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USING DSM STRUCTURES TO ANALYSE UNCERTAINTY IN LOAD-CARRYING SYSTEMS

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ABSTRACT
This article describes a pattern how to use a method to analyse uncertainty in load-carrying structures. Object of this paper is to explain how coherences between uncertainties of process properties influence several successive processes. This uncertainty appears for example during different process operations or by reason of variations during the utilization process of the product. During the planning and development processes uncertainty mainly has to be taken into account for the modelling and forecasting of technical, environmental and economic product and process properties. Furthermore this method can be extended to a complete process chain including a developing and utilization phase to control uncertainty in a holistic way.

Keywords: Uncertainty, process, product, analyse, product properties, dependencies

1 INTRODUCTION

The analysis of uncertainty is an increasing challenge in the manufacturing industry. Due to an expanding variety of products as well as shortened product life cycles an earliest possible identification of uncertainty in processes becomes essential. Uncertainty appears in processes in form of uncertain process properties and can be measured in the product properties which are the final state of a process. Also the deviations of their properties will be indicated .

2 STATE OF THE ART

Uncertainty occurs in all phases of the product life cycle. It appears in processes as uncertain process properties and can be determined in the product properties (Engelhardt, 2009). This fact is particularly important for products with load-carrying function, where misjudgements regarding stress and strength may result in several safety-related and economic consequences (Chalupnik, 2009). The aim of the Collaborative Research Centre (CRC) 805 is to control uncertainty to enhance security, reliability and efficiency during the development, production and usage processes, as well as saving resources. A working hypothesis of the CRC 805 employs the term uncertainty as follows: "Uncertainty occurs when process properties of a system cannot be determined. Uncertainty can be described and quantified with known methods of risk analysis" (Hanselka, 2009). The current paper only refers to the kind of stochastic uncertainty that can be expressed by probability distributions.

2.1 Model of uncertainty

In the CRC 805 uncertainty is divided into three categories according to the increasing state of information about the probability distribution of the value of an uncertain product or process property: unknown uncertainty, estimated uncertainty and stochastic uncertainty (see Figure 1) (Engelhardt, 2010). The enumeration of this classification is divided according to the degree of increasing information.

Unknown Uncertainty describes the situation of unknown deviations of a regarded property of an uncertain process. Unknown uncertainty often occurs in the beginning of product development when only little information about a future product is known and product properties are not determined yet.

Estimated Uncertainty describes a situation in which the effects of a regarded uncertain property are known. However, the probability distribution of the resulting deviation is only known partially. This happens for example when incomplete information about expected properties of a product is known during product development or if, during manufacturing, product properties are only analysed randomly.

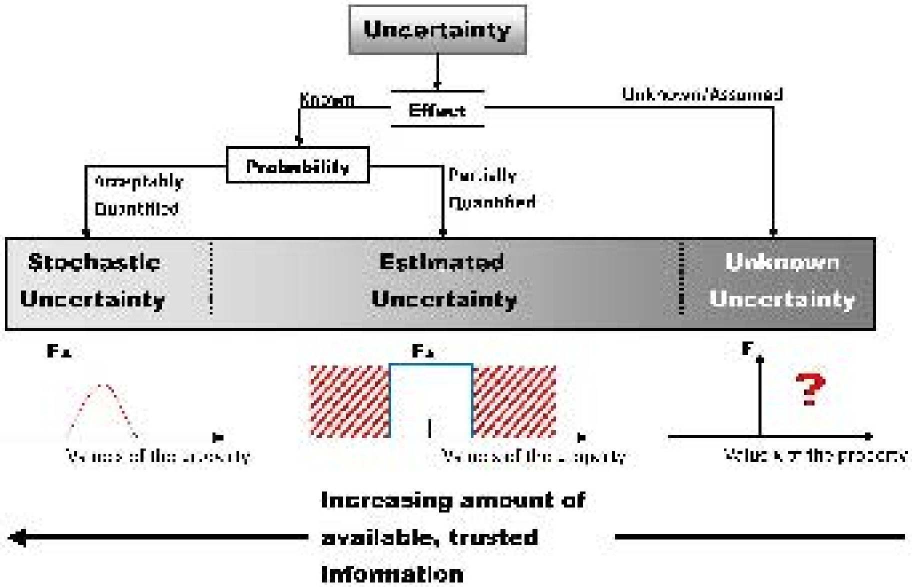

Figure 1. Model of Uncertainty

Stochastic uncertainty occurs when effects and resulting deviations of a regarded uncertain property are sufficiently (ideally completely) described by a probability distribution. Stochastic uncertainty is present after extensive analyses of properties in terms of quantifiable experiments and measurements.

When differentiating between these three categories, no sharp boundary can be drawn. The transition between the categories is fluent. As a general rule, uncertainty moves towards stochastic uncertainty if the amount of available and secure information increases.

2.2 Process model

Based on the process model of Heidemann (2001) and Gausemeier (2009), the CRC 805 has developed a modified version. It clarifies even more the process orientated approach and works up the graphical representation (see Figure 2). Thereby a transformation between two conditions with corresponding in- and output stream can be considered. These describe the incoming product properties of the product including variations as well as the properties of the product leaving the process.

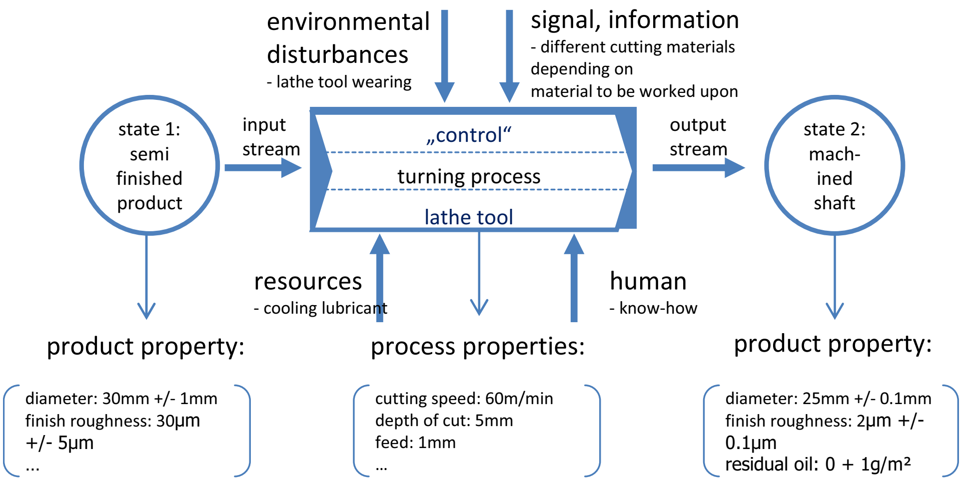

Figure 2. Process model at the example of a turning process

Integrating the classification of product and process properties into the model, the following conclusion can be made: product properties can change from state 1 to state 2 due to influences of process parameters and disturbances. In addition the number of product properties describing a condition, do not have to remain constant. On the contrary new process properties arise after passing through a continuous process. There is also a possibility, that yet existing product properties will become irrelevant after the process. The process model should be clarified using the example of a turning process (see Figure 2). The purpose of the process is to turn a semi-finished product to a specific shaft diameter. Here in state 1 the semi-finished product has, inter alia, the product properties “diameter” and “surface roughness” with associated variations. These are influenced by the process properties cutting rate, cutting depth and feed rate. Furthermore the above mentioned influencing variables affect the semi-finished product. Thereby the disturbance “increasing wastage of the turning chisel” and an insufficient use of cooling lubricant influence mainly the product characteristic “surface roughness”, whereby variations are influenced negatively by the process. Also the selection of wrong cutting tool material affects the “surface roughness” in a negative way and consequently the uncertainty value in a negative way.

3 INFLUENCE OF PROCESS- TO PRODUCT PROPERTIES

At the beginning it is important to establish and to identify a process chain and to identify it for each individual process (if the process influences product and process properties). Then a separate evaluation for each individual process is performed. For this purpose uncertainty is attached to every product and process properties (see Figure 3). Therefore the uncertainty model will be used that distinguishes between ignorance, incertitude and stochastic uncertainty. Depending on the existing type of uncertainty, qualitative or quantitative methods can be used for the identification. Subsequent follows a sensitivity analyses. Thereby firstly the influence of the process properties onto the product properties has to be evaluated. In addition an investigation how product properties influence each other follows. Here it makes sense to represent the solutions in form of a matrix.

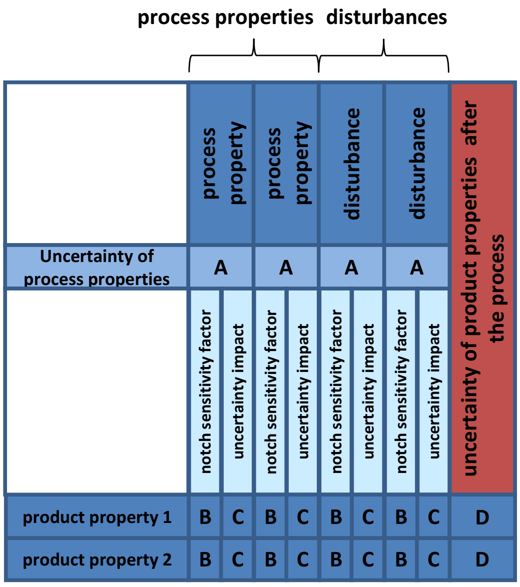

Figure 3. Matrix to identify uncertainty

Finally a mathematical calculation of uncertainty propagation according to Gauß follows. Therefore first of all an uncertainty-influence-value “C” is defined for each influence variable. It bases on uncertainty “A” and the sensitivity coefficient “B” from the sensitivity analysis (see Figure 3). Then these uncertainty-influences “C” are totalled line by line and result in a new uncertainty value “D” for every product characteristic after the process. This procedure is repeated for every individual process. The identification of uncertainty intends to quantify the uncertainty along the created process chain and afterwards to carry out an assessment. Thus this work step switches over seamlessly into a description process (Engelhardt, 2009). So the quantified uncertainty values should be related to the product and process properties. The aim is to orientate oneself by the classification of the uncertainty model. However at this point it has to be noted, that a quantification of uncertainty highly depends on the level of information on the product and process properties. Thus especially in the early phases of product development most of the time only qualitative statements about uncertainty can be made. Furthermore there are parts of the process chain, where quantification is not possible or it seems disproportionate to the effort. Here it is also necessary to change to the qualitative section of uncertainty identification.

Step 1 all identified product properties, process properties and disturbances are inscribed into a matrix (Figure 4).

Step 2 an evaluation of the process properties is made which bases on qualitative assessment criteria according to VDI 2225. Thereby it is indicated how big the uncertainty of the process properties and disturbances are, respectively how wide the variations of the reference value could be.

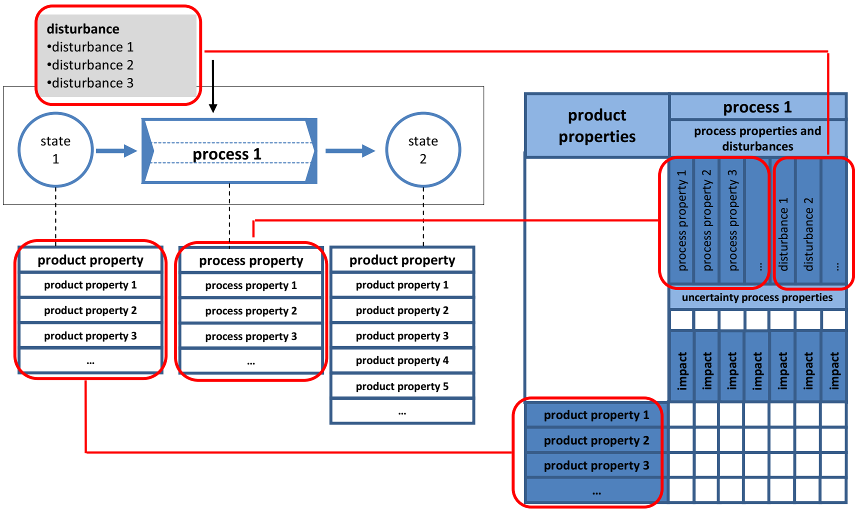

Figure 4. Step 1 – Classification of process properties and disturbances

Step 3 after completing the classification of uncertainty values to process properties and disturbances, the uncertainty of the product properties will be evaluated in its initial condition will be evaluated (thus before the first process). These uncertainty values also reference to the variations of the reference properties. Thereby another time an orientation on the above presented choice of methods can be done.

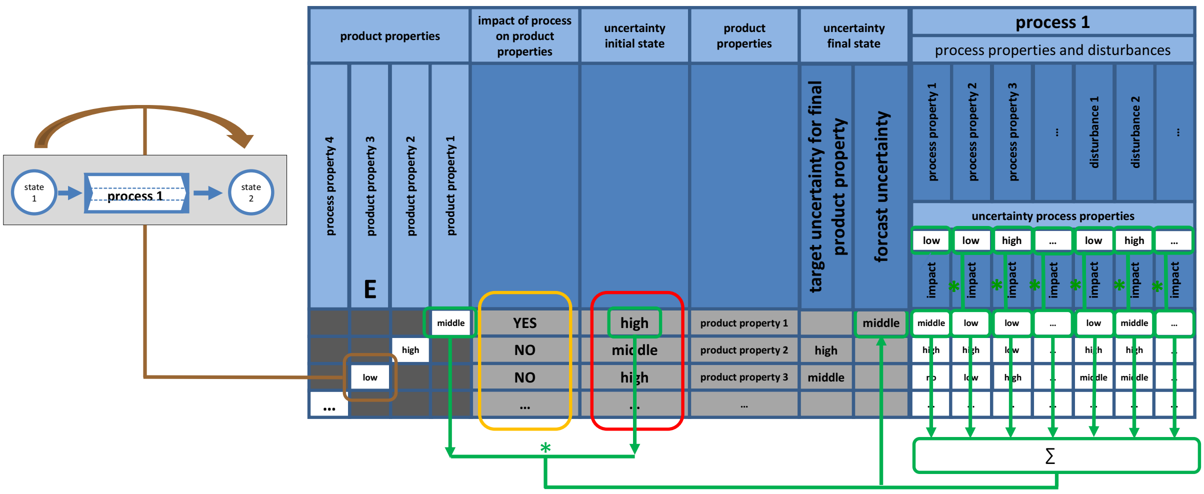

Figure 5. Steps 3-5 Assignment of process properties and disturbances

Step 4 investigates, whether the identified product properties are influenced or changed by process 1 (evaluation with Yes/No). This will indicate how much the identified uncertainty value of the initial stage affects the end stage after the process (using the evaluation criteria of the VDI 2225).

In step 5 a sensitivity analysis follows. It investigates if and how much the process properties and disturbances affect the product properties (see Figure 6). Speaking of uncertainty in the sense of a variation of the reference condition is no longer appropriate. A change of the above mentioned criterion as a basis for an evaluation is done. It will be evaluated with the qualitative, influencing values "very low", "low", "medium", "high" and "very high".

Step 6 executes a calculation of the whole uncertainty of all process properties, which have been changed due to the process. Once again this uncertainty bases on all the values evaluated before (which firstly are converted to numerical values). Thereby repeatedly it is orientated to VDI 2225, which schedule an evaluation scale in 4 steps.

4 CONCLUSION

In this paper an approach is described, which examines if and how much the process properties and disturbances affect the product properties. To this end a chain linking matrix is introduced. This chain linking matrix is part of a holistic Uncertainty Mode and Effects Analysis methodology which does not merely describe uncertainty, but also evaluates it. For the assessment it is pointed out to the procedure described in the paper. Thereby the absolute value of variation of uncertainty can be deviated. With a linkage of uncertainty through an effect chain tree, the affects of uncertainty can be represented along the process chain. This chronological development also has to be represented in the later effect chain tree, so that a cause fair classification of the product properties to the processes can be guaranteed. After the proceeding of the evaluation it is always possible to indicate exactly which critical product characteristic is dedicated to which process.

ACKNOWLEDGEMENT

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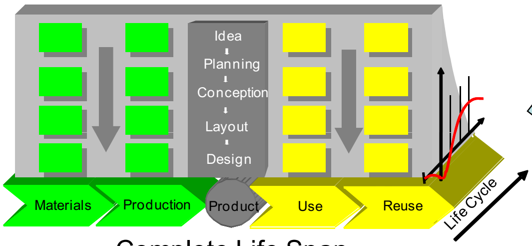
Global Model of Uncertainty



Complete Life Span

Methodology of Analysis

- Uncertainty
- Mode and
- Effects
- Analysis
- (UMEA)

Control Uncertainty

Methodology of Synthesis

Robust Design-Methdology

UMEA ↔ Product- and Process-Development

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What Is Uncertainty in Load Carrying Systems?

- Deviation of nominal value of properties
- Less information about processes
- Not the right methodology to analyse products in the development process
- Causes failures in products

Uncertainty is the deviation of process properties

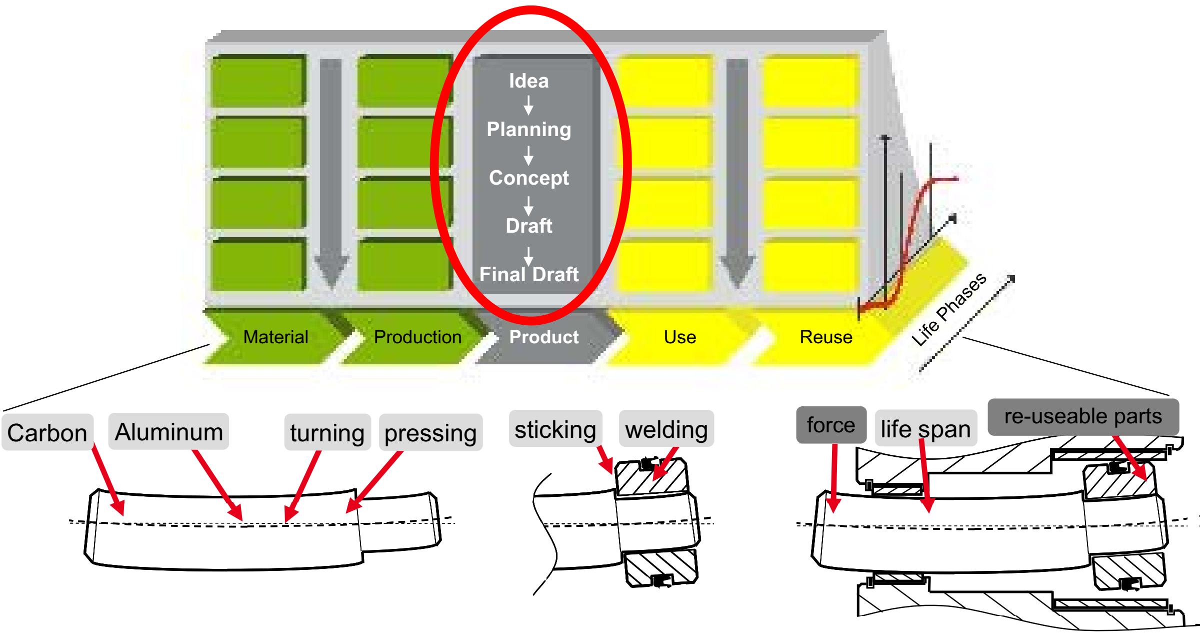
Example: Landing Gear of an Airplane (Piston Rod)

An engineer has to estimate the target achievement of a component in the manufacture.

What is the evaluation of a new product influenced by?

INVEST ON VISUALIZATION

Design Process Where Uncertainty Plays a Role



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Uncertainty Mode and Effects Analysis

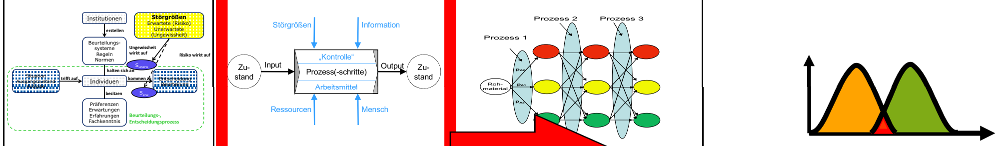
Models

- Goal Analysis
- Lifecycle Model

- Process Model
- Property Model

- Chain of Effects Model
- Linking Modell

- Evaluation Model
- Decision Model



UMEA

Analyse environment/ goal → **Identify uncertainties in processes** → **Determine effects of uncertainty** → **Evaluate uncertainties an effects** → **Decide**

Methods

- Environment analysis (5M), QFD, Danger analysis
- X ra

- HAZOP, Fault-Tree analysis,
- Calculation of process

- FMEA, Event-Tree Analysis
- Monte-Carlo, Markov, Gauß

- FMEA, Risik analysis,
- Sensitivity analysis

A methodology to analyse uncertainty in technical systems

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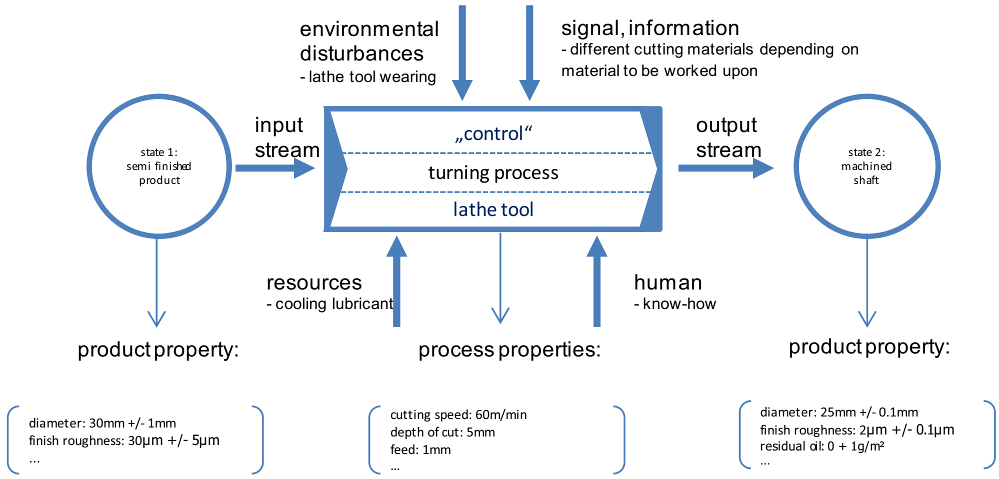
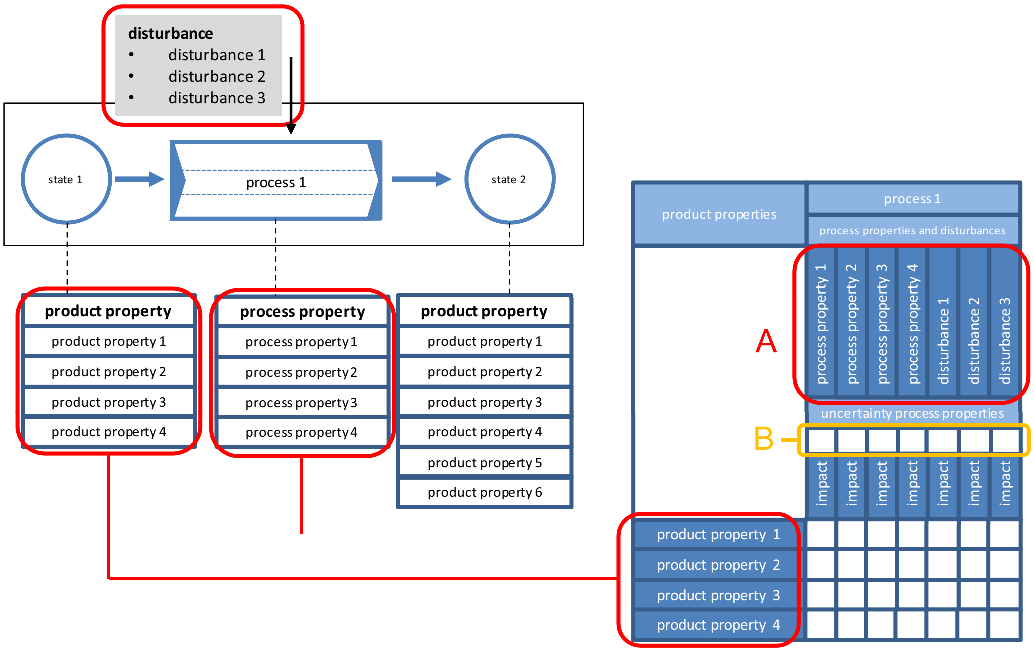
Process Model with Product and Process Properties



Uncertainty occurs in processes

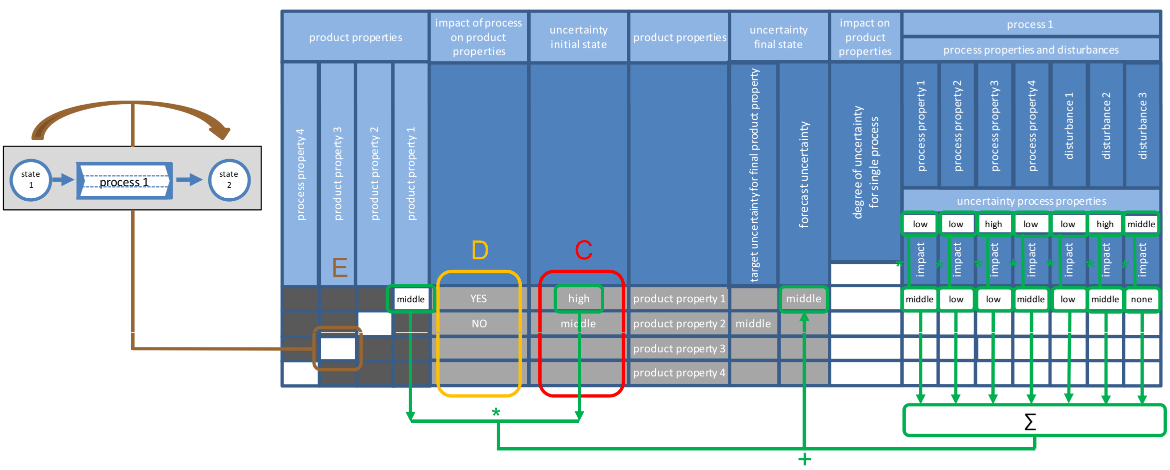
INVEST ON VISUALIZATION

Combination of Product and Process Properties

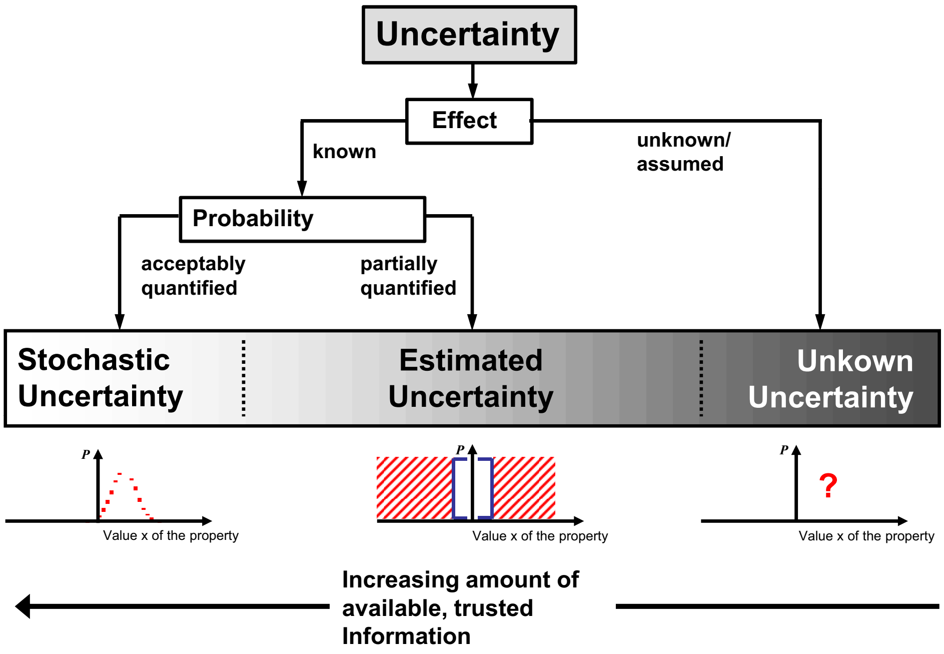


INVEST ON VISUALIZATION

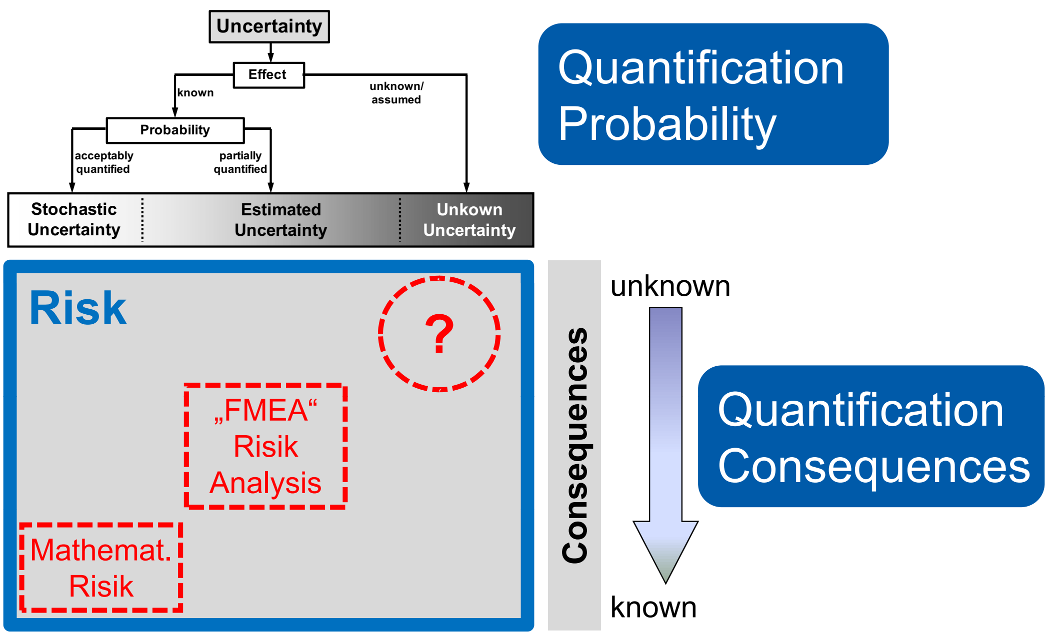
Estimation of Product and Process Properties



Model of Uncertainty



Model of Uncertainty to Analyse Risk



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Conclusion

- First step to analyse uncertainties in technical systems
- Estimation of product and process properties
- Based on the process model for technical systems
- The evaluation is based on risk