Expediency Analysis of Unmanned Aircraft Systems

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Abstract

The goal of this article is to introduce an expediency analysis of unmanned aircraft systems that has been created at the Department of Air Transport CTU in Prague FTS by its employees. A principle of the expediency analysis is to determine if a usage of the unmanned system is suitable for a certain activity. The unmanned system is compared both with the usage of a piloted aircraft and without usage of any flying machine. The unmanned aircraft system is compared from the safety, environmental (including sociological) and financial points of view. The first part is about a current situation in a field of the unmanned aircraft systems and three mentioned points of view. The next part describes most important research methods that have been used for an analysis creation. The third part of the article describes the expediency analysis itself and its creation. There are validation of the analysis and its overall evaluation in the final part of this article.

KEY WORDS: UAS, UA, UAV, RPAS, RPA, unmanned aerial vehicle, expediency analysis, expediency, UAV suitability

1. Introduction

An unmanned aviation is a fast developing area of the aviation in these days. A market with unmanned aerial systems (UAS) that are used for a business usage has been developing in last few years. A prestige resulting from use of the UAS contributes to this trend. The business unmanned systems are mostly used for aerial works. This development has some risks too. One of the risks is a non-competitiveness of the UAS against piloted aircraft or non-flying machines that can be used for the same activity (business plan). In other words, the unmanned system can be unsuitable compared with an alternative way of doing the activity. Because of that, the authors of this article have decided to create a simple analysis that should reduce described risk. The analysis should determine which of the variants is more suitable. A word suitable can be replaced with a word expedient. The second reason for the creation is an absence of the same or similar analysis.

2. Current Situation

This chapter describes the current situation of an unmanned aerial systems evaluation. The evaluation is doing in the three areas – safety, environment and finance. A current situation in the area of the UAS expediency is described at the end of this chapter. Scientific articles have been used for this current situation analysis.

The first analysed area was the safety. Most of the scientific articles are not about comparison, if it is safer to use the unmanned system or its alternative. They are about the safety and reliability of the UAS, its fuselage, its systems, safety of UAS operations and so on. An instance is the article that has been written by J. Chen et al. [1]. It describes the safety analysis of UAS take-offs. The modified STPA (Systems Theoretic Process Analysis) is shown in the article. It analyses risks of the system used for the UAS take-offs. The STPA is complex safety analysis based on the systems theory. It analyses a failure of each component. It helps to detect dangerous scenarios and it account with the human factor too. The authors of the described article demonstrate that the modified STPA is applicable to the UAS and they have detected the risks that may appear during the take-off [1]. It is obvious from the paragraph that the professional public deals with the safety of the unmanned aerial systems. On the other hand, the access that have been chosen for the expediency analysis have not been solved yet.

The second analysed area is the environment. The scientific articles which deals with this topic can be divided into two categories. The first category is about using the UAS for an environment monitoring. An instance is the article “On the Use of Unmanned Aerial Systems for Environmental Monitoring” written by S. Manfred et al. [2]. This article describes common ways how to use the UAS in the environment area. The article gathers information from scientific articles, studies and other sources. The article describes ways how a future research and development should evolve [2]. The second category is about an influence of the UAS to the environment. The study that have been written by Ch. Wargo et al. [3] deals with a growing UAS market. A one part of this article rates the influence of the UAS to the environment. The authors know that the UAS can influence the environment and they think that existing tools for an evaluation of an air transport influence to the environment are applicable onto the unmanned aviation too. Of course, it is necessary to do some changes and corrections [3]. The articles that compare influence of the UAS and its alternative to the environment

have not been found.
The financial area is the third analysed area. Most of the articles deals with the finance only as a one part of the article. Some articles is only about the UAS and finance too. An instance is “Life-Cycle Cost Analysis for Small Unmanned Aircraft Systems Deployed Aboard Coast Guard Cutters” written by T. J. Erdman et al. [4]. This article describes an application of the LCCA (Life-Cycle Cost Analysis) onto the UAS that can take-off from a ship. The first part of this article is about technologies that can be used. Then, used methods are described and after that the analysis itself is described. The results of this analysis can be used for a decision-making process and an analysed system implementation into a Coastal Guard equipment [4]. It is obvious that the professional public deals with the UAS and finance.
The authors of this article have found only one research that deals with the UAS expediency. The research is taking place at National Aviation University at Kiev, Ukraine. The main researcher is A. V. Goncharenko. He have published several articles that deals with the UAS expediency so far. He calculates the expediency by mathematical formulas. The formulas process different aspects that influence a choice between the UAS and piloted aircraft. An instance of his work is the article “Expediency of Unmanned Air Vehicles Application in the Framework of Subjective Analysis” [5]. This article describes a mathematical model that calculates the expediency. The model calculates with technical and economic aspects [5]. The described research and the expediency analysis created by the authors of this article is significant but there are several differences. The Ukrainian scientist calculates the expediency by the complicated mathematical formulas and he chooses between the UAS and piloted aircraft. The created expediency analysis compares the UAS with the non-flying machines too. The analysis uses simple and easy to use tools too.

3. Used Research Methods

The “What If” and “Check List Analysis” methods have been used for the safety area of the expediency analysis. These methods have been used for questions and answers creation. The main parts of the “Environmental Impact Assessment” have been used for the environmental area. These parts evaluate the impact to the environment. The “Net Present Value” and “Internal Rate of Return” methods have been used for the financial area. All other used methods have been used for the expediency analysis creation. These methods are the “Brainwriting”, “100 Points Allocation” and “Pairwise Matching”. Error rates have been calculated by the “Calculating Uncertainties from the Calculated Values”. The “Questionnaire” has been used for gathering a feedback and the validation of the expediency analysis.

4. Expediency Analysis

This chapter describes a principle of the expediency analysis and its creation. As mentioned, the analysis evaluates, if the UAS or its alternative is more expedient for chosen business activity. The creation process of the analysis is following. The first step was to determine main factors that influence one of the three areas. For instance, the factor can be “fall of an unmanned aircraft (UA)”. This factor influences the safety area negatively. Some of the factors had to be specified. So specifications have been defined. For instance, the factor “UA type” influences the safety area. The specifications of this factor are “propellers placement”, “covers” and “fuselage shape”. The questions and answers have been created from the factors and specifications. The questions and answers are used for gaining information necessary to do the expediency analysis. The questions are for a user. The next step was that the questions and answers have been scored and their error rates have been set. The scores represents a scale how the obtained information influences the area. The error rates represents an inaccuracy that the answers can contain. The next step was to define how the UAS can be used for the business usage. Its alternatives had to be defined too. The alternatives are using the piloted aircraft or non-flying machine. The alternatives had to be scored and the error rates have been determined too. A meaning of these scoring and error rates is the same like for the answers scoring. Then, mathematical formulas have been created. These formulas are used for partial analyses that analyse each area. The partial analyses have been connected together and the expediency analysis have arisen. The formula (1) is used for the partial safety analysis.

$$C_s = \frac{(B_U - B + 100) \cdot (200 \cdot V)}{200} \quad (1)$$

where a C_x is the result of the safety analysis, a B_U is the score for UAS, a B is the score for the alternative and a V is the influence (or importance) of the area. An instance of an error rate calculation is represented by the formula (2).

$$E_s = \sum_{i=1}^{n_s} \frac{b_{imax}}{2} \cdot \frac{b_i}{100} \quad (2)$$

where a E_s is the error rate of the safety analysis, a b_{imax} is the maximum score of the question, a b_i is the score achieved by the chosen answer, a i is the number of a question and a n_s is the number of the questions in the safety area. The Fig. 1 shows a creation diagram of the expediency analysis.

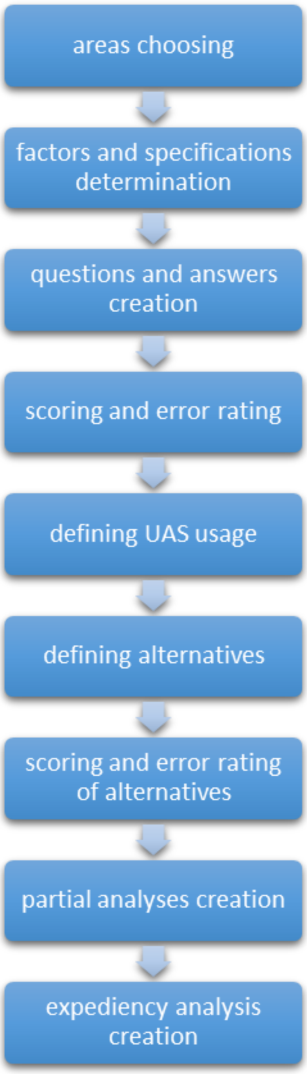

Fig. 1 – The creation diagram of the expediency analysis

An output is numerical and graphical values. These values shows which of the variants is more expedient. The Fig. 2 shows the graphical output. The red point on the main black line shows the analysis result and the red line under the point shows the error rate.

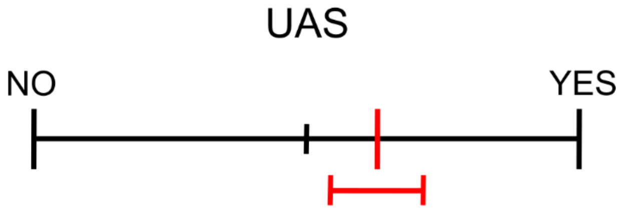

Fig. 2 – The instance of the expediency analysis graphic output

5. Validation

The validation of the expediency analysis has been done at ten examples. First, authors defined these examples. Then, they applied the expediency analysis. All examples have been sent to UAS experts too. The experts evaluated these examples and they determined if it was expedient to use the UAS or alternative. The expediency analysis results and experts´ answers are at Table 1. A grey colour means that a chosen variant is only a small percentage more expedient than the second variant.

Table 1

Comparison of the expediency analysis results and experts´ answers

Activity description	Expediency analysis	Experts´ answers
aerial photographing of forests and meadows	UAS	UAS
checking a condition of statues in a church	alternative	UAS
delivering package to a recipient	alternative	same expediency
airport perimeter security	alternative	alternative
supporting mountain rescuers	alternative	UAS
chemical spraying of a grain	UAS	UAS
scaring birds	alternative	alternative
cattle chasing	alternative	alternative
monitoring flora and fauna condition in National Park	UAS	UAS
checking of a bridge structure	alternative	UAS

It is obvious for the results that six of the ten examples agree. The expediency analysis has the same results like the experts´ answers. The remaining four examples have different answers but the differences are small. It is obvious that the analysis is applicable. It should be noted that the scoring and error rates can be modified. It should be done based on collect data. The modification should refine the analysis results.

6. Conclusions

As mentioned above, it was demonstrated that the expediency analysis is functional tool how to determinate which of the variants in for the business plan more expedient or more suitable. Primarily, its principle is functional and suitable. The expediency analysis has several benefits. The main benefits are for UAS operators and civil aviation authorities. They can use this analysis and their work volume will be smaller thanks to the analysis. They can easily find out if it is expedient to use the UAS too. Further research can be pointed to refining the analysis by modifying the scoring and error rates or to upgrading the financial part of the analysis. The financial part should stay simple.

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