DIAGNOSTYKA POTENCJALNYCH NIEZGODNOŚCI W ŁAŃCUCHU DANYCH I INFORMACJI LOTNICZYCH

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

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.

- **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.
- **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.
- **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.

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

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

![Proceeding diagram for the entire aeronautical data and information chain](自己的研究)

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, reduction, 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 fulfill 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 $W$).

$$RPN = R \times W \times S$$  \hspace{1cm} (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>
<thead>
<tr>
<th>RPN</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 99</td>
<td>Incompatibility does not cause a significant threat</td>
</tr>
<tr>
<td>100 - 1000</td>
<td>Incompatibility is a major threat</td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>Stage No</th>
<th>Stage name</th>
<th>Failure</th>
<th>Reason</th>
<th>Consequence of failure</th>
<th>Proposed corrective actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Data request</td>
<td>Determined data does not comply with needs</td>
<td>Improper staff member, misunderstanding of the document concerning data order, misinterpretation of the procedure</td>
<td>Appointment of the proper representative, careful analysis of the document concerning data order, repetition of the procedure</td>
<td></td>
</tr>
<tr>
<td>1B</td>
<td>Determination of data type and quality requirements</td>
<td>Determined requirements do not comply with regulations</td>
<td>Lack of acceptance of the regulations, failure of stages 1A and 1B</td>
<td>Familiarization with the rules and requirements, unit's certificate out of data limits, repetition of the procedure</td>
<td></td>
</tr>
<tr>
<td>1C</td>
<td>Selection of the unit responsible for data delivery</td>
<td>Selected unit does not comply with the regulations' requirements</td>
<td>Receipt of unnecessary or incorrect data</td>
<td>Familiarization with the rules and requirements, updated list of approved suppliers, repetition of the procedure</td>
<td></td>
</tr>
<tr>
<td>2A</td>
<td>Data order from the selected provider</td>
<td>Incorrectly placed order</td>
<td>Inaccurate orders' checking, appointment of the proper staff member</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2B</td>
<td>Measurement</td>
<td>Measurement error</td>
<td>Errors transferred from stage 1 (A, B, C) + GPS equipment's calibration and alignment error, poor weather and field conditions for geodetic optical measurement execution, improper handling of the measuring device, measurement read/write error</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2C</td>
<td>Calculations</td>
<td>Calculations error</td>
<td>Errors on stage 1 and 2A + incorrect reading of measured values, wrong calculation method, inappropriate measurement conditions, measurement equipment error</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Result</td>
<td>Result's error</td>
<td>Uncaptured errors in all previous phases, error in the calculation method, calculations error, result's error by two independent persons</td>
<td>Verification of the obtained calculation results and the correctness of the obtained result (e.g. by two surveyors)</td>
<td></td>
</tr>
<tr>
<td>Stage No</td>
<td>Stage name</td>
<td>Failure</td>
<td>Consequence of failure</td>
<td>Reason</td>
<td>R</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
<td>---------</td>
<td>------------------------</td>
<td>--------</td>
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</tr>
<tr>
<td>3</td>
<td>Data evaluation and approval</td>
<td>Data error/result's incompatibility, abnormal result of data evaluation from phase 2</td>
<td>Necessity to return to stage 1 and/or 2 (unknown - to which?)</td>
<td>Lack of stage verification in steps 1ABC and 2ABC</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Data product preparation</td>
<td>4A Data registration</td>
<td>Registration error</td>
<td>Registered value is incorrect</td>
<td>Error in writing data to the register</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4B Data/information storage</td>
<td>Storage of data/information not respecting the requirements (confidentiality, accuracy, consistency, etc.)</td>
<td>Reduction of data quality level (accuracy, consistency, etc.), failure to comply with the requirements for the specific data/information</td>
<td>Ignorance of the requirements, lack of attention</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4C Choice of publication form and preparation for publication</td>
<td>Inadequate form of publication, incompatible with the requirements for the selected information type</td>
<td>Lack of information publication in the right place and time</td>
<td>Incorrect choice of the publication's form and place, ignorance of the requirements</td>
</tr>
<tr>
<td>5</td>
<td>Data product issue/distribution</td>
<td>5A Publication of aeronautical information in paper and electronic form</td>
<td>Error/inconsistency in the publication</td>
<td>Lack of information publication in the right place, time and/or form</td>
<td>Errors in the previous stages (eg. 3, 4ABC) + ignorance of the regulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5B Aeronautical information distribution to users</td>
<td>Errors in information distribution, lack of information for distribution</td>
<td>Data delivery to unauthorized users or improper/no data to authorized users</td>
<td>Errors in stages 5A and 3, 4ABC + ignorance of regulations, equipment failure</td>
</tr>
<tr>
<td>6</td>
<td>Application</td>
<td>6A Information preparation and integration with operating systems</td>
<td>Fault information integration</td>
<td>Inability to use/read the received information</td>
<td>Receiving of inaccurate information from stage 5 (ie. improper form)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6B Use of provided information by the end user</td>
<td>Lack of information or information incompatibility</td>
<td>Use of incorrect information - safety risk; misuse of correct information</td>
<td>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)</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>RPN number</th>
<th>Number of results obtained</th>
<th>Number of results obtained in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 99</td>
<td>4</td>
<td>27%</td>
</tr>
<tr>
<td>100 - 1000</td>
<td>11</td>
<td>73%</td>
</tr>
<tr>
<td>Total:</td>
<td>15</td>
<td>100%</td>
</tr>
</tbody>
</table>

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