

# Mobility Challenges in the Cities of the Future

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**Abstract.** Autonomous vehicles have become a logical consequence of implementing the Intelligent Transport Systems strategy. The article analyses the directions of road vehicles intellectualization. This is due to the implementation of new paradigms in the functioning of the Smart City transport system to solve the problems of mobility and logistics, as well as vehicle service. The article presents the concept of an intelligent passenger transportation service called “Social Mobility on Demand”, which allows passengers to choose an acceptable option using a set of options, as well as operators to optimally distribute cars for different travel types, which will reduce the load on the road network, as well as the negative impact on the environment. It is shown that in order to manage the reliability of connected vehicles, it is necessary to improve proprietary maintenance and repair systems. The concept of a branded service system in the transition to fundamentally new modes of transport is described, which will allow maintaining their working condition and increasing the safety and stability of the transport system.

## 1 Introduction

As modern cities grow, the problems created by the transport system are exacerbated: traffic jams and congestion, difficulties with the mobility of the population and the logistics of goods, environmental pollution. This is compounded by the consequences of irrational transport development, such as the lack of parking spaces and the problems of economic and infrastructure development in remote areas. Analysts say, that autonomous vehicles (AVs) can solve many of these problems.

Since transport is involved in the organizational activities of any industry, the problem of developing intelligent transport in smart cities is one of the main ones [1]. One of the tasks that smart transport solves is to minimize harm to the environment through various smart services: ordering and planning trips clients, management of logistics and goods delivery services, organization of a car service. One of the unresolved problems in the field of passenger transportation is the delivery of passengers to attraction places that are not provided by route transport (for example, travel to work, study, places of treatment and leisure), which are characterized by peak demand (the movement of large groups of people

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at certain times). Since this would be inefficient for public transport and would increase traffic by individual travel, on-demand shared travel would be optimal. This article presents the concept of a system for organizing such trips.

Very few researches have looked at the reliability of the AV itself. The growing number of autonomous vehicles will inevitably raise the question of how to share ownership of these vehicles while ensuring control over their technical condition. The latter can be solved within the framework of the branded service system (BSS) and using information about failures during the warranty period. This article considers the concept of interaction between the BSS and the manufacturer by creating a single information space for creating smart mobility.

## **2 State of the problem: Development of intelligent mobility**

Transport systems were among the first to become smart, which means the intellectualization of almost all subsystems and processes in them. First of all, this concerns services that implement user interaction with the transport system to meet the needs for mobility and transportation of goods. The second direction is the creation of smart objects (vehicles and infrastructure equipment). Finally, the third area is the implementation of intelligent control, including traffic optimization, security and sustainability of processes and systems.

### **2.1 How to make the city smart: mobility in a smart city**

Smart cities can be viewed as large-scale cyber-physical systems (CPS) that use data collected by various sensors to improve urban life, in particular, to effectively manage traffic. Intelligent transport systems (ITS) will operate in Smart Cities and will allow to change the concept of mobility management.

The paper [2] proposes a new paradigm of public transport (PT), which provides dynamic movement on demand with the help of efficient forecasting and scheduling algorithms. Public transport can be made more efficient by understanding the variability of travel patterns based on smart card transaction data [3,4].

Smart mobility options include taxis, car and bike rentals [5], and the unique combination of parking, driving, and school buses. The study of electric transport is relevant, including the issues of choosing the type, coverage, size and location of the necessary charging infrastructure [6,7].

Autonomous vehicles (AVs) create new opportunities for traffic planners and policy makers [8]. The article [9] explored the possibility of using unmanned shuttles in addition to the main transport routes to solve the problem of the first and last mile. AV technologies place higher demands on the intelligence level of infrastructure such as road signs and markings [10].

Another option for high-speed travel in metropolitan areas is the flying taxi, a futuristic transport mode that could change the concept of mobility [11]. Urban Air Mobility (UAM) can reduce CO2 emissions as well as reduce congestion, traffic jams and travel time in urban environments.

Hyperloop is a ground transportation concept consisting of capsules moving at very high speeds in near-vacuum tubes that could provide a fast, cheap and sustainable alternative to short-haul flights and high-speed rail. Although according to experts Hyperloop seems to be an effective transport system, there is no clear scientific evidence to support this [12].

## **2.2 Mobility as a Service and Mobility on Demand: Prospects for Changes in Citizen's Mobility**

The digital age has opened up new opportunities to provide personalized services to public transport passengers - Mobility as a Service (MaaS). Point-to-point automotive services such as Uber, Lyft, BlaBlaCar and Ry-dHero (for kids) are currently being developed and plan to work with autonomous vehicles in the future. Simultaneously, traditional bus transportation will remain in those segments where the Smart MaaS market is difficult or irrelevant (for example, school buses). The authors of the article [13] suggest that hybrid multimodal transportation will develop in two segments: based on existing technologies under the contract, as well as on individual requests based on MaaS, the market of which will expand.

Paper [14] presents an innovative transport concept called "Flexible Mobility on Demand", which provides each passenger with a list of travel options optimized according to real-time needs. Flexibility provides a variety of vehicles and types of services: taxi, taxi and minibus.

But uncertainties such as technological feasibility, future demand, and the willingness of key stakeholders to collaborate may hinder its implementation. In [15], the authors state that accessibility will be a temporary problem, since smart cars will not be affordable for all citizens at first. For advance travel planning, there are systems such as "Dial-a-ride", which carry passengers on applications submitted by phone. There are systems with fixed and flexible routes, as well as with the reception of requests from special calling devices.

## **2.3 Using data to improve reliability through on-board diagnostic systems**

The set of on-board intelligent systems functions can be different, for example, means of informing the driver, providing assistance in case of incidents, communication with the dispatcher and service operators, as well as monitoring the vehicle state. Thus, in the article [16], the authors present a prototype of system Vehicle Data Recorder that can improve the accuracy of road accident research, since it is able to record the status of the vehicles and to report an accident by sending a message in the form of an SMS through the GSM module. The article [17] describes an IoT platform for precise positioning in highly automated driving (HAD), which achieves high-precision localization for future AVs by combining IoT with collaborative protocols and ITS algorithms. In addition, such integrated methods of on-board diagnostics and fault tolerance control help to reduce emissions [18].

In the article [19], the authors developed a systematic modeling diagnostic methods based on the structural analysis of electric drive systems, which may be used as the basis for vehicle diagnostic systems for developing electronic control units. vehicles. Remote monitoring of the technical condition includes the use of V2I systems for organizing M & R systems for each vehicle.

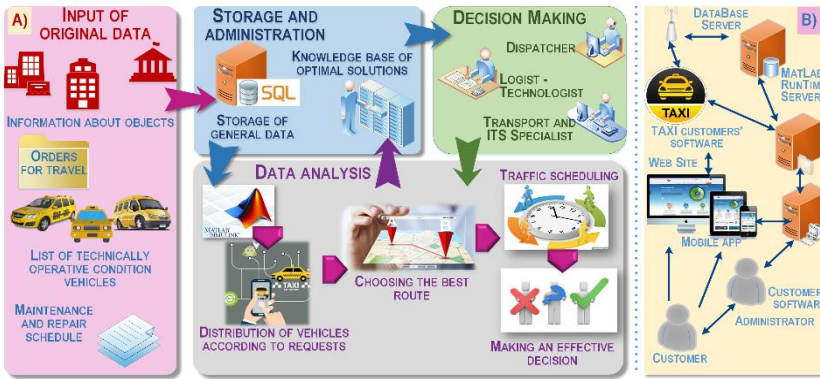
## **3 Results and Discussion**

As the studies analysis has shown, the development main directions in the field of intelligent transport of the future are seen in the creation of mobility management systems, expanding the AVs fleet and ensuring their reliable and safe operation. In this chapter, we will explore the concepts of mobility management systems and branded service for CV and AV.

### 3.1 The concept and principles of implementation of the on-demand mobility system

The proposed system combines the properties of traditional route transport and on-demand mobility. The difference is that the maximum occupancy algorithm of the vehicle is implemented, which is possible if there are orders for travel at a certain time from point A to point B. Clients can place either a preliminary or an urgent order for an individual or joint trip. The order indicates the main data as well as additional options: the presence of a child seat, air conditioning, luggage and the allowable number of passengers for a joint trip. A group of passengers is formed by the end point of the route, taking into account the date and time of the trip. The algorithm determines the optimal route to the destination in accordance with the information about customers placed on the interactive city map, and also calculates the cost of a trip for each client on the route, taking into account the parameters of his order, after which the route is displayed on the city map along with a description of the criteria.

From the point of view of scalability, the optimal variant of the system architecture would be a client-server application with a stand-alone server for a centralized database and a server for mathematical calculations. The conceptual scheme of the system is shown in fig. 1a, and a visual representation of its architecture is shown in Fig. 1b.



**Fig. 1.** a - conceptual diagram of the system, b - movement of information flows.

The goal function of the mathematical model minimizes the number of empty seats in all vehicles for the entire work period:

$$\begin{aligned}
 & \sum_{i=1}^{IC} \sum_{s=2}^{SC} \left[ IV \times \sum_{g=1}^{JC^2 \times ZC \times TFC} X_g^{i,c} + \sum_{a=1}^{s-1} \sum_{k=1}^{KC} \left( \sum_{g=1}^{GC} (GV_g - GP_g) \times GK_{k,g} \times X_g^{i,s} \right) \right] \\
 & + \sum_{i=1}^{IC} \left[ IV_i \times \sum_{g=1}^{JC^2 \times ZC \times TFC} X_g^{i,1} \right] \rightarrow \min
 \end{aligned} \tag{1}$$

where: KC – number of passengers’ categories, k – its recorder: k=1...KC; JC – number of objects participating in the creation of taxi routes, j – its recorder: j=1...JC; TFC – number of time moments; SC – maximum amount of objects, which can be visited by vehicle during the working periods; IC – number of taxicabs on routes, i – its recorder: i=1...IC; IV<sub>i</sub> – total number of seats in taxicab i; ZC – amount of orders during working period, z – its recorder: z=1...ZC; ZP<sub>z,j</sub> = {0;1} – matrix, which determines the getting-in operation for passenger of order z on the object j. ZV<sub>z,j</sub> = {0;1} – matrix, which determines the getting-off operation for passenger of order z on the object j. ZV<sub>z,j,k</sub> – number of k

category passengers on the  $j$  object for  $z$  request, who get in or out of a taxi.  $GP_g$  – vector, which determines the getting-in for operation  $g$ , included data from  $ZPz,j = \{0;1\}$ .  $GV_g$  – vector, which determines the getting-off for operation  $g$ , included data from  $ZVz,j = \{0;1\}$ .  $GKk,g$  – vector of  $k$  category passengers on the  $j$  object for  $z$  request, who get in or out of a taxi, included data from  $ZVz,j,k$ .  $GC$  – supportive array, which is a specially ordered vector to reduce the required parameter's dimension. It turns out by initial data processing and has the dimension, calculated by:

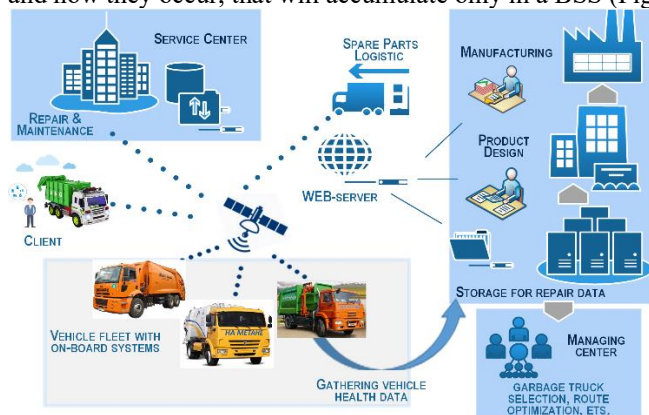
$$GC = JC^2 \times ZC \times TFC + JC \times TC \quad (2)$$

The first element in formula (2) defines all possible combinations of input/output objects, requests, and time. The second element describes "empty trips" to or after the request.

An alternative goal function could be to minimize non-productive time when boarding and disembarking or late passengers, waiting time for passengers or their absence at the boarding point. The system of restrictions includes restrictions on: the desired parameter, time, route, number of passengers, as well as the completeness of order fulfillment. The goal of pre-booking fleet planning is to minimize the total number of vehicles carrying passengers and the total mileage.

### 3.2 The concept of a single information space in the creation of infrastructure for the expansion of the autonomous vehicle fleet

According to analysts' forecasts and the consumer opinions analysis, the concept of autonomous vehicles will be implemented primarily in cargo logistics. At the same time, it is important to understand that, unlike cars, it is almost impossible to service a modern truck in a small garage. This is compounded by a lack of reliable information about failures and how they occur, that will accumulate only in a BSS (Fig. 2).



**Fig. 2.** Unified information space of a manufacturer vehicles.

Since, even with the addition of the controller and other intelligent components, the car is still a complex technical system, as a result much of the technology used to service and repair will remain the same. In addition, for a considerable time to come, smart cars will remain a small part of the fleet. However, despite all these factors, it is necessary to prepare the infrastructure beforehand, both for the organization of the transport process and for the maintenance of a healthy, safe and reliable fleet.

Organization of a single information space of the manufacturing company with BSS subjects enables problems to be identified and resolved quickly [20, 21]. The inclusion of each vehicle (as an active object) into a common cyber-physical system through

communication channels will allow receiving information about the state of components and assemblies and predicting the remaining resource. With an adequate selecting of sensors and improving onboard diagnostics, this makes it possible to determine wear parameters and predict the moment of a probable failure. Thus, it predict spare parts requirements for repairs and establish a single production within the framework of mass production. It should also be borne in mind that the rules for routine and preventive maintenance will obviously change. By removing the driver from the control loop, we eliminate the possibility of preventing a sudden failure of the technical system by means of indirect signs that can be detected either by a person or by a specific sensor (if there is one).

## 4 Conclusion

The digital age opens up new opportunities in the transportation industry: new forms of driving, new forms of routing, changes in business models for owning and using personal vehicles, mobile technologies that enhance the customer experience. At the same time, the integration of new business models with traditional modes of transport can provide a synergistic effect in terms of the efficiency of the transport system, combining the needs of different groups of the population, including people with limited mobility, different modes of transport, etc. presents the concept of intelligent service for passenger transportation, a system for providing personalized transportation services tailored to the individual needs of the passenger, through a list of travel options at the request of each passenger. systems. In our opinion, only comprehensive solutions based on the development of BSS and creation of a single information space can have a positive effect.

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