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RISK DEFINITION IN CIVIL UNMANNED AVIATION

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Abstract

Objective: *The risks in unmanned civil aviation are considered as one of the most important. In the article is proved applicability of ensuring the flight safety of aircraft and considered the basic risks of manned civil aviation.* ***Methods:*** *Analyzed statistical data on aviation accidents, organized probabilities distribution of aviation accidents for manned and unmanned civil aviation to identify factors that influence the occurrence of emergency situations in manned and unmanned aviation.* ***Results:*** *We proposed typology of risk components in civil aviation and systematized methods and techniques to reduce risks. Over the analogies defined possible risks, their causes and remedies in civil unmanned aircraft. Weight coefficients distribution was justified between risk types for development of recommendations on risk management in unmanned civil aviation.* ***Discussion:*** *We found that the most probable risk in manned civil aviation is the human factor, organization of air traffic control, design flaws of unmanned aviation system as a whole, as well as maintenance of unmanned aviation system.*

Keywords: air transport system; factors of aviation accidents; risks in civil aviation; unmanned aerial vehicle.

1. Introduction

Unmanned aviation (UA) gradually shows the signs of gaining enough liquidity from a commercial point of view. This is evidenced by the data on market distribution of unmanned aircraft. At the time of 2010 up to 20% in the development and implementations of in UA focused on Civil Aviation (CA). At the period of 2014-2015 the total flight hours of American MQ-1 and MQ-9 exceeded 400 000 flight hours [1].

However, it is no secret that with the advent of commercial exploitation for UA an entirely new problem arose, the problem of risks resulting from possible violations of flight safety by unmanned aircraft.

2. Applicability

Today, the leading countries of the world, where UA commercialization quickly develops, unmanned aerial vehicle (UAV) operation is held under the so-called "segregated or dedicated airspace," the space reserved in advance and where the UAV has the right to fly. Aircraft type classification and the rules of aircraft navigation, rules of aircraft locating in airspace and other requirements are provided by individual acts of a particular country. However, statistics on air accidents of UA boards (for example aviation accidents dynamics was analyzed with more than 70 UAVs during period 2014-2015, which are in service of defense intelligence of different countries [2]) shows that the trends of risks with UAVs' are similar to the risks of "large" commercial civil aviation accidents, particularly as it concerns the technical component and human factors [3].

Consequently, it seems appropriate to use the method of analogy in order to mark the qualitative and quantitative components of risks that must be considered by developers, manufacturers and operators of UAVs.

3. Solution

In fact, risk is a probability of unforeseen losses in a situation of uncertainty [4]. From the perspective of CA, the risk is understood is the future impact of a hazard that is not controlled or eliminated. It can be viewed as future uncertainty created by the hazard. If it involves skill sets, the same situation may yield different risk [5]. Depending on the causes and the opportunities for elimination, there are two components of risk, namely: non-specific and specific elements.

Non-specific element of risks is conditioned by the external circumstances of universal, i.e. macro character. Non-specific element of risks equally affects the possible market performance. This element includes property relations, regional monopoly, socio - political situation, environmental risks, economic crises, etc. This element of risk is not considered in the article because it is practically impossible to manage this part of risks for the designer, manufacturer or aviation engineering (AE) operator [6].

However, the specific element of risk is by far the type of business risk which is caused by specific features that pertain to particular business activity. This element of risk appears merely at the level of business activity and has no macroeconomic shape. Accordingly, specific element of risk can be considered as a major risk type for CA.

It is common to assume that the most general risks which have a systematic nature are allocated to the specific risks for manned CA (Table 1).

It is known that the main feature of the air transport system of CA is ensuring aircraft flight safety. If risks 4,5,6,7 and 8 (see Table 1), as evidenced of CA current practice, can be adjusted by the state or relate only to the operator and the manufacturer, whereas the specific risks 1,2,3 and 9 can be referred to the sphere of developer regulations or, using a mixed approach, to two or all three subjects of aviation activity. Overall, it concerns the general issues of flight safety, of aircraft (AC) reliability, staff qualification, control and quality management, etc. [7].

Table 1

Types of main specific risks in civil aviation

№	Risk formulation	Applicable methods/techniques of reduction
1	Increasing cost of aviation fuel	Increasing aircraft fuel efficiency. Applicable to operator and developer.
2	Growing cost of services of aircraft repair	Improving AC reliability. Applicable to developer and manufacturer.
3	Increasing cost of continuing service life and further equipping of the aircraft	State regulation. Applicable to operator, developer and manufacturer.
4	Rising of airport and air navigation charges	State regulation is applied. Concerned with the operator.
5	Increasing of agent fees and other significant components of cost(flight hour, ton-km, pass-km)	Large carriers benefit from the developed route network. Can be regulated by the State. Concerned with the operator.
6	Increasing cost for renovation of airline fleet (purchase new / used aircraft)	An important factor in reducing these risks is state regulation of prices for services of natural monopolies: aircraft repair plant; design bureaus; AE manufacturers and airport services. Applicable to operator and manufacturer.
7	Increasing of air tariff	At present situation, when supply shortage is expected on the domestic market, tariffs increase is inevitable, but it will play a positive role because the financial capacity of aviation market will be increased and will not lead to a critical decline in transportation. Applicable to operator.
8	Seasonality of air transportation/aerial work	Large carriers benefit from the developed route network, able to adapt its airline structure during seasonal fluctuations of the market. The impact of this factor is partially offset by flexible seasonal tariff policy that maximizes income or diversification (change) of the airline activity. Applicable to operator.
9	Growing operational risks on air transport	Ensuring AC flight safety. This risk is insured, and therefore threatens by the financial and reputational losses of airlines. Applicable to operator, developer and manufacturer.

Moreover, the risk №9 in CA is insured and therefore threatens not only the financial and reputational (image) losses of airlines.

Specific risks 1,2,3 and 9 (see Table 1) respectively are caused by certain factors which are generalized to reasons caused related to people (human factor) and engineering drawbacks.

A more detailed distribution of all causes of aviation accidents in manned CA are shown in Table 2. In fact, the causes of aviation accidents do not occur in "pure" form: usually aviation accidents result from a combination of several reasons.

Based on statistics during 2009 - 2010 the majority of aviation accidents in manned aviation were related to drawbacks of AC crew activity [8]. This is a consequence of shortcomings in the work carried out in this direction by airlines.

If we assume 1,0 as the common weight of all the causes of aviation accidents, then from the distribution in Table 2 human factor can be considered as the main cause of aviation accidents in manned CA - 0,61, and the remaining four factors share only 0,39. Solution to the problem of significant influence of the human factor in CA can be found by applying a systems approach to safety management based on comprehensive consideration of human factors at all levels of air transport system (ATS) [9].

Using analogy to consider the probable distribution of causes for aviation accidents in unmanned aviation, it can be asserted that the causes shall be similar to CA since the features of ATS which includes UAs as movable fleet shall not be different in context. The aims and objectives of ATS which includes UAs are the same, i.e. to ensure flight safety and provide a competitive service in the market, namely transportation of goods or performance of aviation works [10]. In view of the above said, we can assume that the distribution of aviation accident causes for UA in comparison to the manned aviation can be suggested as follows (see Table 3).

Table 2

Distribution of aviation accidents in manned CA

№	Causes of aviation accidents for manned AC	Specific weight
1	Flight crew (human factor)	0,61
2	The organization of air traffic control	0,11
3	AC design drawbacks	0,11
4	Meteorological Supply	0,09
5	AC maintenance	0,08

Factor №1 will have much less impact on the safety due to the high level of automation and triple redundancy system of unmanned board. Therefore, much less human intervention is observed in flight navigation on all phases of flight, from releasing the brakes at the start of their "chucking" after unmanned aerial vehicle (UAV) run. However, in the "transitional" areas, including the board transfer from one operator to another within one Ground Control Station (GCS) or between two GCSs, problems may happen. Also, problems may arise in the process of drawing up the route of flight and during before-flight checks if they are not automated.

Factor №2 will have much less impact on safety given that a tried and tested system of Air Traffic Control shall be used with appropriate operating standards in CA and technical equipment.

Factor №3 indicates that not only the UAV board but also the GCS and Data Link (DL) need to be considered, i.e. an integrated Unmanned Aviation System (UAS). For example, in 2102, the State Aviation Administration of Ukraine considered the application for type certification of UAV M-7V5 "Sky Patrol" that consists of the UAV itself and its GCS. Direct and return data link between UAV and GCS are certified as well, indicating holistic certification of the UAS.

Since the general approaches to formation of the ATS that includes the fleet of UAVs are being formed today, and it is familiar that the flight safety of AE is being established at the stage of design and creation, so it is possible to identify in advance the directions of the activities and corresponding operators that will affect the right decision in terms of the future level of flight safety of unmanned AC.

First of all, it should be noted that the formation of the safety level and research in this area takes several stages.

At the initial stage fields of boundary parameters and modes of flight, in which the UAV performs the specified functions are defined. These values are determined by aerodynamic and strength calculations, and then it is possible to set the limits of their use with regard to the constraints and assumptions [11].

At the second stage all possible characteristics that allow considering UAVs outside the acceptable parameters are defined. This aspect should cover the fault of UAV itself and failure of all elements of UAS. Among other, the review of the anticipated operating conditions is performed, as in some cases these conditions worsen the negative impact on UAV destabilizing factors. The specified requirements in projects of relevant design and certification documents are formalized. The main document is the certification basis of AC.

At the third stage, the flight safety requirements to all other elements of ATS are developed based on mathematical models of reliability and UAV safety based on practical skills and real aviation accidents.

Factor №4 will probably be the same for all ACs in the airspace. Technical support of a particular board with the appropriate instruments will make an effect, for instance, with meteorological radar, regardless of whether the AC is manned or unmanned [12].

Factor №5 in some ways will exercise an effect similar to factor №3, since the main operator is a the design bureau (developer) which is intended to form the technical policy in relation to AC type during its all lifecycle.

It is indisputable that during operation of UAS, the role of the manufacturer and operator of AE cannot be underestimated. Probable distribution of main AE market operators (developer, manufacturer and operator) depending on the type of major specific risks in civil aviation is shown in Table 1.

Table 3

Probable distribution of reasons (factors) of aviation accidents in unmanned aviation compared to manned CA

№	Reasons of aviation accidents in manned AC as a part of ATS	Specific weight	Probable reasons of aviation accidents of unmanned AC as a part of UAS	Specific weight	Distribution inside the factor
1	Flight crew (human factor)	0,61	External crew of UAV (human factor)	Should be significantly below 0,61	Problems may occur during board transfer from one operator to another
2	Air traffic control management	0,11	Air traffic control management	0,11	Probably there is no difference in the distribution
3	Design drawbacks of a single AC	0,11	Design drawbacks of the UAS as a whole (may be more)	UAV	X -?
				GCS	У-?
				DL	Z-?
4	Meteorological Support	0,09	Meteorological Support	0,09 and can be less	Probably there is no difference in the distribution
5	Maintenance of individual AC	0,08	UAS maintenance (may be above 0,08)	UAV	К-?
				GCS	М-?
				DL	Н-?

4. Conclusions

1. Flight safety in civil unmanned aviation will depend on the influence from developers, manufactures and operators of AE at specific business risks.

2. The most important specific risks in civil UA, by analogy with manned aviation, are the increase in the cost of aviation fuel, rise in the cost of UAV repair services and increased operational risks to air transportation.

3. In general, the reasons (factors) of aviation accidents in civil UA probably are similar to the

factors engaged in manned aviation, however, they differ in terms of distribution within individual factors.

4. The following factors have the most significant differences from the analogue: external flight crew of UAV (human factor), design drawbacks of UAS as a whole and UAS maintenance.

5. With no obvious differences from the analogue, the risks related with air traffic control management, as well as the meteorological support risks shall exercise their influence.

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Визначення ризиків в цивільній безпілотній авіації

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Мета: Ризики у безпілотній авіації цивільного призначення розглядаються як одні із найважливіших. У статті обгрунтовано актуальність питання забезпечення безпеки польотів повітряних суден та розглянуто основні ризики в пілотованій цивільній авіації. **Методи:** Проведено аналіз даних про авіаційні події та проведено розподіл ймовірностей виникнення авіаційних подій для пілотованої та безпілотної цивільної авіації з метою виявлення факторів, які впливають на виникнення позаштатних ситуацій у пілотованій і безпілотній авіації. **Результати:** Запропоновано типологію складових ризиків у цивільній авіації, систематизовано способи та прийоми зниження ризиків. На основі аналогій визначено ймовірні ризики, причини їх виникнення та шляхи подолання в цивільній безпілотній авіації. Обґрунтовано розподіл вагових коефіцієнтів між типами ризиків задля формування рекомендацій з управління ризиками у безпілотній цивільній авіації. **Обговорення:** Встановлено, що найбільш ймовірними ризиками у пілотованій цивільній авіації є людський фактор, організація управління повітряним рухом, недоліки конструкції безплотної авіаційної системи в цілому, а також обслуговування безплотної авіаційної системи.

Ключові слова: авіаційна транспортна система; безпілотне повітряне судно; ризики в цивільній авіації; фактори авіаційних подій.

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Определение рисков в гражданской беспилотной авиации

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Цель: Риски в беспилотной авиации гражданского назначения рассматриваются как одни из важнейших. В статье обоснована актуальность вопрос обеспечения безопасности полетов воздушных судов и рассмотрены основные риски в пилотируемой гражданской авиации. **Методы:** Проведен анализ данных об авиационных происшествиях и проведено распределение вероятностей возникновения авиационных происшествий для пилотируемой и беспилотной гражданской авиации с целью выявления факторов, влияющих на возникновение внештатных ситуаций в пилотируемой и беспилотной авиации. **Результаты:** Предложена типология составляющих рисков в гражданской авиации, систематизированы способы и приемы снижения рисков. На основе аналогий определены вероятные риски, причины их возникновения и пути преодоления в гражданской беспилотной авиации. Обоснованно распределение весовых коэффициентов между типами рисков для формирования рекомендаций по управлению рисками в беспилотной гражданской авиации. **Обсуждение:** Установлено, что наиболее вероятными рисками в пилотируемой гражданской авиации является человеческий фактор, организация управления воздушным движением, недалеко конструкции бесплотной авиационной системы в целом, а также обслуживание бесплотной авиационной системы.

Ключевые слова: авиационная транспортная система; беспилотное воздушное судно; риски в гражданской авиации, факторы авиационных происшествий.

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