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SAFETY RISK AS A TOOL FOR PUBLIC SAFETY ZONES ASSESSMENT AROUND THE RUNWAYS

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РИЗИК ЯК ІНСТРУМЕНТ ОЦІНКИ ЗОН ГРОМАДСЬКОЇ БЕЗПЕКИ НАВКОЛО ЗЛІТНО-ПОСАДКОВИХ СМУГ

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РИСК КАК ИНСТРУМЕНТ ОЦЕНКИ ЗОН ОБЩЕСТВЕННОЙ БЕЗОПАСНОСТИ ВОКРУГ ВЗЛЕТНО-ПОСАДОЧНЫХ ПОЛОС

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Introduction. World Health Organization (WHO) considers that road traffic-related injuries are a major but neglected global public health problem, requiring coordinated efforts to ensure their effective and sustainable prevention [1]. The number of persons killed in road traffic accidents is estimated at over 1 million per year worldwide, while the number injured could rise up to 50 million [1]. Although the number of people impacted by aircraft accidents is several orders of magnitude lower, this number is bound to rise due to the growth of air traffic. As a result, the importance of air traffic safety and its third party risk is bound to rise on the policy agenda. Approaches to improving traffic safety fall into three broad groups: engineering measures (e.g. airport design and air traffic management), vehicle design and equipment (e.g. seat belts for passengers) and operational measures (e.g. speed limits, and restrictions on drinking for pilots and drivers). Since the last major WHO world report on road traffic safety issued over 40 years ago [2], there has been a major change—a paradigm shift—in the understanding of and practical approaches to traffic injury prevention among traffic safety professionals. One of the main elements of this shift was the realisation that transportation safety is a multi-sectoral and public health issue: all sectors need to be fully engaged in responsibility, action and advocacy for crash injury prevention while traditionally transportation safety has been assumed to be the responsibility of the transport sector [1].

Risk assessment can be defined as “a systematic approach to estimating and comparing the burden of disease and injury” resulting from different hazards. According to [3], the first global estimates of disease and injury burden attributable to a set of hazards were reported in the first global burden of disease study [4, 5]. All the defined risk factors that were assessed were either exposures to the environment (for example, unsafe water), human behaviour (for example, tobacco smoking [6]) or physiological states (for example, hypertension [7]). There was a lack of comparability between the different risk factor assessments in this study due to different degrees of uncertainty in risk factors and non-standard comparison groups.

History of Third Party Accidents

The convergence of air traffic over areas surrounding airports implies for people living in the vicinity an involuntary exposure to a number of impacts, such as aircraft accidents [8, 9]. Whilst crashes with significant casualties are infrequent, most aircraft accidents occur on take-off or landing (Figure) and people on the ground near airports run a heightened risk of death or serious injury. Even though only 6% of a flight is spent in the landing or take-off phases, most fatal accidents happen in these two phases. A fatal injury is defined as an injury that results in death within 30 days of the accident. Fatal injuries are further sub-divided into on-board fatalities and third party fatalities. If fatalities concern persons outside the aircraft (and not involved in their operation and maintenance), then they are treated as third party fatalities. In this case, the first party is the aviation personnel (who provide the air transportation service) and the second party the passengers (for whom the air transportation is provided). Accordingly, such a risk is known as Third Party Risk (TPR) when the people exposed are there for reasons unrelated to aviation, for instance people living in the airport vicinity.

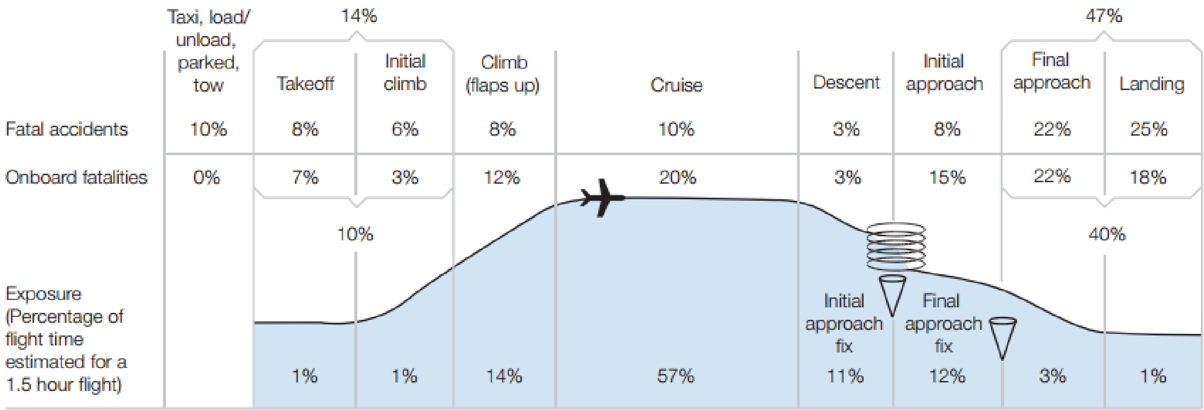

Figure 1. Percentage of fatal accidents by flight phase (worldwide commercial jet fleet, 2004–2013) [8]

Urgent reviews of TPR around airports should be carried out and strict land use policies developed to reduce the numbers of people at risk, preferably with independent health and safety authorities (legally obliged to provide this kind of protection) taking the leading role. There are a number of ways in which the environmental impacts of airports are currently regulated. Planning regimes and policies exist at local, regional and national levels and provide a framework that allows airports to seek permission to construct and operate facilities—runways, passenger terminals and so on—and expand to meet demand. These actions are subject to scrutiny of varying degrees. A zoning policy with land use restrictions applied to residential and commercial development, and transport links based on rigorous risk assessment, consequence and cost benefit analysis (including societal risk) should underpin the definition of protection zones. In the TPR context, these zones are usually called Public Safety Zones (PSZs). The stated aim of this policy is: “to minimise the number of people on the ground at risk of death or injury in the event of an air crash on take-off or landing”.

Table 1 gives an indication of events where aviation related objects (aircraft, aircraft parts and ice from aircraft) have hit third parties or their property. In the 10 years reported, there were two injuries as a result of these events, in 1994 and 2000. Both resulted from falling ice and/or debris created by such a fall. The term ‘Falling Aircraft’ below indicates events where a whole aircraft has struck or ended up on third party property, e.g. the Air Algeria B737 on 21 December 1994.

Table 1 Events where aviation has impinged on third parties, 1992-2001

Incident type	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Icefalls	23	25	26	23	33	36	29	34	39	34
Falling Aircraft Parts	17	13	16	10	19	14	17	7	10	5
Falling Aircraft	2	3	3	2	5	4	3	2	6	4

Local risk levels around large airports are of the same order of magnitude as those associated with road traffic. Because an increase in airport capacity usually involves changes to runway and flight route layouts, and air traffic distributions among them, which in turn affect the risk values around the airport, TPR is an important issue in decision making on airport development [9]. Wherever major terminal, runway or other capacity enhancing developments trigger Environmental Impact Assessments (EIAs) [10], mandatory third party risk assessment should also be undertaken as part of the EIA process. The European EIA Directive 85/337/EEC does not specifically require a TPR assessment; however, as it requires the assessment of the direct and indirect effects of a project on human beings, TPR aspects can be taken as implicit. (For amendments of the Directive, see 2011/92/EU and 2014/52/EU.) Although at present of less significance than noise and air quality, it is widely believed that third party risk is moving rapidly up the policy agenda.

The results of this could be increased constraints on airport capacity and obligations on operational stakeholders to act to meet regulatory requirements.

Third party risk deals with risk to an individual on the ground of being killed or injured by an aircraft; these accidents are also called groundling accidents (an aviation accident involving groundlings). The concept of TPR or *external* risk was first analysed in the nuclear and chemical industry since the risk of the release of substantial amounts of radioactive or otherwise toxic substances poses direct a threat to the environment and therefore has to be managed [8, 4]. For the chemical and nuclear industry, the term ‘external’ refers to everything happening outside the nuclear or chemical plant (for example, incidents during the transport of toxic or radioactive materials of the plant or leaks from storage facilities to the environment), whereas ‘internal’ refers to everything inside the plant (any kind of internal accidents or incidents, for example as a consequence of technical failures and/or operator errors). The distinction between external and internal safety is pertinent as there are various additional safety measures, such as secondary containment; these measures can mitigate or even prevent the escalation of internal losses of containment to external. For nuclear reactors, prevention measures such as concrete domes around reactors can prevent negative consequences for third parties in populated areas [11].

The concept of external risk is also relevant in transport systems, such as aviation; nevertheless, there are also notable differences. Contrary to chemical or nuclear plants, aviation systems are not static: the main threats are posed by aircraft flying to and from the airport. Hence aviation risks are also produced outside the airport perimeter. Consequently, in the case of aviation risk containment at the source is not possible as for static facilities [8, 4] Potential risks of aircraft accidents and their effects should be considered when planning activities involving large groups of people in airport proximity. As an increase in airport capacity usually involves changes to runway and route layouts, and aircraft traffic distributions within them, this in turn affect the risk levels around the airport, making third party risk is an important issue in decision making on airport development.

Systematic assessment of risk has addressed public concerns at Public Inquiries and in EISs and has helped to produce a batter informed overall assessment of airport development plans. Hence there are a number of positive aspects that could flow from more attention to third party safety, just as has happened in major hazard industries (e.g. chemical). Public concerns over safety around airports will not go away. Therefore, in order to enable airports to develop long-term plans for the future, these concerns need to be addressed.

Basic Risk Concepts and Their Mathematical Formulation

Generally speaking, *safety* is defined as the property of a system not to cause damage to human health or the environment. However, in practice the safety of a system cannot be taken as a total absence of hazards and the objective is not to eliminate all risks regardless the cost; the aim is to bring the risks to an acceptable level. The concept of safety is complex and difficult to understand in all its dimensions—physical, social and psychological—and, therefore, difficult to manage. Safety has been defined in [9] as “a state in which hazards and conditions leading to physical, psychological or material harm are controlled in order to preserve the health and well-being of individuals and the community. Safety is the result of a complex process where humans interact with their environment, including the physical, social, cultural, technological, political, economic and organisational environments.” Effective safety enhancement requires the use of an integrated approach, taking into account its different facets in a comprehensive framework [1]. Major accident investigations, particularly in nuclear power production, have identified poor safety culture as a causal factor increasing the probability and severity of occurrence of accidents and their consequences [**Ошибка! Источник ссылки не найден.**4]. A proactive approach that would allow the integration of safety culture at the organizational level is needed in order to prevent undesirable behaviours and practices in safety-related functions even before any accident occurs. The safety culture concept explains how the lack of adequate knowledge and understanding of as well as the (low) priority placed on risk and safety among managers and employees can contribute to disasters.

Risk is assessed by identifying hazards and determining the probability of the consequences that arise from them. The procedure of risk assessment is essentially a probability calculation. The probability might be formulated as the average value of the realization of the event during a given time period. The basic idea of risk assessment is to identify or quantify risks, at least in comparative form (qualitatively) with respect to other risks. Risk assessments can be complex and cover a variety of risks. The relation of risk to hazard may be formally expressed as:

$$\text{Risk} = f(H \text{ x } E) = f(H \text{ x } D \text{ x } t), \quad (1)$$

where *f* is a function, *H* is a hazard, *E* is an exposure, *D* is a dose and *t* is time. A risk is here defined as a measure of the probability that harm will occur under defined conditions of exposure to a stressor.

In general, the *danger* is the location of objects and combination of conditions or situations that may result in harm to human health or environment, or in material damage. *Hazard* is the potential of all or any of them to cause damage. *Stressor* (synonymous with the terms ‘agent’ or ‘factor’) is any physical, chemical or biological entity (a phenomenon, object, substance, etc.), which may cause an unacceptable response, usually called *damage*. *Receptor* is an entity that is exposed to the stressor. *Exposure* is the phenomenon of a stressor’s contact with the receptor. The effect is determined by the potential consequence to the receptor, most often in the form of damage caused by a danger that exists at a particular state of the system under consideration. *Vulnerability* is used as a set of conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a receptor (community or an individual) to the impacts of hazards. In other words, vulnerability is an inability to avoid or absorb potential harm in case of exposure to risk. Conceptually, hazard and vulnerability interact producing and amplifying risk as shown in Figure .

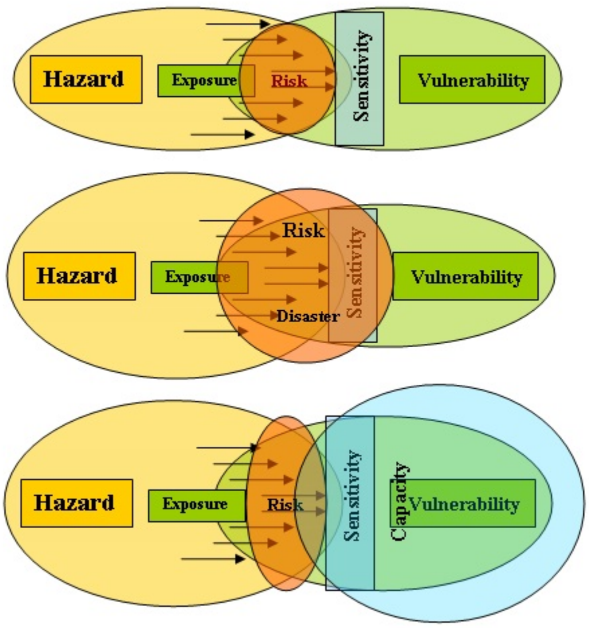

Figure 2. Hazard and vulnerability interference in risk production (source: NAU)

The severity of hazardous events is categorized as follows according to the European Space Agency standards [6, 15, 3]:

Catastrophic hazards

- Loss of life;
- Life threatening or permanently disabling injury;
- Occupational illness;
- Loss of an element of the interfacing manned flight system;
- Loss of launch site facility;
- Long-term detrimental environmental effects.

Critical hazards

- Temporarily disabling (not life threatening injury);
- Temporary occupational illness;
- Loss of, or major damage to flight systems, major flight system elements;
- Loss of, or major damage to ground facilities;
- Loss of, or major damage to public or private property;
- Short-term detrimental environmental effects.

The opposite characteristic to vulnerability and important criteria for risk assessment is the *capacity* of a person or group or society as a whole to anticipate, cope with, resist and recover from the impacts of a hazard [14]. First of all, capacity is defined by the knowledge of persons of possible hazards or threats, their stressors, exposures and vulnerabilities. Secondly, capacity implies the knowledge and skills of persons on how to protect themselves. It is governmental responsibility to provide these knowledge and skills to citizens and to provide the means for personal and collective protection and prevention. In some cases, the term *capacity* also means the positive managerial capabilities of a receptor (individuals and communities) to confront the threat of disasters, accidents, etc. (e.g. through awareness raising, early warning systems and preparedness planning).

Since different disciplines are working with the concepts of hazard, vulnerability and capacity, all the concepts have broadened and deepened over time. The conceptual formula for risk assessment from Eq. 1 has evolved as follows (exposure and/or dose are omitted here):

Conceptual formula for risk assessment:	Main attributes to risk assessment:
Risk = H	Hazard (H)
Risk = $H \cdot V$	+ Vulnerability (V)
Risk = $H \cdot V / C$	+ Capacity (C)
Risk = $H(V,C) \cdot V(H,C) / C(H,V)$	Complex interactions between all attributes

Risk is generally defined as a combination of the probability of an event and the severity of that event. Two measures of risk are mainly used in TPR analyses: **Individual Risk** (IR) and **Societal Risk** (SR). In an airport context, individual risk represents the probability that a person permanently residing at a particular location in the airport vicinity is killed as a direct consequence of an aircraft accident. Societal risk is defined as the probability that a given number of people are killed on the ground. While individual risk is location-specific, societal risk applies to an entire area around the airport (Figure). Societal risk only exists when there are people residing near the airport (in an unpopulated area, societal third party risk is equal to zero by definition), whereas location-specific individual risk values can be calculated regardless of the number of inhabitants—it is a characteristic of the source of hazard.

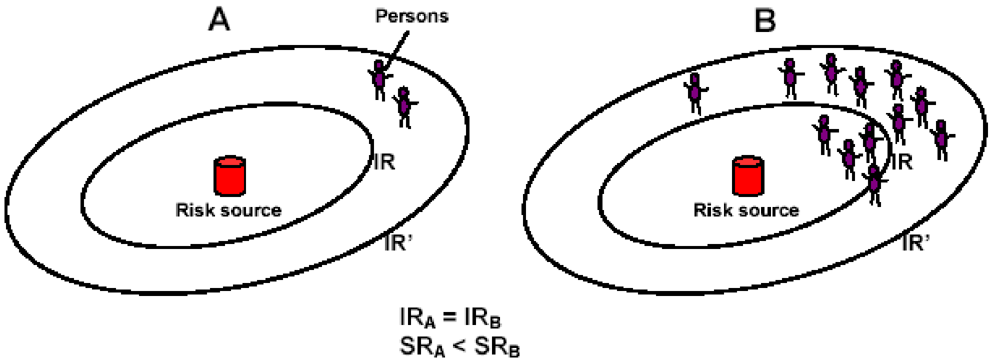

Figure 3. Difference between individual and societal risk

The criteria for acceptable/unacceptable risk levels vary according to the type of risk and country. Generally speaking, risks above 1 in 100,000 per year (1 in 10,000 for workers) are judged ‘unacceptable’. Risk levels of less than 1 in 100 million per year can be considered ‘acceptable’. The risk level of 1 in 1 million per year is often ‘acceptable’. The level associated with ‘unacceptable’ risk can be thought to correspond to roughly 10% of the risk level of various ‘voluntary’ risks such as driving. This level is similar to the higher ‘involuntary’ risks, such as being murdered or hit by a car. These everyday risk figures are merely averages and clearly there might be very significant variations due to different lifestyles. Determination of individual and societal risk is shown schematically in

Table 2.2.

Table 2. Schematic view of individual and societal risk determination

Pdf of initial effects $f_{I_0}(I_0)$		**Individual risk**	**Societal risk**
Dispersion modelling for exposure assessment $I(I_0,x,y)$	$F^*_D(I_0,x,y)$		
Dose response function $F_D(I)$			

Two measures of risk are mainly used in TPR analyses: individual risk and societal risk. Individual risk represents the probability that a person residing permanently at a particular location in the airport vicinity is killed as a direct consequence of an aircraft accident. Individual risk is used in TPR contours assessment and in Public Safety Zone definition. While individual risk is location-specific, societal risk applies to an entire area around the airport. Societal risk is defined as the probability that a given number of people are killed. The F_N-curve represents the cumulative distribution of multiple fatality events and is therefore useful in the representation and assessment of societal risk.

Individual Risk to life has a range of numerical values [**Ошибка! Источник ссылки не найден.**6]:

- Accidents with a death rate 10^{-6} are not usually noticed by the society; however, accidents with a frequency of 10^{-3}—10^{-4} are regarded as something to be prevented.
- The permitted level of individual risk, for which regulatory action is taken to reduce public risk, is identified in a range between 10^{-4}—$5 \cdot 10^{-5}$ per year. In some cases, the regulatory effect can be applied at lower values of risk depending on the number of population, which is exposed to a hazard.
- The minimum level of individual risk, which does not require regulatory action to reduce public risk, can be given at 10^{-7}.
- The upper limit of acceptable risk to a third party in the vicinity of a power plant or transport network is around 10^{-4} per year (usually it is predefined legally from how the risk is perceived by society and hence regulatory authorities: it reflects the culture of the society and changes with time as more information becomes available)

The main calculation formula of current TPR models involves three main components: accident probability $P(I)$, accident crash location conditional probability $P(G|I)_{ijk}$ and accident consequence conditional probability $P(T|G)_{ij}$. As a consequence, TPR models rely in general on three main building blocks: accident probability, accident location and accident consequence models. The probability of an aircraft accident in the vicinity of an airport is calculated based on the probability of an accident per aircraft movement and the number of movements (landings and take-offs) per year. Risk dependence on location is represented by accident location models. The distribution of accident locations can be modelled through statistical functions as a function of the distance to arrival and departure routes or to the runway. By bringing together the accident location model and the accident probability, the local probability of an accident can be calculated at each location in the airport vicinity. The dimensions (or simply a given radius) of the impact location area depend on various aircraft and crash-related parameters (aircraft size, quantity of fuel on board, impact angle, etc.) and on the characteristics of the terrain. The influence of these parameters as well as the impact area and the accident consequences are defined by a consequence model. The lethality is in this respect defined as the actual probability of being killed within the impact area.

Conclusion. A number of third party risk models exists and are used for SR assessment for the airports under consideration, for IR calculations in points of risk control or for determining IR contours. The most well-known and used models—and particularly the original European models created by NATS Model (UK and Ireland) and NLR—were analysed and compared.

The EU Directive Seveso III [17] requires the Member States to limit the consequences of major accidents for human health and the environment in their land-use policies; this is done by controlling the siting of new establishments and developments including transport routes, locations of public use and residential areas when these developments may create or increase the risk or consequences of a major accident. In addition, appropriate safety distances should be maintained between major transport routes and residential areas, buildings and areas of public use, as far as possible. Public Safety Zones (PSZ) are defined as areas of land at the ends of runways, within which development is restricted in order to limit the number of people on the ground exposed to a risk of death or injury from an aircraft accident on take-off or landing. PSZs around airports are the particular examples of the Seveso policy requirements in EU Member States.

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РЕФЕРАТ

Запорожець О.І. Ризик як інструмент оцінка зон громадської безпеки навколо злітно-посадкових смуг. О.І.Запорожець // Вісник Національного транспортного університету. Серія “Технічні науки”. Науково-технічний збірник. – К.: НТУ, 2016. – Вип. 2 (35).

В статті виконано узагальнення та порівняння відомостей щодо ризику третьої сторони в околиці аеропорту.

Об'єкт дослідження - зон громадської безпеки навколо злітно-посадкових смуг аеропортів.

Мета роботи - визначення і обґрунтування зон громадської безпеки навколо злітно-посадкових смуг аеропортів.

Метод дослідження - аналіз, узагальнення та порівняння наявних відомостей про зони громадської безпеки навколо злітно-посадкових смуг аеропортів.

Використання оцінки ризику третьої сторони для обґрунтування зон громадської безпеки навколо злітно-посадкових смуг аеропортів..

Результати статті можуть бути впроваджені в процесі експлуатації авіатранспортних систем.

КЛЮЧОВІ СЛОВА: АЕРОПОРТИ, РИЗИК ТРЕТЬОЇ СТОРОНИ, ЗОНА ГРОМАДСЬКОЇ БЕЗПЕКИ

ABSTRACT

Zaporozhets O.I. Safety risk as a tool for public safety zones assessment around the runways. Visnyk National Transport University. Series “Technical sciences”. Scientific and Technical Collection. – Kyiv. National Transport University, 2016. – Issue 2 (35).

In the paper the synthesis and comparison of the available information on third party risk in the vicinity of the airports presented.

Object of study - the public safety zones around the airport.

Purpose - to identify and study the prospects for public safety zones in the vicinity of the airports.

Research methods - analysis and comparison of available information on public safety zones in the vicinity of the airport.

The use of third party risk assessment to justify public safety zones around runways of airports.

The results can be incorporated into the operation of aviation vehicles in intelligent transport systems.

KEYWORDS: AIRPORTS, THIRD PARTY RISK, PUBLIC SAFETY ZONE

РЕФЕРАТ

Запорожец А.И. Риск как инструмент оценки зон общественной безопасности вокруг взлетно-посадочных полос / А.И. Запорожец // Вестник Национального транспортного университета. Серия "Технические науки". Научно-технический сборник. – К.: НТУ, 2016. – Вып. 2 (35).

В статье выполнено обобщение и сравнение сведений о риске третьей стороны в окрестности аэропорта.

Объект исследования - зон общественной безопасности вокруг взлетно-посадочных полос аэропортов.

Цель работы - определение и обоснование зон общественной безопасности вокруг взлетно-посадочных полос аэропортов.

Метод исследования - анализ, обобщение и сравнение имеющихся сведений о зонах общественной безопасности вокруг взлетно-посадочных полос аэропортов.

Использование оценки риска третьей стороны для обоснования зон общественной безопасности вокруг взлетно-посадочных полос аэропортов.

Результаты статьи могут быть внедрены в процессе эксплуатации воздушных систем.

КЛЮЧЕВЫЕ СЛОВА: АЭРОПОРТЫ, РИСК ТРЕТЬЕЙ СТОРОНЫ, ЗОНА ОБЩЕСТВЕННОЙ БЕЗОПАСНОСТИ

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