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DIAGNOSTICS OF POTENTIAL INCOMPATIBILITIES IN AERONAUTICAL DATA AND INFORMATION CHAIN

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Abstract

The influence of potentially erroneous, incomplete or inaccessible aeronautical data and information on the occurrence of an accident or serious incident in air traffic and transport is enormous. Those data and information quality has a direct impact on flight operations' safety. Moreover, much of the information provided, is the basis for planning and safe conduct of the flight and is used to achieve safety, regularity and efficiency of Air Traffic Management, so they must always be up to date and ready to use. In this paper the aeronautical data chain, described in one of the Eurocontrol specifications, was analysed. Then a proceeding diagram, compliant with holding true requirements, was elaborated, pointing out its weaknesses in terms of diagnosis of potential non-compliance that may occur during data request, origination, evaluation, preparation, distribution as well as its end use. In order to facilitate the detection of potential errors, diagnostics of potential incompatibilities' effects and causes the risk analysis using FMEA method was conducted, giving as an output a rating of non-compliance importance based on the risk priority number (RPN).

Keywords: diagnostics, incompatibility, aeronautical data and information chain

DIAGNOSTYKA POTENCJALNYCH NIEZGODNOŚCI W ŁAŃCUCHU DANYCH I INFORMACJI LOTNICZYCH

Streszczenie

Wpływ przyczynowy potencjalnie błędnych, niekompletnych lub niedostępnych danych i informacji lotniczych na wystąpienie wypadku lub poważnego incydentu w ruchu lotniczym jest ogromny. Jakość tych danych i informacji ma bezpośrednie znaczenie dla zapewnienia bezpieczeństwa wykonywania operacji lotniczych. Ponadto większość dostarczanych informacji stanowi bazę do planowania i bezpiecznego wykonania lotu, jak również jest wykorzystywana do zapewnienia bezpieczeństwa, regularności oraz efektywności zarządzania ruchem lotniczym (ATM), stąd też informacje te muszą zawsze być poprawne, aktualne i gotowe do użycia. W niniejszej publikacji przeanalizowano łańcuch danych lotniczych, przedstawiony w jednej ze specyfikacji Eurocontrol. Następnie opracowano schemat postępowania, zgodny z obowiązującymi wymaganiami, wskazując jego niedoskonałości w aspekcie diagnostyki potencjalnych niezgodności, które mogą wystąpić podczas zamówienia, tworzenia, ewaluacji, przygotowania, publikacji czy też końcowego wykorzystania danych i informacji lotniczych. Aby ułatwić wykrycie ewentualnych błędów oraz diagnostykę skutków i przyczyn potencjalnych niegodności, przeprowadzono analizę ryzyka z wykorzystaniem metody FMEA, uzyskując jako efekt zestawienie wag niezgodności w oparciu o liczbę priorytetu ryzyka (RPN).

Słowa kluczowe: diagnostyka, niezgodność, łańcuch danych i informacji lotniczych

1. INTRODUCTION

The influence of potentially erroneous, incomplete or inaccessible aeronautical data and information on the occurrence of an accident or serious incident in air traffic and transport is enormous. Those data and information quality has a direct and significant impact on flight operations' safety. Moreover, much of the information provided, in Aeronautical Information Publication (AIP) (AIP Poland for example), is the basis for planning and safe conduct of the flight and is used to achieve safety, regularity and efficiency of Air Traffic Management (ATM), so they must always be up to date and ready to use.

This article is a continuation of the authors' study on the ways to ensure the quality and safety of aeronautical data and information in the entire process (considered as the supply chain) of those data and information creation, collection, processing and publication. In previous works (e. g. [6, 7]) the authors proposed a comprehensive and systematic approach to quality assurance at all stages of the aeronautical data and information chain. This time they focused on diagnostics of potential incompatibilities in mentioned data chain that may arise despite numerous regulations, requirements and implemented verification procedures. As the issue in question is complex, in order to facilitate the detection of potential errors, diagnostics of potential incompatibilities' effects and causes the risk analysis using FMEA method was conducted, giving as an output a rating of non-compliance importance based on the risk priority number (RPN).

2. AERONAUTICAL DATA CHAIN

Aeronautical Data Chain is (according to [8]) a conceptual representation of the following stages of aeronautical data and information production starting with data request and origination through to its operational use – Fig. 1.

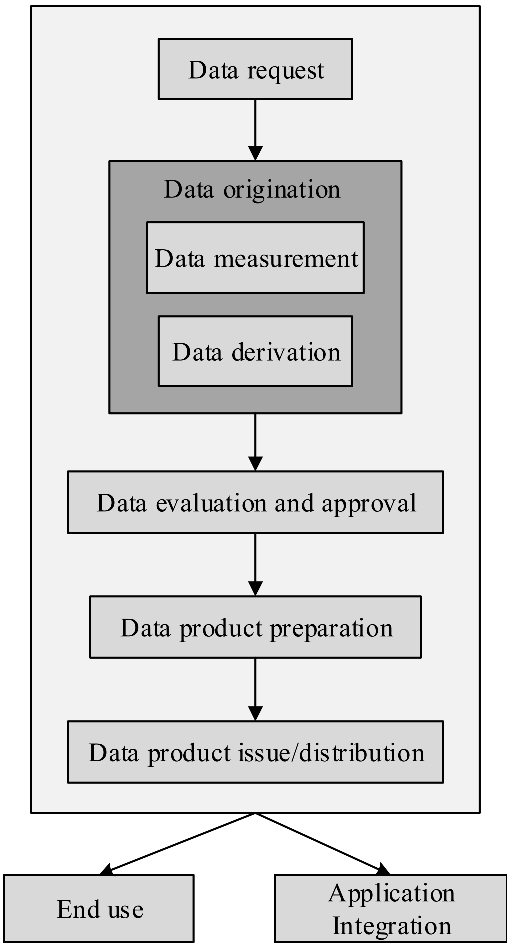

Fig. 1. Aeronautical data and information chain (based on [8])

1.1. Aeronautical data chain's stages

In the basic data life cycle, presented in Fig. 1, a certain number of stages can be distinguished:

- Data request – it is considered to be the most critical chain's stage, as the quality of data created in its effect strongly influences the overall quality of data used operationally. It is precisely at this phase when user's requirements, to be fulfilled in the following parts of the chain, are identified.
- Data origination is associated with the collection of source data and the production of derived data. At this stage it is dealt with data that is measured, designed or calculated/acquired from other data. Data origination is strictly associated with such activities as design of procedures and geodetic measurements.
- At the stage of Data evaluation and approval, with regard to the created data, the process of evaluation and acceptance is carried out, preparing them for storage, further processing and publication.
- Data product preparation – at this stage the data resulting from the previous step is subject to registration and storage. At the same time the form of their publication is chosen. This phase also includes all activities related to the data preparation for publication. It is worth noticing that after placing the accepted data in the registry, they become the Information (Figure 2). Preparation of the product includes activities on the data accepted and the activities carried out after the fact, when the accepted data becomes aeronautical information.

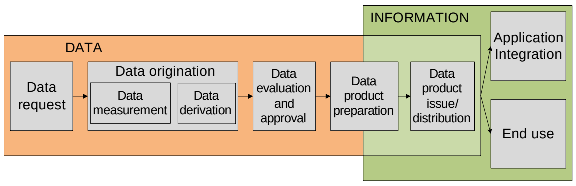

Fig. 2. Aeronautical data and information chain including division to data and information (own work based on [8])

- Data product issue/distribution includes activities related to printing, publication and distribution of aeronautical information in both paper and electronic forms, delivered to the target user.
- Application/end use is related to the preparation and integration of information to the operating systems. At this step, the information provided is used by the end user.

In the discussed aeronautical data and information chain (Fig. 1) authors attention was drawn to the fact that evaluation of the obtained results is carried out only after the completion of stages 1 and 2, respectively: data request and data origination. Moreover, the process of potential incompatibilities appearance diagnostics at the remaining phases of the chain (e.g. data product preparation, publication or information distribution) is not carried out at all. In this situation, early diagnostics of non-compliance unfortunately seems to be out of question.

1.2. Proceeding diagram and potential incompatibilities diagnostics

In Fig. 3 a proceeding diagram for the entire aeronautical data and information chain, developed on the basis of Fig. 1 as well as practical experience, was shown.

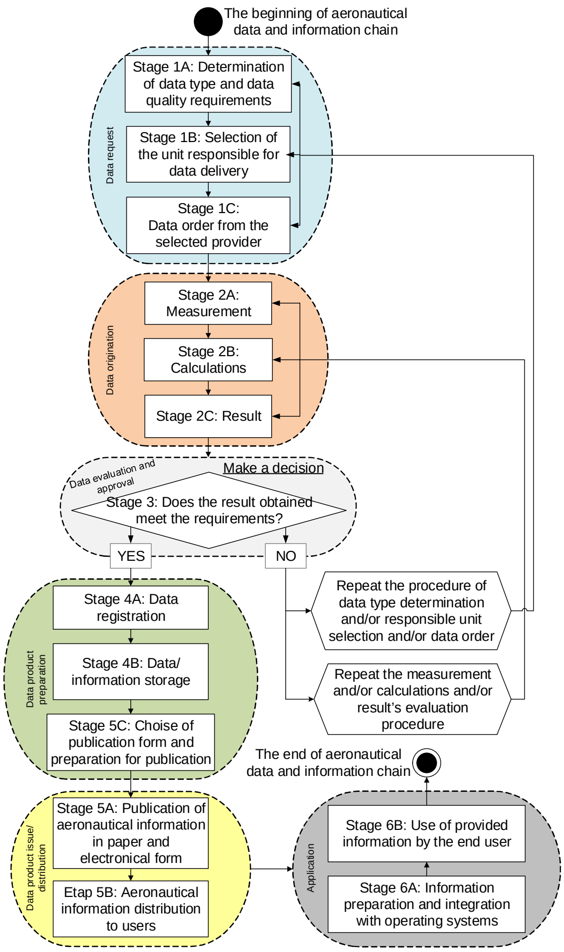

Fig. 3. Proceeding diagram for the entire aeronautical data and information chain [own study]

In terms of potential incompatibilities diagnostics, mostly resulting from being in force proactive approach to aviation safety management and aeronautical data and information quality assurance, in the proceeding diagram, presented in Fig. 3 authors attention was paid to two main aspects. First of all, in case of a potential aeronautical data and information non-compliance' detection it is necessary to determine the actual status and place of its occurrence. Secondly conducting the analysis of the mentioned non-compliance in accordance with the formally approved creation and publication schemes (Fig. 1 and Fig. 3) one should bear in mind that the mentioned incompatibility can be identified only after the publication, which means at the stage of aeronautical information final use (Fig. 1), where a single error may cause serious consequences. And yet a data error can occur at any stage of the aeronautical data and information supply chain [6] also in transfer, publication and interpretation phases, while its cause, source, place, and manner of materialization can be extremely different. What's more, aeronautical data error's appearance may not be (and most unfortunately is not) identified at the time (or place) of its occurrence.

In this case, as described in [5], the analysis of the incompatibility, starting with the determination of its occurrence place and then its causes as well as determination of the adequate preventive and corrective measures, should be carried out using the "upstream" method, taking into account that in the extreme case, the occurrence of the non-compliance may have occurred at the stage of data request (Fig. 1) or sharing of source data.

Analysis of the presented scheme (Fig. 3) leads to the obvious conclusion that its use in practice makes the uninterrupted diagnostics of incompatibilities impossible, as well as hinders the subsequent determination of the place/stage where the mismatch occurred (the "NO" result in stage 3). Analysing each step, it is necessary to diagnose the compatibility of input data, method and the processing result (measurement, analysis, redaction, editing, formatting), as well as finally the compatibility of the output data. Moreover, further verification of input and output data compatibility between successive stages is required. All those operations in total will unfortunately be a heavily time-consuming task.

Therefore, in some previous publications [5, 7] the authors proposed introduction of modifications to the aeronautical data and information chain's proceeding diagram. Till now the scheme of aeronautical data origination was analysed in details and modified by introducing into each step the verification and validation procedures [7], so that a potential or real incompatibility is diagnosed and identified up to date, and planning and implementation of preventive and correction actions occupies much less time.

Modified schemes for the remaining aeronautical data chain's stages may naturally be developed, which will be subject of authors' future work. However, before is it done for the existing scheme, arising from aeronautical requirements, risk assessment analysis, using FMEA method, was conducted, in order to help detect possible incompatibilities and diagnose the causes and effects of potential non-compliances.

3. IMPLEMENTATION OF FMEA METHOD FOR AERONAUTICAL DATA AND INFORMATION ANALYSIS

3.1. General description

In order to conduct the risk assessment process correctly it is important to properly select the techniques used. Suitable techniques should exhibit the following characteristics [13]:

- it should be justifiable and appropriate to the situation or organization under consideration;
- it should provide results in a form which enhances understanding of the nature of the risk and how it can be treated;
- it should be capable of use in a manner that is traceable, repeatable and verifiable.

The FMEA method, thanks to taking into account the potential non-compliance and hazard/threat identification factor and preventing them, is suitable for the proactive safety management formula, which is the basis of the Safety Management System (SMS), required by SARPs of ICAO Annex 19 [4]. Therefore, the authors have chosen this method.

As we can read in [13] Failure modes and effects analysis (FMEA) is a technique used to identify the ways in which components, systems or processes can fail to fulfil their design intent.

FMEA identifies:

- all potential failure modes of the various parts of a system/process (a failure mode is what is observed to fail or to perform incorrectly);
- the effects these failures may have on the system or process;
- the mechanisms of failure;
- how to avoid the failures, and/or mitigate the effects of the failures on the system/process.

The FMEA procedure contains the following activities:

- define the scope and objectives of the study;
- assemble the team;
- breakdown the system/process into its components or steps;
- for every component or step listed, define error/failure types, their reasons and effects induced in case of appearance;
- identify corrective actions to compensate for the failure.

With the analysis carried out in the described way it seems natural that as the output from the FMEA process a list of potential incompatibilities, failure modes and their influence on all mentioned system's/process' components or steps is obtained. Moreover, information concerning the effects of identified discrepancies and their consequences for the system as a whole may be obtained.

The identified failures modes may be classified according to their criticality. One of the most common methods involves the use of the Risk Priority Number (RPN) [11, 13], which is a measure of criticality obtained by multiplying numbers from rating scales (usually between 1 and 10) for consequence of failure (variable *S*), likelihood of failure (variable *R*) and ability to detect the problem (variable *W*).

$$RPN = R * W * S \tag{1}$$

It is worth noting that in various FMEA applications different scale of *R*, *W* and *S* values are used. In some cases they are rated from 1 to 4 or 5, though usually [9, 10, 14] each of those three criteria is assigned a value of 1 to 10, thereby forcing that the RPN number may assume values from 1 to 1000. A value is given a higher number when its consequences are more intense. A failure is given a higher RPN number and priority if it is difficult to detect and the risk associated with the non-compliance is higher.

3.2. FMEA for aeronautical data and information chain

In order to facilitate the diagnostics of potential aeronautical incompatibilities in the entire aeronautical data and information chain, presented in Fig. 1 and 3, the FMEA analysis was conducted. The values of variables *R*, *W* and *S* were adopted according to the literature [10, 11] as well as ICAO Annexes 4 [1], 8 [2] and 13 [3] to the Convention on International Civil Aviation and they were assigned values 1 to 10 each. The obtained results are shown in Table 1.

One more thing from the results shown in Table 1 require additional explanation - the criteria of RPN interpretation. According to literature [14] – Table 2 - all system/process parts with RPN number equal or greater than 100 may be a major threat.

Table 2. Criteria for RPN interpretation (based on [14])

RPN	Criteria
1 – 99	Incompatibility does not cause a significant threat
100 - 1000	Incompatibility is a major threat

That is why they are highlighted in Table 1 with soft red colour. They require action in first place. The rows marked with light green have RPN number minor to 100, so those process phases do not cause a significant threat.

Table 1. FMEA analysis for the entire aeronautical data and information chain [own study]

Stage No.	Stage name	Failure	Consequence of failure	Reason	*R*	*S*	*W*	*RPN*	Proposed corrective actions
1	**Data request**								
1A	**Determination of data type and data quality requirements**	Determined data does not comply with real needs	Preparation of data request for unnecessary data	Improper staff member, misunderstanding of the document concerning data order, misinterpretation of needs	1	1	9	9	Appointment of the proper representative, carefull analysis of the document concerning data order, repetition of the procedure
		Determined requirements do not comply with regulations	Inability to order data, necessity to repeat the procedure	Ignorance of the rules and requirements	3	2	9	54	Familiarization with the rules and requirements, repetition of stage's 1A procedure
1B	**Selection of the unit responsible for data delivery**	Selected unit does not comply with the regulations' requirements	Lack of acceptance of the selected provider, data order from a non-certified supplier - necessity to repeat the procedure	Ignorance of the rules and requirements; units' certificates out of date	2	2	9	36	Familiarization with the rules and requirements, updated list of approved suppliers, repetition of the procedure
1C	**Data order from the selected provider**	Incorrectly placed order	Receipt of unnecessary or incorrect data	Incorrect execution of stages 1A and 1B + editing mistake in data order composition, inattentiveness, lack of staff competence	4	5	10	200	Accurate orders' checking, appointment of the proper staff member
2	**Data origination**								
2A	**Measurement**	Measurement error	Obtained measured value is incorrect	Errors transfered from stage 1 (A, B, C) + theodolite's calibration and stability error, GPS synchronization and calibration error, poor weather and field conditions for geodetic optical measurement execution (eg .: haze, glare, reflections and interferences), runtime error in measurement procedure, improper handling of the measuring device, measurement read/write error	7	7	10	490	Introduction of verification procedures at stage 1 + correct selection and calibration of equipment, measurement performance by trained personnel, appropriate measurement conditions
2B	**Calculations**	Calculations error	Obtained calculated value is incorrect	Errors on stage 1 and 2A + incorrect reading of measured values, wrong calculation method, calculations error, an error in the calculations record	7	7	10	490	Verification at stages 2A and 1ABC + precision in calculations performance, verification of calculated values and record's correctness
2C	**Result**	Result's error	Creation of incorrect data	Uncaptured errors in all previous phases + error in calculation result's reading, the lack of verification (eg. by two surveyors)	7	7	10	490	Verification of the obtained calculation results and the correctness of the obtained result by two independent person

Stage No.	Stage name	Failure	Consequence of failure	Reason	*R*	*S*	*W*	*RPN*	Proposed corrective actions
3	**Data evaluation and approval**								
		Data error/result's incompatibility, abnormal result of data evaluation from phase 2	Necessity to return to stage 1 and/or 2 (unknown - to which?)	Lack of stage verification in steps 1ABC and 2ABC	1	10	9	90	Introduction of stage verification instead of unitary
4	**Data product preparation**								
4A	**Data registration**	Registration error	Registered value is incorrect	Error in writing data to the register	3	4	10	120	Verification whether the data has been recorded correctly
4B	**Data/information storage**	Storage of data/information not respecting the requirements (confidentiality, accuracy, consistency, etc.)	Reduction of data quality level (accuracy, consistency, etc.), failure to comply with the requirements for the specific data/information	Ignorance of the requirements, lack of attention	4	7	10	280	Verification whether the data/information is stored in accordance with the requirements, familiarization with the rules and requirements for specific types of data/information
4C	**Choice of publication form and preparation for publication**	Inadequate form of publication, incompatible with the requirements for the selected information type	Lack of information publication in the right place and time	Incorrect choice of the publication's form and place, ignorance of the requirements	5	10	10	500	Verification whether the proposed form of publication corresponds with the requirements
5	**Data product issue/distribution**								
5A	**Publication of aeronautical information in paper and electronical form**	Error/inconsistency in the publication	Lack of information publication in the right place, time and/or form	Errors in the previous stages (eg. 3, 4ABC) + ignorance of the regulations	6	10	10	600	Verification of procedures and actions at stages 4ABC + verification whether the information is published in accordance with the requirements
5B	**Aeronautical information distribution to users**	Errors in information distribution, lack of information for distribution	Data delivery to unauthorized users or improper/no data to authorized users	Errors in stages 5A and 3, 4ABC + ignorance of regulations, equipment failure	3	10	10	300	Verification of data obtained in stage 5A, verification of disrtibution process and authorized personnel
6	**Application**								
6A	**Information preparation and integration with operating systems**	Fault information integration	Inability to use/read the received information	Receiving of inaccurate information from stage 5 (ie. improper form)	3	10	10	300	Introduction of stage verification instead of unitary
6B	**Use of provided information by the end user**	Lack of information or information incompatibility	Use of incorrect information - safety risk; misuse of correct information	Accumulation of errors from previous stages (eg. 3, 4 and 5) + errors in training, lack of knowledge and skills, the wrong member of staff, human error (eg. crew captain, controller)	5	10	10	500	Modification of the proceeding diagram in the entire data and information chain (introduction of stage verification instead of unitary)

4. CONCLUSION

The results of conducted FMEA analysis, carried out for each of the 15 evaluated aeronautical data and information chain's sub-stages, indicate (Table 3) that only for 27% of process steps the risk is on a tolerable level. In the remaining 73% of stages the identified risk requires corrective actions.

Table 3. Summary of FMEA results for diagram shown in Fig. 3

RPN number	Number of results obtained	Number of results obtained in %
1 - 99	4	27%
100 - 1000	11	73%
Total:	15	100%

However, it must be noted that the *W* variable in the conducted analysis was given only values 9 and 10, as the ability to detect the incompatibilities within the proceeding schemes being actually in force does not allow usage of smaller indications.

Results interpretation according to the theory of process' quality statistical management indicates that the analysed aeronautical data and information process, considered within the scope of the methods and procedures determined in currently being in force specifications, may be unstable and often out of control, which means that in terms of incompatibility diagnostics it cannot be effectively and efficiently managed. This is important in terms of the Compliance Management System (CMS) [12] implementation that was included in the Polish National Civil Aviation Safety Program [15].

This demonstrates the need to implement activities allowing minimization of likelihood of non-compliance appearance and increasing the chance of early (in fact uninterrupted and continuous) diagnostics of incompatibilities as well as taking the appropriate corrective actions. To achieve this goal the authors propose modification of presented proceeding diagram for the entire aeronautical data and information chain by implementing stage verification instead of unitary, which will be subject of authors further work.

LITERATURE

1. Annex 4 to the Convention on International Civil Aviation, Aeronautical Charts, 2009.
2. Annex 8 to the Convention on International Civil Aviation, Airworthiness of Aircraft, 2010.
3. Annex 13 to the Convention on International Civil Aviation, Aircraft Accident and Incident Investigation, 2010.
4. Annex 19 to the Convention on International Civil Aviation, Safety Management, 2013.
5. Dudek E, Kozłowski M. Analysis of aeronautical information potential incompatibility – case study, article submitted for publication in the Journal of KONBiN, 2017.
6. Dudek E, Kozłowski M. Koncepcja zarządzania jakością danych lotniczych. Prace Naukowe Politechniki Warszawskiej – Transport, 2016, z. 113, str. 141-150
7. Dudek E, Kozłowski M. Koncepcja zastosowania metodyki DMAIC do zapewnienia jakości danych lotniczych, [w] Kwasiborska A. (red.): Transport lotniczy i jego otoczenie, Wydział Transportu Politechniki Warszawskiej, 2016, str. 67-78.
8. Eurocontrol Specification for Data Assurance Level, Reference nr: EUROCONTROL-SPEC-148, 2012.
9. Gajdzik B, Wieszała R. Wybrane zagadnienia jakości wyrobów przemysłowych i usług transportowych, Wydawnictwo Politechniki Śląskiej, Gliwice 2011
10. Hamrol A, Mantura W. Zarządzanie jakością: teoria i praktyka, 2013, Wydawnictwo Naukowe PWN.
11. IEC 60812:2006, Analysis techniques for system reliability, Part 2 Procedure for failure mode and effects analysis (FMEA), 2006.
12. ISO 19600 Compliance management systems – Guidelines, 2014.
13. ISO 31010, Risk management – Risk assessment techniques, 2009.
14. Myszewski J. Po prostu jakość: podręcznik zarządzania jakością, 2009, Wydawnictwa Akademickie i Profesjonalne.
15. Polish National Civil Aviation Safety Program, Civil Aviation Authority of the Republic of Poland, 2016.

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