Development of a project to create a road transport infrastructure using small unmanned aircraft

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Abstract. The infrastructure for small unmanned aircraft has not yet been formed: there are no organized ground-based stations, there are no clear operating regulations for performing specialized types of work. It is proposed that when creating projects for an updated road transport infrastructure using ground-based autonomous vehicles, take into account the ability to maintain and maintain the operability of unmanned aircraft systems. Unmanned aerial vehicles can be used not only when conducting an inspection of the accident site, but also when checking on-site readings, investigative experiments, determining visibility on the road, etc. In the course of these investigative and procedural actions. The use of traffic control methods using small unmanned aircraft will make a significant contribution to ensuring road safety and reducing the level of accidents on highways. It is proposed that when creating projects for an updated road transport infrastructure using ground-based autonomous vehicles, take into account the ability to maintain and maintain the operability of unmanned aircraft systems.

1 Introduction

Eleven directions are being implemented within the framework of the Scientific and Technical Initiative of the Russian Federation, including Autonet and Aeronet.

Let's take a closer look at the trends in these areas over the past 5 years in order to analyze and predict the ways and options for development.

In one of the six initiatives of the digital transformation strategy of the Russian transport industry, the Ministry of Transport of the Russian Federation indicated that data collection on the transport complex using data unification and verification mechanisms and integration into a single management contour should be ensured, management decisions should be made using artificial intelligence. In order to start the process of digitalization of transport infrastructure at the right speed, it is necessary to obtain more high-quality, correctly labeled data [1].

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The Avtonet development roadmap is aimed at the development and implementation of autonomous ground vehicles. The concept of the transport industry in the future involves moving away from the use of personal vehicles towards the mass operation of commercial and public unmanned vehicles. At the moment, the market for unmanned vehicles has not been formed. There is no reliable experimental data on the interaction of a large number of sensor systems. The methods of intelligent analysis of the road scene in the operation of unmanned vehicles are not sufficiently developed.

The existing transport infrastructure is mainly focused on the human driver, including service centers, gas stations. The field of operation and maintenance of vehicles in the coming years will face the problem of maintaining the technically sound condition of the entire fleet of vehicles, consisting simultaneously of existing classic vehicles and new generation vehicles, which require different approaches in the organization of service support. Car service companies will have to monitor the technical condition of cars in real time, which will lead to the improvement and, in some cases, complete replacement of existing systems for the organization of transport and service enterprises. To date, there are no regulatory requirements for the use of new standardized V2X systems, which are planned to be used in autonomous ground vehicles[2].

The study assumes the development of the following techniques and systems according to the main points of the Avtonet and Aeronet roadmap.

1. Development of a methodology for collecting and processing data for the subsequent use of artificial intelligence technologies using small aircraft.
2. Development of theoretical and practical recommendations for optimizing the work of road safety services using small aircraft.

The creation and implementation of disembodied ground-based autonomous vehicles requires a new approach to the organization of road transport infrastructure.

In turn, the Aeronet direction, with the progressive development of small unmanned aircraft over the past 3 years, has entered a new stage of development, which contributes to the comprehensive development of air transport based on unmanned aircraft systems technologies. The use of unmanned aircraft has been developed in such areas as remote sensing and monitoring, agriculture, transportation of goods and, in the future, people, search and rescue.

The infrastructure for small unmanned aircraft has not yet been formed: there are no organized ground-based stations, there are no clear operating regulations for performing specialized types of work. It is proposed that when creating projects for an updated road transport infrastructure using ground-based autonomous vehicles, take into account the ability to maintain and maintain the operability of unmanned aircraft systems[3-4].

2 Materials and Methods

Currently, due to the increase in the number of cars and the length of highways in the Russian Federation, the reduction of traffic accidents and the prevention of accidents with road users remains an urgent issue for the departments of the State Road Safety Inspectorate. Table 1 shows the length of highways in the Belgorod region [5].

As of November 1, 2023, the number of deaths in road accidents in the region compared to the same period last year was reduced by 13.5% (115 deaths), while the number of deaths in vehicle collisions decreased by 15.1% (45 deaths).
Table 1. The length of highways in the Belgorod region

<table>
<thead>
<tr>
<th>Name of the highway</th>
<th>Length of highways, km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal road M-2 &quot;Crimea&quot;</td>
<td>451,1</td>
</tr>
<tr>
<td>Regional and inter-municipal roads</td>
<td>6360,2</td>
</tr>
<tr>
<td>Streets of settlements</td>
<td>15023,9</td>
</tr>
<tr>
<td>Highways of the Belgorod region total</td>
<td>21835,2</td>
</tr>
</tbody>
</table>

Fig. 1. Statistical data analysis. Accident rate analysis in comparison with the same period last year.

Belgorod State University named after V.G. Shukhov has developed an information and analytical system in the form of a web application "Digital Road Transport Infrastructure", which allows automating the collection, storage and processing of big data to predict possible places of occurrence of road accidents based on dynamic statistical data on accidents and technical and operational indicators of the public road network taking into account the characteristics of traffic and pedestrian flows (see Fig. 1-2).

Fig. 2. Accident rates for the period from 2005 to October 2023

For the organization of road safety at an appropriate level, it is proposed to use unmanned aerial vehicles when collecting data from the road transport infrastructure.
Unmanned aerial vehicles (UAVs), or drones, are unmanned aerial vehicles that are controlled remotely (for example, from the ground or from another aircraft); using autonomous software installed on board the UAV; using GPS navigation.

UAVs have a frame made of lightweight composite materials or light metal alloys, to which the remaining elements are attached:

1. A flight controller that receives signals from the ground control panel or on-board computer and redirects them to other structural elements. The basic set of controller elements includes:
   2. Altitude sensors (barometer) and spatial position sensors (gyroscope),
   3. Acceleration measuring device (accelerometer),
   4. GPS navigator, Wi-Fi, RAM;
   5. Engines, propellers and speed controls that ensure flight;

According to the variety of designs, there are 3 main types of unmanned aerial vehicles: multirotor type, fixed-wing UAVs and hybrid type.

During the development of the project, the following studies were carried out:

1. Analysis of existing unmanned aerial vehicles and their application;
2. Choosing a UAV and a research site;
3. Analysis of routes used at the scene of accidents.

The development of the procedure for the use of unmanned aerial vehicles in carrying out measures to quickly eliminate an accident from the scene determined the sequence of actions, namely:

1. Drawing up a flight program taking into account the features of the functional payload equipment installed on an unmanned aircraft and the nature of the external cargo being transported.
2. Procedures for the prevention, identification and elimination of direct and indirect causes of a decrease in the reliability of remotely piloted aircraft, an external pilot station, flight support systems and their functional elements.
3. The procedure for keeping records of the service life, operating time of facilities, causes of failures, malfunctions and damage to unmanned aircraft.
4. Planning, preparation and execution of flights on a remotely piloted aircraft and an autonomous aircraft.
5. Processing of data obtained by using remotely piloted aircraft.

One of the key problems of accident investigation is the collection and analysis of data at the scene of the incident. At the same time, the traffic police services face two main problems that contradict each other: thoroughness and duration of information collection collecting information and the need to resume traffic on the highway as soon as possible.

The main disadvantages of existing data collection methods are: significant time spent at the accident site; problems with traffic on the motorway with corresponding economic and social consequences; loss of valuable data due to insufficient detail of the sketch; risks for police officers and civilians in the data collection process. Fatal accidents have been recorded after the accident, when police officers perform their duties to investigate the previous accident [7].

Using the example of the Russian practice of fixing accidents using traditional methods, analysts draw attention to the following disadvantages:

1. A long time to complete the procedure – from 20 minutes to 1 hour – leads to congestion on the highway or city street;
2. The negative impact of factors such as the personal qualities of inspectors, weather conditions and time of day during the investigation;
3. The inability to carry out additional data collection without going to the scene of an accident;
4. Lack of human resources, financial resources and equipment to conduct more detailed investigations of the incident.

These circumstances encourage the search for new, more advanced, safer and less expensive research technologies and techniques. All these technologies are associated with the development of digital technologies, including digital image processing, computer vision technologies (in particular, scale-invariant feature transform, SIFT) and artificial intelligence. The technique of analyzing the structure from motion analysis (SfM) is also associated with computer vision technology, as well as with photogrammetry methods. But this would not be enough if we still had to collect information on earth.

However, the use of UAVs makes it possible to carry out almost the entire range of measures for the reconstruction of an accident with minimal participation of people directly at the accident site [8].

The technical capabilities of unmanned aircraft help to record the situation at the inspection site and the surrounding area, to detect and record traces of a crime, even if they are located at a great distance from the inspection site itself. Using a UAV at the inspection site will allow the person conducting the inspection to navigate the area, correctly determine the boundaries of the inspection, see and analyze the environment, and detect possible traces of a crime at a greater distance from the crime scene itself. Also, the use of UAVs in the production of investigative actions will allow an inspection from various angles and detect traces, objects that are invisible at first glance.

Under certain conditions and the creation of special specialized programs, the UAV can fully carry out, under human control, the entire range of actions during the inspection of the accident site, starting from the fixation of traces, measurements and drawing up an accident diagram. At the initial stage of fixing the accident site, it is possible to use a UAV to take photos and videos of the area from a great height and shooting clarity, which will help to record the entire situation of the accident, the highway and the terrain in this area, that is, to really make an overview photo and video recording [9].

Next, the UAV will help to take a more detailed survey of individual objects, traces, and the situation at the accident site, after which it will make a nodal fixation of the accident objects by itself. In addition, with the help of a UAV, it is possible to take photos and videos of the accident site from different angles and at different viewing angles. In particular, it is possible to fix the angle of inclination of the road surface (descents, ascents), visibility on the highway several kilometers from the accident site, namely exits from the turn and general visibility under certain weather conditions. The use of UAVs contributes to the efficiency of obtaining high-resolution images, not only stored on digital media, but also transmitted online.

Also, at the accident site, the width of the roadway in close proximity to the accident site is measured, since it may noticeably narrow or, conversely, be wider relative to the accident site, which may not be reflected in the inspection protocol, since it is not visually noticeable. This condition, under certain circumstances, can play a significant role in the mechanism of an accident, when the driver of a vehicle imperceptibly approaches another vehicle or performs sudden maneuvers, drives to the curb, etc. It is precisely this circumstance, that is, the narrowing or widening of the roadway, that can be noticed if photo and video recordings are made using a UAV. The navigation capabilities of the UAV and the equipment installed on it will allow you to accurately record the geographical coordinates of the accident site, as well as measure both long distances (linking accident objects to a fixed, permanent object), and fix and bind objects (participants) directly Accidents to each other (scree, fragments, location of vehicles, fuel and lubricants stains, traces of braking, sliding, peeling, etc.).

The UAV has the ability to recognize and monitor moving objects such as people, vehicles, using the intelligent tracking function, and use it to stabilize tracking and review.
The moving location of the object is constantly updated and transmitted to the second control panel [1].

The built-in LiDAR module, a laser locator using the technology of laser emission of optical waves with further registration of laser pulses that were scattered by objects, allows you to solve the following tasks:
1. To establish the exact location of traffic participants and injured persons using location reference;
2. Detect and fix the brake track of the car;
3. Detect and fix traces of dirt and broken glass;
4. Detect and fix damage to road users;
5. Accurately determine the distance between objects (with an error of up to several millimeters);
6. Provide data on the extent of damage to the vehicle for the investigation.

3 Results and Discussion

An information and analytical system has been developed in the form of a web application "Digital Road Transport Infrastructure", which allows automating the collection, storage and processing of big data to predict possible places of occurrence of road accidents based on dynamic statistical data on accidents and technical and operational indicators of the public road network, taking into account the characteristics of traffic and pedestrian flows. The technology is based on statistical analysis of data from the sites of road accidents in the Belgorod region for the period from 2015 to 10 months of 2023 and allows you to take into account dynamic changes in static data [11-13].

As well as geometric parameters of public roads and the road network, transport and technological parameters of the roadway, components of the transport infrastructure, characteristics of traffic and pedestrian flows. These data were obtained using geoinformation analysis of the road graph, which was also built on the basis of data obtained from unmanned small aircraft. Based on the aggregate information, using a specialized mathematical model, the factors that have the greatest impact on the possibility of various types of accidents have been identified.

In order to carry out video surveillance, the operator must plan the flight route of the UAV in advance. The flight route will depend on the nature of the terrain and the tasks to be solved. Most often, the UAV is sent to the monitoring area, where it performs a flight according to a given program. During the flight, the UAV transmits a video image of the terrain and objects on it to the ground control station (GCS) in real time. At the same time, the UAV is capable of repeatedly repeating visits to the object of study.

For a general inspection of the territory, a circular closed route is the most appropriate. The main advantages of this method are the coverage of a large area. A parallel route (Fig. 4) is recommended for aerial photography of terrain areas (see Fig. 3).
A flyby of a given object is used when conducting inspections of specific objects. It is widely used in cases where the coordinates of an object are known and its condition needs to be clarified.

Figure 4 shows an example of choosing a takeoff and landing location that is located near the river. The free embankment gives the advantage of unobstructed access for piloting UAVs. The method of investigation in case of a traffic accident is a flyby of a given object.

The main goal of the project is to create a new information and analytical system to support solutions for transport management and road transport infrastructure based on big data, which will also be formed with the participation of data collection using small disembodied aircraft.

The documentation of offenses is carried out using photo and video recording cameras installed on an unmanned aerial vehicle, the materials of which are evidence of the commission of an administrative offense, while the registration of violations is carried out automatically through the Center for Automated Recording of Offenses [14].

In addition to the psychological effect of influencing road users to force them to comply with traffic Rules, it is assumed that UAVs will be used to solve other tasks, including analysis of the road traffic situation in places caused by traffic congestion, which will allow timely adjustments to the organization of traffic, as well as identification of vehicles in traffic wanted.

But it is worth mentioning the lack of UAVs:
1. Air barriers. UAVs cannot fly in conditions of poor visibility, for example, in fog or clouds. This limits their ability to perform many tasks, including close combat support.

2. Dependence on communication. UAVs require constant communication with the operator on the ground. If communication is disrupted, the UAV may become lost or useless.

3. The need for maintenance. Like any technical equipment, UAVs require maintenance and repair. This can create problems when performing tasks in resource-limited environments.

4. The procedure for keeping records of the service life, operating time of facilities, causes of failures, malfunctions and damage to unmanned aircraft [12].

The service life of a UAV can be influenced by many factors, including the conditions of service and storage. Understanding how to extend the life of a UAV can help pilots get the most out of their purchase.

1. Maintenance. Regular maintenance and cleaning are necessary to keep the UAV in working condition. Pilots should regularly check the engines, propellers and battery to make sure they are in the required condition. In addition, they should also inspect the UAV frame and other components to make sure nothing is damaged or worn.

2. Storage conditions. The storage conditions of a UAV can have a big impact on its service life. It is important to store UAVs in a dry room with a controlled climate and minimal temperature fluctuations. Batteries should be removed and stored separately in a cool, dry place.

3. Battery care. Proper care of the battery is necessary to extend the service life of the UAV. The battery cannot be recharged or stored in a fully discharged state. In addition, pilots should not operate the UAV until the battery is completely discharged. The battery should also be balanced and checked regularly for signs of damage or wear.

4. Flight conditions. The conditions in which the UAV flies can have a significant impact on its service life. Pilots should avoid flying in gusty or windy conditions, as well as in areas with high levels of dust or debris. In addition, they should never fly their UAV too close to obstacles or at excessively high or low altitude.

By following these steps, pilots can extend the life of their UAV and get the most out of the purchase. Regular maintenance, proper storage and care of the battery are necessary to extend the life of the UAV. In addition, pilots should be aware of the conditions in which they operate their UAV. By following these tips, pilots can be sure that they will get the most out of their UAV [15].

The UAV flight plan is submitted to obtain a permit, regardless of the class of airspace. The submitted plan (application for the use of airspace) contains the following information:

1. On the identification index of the aircraft (airborne vehicle number);
2. About the number and type of aircraft;
3. About the place of the launch site and departure time;
4. About the flight route (flight zone);
5. The location of the landing site and the total estimated elapsed time before the landing of the unmanned aircraft;
6. Other information necessary to describe the features of the flight route and other necessary information.

4 Conclusion

UAVs can be used not only when conducting an inspection of the accident site, but also when checking on-site readings, investigative experiments, determining visibility on the road, etc. This will allow the person conducting the investigative (procedural) action on the
spot to determine the completeness and quality of the event, the sufficiency of the materials received, as well as subsequently understand the situation and circumstances of the accident. The technical capabilities of the quadcopter are invaluable in conducting an inspection of the area in hard-to-reach places, when it is very difficult and sometimes impossible to get to the crime scene.

The use of UAVs in collecting information for the information and analytical system made it possible to obtain data on the prediction and prevention of road accidents. A forecast of upcoming changes in the driver-car-road-environment system has been made when it operates in a digital transport environment. An approach has been developed to collect data necessary for the design of transport infrastructure using small unmanned aircraft.

The use of traffic control methods using small unmanned aircraft will make a significant contribution to ensuring road safety and reducing the level of accidents on highways.

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