagnetic boards (type FLIP-DOT), the text is created by electromagnetically controlled moving thin plates colored strongly fluorescent yellow-green on one side and black on the other side - **Figure 1**. The text consists of plates facing away from the viewer, while the black ones form a background. Inverting the plates causes an electromagnetic pulse. These plates draw current only when the text changes. The text is maintained for an infinitely long time by magnetic memory.

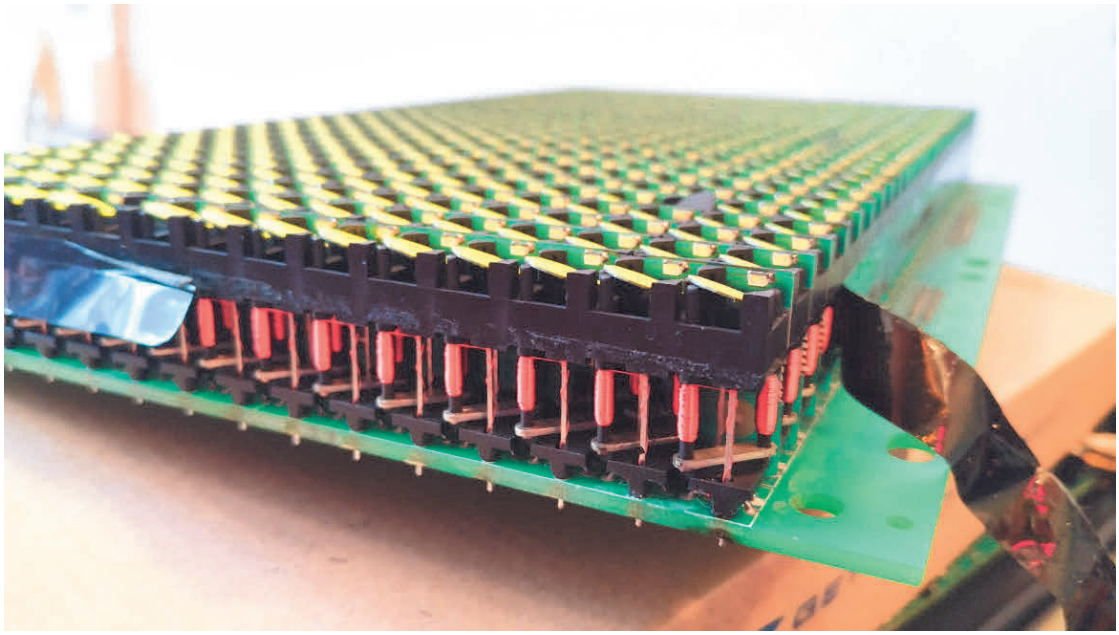

Figure 1 Construction of FLIP-DOT display board

Classification of boards according to their position in the vehicle:

- front display board,
- side display board,
- back display board.

The front display board is usually located above the windscreen of the vehicle and is designed to display the line number and the direction to which the vehicle is heading. The board can also display additional information

such as: negative - informs that a given line runs a changed route, pictogram - e.g. train symbol informing that a vehicle is going to a station, text "changed route", text "departure in X minutes". - indicating in how many minutes the vehicle will leave the starting point. The most popular size of the board is 24 x 200 light points.

Depending on the position in the vehicle, each display board has its own unique address. The address of the display boards is set using switches shown in the **Figure 2**.

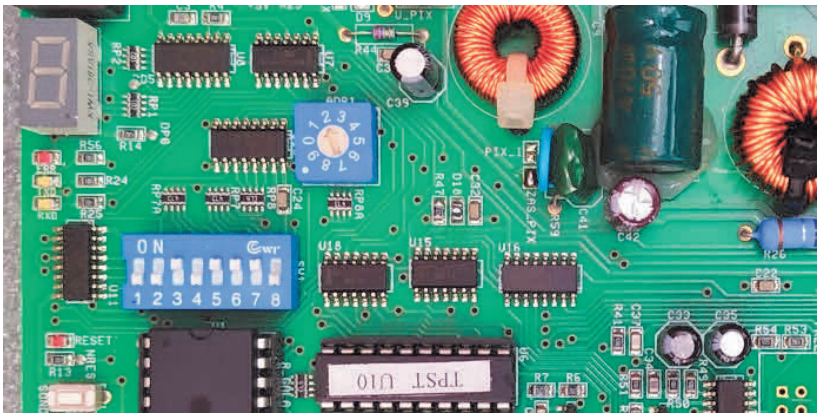

Figure 2 Switches for changing the address of display boards

The side display board is usually located on the right-hand side of the vehicle. The most common dimension is 24 x 60 light points. The area of line and direction can be separated. The board displays the line number and direction.

The back display board is used to display the line number in most cases. It happens that a wider board is mounted on the rear of the vehicle to display the line number and direction.

3.2. VISIBILITY OF BOARDS EXPERIMENT

Visibility of displays was tested in the same conditions in a group of 15 people. The distance of display boards visibility was read out after prior inventory of the area and evaluation of the distance of individual characteristic points on the map (poles, lanterns). The distances of visibility of the display board were recorded in a group of 15 people for one situation. The arrangement of the observer and the characteristic points on the testing ground is shown in the **Figure 3**.

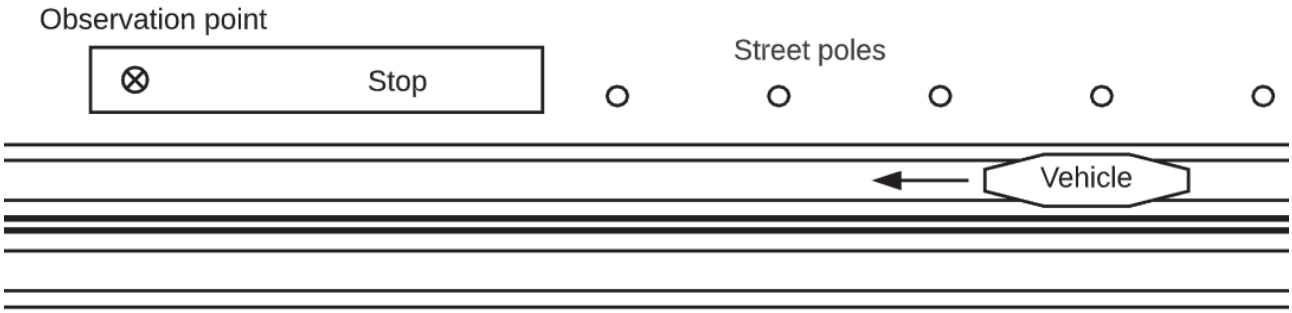

Figure 3 Characteristic points on the testing ground

Vehicles of all types of display boards and text were recorded. **Figure 4** shows the results of the research. The probability of reliable information reading (PRIR) has been calculated in function of reading distance. The most visible were the newest type of display boards mounted in buses (LLEC) - **Figure 4B**. Small new-type display boards in trams (SLE) - **Figure 4D** were less visible than old type FLIP-DOT boards (LFD) - **Figure 4E**.

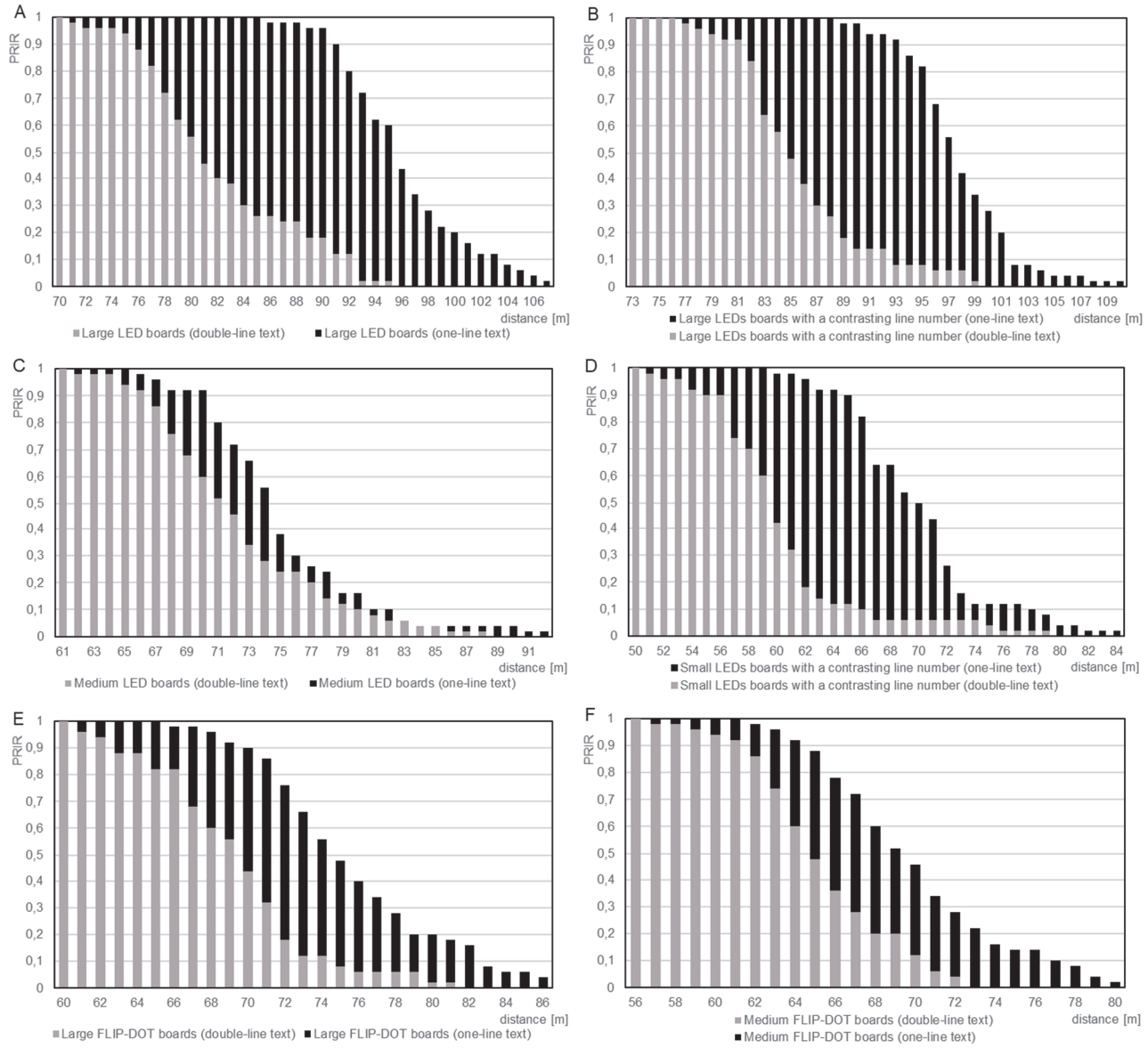

Figure 4 Visibility research results by type of boards

Due to the lack of formal regulations Due to the lack of formal regulations of the city carrier concerning the distance of visibility of the displayed text on the outside display boards of vehicles, research was carried out. The following types of display boards were inventoried and subsequently evaluated:

- large LED boards (LLE) - **Figure 5A**, **Figure 5D**,
- large LEDs boards with a contrasting line number (LLEC) - **Figure 5C**,
- medium LED boards (MLE),
- small LEDs boards with a contrasting line number (SLE),
- large FLIP-DOT boards (LFD) - **Figure 5B**,
- medium FLIP-DOT boards (MFD)

Due to the type of text displayed on the boards:

- one-line text - **Figure 5A**, **Figure 5C**,
- double-line text - **Figure 5B**, **Figure 5D**.

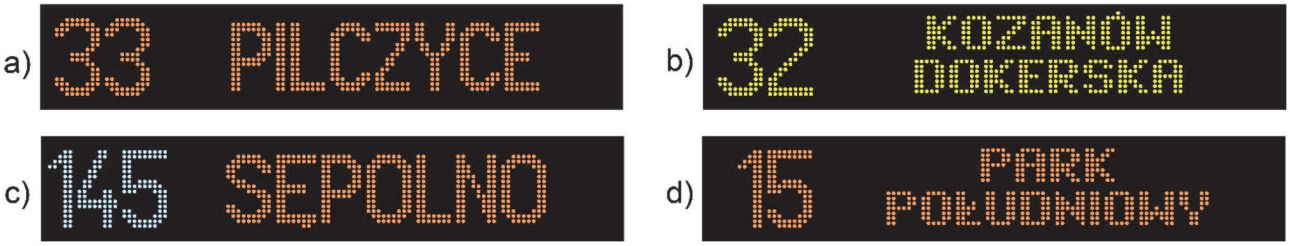

Figure 5 Display types and types of texts

Probability of reliable information reading (PRIR) allows to determine the distance from which the text of a given type on a given display board will be visible. This method is widely used in transport systems [27,28,29,30,31,32]. The correct and fast selection of the vehicle by the passenger, and thus the punctual departure time, depends on the visibility of the text.

4. CONCLUSION

The distances of visibility of display boards of different types were determined on the basis of the research carried out. The most visible were the newest type of display boards mounted in buses (LLEC) and the display boards of the same size, but without the contrasting line number (LLE). In the newest trams, smaller display boards than in buses (SLE) were installed. They are less visible than the old FLIP-DOT (LFD and MFD) boards. The reason may be that the distance of visibility of the signs displayed on the outside boards is not regulated. In auction for the purchase of new vehicles there are no requirements for the visibility of the display board. These analyses may be used to introduce such adjustments. Clear passenger information is important because it reduces travel time and increases the competitiveness and attractiveness of public transport.

REFERENCES

[1] [WTZ2019] WANG, W., TIAN, Z., JIANG, Y., WU, L., GAO, J. Dynamic control strategy based on passenger choice behavior with real-time information. *Simulation* [online]. 2019. vol. 95, pp. 809-822 [viewed 2019-11-13]. Available from: DOI: 10.1177/0037549717742508.

[2] [SZ1] ZAJĄC, P., HAŁADYN, Sz., KWAŚNIOWSKI, S. Concept of reducing harmful emissions by road transport vehicles in the tourist route Karpacz-Jelenia Góra. In *11th Conference on Interdisciplinary Problems in Environmental Protection and Engineering EKO-DOK 2019*. Polanica-Zdrój, 2019, pp. 1-9. Available from: DOI: 10.1051/e3sconf/201910000091.

[3] [R1] GIEL, R., PLEWA, M. The evaluation method of the process of municipal waste collection. In *Carpathian Logistics Congress*. Jesenik, 2015, pp. 281-287. Available from: WOS: 000387950100043.

[4] [GS2017] GUZE, S. An application of the selected graph theory domination concepts to transportation networks modeling. *Scientific Journals of the Maritime University of Szczecin* [online]. 2017. vol. 52, pp. 97-102 [viewed 2019-11-13]. Available from: DOI: 10.17402/250.

[5] [NNH2019] NASSIR, N., HICKMAN, M., MA, Z.-L. A strategy-based recursive path choice model for public transit smart card data. *Transportation Research* [online]. 2019. vol. 126, pp. 526-548 [viewed 2019-11-13]. Available from: DOI: 10.1016/j.trb.2018.01.002.

[6] [ATB2012] TIBAUT, A., KAUČIČ, B., REBOLJ, D. A standardised approach for sustainable interoperability between public transport passenger information systems. *Computers in Industry* [online]. 2012. vol. 63, pp. 788-798 [viewed 2019-11-13]. Available from: DOI: 10.1016/j.compind.2012.08.002.

[7] [IPP2010] POLITIS, I., PAPAIOANNOU, P., BASBAS, S., DIMITRIADIS, N. Evaluation of a bus passenger information system from the users' point of view in the city of Thessaloniki. *Research in Transportation Economics* [online]. 2010. vol. 29, pp. 249-255 [viewed 2019-11-13]. Available from: DOI: 10.1016/j.retrec.2010.07.031.

[8] [HYJ2019] YIN, H., WU, J., LIU, Z., YANG, X. Optimizing the release of passenger flow guidance information in urban rail transit network via agent-based simulation. *Applied Mathematical Modelling* [online]. 2019. vol. 72, pp. 337-355 [viewed 2019-11-13]. Available from: DOI: 10.1016/j.apm.2019.02.003.

[9] [CCE2017] CSISZAAR, C., NAGY, E. Model of an integrated air passenger information system and itsadaptation to Budapest Airport. *Journal of Air Transport Management* [online]. 2017. vol. 63, pp. 33-41 [viewed 2019-11-13]. Available from: DOI: 10.1016/j.jairtraman.2017.06.022.

[10] [ONB2019] OLIKER, N., BEKHOR, S. A frequency based transit assignment model that considers online information. *Transportation Research* [online]. 2019. vol. 88, pp. 17-30 [viewed 2019-11-13]. Available from: DOI: 10.1016/j.trc.2018.01.004.

[11] [KA1] KIERZKOWSKI, A., KISIEL, T. A model of check-in system management to reduce the security checkpoint variability. *Simulation Modelling Practice and Theory* [online]. 2017. vol. 74, pp. 80-98 [viewed 2019-11-13]. Available from: DOI: 10.1016/j.simpat.2017.03.002.

[12] [KA3] KIERZKOWSKI, A., KISIEL, T. Functional Readiness of the Check-in Desk System at an Airport. *Advances in Intelligent Systems and Computing* [online]. 2015. vol. 365, pp. 223-233 [viewed 2019-11-13]. Available from: DOI: 10.1007/978-3-319-19216-1_21.

[13] [KA4] KIERZKOWSKI, A., KISIEL, T. Airport Security Screeners Reliability Analysis. In *IEEE International Conference on Industrial Engineering and Engineering Management*. Bali, 2016, pp. 1158-1163. Available from: DOI: 10.1109/IEEM.2015.7385830.

[14] [BC2019] BRAKEWOOD, C., WATKINS, K. A literature review of the passenger benefits of real-time transit information. *Transport Reviews* [online]. 2019. vol. 39, pp. 327-356 [viewed 2019-11-13]. Available from: DOI: 10.1080/01441647.2018.1472147.

[15] [WJ2019] WEN, J., NASSIR, N., ZHAO, J. Value of demand information in autonomous mobility-on-demand systems. *Transportation Research* [online]. 2019. vol. 121, pp. 346-359 [viewed 2019-11-13]. Available from: DOI: 10.1016/j.tra.2019.01.018.

[16] [MCC2017] MULLEY, C., CLIFTON, G.T., BALBONTIN, C., MA, L. Information for travelling: Awareness and usage of the various sources of information available to public transport users in NSW. *Transportation Research* [online]. 2017. vol. 101, pp. 111-132 [viewed 2019-11-13]. Available from: DOI: 10.1016/j.tra.2017.05.007.

[17] [DEI2015] DIAB, E.I., BADAMI, M.G., EL-GENEIDY, A.M. Bus Transit Service Reliability and Improvement Strategies: Integrating the Perspectives of Passengers and Transit Agencies in North America. *Transport Reviews* [online]. 2015. vol. 35, pp. 293-328 [viewed 2019-11-13]. Available from: DOI: 10.1080/01441647.2015.1005034.

[18] [LZF2011] ZHU, L., YU, F., NING, B., TANG, T. Cross-Layer Design for Video Transmissions in Metro Passenger Information Systems. *IEEE Transactions on Vehicular Technology* [online]. 2011. vol. 60, pp. 1171-1181 [viewed 2019-11-13]. Available from: DOI: 10.1109/TVT.2011.2107927.

[19] [MDH1995] HICKMAN, M., WILSON, N. Usability Evaluation of Mobile Passenger Information Systems. *Passenger travel time and path choice implications of real-time transit information* [online]. 1995. vol. 3, pp. 211-226 [viewed 2019-11-13]. Available from: DOI: 10.1016/0968-090X(95)00007-6.

[20] [BLS2014] BEUL-LEUSMANN, S., CHRISTIAN, S., WIEDERHOLD, M., KREMPELS, K., JAKOBS, E., ZIEFLE, M. Usability Evaluation of Mobile Passenger Information Systems. User Experience, and Usability. *Theories, Methods, and Tools for Designing the User Experience* [online]. 2014. vol. 8517, pp. 217-228 [viewed 2019-11-13]. Available from: DOI: 10.1007/978-3-319-07668-3_22.

[21] [KA2] KIERZKOWSKI, A., KISIEL, T. Simulation Model of Logistic Support for Functioning of Ground Handling Agent, Taking into Account a Random Time of Aircrafts Arrival. In *5th International Conference on Military Technologies*. Brno, 2015. Available from: DOI: 10.1109/MILTECHS.2015.7153694.

[22] [GS2018] GUZE, S. Business Availability Indicators of Critical Infrastructures Related to the Climate-Weather Change. In *Contemporary complex systems and their dependability: proceedings of the Thirteenth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX*. Brunów, 2018, pp. 248-257. Available from: DOI: 10.1007/978-3-319-91446-6_24.

[23] [TU3] T., TUBIS, A., WERBIŃSKA-WOJCIECHOWSKA, S. Balanced Scorecard use in passenger transport companies performing at Polish market. *Procedia Engineering* [online]. 2017. vol. 187, pp. 538-547 [viewed 2019-11-13]. Available from: DOI: 10.1016/j.proeng.2017.04.412.

[24] [KZV2008] KONSTANTINOS, Z., VASSILIS, S., KONSTANTINOS, A. Integrated Passenger Information System for Multimodal Trip Planning. *Journal of the Transportation Research Board* [online]. 2008. vol. 2072, pp. 20-29 [viewed 2019-11-13]. Available from: DOI: 10.3141/2072-03.

[25] [TU1] TUBIS, A. Information needs of decision makers for risk assessment in road transport. In *Engineering in dependability of computer systems and networks: proceedings of the Fourteenth International Conference on Dependability of Computer Systems DepCoS-RELCOMEX*. Brunów, 2020, pp. 525-533. Available from: DOI: 10.1007/978-3-030-19501-4_52.

[26] [TU2] TUBIS, A. Route risk assessment for road transport companies. In *Contemporary complex systems and their dependability: proceedings of the Thirteenth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX*. Brunów, 2018, pp. 492-503. Available from: DOI: 10.1007/978-3-319-91446-6_46.

[27] [WW1] JODEJKO-PIETRUCZUK, A., WERBIŃSKA-WOJCIECHOWSKA, S. Block inspection policy for non-series technical objects. In *Safety, reliability and risk analysis: beyond the horizon: proceedings of the European Safety and Reliability*. Amsterdam, 2013, pp. 889-898. Available from: DOI: 10.1201/b15938-133.

[28] [WW2] NOWAKOWSKI, T., TUBIS, A., WERBIŃSKA-WOJCIECHOWSKA, S. Maintenance decision making process - a case study of passenger transportation company. In *Theory and engineering of complex systems and dependability: proceedings of the Tenth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX*. Brunów, 2015, pp. 305-318. Available from: DOI: 10.1007/978-3-319-19216-1_29.

[29] [GS2010] GUZE, S. Reliability analysis of multi-state ageing series-consecutive "m out of k: F" systems. *Reliability, Risk and Safety: Theory and Application* [online]. 2010. vol. 1-3, pp. 1629-1635 [viewed 2019-11-13]. Available from: DOI: 10.1201/9780203859759.CH226.

[30] [GS2016] GUZE, S., KOŁOWROCKI, K. Modelling Operation Process of Baltic Port, Shipping and Ship Traffic and Operation Information Critical Infrastructure Network. *International Journal on Marine Navigation and Safety of Sea Transportation* [online]. 2016. vol. 10, pp. 275-284 [viewed 2019-11-13]. Available from: DOI: 10.12716/1001.10.02.10.

[31] [R2] DĄBROWSKA, A., GIEL, R., PLEWA, M. The Picking Process Model in e-Commerce Industry. In *Engineering in dependability of computer systems and networks: proceedings of the Fourteenth International Conference on Dependability of Computer Systems DepCoS-RELCOMEX*. Brunów, 2020, pp. 525-533. Available from: DOI: 10.1007/978-3-030-19501-4_12.

[32] [R3] GIEL, R., PLEWA, M. Analysis of the impact of changes in the size of the waste stream on the process of manual sorting of waste. In *Proceedings of 37th International Conference on Information Systems Architecture and T*echnology. Karpacz, 2017, pp. 127-136. Available from: DOI: 10.1007/978-3-319-46589-0_10.