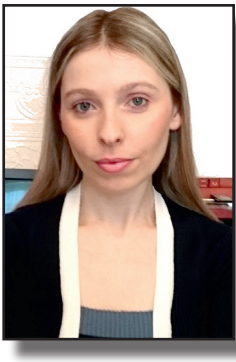
DOI: https://doi.org/10.30932/1992-3252-2019-17-5-286-297

Safety Analysis of Goods Transportation by Unmanned Aerial Vehicles



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ABSTRACT

Modern transport companies around the world actively study the possibility of intra-urban transportation of goods using unmanned aerial vehicles (UAV).

The objective of the study is to reveal the existing problems preventing full-scale introducing of UAVs into the operations of logistics centers that accomplish cargo delivery in modern megacities as well as to propose a possible option for their solution.

The study conducted applying the methods of comparative analysis and generalization showed that the main obstacle to the use of unmanned aerial vehicles for cargo delivery is currently unsettled problem of safety when UAVs operate in the urban environment.

The study has analyzed the worldwide UAV traffic safety management programs. Among the programs reviewed were U-Space (the program is implemented by the European Commission and other participants); NASA Unmanned Aircraft System Traffic Management (the program is implemented by NASA and the US Federal Aviation Administration); European Aviation Safety Agency drone categories (the program is implemented by European Aviation Safety Agency (EASA)); Urban Traffic Management of Unmanned Aircraft System (the program is implemented by Air Traffic Management Research Institute (ATMRI) and other participants). The analysis showed that these programs paid a lot of attention to preventing the UAVs collisions with other air vehicles. But almost no attention was paid to the fact that the flight routes of unmanned aerial vehicles would intersect with the ground highways.

The analysis carried out in the article allows us to conclude that one of the solutions to the problem of UAV implementation in the field of cargo delivery is the development of a new concept of UAV traffic safety in the urban conditions, which will take into account the threat of collision of cargo UAV not only with air vehicles but also with ground ones. The concept should determine the requirements for the technology for safe traffic of drones over the main surface transport routes including highways, high-speed railways, etc. The development of such a concept will be a turning point for starting the full-scale use of UAVs as a new and effective means of cargo delivery in the city, which, in its turn, will create the next-generation transport infrastructure in the cities.

Keywords: *unmanned aerial vehicle, air drone, UAV transportation of goods, safety, aviation, urban transport.*

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Article received 13.06.2019, revised 25.09.2019, accepted 01.10.2019.

For the original Russian text of the article please see p. 286.

Introduction

Unmanned aerial vehicle (other names: UAV, unmanned aircraft, drone) according to the definition approved by International Civil Aviation Organization (ICAO) is «any aircraft intended to be flown without a pilot on board which can be remotely and fully controlled from another place (ground, another aircraft, space) or pre-programmed to conduct its flight without intervention» [1].

In the past few decades, UAVs have been implemented in various industries for various applications. Among those who use this technology, there are transport companies.

The undoubted advantage of this method of delivery is the higher delivery speed, independence from traffic jams, reduction of the number of the employees directly involved in delivery process.

One of the pioneers in the cargo delivery using the UVAs is Amazon which developed a conceptual cargo delivery system named Prime Air [2].

Prime Air is a service that will deliver packages up to five pounds in 30 minutes or less using hybrid aircrafts capable to make vertical takeoff (Pic. 1). It is planned to deliver goods in the areas within a radius of 16 kilometers from the company's logistics centers.

On December 7, 2016, Amazon first delivered the goods using the Prime Air service in Cambridge (UK).

In 2017, Matternet (USA) introduced a development in the field of urgent delivery of medical supplies by unmanned aerial vehicles consisting of the Station Matternet drone station and the M2 Drone [3]. The importance of this development is linked primarily to the fact that it is aimed at the emergency delivery of organs for transplantation, laboratory samples and other medical supplies; speed and reliability of their delivery is vital for patients of medical institutions. Moreover, according to the developers, it is this method that is independent of the city traffic jams which can provide the reliable and, above all, fast delivery.

Matternet has been transporting laboratory samples by drones from University Hospital Zurich to the Zurich University campus. «Compared to a courier on the road in Zurich, the drone with laboratory samples is able to travel the route twice as quickly; the time saved can be invaluable for patients, doctors and other medical professionals» [3].

It is necessary to point out that despite all the advantages of using unmanned aerial vehicles for cargo delivery this technology at the moment, as a rule, is introduced so far only within the framework of experiments and small startups.

The objective of this study is to identify the existing problems in introducing of UAVs in the operation cycle of logistics centers engaged in the freight delivery in modern megacities as well as to propose certain options for their solution.

Safety of cargo delivery by UAVs

According to the data provided in [4] in the near future in Russia it is planned to give the UAV owners the right to transport goods on a commercial basis in accordance with the road map prepared by the Ministry of Transport of Russia.

At present in accordance with the current legislation of the Russian Federation air drones do not have the right to make commercial transportation, what becomes one of the causes for shadow schemes in this sector.

It is expected that the program that ensures the arrangement of conditions for commercial use of UAVs will be developed by the Ministry of Transport of Russia in the near future. In this case, the owners of air drones will not need to register an airline and be issued an Air Operator Certificate as it can be obtained according to a simplified scheme. Flight safety requirements will remain standard.

Meanwhile analysis of the sources [5–12] allows to draw a conclusion that it is safety that can be considered as one of the main problems that delay the introduction of air drones in the cargo delivery market.

To illustrate, in 2018 Federal State Unitary Enterprise *Russian Post* carried out a trial delivery of mail correspondence by a cargo

Pic. 1. Prime Air delivery drone [2].

Pic. 2. Russian Post's drone crashed on the trial delivery of mail correspondence [8].

unmanned aerial vehicle. The tests ended in an accident, the UAV lost control, clashed with the building and fell to the ground [8] (Pic. 2).

UAV safe operation programs: global experience

A number of programs are currently being developed in the world, which are aimed at ensuring the safe operation of unmanned aerial vehicles, including the following.

1. U-Space

The most significant program of unmanned aerial vehicle integration currently underway in Europe is the U-Space initiative [9], which is part of a joint research project on a Single European Sky. SESAR is a public-private partnership involving the European Commission, Eurocontrol and a number of air navigation service providers and industry stakeholders. These stakeholders are developing the U-Space concept which includes a set of digitally controlled services that will make it possible to perform complex large-scale unmanned operations, taking into account the high level of independence in difficult (especially urban) conditions.

2. NASA Unmanned Aircraft System Traffic Management

NASA is cooperating with the US Federal Aviation Administration in the Unmanned Aircraft System Traffic Management program. The purpose of the program is the development of civil UAV motion control systems to ensure low-level flights in airspace [10]. The project takes a step-by-step approach which provides four consecutive levels of technological capabilities. The previous demonstrations within the frame of the program included the flights in sparsely populated areas and in moderately populated areas. The final stage of the program will make it possible to carry out the operations in densely populated (i.e. urban) areas and to get through the large volume of traffic. The project details are available on the NASA website [10].

3. European Aviation Safety Agency drone categories

The European Aviation Safety Agency (EASA) is currently developing new rules [11] regarding the private use of UAVs and takes a risk-based approach that breaks down UAVs into three main categories:

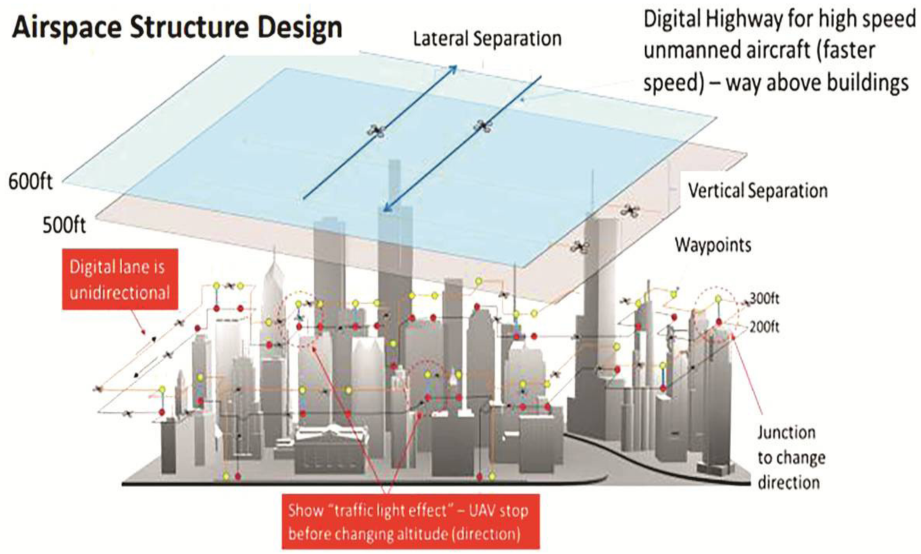
• *Open*: this is the low risk category; UAVs certified in this category will operate in accordance with certain principles without an operation permission of the respective authority.

• *Specific*: high risk category which requires authorization for UAV deployment/type of deployment. That means that a risk shall be assessed taking into account the capabilities of a drone, operator, environment and a specific task.

• *Certified*: maximum risk category which requires the drone and operator certification by the respective authority.

All three categories can be used for different applications of UAVs. Part of the task involves the integration of various risk profiles for UAVs which perform missions of various types.

4. Urban Traffic Management of Unmanned Aircraft System (UTM-UAS)



Pic. 3. Singapore Airspace Urban Traffic Control Structure developed by NTU [12].

The researchers from Nanyang Technological University (NTU) are working on the creation of the UAV movement control system [12] so that UAVs can efficiently and safely fly in Singapore's airspace (Pic. 3). This program is focused on such areas as intellectual and safe routing, motion detection and prevention and control systems for air traffic coordination.

Air Traffic Management Research Institute (ATMRI), a joint NTU research center and Civil Aviation Authority of Singapore (CAAS) take charge of the project. The leader of the research program is NTU Professor Low Kin Huat, an expert in robotics and unmanned aerial vehicles from the School of Machine Engineering and Aerospace Engineering.

A comparative analysis and synthesis of the information presented in the programs mentioned above shows that the main safety principle applied there is the choice of routes for UAV flights over such areas of the city which will not be damaged or will be slightly damaged by accidental crash. These areas cover water reservoirs, parks, etc. The programs also paid a lot of attention to preventing the UAVs collisions with other air vehicles. But almost no attention was paid to the fact that the flight routes of not only amateur UAVs but also cargo UAVs would intersect with the main land driveways, transport routes, e.g. highways and railways, including high-speed ones. An accidental crash of a cargo drone on the main

Pic. 4. Air drone breaking through the airliner's windshield during testing [13].

Pic. 5. Airliner damaged following the collision with UAV [20].

land transport route can cause disastrous effects due to, for example, a highway accident or a high-speed railway accident.

Thus one can cite a test of British scientists conducted in the laboratory of the Aviation Research Center in Farnborough (England) as an example of possible consequences of the accident involving UAVs. The test was carried out using an air gun, unmanned aerial vehicles as well as helicopter and airliner cabs [13].

The test has shown that even a small amateur drone can constitute a serious danger, and that the heavier UAVs which are in ever-growing use can break the airliner's windshield at collision at the heights and speeds typical of the airplane approaching to land (Pic. 4). In this regard it should be borne in mind that such a speed is quite comparable to the speed of a high-speed train, and the design and shape of the airliner's cabin are also very similar to that of a high-speed train.

«While an existing probability of a collision of UAVs with other vehicles seems to be low» [14], its consequences according to researches [15–18] might be rather important (Pic. 5), considering particularly the weight of professional drones that can attain tens of kilogrammes and the fact that some of them use liquid fuel [19].

We can also cite several examples of collision of UAV with land vehicles, comprising trains [21] and automobiles [22; 23]. «UAV collided with a vehicle on the highway A99 near the city of Germering in Bavaria. No driver, neither a passenger were victims, but the accident damaged the front part of the vehicle. The UAV pilot surrendered to the police after addressing the media, but still insisted that the fault was caused by a technical malfunction of the UAV. The man, 51 year old resident of Munich stated to the police that the UAV came out of control due to technical malfunction or a fault of the control signal transmission. The UAV of 1,2 kg was launched in Munich Neuaubing district located at some kilometres from the accident site, landed on the highway, and the vehicle drove directly into it. The police was investigating whether dangerous obstacles had been created to road traffic» [22]. It is not for the first time that a UAV is engaged in accidents on highways in Germany [23], so now the flights of UAVs over the highways are prohibited [23].

«The events of such kind can be caused by pilots' errors or by technical malfunctioning of the UAV. Not only amateur pilots but professional operators can also commit errors while piloting the UAV» [18].

«It worth noting that cyber interference, like interference of the control channel of the UAV, is a serious threat for safety of operation of UAVs» [24], as well as radio frequency interference, resulting in the loss of operator's control of the aircraft [25; 26].

Currently «UAVs are still a developing sphere of aviation with a huge quantity of factors of unaccountable risks» [18].

Conclusions

The analysis showed that there is a need to develop a new concept of the safety of cargo drones in the urban environment, which will pay special attention to the threat of UAVs collision with other vehicles.

The concept should, among other things, define the requirements for the technology of safe UAV flight over the transport routes, including highways, high-speed railways, etc. The development of such a concept will be a turning point to start the full-scale use of UAVs as a new and effective means of cargo delivery what will create the next-generation transport infrastructure in cities.

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