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PROCESS-INTEGRATED ANALYSIS OF THE DEVELOPMENT SITUATION FOR AN EFFICIENT SIMULATION PLANNING

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ABSTRACT

To save costly and time-consuming physical prototype testing, product functionality is increasingly validated by means of simulations. However, the specificity of product properties is generally strongly influenced by the course of the development process respectively by the boundary conditions of the development situation. Therefore, it is to provide methods and tools to targeted support property validation.

Focus of actual research activities is on a process orientated support of virtual property validation by means of simulation planning. The approach presented in this paper is based on a specific data processing of the design data which differs between characteristics and properties. The development context is described by means of context factors which are linked to this. The demonstrated process integration supports to evaluate the meaningfulness of a simulation and to facilitate operational planning of simulations.

Keywords: decision making, design process, simulation, development context, data processing

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1 INTRODUCTION

Due to the trend to ensure product functionality without costly and time-consuming physical prototype testing, the focus of actual research activities is on a process orientated support of virtual property validation by simulations: appropriate methods and tools should be more effectively integrated into development processes by simulation planning to execute virtual property validation in a more goal-oriented way (Paetzold and Reitmeier, 2010).

The basic idea is shown in Figure 1: product data and information will be processed in such a way so that they can be context-sensitive evaluated and used. This data processing is based on the distinction of product data between characteristics and properties (CPM-approach) by Weber (2005) that supports the developer to identify appropriate "set-screws" to optimize his solution. In addition, a link-up of these kinds of product data to the alternating development steps synthesis and analysis is given (PDD-approach) – this supports the planning of following process steps due to recent simulation results. The basic design of the data processing respectively the data model is based on matrices (see chapter 4).

Continuous validation of product functionality must be ensured throughout the entire development process. The process design is, however, strongly influenced by the boundary conditions of the development situation and the specific requirements for each development task (Roelofsen, 2011): here it is to provide methods and tools to targeted support operational activities. The actual specificity of product properties is generally strongly influenced by the course of the development process respectively the specific decision-making situation (which is derived from the concrete specificity of the development context) and the information associated therewith (Reitmeier and Paetzold, 2012): this requires to complement the underlying product description by adding process relevant information respectively criteria. Finally, this supports decision-making situations concerning the execution of simulations and the evaluation of results with the determination of following activities (e.g. iteration management) in mind.

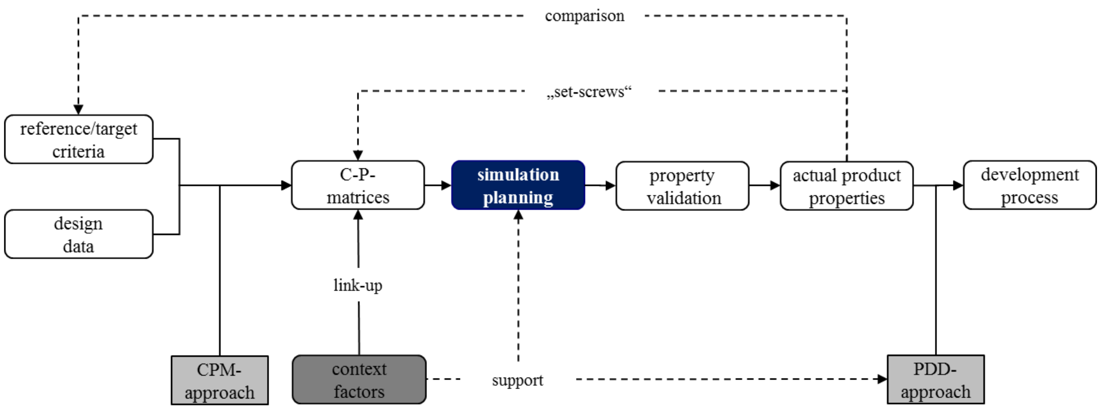

Figure 1. Basic concept of simulation planning

In the context of this paper, the link-up of metadata (in terms of situational described context factors) to the characteristic-property-matrices (C-P-matrices) is shown in chapter 4. In this respect, the terms "development context" and "development situation" are firstly discussed (chapter 2.1) and below described by situational assessable factors (chapter 2.2) for the simulation context to support the virtual property validation. In addition, the embedding of the description of the development situation in a suitable process model for development projects (chapter 3) is shown. Finally, it is focused to describe the meaningfulness and expected result quality of a property validation in the context of a simulation planning to consequently determine analysis efforts and iteration cycles more efficiently.

2 DESCRIPTION OF THE DEVELOPMENT SITUATION IN THE SIMULATION CONTEXT

In product development, terms like „development context" or „development situation" are often used. There are various concepts in the literature to make these terms more tangible: an excellent overview and analysis provide Ponn (2007) as well as Roelofsen (2011). Existing approaches are based on different objectives, types of situations and conditions, thus, there is no universal description of the

situation respectively development situations in particular (Roelofsen, 2011): it shows, however, a tendency to describe situations on the basis of defined factors, which are adapted to the respective situation context. Ponn (2007) also noted that very different description criteria are used that have different relevance depending on the specific perspective.
Consequently, this also applies in the context of a simulation planning. For this purpose, a clearer definition is first needed of what the development context for virtual property validations exactly includes, so that targeted context factors can be determined to enable to describe the present situation.

2.1 Definition of the development context

Ponn (2007, page 14) considers the differentiated analysis of the development situation and the development context as a necessary prerequisite, if appropriate tools should be used to support development processes and uses the following terms/definitions: *"A developing situation represents a specific point in the development process that can be described by the status of the product to be developed and the development process, as well as by factors that influence product and process. […] The development context is the surrounding context of the development process that can be described by context factors that have an influence on product and process."* In addition, Ponn (2007) differs within the description of the development situation between indirect (no direct influence on the selection of appropriate tasks in the development process; used for the selection of methods) and direct (described by present or desired situations; concretized by results, events and insights) context. Therefore, the direct context is the primary driver for the operational procedure and aspects like "existing product models", "a more detailed list of requirements" as well as "priorities for product optimization" are mentioned. This is also crucial in the context of simulations: especially in the early stages, data are characterized by high uncertainty and only become concrete in the course of the development process. Consequently, the simple availability of required data as well as the herewith prevalent data quality is closely connected. Both have a direct impact on the meaningfulness of simulations respectively on the quality of achievable results (Reitmeier and Paetzold, 2011). In terms of virtual product development processes, the simulation results are in turn drivers for the following activities: e.g. they provide the basis for the iteration management and optimization cycles when a difference between the desired and the current development state is identified. Based on the foregoing statements, the fundamental way of thinking of Ponn (2007) will be picked up when developing a methodology for simulation planning as well; however, adequate factors or criteria must be defined (chapter 2.2) to be able to describe and evaluate the development situation in the context of simulations. For this purpose, the essential boundary conditions from the perspective of the developer are shown as a starting basis (Reitmeier and Paetzold, 2012), see Figure 2:

- boundary conditions of the *1st grade*:
  These are directly related to a developer's daily work. The corporate strategy limits his degree of freedom and determines a development context that is difficult to change (e.g. only by the top management); however, there is an effect through derivable requirements on his daily work (What am I supposed to develop exactly?). Equally specified and difficult to change is the given availability of resources (software licenses, department capacities,...). These are to be used purposefully and have particular impact on the daily activities, e.g. the concrete processing of projects. Here, "product" and "process" are the main aspects that have to be analyzed depending on the current situation. Resources and corporate strategy represent a long-term context, but, must also be considered, since they have influence on the direct development context.
- boundary conditions of the *2nd grade*:
  These add indirect aspects to the development context. Due to their higher degree of abstraction they are not considered separately, but indirectly: for example, processes regarding networked development projects within globalized companies or explicit product requirements due to country-specific law have influence on the product development. Therefore, such aspects are included in the direct development context via interface descriptions, the requirements management or Design for X (DfX-) guidelines.

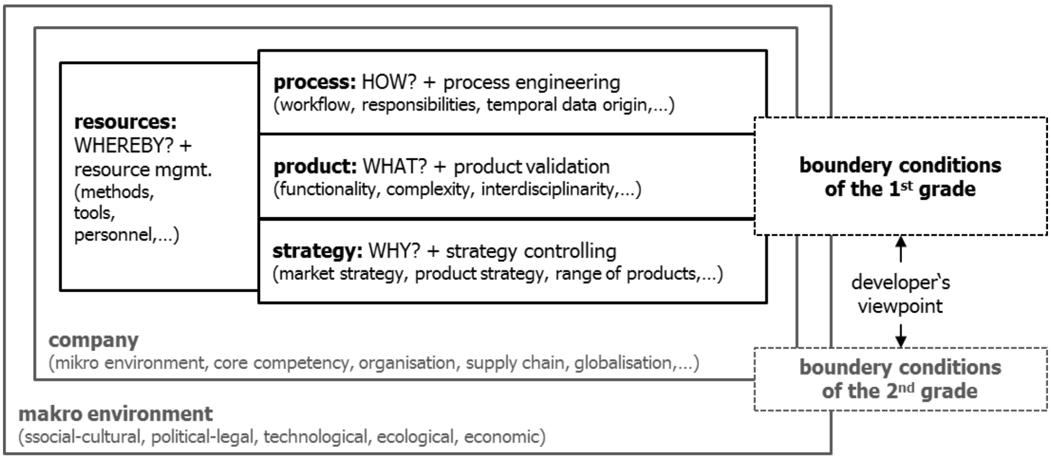

Figure 2. Boundary conditions in the simulation context (Reitmeier and Paetzold, 2012)

2.2 Definition of context factors

As already noted, factors have to be defined, which can be used to describe the present development situation to support decision-making situations with regard to the execution of virtual property validations. These need to have strategic (long-term) and general (e.g. for different projects applicable) validity; in addition, they must be easily and quickly determinable.

Based on student projects, the previous theoretical considerations of the simulation context and considerations of the prevalent data quality according to Reitmeier and Paetzold (2011), corresponding factors with their specificity and their objective are (initially) proposed in Table 1. In addition, “validity periods” are assigned to the context factors to point out that each factor is subject to different temporal changes: strategic factors ("s") are generally valid in the long term, operative factors ("o") are subject to a rather high turnover - this is also an indication of how often they need to be analyzed/evaluated.

The table is divided into three parts to give considerations to the origin of the factors and display this in a transparent way:

- with reference to the *product*:
  evaluation of the current development status
- with reference to the *process*:
  support of the simulation planning and the evaluation of simulation results
- with reference to *resources*:
  identification/allocation of available resources (supported by methods of project management)

Context factors (e.g. novelty or complexity) are also proposed that cannot be easily quantitatively measured and, therefore, are more likely to be described qualitatively; in addition, their assessment is subject to the evaluator‘s perspective. Nevertheless, even a qualitative description makes sense to raise awareness of the present task. There are interdependencies between the factors as well. The degree of novelty or the complexity of the task, for example, may have an impact on the model quality: the newer and more complex the product the more uncertain the virtual model can be. Interdependencies, however, relate to factors which are rather described qualitatively; this fact is considered to be rather uncritical. Other potential context factors such as quality of communication and team culture are not included: the focus is on the property validation; from the authors' view, these or similar context factors are more appropriately addressed elsewhere, e.g. within the overall project or personnel management.

An important aspect that has to be considered is the practical orientation and the easy evaluation/provision of context factors in order to make them usable in the context of simulations. For this purpose, a study (consisting of personal interviews and, build thereon, a subsequent questionnaire) is currently planned to check the specified factors of Table 1 with regard to their usefulness; appropriate industry partners are available. In addition, the feasibility of a fast and easy data collection and evaluation in practice is to be analyzed. Findings with respect to additional practice-relevant factors, their process links as well as requirements and requests of the industry are also expected. The final set of context factors will be linked with the characteristic-property-matrices (see chapter 4).

Table 1. Context factors

factor		possible specificity	objective
product			
design space characteristic	o/s	range of values	scope for development
relevance characteristic	o/s	quant./qual. value	regarding certain properties
design space property	o/s	range of values	scope for development
relevance property	o/s	quant./qual. value	regarding product success or maturity (e.g. legal standards)
origin of the reference value	o/s	law, norm,…	estimate origin
relevance of validation	o/s	required, mandatory, optional	prioritization
product complexity	o	low, middle, complex	awareness raising
novelty	o	new, incremental, known	awareness raising
process			
revision state of data	o	date	identify actuality
availability of data	o	yes/no/when?, access rights	usability, time of their origination, completeness
input quality of data	o	quant./qual. value	estimate meaningfulness of simulation
processing state of data	o	open, in progress, (for now/definitely) finished	estimate temporal validity
authorized person (design data)	o/s	name and contact data	skills/competencies, facilitate communication
authorized person (validation)	o/s	name and contact data	skills/competencies, facilitate communication
simulation: output quality	o	quant./qual. value	estimate achievable results
simulation: model quality	o/s	quant./qual. value	awareness raising
simulation: focus	o	rough or highly detailed analysis	estimate required data resp. data quality
simulation: level of abstraction	o	low, middle, high	awareness raising
resources			
simulation tools	s	list	identify available tools
competence of the personnel	o/s	level of experience	consider modeling skills
simulation effort	s	cost, time, preparatory and subsequent work	cost/benefit ratio
available capacity of tools	o	working hours	overview free capacities
available capacity of personnel	o	working hours	overview free capacities

3 PROCESS INTEGRATION

Having determined the essential context factors, the question arises, how these can be made available in the course of the process and evaluated to targeted support property validations. The FORFLOW-process (Krehmer et al., 2009), which got constant positive feedback from industry, will be used as a reference process: this process model is a detailed and variable, yet universally oriented approach to address current challenges of product development. The aim was to support the developer by means of process and workflow support best possible to make operational procedure in the product development process more effectively and efficiently. This process representation has several advantages (Krehmer et al., 2009), which should be used accordingly for simulation planning (Paetzold and Reitmeier, 2010): situation-specific process planning (the process planned at the beginning can be easily modified if necessary as process activities are not entirely fixed) and the integration of design iterations (provision of multiple process interfaces to return to a certain process step) are the main aspects that have to be mentioned here.

The FORFLOW-process model (FFPM) consists of approximately 90 single-step and explicitly refers to steps of analysis respectively property validations, followed by a review of the analysis and decision-making situations concerning the progress of the process. An exemplary section of this is shown in Figure 3.

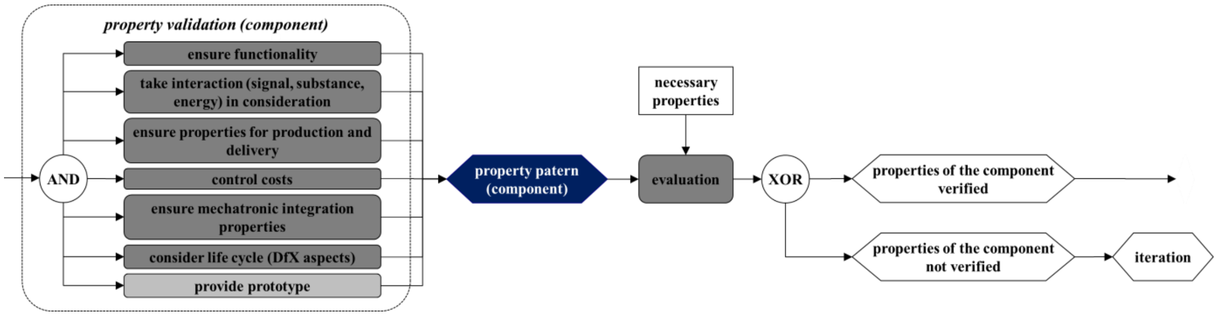

Figure 3. Exemplary section of the FORFLOW-process (derived from Roelofsen, 2011)

This and similar process sections are to be used, the basic idea is shown in Figure 4. In the context of virtual property validation, there are 2 decision-making situations that require a split situational process planning:

- *(Before execution)* Determine the meaningfulness of the simulation:
  - Are all necessary data available in a sufficient quality?
  - Are the required resources available?
  - What is the cost-benefit ratio?
- *(After execution)* Determine the progress of the process:
  - Are the achieved properties satisfactory?
  - What are the efficient “set-screws” for optimizations?
  - Which follow-up activities have to be defined?

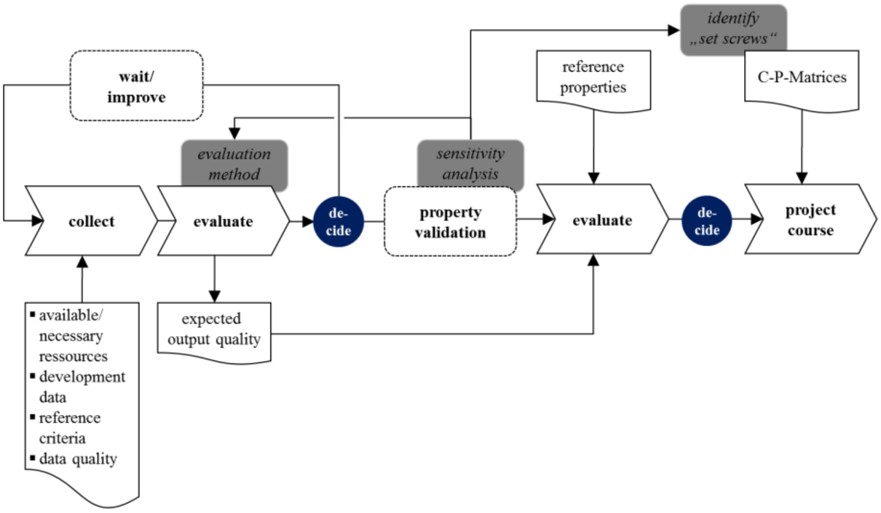

Figure 4. Situational planning of activities in the context of simulations

The support of the first decision situation respectively their explicit consideration is the core objective of the present project (Reitmeier and Paetzold, 2011): it is absolutely necessary to indicate which input data the simulation results are based on in order to prevent systematic errors and avoid implying a precision that does not exist; data quality must be pre-defined depending on the current process step if simulations are to be executed efficiently. Therefore, the objective must be to be able to describe the available data basis, to provide methodical support to assist engineers at the decision-making process and, consequently, to determine appropriate subsequent process steps respectively to carry out more goal-oriented iteration loops. Moreover, information concerning modeling and modeling constraints can be derived not only from the requirements but also from the necessary determination of characteristics.

The first section, before the execution of the simulation, initially focuses the target and actual situation with regard to the available data base. Here it is to collect all the necessary data (design data, reference/target values, data quality) to evaluate the meaningfulness of a simulation at the present time: a decisive decision-making basis for this is the expected result quality, which is determined by the method described in Reitmeier and Paetzold (2011) and, therefore, includes a target/actual comparison of the available data base. In addition, information about available and required resources concerning computer time or man-hours identifies the actual feasibility. If one of these points is not rated positively, appropriate waiting periods (waiting for data or freed-up resources) have to be accepted or optimization efforts regarding the required data and resource basis have to be done. Sensitivity analyses will be carried out in parallel to the property validation to support both evaluations of the expected quality of results as well as to identify effective “set-screws” for the iteration management (Reitmeier and Paetzold, 2011). This is primarily useful for validations of new products or new validation methods for which no empirical data exist, to learn about “set-screws” as well as the model quality. In such cases, costs and benefits must be always weighed, so that e.g. sensitivity analyses (even if only OAT-experiments) are only operated for essential rated input parameters. The second section, after the execution of the simulation, focuses on the evaluation of the target and actual situation with regard to the product and is accordingly integrated in the FFPM. A supportive statement about the obtained quality of the simulation result is to be integrated as well.

The shown approach of simulation planning shall be integrated in the FFPM (Figure 5) as follows: the evaluation of the meaningfulness of a simulation is put in front and supported by the analysis of the context factors. The subsequent evaluation of the validation results is therefore supported by the analysis of the simulation quality; in addition, the specific data processing helps to identify the most efficient “set screws” if the profile of properties is evaluated to be unsatisfactory.

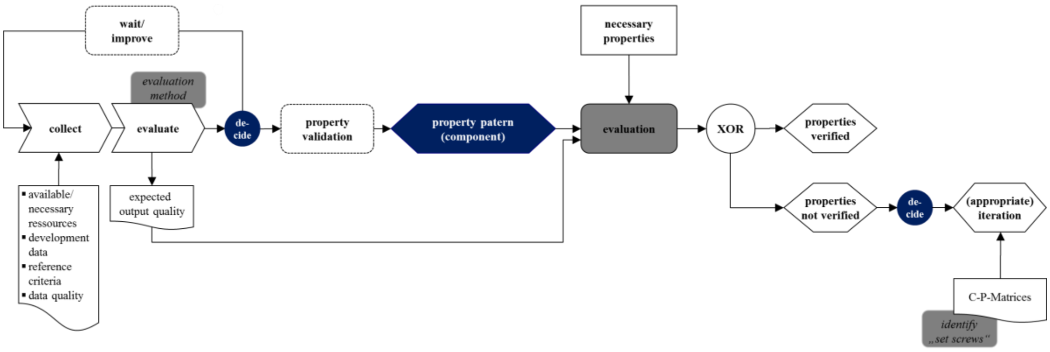

Figure 5. Elements of simulation planning integrated into the FORFLOW-process

Consequently, the approach to simulation planning has to take account of the progress in the development process (product maturity, data availability,…). A holistic evaluation of the resulting product properties is possible only by giving consideration to the process-dependent factors.

4 LINK-UP OF CONTEXT FACTORS TO THE DATA MODEL

Initial studies show that there are network-like dependencies between characteristics and properties; this can be targeted displayed by the means of matrices. This fulfills the core objective respectively requirement for an efficient data processing in the context of simulation planning (Reitmeier and Paetzold, 2012): the illustration of dependencies between characteristics and properties and among each other. In addition, the mentioned data processing allows, for example by means of subordinate matrices, databases or files to link up the context factors, which were discussed in chapter 2.2, as metadata. Figure 6 shows the basic principle. A color coding of the context factors, e.g. using a traffic light scale, can support a quick overview of the present status. A grouping of characteristics and properties, or a filtering of context-relevant information is also to be realized: this can support the focus on specific components/assemblies, responsibilities, DfX-guidelines, property validations, domain-specific views, etc. and, consequently, enables the display of a situational required view.

Identification/allocation of available resources (tools/staff) should be done with common tools of project management. This is very different depending on the company; therefore, it is not discussed in more detail in the context of simulation planning: the focus remains on the specific data processing of product data and context factors that is independent of project management methodologies.

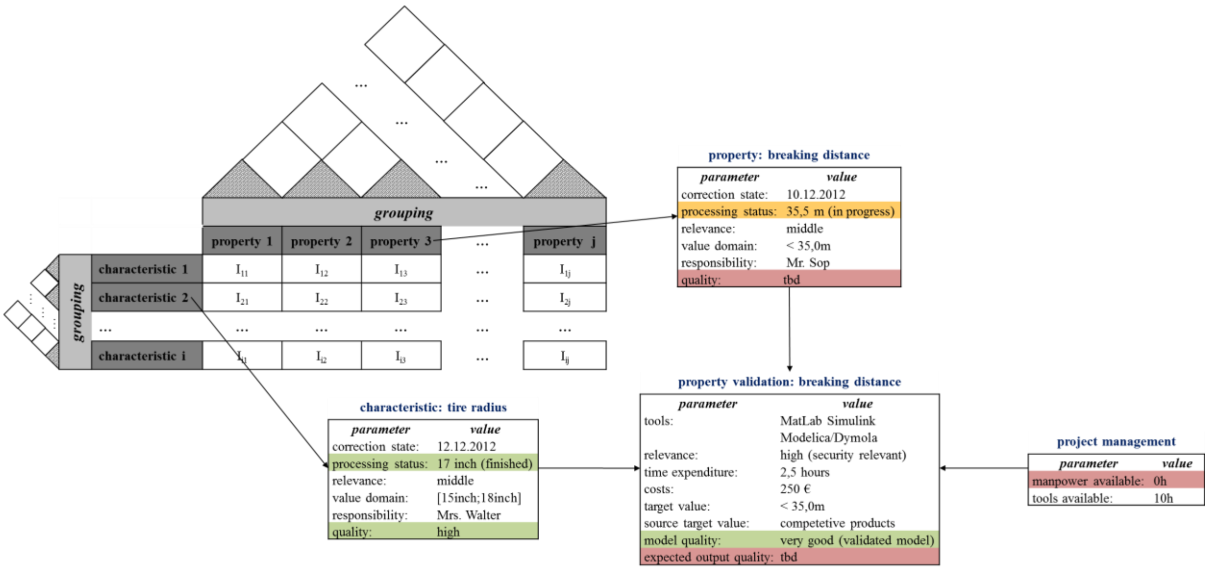

Figure 6. Link-up of context factors to the data model

5 OUTLOOK

The aim of current research is to develop a situation-specific approach to a product-oriented management of simulations, where the interplay of synthesis and analysis steps is supported by the consideration of relevant influences on property validations. This should not only be used as a standalone process proposal, but, rather integrated in existing/described information flows and processes like the FFPM.

The presented approaches set the theoretical basis to support decision making processes regarding property validations. As the next step, a study is necessary to review their practical usefulness and to get further information for improvements. Moreover, an implementation of the data model into a product data management system is intended to control development processes by workflows.

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