On the Necessity and Possibility of Introducing Self-Driving Systems in an Urban Environment

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Abstract. This article analyses the possibility of using self-driving systems in the field of public transport. In this study, the type of public transport considered is the tram. Today, self-driving innovative technologies are becoming publicly available. It is shown that in the field of modernization of the artificial intelligence of the tram, maximum practical experience is needed to improve its adaptation to various external situations. The study suggests the practical application of self-driving systems in a city with a population of 1.5 million people. This city is Yekaterinburg, Russia. The best world experience in the field of automation of public transport processes is considered. The article also provides an algorithm for the introduction of self-driving systems into the urban environment. The advantages and disadvantages of the existing and modernized tram fleet are shown on the example of the city of Yekaterinburg. SWOT analysis was used as a tool for assessing the need and possibility of introducing a tram.

1. Introduction

The overall global demographic growth, among other global problems, contributes to the growth of the sphere of motorization. City streets are increasingly filled with various vehicles that promote the mobility of the population. However, not all people can afford a personal car. Some people consciously refuse cars. Others are temporarily unable to operate their cars. And for someone, a faster way to move in a modern urban environment is important because of congestion and traffic jams. Therefore, these categories of people use public transport. With the proper allocation of the city budget, spending on urban transport can partially solve the problems that arise when the streets of cities are crowded. Hence, there is a need for technological improvement of the existing types of public transport [1,2].

1.1. Problem

The emerging global environmental trend is such that there is a transition from diesel internal combustion engines to biofuel-powered engines and electric engines. In Russian cities, there are ground-based public transport that runs on electricity - a trolleybus and a tram. A trolleybus is a type of land-based trackless vehicle that moves within city streets equipped with a two-wire contact network. The development of an unmanned system for a trolleybus is quite complex. Because of the railless movement, it is difficult to coordinate the actions of the route, and it is even more difficult to consider the behavior of cars and pedestrians on city streets. In turn, the tram is a type of ground rail public transport, operating mainly on electric traction. This type of public transport has a great
potential for improvement not only in terms of convenience and comfort in a comfortable urban environment, but also in terms of automating the travel process [3]. However, the problem is that in most cases, the city budget is not directed to the modernization of electric public transport. Most often, it is distributed as a priority to buses and minibuses. In addition, this process is accompanied by the dismantling of tram tracks and the overhead line voltage of trolleybuses, that is, the elimination of electric transport. Accordingly, the introduction of unmanned systems becomes a difficult task. The administration of the city authorities associates the re-equipment and automation of trams with the high cost of modernization, with questionable safety and, in general, with the unpromising idea of introducing such technologies. These provisions don’t correspond to the global position on unmanned systems. This contradiction is the problem of automating the processes of public transport.

1.2. Practical significance
The significance of the presented work lies in the practical application of unmanned systems in Russian cities. A solution is proposed that will make it possible to introduce self-driving trams in Yekaterinburg on the tram tracks under construction from Yekaterinburg to Verkhnyaya Pyshma [4,5].

1.3. Purpose and objectives of the study
The purpose of this research work is a comprehensive solution to pressing problems in Russian cities and in Yekaterinburg in the field of modernization of public transport, namely trams. To do this, we need to complete several tasks to fully unlock the potential of the goal:
1. Analyze the feasibility of implementing unmanned systems in the urban environment;
2. To research the known results of the introduction of unmanned systems in the urban environment;
3. Develop methods for implementing unmanned systems for trams in Yekaterinburg.

2. Known results
Consider the domestic experience of implementing unmanned transport systems. In 2019, an unmanned system was successfully tested – a Vityaz–M tram produced by PC Transport Systems and Cognitive Technologies. Developers of unmanned systems in joint activities carried out the necessary tests (fig. 1). On the route No. 17 (Ostankino–Medvedkovo), a tram was launched, which independently moved along the route using automated processes. However, to avoid emergency situations, the driver was sitting in the cab [6].

Consider the foreign experience. In the Chinese city of Zhuzhou, a trackless automated tram produced by CRRC Zhuzhou Locomotive Co Ltd was launched (fig. 2). The tram runs on a road marked with markings that serve as rails. Unmanned equipment allows drive without a driver and at the same time independently create routes [7].
3. Hypothesis
The modernization of trams is an important step towards improving the road situation in the city. Higher punctuality and safety are the basic functions that a tram should perform. Also, with the automation of this process, the economic component will improve. The initial stage of re-equipment of trams in Yekaterinburg may begin with the Yekaterinburg – Verkhnyaya Pyshma tram line. This is a suburban line under construction, passing through sparsely populated places. On this section of tram tracks, you can start testing new unmanned systems installed on trams of a new type. Thanks to the tests on a quiet, but with a large passenger traffic section, it will be possible to introduce innovative technologies into everyday life.

4. Theoretical foundations
A tram is a means of urban ground transport that can only move on rail tracks. From here, there is a base for making it easier to write code and implement the system in real life. The tram is guaranteed to travel along a pre-planned route. Thanks to this, it is possible to study and implement all available intersections, traffic lights, and potentially dangerous places in the system to further facilitate the recognition of these places by the system. The big advantage is that the system is not aimed at performing maneuvers, but at speed control, braking, recognition of potential hazards, safety, and punctuality [7].

In Russia, electric transport is controlled in the GoA0, GoA1, and in rare cases GoA2 modes [9]. That is, mainly manual control. The driver of the car can act unconventionally in critical situations, but not always carefully approaching the solution of a certain task. Mistakes and fatigue introduce a human factor into the tram movement, which negatively affects the safety and punctuality of the tram movement [10]. Studying current trends, experts conclude that the transition to unmanned systems is a necessity. That is why the introduction of unmanned systems is now an important and promising initiative.

5. The conducted research and results
Within the framework of this research, the most rational solution will be to use the technologies of Cognitive Pilot, as the leading developer of artificial intelligence systems for unmanned vehicles. The company develops solutions in various directions; however, we are interested specifically in the Cognitive Tram Pilot—an unmanned system for trams. The system consists of a video camera unit with an electronic climate control and maintenance system, as well as a three-axis vibration damping system (fig. 3), a specialized high-resolution millimeter-wave radar (fig. 4) and a high-performance computing unit in industrial design (fig. 5) [11]. The operation of this system is shown in fig. 6. It was as part of the tests of this unmanned system that the tram traveled along route No. 17 in Moscow, as indicated earlier. The main goal of a fully autonomous tram is the absence of road accidents. In addition to accidents involving pedestrians, there are economic losses in road accidents involving cars. The costs will be spent on the repair of an expensive trams, and long tram downtime – lost profit. Any traffic accident will affect the entire tram line, the line will be paralyzed, which cannot be allowed. That is why the unmanned system must clearly and promptly respond to emergency situations on the road. Speed control, driving through intersections, responding to traffic lights, stopping at special places, controlling the opening of doors – these are the parts that the Cognitive Tram Pilot unmanned system monitors by recognizing various elements of the urban environment. A tram equipped with this system must be able to stop in front of obstacles and resume movement when they disappear, calculate a safe distance to the vehicle in front [12].
The proposed unmanned system requires a modern tram that meets the requirements of comfort, safety, as well as accessibility and autonomy. In Russia, such trams are produced by several factories, including Ust-Katav car-building plant, the Ural Plant of Transport Engineering, and PC Transport Systems. According to the documentation of the Yekaterinburg–Verkhnyaya Pyshma tram line, the purchase of 11 low-floor, single-section tram cars is being considered \[13,14\]. Data on tram cars that meet the requirements are presented in table 1.

**Table 1.** Tram cars potentially suitable for the use of unmanned systems on the Yekaterinburg – Verkhnyaya Pyshma tram line.

| Production          | Name          | Image       | Year of manufacture | Data source / photo source |
|---------------------|---------------|-------------|---------------------|---------------------------|
| PC Transport Systems| 71-911EM      | "Lion Cub"  | 2018                | [15]/[16]                 |

**Figure 3.** Video camera unit. Source [11].

**Figure 4.** Millimeter-wave radar. Source [11].

**Figure 5.** Calculation block. Source [11].

**Figure 6.** Image of the operation of the unmanned system. Source [11].
To introduce unmanned systems in Yekaterinburg, it is necessary to gradually achieve certain tasks. At the first stage, the system should assist the driver of the car driver. The goal of this stage is to achieve collision avoidance, the driverless system should react faster to potential hazards than the tram driver. At the second stage, the unmanned system should monitor the actions of the driver of the car driver. Compliance with the speed limit, as well as ensuring that the arrow switches along the route – the necessary actions of the system. Further, it is important that the unmanned system opens and closes the doors in a timely manner, and announces information using an auto-informer. The last stage is a fully autonomous tram [7].

The SWOT analysis presented in table 2 clearly demonstrates the advantages, disadvantages, and prospects of the need to develop a tram fleet in Yekaterinburg. In each side of the SWOT analysis, the factors were rated according to a 5-point system to track its change during further research.

### Table 2. SWOT analysis of tram cars operating in the city of Yekaterinburg.

| Strengths | Weaknesses | Treats |
|-----------|------------|--------|
| **S1** Reliable and environmentally friendly electric transport | 4 points Moderate factor | **T1** Replacement with high-tech types of trams |
| **S2** A familiar, conservative form of public transport | 3 points Moderate factor | **T2** Replacement by other types of public transport |
| **S3** Consistency of trips | 2 points A weaker factor | **T3** Complete |
| **Opportunities** | **Weaknesses** | **Treats** |
| **O1** Reconstruction for tourist needs | 3 points Moderate factor | **Replacement** with high-tech types of trams |
| **O2** Historical value of railcars | 2 points A weaker factor | **Replacement** by other types of public transport |
| **O3** Transfer of | 2 points A weaker factor | **Complete** |

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[17]/[17] 2018

[18]/[19] 2021
functioning trams to the balance of regional cities factor disposal factor

The SWOT analysis presented in table 3 clearly demonstrates the advantages, disadvantages, and emerging opportunities for the development of unmanned trams in Yekaterinburg.

Table 3. SWOT analysis of potential high-tech tram cars provided with an unmanned control system in an urbanized environment.

| Strengths | Weaknesses |
|-----------|------------|
| S1        | W1         |
| Reliable and environmentally friendly electric transport with improved safety | High cost of implementation |
| 5 points | 4 points |
| Gain | Moderate factor |
| S2        | W2         |
| Systematic travel with improved punctuality | Expensive service |
| 4 points | 3 points |
| Gain | Moderate factor |
| S3        | W2         |
| Full automation of processes | Expensive service |
| 5 points | 3 points |
| New strength | Moderate factor |
| S4        |            |
| Comfort |            |
| 5 points |            |
| New strength | |

| Opportunities | Treats |
|---------------|--------|
| O1            | T1     |
| High-tech modernization of processes in the future | Unlikely but possible tram control failures |
| 5 points | 3 points |
| Gain | Moderate factor |
| O2            | T2     |
| The updated form of public transport replaces minibuses | Unlikely but technically possible cyberterrorism |
| 4 points | 2 points |
| Gain | A weaker factor |
| O3            |        |
| Assistance in implementing similar projects in other cities | |
| 4 points | |
| New opportunity | |

Thus, we see the transformation of weaknesses into strengths, and threats into opportunities.

The implementation of an unmanned tram system in Yekaterinburg is a difficult task. A survey of the SuperJob portal showed that 42% of the surveyed citizens are ready to try themselves as a passenger of self-driving tram [20]. It is noticeable that people are ready to give a chance to unmanned systems, but it is important that the initiative comes not only from a small group of citizens, but also from the administrations of Yekaterinburg and Verkhnyaya Pyshma, including. According to the documents of the lot, 495 million rubles are allocated for the purchase of rolling stock, some of which can be allocated for the purchase of unmanned systems [13].

6. Conclusion
As a result of the conducted research, we can talk about a good prospect for the development of unmanned tram systems in Yekaterinburg. There is a field for the use of autonomous systems – the suburban tram line Yekaterinburg–Verkhnyaya Pyshma under construction. For this purpose, domestic single-section, low-floor trams of a new type will be purchased, in which it is possible to integrate the unmanned Cognitive Tram Pilot system of a leading developer of artificial intelligence. The modernization of trams on the new line will improve safety and punctuality, as well as these changes will give an impetus to the development in the field of artificial intelligence and automation of processes in general.
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