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AIRCRAFT PERFORMANCE CHECKING PROCESS TO ACHIEVE AN ACCEPTABLE LEVEL OF SAFETY THROUGH THE COMPLIANCE MONITORING FUNCTION

Summary

This paper presents a methodology for developing a model for managing the checking process of aircraft performance by forming an audit checklist and examines the possibility of applying the method of multiple criteria decision-making as decision support. In developing this model, Expert Choice software was used and IOSA (IATA (International Air Transport Association) Operational Safety Audit) standards were ranked on the basis of their relevance for aircraft performance and the airline's relevant data for the particular year by the method of the multiple criteria decision-making Analytical Hierarchy Process (AHP). AHP served as the basis for selecting "critical" standards for a certain audit as an aid to the compliance manager in defining the audit areas and standards to be checked, while using optimum resources. Apart from ranking the standards, the recommended model can be used, by applying a sensitivity analysis, for predicting the need for additional audits.

Key words: *safety, compliance, IOSA, AHP, ranking*

1. Introduction

Rapid technological development in the last century have had a considerable effect on aviation, leading to great progress in this area. However, such progress would not have been possible without the simultaneous development of control and considerations pertaining to reducing safety hazards and risks. Having in mind that the consequences of improper action may cause significant injuries and damage, importance was given to the management system, leading to a remarkable reduction in the frequency and severity of negative consequences.

The quality management system (QMS) as part of the management system is a system of processes designed to monitor compliance with, and the adequacy of, procedures required to ensure safe operational practice and airworthy aircraft [1].

The safety management system (SMS), also part of the management system, constitutes a systematic and explicit approach to managing safety, including accountabilities, responsibilities, organizational structures, policies and procedures [2]. Guidance for SMS implementation are generally described for all aviation subjects [3], while an airline's activities to achieve an acceptable level of safety, are described for continuing airworthiness [4] as well as air operations [5].

Given that airports are very closely connected with airline operations, special attention is dedicated to hazard identification, risk assessment and mitigation for aerodrome operators [6].

However, observing the SMS separately, it was concluded that it was a relatively incomplete management system which needed to be supported by numerous disciplines regarding compliance. These additional disciplines are available in the QMS and therefore it was natural to integrate the QMS and SMS into a single system – a safety management system with a compliance monitoring function, as described in the regulation relating to air operations [5].

Once established, the SMS with the compliance monitoring function should be monitored and, based on certain indicators, assessed regarding its performances as well as its effectiveness. Liou et al. [7] considered that safety within an airline was affected by many factors such as management, operations, maintenance, environment, aircraft design, etc. They worked on the assessment and measurement of airline safety, while independence of the criteria and the relationships among them were discussed, showing interdependence between the criteria and the feedback obtained based on them. Quantitative measurement of the airline safety index was considered by Liou et al. [7] with a focus on previous efforts to measure aviation safety with the assumption that the criteria were independent, and the fact that this was not the case in the real world. Liou et al. [7] also discussed the traditional attitude that safety was assessed on the number of accidents, while these statistics were not always helpful, due to the fact that “latent” events were not always reflected in them. Hsu et al. [8] described the development of a quantitative evaluation model, where the key components of the airline SMS were identified and where the interaction between them was considered. Chen and Chen [9] examined the evaluation of the performance of a company’s SMS from the perspective of aviation experts and airline managers, where it was recognized that most of the items excluded by the exploratory factor analysis were related to the dimension of “safety oversight and audit” from the initial scale. Kraus and Ondraskova [10] discussed the methods used to assess the safety of aviation and, as a result, the method which, based on a combination of safety audits, the reporting of events in flight, maintenance, ground operations, assessment, analysis, investigation and monitoring of corrective measures, produced the best evaluation. A multiple-criteria decision model was developed using thirteen safety criteria, divided into four dimensions with the worst evaluation.

The authors of this paper are only in partial agreement with the results of the work by Chen and Chen [9]. An audit performed in such a way where thousand and more standards are checked in a very short or in an inappropriately long period of time, as a large number of airlines do, does not give a realistic assessment of SMS. However, the authors of this paper will give a different vision of the audit and allocation of resources related to the same, by which the audit will regain the position it deserves, and fill a gap in the literature as well as in practice. Partial agreement was reached with the results of the study by Kraus and Ondraskova [10], and the results of this paper will go further in designing such a model that will encompass everything listed under the audit with optimal resources, covering a gap in the literature and in practice. In addition to the model considered by Kraus and Ondraskova [10], the model designed in this paper will be based on a much larger number of criteria.

The starting point of this paper is that auditing represents a key activity of the management system, since it enables an assessment of the extent to which an airline complies with the established aims regarding safety. While implementing the compliance monitoring programme, it is necessary to produce an audit plan for a particular year as well as to define audit areas and checklists based on which it will be conducted [5]. The question arises as to how to define the mentioned checklists – on what grounds and according to what resources. This is when the compliance manager encounters the problems of defining the checklist; while the checklist needs to be sufficiently comprehensive and detailed in order to meet the purpose of the audit, it is at the same time necessary to use resources rationally. Each reputable airline and its compliance manager encounter this problem; clearly, it is necessary to take a serious approach to find an adequate solution and thereby achieve a mature SMS and compliance monitoring programme by means of which an acceptable level of safety will be reached.

At first glance, the simplest solution is to outsource the audit function. But Hsu and Liou [11] explain that outsourcing is a critical business process that needs to be considered by airlines. Their results show that a risk exists if the service is performed by an outsourced company. Rieple and Helm [12] note that the practice of outsourcing certain functions is not always successful and does not always produce the advantages described in the theory. The authors of this paper, based on their own experience, fully agree with these attitudes and accept this point of view for the purpose of this paper.

The solution of designing your own checklist is the best; however, there are numerous problems arising in this case. First of all, there is the question of the basis of determining critical system areas necessary for checking, and deciding which of these have higher or lower priority. Then, the question arises as to the extent of the checklist necessary to check all relevant standards. All this involves a very high level of responsibility – if certain standards are included in the checklist and afterwards examined, but then certain problems occur in an unchecked area in the near future, there may be difficulties in supporting the decision taken and proving that those particular standards were the most important at the moment of forming the checklist. The point is to form the checklist in such a manner that even if something occurs in an area which was not checked, the compliance manager can prove that his/her decision was the right one and made according to relevant indicators.

Through an insight into the literature, it is clear that the field of auditing is the most discussed in the domain of finance, while, despite the large number of audits in aviation and requests for them in accordance with the regulations for continuing airworthiness [4] and air operations [5], to the best knowledge of the authors, very few papers have dealt with this subject. Abbott and Parker [13] note that auditors specialized in the particular industry are expected to provide a higher level of audit quality in contrast to auditors who are not specialized. Besides, the research of Okaro and Okafor [14] shows how some cultural factors strongly affect audit quality. Frazier et al. [15] describe safety culture as a higher-order latent variable which means that what works well in one organization might not work in another. All these factors can be accepted for the purpose of this paper and support the selection of an auditor from internal sources.

With the introduction of the IOSA (IATA (International Air Transport Association) Operational Safety Audit) Programme [16], airlines were given a significant opportunity to use the checklists according to which IOSA Audit Organizations conduct external audits, for their internal audits for all areas, or for targeted audits in certain domains [17]. When using these checklists the compliance manager can be certain that everything that should be checked has been checked and therefore that responsibility has been met.

Unlike the case of IOSA auditors who conduct IOSA to obtain or renew certificates and who check approximately 900 standards with five to six experienced auditors within five days, it is impossible to conduct an internal audit, extraordinary audit or targeted audit in such a short period of time or to a satisfactory extent if the real intention is to use the benefits of the audit and not make it just a formal box ticking exercise. According to the long experience of the authors of this paper, a detailed check of about 900 standards from the IOSA Standard Manual (ISM) [17] requires approximately six weeks and five experienced auditors.

One should also bear in mind that the organizational units whose work affects safety are operational ones and it is rather difficult to set aside an interrupted period of time because necessary regular duties must be fulfilled by the staff of the organizational unit which is the subject of the audit. One must not neglect the fact that the audit is an exhausting activity both for auditors and the audited. Therefore, during the six-week period it may happen that initial standards are considered in full detail while with the passage of time enthusiasm fades, which may lead to omissions in the assessment of important areas of the system.

Kruger and Hattingh [18] state that only 75 hours are needed to cover the audit area satisfactorily, but they consider the audit in an area different from the airline with different standards. Mohamed [19] presents a survey of operation research models developed for internal audit planning which should assist audit managers in devising an optimal audit plan regarding internal audit timing, the allocation of audit resources and audit-staff scheduling, which recognizes the mentioned problem, but in areas different from aviation, too. Consequently, the published facts cannot be considered relevant for the purpose of this paper, which will consider the resources necessary for an airline’s internal audit and cover that gap in the literature and practice.

Furthermore, there is the question of targeted/extraordinary audits because the selection of IOSA standards relating to a certain area (to aircraft performance in the case of this paper) may lead to two extremes. First of all, only those standards relating strictly to a certain area can be selected (in the case of this paper, the area of *operations engineering specifications* [17]), which leads to the routine examination of standards which are not necessarily relevant. On the other hand, it is also possible to apply deeper consideration and connect other standards, taking into account those which, if the airline does not comply with them, may indirectly lead to a reduction of the desired aircraft performance and therefore jeopardize safety, as well as those standards which may be expected to be non-compliant due to indirect influence. If the selection of standards for a checklist is approached in this manner, one will realize very soon that it is necessary to check all 900 standards, since all of them are either directly or indirectly related to both aircraft performance and any other area selected for a targeted/extraordinary Audit.

In his study, Bamber [20] recognizes that the level of experience of the auditor and the initial planning effort are associated with differences in manager review practices and perceptions. The objective of a case study by Sueyoshi et al. [21] was to identify the most critical business units within a corporation in order to use efficiently and effectively internal auditing resources. Based on this and on the experience of the authors of this paper, both attitudes can be accepted for the purpose of this paper.

Accordingly, the challenge for this paper is to use the standards defined in the ISM, the airline’s analysis of the data relevant to safety, aircraft performance and the respective experience of the compliance manager and auditors in order to ensure the review of “critical” areas regarding safety and their auditing through the use of optimum resources, which will contribute to saving time and money and will support the principle “to a lesser extent but in more detail”. In this way, the performance and effectiveness of SMS will be assessed and, based on the results, further improvement and goals will be defined.

In order to achieve this goal, the method of multiple criteria decision-making was used to help in the decision-making. Expert Choice software [22] was employed to create a model, and IOSA standards were ranked according to the airline’s relevant data for the specific year and for their relevance for aircraft performance, by the method of the multiple criteria decision-making Analytical Hierarchy Process (AHP), which served as the basis for selecting “critical” standards for a certain audit. In this manner, the compliance manager can be responsible for defining audit areas and standards which will be checked while using optimum resources. The recommended model can be used by applying a sensitivity analysis for predicting the needs for additional audits, which will facilitate the drawing up of an audit plan for the following period and provide new auditors with substantial help in decision-making with regard to focusing on certain standards.

The rest of the paper is organized as follows. Section 2 shows the theory on which the paper is based. Section 3 describes the model-creating methodology for managing the checking process of aircraft performance, while Section 4 describes its development. Sections 5 and 6 present the results of the paper together with a discussion and conclusion.

2. Theoretical basis of this paper

2.1 IOSA

The IOSA Programme [16] was initiated by IATA and is aimed at implementing the standardized Audit Programme for operational management as well as the airline's control systems. It is based on internationally recognized standards to improve operations worldwide and to reduce the number of operational audits. ISM [17] gives a fully detailed description of about 900 standards (depending on the edition) with guidance material, which the airline's operations must comply with so as to reach an acceptable level of safety.

2.2 Aircraft performance

Aircraft performance refers to an aircraft's capacities and limits [23].

It is necessary to consider all the factors affecting them, such as the aircraft weight, atmospheric conditions, runways, surroundings, and the basic physical laws affecting the aircraft. The main performance elements are the distances necessary for taking off and landing, the climb rate, the maximum height the airplane can reach and the payload, range, speed, manoeuvrability, stability and fuel economy. Some of these factors sometimes are in conflict with one another – long range against a high payload, high speed against short landing distance, high rate of climb against fuel economy, etc. [24].

The influence of such parameters as airspeed, air pressure, air temperature, altitude as well as the importance of their accurate values, in order to achieve flight safety, have been described by Novak et al. [25]. The influence of outside air temperature on aircraft airspeed and its accuracy and reliability, as basic elements required for flight safety, were considered by Novak et al. [26]. Further, flight path and flight/climb angle were examined by Iskrenovic-Momcilovic [27], where these parameters were highlighted. Despite the fact that the cited authors [25], [26] and [27] considered different aspects of aircraft performance and solutions, all considerations and solutions ultimately lead to improved performance. This results in better aircraft safety, which clearly shows how important this area is and justifies the purpose of this paper.

Various aircraft performance elements derive from the combination of the aircraft and its engine characteristics. The aerodynamic characteristics of an aircraft generally define the power and thrust required in various flight conditions, whereas the engine characteristics define the power and thrust available in various flight conditions. The matching of the aerodynamic configuration with the engine is achieved by the manufacturer to attain the desired performance in the specific design conditions, such as range, endurance, climb, etc. [24], while the airline has to make sure that everything progresses at an acceptable level of safety and in accordance with all the required regulations, which is ensured by the compliance function.

2.3 Decision-making

Decision-making represents one of the essential management functions [28]. Decision-making is a cognitive process of selection among several alternative paths of action directed at achieving the aim. The greatest progress in decision-making theory was made by developing a series of methods which subsequently became known as operational research methods, and which combined knowledge in mathematics, statistics, economics, and natural sciences.

In addition, great progress was made by using the analytical power of computer technology. Therefore, it is evident today that a good-quality decision cannot be made without the integrated action of the human factor, mathematical methods, and computer tools. Decision-making based solely on a personal review of a situation or on a person's intuition is almost impossible, while in some cases it is even irresponsible and can have serious negative consequences. Computer support is increasingly used in decision-making in the form of special software commonly called Decision Support Systems (DSSs) based on simplified but correct mathematical models. DSSs enable the decision-maker to try out variants and change their opinion accordingly within an acceptable time interval so as to make a timely and adequate decision. It is important to emphasize that while DSSs provide support to the decision-maker, they cannot act as his/her replacement.

Although the application of decision making is described within many areas of aviation as quality function deployment by Ho et al. [29], choosing from among alternative transportation projects by Ferrari [30], the evaluation of air transportation network by Ceha and Ohta [31], group decision support by Dyer and Forman [32], forecasting the capabilities of the civil aircraft industry by Kim and Whang [33], the selection of pilot projects by Ahire and Rana [34], etc., the authors of this paper have not found any paper which considers the function of auditing of airlines or the importance of the selection of necessary standards in order to use optimum resources, which will constitute the contribution of this paper to the current literature. The optimal allocation of internal auditing time as a multi-criteria problem that includes both qualitative and quantitative factors is described in Kruger and Hattingh [18], but for an area different from aviation.

2.4 Analytical Hierarchy Process (AHP)

The AHP method was developed by Thomas Saaty at the beginning of the 1970s [28]. It is a tool in decision-making analysis created to help the decision-maker solve complex decision-related problems (a larger number of decision-makers, a larger number of criteria and multiple periods of time). AHP is based on the balance concept used to determine the overall relative significance of a group of attributes, activities or criteria. This is achieved by assigning weight in the form of a series of paired comparison matrices and then by using systems for supporting decision-making in order to determine normalized weights. These weights are used for assessing attributes at the lowest hierarchy level.

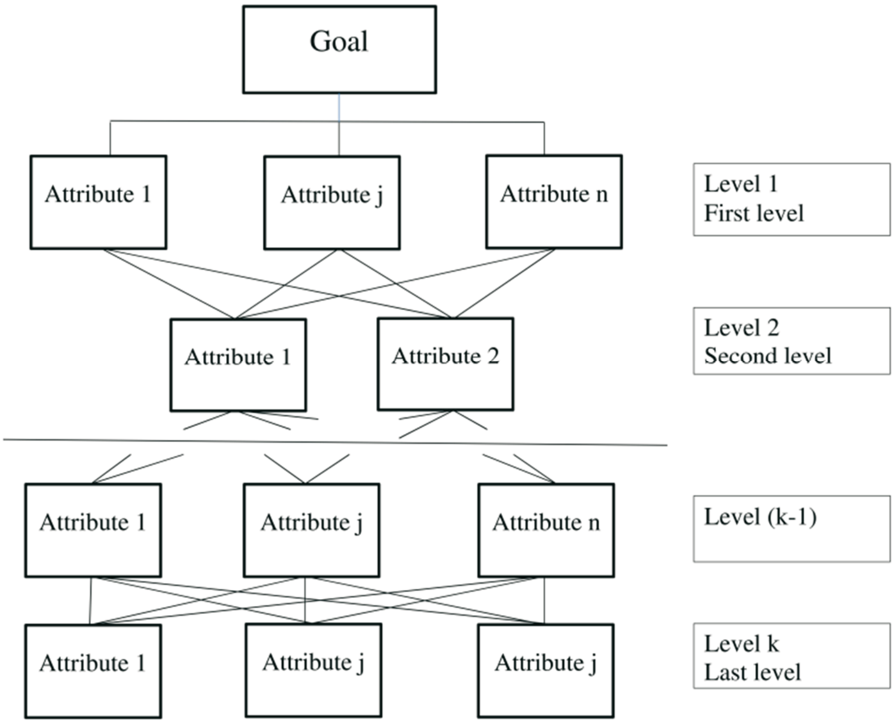

Fig. 1 Problem structuring

The modelling process defined in this manner consists of four stages: problem structuring, data collection, relative weight assessment and problem solution determination.

The first stage includes problem structuring where the complex problem of decision-making is decomposed into a hierarchy series so that each level constitutes a smaller number of manageable attributes. These are subsequently decomposed into a group of elements corresponding to the next level, etc., as can be seen in Fig. 1.

This is a very efficient way of identifying important attributes to achieve the overall goal. Moreover, the AHP method ensures the decomposition of relations of dependence and independence between attributes into different hierarchy levels.

The second stage involves data collection and their measurement, while the assessor assigns relative grades in attribute pairs of one hierarchy level to the given attributes of the next higher hierarchy level. This process is repeated for all levels of the overall hierarchy. Weights are most frequently assigned on the basis of the best-known scale with nine items, since its application has proven to be quite reliable. The scale with nine items is shown in Table 1. In this case, the assessors will assign weights to each pair as a measure of how much more important one pair of attributes is compared with the other.

Table 1 Saaty's scale of relative importance [28]

Intensity of importance (AHP)	Definition
9	Extreme importance
8	Very, very strong
7	Very strong or demonstrated importance
6	Strong plus
5	Strong importance
4	Moderate plus
3	Moderate importance
2	Weak
1	Equal importance

The assessors can use their own beliefs, estimates or information if they do not possess objective information. At the end of the second stage, there is a comparison matrix by the pairs which correspond to each hierarchy level.

The third stage is constituted by grading relative weights when paired comparison matrices are translated into the problem of determining own values in order to obtain normalized and unique weight vectors for all attributes at each hierarchy level. It is assumed that the given hierarchy level has n attributes $A_1, A_2, ..., A_n$ with the weight vector $t = (T_1, T_2, ..., T_n)$. It is necessary to determine t in order to determine the relative significance of $A_1, A_2, ..., A_n$. If the person grading weights compares each pair A_i and A_j of all attributes as a degree with which A_i dominates over A_j, then a paired comparison matrix can be formed as follows:

$$A = (a_{ij}) = \begin{bmatrix} t_1/t_1 & \cdots & t_1/t_n \\ \vdots & \ddots & \vdots \\ t_n/t_1 & \cdots & t_n/t_n \end{bmatrix}. \tag{1}$$

Then the normalized weight vector can be found by solving the corresponding problem of the highest own value, where A is a reciprocal matrix with the characteristic $A_{ij} = 1 / a_{ij}$ and $a_{ii} = 1$ for all $i, j = 1, ..., n$.

$$At = nT \tag{2}$$

As it is known that if the elements on the matrix diagonal A are equal to one and if A is a regular matrix (determinant of A different from zero), it follows those small changes in the values for a_{ij} maintain the highest own value at λmax while the other own values are approximately equal to zero. Accordingly, vector t is solved in the following manner:

$$At = \lambda \max t. \tag{3}$$

This vector *t* is not normalized. By defining

$$\alpha = \sum t_i \text{ and } t = t/\alpha, \tag{4}$$

a normalized vector is obtained for determining the attribute significance A_1,A_2,...,A_n.

The Consistency Index (*CI*) representing the measure of consistency of deviation *n* from *λmax* is calculated as follows:

$$CI = \frac{\lambda \max - n}{n-1}. \tag{5}$$

CI values lower than 0.10 are considered to be a satisfactory measure indicating that the assessment for a_{ij} is consistent and that the determined value for *λmax* is close to the ideal value we wish to assess.

The fourth stage represents the determination of the problem solution where there is the composite normalized vector. Since successive hierarchy levels are inter-related, the unique composite vector of unique and normalized weight vectors for the overall hierarchy will be obtained by multiplying the weight vectors of all successive levels. The obtained composite vector will be used for finding the relative priorities of all entities at the lowest hierarchy level, which ensures that the set aims are achieved.

The application of the AHP method in the domain of ranking is described in the literature within many areas such as selecting an automobile purchase model by Byun [35], site selection for a terminal by Hegde and Tadikamalla [36], casting supplier evaluation by Akarte et al. [37], choosing from among alternative transportation projects by Ferrari [30], the ranking of enterprises by Babic and Plazibat [38], the ranking of the operating cost of airlines by Berrittella et al. [39], the evaluation and selection of a strategic alliance partner in the airline industry by Garg [40], safety performance monitoring by Chen and Li [41], identifying the relative importance of specific factors by Yoo and Choi [42], etc. To the best knowledge of the authors, there is no paper which considers the ranking of the numerous standards which every airline has to comply with, despite the fact that, based on the experience of the authors, compliance managers and safety managers are faced with the problem mentioned in Section 1 of this paper every day. This paper will contribute to the current literature in this area.

3. Methodology of creating a model for managing the checking process of aircraft performance

3.1 Selection of a method and software for creating a model

Many methods of multiple criteria decision-making (AHP, PROMETHEE and ELECTRA) [28] as well as the application of artificial neural networks [43] were considered in solving the given challenge. After detailed consideration of the advantages and disadvantages of each of the above, AHP was selected as it gives a clear review of the hierarchy of all criteria and sub-criteria including alternatives; additionally, it is quite suitable for presenting the given challenge and its solution. When AHP, as the most suitable method, was selected, an AHP model with fuzzy logic was considered, where triangular fuzzy members and linguistic variables are used, in order to overcome imprecise and subjective judgment [44]. In accordance with the fact that in addition to the subjective assessment of the authors, the assessment was supported by the real data of the airline, it was decided that regular AHP would be quite reliable. Besides, regular AHP will be easier to accept by the airline's employees who should use it in the future.

Expert Choice [45] was used for creating the model, as it is one of the software packages based on an analytical hierarchy process and as it ensures considerable help in solving problems related to decision-making. The software guarantees excellent problem structuring, while alternative and criteria pairs can be compared in numerous ways. This software supports an infinite number of alternatives and criteria and gives the possibility of a large number of hierarchy levels. Excellent manipulation of criteria and alternatives is ensured, and there are tools for sensitivity analysis as well as various reviews and reports.

3.2 Aircraft selection

The B737-300 aircraft was selected for creating the above-mentioned model. This aircraft was selected due to data availability and the fact that it belongs to the fleet of the airline where the authors of this paper have obtained long-term experience as consultants, members of top management as well as lead auditor.

3.3 Selection of a group of relevant data and their analysis

The data necessary for creating this model are included in the following areas:

3.3.1 Safety Assessment of Foreign Aircraft (SAFA) / Ramp inspection

In 1996 the European Civil Aviation Conference (ECAC) launched the SAFA programme [46] which was not aimed at replacing or assuming responsibility in relation to safety oversight by states or airlines. In safety oversight by states or airlines, safety is considered in much more detail and much more deeply, whereas SAFA gives general indications regarding the foreign operator’s safety. SAFA results in information about the safety operations of an aircraft which was the subject of inspection while the airline undertakes certain corrective measures to correct irregularities identified by SAFA inspectors. On 28 October 2012, the Implementing Rules on Air Operations entered into force as the new legal basis for the European Union (EU) ramp inspection programme, replacing the original system established by the SAFA Directive and its implementing regulations with a new system, represented by the new EU Ramp Inspections Programme [47]. On 28 October 2014, the European standard procedures for SAFA were integrated into the Commission Regulation under Part-ARO (authority requirements in the Air Operations Regulation) and is fully applicable from the mentioned date [5].

The SAFA/Ramp Inspection results reach the airlines and aviation authorities with the fully described irregularities and their category [5]. The irregularity category can be cat. 1 (information to pilot-in-command / operator representative), cat. 2 (information to authority and operator), cat. 3 (cat. 3a – restriction on aircraft operation, cat. 3b – corrective actions before flight required, cat. 3c – aircraft grounded by competent authority, cat. 3d – immediate operating ban) [47]. According to SAFA/Ramp Inspection data which are permanently monitored, the compliance manager of the airline gains insight into the weaknesses of the system and then creates the inspection and audit plan and defines critical areas as their subsequent subject. Elements which are checked during the SAFA/Ramp Inspection, as well as the methodology, guidance and best practice, are defined in the Ramp Inspection Manual [47] with reference to the Air Operations regulation [5] which, for the purpose of this paper, is divided into three levels, as described in Table 4.

3.3.2 Technical and Operational Delays (DEL)

IATA delay codes [48] were created to help airlines standardize the reasons for delays of commercial flights from departure airports and to be able to define critical points in the system and undertake adequate corrective measures. For the purpose of this paper, IATA delay codes are divided into two levels, as described in Table 5.

3.3.3 Aircraft Reliability (REL)

Maintenance of aircraft covers overhaul, repair, inspection, replacement, modification or defect rectification of an aircraft or component [4]. Maintenance of aircraft is performed in accordance with the Aircraft Maintenance Programme, approved by the competent authority, which contains details relating to the maintenance to be carried out, including the frequency and all specific tasks connected to the type and specificity of operations, associated procedures and recommended maintenance practices [4].

The Reliability Programme is developed for the Aircraft Maintenance Programme to ensure that the Aircraft Maintenance Programme tasks are effective and their timing is adequate. This may result in the escalation or deletion of maintenance tasks, while monitoring the effectiveness of the Aircraft Maintenance Programme is constant [4].

In accordance with the complexity of the aircraft and the nature of the particular operation, the Aircraft Maintenance Programme procedures should contain a reliability centred maintenance approach [4]. A reliability centered maintenance approach consists of preventive maintenance, predictive testing and inspections, repair, known as reactive maintenance, and proactive maintenance. The mentioned approach increases the probability that an aircraft or component will function in the required manner over its design life cycle with a minimum of maintenance and downtime [49].

To measure aircraft reliability in exploitation, it is necessary to register certain data which, on one hand, must be relevant for demonstrating reliability and, on the other hand, must be available. These data usually represent situations in which there is unreliability in exploitation and defined by the airline in accordance with the Continuing Airworthiness Regulation [4] and the benefits of the reliability centred maintenance strategies [49].

Aircraft systems are presented by ATA (Air Transport Association) [50].

For the purpose of this paper, data for aircraft reliability monitoring are divided into two levels, as described in Table 7.

3.3.4 Flight Data Recorder (FDR)

The Flight Data Analysis (FDA) Programme, known in literature as the Flight Data Monitoring (FDM) Programme or the Flight Operations Quality Assurance (FOQA) Programme, constitutes a tool for proactive hazard identification [51]. Initially, the Flight Data Recorder (FDR) was used for conducting accident investigation, particularly if the crew members did not survive [52]. It was established that the analyses of recorded data were very useful for better understanding serious incidents. Thanks to the FDR, and the regulatory obligations relating to the FDR [53], important data on everyday operations became available while the analyses of de-identified data ensure safety hazard identification before the occurrence of serious incidents or accidents. For the purpose of this paper, the data presented in Table 11 were used and divided into two levels.

3.3.5 Results of previous audits (EXA)

Since the regulations stipulate that audit documentation must be kept for at least five years, it is also used for some other purposes [5]. Data from previous audits are very useful both for preparing new auditors for their work as well as for insights into critical areas of the system. Regardless of the fact that irregularities are “closed” for a certain period of time, the very existence of an irregularity at a certain moment may indicate problems in a unit or area of work which may have much more far-reaching consequences than may appear at first sight. Therefore, the data from previous audits should be observed in a broader context while considering the following questions: whether an irregularity affects or may affect some other standard; whether several different irregularities have the same cause; whether several different irregularities have the same negative consequences, etc. The data from previous audits can be properly used only on the basis of the facts obtained by such considerations. It is also very important to consider the standards where irregularities reoccur, although a certain irregularity may have been corrected within a defined period of time. For the purpose of this paper, data defined in Table 12 were used and constitute only one level.

3.3.6 "Weights" of standards regarding aircraft performance (WGH)

Looking at ISM [17], it cannot be said that a certain standard is important while another is not, as long as each of them can be associated directly or indirectly with aircraft performance. There are data monitored by the compliance manager in everyday activities which may or may not be presented in an official form, but they provide plenty of important information to the compliance manager. These include flight attendants' reports, reports of station managers, reviews of passengers' complaints, various correspondence on certain issues, as well as information exchange at meetings. All this information is monitored by the compliance manager and is used as the basis for considering certain standards with a higher priority over others. The factors of the experience and ability of a broader overview are quite important here as well, and they are of invaluable significance to the selection of the standards to be included in the checklist. For the purpose of this paper, the mentioned data were used and constitute only one level.

3.3.7 Important changes in the airline (COR)

Substantial changes in the airline, such as changes in the organization or key management, the introduction of new equipment or new technologies and the like, create fertile ground for conditions where safety may be jeopardized, regulations violated, or unsuitable practice applied. Whenever such a situation occurs, it is necessary to include this component in deciding on the audit and the importance of certain standards.

For the purpose of this paper, data defined in Table 13 were used and divided into two levels.

3.3.8 Occurrences to be mandatorily reported (OCC)

Every airline is obliged to define SMS and within it the mandatory reporting system [5]. The EU (European Union) regulation [54] lays down a list of occurrences in civil aviation regarding the aircraft itself or those affecting the aircraft, which have to be mandatorily reported to the Civil Aviation Authority (CAA), while accident and incident investigation is required by the International Civil Aviation Organization (ICAO), too [52].

The mandatory reporting system is very significant because it improves aviation safety by ensuring that relevant safety information is reported, collected, stored, protected, exchanged, disseminated and analysed [54]. For the purpose of this paper, data defined in Table 14 were used and divided into two levels.

4. Model of ranking IOSA standards regarding aircraft performance by applying the AHP method

4.1 Model development

The top of the model contains the goal that all 922 IOSA standards should be ranked according to the above-listed data so as to select an adequate number of standards for the audit in line with the available time, staff and other resources.

The first level (L1) includes 8 criteria – SAFA, DEL, REL, FDR, EXA, WGH, COR and OCC – which are defined in Section 3.3. Each of these 8 criteria is further divided into levels, described in Tables 4, 5, 7, 11, 12, 13 and 14.

Accordingly, it can be concluded that there are 5 hierarchy levels and 377 criteria defined, while the last hierarchy level includes all 922 IOSA standards, and all the criteria from the last level are related to all of them. This can be seen in Fig. 2.

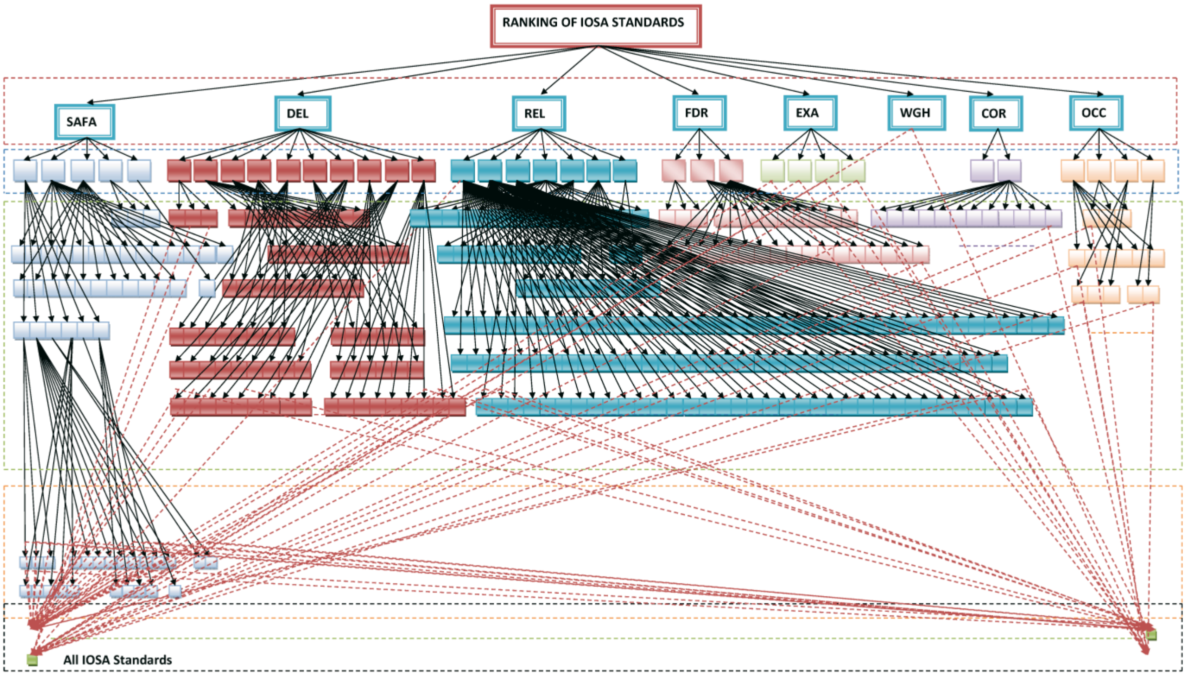

Fig. 2 IOSA standards ranking hierarchy

There are 922 alternatives at the lowest level and their comparison in pairs was rather impractical and time consuming. Therefore, the assessment in relation to the fixed scale was applied at the given level where the scale was defined and each level was assigned one number from zero to one so that the defined scale levels are assigned to each alternative, and then the software compares all the alternatives. For other levels, there was a comparison in pairs so that while selecting a desired level relevant pairs were shown and each pair was allocated its value on a scale from 1 to 9.

Assigning a certain value of the fixed scale to each standard and a comparison in pairs were conducted in line with the authors' experience and the airline's data for the observed year for all 377 criteria which are monitored in this company in the following way:

With the data regarding SAFA/Ramp Inspection, the number of stated irregularities for the observed year was taken into account. Since there are three categories of irregularities (cat. 1, cat. 2 and cat. 3), the number of first-category irregularities was multiplied by 1, the number of second-category irregularities was multiplied by 4, the number of third-category irregularities was multiplied by 8.

With the data regarding delays for operational and technical reasons, the number of irregularities was observed by certain categories and expressed in minutes of delay for a certain category for the observed year.

With the data regarding aircraft reliability, the number of pilot complaints was observed as well as the number of unscheduled component replacements, incidents, occurrences and their consequences and technical delays which were expressed in minutes for the observed year.

With the data regarding the FDR, the number of exceedances was observed by the given criteria for the observed year. The data were ranked in 4 trigger levels (white, yellow, orange and red). At the white level, the number of exceedances was multiplied by 1; at the yellow level, the number was multiplied by 2; at the orange level, the number was multiplied by 3, while at the red level the number of exceedances was multiplied by 4.

With the data regarding the previous audit, the number of irregularities was observed. Since there are three types of irregularities (cat. 1 - critical resolve immediately, cat. 2 - major resolve in 1 month, cat. 3 - major resolve in 3 months) and observations stated during the audit, the number of cat. 1 irregularities was multiplied by 8, the number of cat. 2 irregularities was multiplied by 4, the number of cat. 3 irregularities was multiplied by 1, while the number of observations was multiplied by 0.5.

With the data regarding the weight of each standard in relation to aircraft performance, the data were assigned on the basis of the authors' experience, as well as all the general data monitored throughout the observed year (minutes from the meetings, pursers' reports, passengers' complaints, complaints from other organizational units, etc.).

With the data regarding changes in the organization, the number of changes was observed by the given criteria for the observed year.

With the data regarding occurrences which are mandatorily reported, the number of occurrences was observed by the stated categories for the observed year.

For every mentioned quantitative measure, a qualitative measure was added, based on the experience of the authors of this paper, both in the company to which the numerical data refer, and in numerous other companies over the territory of Europe, Asia and Africa, with which the authors of this paper are acquainted on the basis of audits, inspections, surveys and various reports and collaborations.

When comparing different types of data, first their normalization was performed in order to enable the comparison. In all comparisons (for each level), the software automatically provided the consistency index so that it was possible to see immediately whether the comparison had been conducted properly.

5. Results and discussion

After applying the data, the software ranks all the alternatives (922 IOSA standards) in relation to the overall goal as well as to the observed hierarchy level (knot). All consistency indices meet the condition that the error does not exceed 10% (CI≤0.10). Accordingly, it may be concluded that the model has been designed properly and that its results are satisfactory.

All ranked alternatives (IOSA standards) and their priorities were observed, and the authors decided that all the ranked IOSA standards whose priority value is less than or equal to 0.001 are rejected, except the standards directly related to aircraft performance, while other standards are accepted for further audit. Thus, 147 standards from 922 were selected and divided by priority. They are presented in Table 2.

Table 2 Selected IOSA Standards divided by priority

Selected standards listed by priority	Priority level 1	ORG 1.1.1 / ORG 1.1.10 / ORG 3.1.1 / ORG 3.4.1 / ORG 3.4.3
	Priority level 2	ORG 3.3.1 / ORG 3.5.2 / FLT 2.1.1 A
	Priority level 3	ORG 3.1.2 / ORG 3.2.2 / MNT 1.3.1 / MNT 2.1.1 / MNT 4.3.1
	Priority level 4	ORG 1.1.4 / ORG 1.1.12 / ORG 1.2.1 / ORG 1.2.2 / ORG 1.2.3 / ORG 1.3.1 / ORG 1.3.5 / ORG 1.5.1 / ORG 1.5.2 / ORG 1.6.1 / ORG 1.6.2 / ORG 1.6.3 / ORG 1.6.4 / ORG 1.8.1 / ORG 3.1.3 / ORG 3.2.1 / ORG 3.3.3 / ORG 3.3.11 / ORG 3.4.4 / ORG 3.5.1 / ORG 3.5.3 / ORG 3.6.1 / FLT 1.1.1 / FLT 1.3.1 / FLT 1.3.6 / FLT 1.4.1 / FLT 1.4.2 / FLT 1.4.3 / FLT 1.5.2 / FLT 1.10.1 / FLT 1.10.2 / FLT 1.10.3 / FLT 1.10.4 / FLT 1.11.1 / FLT 1.11.2 / FLT 1.11.3 / FLT 1.11.4 A / FLT 1.11.4 B / FLT 1.11.5 / FLT 1.12.1 / FLT 1.12.2 / FLT 1.12.3 / FLT 1.12.4 / FLT 1.12.5 / FLT 2.2.10 / FLT 2.2.16 A / FLT 2.2.16 B / FLT 3.8.3 / FLT 3.8.6A / FLT 3.8.6B / FLT 3.8.7 A / FLT 3.15.2 / FLT 3.15.3 / FLT 3.15.4 / DSP 1.1.1 / DSP 1.5.1 / DSP 1.5.2 / DSP 1.10.1 / DSP 1.10.2 / DSP 1.10.3 / DSP 1.10.4 / DSP 1.12.1 / DSP 1.12.2 / DSP 2.1.1 / MNT 1.1.1 / MNT 1.1.2 / MNT 1.1.3 / MNT 1.2.1 / MNT 1.3.2 / MNT 1.3.3 / MNT 1.4.1 / MNT 1.4.2 / MNT 1.4.3 / MNT 1.5.1 / MNT 1.8.1 / MNT 1.10.1 / MNT 1.10.2 / MNT 1.10.3 / MNT 1.10.4 / MNT 1.11.1 / MNT 1.11.2 / MNT 1.11.7 / MNT 1.11.9 / MNT 1.12.1 / MNT 1.12.2 / MNT 1.12.3 / MNT 1.12.4 / MNT 1.12.5 / MNT 2.2.1 / MNT 2.4.1 / MNT 2.4.2 / MNT 2.4.3 / MNT 2.5.1 / MNT 2.5.2 / MNT 2.6.1 / MNT 2.7.1 / MNT 2.10.1 / MNT 2.12.2 / MNT 2.12.7 / MNT 3.2.2 / MNT 3.4.1 / MNT 4.2.3 / MNT 4.3.5 / CAB 2.1.1A / GRH 1.1.1 / GRH 1.2.1 / GRH 1.4.1 / GRH 1.4.2 / GRH 1.9.1 / GRH 1.9.2 / GRH 1.10.2 / GRH 1.11.1 / GRH 2.1.1 / CGO 1.1.1 / SEC 1.1.1 / SEC 1.2.1 / SEC 1.3.1 / SEC 1.5.2 / SEC 1.9.1 / SEC 1.10.1 / SEC 1.10.2 / SEC 1.10.3A / SEC 2.1.1 /
	Priority level 5	FLT 4.1.1 / FLT 4.1.2 / FLT 4.1.3 / FLT 4.1.4 / FLT 4.2.1 / FLT 4.2.2 / FLT 4.2.3 / FLT 4.2.4 / FLT 4.2.5 / FLT 4.3.1 / FLT 4.3.5

Observing the standards and their number, obtained by the overall ranking of the model (147 standards) and the standards and their number obtained by the model according to the WGH criteria (453 standards), it is clear that the standards which were chosen only on the basis of the auditor's opinion do not represent the best solution – the number of 453 standards chosen by the auditor instead of 147 standards chosen by the model is 308% of the optimal number of standards which must be checked. Within the selected 147 standards, obtained by the overall ranking of the model, 10 standards were not selected by the auditor, which is 6.8% of the number of standards obtained as optimal. Based on the above, the authors of this paper confirm their own assumption that the design of the audit checklist, based only on the auditor's own attitude, even if he/she is supported by DCS and possesses very good knowledge and experience, is not appropriate.

It is very interesting that eleven standards which are directly relevant for aircraft performance, covered by the area of *Operations Engineering Specifications,* are ranked at the last level of priority. This confirms the assumption of the authors (described in Section 1) that checking only these standards leads to a routine examination of the given standards which is not necessarily relevant. The mentioned standards refer to aircraft performance, navigation and facilities and aircraft systems and equipment specifications, and all the related details must be described in the Operations Manual, which is one of several manuals to be approved by the Civil Aviation Authority (CAA) before the issuing of an Air Operator Certificate (AOC) and the start of operations. Beside, these standards are regularly checked by the CAA, in accordance with the audit plan. This leads to a situation where all the requirements must be satisfied earlier than the audit performed and, based on the experience of the authors of this paper, very rarely do findings exist regarding these standards, which does not mean that all the requirements regarding safety in the domain of aircraft performance are satisfied. As can be seen in Table 2, most of the priority standards lie in the domain of maintenance, organization, and flight operations, indicating areas for special attention.

All contributions at all levels could be considered and, based on them, the compliance manager, apart from ranking the standards, could recognize areas for improvement as well as areas for savings resources. It is clear that the basic goal was achieved – ranking IOSA standards regarding aircraft performance, the number of IOSA standards was reduced from 922 to 147 standards ranked by priority. This is an acceptable number of standards to be checked in accordance with available resources – approximately five working days with two (a maximum of three) auditors supported by periodically engaged experts from particular areas (pilot, cabin crew, ground and maintenance staff). The ranking of standards by each criterion and sub-group defined within the given model was obtained in the same manner, which is an excellent source for defining the checklist by all the stated criteria or certain groups composed of them. According to the obtained results, the compliance manager can easily define the checklist both for the annual audit regarding aircraft performance and targeted/extraordinary audits regarding each of the stated criteria or groups composed of them.

This model shows the contributions as well as the standards which must be checked for every criterion, at every level. Further in the text, the contributions will be shown and discussed, given that the showing of particular standards for every group would require too much space.

At level 1, the contribution of eight criteria as well as the rank are as follows (contribution/rank):

Table 3 Contribution and rank of criteria at level 1

Criterion	SAFA	DEL	REL	FDR	EXA	WGH	COR	OCC
Contribution/Rank	0.221 / 1	0.165 / 2	0.106 / 4	0.041 / 6	0.029 / 7	0.221 / 1	0.118 / 3	0.099 / 5

The model shows that two criteria of eight, SAFA and WGH, at the first level, have the biggest contribution, which indicates that the covered areas of work described with the mentioned criteria could be a weakness of the system and could represent areas appropriate for deeper checking and further improvement. The results also show that one criterion out of eight, at the first level, has the lowest contribution – EXA (results of previous audit). This confirms the suspicions of the authors of this paper that the results of a previous audit, conducted in the most standard manner (checking yes or no options within a set of standards defined in regulations covering a couple of thousands of pages) do not show the real condition within the system and neither are they relevant with a high degree of reliability, despite the fact that many airlines (based on the authors' practical knowledge) use them as major lead parameters during the process of defining the scope of the audit as well as the checklist. The results shown by the model confirm the hypothesis of the authors when they started work on this paper that the data from previous audits should be observed in a broader context (described in Section 3.3.5 of this paper).

In respect of the SAFA criterion, all contributions and ranks are visible in Table 4, indicating that the criterion "aircraft condition" has the biggest contribution, and within it the sub-criterion "general external conditions". If we exclude the criterion "general" in fifth position, which characterizes general remarks, in last place there is the criterion "Cargo" and the sub-criterion "Dangerous goods", which indicates that every criterion with precise regulatory requirements very rarely causes non-conformities and has hidden causes of endangering safety, while globally described areas could be very fertile soil for hidden areas for non-conformities. It is very interesting that within the criterion "Documentation" the biggest contribution is made by the sub-criterion "Minimum equipment list", indicating the importance of aircraft maintenance and the proper application of MEL (Minimum Equipment List).

Table 4 Data for SAFA / Ramp Inspections [47]

Level 1	Level 2		Level 3		Level 4	
SAFA (0.221/ 1)	Flight deck	(0.330 / 2)	General	(0.467 / 1)	General condition	(0.818 / 1)
					Emergency exit	(0.091 / 2)
					Equipment	(0.091 / 2)
			Documentation	(0.141 / 3)	Manuals	(0.061 / 3)
					Checklist	(0.290 / 2)
					Radio navigation charts	(0.034 / 4)
					Minimum equipment list	(0.416 / 1)
					Certificate of registration	(0.034 / 4)
					Noise certificate	(0.061 / 3)
					AOC or equivalent	(0.034 / 4)
					Radio licence	(0.034 / 4)
					Certificate of airworthiness	(0.034 / 4)
			Flight data	(0.042 / 5)	Flight preparation	(0.100 / 2)
					Weight and balance	(0.900 / 1)
			Safety equipment	(0.032 / 6)	Hand fire extinguishers	(0.200 / 1)
					Life jackets/flotation dev.	(0.200 / 1)
					Harness	(0.200 / 1)
					Oxygen equipment	(0.200 / 1)
					Independent portable light	(0.200 / 1)
			Flight crew	(0.065 / 4)	Flight crew licence	(1.000 / 1)
			Journey log book / Technical Log or equivalent	(0.253 / 2)	Journey log book	(0.072 / 3)
					Maintenance release	(0.072 / 3)
					Defect notification & rectification	(0.727 / 1)
					Pre-flight inspection	(0.129 / 2)
	Safety/ Cabin	(0.081 / 3)	General internal condition	(0.178 / 2)		
			Cabin attendant's station & crew rest area	(0.028 / 6)		
			First aid kit / Emergency medical kit	(0.028 / 6)		
			Hand fire extinguishers	(0.028 / 6)		
			Life jackets / Flotation device	(0.028 / 6)		
			Seat belt and seat conditions	(0.130 / 3)		
			Emerg. exit, light/marking, indep. port. Light	(0.048 / 5)		
			Slides / Life rafts (as required), ELT	(0.028 / 6)		
			Oxygen supply (Cabin crew and passengers)	(0.311 / 1)		
			Safety instruction	(0.028 / 6)		
			Cabin crew members	(0.085 / 4)		
			Access to emergency exit	(0.028 / 6)		
			Safety of passenger baggage	(0.028 / 6)		
			Seat capacity	(0.028 / 6)		

Level 1	Level 2		Level 3		Level 4
	Aircraft conditions	(0.485 / 1)	General external conditions	(0.363 / 1)	
			Doors and hatches	(0.034 / 8)	
			Flight controls	(0.037 / 7)	
			Wheels, tyres and brakes	(0.034 / 8)	
			Undercarriage, skids/floats	(0.056 / 6)	
			Wheel well	(0.069 / 5)	
			Power plant and pylon	(0.128 / 2)	
			Fan blades, Propellers, Rotors (main & tail)	(0.033 / 9)	
			Obvious repairs	(0.075 / 4)	
			Obvious unrepaired damage	(0.103 / 3)	
			Leakage	(0.037 / 7)	
	Cargo	(0.061 / 4)	General conditions of cargo compartment	(0.231 / 2)	
			Dangerous goods	(0.060 / 3)	
			Safety of cargo on board	(0.709 / 1)	
	General	(0.043 / 5)	General	(1.000 / 1)	

In respect to the DEL criterion, all contributions and ranks are visible in Table 5 and Table 6, indicating that the criterion "Delay codes with 9 – reactionary" has the biggest contribution, and within it the sub-criterion "aircraft rotation". This indicates that the very short period of rotation, which most airlines strive to achieve in order to save time, has a direct impact on cabin and flight crew and their behaviour. The short time of rotation causes delay and consequently flight crew try to make up for lost time on the ground during the flight, deviating from the desired or optimal flight characteristics. On the other hand, in last position is the criterion "Delay codes with 2 – cargo and mail" and within it five sub-criteria, indicating actions which are usually performed by the handling agent, who must work in accordance with agreements if the agent does not want to lose money. Consequently, in this area conditions rarely exist for deeper consideration when the airline operates at an airport with many handling agents. However, if selecting and changing the handling agent is not possible, in unsatisfactory circumstances, deeper consideration of this area is necessary.

Table 5 IATA delay codes [48]

Level 1	Level 2		Level 3	
DEL (0.165 / 2)	D0 - Delay codes with "0" –internal purpose of Operator/Others	(0.053 / 4)	D00-D05 airline internal codes	(0.194 / 2)
			D06 no gate/stand availability due to own airline activity, including early arrivals	(0.063 / 3)
			D09 scheduled ground time less than declared minimum ground time	(0.743 / 1)
	D1 - Delay codes with "1" – passenger and baggage	(0.053 / 4)	D11 late check-in, acceptance after deadline	(0.104 / 4)
			……….[48]	Table 6
			D19 reduced mobility, boarding / de-boarding of passengers with reduced mobility	(0.035 / 6)
	D2 - Delay codes with "2" – cargo and mail	(0.029 / 5)	D21 documentation, errors etc.	(0.349 / 1)
			.... [48]	Table 6
			D29 late acceptance *(mail only)*	(0.030 / 5)
	D3 - Delay codes with "3" –aircraft and ramp handling	(0.053 / 4)	D31 aircraft documentation late/inaccurate, weight and balance, general declaration, pax manifest, etc.	(0.065 / 4)
			……….[48]	Table 6
			D39 technical equipment, lack of or breakdown, lack of staff, e.g. push-back	(0.060 / 5)
	D4 - Delay codes with "4" –technical and aircraft equipment	(0.100 / 3)	D41 aircraft defects	(0.359 / 1)
			……….[48]	Table 6
			D48 scheduled cabin configuration/version adjustments	(0.034 / 3)
	D5 - Delay codes with "5" –damage to aircraft and automated equipment failure	(0.053 / 4)	D51 damage during flight operations, bird or lightning strike, turbulence, heavy or overweight landing, collision during taxiing	(0.112 / 3)
			……….[48]	Table 6
			D58 other automated system format	(0.061 / 4)
	D6 - Delay codes with "6" –flight operations and crewing	(0.053 / 4)	D61 flight plan, late completion or change of flight documentation	(0.214 / 2)
			……….[48]	Table 6
			D69 captain request for security check, extraordinary	(0.038 / 7)
	D7 - Delay codes with "7" –weather	(0.053 / 4)	D71 departure station	(0.328 / 1)
			……….[48]	Table 6
			D77 ground handling impaired by adverse weather conditions	(0.028 / 5)
	D8 - Delay codes with "8" - Air Traffic Flow Management /Airport and Governmental Authorities	(0.154 / 2)	D81 ATFM due to ATC en-route demand/capacity, standard demand/capacity problems	(0.424 / 1)
			……….[48]	Table 6
			D89 restrictions at airport of departure with or without ATFM restrictions, including air traffic services, start-up and pushback, airport and/or runway closed due to obstruction or weather (restriction due to weather in case of AFTM regulation only, else refer to code 71), industrial action, staff shortage, political unrest, noise abatement, night curfew, special flights	(0.081 / 3)

Level 1	Level 2		Level 3	
	D9 - Delay codes with "9" – reactionary	(0.398 / 1)	D91 load connection, awaiting load from another flight	(0.101 / 2)
			……….[48]	Table 6
			D99 used only when it is clear that a reason cannot be matched to a code above	(0.025 / 6)

Due to the large amount of data regarding all groups of delay codes, Table 6 was established with all contributions and ranks for all criteria defined in [48].

Table 6 Contributions / ranks of criteria at level 3 for DEL (part of Table 3)

D0	D00 - D05 (0.194 / 2)					D06 (0.063 / 3)	-	-	D09 (0.743 / 1)
D1	D11 (0.104 / 4)	D12 (0.038 / 6)	D13 (0.075 / 5)	D14 (0.038 / 6)	D15 (0.363 / 1)	D16 (0.168 / 2)	D17 (0.021 / 7)	D18 (0.158 / 3)	D19 (0.035 / 6)
D2	D21 (0.349 / 1)	D22 (0.103 / 4)	D23 (0.030 / 5)	D24 (0.166 / 3)	D25 (0.231 / 2)	D26 (0.030 / 5)	D27 (0.030 / 5)	D28 (0.030 / 5)	D29 (0.030 / 5)
D3	D31 (0.065 / 4)	D32 (0.259 / 2)	D33 (0.041 / 7)	D34 (0.065 / 4)	D35 (0.041 / 7)	D36 (0.343 / 1)	D37 (0.078 / 3)	D38 (0.047 / 6)	D39 (0.060 / 5)
D4	D41 (0.359 / 1)	D42 (0.060 / 2)	D43 (0.060 / 2)	D44 (0.060 / 2)	D45 (0.034 / 3)	D46 (0.359 / 1)	D47 (0.034 / 3)	D48 (0.034 / 3)	-
D5	D51 (0.112 / 3)	D52 (0.280 / 2)	-	-	D55 (0.452 / 1)	D56 (0.061 / 4)	D57 (0.035 / 5)	D58 (0.061 / 4)	-
D6	D61 (0.214 / 2)	D62 (0.074 / 5)	D63 (0.110 / 4)	D64 (0.276 / 1)	D65 (0.169 / 3)	D66 (0.023 / 8)	D67 (0.038 / 7)	D68 (0.056 / 6)	D69 (0.038 / 7)
D7	D71 (0.328 / 1)	D72 (0.328 / 1)	D73 (0.078 / 3)	-	D75 (0.193 / 2)	D76 (0.045 / 4)	D77 (0.028 / 5)	-	-
D8	D81 (0.424 / 1)	D82 (0.081 / 3)	D83 (0.051 / 4)	D84 (0.116 / 2)	D85 (0.051 / 4)	D86 (0.051 / 4)	D87 (0.116 / 2)	D88 (0.029 / 5)	D89 (0.081 / 3)
D9	D91 (0.101 / 2)	D92 (0.068 / 4)	D93 (0.500 / 1)	D94 (0.035 / 5)	D95 (0.068 / 4)	D96 (0.100 / 3)	D97 (0.035 / 5)	D98 (0.068 / 4)	D99 (0.025 / 6)

In respect to REL, all contributions and ranks are visible in Tables 7, 8, 9 and 10 relating to criteria with the biggest and lowest contribution. Due to the vast amount of data regarding ATAs, Tables 8, 9 and 10 were established with all contributions and ranks for all criteria defined in [50]. For this paper, the following ATAs were considered: 21-36, 38, 49, 51-57, 71-80.

Table 7 Data for aircraft reliability monitoring

Level 1	Level 2		Level 3	
REL (0.106 / 4)	Flight crew complaints divided by ATA (Air Transport Association)	(0.416 / 1)	ATA 21 – Air conditioning	(0.034 / 5)
			……….[50]	Table 8
			ATA 80 – Starting	(0.019 / 7)
	Technical delays more than 15 min divided by ATA and flight cancelation cause	(0.089 / 3)	ATA 21 – Air conditioning	(0.034 / 4)
			……….[50]	Table 9
			ATA 80 – Starting	(0.015 / 8)
			Environmental (external) cause (EC)	(0.046 / 2)
			Other unscheduled action (OUA)	(0.015 / 8)
			Scheduled and special check (SSC)	(0.025 / 6)
			Indirect technical reasons (ITR)	(0.025 / 6)
	Unscheduled replacement of components divided by ATA	(0.304 / 2)	ATA 21 – Air conditioning	(0.038 / 3)
			……….[50]	Table 10
			ATA 80 – Starting	(0.020 / 6)
	Technical incidents and serious defects	(0.053 / 4)	Fire / smoke warning real	(0.029 / 4)
			Fire / smoking warning false	(0.089 / 2)
			Fire on board	(0.053 / 3)
			Smoke on board	(0.089 / 2)
			Depressurization	(0.053 / 3)
			Engine in-flight flame out / steam out	(0.029 / 4)
			Engine in-flight shutdown	(0.029 / 4)
			Fuel system failure	(0.029 / 4)
			Landing gear system failure including major tire defect	(0.053 / 3)
			Brake system failure	(0.029 / 4)
			Flight control failure	(0.029 / 4)
			Structural failure requiring major repair	(0.029 / 4)
			Damage caused by engine exhaust system	(0.029 / 4)
			Other failure resulting in an emergency procedure	(0.341 / 1)
			Serious defect found or occurring during maintenance	(0.089 / 2)
	Technical occurrences	(0.053/ 4)	Turbulence	(0.033 / 6)
			Lightning strike	(0.033 / 6)
			Bird strike	(0.169 / 2)
			Foreign Object Damage (FOD)	(0.033 / 6)
			Hard landing	(0.033 / 6)
			A/C damaged by ground equipment	(0.090 / 4)
			Failure not included in incidents occurring before Vr speed	(0.424 / 1)
			Failure not included in incidents occurring after Vr speed	(0.123 / 3)
			Failure noticed before engine start causing technical delay	(0.060 / 5)

Level 1	Level 2		Level 3	
	Technical incidents and technical occurrences consequences	(0.053 / 4)	Aborted take off	(0.062 / 4)
			Fuel damping	(0.035 / 6)
			Air interruption, technical – turn back	(0.172 / 2)
			Air interruption, technical – diversion	(0.062 / 4)
			Ground interruption, technical	(0.436 / 1)
			Ferry flight	(0.062 / 4)
			Engine replacement	(0.036 / 5)
			Aircraft replacement	(0.100 / 3)
			Flight cancelation – technical	(0.035 / 6)
	Power unit	(0.032 / 5)	Unplanned engine removals	(0.900 / 1)
			In-flight shut downs	(0.100 / 2)

The criterion “Flight Crew compliance divided by ATA” makes the biggest contribution and within it the sub-criterion “Navigation”, which highlights the importance of pilot feedback as well as the well-established reporting system. The sub-criterion “Navigation” covers numerous systems such as the flight management system, the global positioning system, the head-up guidance system, etc., which all directly affect aircraft performance. In last position is the criterion “Power Unit” and the sub-criterion “In-flight shut downs”, which is very rare and followed by serious investigation.

Table 8 Contributions/ranks at Level 3 (Flight crew complaints)

ATA 34	ATA 33	ATA 49	ATA 23	ATAs 21/22/25/ 27/28/30	ATA 32	ATAs 26/29/31/35/36/38/51/52/53/54/56/ 57/71/72/73/74/76/77/78/79/80	ATA 24	ATA 75	ATA 55
(0.150 / 1)	(0.079 / 2)	(0.058 / 3)	(0.041 / 4)	(0.034 / 5)	(0.030 / 6)	(0.019 / 7)	(0.018 / 8)	(0.014 / 9)	(0.010 / 10)

Table 9 Contributions/ranks at Level 3 (Technical delays of more than 15 mins and cause of flight cancellation)

ATAs 32/34	EC (Table 7)	ATAs 25/27/33/49	ATA 21	ATA 30	ATAs 22/23/24/28/35/56/78/ SSC/ITR (Table 7)	ATA 76	ATAs 26/29/31/36/38/52/53/71/72/ 73/74/75/77/80 and OUA (Table 7)	ATA 79	ATAs 51/54/55/57
(0.122 / 1)	(0.046 / 2)	(0.035 / 3)	(0.034 / 4)	(0.026 / 5)	(0.025 / 6)	(0.016 / 7)	(0.015 / 8)	(0.012 / 9)	(0.008 / 10)

Table 10 Contributions/ranks at Level 3 (Unscheduled replacement of components)

ATA 32	ATAs 34/35	ATA 21	ATAs 25/27/49	ATA 56	ATAs 22/23/24/26/28/29/30/31/33/36/38/54/71/73/74/75/77/78/79/80	ATAs 51/52/53/55/57/72/76
(0.146 / 1)	(0.101 / 2)	(0.038 / 3)	(0.037 / 4)	(0.021 / 5)	(0.020 / 6)	(0.011 / 7)

In respect of FDR, Table 11 shows all contributions and ranks, indicating that the criterion with the biggest contribution is “Requirements regarding flight path, speed and configuration” and the sub-criterion “Thrust reverse status”, while in the last position is the criterion “Requirements regarding engine power” and all the sub-criteria except “Total air temperature”. Thrust reverse status is a significant parameter regarding aircraft performance due to the use of braking by thrust reverse, where the deceleration of the aircraft is improved on landing, just after touch down, enabling shorter landing distances. The efficiency of this type of braking is higher at higher speeds, but at a speed of about 100 km/h this type of braking must be stopped, because the exhaust gases that the thrust system directs forward are sucked back into the engine, which can have negative consequences for the engine [23].

Table 11 FDR data

Level 1	Level 2		Level 3	
FDM (0.041 / 6)	Requirements regarding aircraft attitude	(0.278 / 2)	Pitch	(0.793 / 1)
			Roll	(0.076 / 3)
			Heading	(0.131 / 2)
	Requirements regarding engine power	(0.058 / 3)	N1 (rotation speed, low pressure compressor) eng1	(0.059 / 2)
			N1 (rotation speed, low pressure compressor) eng2	(0.059 / 2)
			N2 (rotation speed, high pressure compressor) eng1	(0.059 / 2)
			N2 (rotation speed, high pressure compressor) eng2	(0.059 / 2)
			EGT (Exhaust Gas Temperature) eng1	(0.059 / 2)
			EGT (Exhaust Gas Temperature) eng2	(0.059 / 2)
			TLA (Thrust Lever Angle) L	(0.059 / 2)
			TLA (Thrust Lever Angle) R	(0.059 / 2)
			TAT (Total Air Temperature)	(0.529 / 1)

Level 1	Level 2		Level 3	
	Requirements regarding flight path, speed and configuration	(0.663 / 1)	Altitude	(0.025 / 4)
			Calibrated Air Speed	(0.026 / 3)
			Gz (gravitational force)	(0.025 / 4)
			Gz max (maximal gravitational force)	(0.041 / 2)
			Longitudinal Acceleration	(0.015 / 6)
			Lateral Acceleration	(0.015 / 6)
			Flaps L	(0.041 / 2)
			Flaps R	(0.041 / 2)
			Communication events	(0.015 / 6)
			Thrust reverse status Eng1RevL Nstowed	(0.170 / 1)
			Thrust reverse status Eng1RevR Nstowed	(0.170 / 1)
			Thrust reverse status Eng2RevL Nstowed	(0.170 / 1)
			Thrust reverse status Eng2RevR Nstowed	(0.170 / 1)
			Disambiguation Altitude/Aerodrome Reference Point	(0.025 / 4)
			Ground Speed	(0.024 / 5)
			Longitude	(0.015 / 6)
			Latitude	(0.015 / 6)

In respect of EXA, all contributions and ranks can be seen in Table 12, indicating that the criterion with the biggest contribution is “Finding cat. 2”, while in last position is the criterion “Finding cat. 1”. This indicates that “Finding cat. 2” is the real finding with a real time frame for resolution, while “Finding cat. 1” is a very serious systematic finding and, based on the experience of the authors, is very rare. “Finding cat. 3” as well as “Observation” are categories which are better avoided during the internal audit, since the time frame for solving “Finding cat. 3” is rather long and employees do not take them seriously, while resolving “Observation” is not obligatory and needs a very high level of awareness of the purpose of the audit.

Table 12 Data from previous audit

Level 1	Level 2	
EXA (0.029 / 7)	Observation	(0.113 / 3)
	Finding cat. 1	(0.050 / 4)
	Finding cat. 2	(0.656 / 1)
	Finding cat. 3	(0.180 / 2)

In respect of COR, all contributions and ranks are visible in Table 13, indicating that the criterion with the biggest contribution is “Important changes in management” and the sub-criterion “Ground safety officer”, while in last position is the criterion “Important changes within organization and systematization”.

Table 13 Data regarding important changes in airline

Level 1	Level 2		Level 3	
COR (0.118 / 3)	Important changes within organization and systematization	(0.100 / 2)		
	Important changes of management	(0.900 / 1)	Accountable Manager	(0.070 / 3)
			Compliance Manager	(0.014 / 5)
			Safety Manager	(0.070 / 3)
			Security Manager	(0.014 / 5)
			Nom. Person for Flight Operations	(0.069 / 4)
			Nom. Person for Ground Operations	(0.070 / 3)
			Nom. Person for Crew Training	(0.070 / 3)
			Nom. Person for CAMO	(0.014 / 5)
			Flight Safety Officer	(0.178 / 2)
			Ground Safety Officer	(0.184 / 1)
			Crew Training Safety Officer	(0.070 / 3)
			CAMO Safety Officer	(0.178 / 2)

It is clear that safety is greatly influenced by the human factor and that people who work directly in operations regarding safety have enormous importance. People who work in ground operations with regard to safety are specific since, contrary to employees from flight operations and the continuing airworthiness management organization (CAMO) who are pilots or mechanical engineers in aviation, they do not have deep knowledge of aviation regarding performance and their primary goal is to ensure that operations go smoothly. Such an approach is always risky.

In last position are the criteria “Security Manager”, “Compliance Manager”, and “Nominated Person for CAMO”. For all these positions, the regulatory requirements are very strict and demanding and consequently persons in these positions are always carefully recruited, which results in few changes of managers. Apart from this, in the mentioned areas there are very precisely defined requirements regarding documentation, which the new manager inherits, so that the impact of the change is minimized. In contrast, changes regarding the position of safety manager have a bigger influence, since in most cases a pilot is in this position, with a completely different approach to the issue. A pilot is much more oriented towards flying than performing office work and paperwork and therefore more often leaves this position in favour of flying. The documentation he leaves behind requires the next manager to have a period of adjustment.

In respect of OCC, all contributions and ranks can be seen in Table 14, indicating that the criterion with the biggest contribution is “Occurrences related to technical conditions, maintenance and repair of the aircraft” and the sub-criterion “Design”, followed by the sub-criterion “Manufacturing”, while in last position is the criterion “Occurrences related to air navigation services and facilities” and all the sub-criteria except “Other occurrences”.

Table 14 Occurrences to be mandatorily reported

Level 1	Level 2		Level 3	
OCC (0.099 / 5)	Occurrences related to the operation of the aircraft	(0.196 / 2)	Air operations	(0.439 / 1)
			Technical occurrences	(0.104 / 3)
			Interaction with Air Navigation Services and Air Traffic Management	(0.187 / 2)
			Emergencies and other critical situations	(0.062 / 4)
			External environment and meteorology	(0.104 / 3)
			Security	(0.104 / 3)
	Occurrences related to technical conditions, maintenance and repair of the aircraft	(0.647 / 1)	Manufacturing	(0.420 / 2)
			Design	(0.507 / 1)
			Maintenance and continuing airworthiness management	(0.073 / 3)
	Occurrences related to air navigation services and facilities	(0.043 / 4)	Aircraft-related occurrences	(0.507 / 1)
			Degradation or total loss of services or functions	(0.420 / 2)
			Other occurrences	(0.073 / 3)
	Occurrences related to aerodromes and ground services	(0.114 / 3)	Safety management of an aerodrome	(0.932 / 1)
			Ground handling of an aircraft	(0.068 / 2)

All this highlights the importance of aircraft maintenance and the monitoring of all functions.

5.1 Gaps addressed in the current model

To the authors’ best knowledge, there is no paper that considers the ranking of numerous standards that must be applied by each airline. This indicates the significance of this paper and its contribution, and covers a gap in the literature as well as in practice.

In addition, the authors did not find papers related to airline audits, or related to aircraft performance, so this work and the model also close the gap.

There is also a major gap in aviation literature regarding the necessary resources for the internal auditing of an airline, despite the fact that internal auditing is wholly different from the audit of external auditors. This paper gives specific data related to resources and covers this gap in the literature and makes suggestions for practice.

As a contribution to the literature and practice, it has been shown that the documented and implemented IOSA standards, which directly relate to aircraft performance, are no guarantee that the appropriate level of safety in the domain of aircraft performance has been fully reached.

The contribution and rank of each criterion (as well as the necessary standards for checking them) by levels are shown, providing a rich source of data. Based on them, different analysis and different checklists could be prepared, which also represents a contribution to the literature and practice.

Although the literature mentions that decision-making and AHP are suitable for the development of models with a large number of criteria, the authors did not find this in the models described in the reviewed literature, while the model in this paper shows the very successful application of a large number of criteria in practice, with the possibility of a sensitivity analysis.

In the aforementioned literature, it is mentioned that audit results are not satisfactory indications of the achieved level of safety in the airline, but the authors have proven the contrary through a wholly different approach to auditing from the standard one.

The education and qualifications of auditors are defined in the regulations and by the airline itself, but, based on the experience of the authors, the level of education of the internal auditor must be very high. This is also indicated by the complexity of the presented model, as well as the knowledge and skills that need to be possessed in order to develop it. This paper suggests that operations staff should participate in auditing as experts, while auditing must be led by persons focused not just on one item or area but with a wide view of the global picture if the audit is to be used to assess the achieved level of the airline's safety, generally or regarding a particular area. The option of somebody preparing the checklist and somebody else using it is also not ideal.

To the best of the authors' knowledge, the literature does not describe a model that can be applied specifically for a similar purpose without the use of large software systems that are too expensive for small companies with a small number of aircraft. However, the model presented here is successful without using great resources, so that this gap in the literature and in practice is filled.

5.2 Current model's stability

Apart from the above-stated, the given model can be used for other audits as well. The largest part of work which is most time consuming is the pairing of all 922 standards with 377 criteria, i.e. deciding which standard is connected to which criterion. This part of the work will be valid for as long as the ISM does not undergo substantial changes – the complete alteration of a large number of standards. So far, the authors' experience has shown that even in new editions of the above-mentioned manual, a large number of standards have been changed in the domain of the better understanding of standards with newly introduced details which do not affect the essence of the standard itself in relation to the monitored criteria. In the event of introducing new standards, it is not even necessary to rank them because new standards must be examined regardless of the resources.

The stability of the obtained solution in the case of an entry change is determined by the sensitivity analysis procedure. Expert Choice software is able to perform a sensitivity analysis in many ways so that it can be seen how the weights of certain criteria affect the current and overall rank of alternatives, how changes (gradients) in the weights of certain criteria affect certain alternatives, how the priorities of alternatives change dynamically due to the change in the weighting of certain criteria with the aim of reviewing the overall influence of the weights of certain criteria in the overall priority of alternatives as well as the mutual qualitative relations of two alternatives [45]. After the designed model and applied data have ranked all the standards and selected the desired ones, a sensitivity analysis facilitates the analysis of various possibilities by applying various charts given here. On this basis, various predictions can be made in relation to potential situations in the future. For example, it can be predicted how the ranking of alternatives will change if the share of each of the eight criteria is increased at the first level as well as at all other levels except for the last one containing alternatives. Such overviews can substantially contribute to future work.

5.3 Future directions

It must be taken into account that groups of data considered in this paper (apart from the weight of the standard regarding aircraft performance) need to be monitored both for internal audit and for the audits of subcontractors so that a large part of this paper and the designed model can be exploited. By adding several more criteria or removing the existing ones it is very easy to obtain models for the standard ranking of other types of audit.

All of the above constitute guidelines for further work while a uniform database with all relevant data should be made at the level of the company regarding safety and compliance as well as other areas, connect this uniform database with Expert Choice software and then link everything to one of the programme packages (depending on the base size and the needs of the airline) with a graphic interface. This would fully automate all the features described in this paper and display various entries from the start screen while the exit would rank standards for any desired audit from the audit plan.

The guidelines for further work also encompass the establishment of new standards in the domain of the internal audit of the airline, as well as new standards for the qualification of internal auditors, by drawing up papers based on the differences between the results of the audit carried out only by operational staff and the results of the audit carried out by auditors with a high level of education and knowledge in the field of aviation, as well as other tools and skills, in combination with operating personnel who will not have the lead auditor's role but will be present as experts.

Finally, despite the fact that the authors of this paper used precise numerical data from one airline, and for one type of aircraft, supported by the results of work with many companies from Europe, Asia and Africa, which are also translated into numerical data, enabling the use of the model and its results by other companies, it will be very useful to compare the results of the application of the data of airlines with a similar safety culture, type of aircraft, number of aircraft, etc., as well as with completely different data in order to define a common data set for implementation.

6. Conclusion

This paper has described a model for managing the checking process of aircraft performance by forming an audit checklist and has examined the possibility of applying the method of multiple criteria decision-making as decision support. Expert Choice software was used and IOSA standards were ranked on the basis of the airline’s relevant data for the particular year by the AHP method. The main goal was achieved: “critical” standards were selected for a certain audit as an aid to the compliance manager in defining the audit areas and standards to be checked, while using optimum resources. Apart from ranking the standards, the recommended model can be used, by applying a sensitivity analysis, to predict the needs for additional audits, which will facilitate the drawing up of an audit plan for the following period, while new auditors will be given substantial help in decision-making with regard to focusing on certain standards. The designed model can be adjusted, whereas by adding several more criteria or removing existing ones it would be easy to obtain models for the standard ranking of other types of audit.

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