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An enhanced model for risk analysis in new product development

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Abstract
New product development is characterized by uncertainties that are a consequence of insufficient experience and missing knowledge, finally leading to risks. In literature, a multitude of different risk models is provided. However, a comprehensive risk model that is suitable for analysing different types of uncertainties and their interdependences does not exist. In this publication we present the concept of an enhanced risk model that combines the main ideas of the Standard Risk Model with the basics of tree analysis in order to analyze uncertainties in new product development. Furthermore, we operationalize the application of the model by the use of Multiple-Domain Matrices.

Keywords: *risk analysis, new product development, Multiple-Domain-Matrices*

1. Introduction

The development of innovative products provides one of the key factors of business success on global markets. However, new product development is notably affected by uncertainties that are a consequence of insufficient experience and missing knowledge. In literature, uncertainty is interpreted as any potential deficiency that is characterized by being not definite, not known or not reliable [1]. If uncertainties are not handled in an adequate way, they finally lead to risks. In comparison to the term "uncertainty", risk is defined as an evaluation quantity that provides information about the occurrence probability of damage as well as the expected impact of that damage [2], [3]. In this regard, "damage" must be understood as a restriction of the specifications of schedule, costs and quality [4].

The evaluation of risks resulting from uncertainty is one challenge within new product development. The particular challenge of risk analysis in new product development is intrinsically founded in the novelty of the development task itself and is further enhanced by an increasing complexity of products and their development processes. Due to the existence of strong interdependencies within the product and process structure, the consequences of uncertainties are often not restricted to the place of their occurrence. Instead the presence of an uncertainty can lead to new uncertainties, making it difficult to overlook their consequences totally [5].

To support the successful development of innovative products, effective risk models are needed that integrate the analysis of uncertainty propagation. By following a model-based approach to deal with uncertainties and risks, the inherent complexity of reality can be reduced by focusing on specific information of interest. Models are furthermore established as an adequate way of documentation and support communication between different stakeholders by providing a common comprehension about a situation.

In this publication we present the concept for a risk model that was developed under the particular view of uncertainty in new product development.

2. Literature Review

The literature provides quite a lot of models and methods supporting risk analysis. One of the more commonly mentioned models is the "Standard Risk Model", e.g. presented in [6]. The Standard Risk Model contains three components, denoted as risk event, impact and total loss to finally determine an expected loss. Risk Event and Impact are each accompanied by an occurrence probability as well as associated drivers. The expected loss is calculated by using the occurrence probabilities of risk event and impact along with the total loss.

While the Standard Risk Model constitutes a very theoretically driven approach for risk modelling, some of its basic aspects can be found in the underlying risk model of the well known Failure Mode and Effects Analysis (FMEA) [7]. Two major types of FMEA are distinguished: The Process-FMEA is carried out for identification of failures in processes, like e.g. the manufacturing process, while the Product-FMEA is used to analyse systems, subsystems or their components. For each potential failure, the consequences and causes are identified and evaluated by taking into consideration the likelihood of occurrence (O), its significance (S) and the probability of detection (D). The failures are prioritized by assigning the risk priority number that is defined as the mathematical product of O, S and D.

Fault Tree Analysis (FTA) and Event Tree Analysis (ETA) are methods that allow more detailed diagnosis in comparison to FMEA [8]. The risk model of FTA is based on the principle of causality, expressing that each fault can be traced back to at least one cause. As a result, a set of lower level causes is defined that are connected to each other using Boolean operations. The occurrence probability of the top fault is computed by evaluating the occurrence probabilities of the unions and intersections of the basic events. ETA inverts the principal of FTA and studies the effect of an initiating event on the system.

The presented risk models all show up specific pros and cons. One aspect that limits the capability of the Standard Risk model and FMEA is the fact that they can usually cover only major failure modes. Analysing complex failure modes like failure chains is not supported sufficiently. In contrast FTA and ETA do not deliver information about a prioritization of the results. They are intended to be used for system failure analysis and are not adapted to domain overlapping analysis of uncertainty propagation. An enhanced model that combines the benefits of the different models in order to be suitable for the analysis of risks, resulting from uncertainties in new product development, could not be identified in literature.

3. Concept of an enhanced risk model

In [5] we published the framework for a model based method, supporting the analysis of uncertainty propagation. The concept of the risk model presented in the publication at hand is based on these results. To generate a better understanding of the proposed risk model, the theoretical background of the uncertainty model is presented first.

Uncertainty propagation modelling

In general we differentiate between three types of uncertainties, denoted as requirement uncertainties, system uncertainties and process uncertainties. We denote the effect that one uncertainty causes another uncertainty as uncertainty propagation. Changing e.g. an initially defined requirement later on in the project will require changes of related product elements and in turn lead to revision of associated process steps. The uncertainty model, depicted in fig. 1, is based on Multiple-Domain-Matrices (MDM) to represent uncertainty propagation. MDM consist of Design-Structure-Matrices (DSM) and Domain-Mapping-Matrices (DMM), enabling the representation of interdependencies within and between different domains [9]. As it can be seen in fig. 1, each type of uncertainty is described in an own DSM. In order to express the connectivity of uncertainties to the corresponding requirements, system elements and process elements, the uncertainty model is linked to a product and development process model, also integrated in the MDM. Hereby the analysis of uncertainty propagation is supported and higher consistency of the uncertainty model can be achieved.

Two uncertainty propagation paths are exemplified in fig. 1. The first one is initialized by an uncertain requirement and ends in a process uncertainty. The second one runs in the opposite direction starting with a process uncertainty finally leading to a requirement uncertainty (here an requirement uncertainty must be interpreted as an uncertainty of not fulfiling certain requirements). Uncertainty modelling is of course not restricted to the paths visualized in the figure. Several other paths are possible, e.g. one that directly starts with a system uncertainty. It is to note that tree structures, similar to the ones of FTA and ETA, can be deducted out of the matrix.

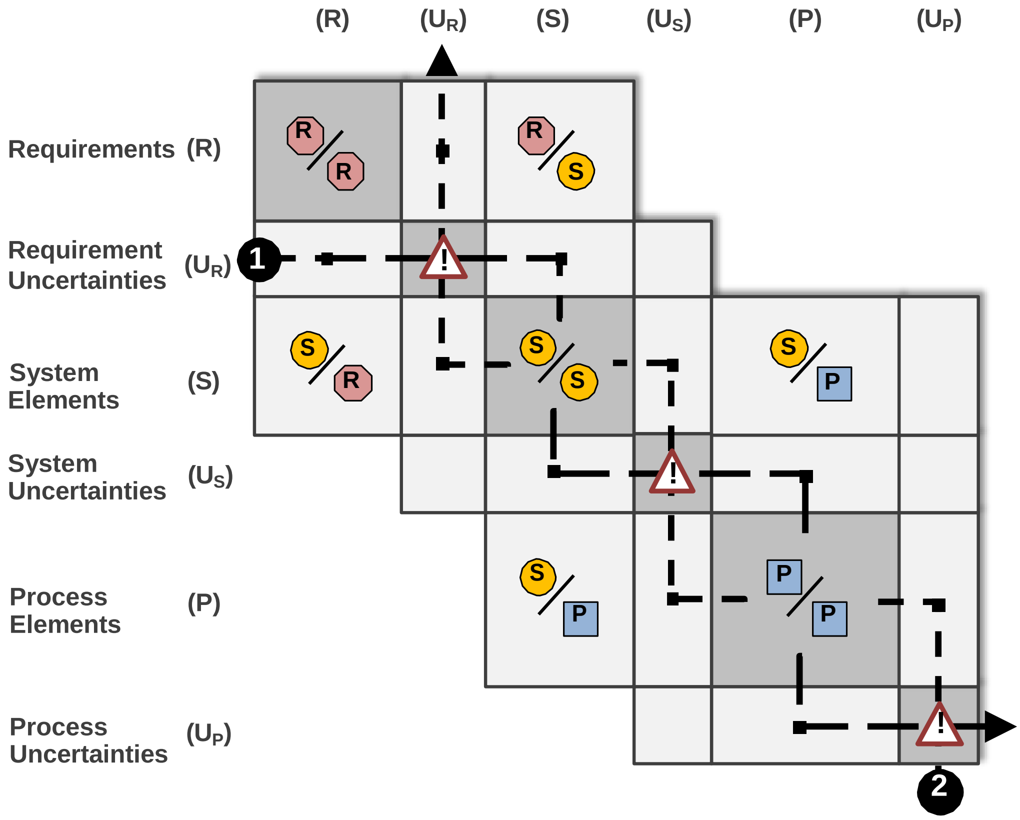


Figure 1: Uncertainty modelling using Multiple Domain Matrices

Risk modeling

For risk modelling, we enhance the uncertainty model by two additional DSMs, as shown in fig. 2. The first one, denoted as Cost&Schedule Risk DSM, is located right behind the process uncertainty DSM on the main diagonal of the model (see upper half of fig. 2). The second one, named Quality Risk DSM, is arranged above the requirement uncertainty DSM (see lower half of fig. 2). Within the risk DSMs, the single risks as well as the relations between them can be represented. In other risk models, like FMEA and FTA, risk aggregation is often neglected. Furthermore, a prioritization of the single risks can be conducted.

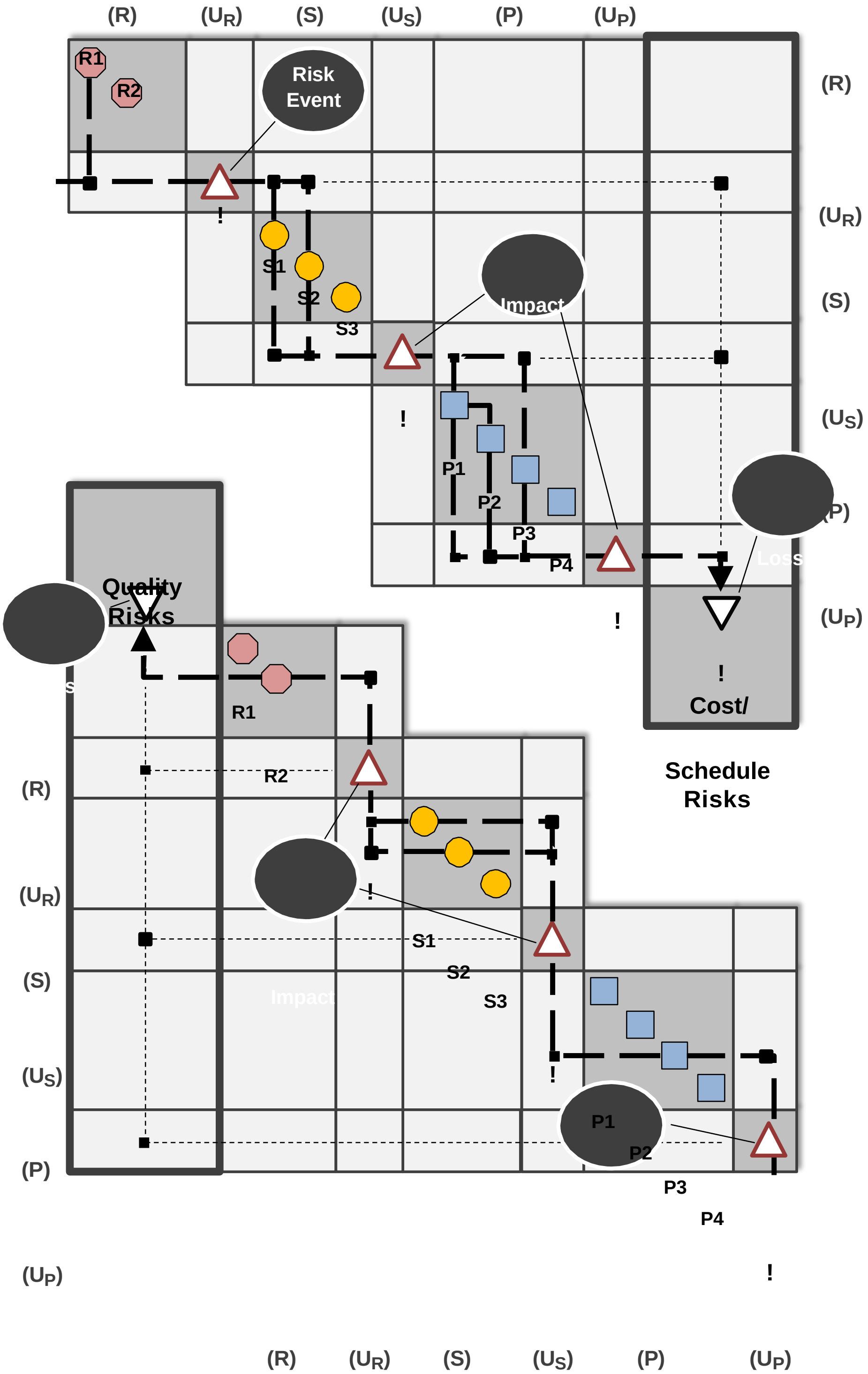


Figure 2: Enhanced uncertainty model prepared for risk modelling

As described by the discussed definition of risk (see chapter 1), uncertainty is a necessary, but not a sufficient feature of risk. According to the Standard Risk Model, risk calculation necessitates information about the likelihood of occurence of risk event and impact as well as a valuation of the total loss. Within the proposed risk model, the initial uncertainty is interpreted as the risk event and the propagation of uncertainty as its impact. The loss finally can be expressed in the added risk matrices. In fig. 2, both paths that were already exemplified above are visualized in the enhanced matrix. In order to insert further information about the model elements, like e.g. the occurrence probabilities of risk event and impact as well as the valuation of total loss, a set of standardized forms is provided that can be attached to the entries of the MDM. Basically one type of form is given to describe uncertainties and one to specify the risks (see excerpt in fig. 3).

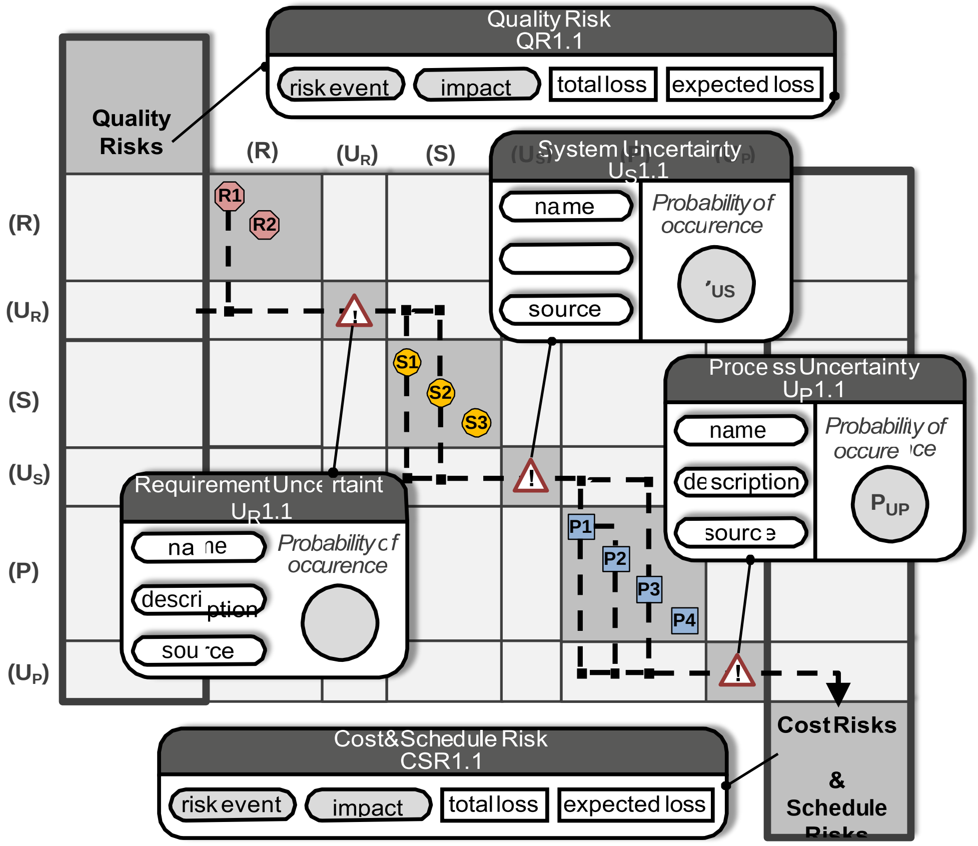
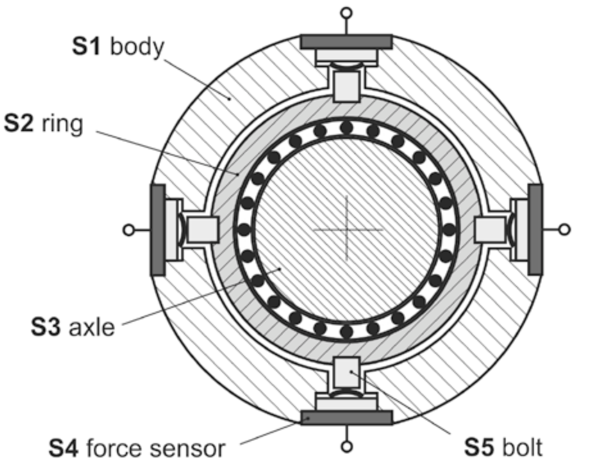


Figure 3: Provision of standardized forms enabling the modeling of risk associated information

4. Example

To clarify the proposed concept of risk modelling, the model is applied in a fictive development process of a radial-force measurement unit for rotating axles. In order to keep the example simple, the measurement unit is simplified to five components, denoted as body S1, ring S2, axle S3, force sensor S4 and bolt S5. A conceptual sketch of the measurement unit as well as essential requirements and relevant development steps are given in fig. 4.



Requirements	
R1	measurement accuracy: +/- 15%
R2	measurement range: 1N - 25 N

Development process	
P1	Embodiment design of body S1
P2	Embodiment design of ring S2
P3	Embodiment design of axle S3
P4	Selection of force sensor S4
P5	Detailed design of body S1
P6	Detailed design of ring S2
P7	Detailed design of axle S3
P8	Detailed design of bolt S5

Figure 4: Development of a Radial-Force Measurement unit for rotating axles

The system elements and consequently the corresponding process elements are strongly coupled, as marked by white crosses in the Multiple-Domain-Matrix presented in fig. 5. Thus, an extensive propagation of uncertainties can be expected. Risk analysis is started with an uncertain requirement that regards the required measurement range R2 of the measurement unit. The results of a scenario analysis have shown that requirements are possible to change from an acutally requested value of 1N – 25 N to 0 N – 50N to fullfil future markets. This event is expected to occur with a probability of 0.4. In case of coming true, the chosen force sensor S4 is probably unsuitable to fullfil the new requirements. A change of the force sensor is necessary, also entailing a constructional adaption of the body S1. The potential system changes resulting from the uncertain requirement U_R1.1 are expressed in the system uncertainty U_S1.1 and are evaluated with an occurence probability of 0.9. The influence of the potential system changes on the development process is finally described in process uncertainty U_P1.1. Here, a rework of the system is expected to demand a repetition of 70% of process step P4 (selection of force sensor S4) and 20% of process step P5 (detailed design of body S1). Breaking down the consequences of the initial requirement uncertainty U_R1.1 enables the project manager to value the total loss that will occure in case the change of requirement comes true. A time delay of 30h for rework and 2400 € additional labor costs are assumed. The expected loss can finally be estimated by using the occurrence probabilities of the single uncertainties along with the total loss.

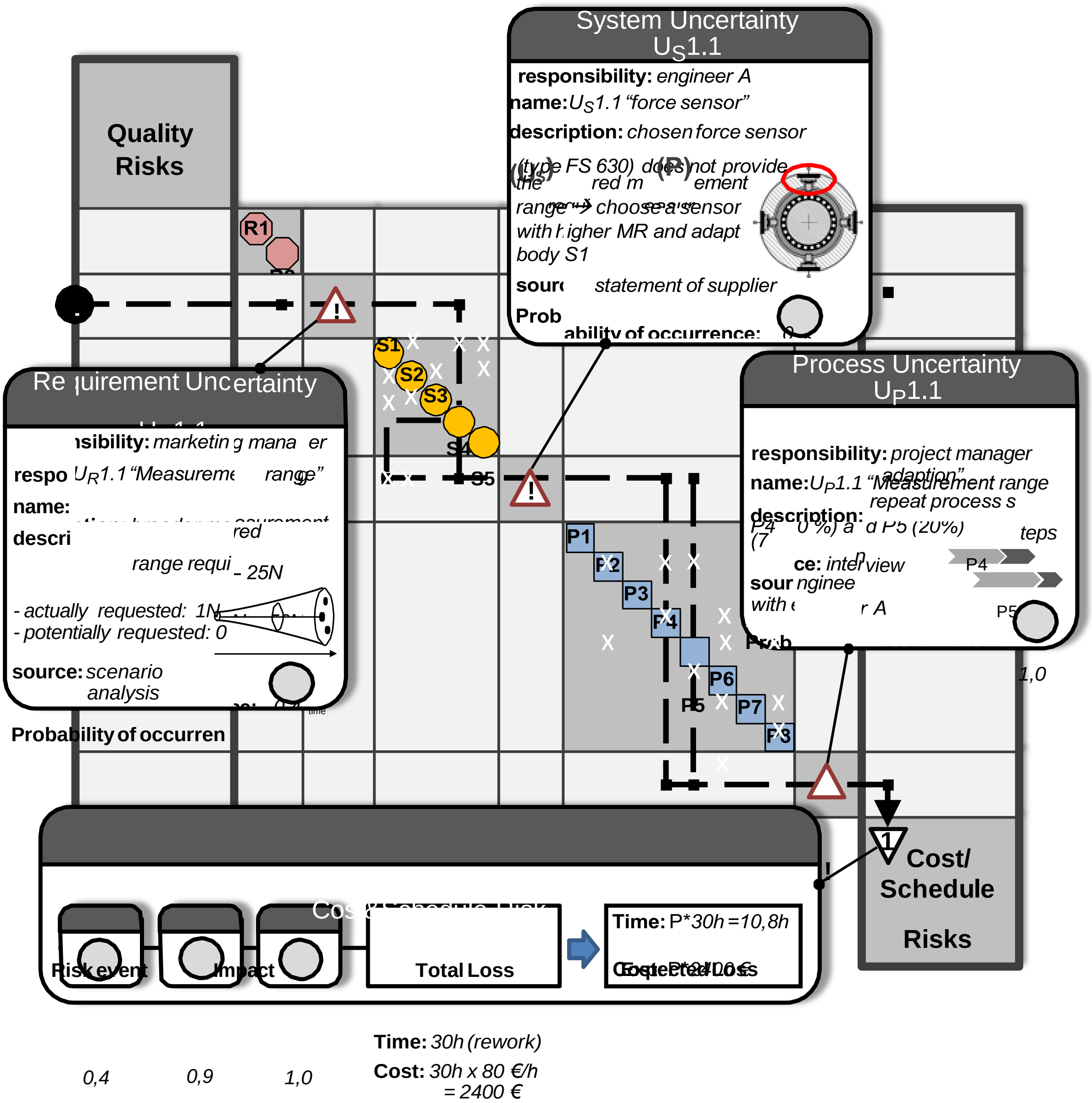


Figure 5: Applying the risk model to the development process of the Force Measurement Unit

5. Conclusion

Risk analysis, as part of risk management, is a key factor of success in new product development. A concept of an enhanced risk model was created that allows the evaluation of uncertainties under the aspect of risk. The presented risk model is based on an uncertainty model that supports the analysis of uncertainty propagation. By integrating two additional DSMs on top of the uncertainty model and assigning occurrence probabilities to each uncertainty, the consequences can be expressed as an expected loss of quality, costs and time. Hereby it is possible to proactively include counteractions, which minimize the overall risk. The demonstrated application of the risk model within the example indicates that its practical usability is strongly related to the implementation of the model within a software tool. We will therefore extend and detail the model in future work and transfer the results into a software application.

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