Mathematical Model of Airport Aviation Security

Olena Sokolova, Kostiantyn Cherednichenko(✉), and Viktoriia Ivannikova

National Aviation University, Kyiv 03058, Ukraine
cherednichenko.kostya@gmail.com

Abstract. Nowadays there is a duality in the definition of aviation security. In the study, the authors considered aviation security as a state of protection of aviation security from acts of unlawful interference, which is provided by a set of measures involving human and material resources. Current research on this topic leaves quite unexplored the impact of criminality and economic factors that could potentially affect the level of threats to the airport. Developed multiple regression aviation security model Schiphol Airport clearly demonstrates the importance of such factors, which have been deprived of attention among scientists. Potentially, the model could be expanded by creating a multi-level aviation security model that requires further research (particularly in terms of the Occam razor principle) and a significant sample of statistics. The obtained results confirmed authors assumption about the dependence of acts of unlawful interference and criminality of area in which the airport is located: there is a significant positive correlation; with an increase in criminality there is +0.017 increase in acts of unlawful interference. From a practical point of view, the developed model of aviation security allows to manage and forecast the level of danger in order to ensure the airport operation safety.

Keywords: Aviation security · Safety · Mathematical model · Risk · Interference · Airport

1 Introduction

Today, aviation security in Ukraine is dualistic: ICAO defines it as a combination of measures and human and material resources intended to safeguard civil aviation against acts of unlawful interference; Air Code of Ukraine (ACU) determines it as a protection of civil aviation (CA) from acts of unlawful interference (AUI), which is provided by a set of measures involving human and material resources [1].

Authors believe these statements is insufficiently disclosed and describe only a normative and legal aspects of security. It is recommended to understand this term as follows: according to the ACU, aviation security is one of the areas (subsystems) of civil aviation safety, defined as: "…the state of civil aviation with acceptable level…" [2]; therefore, if the supersystem is considered as a "state", then the subsystem must be interpreted in a similar way. Integrated and supplemented definition of aviation security - the state of

O. Prentkovskis et al. (Eds.): TRANSBALTICA 2022, LNITI, pp. 773–781, 2023.
https://doi.org/10.1007/978-3-031-25863-3_75

protection of aviation security from acts of unlawful interference, which is provided by a set of measures involving human and material resources. Typically, in order to assess the level of security, a comprehensive model is built, which consist of:

– the surface with a set of "vectors" by which the intruder could attack;
– risk, which is defined as a mathematical expectation (probability) of attack and losses from it;
– human and material resources designed to prevent and protect from attacks on civil aviation infrastructures.

However, in most of the analyzed scientific studies on this topic [2–7], the models of intruders (violators) either limited by the definition of "terrorism", or are not considered at all, which is inaccurate.

Intruders (violators) of aviation security may be divided into the following groups: "insiders" (dismissed employee; employee, responsible for an operational incident); "accidental" intruder (for example, burglars and robbers); terrorists. It should be noted that the last-mentioned group is the smallest in of incidents, but it is the most dangerous one.

The concept of terrorism has a very narrow field of interpretation, so today in counter-terrorism study, scholars use term "violent extremism", which includes "terrorism" [8–11]. Violent extremism (VE) is the phenomenon of non-state actors, or individuals, or organizations, who commit violence or contribute to it for social or political purposes, or promote ideas that rationalize, justify and encourage the mobilization of violence [8]. The VE also includes ideologically motivated crimes, such as hate crimes, which may not reach the threshold of terrorism.

The authors claim it necessary to, firstly, consider the term "violent extremism" in comprehensive model of aviation security; secondly - to analyze potential intruders (violators) by assessing the criminality of the area in which the airport is located.

It is critical to avoid a fundamental attribution error: to claim that airports with higher security and low operations values are "safer" than airports with lower security at higher operations is incorrect. Therefore, it is recommended to add to the complex model such indicators as passenger or freight traffic [12]. Such indicators could be also be used to in order assess the "attractiveness" of an airport for attack.

Also, the economic aspects remain rather unexplored, for example, the expanses on airport's security services and its impact on safety. The concept of CA security has some uncertainty: there is no clear definition "acceptable level" of damage risks, which indicates the diversification of costs dedicated to ensure such level.

2 Results

Schiphol Airport (Amsterdam, Netherlands) operations data was taken in order to create a mathematical model with the above assumptions.

The initial production statistics were taken from Royal Schiphol Group «Traffic Reviews» [13] (Table 1):

Table 1. Initial production statistics Amsterdam Schiphol Airport.

Year	Freight (in million tons) [13]	Passengers (in millions) [13]	Air transport movements (in thousands) [13]
2000	1,222	39,271	414,928
2001	1,180	39,531	416,462
2002	1,240	40,588	401,385
2003	1,310	39,960	392,997
2004	1,420	42,541	402,738
2005	1,450	44,163	404,594
2006	1,530	46,066	423,122
2007	1,610	47,794	401,888
2008	1,570	47,392	428,336
2009	1,290	43,523	418,742
2010	1,510	45,137	386,316
2011	1,520	49,681	420,349
2012	1,480	50,976	423,407
2013	1,530	52,569	409,835
2014	1,630	54,978	404,728
2015	1,620	58,284	424,728
2016	1,670	63,625	460,145
2017	1,760	68,515	484,000
2018	1,720	71,053	476,934
2019	1,570	71,700	496,826
2020	1,400	20,900	227,304
2021	1,670	25,500	266,967

Royal Schiphol Group's Annual Reports were also analyzed [14] on security costs and acts of unlawful interference (Table 2):

Table 2. Dynamics of security costs and AUI of Schiphol Airport.

Year	Aviation security expanses (in millions) [14]	Acts of unlawful interference [14]
2000	198	40
2001	203	42
2002	201	43
2003	199	43
2004	200	44
2005	203	46
2006	204	45
2007	221	40
2008	221	41
2009	241	32
2010	242	31
2011	261	36
2012	247	42
2013	232	23
2014	271	17
2015	238	41
2016	247	47
2017	293	46
2018	300	30
2019	270	35
2020	254	25
2021	243	24

In order to simplify the study, the number of cases of violence in Amsterdam were used as an assessment of criminality [15, 16]: (Table 3)

Table 3. Public violence in Amsterdam.

Year	Number of cases of public violence in Amsterdam [15, 16]
2000	570
2001	539
2002	609
2003	628
2004	646
2005	685
2006	636
2007	500
2008	501
2009	665
2010	585
2011	485
2012	465
2013	380
2014	305
2015	330
2016	295
2017	395
2018	260
2019	335
2020	250
2021	385

The multiple regression model was programmed with RStudio software. The results are presented in Fig. 1.

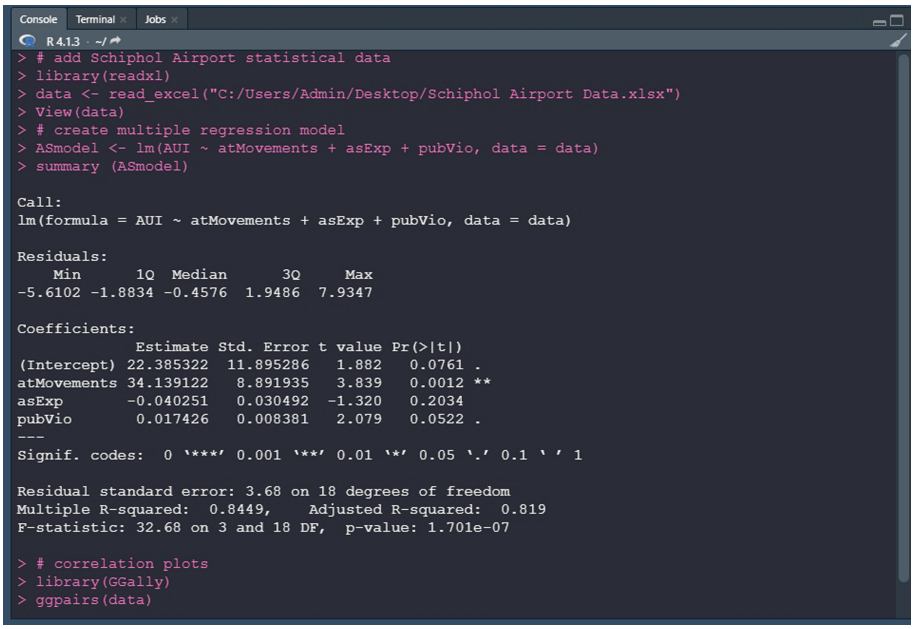

Fig. 1. Coded in RStudio aviation security multiple regression model of Schiphol Airport.

The results may be interpreted as follows:

- adjusted R-squared, which characterizes the accuracy of the model, is 0.819;
- there is positive correlation of AUI number and air transport movements; the significance is high ($p - value = 0.0012 < 0.05$); that means that every 100,000 operations lead to +3.4 AUI.
- negative correlation of AUI number and aviation security expanses; the significance is quite low ($p - value = 0.2034$); that means that every 1,000,000 EUR spent on security leads to the −0.04 of AUI; potentially, low significant may be explained in terms of "security theater" [17].
- positive correlation of AUI number and number of cases of public violence, the significance is quite high ($p - value = 0.0522$); that means that with an increase in criminality there is +0.017 increasement in AUI.

Correlation graphs (Fig. 2):

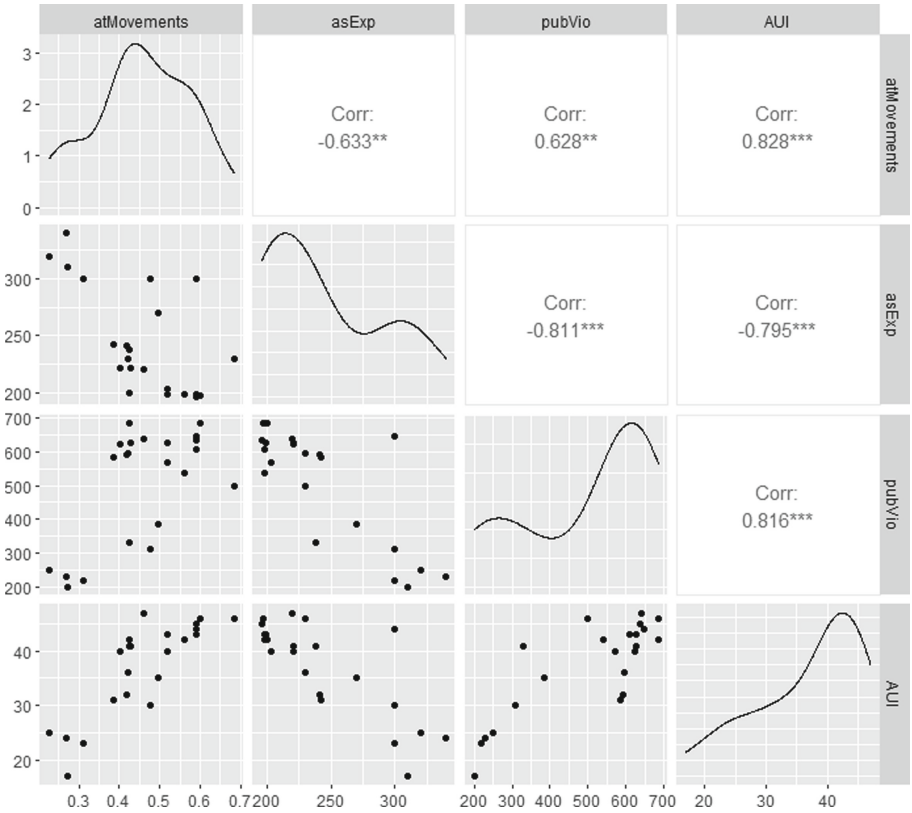

Fig. 2. Correlation of multiple regression model indicators.

The developed model could be presented mathematically:

$$AS_{Schiphol} = 22.3853 + 34.1391 \cdot \alpha - 0.0402 \cdot \beta + 0.0174 \cdot \gamma, \quad (1)$$

where $AS_{Schiphol}$ – acts of unlawful interference of Schiphol Airport; α – number of air transport movement, in millions; β – aviation security expanses, in millions of EUR; γ – number of cases of public violence in Amsterdam.

However, this model has certain disadvantages, namely:

- local optimum problem, which may be corrected in further research by a multi-level model development that includes performance indicators of other airports;
- the accuracy of the model may be improved by increasing the sample of statistical data, particularly, on acts of unlawful interference;
- potentially, such indicators as risk, human and material resources intended for the protection of civil aviation infrastructure may be added to the model in order to improve accuracy.

3 Conclusions

Aviation security should be defined as the state of protection of civil aviation from acts of unlawful interference, which is provided by a set of measures involving human and material resources. Modern researches on this topic are one-sided in aviation security models development: they ignore criminal and economic aspects that could potentially affect number of acts of unlawful interference and the level of threats.

During the study, a mathematical model of airport aviation security of the was developed, which includes the following indicators: 1) acts of unlawful interference of Schiphol Airport; 2) number of air transport movement, in millions; 3) aviation security expanses, in millions of EUR; 4) number of cases of public violence in Amsterdam. Developed with the RStudio multiple regression aviation security model clearly demonstrates the importance of mentioned factors, which have been undeservedly deprived of attention among scientists. Potentially, the model could be expanded (to increase accuracy) by creating a multi-level aviation security model that requires further research (particularly in terms of the Occam razor principle) and a significant sample of statistics.

The obtained results confirmed authors assumption about the dependence of AUI and criminality of area (presented in paper as the number of cases of violence) in which the airport is located: there is a significant ($p - value = 0.0522$) positive correlation; with an increase in criminality there is $+0.017$ increase in AUI.

From a practical point of view, the developed model of aviation security solves the attribution problem and allows to manage and forecast the level of danger in order to ensure the airport operation safety.

References

1. Cherednichenko, K.: Model of aviation safety intruder. XXII International Scientific and Practical Conference "Flight. Modern problems of science" (2022). https://bit.ly/3zu2I9o
2. Cherednichenko, K., Yanchuk, M.: Mathematical formalization of transport safety assessment (2020). https://bit.ly/3Qf8DF9
3. Lin, H.Z., Wei, J.: Optimal transport network design for both traffic safety and risk equity considerations. J. Clean. Prod. **218**, 738–745 (2019). https://doi.org/10.1016/j.jclepro.2019.02.070
4. Sdoukopoulos, A., Pitsiava-Latinopoulou, M., Basbas, S., Papaioannou, P.: Measuring progress towards transport sustainability through indicators: analysis and metrics of the main-indicator initiatives. Transp. Res. Part D: Transp. Environ. **66**, 316–333 (2019). https://doi.org/10.1016/j.trd.2018.11.020
5. Li, T., Rong, L., Yan, K.: Vulnerability analysis and critical area identification of publictransport system: a case of high-speed rail and air transport coupling system in China. Transp. Res. Part A: Policy Practice **127**, 55–70 (2019). https://doi.org/10.1016/j.tra.2019.07.008
6. McFarlane, P.: Developing a systems failure model for aviation security. Saf. Sci. **124**, 104571 (2020). https://doi.org/10.1016/j.ssci.2019.104571
7. Tamasi, J., Demichela, M.: Risk assessment techniques for civil aviation security. Reliab. Eng. Syst. Saf. **96**, 892–899 (2011). https://doi.org/10.1016/j.ress.2011.03.009
8. Jensen, M., Yates, E., Sheehan, K.: Extremism in the Ranks and After, START: College Park, MD (2021)

9. Szumowska, E., Czernatowicz-Kukuczka, A., Kossowska, M., Król, S., Kruglanski, A.W.: Truth and Significance: A 3N Model (Needs, Narratives, Networks) Perspective on Religion. In: The Science of Religion, Spirituality, and Existentialism, eds. Kenneth Vail III and Clay Routledge, pp. 225–242. Elsevier, London (2020)
10. Karagiannis, E.: European Converts to Islam: Mechanisms of Radicalization. Politics Religion Ideology **13**(1), 99–113 (2012)
11. Leiken, R.: Europe's Angry Muslims: The Revolt of the Second Generation. Oxford University Press, Oxford (2012)
12. Ivannikova, V., Shevchuk, D., Konovalyuk, V., Borets, I., Vysotska, I.: Estimation of the innovative technologies influence on passengers processing procedures at the airport. Transp. Res. Procedia **59**, 127–136 (2021). https://doi.org/10.1016/j.trpro.2021.11.104
13. Royal Schiphol Group. 2000–2021 Royal Schiphol Group traffic and transport figures (2021). https://bit.ly/3mD4IUZ
14. Royal Schiphol Group. 2000–2021 Royal Schiphol Group Annual Report. (2021). https://cutt.ly/bnWh8fi
15. Number of cases of public violence in Amsterdam (2022). https://bit.ly/3zoYhN6
16. Netherlands Crime Rate & Statistics 1990–2022 (2022). https://bit.ly/3myPGzE
17. Schneier, B.: Beyond Fear: Thinking Sensibly About Security in an Uncertain World. Copernicus Books, New York (2003)