Enhancement of the Methodology for the Selection of the Optimal Location of the Remote Tower Centre

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Abstract

Consistent and coherent development of regional airports of Ukraine to ensure enhancement of the air transportation network of Ukraine is one of the priorities outlined in the Ukrainian National transport strategy. The remote tower concept can be considered as one of the enablers for the development of the small regional airports of Ukraine. One of the steps of the implementation of the remote tower concept is a selection of the location for the remote tower centre/module and its facilities which is vital for the efficient and safe provision of air traffic services. The focus of the research is an enhancement of a methodology for the selection of an optimal location of a remote tower centre described in the previous research. The article elaborates on the factors that can have an impact on the decision of the selection of the location of the remote tower centre (e.g., the density of traffic, availability of resources, etc.) and provides a means to quantify and process the factors using the decision-making model under uncertainty to select the optimal location and minimise impact and risks related to the implementation of the remote tower centre.

Keywords

airport, air traffic control, air traffic management, decision-making process, decision-making under uncertainty, risk minimisation, regional airport, remote tower concept.

1. Introduction

A common issue for small regional airports across the world is a low level of air traffic that limits their ability for development and often does not allow them to be profitable. However, at the same time, these small regional airports provide necessary access points and expand the air transportation network with distant and remote locations and contribute to the development of the local economies [1, 2].

One of the tasks outlined in the National transport of Ukraine up to 2030 is to expand the air transportation network of Ukraine through consistent development of the regional airport of Ukraine that would serve as nodes in the air transportation network [3]. One of the ways to

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accomplish this task is to reduce the air transportation costs for airspace users and attract more flights to the regional airports of Ukraine.

Typically, airspace user costs for a flight consists of various components such as costs of maintenance and fuel, airport charges, air navigation services costs and so on. A decrease in one of these costs could lead to the overall reductions in the costs of air transportation and thus make flights to regional airports more attractive for airspace users.

One of the significant costs in the overall costs of a flight is the provision of air navigation services, specifically air traffic control in airports [4]. The decrease in air navigation service costs can be achieved through optimisation of the operational costs and enhancement of the overall efficiency of their provision. This has been addressed by several Single European Sky Air Traffic Management (ATM) Research (SESAR) solutions that were developed to improve the current operations at the airport and provision of the air traffic services (ATS). A few of those solutions are dedicated to the use of the remote tower concept for different operating scenarios and environments. This concept allows increasing the operational efficiency, flexibility, and safety at airports where building or maintenance of a conventional tower is not economically beneficial. The flexibility component becomes of utmost importance due to the issues experienced by the aviation industry as the result of the COVID-19 pandemic [5].

One of the stages of the implementation of the remote tower concept is the selection of the location for the remote tower centre/module and its facilities which is vital for the efficient and safe provision of the air traffic services. The focus of this research is to enhance a methodology for the selection of an optimal location of a remote tower centre described in [5]. The research is focused on the factors that can have an impact on the decision of the selection of the location of the remote tower centre (e.g. density of traffic, availability of resources, etc.) and provides a means to quantify and process the factors using the decision-making model under uncertainty to select the optimal location and minimise impact and risks related to the implementation of the remote tower centre.

2. Analysis of the current state of the Ukrainian regional airports

To analyse the current state of the regional airports, it is necessary first to establish which airports can be classified as regional ones in Ukraine. There is no single definition of the regional airports thus it can vary from the context in which it is used. According to Airports Council International (ACI) Europe, an airport can be considered as a regional if in general:

- serves short and medium-range flights;
- serves point-to-point connections [6].

European Commission defines regional airports as ones that have less than 3 million passengers per year [7]. Also, airports can be split into two types: hub and feeder. Hub airports are used to create a widespread air transportation network that connects a high number of flights with different departure and destination airports with transit in the hub. The feeder airport is one of the branches of such air transportation network and feeds the hub airports with connections to remote regions [8].

The airport network of Ukraine is composed of 29 certified airports (16 of which can serve international flights). Six airports (Kyiv Boryspil, Kyiv Zhuliany, Odesa, Lviv, Kharkiv and Dnipro) are considered strategic airports [9]. Thus for the Ukrainian context, regional airports can be defined as airports with a low number of flights, which serve point-to-point connections of short or medium range and provide connections for hub airports and are not considered as strategic airports.

Using the abovementioned definition of the regional airport, the following airports of Ukraine can be classified as regional ones: Poltava, Kherson, Rivne, Sumy, Vinnytsia, Zaporizhzhia, Uzhorod, Ivano-Frankivsk, Chernivtsi, Kropyvnytskyi, Kryvyi Rih, Mykolaiv, Kaniv Pekari, Ternopil, and Cherkasy. Five of those airports (Mykolaiv, Kavin, Pekari, Ternopil, and Cherkasy) provide aerodrome flight information service (AFIS) while others – air traffic service (ATS) in a conventional manner (using a facility, e.g., air traffic control tower located at the corresponding airport).

Most of the airports provide ATS or AFIS services for at least 8 hours a day (with some exceptions for weekends and holidays) which means that their air traffic control or flight information service units have to be manned by at least 4 air traffic control officers (ATCO) or aerodrome flight information service officers (AFISO) to ensure the safe and orderly provision of the services [10, 11].

For the period from June 2016 to January 2021 regional airports of Ukraine have served on average from 0 (the lowest) to 12 (the highest) number of regular flights per day meaning that the resources of the ATCOs/AFISOs were not used in the most efficient way. The distribution of the number of regular flights in the regional airports of Ukraine is presented in Figure 1 [12].

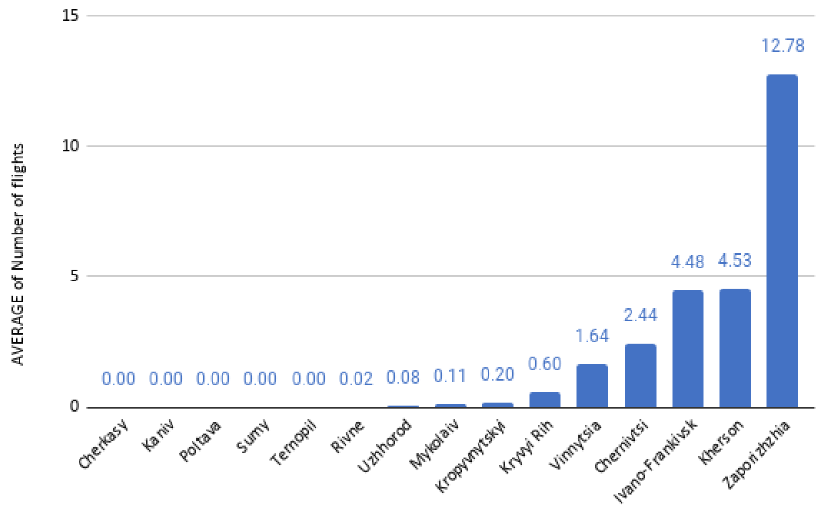

Figure 1: Average amount of daily flights (only for airports with more than 1 flight/day) for Ukrainian airports in the period from June 2016 to January 2021 [12]

Apart from that, some of the regional airports of Ukraine are affected by the seasonal variability of air traffic. This can be clearly seen in Figure 2 – more traffic during the summer season due to regular charter flights to touristic destinations and less or none during winter. The rapid drop in the number of flights for airports in the period from February 2020 to August 2020 can be explained by the restrictions introduced across the world due to the COVID-19 pandemic.

Due to the seasonal variability and low level of air traffic at the regional airports of Ukraine, it is not efficient to maintain local aerodrome control towers or aerodrome flight information service units to provide services to a small number of flights. One of the possibilities to optimize the use of the resources and increase their flexibility at regional airports of Ukraine is to deploy a remote tower concept that will be further detailed in the next section. [5]

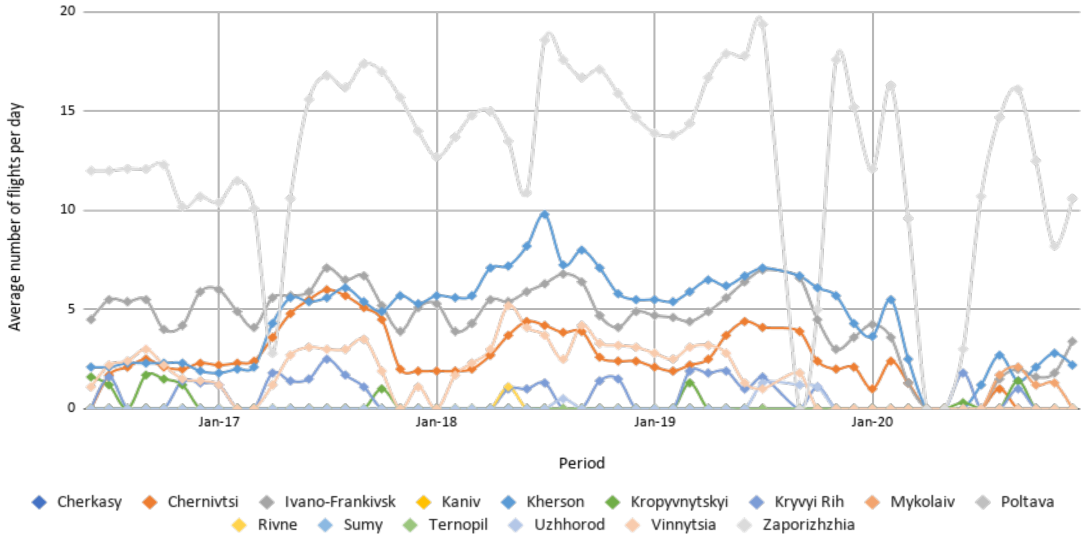

Figure 2: Evolution of the number of flights in regional airports of Ukraine over time (only for airports with more than 1 flight per day) [12]

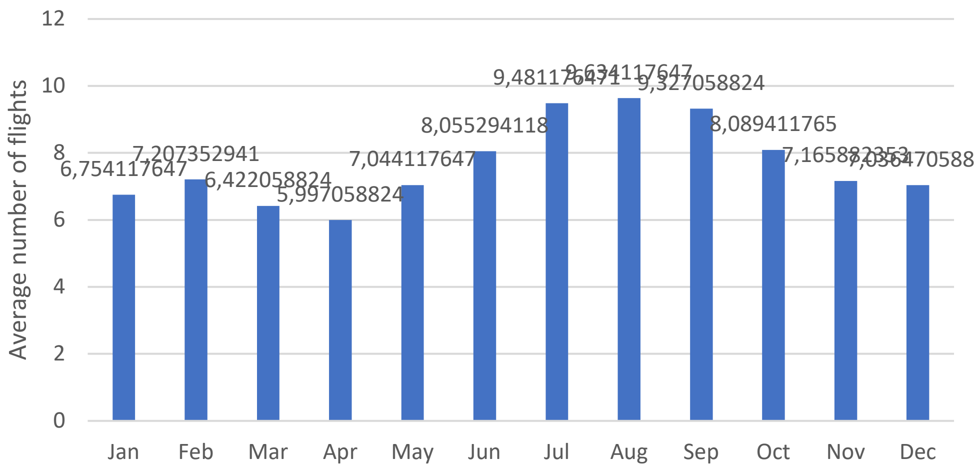

Figure 3: Distribution of average number of flights in regional airports of Ukraine per month (only for airports with more than 1 flight per day) [12]

3. Remote tower concept and its implementation

The core of the remote tower concept is the provision of air traffic services to one or multiple airports from a remote location. That's means that, in comparison with the conventional aerodrome control tower or AFIS unit, ATCO or AFISO do not have to be physically located at the airport to be able to provide services to it.

To provide ATCO/AFISO with the ability to visually observe and monitor the situation at the aerodrome and its vicinity, a set of cameras located at the aerodrome is used to provide out of the window (OTW) view. This OTW view can be also combined with data from other sensors (e.g. surface movement radars, ADS-B, and so on) to increase the situational awareness of the ATCO/AFISO. [13, 14, 15]

Different configurations have been envisaged for the implementation of the remote tower concept: remote provision of ATS to a single airport, remote provision of ATS to multiple airports and provision of remote ATS in contingency cases.

For the provision of the remote ATS, a remote tower module (RTM) that combines CWP and OTW view is set up. The RTM might contain more than one position (for example, for another ATCO or remote tower supervisor) depending on the complexity of the traffic and operating environment.

For the provision of the remote ATS to multiple airports, there are two possible configurations: sequential (RTM is connected to multiple airports but serve one airport at a time) or simultaneous (RTM is connected to multiple airports and serve multiple airports at the same time). The high-level diagram of the remote tower concept implementation is shown in Figure 3. [14, 15, 17]

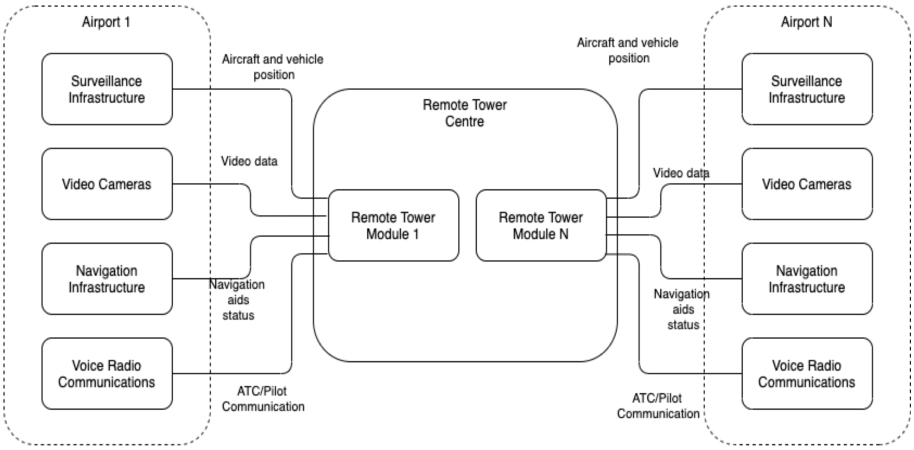

Figure 3: High-level diagram of the remote tower concept implementation

Conducted large-scale demonstrations showed that the most optimal implementation option in terms of the use of resources and reduction of the costs is a grouping of multiple RTMs in a centralised facility which is called remote tower centre (RTC). [18]

Sweden is the first country that has successfully implemented the remote tower concept in its airports. In 2015 a fully operational remote tower has been deployed at Örnsköldsvik airport with cameras located at the Örnsköldsvik airport and remote tower centre at Sundsvall airport. Later, the remote tower centre has been enhanced to also cover Sundsvall Timra airport.

At the end of 2020, Norway has opened the largest in the world remote tower centre located in Bodø. The final goal is to provide remote ATS to 15 airports in Norway by 2022. [19]

Another country that decided to implement the remote tower concept is Germany. Deutsche Flugsicherung (DFS), German air navigation service provider (ANSP) has launched a project to provide remote ATS to three airports: Saarbrucken, Dresden, and Erfurt. In 2018, ATCOs of Saarbrucken airport have been moved to Leipzig where a remote tower centre has been opened. It is planned to move the provision of ATS for Dresden and Erfurt to Leipzig as well. [20, 21]

Several other countries have decided to follow the same approach and launched projects to implement the remote tower concept. Those are – Belgium, the United Kingdom, Hungary, Denmark, etc.

4. Factors influencing the decision of the selection of the location for a remote tower centre

Selection of the location and facilities for the remote tower centre is one of the steps that have to be considered during the planning of the implementation of the remote tower concept. [17] In [5] an initial methodology for the selection of an optimal location for a remote tower centre has been described. However, it has been identified that the methodology is based only on one factor while a decision for the selection of the optimal location is influenced by multiple factors. The purpose of this research is the identification of those factors and enhancement of the methodology with them. The selection of the criteria is based on the subject-matter expertise due to the lack of information and research of factors influencing the selection of the location of the remote tower centre.

The first factor has been identified and partially described in the initial methodology – the distance between a possible location of a remote tower centre and airports within a segment. The initial methodology allows the grouping of airports into segments and obtaining a set of coordinates of an optimal location of the remote tower centre from the point of view of minimization of the distance between the RTC and airports within a segment.

The minimal distance is required to ensure stable and reliable network performance (through minimization of network latency or data transmission delay) since the remote tower concept relies heavily on real-time video and audio transmission for the cameras and communication infrastructure (e.g., radio equipment) located at the airport to the remote location. With the higher distance between remote locations and airports, it might not be possible to achieve the required level of network performance and render the provision of remote ATS unsafe. Thus, the first factor can be calculated as a difference between a possible location of the RTC and an optimal location of the RTC calculated by the initial methodology [5, 15].

The second factor that has to be taken into account is the density of the traffic at the airports within the segment. The higher the density of the traffic at the airport, the more often resources of the RTC will be dedicated to that airport. That means also that there will be more data exchanged between that airport and the RTC. Besides that, the airports with higher density will have more human resources available to serve the higher number of aircraft. Placing the RTC closer to or at the high-density airport might allow to make use of those human resources and reduce the number of relocations.

Another factor (linked to the previous one) is the availability of the personnel at the possible location of the RTC. A pool of qualified resources (ATCOs or AFISOs) is needed to satisfy the needs of the RTC to be able to efficiently serves airports within the segment. In case of the lack of resources or their absence, the personnel will have to be redeployed from another location that could lead to additional expenses for the implementation of the RTC as well as issues with social dialogue between personnel and organisation.

The fourth factor that has to be considered is the remoteness of the Communication, Navigation and Surveillance (CNS) equipment from the possible RTC location. Even though it is relatively common to have CNS (e.g. non-directional beacons, radio communication stations, etc.) equipment collocated with the airport, however, that's not the case for some airports, thus this has to be considered as well. The RTC has to be located within a reasonable distance from the CNS equipment to ensure that the reliable connection between the RTC and the equipment is ensured.

The last factor identified as part of this research is technical capabilities at the possible location of the RTC. The deployment of the RTC requires the installation of data centre infrastructure (to process and store information), controller working positions, supervision positions, etc. It also poses certain requirements on the physical space needed for the remote tower modules, on the power supply needed for the RTMs and data centre and so on [17]. Availability of the needed infrastructure and technical capabilities would facilitate the deployment of the RTC.

To assess the factors and support the decision-making process for the selection of the optimal location of the RTC, the decision-making under uncertainty methodology can be used. This methodology is suitable for cases with a high level of data incompleteness and uncertainty for:

- decision-making under stochastic risk (uncertainty) conditions when data can be described using the probability distribution. In this case, the alternative solutions are compared from the point of view of minimisation of expected losses. The optimal solution would be the one that corresponds to a minimum loss:

$$R^* = min\,\{R_i\}, \qquad (1)$$

where R_i – expected losses from the solution A_i

- decision-making under risk (uncertainty) when probability distributions are not available.

The decision-making under uncertainty methodology allows defining payoff and risk matrixes for the alternative solutions and factors influencing the decision-making process and analysing them using various criteria (Minimax or Wald, Laplace, Savage, and Hurwicz) [22].

The payoff matrix for the selection of the optimal location of the remote tower centre is represented in Table 1. The factors λ_1 - λ_6 are the ones described above:

- λ_1 – the remoteness of the possible location of the RTC from other airports within the segment;
- λ_2 – density of the traffic at the possible location of the RTC;
- λ_3 – availability of the personnel at the possible location of the RTC;
- λ_4 – the remoteness of the CNS equipment;
- λ_5 – technical capabilities at the possible location of the RTC;

Table 1

Payoff matrix for the selection of the optimal location of RTC

Alternative decisions	Factors				
	λ_1	λ_2	λ_3	λ_4	λ_5
Location 1	u_{11}	u_{21}	u_{31}	u_{41}	u_{51}
Location 2	u_{12}	u_{22}	u_{32}	u_{42}	u_{52}
….	…	…	…	…	…
Location n	u_{1n}	u_{2n}	u_{3n}	u_{4n}	u_{5n}

The cost of every alternative decision for each factor is described by u_{in}. The values for each factor are calculated as following:

- u_{1n} is determined as a difference between the optimal location for the remote tower centre from the point of view of minimization of the distance between RTC and airports within the segment (calculated with the help of the initial methodology) and the possible location of the RTC. The lowest value of the difference is ranked as 0 and the highest as *n*, where *n* is a number of possible alternative locations.

- u_{2n} is determined based on the density of traffic at the possible location of the RTC. If the possible location of the RTC is not an airport, then the density of the closest airport is assigned to that possible location. The location with the highest density is ranked as 0 and with the lowest – as *n*.
- u_{3n} is calculated based on the amount of personnel available at the possible location of the RTC. If the possible location of the RTC is not an airport and there is an airport within a commutable distance (e.g. 50 km) then the amount of personnel available at the airport is assigned to that location. Otherwise, the value of the available personnel for that location is equal to 0. The possible location with the highest value of the available personnel is ranked as 0 and with the lowest – as *n*.
- u_{4n} is defined similarly as u_{1n} – as a difference between the optimal location for the RTC from the point of view of minimization of the distance between the possible location of the RTC and CNS equipment within the segment. The lowest value of the difference is ranked as 0 and the highest as *n*.
- u_{5n} is determined as an expert estimate of the technical capabilities of the possible location of the RTC since the setup of each airport or possible location can vary significantly and that's why requires expert assessment. The possible location of the RTC with the best technical capabilities would be ranked as 0 and the lowest as *n*. For this research, all possible locations of the RTC co-located with an airport will receive the same value – 0 and those that are not co-located – 1.

The payoff matrix with values is analysed using four criteria: Wald (minimax), Laplace, Hurwitz, and Savage. The Wald or minimax criterion implements a principle of "conservative attitude" and provides a means to find the best option out of the worst ones (stable, guaranteed result):

$$A_W^* = \{u(a_i, \quad _j)\}, \tag{2}$$

where A_W^* - the evaluation function for the Wald criterion for the payoff matrix; $u(a_i, \quad _j)$ – costs for alternatives a_i and factors λ_j.

The Laplace criterion is based on the principle of insufficient reason, according to which all of the factors λ_j have equal weights for the decision-making process:

$$A_L^* = \left\{ \sum_{j=1}^{m} \quad u(a_i, \quad _j) \right\}, \tag{3}$$

where A_L^* - the evaluation function for the Laplace criterion for the payoff matrix; $u(a_i, \quad _j)$ – costs for alternatives a_i and factors λ_j; *m* – number of factors.

The criterion of Savage aims at reducing conservatism of the Wald criterion by replacing the payoff matrix with the risk matrix (Table 2):

$$A_S^* = \{r(a_i, \quad _j)\}, \tag{4}$$

$$r(a_i, \quad _j) = u(a_i, \quad _j) - min\{u(a_i, \quad _j\}_{a_i} \tag{5}$$

where A_S^* - the evaluation function for the Savage criterion; $r(a_i, \quad _j)$ – elements of the risk matrix for alternatives a_i and factors $\quad _j$.

Table 2

The risk matrix for Savage criterion

Alternative decisions	Factors				
	└$_1$	└$_2$	└$_3$	└$_4$	└$_5$
Location 1	r_{11}	r_{21}	r_{31}	r_{41}	r_{51}
Location 2	r_{12}	r_{22}	r_{32}	r_{42}	r_{52}
….	…	…	…	…	…
Location n	r_{1n}	u_{2n}	r_{3n}	r_{4n}	r_{5n}

The Hurwitz criterion provides a more complete approach to assess the alternative options covering the most optimistic and pessimistic approaches:

$$A_H^* = \{\alpha u(a_i, \quad _j) + (1 - \alpha) u(a_i, \quad _j)\}, \qquad (6)$$

where A_H^* - the evaluation function for the Hurwitz criterion; α – optimism index ($0 \leq \alpha \leq 1$) [22]. The results of the calculations can be summarized in Table 3 for analysis.

Table 3

Processed payoff matrix for the selection of the optimal location of RTC

Alternative decisions	Factors					Criteria			
	└$_1$	└$_2$	└$_3$	└$_4$	└$_5$	Wald	Laplace	Savage	Hurwitz
Location 1	u_{11}	u_{21}	u_{31}	u_{41}	u_{51}	A_W^1	A_L^1	A_S^1	A_H^1
Location 2	u_{12}	u_{22}	u_{32}	u_{42}	u_{52}	A_W^2	A_L^2	A_S^2	A_H^2
….	…	…	…	…	…	…	…	…	…
Location n	u_{1n}	u_{2n}	u_{3n}	u_{4n}	u_{5n}	A_W^n	A_L^n	A_S^n	A_S^n

5. Selection of the optimal location for the RTC using the described methodology

To demonstrate how the methodology can be applied in practice, one of the segments (Segment 1) calculated in the initial methodology [5] will be considered and an optimal location for the RTC will be selected. As the result of the execution of the initial methodology [5], an optimal location for the RTC from point of view of minimization of distances between the RTC and airports within the segment has been identified (Figure 4).

Figure 4: Calculation of optimal locations for the RTC (to minimize distance) for Segment 1 (green dots – initial coordinates; blue dots – refined coordinates)

A list of possible locations for the RTC can be composed of the calculated location of the RTC by the initial methodology and airports within the segment: Uzhgorod, Chernivtsi, Ivano-Frankivsk, Lviv. For each of the it is necessary to calculate values u_{ij} for factors identified in the previous section. For factors $\lambda_{1,}$ λ_4 it is enough to have coordinates of the airports and CNS equipment while for factors $\lambda_{2,}$ $\lambda_{3,}$ and λ_5 additional information is required. The density of the traffic per airport can be retrieved from EUROCONTROL STATFOR Dashboard [9] and information about available personnel at each airport can be retrieved from the operational hours of the aerodrome control towers at the airports and regulations on working hours for ATCO/AFISO, taking into account that at least two ATCO/AFISO (a controller and a supervisor) must be present at the workplace during a shift [10, 11].

Based on this information, it possible to create a payoff matrix for the airports in segment 1 and calculate criteria for each alternative option (Table 4).

Table 4
Processed payoff matrix for the alternative options in the segment 1

Alternative decisions	Factors					Criteria			
	L_1	L_2	L_3	L_4	L_5	Wald	Laplace	Savage	Hurwitz
RTC calculated location	0	1	1	1	1	***1***	0,8	***1***	0,5
Uzhgorod	4	3	3	4	0	4	2,8	4	2
Chernivtsi	3	2	2	3	0	3	2	3	1,5
Lviv	2	0	0	3	0	3	1	3	1,5
Ivano-Frankivsk	1	1	1	0	0	***1***	***0,6***	***1***	***0,5***

According to the four criteria, the most suitable location for the RTC in segment 1 for the defined factors is at the airport of Ivano-Frankivsk since it scores the lowest in each criterion.

The presented methodology can be applied to other segments of airports within Ukraine or any other group of airports in other countries. The list of factors defined is not finite and can be extended if a local context requires that. The use of the methodology and the criteria (Wald, Laplace, Savage, and Hurwitz) will ensure that all factors are taken into account when making a decision about an optimal location of the Remote Tower Centre.

6. Conclusions

An increase in the level of traffic at regional airports of Ukraine is an important enabler of their development and therefore enhancement of the Ukrainian air transportation network. The reduction of the costs (air navigation costs, airport charges, etc.) for airspace users is one of the ways to attract more flights to the Ukrainian airports.

One of the ways to reduce one of the airspace user costs – air navigation service costs – is through the increase in the operational efficiency and use of the resources for the provision of the air traffic services at the airport. This can be achieved through the implementation of the remote tower concept at the airport.

Selection of a location for a remote tower centre and facilities for it is one of the steps that has to be considered during the implementation of the remote tower concept [12]. The decision for the selection of the optimal location of the RTC is influenced by multiple factors. The initial methodology to support the decision-making process for the selection of the optimal location has been developed and described in [5], however, focusing only on one factor. The purpose of this research was to identify additional factors and enhance the methodology with them.

The enhanced methodology takes into account different factors such as density of the traffic, availability of the resources, technical capabilities, etc. and utilizes decision-making under an uncertainty model to assess the factors and select the optimal location based on them to minimise the impact and risks related to the implementation of the remote tower centre. The methodology allows defining a payoff matrix for the alternative options and factors influencing the decision-making process and analyzing them using various criteria (Minimax or Wald, Laplace, Savage, and Hurwicz). It can be used for different segments of airports in Ukraine or any other group of airports in other countries.

References

[1] A.Kazda, M.Hromadka, B.Mrekaj, Small regional airports operation: unnecessary burdens or key to regional development, in: 6th International Conference on Air Transport (INAIR 2017), Elsevier, Prague, 2018, pp. 59-68. doi: 10.1016/j.trpro.2017.12.169

[2] K.Button, S.Doh, J.Yuan, The role of small airports in economic development, Journal of Air Transport Management, 4(2), 2010, pp.125 – 136

[3] Cabinet of Ministers of Ukraine: National transport strategy of Ukraine for the period up to 2030, 2021. URL: https://zakon.rada.gov.ua/laws/show/430-2018-%D1%80

[4] T.A.Granberg, P.Axelsson, J.Petersson, T.Polishchuk, V.Polishchuk, C.Schmidt, Configuration and planning of the remote tower modules in a remote tower center, in: 7th International Conference on Research in Air Transportation, Philadelphia, 2016. URL: https://weber.itn.liu.se/~valpo40/pages/rot.pdf

[5] T.Shmelova, S.Kredentsar, M.Yastrub, Methodology for the selection of an optimal location of Remote Tower Centre, in: 16th International Conference on ICT in Education, Research, and Industrial Applications, Kharkiv, 2020, pp. 102-115. EID: 2-s2.0-85096107256

[6] Airports Council International Europe: European Regional Airport: connecting people, places & produces, Airports Council International Europe, 2017

[7] European Commission: Guidelines on State aid to airports and airlines, Official Journal of the European Union, C99, 2014, pp. 3-34. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52014XC0404%2801%29

[8] M.N.Postorino, Development of regional airports: Theoretical analyses and case studies, WIT Press, Ashurst, UK, 2010. ISBN: 978-1-84564-143-6
[9] EUROCONTROL: Local Single Sky Implementation 2020 – Ukraine, Level 1-Implementation Overview. Brussels, 2019. URL: https://www.eurocontrol.int/sites/default/files/2021-04/eurocontrol-lssip-2020-ukraine-level1.pdf
[10] Aeronautical Information Department, UkSATSE.: Aeronautical Information Publication of Ukraine, 2020. URL: https://www.ead.eurocontrol.int/cms-eadbasic/opencms/en/login/ead-basic/
[11] UkSATSE: Regulations on working hours and rest time of ATS employees. Boryspil, 2010
[12] Average Daily Flights – Airport, EURCONTROL STATFOR Dashboard, 2021. URL: https://www.eurocontrol.int/statfor
[13] International Civil Aviation Organisation: ICAO Doc 4444 – Procedures for Air Navigation Services – Air Traffic Management (16th edition), Montreal, 2016. URL: https://store.icao.int/en/procedures-for-air-navigation-services-air-traffic-management-doc-4444
[14] EUROCONTROL: Manual for Aerodrome Flight Information Service (AFIS), Brussels, 2010. URL: https://skybrary.aero/bookshelf/books/1446.pdf
[15] EASA: Guidance Material remote aerodrome air traffic services – Annex I to ED Decision 2019/004/R, Cologne, 2019. URL: https://www.skybrary.aero/bookshelf/books/4564.pdf
[16] SESAR Joint Undertaking: D02/D04 OSED for Remote Provision of ATS to Aerodromes including Functional Specification. Brussels, 2014. URL: https://www.sesarju.eu/sites/default/files/documents/solution/Sol71%204_Single_Remote_Tower_OSED.pdf
[17] Frequentis AG: Whitepaper: Introduction to remote virtual tower, Vienna, 2016. URL: https://www.frequentis.com/sites/default/files/support/2018-02/RVT_whitepaper.pdf
[18] SESAR Joint Undertaking: Remote Towers Demonstration Report, Brussels, 2015. URL: https://ec.europa.eu/transport/sites/default/files/LSD0204DemonstrationReportIAARemoteTowers.pdf
[19] The World largest Remote Tower Centre opens in Norway, 2021. URL: https://kommunikasjon.ntb.no/pressemelding/the-worlds-largest-remote-towers-centre-opens-in-norway?publisherId=17507039&releaseId=17894325
[20] European Commission: Deploying Remote Tower Control (RTC): Implementation of SES by Improving Performance and Modernising ATM for Tower Service Provision in Germany, Brussels, 2016. URL: https://ec.europa.eu/inea/sites/default/files/fiche_2015-de-tm-0268-w_final.pdf
[21] DFS controls traffic at Saarbrücken Airport remotely, 2018. URL: https://www.dfs.de/dfs_homepage/en/Press/Press%20releases/2018/04.12.2018.-%20DFS%20controls%20traffic%20at%20Saarbr%C3%BCcken%20Airport%20remotely/
[22] N.Rizun, T.Shmelova, Strategic Imperatives and Core Competencies in the Era of Robotics and Artificial Intelligence Chapter 9, Decision-Making Models of the Human-Operator as an Element of the Socio-Technical Systems IGI Global, Hershey, USA, 2019, pp. 167-204. doi: DOI: 10.4018/978-1-5225-1656-9.ch009