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Development of System Solution for Public Transport System Sustainability and Adapting it to the Challenge of COVID-19

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Abstract

The main goal of current article is to offer a system solution for keeping public transport system in sustainable and safe position by adapting it to the COVID-19 challenge, ensuring its sustainability. The introduction of the paper deals with the analysis of the public transport system in 2020 under the unclear epidemiological situation in the World by spread of Covid-19. Second chapter shows the beginning of the process of planning of system solution for adapting the public transport system to the challenge of Covid-19. Author deals with own vision of such solution. In third chapter author shows the vision of the system solution for the control of public transport system to ensure its sustainability taking into account also epidemiological situation. Last chapter shows some ideas, advanced practices and last achievements for public transport system sustainability.

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1. Introduction

On December 31, 2019, the Chinese authorities announced an outbreak of pneumonia in the city of Wuhan. The causative agent of the disease is a new type of coronavirus SARS-CoV-2, which causes the disease COVID-19. On March 11, the World Health Organization (WHO) declared the outbreak of the new coronavirus a pandemic. The first wave of pandemic begun. Summer of 2020 was a little safer, but autumn bring the second wave, that is more serious.

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The first wave of the corona-virus pandemic ended in the summer of 2020 and smoothly moved into the second. The world is shuddered at its power and trying to survive in a new epidemiological reality. The main task of governments is to support the economy in the safest way for people. At the same time, perhaps the most vulnerable link in all these plans is the transport function and the possibility of its implementation. The transport industry, and specifically passenger transportation, found itself in a difficult situation. The obvious risks and fears of being in a confined space with potential carriers of the virus will drag down passenger flows and carriers' income. Obligations to maintain social distance and the need to use personal protective equipment will also contribute.

Companies operating in the field of passenger transportation on all modes of transport are now experiencing catastrophic financial pressures associated with the shocks of falling box office receipts and a sharp contraction of the market Karlov (2020). It is already clear that the markets are waiting for major changes: layoffs of staff change of leaders and a chain of bankruptcies. Which industry will come out of these tests depends on what methods will be adopted in the near future.

Urban public transport stands apart: you can refuse to travel within the country or abroad, but it is difficult to avoid traveling around the city by public transport in the absence of a car.

The International Association of Public Transport UITP (2020) and The World Economic Forum WEF (2020) note that encouraging individual micro-transport: bicycles, scooters and gyro-scooters has become an important direction of the transport policy of cities in the context of the pandemic. In this way, the city authorities solve three problems: they unload public transport to improve its safety, reduce the congestion of roads with personal transport and reduce greenhouse gas emissions. WHO (2020) also gives similar recommendations for switching to use of the personal non-motorized transport.

Even rented micro transport is considered by the townspeople as safer: the number of bike-sharing trips in Beijing increased by 187%; in New York, by mid-March, “CityBike” service reported a 67% increase in demand.

Some cities go even further and look to seize an unexpected window of opportunity for a global restructuring of urban transport links. The most ambitious plan, called “Strade Aperte” (“open roads”), will be implemented in Milan: it is planned to accelerate the reconstruction of 35 km of city streets with the creation of temporary cycle paths, widening of sidewalks, limiting the speed of transport to 30 km / h, ensuring the priority of pedestrians and micro-transport users. Brussels is implementing post-quarantine measures to reduce the number of cars in the city centre, reduce transport speeds to 20 km / h and ensure the priority of pedestrians and cyclists.

Similar processes are taking place in Budapest, New York, Bogota, Mexico City and in the post-Soviet space. The French government is encouraging the switch to bicycles by providing subsidies that cover part of the cost of repairs, and the Paris authorities are creating a network of 650 km of dedicated bike paths, closing streets to cars until the end of summer. The British authorities will allocate significant funds for measures to improve bike paths, sidewalks and dedicated lanes for public transport, and in London they are creating a bicycle alternative to the metro, duplicating its routes.

Now it is the time to think about the sustainability of public transport system taking into account new conditions and new rules that are dictated by epidemiological situation in the World and by spread of COVID-19.

2. Planning of System Solution for Public Transport System Sustainability and Adapting it to the Challenge of COVID-19

The beginning of the adapting of the public transport system to the Covid-19 challenge, ensuring its sustainability is described in Patlins (2021). The topic of the current research is focused on the impact of Covid-19 and the development of innovative solutions in public transport sustainability that perfectly fits the current situation in the World. Accordingly, the impact of the research is convincing and useful for any public transport companies in Europe. At the same time, it should be clearly defined the expected functions of the planned "framework" to tackle the problems of coronavirus in relationship with public transportation. It is clear, that the disinfection of vehicles with UV light is good but not enough for completely resolving the proposed problem. The strengths of the current research is the practical usability of the results, i.e. how to maintain and foster the transport sustainability in the "COVID times". It is proposed to research the spectrum and intensity of UV radiation that is most effective to kill or inactivate corona virus, and combine such UV-emitting elements with energy-efficient LED technology to design devices for disinfection of public transport vehicles.
The main recommendation to the system solution is that not only passive methods (disinfection of the vehicles) should be considered, but also dynamic, organizational methods i.e. transport scheduling and management should be reformulated in order to avoid too dense vehicles. This can be achieved by hard and soft methods as well, e.g. recommendation and influencing via public transport application/route planner or simply reorganizing the bus/tram/metro schedule in order to make lighter passenger density of vehicles whilst the economic issues must be also considered of course (more drivers/vehicles mean more cost for the Public Transport company).

From the point of view of the management of the large dynamical systems, it is possible to offer current scheme in most common way. It is possible to define public transport system (PTS) as dynamical system with X and Y as input and output signals/data. Then it is possible to make discussions about the changes to the system in time - such systems are characterized by changes in time. The system can be described at different time moments and define the necessary parameters, or to perform calculations continuously at all times. Such control is called a dynamic process control (Figure 1).

For systems of nonlinear equations, especially under the uncertainty conditions, there are not known direct methods of solution. Only in some rare cases, the systems can be solved directly. For example, for a system of two equations is sometimes possible to express one unknown by another and thus reduce the problem to the solution of a nonlinear equation in one unknown. Therefore, iterative methods for nonlinear systems are actual here Patlins (2012). It is also possible to use the method of intervals here Patlins (2012).

For dynamic systems, knowing the set of input parameters X1 at time t1, can develop such control C to time t2 it would be an output parameters set Y2, so we can make the technological system regulation by following condition.

\[ S(t_1) \rightarrow S(t_2) \]  

(1)

According to automatic control, public transport system solution functional scheme of control can be shown as Figure 2.

3. The system solution for the monitoring and control of public transport system

According to Zietsman (2008) such principles of sustainable transportation could be implemented, using Intelligent Transportation System (ITS): [Intergenerational equity; Multi-dimensional; Dynamic; Continuum].
Properties of the agent should provide necessary functions of ITS. The main properties of agents: [Independent execution and interaction with other agents and/or applications, supervision over environment; Ability to use abstraction; Ability to use knowledge of a subject; Ability to adaptability for purpose achievement; Ability to be trained at environment; Stability to errors and wrong signals; Functioning in real time; Interaction between intellectual agents].

Constraints of ITS implementation are [environment, ecology, resources and technologies].

Examples of Technologies and functions which are now integrated with ITS: [Electronic License Plate Matching; Cellular Phone Tracking; Global Positioning System; Loop Detectors; Video Imaging; Automatic Vehicle Location; Automatic Vehicle Identification; Micro Simulation].

ITS system is a powerful tool for traffic flow organization; ITS system application could be different. However, the priority of Riga transport network development is to integrate railway transport with city transport network Vircavs (2004). Regional rail can carry considerable number of passengers without overloading transport infrastructure, more particularly Riga road network.

A design, simulation and verification environment for hybrid control systems are shown in (Figure 3).

Fig. 3. System design environment.

The specifications will be described by the desired emergent behaviour of the collection of agents. These are simple requirements usually described linguistically: increased throughput and safety and reduced emissions for vision-based traffic measurement system, Passenger counting system etc.

The requirements have to be parsed into system architecture. Designing control architecture involves decomposing the system into a subsystem hierarchy, specifying the subsystem interconnections and determining the limits of the environmental inputs. It is possible to concentrate on partially decentralized architectures, with coordinating semi-autonomous agent operation. A multi-layer hierarchy describes the controller of each agent. The higher layers are typically modelled by discrete event systems and take strategic decisions in coordination with other agents. The lower layers, on the other hand, typically involve continuous dynamics, performing path planning, and regulation tasks. The control laws at different layers along with the inter-agent coordination schemes are to be designed using design tools, in order to satisfy the specified properties such as safety, productivity, efficient resource utilization, etc. The design tools may be conventional discrete and continuous tools as well as specialized tools for hybrid control. According to
control theory and system theory fundamentals, it is offered scheme to global control of public transport system (Figure 4).

Fig. 4. The system solution structure for the control of PTS. The global level of control.

PTS – Public transport system; \{St1-Stn\} \in St – subsystems in whole transport system; \{Tr1-Trn\} – kinds of public transport; \{V1-Vn\} – vehicles of public transport; \{I1-In\} – infrastructure objects in public transport system; \{P1-Pn\} – passengers; \{Cr1-Crn\} – public transport system sustainable development criteria list: (environmental sustainability, passenger safety (also from epidemiological point of view), comfort level, economical aspects, influence of governance).

It will allow to plan more competently work of transport system using corresponding methods of the theory of management, more effectively to transport passengers.

The next step is to integrate necessary devices into the system solution, as well as to define appropriate indicators and criteria for public transport system sustainability. To be able formulate such lists and for better understanding them, it is significant to study advanced practices for public transport system sustainability.

4. Advanced Practices for Public Transport System Sustainability

Looking into recommendation of World Health Organisation (WHO) it is clear, that people must be more active in meaning of active way of life. Active way of life can help to feel better and, possibly can reduce the risk of infection by COVID-19. With the help of different devices, public transport system can become more sustainable also from the healthcare and fitness point of view (Patlins, 2016). Another recommendation of WHO – to be more pedestrian, then passenger – it also can improve the level of peoples activity. In this case the high level of impotence is pedestrian safety Várhelyi (1996), Johansson (2001), Diependale 2015), Gitelman (2017), Buehler et al. (2017), Budzynski et al. (2017). Researches made by Patlins et al. (2018, 2019) are also done for safety of pedestrian crossings and additional lighting using green energy, as well as for improvement the infrastructure and for public transport system sustainability.

Great description of overall sustainability of transport systems is given by Litman (2003, 2004, 2007, 2010) and Beatley (1995). There are a lot of fresh ideas. Other researches of authors also must be relieved in the case of high interest of sustainability, but Patlins (2017) offer the improvement of sustainability definition facilitating sustainable development of public transport system. It is a promising idea but the research is done before the COVID-19 pandemic, therefore, author plan to improve this study in nearest future.
To be able to take into consideration the recommendations of WHO, such as keeping the distance from each other to reduce the damage of infection by COVID-19 during the journey, it is significant to understand, that vehicle free enough and passengers are able to keep the distance from each other. The result could be achieved by appropriate scheduling. To be able to plan it in most efficient way it is needed to know the real number of passengers in each vehicle in each time Patlins (2014, 2015) and Kondratjevs et al. (2016).

Reducing the negative effect of COVID-19 is significant for public transport system sustainability, but significant is also environmental factor. Gudmundsson (2001) describes indicators and performance measures for transportation, environment and sustainability in North America give a good review for sustainable mobility and indicator systems in transport policy Gudmundsson (2003). In other hand Dudson (1998) shows his vision of clever and clean cars. Hall (2006) shows understanding and applying the concept of sustainable development to transportation planning and decision making in the U.S.

Renewable and green sources of clean energy are significant not only for all the World, but also for the sustainability of public transport system in particular. For these purpose Hnatov et al. (2019) offers such solution as researching the model of electric propulsion system for bus using “Mat lab Simulink”, but Patlins et al. (2018, 2019) shows how it is possible to use the green energy from sustainable pavement plates. The determination of the best load parameters for productive operation of PV panels of series FS-100M and FS-110P for sustainable energy efficient road pavement is also studied.

A significant part of sustainable transport system is sustainable and smart monitoring of energy flows and its consumption Apse-Apsitis et al. (2013). It must be mentioned, that often the costs of such solutions are high (Apse-Apsitis et al. (2015), therefore it is significant to reduce them Apse-Apsitis et al. (2011, 2012)– as a solution could be also fuzzy measurements Apse-Apsitis et al. (2014).

All the measures listed above can help to improve the sustainability of public transport system and developing it taking into account current situation and existing challenges.

5. Conclusions

Using the previous experience and researches done, author shows the significance of the public transport system sustainable development and possibility to react to the nowadays challenges. Current situation of pandemic is analysed and described.

In the introduction of the paper author shows the analysis of the public transport system in 2020 under the unclear epidemiological situation in the World by spread of Covid-19.

In second chapter, the beginning of the process of planning of system solution for adapting the public transport system to the challenge of Covid-19 is described. Author deals with his own vision of such solution.

In third chapter author shows the vision of the system solution for the control of public transport system to ensure its sustainability taking into account also epidemiological situation. Here author offer both - system design environment and transport control system solution’s structure from the point of view of global level of control.

In last chapter author describe some ideas, advanced practices and last achievements from own previous researches and researches made by other scientists for public transport system sustainability.

The main goal of this research - to offer a system solution for keeping public transport system in sustainable and safe position by adapting it to the COVID-19 challenge, ensuring its sustainability - is reached. Of course, the research will be continued, but, thanks to previous experience obtained, it was possible to adopt and enhance previous studies of the author for current situation. Concluded, that controlling of public transport system like large-scale dynamical system, give the possibility for centralized control of all the public transport system. Current solution can help to keep public transport system in sustainable position, taking in account ecological and epidemiological problems, priorities of passengers and economical effect.

Integrated tools, such as communication system solution for public transport network, alarming system solution and safety system solution must work together, as good as technologies and special algorithms must be used for making public transport system safer, better and sustainable. Possibly, it can also improve the public transport system performance in Riga city as well as can be used for the needs of other cities.

Offered system solution is open for further researches. Author plan to achieve the research and implement the project fully in the period of 30 months. Next results also will be published in further papers. Author is open for
cooperation in the frame of current topic as well is for communication in close fields of interest. Dissemination of research results, will give a positive impact to bring closer society and science.

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References

Karlov. A. “Neither take off nor swim: what will be left of the field of passenger transportation?” 2020. https://www.forbes.ru/biznes/402157-ni-vzletet-ni-polivvat-chto-ostansteyat-o-sterye-passazhirskih-perevozok

Apsītis, P.; Avotins, A.; Ribickis, L. A different approach to electrical energy consumption monitoring, Power Electronics and Applications (EPE’14-ECCE Europe), 2014, DOI: 10.1109/EPE.2014.6910970, IEEE CONFERENCE PUBLICATIONS

Apsītis, P., Avotins, A., Ribickis, L. Bidirectional DC/AC Energy Flow Measurement. In: 2015 IEEE 5th International Conference on Power Engineering, Energy and Electrical Drives (POWERENG): Proceedings, Latvia, Riga, 11-13 May, 2015. Riga: Riga Technical University, 2015, pp.465-468. ISBN 978-1-4673-7203-9. e-ISBN 978-1-4799-9978-1. Available from: doi:10.1109/PowerEng.2015.7266362

Beatley T. (1995), “The Many Meanings of Sustainability,” Journal of Planning Literature, Vol. 9, No. 4, May, 1995, pp. 339-342.

Budzynski M., Jamroz K., Mackun T. Pedestrian Safety in Road Traffic in Poland. IOP Conf. Series: Materials Science and Engineering 245 (2017) 042064 do:10.1088/1757-899X/245/4/042064

Buehler R., Pucher J. Trends in walking and cycling safety: recent evidence from high-income countries, with a focus on the United States and Germany. American journal of public health. 2017. – 107(2). P 281-287.

Diependale K. Do pedestrians comply with traffic lights in Belgian cities? Symposium Belgian Road Safety Institute, Brussels 2015

Dudson B. (1998), “When Cars are Clean and Clever: A Forward looking View of Sustainable and Intelligent Automobile Technologies,” Transportation Quarterly, Vol. 52, No. 3, Fall 1998, pp. 103-120.

Gitelman V., Carmel R., Pesahov F., Hakkert S. An examination of the influence of crosswalk marking removal on pedestrian safety as reflected in road user behaviours. Transportation research part F: traffic psychology and behaviour. 2017. – № 46. P. 342-355. doi: https://doi.org/10.1016/j.trf.2016.03.007

Gudmundsson H. (2003), Indicators and Performance Measures for Transportation, Environment and Sustainability in North America, National Environmental Research Institute, Roskilde, Denmark (www.dmu.dk/1_viden/2_Publikationer/3_arbrapporter/default.asp)

Gudmundsson H. (2003), “Making Concepts Matter: Sustainable Mobility And Indicator Systems In Transport Policy” International Social Science Journal (www.blackwellsynergy.com/rd.asp?code=iss&goto=journal), Vol. 55, No. 2, Issue 176, June 2003, pp. 199-217.

Johansson C. Towards a Method to Improve Road Safety for Pedestrians and Cyclists, Especially in Child Pedestrian Environments.; 2001.

Hall R. (2006), Understanding and Applying the Concept of Sustainable Development to Transportation Planning and Decision-Making in the U.S., PhD Dissertation, Massachusetts Institute of Technology (http://esd.mit.edu/students/esdphd/dissertations/hall_ralph.pdf).

Hnatov, A., Arhun, S., Tarasov, K., Hnatova, H., Mygal, V., Patlins, A. Researching the Model of Electric Propulsion System for Bus using Matlab Simulink. In: USB Proceedings of 2019 IEEE 60th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON2019), Latvia, Riga, 7-9 October, 2019. Piscataway: IEEE, 2019, pp.#051-1-#051-6. ISBN 978-1-5386-6902-0.

Kondratjevs, K., Kuņicina, N., Patlins, A., Zabašta, A., Galkina, A. Vehicle Weight Detection Sensor Development for Data Collecting in Sustainable City Transport System. In: 2016 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), Latvia, Riga, 13-14 October, 2016. Piscataway, NJ: IEEE, 2016, pp.305-309. ISBN 978-1-5090-3732-2. e-ISBN 978-1-5090-3731-5. Available from: doi:10.1109/RTUCON.2016.7763136

Latvian State Chancellery. 2020. The COVID-19 disease information website has been developed and maintained by the Latvian State Chancellery. https://covid19.gov.lv/ru/podderzhka-zhitelyam/zdorove/dlya-organizatorov-obschestvennogo-transporta
