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Functional / Process Simulation of the Risk Analysis Procedure with IT Support

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Abstract. The article contains results of the functional/process simulation of the risk analysis procedure based on the FMEA (Failure Mode and Effects Analysis) methods. The authors reviewed the primary literature sources on this issue and decided that it was necessary to simulate this procedure in two notations - IDEF0 and BPMN. They compared the two notations and revealed their advantages and disadvantages. They also provided the structure of the FMEA procedure, which serves as the basis for both models - the functional model (IDEF0) and the functional/process model (BPMN). Two diagrams of the top tier of both models of the procedure are presented. THE BPMN diagram demonstrates interaction with modules of information system support of the FMEA procedure. The authors also give recommendations on the practical use of obtained models.

1. Introduction

Risk analysis is a very important element of many standards related to quality (ISO 9001, IATF 16949), ecology (ISO 14001) and safety (ISO 45001). Correct use of risk analysis methods is a key to successful functioning of relevant control systems. Most organizations use in-house risk analysis procedures; however, they are based on standards or guidelines or reference a standard in the part of the procedure dedicated to methods of analysis. These procedures are usually not sufficiently detailed in terms of both structure and the process of execution. The methods of risk analysis are even less detailed. This article concern the best known and methodologically described risk analysis procedure - the FMEA (Failure Mode and Effects Analysis) method. Let us describe its functional and process structure taking into account the possibility of using IT solutions to support the analysis procedure.

2. Brief review of the issue

The FMEA method is best known and most widely used instrument of risk analysis concerning design of products and manufacturing processes. Such a popularity is justified by its universal nature, optimal combination of relative simplicity of use and the obtained result in the form of more reliable and less faulty products and manufacturing processes on the one hand, and the fact that car makers require suppliers of car components to use it on the other hand. This method is well described in such standards as GOST 27.310-95 [1], GOST R 51814.2-2001 [2], GOST R 51901.12-2007 [3], GOST R 51901.3-2007 [4], as well as in various publications dedciated to FMEA [6-9]. Furthermore, there are

guidelines developed by various car makers, the best known and convenient whereof was developed by the AIAG (Automotive Industry Action Group) under the name "FMEA Handbook" (current edition - 5) [5]. All the aforementioned documents describe the FMEA procedure to a varying detail; however, descriptions are at best accompanied by regular flow charts providing the sequence of primary actions without indicating document flows (not to mention information flows) and responsible persons, or the procedure model is very restricted in its structure [10], although the authors of this article make an attempt to describe information flows.

3. Problem setting

In order to resolve this issue, let us develop a FMEA procedure model in two notations - IDEF0 and BPMN. In the IDEF0 notation, let us describe the procedure without IT support, and in the BPMN notation - how the FMEA procedure must be performed if a specialized software solution is available for this method. Both notations allow visualizing a model of any process, however, IDEF0 is first and foremost intended for describing functions and the sequence thereof focusing on the result of a function's performance with multilevel decomposition without any clear temporal identification of actions, whereas BPMN is better suited precisely for process simulation, i.e. for describing the very temporal sequence o actions within a process by each operator with the possibility of decomposing actions to the level of the simplest tasks. The key difference between the process simulation (BPMN) and the functional simulation (IDEF0) consists in the fact that the primary attention of the process simulation is given not to what we want to obtain, but to what needs to be done to obtain a result, i.e. not to the results of one activity or another, but to the sequence of actions itself.

4. Generation and description of models

First of all, let us determine stages of the FMEA procedure and the key operators, as well as the documents required for each stage of the procedure in whole. Let us use standard GOST R 51901.12-2007, AIAG FMEA and publications [8, 9] as the basis.

A complete FMEA cycle consists of the following main stages:

- Planning of FMEA within the general APQP procedure.
- Planning and preparation to the FMEA procedure (*initiation of the current procedure*).
- Structural and functional analysis of the study object.
- Risk assessment.
- Development and implementation of risk mitigation measures.
- FMEA data report (*completion of the current procedure*).
- FMEA review.

We did not review the first stage from this list within the model, because it does not directly concern the procedure itself as such, apart from the specification of responsible persons and the FMEA due date. For our model, this is input information.

The last item is also obligatory; it consists in the planning of future FMEA reviews, which may be conducted according to a pre-approved plan (i.e. this is basically a return to the first stage) or as a result of the decisions associated with a reaction to the problems with the product or the manufacturing process taking place in the process of manufacturing and use. However, we did not include this stage in the common model of the FMEA procedure, because this is basically an action external to the procedure itself.

Let us form level A0 of the IDEF0 model of the FMEA procedure on the basis of the list above (Figure 1). This level of representation is the main in this model and consists in the description of the sequence of the primary stages of the FMEA procedure.

Unfortunately, IDEF0 notations do not allow visualizing the role of each participant of the FMEA procedure on each stage/function. It also rather difficult to visualize service functions when using IT support of the FMEA procedure in an IDEF0 notation. Furthermore, IDEF0 notations do not allow using different events to visualize key events, and also do not feature a possibility to divide actions in

the diagram for clarity. BPMN notations feature all the aforementioned and many other possibilities and thus allow visualizing a model of any process sufficiently flexibly.

It ought to be mentioned that the described model of the FMEA procedure is not a full-scale BPMN model, as it does not contain a comprehensive list of actions, events and processes taking place during a FMEA. We only tried to lift the veil off the FMEA "kitchen" by making an attempt to describe the procedure of using this method as a multi-stage and a rather multi-level process characterized by the participation of different agents on each stage, demonstrate their roles, as well as a possible way of using IT support of the FMEA method. Creation of a full-scale model requires significantly more work over the description of separate functions as processes such as, for instance, *structuring of the analysis object, functional analysis, identification of causes,* or *development of corrective actions.* All of these are objectives of our further work, but on this stage our goal was to represent a functional/process model of the FMEA procedure with elements of IT support on different stages.

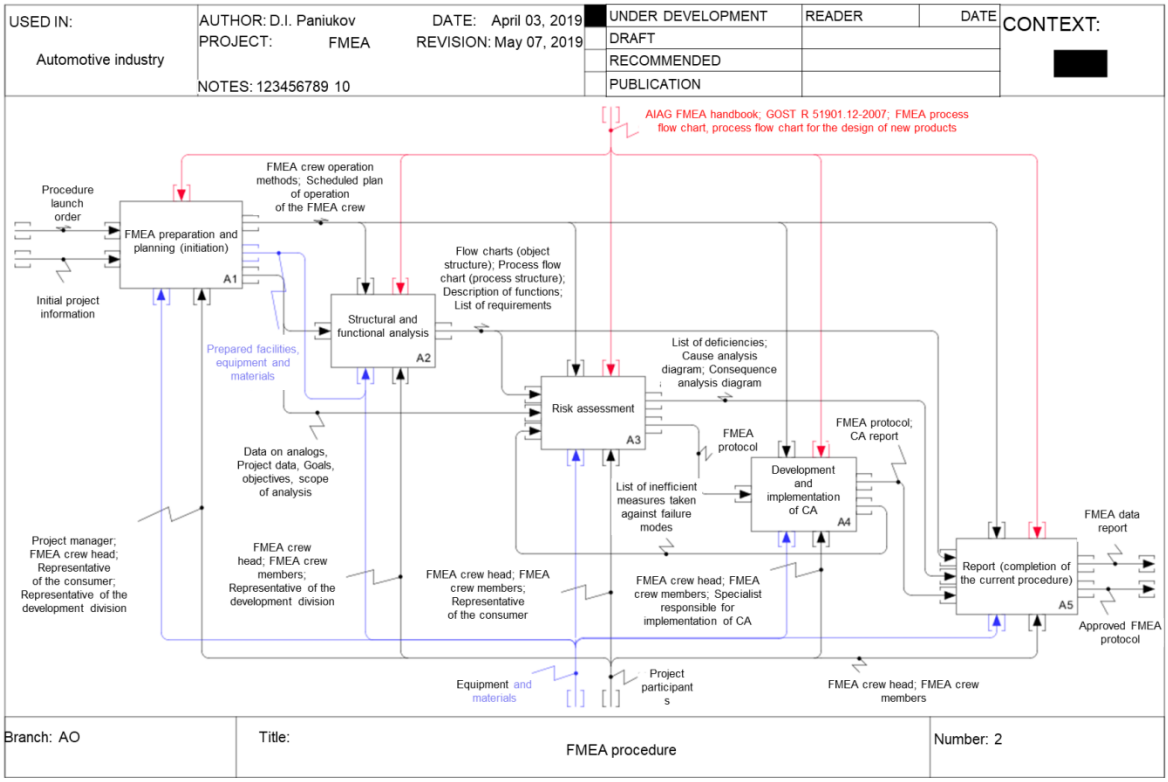

Figure 1. Level A0 of the IDEF0 model of the FMEA procedure.

On this stage of evolution of IT, the FMEA procedure may be completely computerized, except for the initial data input for each project, and even this operation may be transferred to an earlier stage if the IT infrastructure of the consumer and the supplier is the same or allows converting data easily and conveniently. A complete IT-fication of the FMEA procedure would require significant modernization of the IT arsenal of the involved specialists and supplementation with modern tablets for mobility and convenience of supporting different stages of the FMEA procedure. Tablets are also more convenient for group work. Of course, it is difficult to imagine that at regular supplier facilities, yet everything is possible, time flies fast, so these solutions will soon be available to everyone. Such solutions are already beginning to spread in the Western countries [11]. However, we believe that a semi-manual mode when a part of work is done manually and the other part - with the help of IT solutions, will remain popular for a long time, because it will be expensive to fully computerize the FMEA procedure and require a lot of time for training specialists. It is considerably easier to computerize certain

elements of the procedure to make them simpler and more convenient, and leave complex stages requiring a creative approach on paper with further transfer of information to a computer, i.e. in relevant databases. Therefore, to ensure that the analysis is as efficient as possible it is necessary to have an information system (IS) supporting certain functions of the FMEA procedure and joining them together by means of transferring relevant data from one stage to another. This means that an IS for FMEA support must feature a range of interconnected software modules responsible for the appropriate set of functions. Such software products exist (see publication [11]). Unfortunately, not all the software products matching the aforementioned requirements have Russian interface and the full set of required functions.

Let us now describe the developed BPMN model of the FMEA procedure. First of all, it ought to be mentioned that the model is described taking into account the fact that the procedure is performed by 5 main participants: *the project manager*, *a representative of the development division*, *a representative of the consumer*, and two groups of people - *crew candidates* and the *FMEA crew* itself, which consists of *the head* and *members*.

To facilitate the comparison, we divided the BPMN model of the FMEA procedure into the same primary blocks as with the IDEF0 simulation; furthermore, alphanumeric designations of separate stages/functions are also the same. The BPMN model was supplemented by the support on almost all stages. We did not describe each stage of the model from the point of view of the FMEA procedure in detail, because it had already been done to describe the IDEF0 model of the FMEA procedure. Let us pay attention to the IT support, roles of all participants in the procedure, and also to the new elements characteristic of BPMN notations and not present in the IDEF0 model.

The top level of the BPMN model of the FMEA procedure is provided in Figure 2. It includes all the main operations reflecting the primary stages of the FMEA procedure, as well as roles of all participants in the procedure and the set of IS modules for FMEA support used for appropriate enlarged stages of the procedure.

According to the given BPMN model, a FMEA support IS must include the following main modules:

- *FMEA testing and training module* - stage *A1 "FMEA preparation and planning"*;
- *Structure, functions and requirements analysis module* - stage *A2 "Structural and functional analysis"*;
- *Failure analysis module (FMEA protocol generation)* - stage *A3 "Risk assessment"* - stage *A4 "Development and implementation of CA"*;
- *Corrective actions (CA) control module* - stage *A4 "Development and implementation of CA"*;
- *FMEA report control module* - stage *A5 "Report (completion of the FMEA procedure)"*.

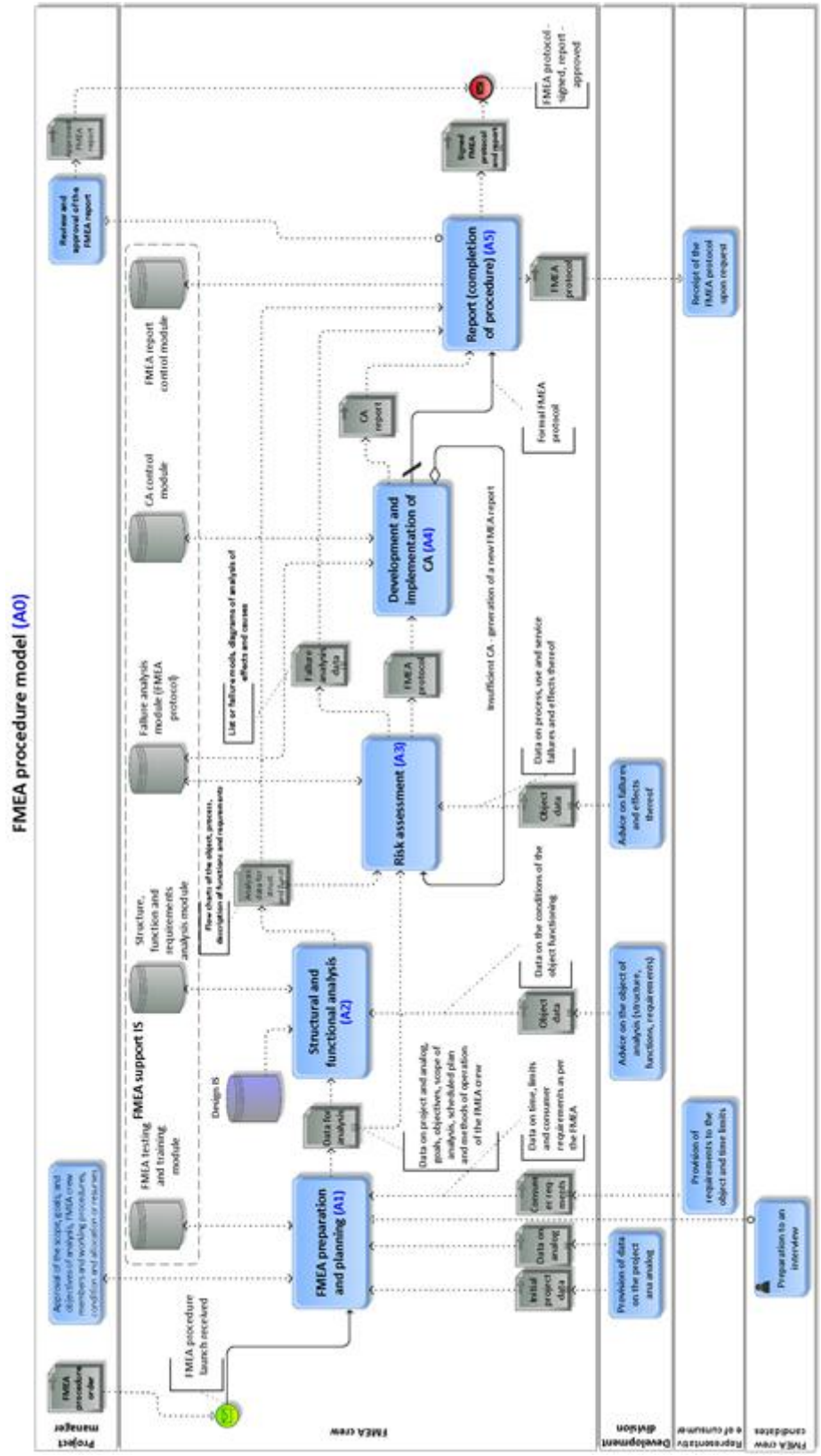

Figure 2. BPMN model of the FMEA procedure.

This model also presents an external information system, which contains data on the design and the manufacturing process generated in CAD/CAM/CAE/PLM systems. These data are required for stage A2, i.e. for the structural and functional analysis of the study object.

The FMEA procedure in a BPMN model begins and finishes with the following events: *"Receipt of a FMEA procedure launch order"*, FMEA protocol signing and approval of the procedure completion report. Data flows and paperflow are visualized in this notation.

Another practical element consists in the division of the flow on the condition whether there are inefficient corrective actions after the implementation or not on stage *A4 "Development and implementation of CA*. By default, there are no such actions, so we proceed to stage *A5 "Report (completion of the FMEA procedure)"*; if present, we return to stage *A3 "Risk assessment"* to reanalyze failures, against the causes whereof inefficient CA were used. To do that, it is necessary to check whether causes of failures were determined correctly and rework CA in case of mistakes. If causes were determined correctly, new CA must be designed and proposed.

5. Practical relevance

The represented models describe the risk analysis procedure in sufficient detail and, on the one hand, help to develop a clear and understandable documented procedure at the plant and, on the other hand, help to understand the role of the support information system in the overall risk management process. A BPMN model may be used to generate a conceptual model of FMEA support IS, as well as other IS models (functional model, data flow model, sequence diagram).

6. Conclusions

FMEA procedure simulation using an IDEF0 notation helps to visualize all the necessary actions required for planning and performing a FMEA, demonstrate their sequence and interconnection, and also understand types of necessary documents and on which stages they need to be generated. Furthermore, this model helps to indicate the resources necessary for each stage, including managers and immediate operators. The BPMN model of the FMEA procedure helps to look at the procedure as a multi-level non-linear process with repeating elements and branching on specific conditions and without them. The IT support provided in this model helps to visualize possibilities of information technologies and understand their role and benefits for such complex procedures as risk analysis.

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