Verification and Validation for Simulation in Production and Logistics

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Verification and Validation (V&V) of simulation models and results are very important parts of discrete event simulation studies for production and logistics applications, as wrong or inadequate simulation results can have massive impact on strategic and investment-related decisions. The authors propose a procedure model for V&V that is applicable for simulation studies in this sector, based on a simulation procedure model that clearly defines the phases of the study and the results of each phase. This paper summarises the background of these procedure models, gives an overview on both models and then illustrates the elements of the V&V procedure model on selected examples, giving exemplary questions to be answered during the V&V and explaining the context of these questions in the framework of the procedure model.

Introduction

Discrete event simulation (DES) is an established analysis method for production and logistic systems. It is frequently used when decisions with high risks have to be taken, and the consequences of such decisions are not directly visible, or no suitable analytical solutions are available. This, however, implies that correctness and suitability of the simulation results are of utmost importance. Therefore, verification and validation (V&V) are highly relevant within simulation studies in this application domain.

According to the differentiation of the terms verification and validation in the literature, the authors associate verification with the question "Are we creating the X right?" and validation with the question „Are we creating the right X?" (cp. [1]). Verification does not prove the correctness of X, e.g. the data or the model, but the *correctness of the transformation* from one phase into another one. Validation in contrast aims to analyse the suitability of X related to the given task and the sufficiently accurate modelling of the system under consideration. For both – correctness and suitability – it is characteristic that they cannot be completely proven. Thus, the goal of V&V is not the complete and formal proof of the model validity, but the estimation of its credibility.

Only by a systematic approach and by structuring into single, directly usable sub-tasks with specific V&V techniques, V&V can be managed. Therefore, a procedure model is required that defines V&V-related activities for each single modelling step and its results.

1 Related work

There is a great amount of research efforts dedicated to procedure models, V&V, and simulation. The intention of this chapter is to give a short overview on some of literature in the field. However, at the beginning it is important to clarify the differences between simulation procedure models and V&V procedure models. A similar survey on procedure models can be found in [2], and a more detailed overview on such models is provided in [3].

1.1 Classes of related procedure models

In general, the related work on procedure models may be divided in two different classes: The first class contains *procedure models for simulation studies*, which to a different degree include elements for V&V. The second class of procedure models consists of *procedure models for V&V*. They are meant to support a professional handling of V&V activities within a simulation study, i.e. they describe V&V activities in detail and the relationship of these activities to the procedure model for the simulation study.

However, research on V&V is not limited to the application domain of simulation in production and logistics, which is the focus of this paper. For example, simulation in the military domain is an application area were procedure models for V&V are of high importance. Also, other scientific disciplines, e.g. management science and, especially, computer science, have developed procedure models covering V&V activities to a certain degree. There are approaches, e.g. the V-model XT mandatory for IT development processes for German federal engineering projects, with a large relevance for the development of simulation models.

1.2 Procedure models for simulation

Several procedure models for simulation have been published and can be found in textbooks (cp. [4, 5, 6]) as well as in guidelines (cp. [7, 8]). These models are quite heterogeneous in scope and level of complexity. However, they typically do have in common the following five elements which can be found in nearly all of the models:

- Initialisation phase, defining the task and its feasibility
- Plan for tackling the task
- Detailed model design, including the actual computer code
- Testing
- Operation and maintenance

The cited models cover V&V activities within the proposed procedure to a very different extent. What they again do have in common, though, is that they typically name V&V as an essential part of the procedure without giving clear indications on how to perform V&V activities.

1.3 Procedure models for V&V in the simulation domain

The main purpose of procedure models for V&V is to support the performance of a professional V&V process. This requires a consistent procedure that is related to a procedure model for simulation.

In the literature, papers on V&V procedure models as well as on V&V techniques can be found. V&V techniques are not in the focus of this paper. A very broad overview on techniques is given in [9]. The use of the techniques in different phases of the simulation study is outlined in [10] and [3].

The General Accounting Office of the US Government provided an approach that names criteria for V&V such as documentation, theoretical validity (concerning the validity of the conceptual model), data validity, operational validity (concerning the validity of the executable model), model verification, ease of maintenance, and usability [8].

The US Department of Defense (DoD) with its Defense Modelling and Simulation Office (DMSO) considers the V&V process to be part of a general problem solving approach, comprising a procedure model for simulation as well as a process for accreditation [11]. Additionally, [12] recommends good practices as a guideline for each process element. In the defense domain in Europe similar research towards a generic V&V process can be found. In the year 2004, first efforts have been started to harmonise these approaches, internationally [13].

The procedure model presented in the remainder of this paper has been significantly influenced by the work of Brade [14], who defined a stepwise procedure for the V&V of models and simulation results. It is based on a simulation procedure which leads to explicit intermediate results for each phase as input for the next phase. Following Brade's approach, the result of a phase needs to be checked intrinsically, with respect to the directly preceding phase, and also with respect to *all* preceding phases. The number of checks grows with each phase of the modelling process.

Some more recent papers acknowledge the role of data for simulation applications by emphasising the specific importance of data validity. Skoogh and Johansson [15] present a methodology for input data management including some aspects on data validation. Wang and Lehmann [16] propose an extension of Brade's V&V triangle by explicitly covering data validation.

Comparing the approaches discussed in this subsection, it becomes obvious that focus and level of detail are very different. The DMSO for example is rather proposing a general procedure for the V&V process. Other models suggest more specific procedures, however, differing in scope and content. The models do have in common, though, that they were not specifically designed for applications in production and logistics.

1.4 Models related to V&V from other domains

Simulation in production and logistics covers aspects of operations research, mathematics, statistics, computer science, and engineering. Most of these disciplines consider to some extent verification and validation of their applications, techniques, or models. Thus, for an interdisciplinary research field like simulation in production and logistics it is necessary to analyse the results of these domains, too.

Examples of V&V in *Operations Research* can be found in Landry und Oral [17], which show large similarities with the procedure models given above. In *Computer Science*, Bel Haj Saad et al. [18] propose an extension of procedure models used in software engineering, thus enabling their application for simulation purposes. A broad discussion of V&V in other disciplines can be found in [3].

1.5 Conclusions from related work

The comparison of the summarised procedure models shows some similarities, but also significant differences. There is a similar set of basic steps in each procedure model for simulation and V&V typically is included as a necessary activity, e.g. as one of the steps. However, the consideration of V&V ranges from just naming its relevance to detailed procedure models. The idea behind this paper is that verification and validation are essential parts of a simulation project from its very start until completion. This conviction leads to the three basic requirements for a valid procedure model for V&V:

- A simulation procedure model, defining the phases of a simulation study as reference points needs to be formulated.
- The results of the specific phases of the simulation procedure model ("Phase Results") need to be defined.
- An explicit V&V procedure model that supports the execution of V&V needs to be stated.

Accordingly, Chapter 2 firstly defines a simulation procedure model with the Phase Results. Then, a

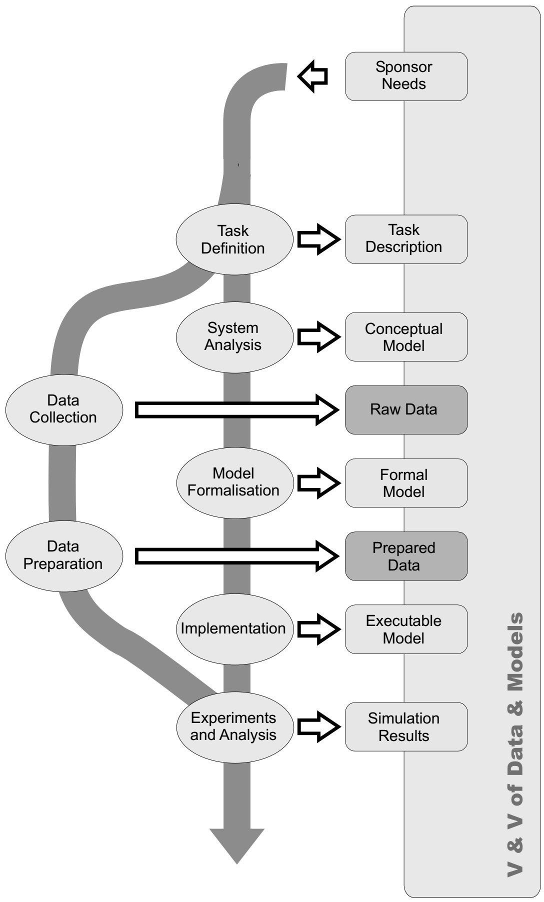

Figure 1. Procedure model for simulation incl. V&V [3].

V&V procedure model is defined in Chapter 3 and its elements are illustrated in Chapter 4.

2 Procedure model of simulation with V&V

In order to be able to propose a procedure for V&V, it is necessary to understand the role of V&V within the procedure that is applied for simulation. The authors propose a suitable procedure model for simulation including V&V (Figure 1), based on a guideline of the German engineers' association VDI [8].

Starting from the Sponsor Needs, this procedure model considers only tasks that normally occur after the acceptance of the task and cost plan for a simulation study, not distinguishing between external and internal service providers. Therefore, the proposed procedure starts with the Task Definition, which is considered to be the first analysis step within a simulation study. The procedure model is characterised by the stringent definition of intermediate results, and separate paths for models and data. The model path is structured into Task Definition, System Analysis, Model Formalisation, Implementation, and finally Experiments and Analysis (ellipses in Fig. 1). A Phase Result is assigned to each phase (rectangles in Fig. 1). Phase Results can be models, documents, or a combination of both. In the following, for simplification the term document is used for the Phase Results in general. The document *Sponsor Needs* is no Phase Result, but the base for starting the simulation study.

According to the importance of the Phase Results, the authors recommend a generic document structure for each of the Phase Results [3, summarised in 2].

The phases Data Collection and Data Preparation (with the results Raw Data and Prepared Data) are deliberately defined in a second path, as they can be handled in parallel with respect to content, time, and involved persons. Therefore, the position of Raw Data in Figure 1 does not indicate that they can only become available after the Conceptual Model. Raw Data does not need to be completely collected before the elaboration of the Formal Model. The same applies to the Prepared Data, analogously. The procedure model just defines that Data Preparation requires Data Collection to be done, and that for the use of the Executable Model the Prepared Data have to be available.

As V&V has to be conducted during all phases of the modelling process, V&V – both of the data and the models – is arranged along the whole simulation study (see the rectangle on the right of Fig. 1). Even the document Sponsor Needs, whose development is not subject of the simulation study, should be validated before starting the Task Definition, with respect to consistency and completeness in terms of the major topics to be covered.

Thus, V&V is not at all a task that is conducted at the end of a study. In particular, it should never be considered as a procedure that is iterated after the implementation until the model seems to operate correctly. In contrast, V&V has to accompany the simulation study from the start until the very end, and specific V&V activities are indispensable within each single phase of the modelling process.

3 Procedure model for V&V

Based on the procedure model for simulation in production and logistics including V&V (Figure 1), the procedure for V&V itself can be defined. The considerations in the previous chapter already imply that this procedure model for V&V must support all phases of the simulation procedure model. In addition, the procedure model should list and structure the single steps that are necessary for V&V, and provide guidelines for the execution of these steps.

In general, at each point of time during a simulation study all documents and models can be analysed with respect to all other documents and models that have previously been created. However, in most cases this approach will be neither acceptable in terms of time consumption, nor economically feasible. On the other hand, the execution of activities for V&V just "by accident" can never be acceptable. For a systematic procedure it is essential that a dedicated decision procedure is applied to identify those activities that are necessary and economically reasonable for the specific project. For this purpose, a V&V *Procedure Model* is required. This procedure model can be used to establish and monitor process quality at the simulation service provider itself as well as for the communication between the service provider and the customer. In the latter case, it can be used as a common guideline. The scope and the level of detail of this procedure model need to be adapted to specific modelling constraints, in order to achieve an efficient and pragmatic application.

3.1 Systematic of the V&V Procedure Model

The V&V Procedure Model proposed by the authors is shown in Figure 2. It takes into account the principles given by the simulation procedure (Fig. 1). Therefore, it is separated into two major sections representing the model path and the data path. The lower part of the procedure model relates to data collection and preparation; the upper part relates to modelling and simulation. Thus, the eight rows of the V&V Procedure Model represent the results of the phases defined by the simulation procedure model.

In order to conveniently refer to the Phase Results, they are enumerated from 1 (Sponsor Needs) to 6 (Simulation Results).

The results with respect to data cannot be clearly related to the modelling phases, as explained above. In order to avoid any misinterpretation, they are not characterised by numbers. Instead, the letters "R" (Raw Data) and "P" (Prepared Data) are assigned to these documents.

Each row of the V&V Procedure Model consists of *V&V Elements*, which are depicted as rectangles. The V&V Elements comprise a set of possible *V&V Activities*. In order to establish a unique relation to the V&V procedure, each V&V Element is denoted by two indices:

- The first index defines the Phase Result which is validated by the activities of this V&V Element
- The second index defines the Phase Result which is used as the reference for the V&V with respect to this V&V Element

3.2 Classification of V&V Elements

The circle in some of the V&V Elements given in Figure 2 stands for an intrinsic test, i.e. the document is analysed with respect to itself, and only to itself. Such *Intrinsic V&V Elements* always have an index with two identical digits (or letters), as both the first and the second index indicate the same Phase Result.

A simple arrow indicates the test of a Phase Result with respect to the results of a previous phase. For example, the simple arrow in element (3,2) stands for the reference from the Conceptual Model to the Task Description, asking if the requirements defined by the latter document are correctly mirrored by this Conceptual Model. The arrow indicates the direction of this relation.

The third type of V&V Elements provides a relationship between the Phase Results of modelling phases and the results of data collection and preparation. Therefore, these elements are indexed by one letter and one digit, and represent tests in combination of both documents. As the modelling and the data collection and preparation phases of the simulation process model are to a certain degree independent, the test of a data document *against* a modelling document or vice versa do not appear to be an appropriate description. None of the documents can be fully derived from the others, even if this can be the case for some parts of the documents. Therefore, there is no direction of the relationship, and the element is indicated by a double-sided arrow.

The last type of V&V Elements, which is marked by a triangle, stands again for the test of one Phase Result (of the modelling phases) to another one. But, for the tests of this fourth type the availability of the Prepared Data is a precondition, and the test is conducted using these Prepared Data. Negative results can have their roots in any of the three Phase Results used for the test. This type of V&V Element is applicable only in the two last phases (Implementation as well as Experiments and Analysis).

3.3 V&V Documentation

The results of the V&V Activities conducted for each V&V Element have to be carefully documented as this is the only way to review the validation activities at a later point in time. This leads to a set of reports for each phase of the simulation study, which can be used for detailed credibility assessment of the simulation study. In addition, these reports might be exploited in case of a change in the targets of the simulation study, in order to decide if the model is valid for the modified Task Description. Similar to further accompanying documents (proposals, project plans, meeting minutes, decisions on assumptions, status reports) these reports can be related to the Phase Results according to Figure 2.

4 V&V Elements

In this section, the V&V Procedure Model will be illustrated using seven V&V Elements as examples. The examples have been selected in order to cover all the classes of elements defined in section 3.2. For all these elements, key issues are briefly explained and typical questions given, starting with two intrinsic elements.

The questions for the V&V Element (1,1) check whether the documentation is complete, consistent, accurate and currently valid, e. g., whether the document Sponsor Needs comprises all sections of the proposed document structure and whether the given requirements are free of contradictions (Figure 3). Other questions check whether the described solution approach and methods as well as the project objectives sufficiently fulfil the intended purpose of the study. Additionally, some of the questions are meant to prove that the project plan is free of contradictions and the specification of the project scope is reasonably justified. Important questions relate to the feasibility of the specified Sponsor Needs with regard to

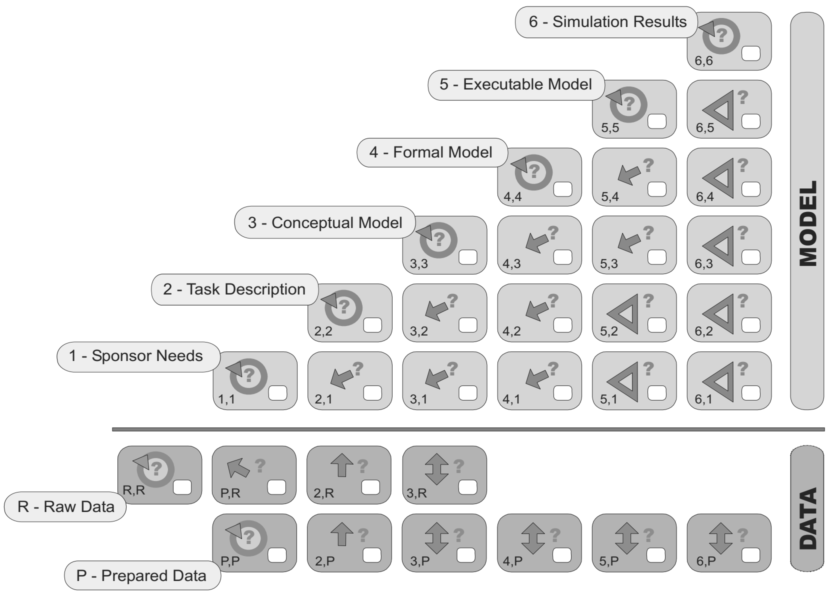

Figure 2. Procedure model for V&V of simulation in production and logistics applications (cp. Rabe et al. 2008).

- Do the Sponsor Needs comprise all bullet points mentioned in the document structure?
- Are good reasons given in case of omitted bullet points?
- Are the indicated system variants sufficient for the intended purpose of the study?
- Are the given simulation study requirements free of contradictions?
- Are the given system variants to be examined free of contradictions?
- Will the expected results serve the intended purpose of the study?
- Does the planned use of the model match the problem definition?
- Is the specified scope of the project reasonably justified?
- Is the solution approach comprehensible and free of contradictions?
- Can the described situation at the sponsor, the preconditions and the study goals be confirmed?
- Do problem definition and study goals indicate which solution method should be selected and whether simulation is an adequate method?
- Are the tasks to be contributed by other departments or external partners defined in a clear and reasonable way?
- Is the conduction of the project possible under the given organisational, financial and technical constraints?
- Are the buy-off criteria for the successful execution of the project described clearly?

Figure 3. Questions for V&V Element (1,1).

- Is the documentation complete?
- Are the data available in accordance with the Raw Data document?
- Is a process in place to ensure that the data acquisition is repeatable?
- Are standards and specifications of the IT department taken into account (e.g. interface specifications)?
- Has the data acquisition been performed completely and accurately according to the given specifications?
- Have the data been checked for measuring errors?
- Are the specifications for consistency fulfilled on entity type and entity level?
- Are the attributes within the given ranges?

Figure 4. Questions for V&V Element (R,R).

the given organisational, financial and technical constraints as well as the complexity of the task and the scope of the system.

Some of the questions for the V&V Element (R,R) are meant to check organisational issues such as the existence of a process for repeated data acquisition or the handling of regulations possibly imposed by an IT department (Fig. 4). As with all V&V Elements, the completeness of the documentation needs to be verified. Specifically for intrinsic data validations, questions about data availability, data completeness, data accuracy as well as consistency need to be answered.

- Are all system components with their characteristics and relations represented in the Conceptual Model in an appropriate way?
- If system components or relations are omitted, is this sufficiently justified?
- Does the Conceptual Model take the system interfaces into account as given by the Task Description?
- Are all assumptions given by the Task Description transformed into the Conceptual Model?
- Does the Conceptual Model contain explicit or implicit assumptions, which are in conflict with the Task Description?
- Does the Conceptual Model take into account all organisational system data (e.g. shift models) or system load descriptions (e.g. seasonal fluctuations) that are relevant according to the Task Description?
- Are the control rules specified in the Task Description taken into account in the Conceptual Model, and are their relationships defined?
- Is there a suitable variant in the Conceptual Model for each system variant required according to the Task Description?
- Can the output values required by the Task Description be determined on the basis of the Conceptual Model?
- Does the Conceptual Model represent the goals defined in the Task Description appropriately in scope and level of detail?
- Is it comprehensible that the indicators (e.g. for model acceptance or result evaluation) can be computed by the simulation model?
- Does the model structure specified in the Conceptual Model support the allocation of tasks as specified by the Task Description (e.g. distributed modelling)?
- Does the Conceptual Model take into account the modelling constraints as given by the Task Description (libraries, modelling conventions)?
- Does the Conceptual Model permit the variation of parameters and - if necessary - of structures according to the project goals and the requirements of the experimental design?
- Are the period of use, the users, their qualification and the kind of the use taken into account as requirements in the Conceptual Model?
- Are there elements specified in the Task Description that should be re-used? Are these recognisable and described as re-usable within the Conceptual Model?
- Is it conceivable that the run time of the simulation model will be in the desired range as given by the Task Description
- Are the solution methods that should be applied defined in the Conceptual Model and does their use seem to be plausible?

Figure 5. Questions for V&V Element (3,2).

For the V&V Element (3,2) the V&V of the documentation of the Task Description as well as the description of the planned or real production or logistics system is part of the V&V investigation (Figure 5). The element is meant to check the Conceptual Model with respect to the task specified in the Task Description, the planned use of the model, the defined solution approach and the model requirements. Therefore, questions concern whether all specified processes and structures, system elements and structuring requirements as well as organisational and system load specifications are adequately considered. Also, the level of detail and the specified output values have to be checked taking into consideration the problem definition and the system as given.

Complementing the V&V Element (3,2), the V&V Element (3,1) validates the adequate consideration of the intended goals and constraints described in the Sponsor Needs within the Conceptual Model (Figure 6). Therefore, V&V questions check whether the external partners named in the Sponsor Needs are involved in designing the Conceptual Model and whether the functionality of the system is taken into account as given in the Sponsor Needs. If there are any substantial differences these have to be justified as well. However, the most important validation aspect is the applicability of the Conceptual Model, which has to be checked by different questions. It has to be made sure that the Conceptual Model is specified adequately for the intended model application, i.e., that the Conceptual Model represents the Sponsor Needs appropriately in scope and level of detail and that the specified output values and measuring points are appropriate to achieve the kind of results requested in the Sponsor Needs.

- Are the external partners named in the Sponsor Needs involved in designing and aligning the Conceptual Model?
- Is the Conceptual Model agreed upon with the sponsor concerning goal and purpose of the simulation study?
- Is the functionality of the system taken into account as given in the Sponsor Needs, including the system's processes and structures?
- Are the system interfaces taken into account as given in the Sponsor Needs?
- Are the specified output values, analysis approaches and measurement points appropriate to achieve the kind of results requested in the Sponsor Needs?
- Do the problem definition and the purpose of the study suggest a re-use of model parts? If so, is this accordingly covered by the Conceptual Model?
- Does the design of the Conceptual Model lead to implicit assumptions, which are in contradiction to the Sponsor Needs?
- Does the Conceptual Model represent the Sponsor Needs appropriately in scope and level of detail?
- Is it comprehensible how the different kinds of results expected according to the Sponsor Needs are going to be generated by the model?
- Are variable parameters specified as such? Are their impacts comprehensible? Do they help to achieve the simulation goals?
- Are all described system variants specified in the Conceptual Model? Can the simulation goals be achieved with the intended model variants?
- Are the Conceptual Model and the simulation model implementation specified therein adequate for the intended model usage?
- Is it conceivable that the run time of the simulation model will be in the desired range?
- Is it conceivable that the buy-off criteria will be fulfilled?

Figure 6. Questions for V&V Element (3,1).

The Conceptual Model as well as the documentation on Prepared Data comprises information about data structures and attributes. Hence, the V&V Element (3,A) asks for consistency of the two specifications (Figure 7). Additionally, it is intended to ensure that the data required according to the descriptions in the Conceptual Model are available and at an appropriate level of detail. Also, (qualitative) estimates of the expected model performance should be done. The question on data preparation during runtime also strives to preserve computational performance. To conclude with, data at system's interfaces and data not explicitly required by the Conceptual Model should be investigated more closely.

- Do structure and attributes of the data specified in the Conceptual Model and the Prepared Data match?
- Are the data available that are required to set the parameters for the model elements?
- Is the granularity of the data sufficient with respect to the level of detail of the Conceptual Model?
- If a preparation of data is required that is not specified in the Conceptual Model: What are the reasons?
- Are the data that are necessary at the system interfaces available in accordance with the Conceptual Model (scope, level of detail)?
- If the Conceptual Model specifies data preparation at runtime, why can this preparation not be done in advance (independently from the model)?
- Given the level of detail of the Conceptual Model and the expected amount of Prepared Data: Can a satisfying performance of the model be expected?

Figure 7. Questions for V&V Element (3,A).

The V&V Element (5,2) validates the Executable Model against the Task Description using to a certain extend Prepared Data (Figure 8). The Task Description contains specifications on issues such as system components with their features and relations, control rules, visualisation and required output. Part of the V&V Element (5,2) is to check whether these specifications are met by the Executable Model. While these checks are rather a matter of completeness, some more complex assessments need to be made with respect to the overall model behaviour: core questions are whether the level of detail of the Executable Model matches the Task Description's requirements and whether the Executable Model may be considered as an appropriate representation of the subject given in the Task Description. Additional considerations in this context are the features of the implemented interfaces, the overall structure of the Executable Model, and the completeness of the computed output values, all in comparison with the information in the Task Description. Furthermore, some more formal or technical aspects have to be verified: possible modelling guidelines must have been observed, the simulation software package needs to be compliant with the requirements as well as other hard- or software. Other V&V steps in this element analyse possible additional assumptions made during the modelling process against the Task Description. Finally, the model runtime needs to be studied using the Executable Model together with some Prepared Data and it has to be made sure that all indicators needed for a possible buy-off process are calculated.

- Can all system components with their features and relations be found in the Executable Model?
- Can the control rules and mechanisms given in the Task Description be clearly identified within the Executable Model and are they understandable?
- Does the Executable Model comprise additional assumptions with respect to those given in the Formal Model, and are these assumptions acceptable with respect to the Task Description?
- Are the elements that are visualised in the Executable Model in line with the Task Description?
- Is the required presentation of the output provided (e.g. 3D-Animation)?
- Are all modelling guidelines maintained (libraries, naming conventions)?
- Does the used simulation software fulfill the requirements given in the Task Description?
- Is the specified hard- and software used in compliance with all given restrictions?
- Does the level of detail of the Executable Model match the Task Description?
- Is the impact of parameters and structures as given in the Task Description?
- Do all interfaces provide the specified functionalities?
- Does the executable model reflect all model structuring requirements?
- Is it possible to compute all specified output values with the Executable Model?
- Are all indicators calculated that are necessary for the buy-off criteria specified in the Task Description?
- Does the Executable Model represent the Task Description appropriately in scope and level of detail?
- Is the model run time in line with the Task Description?

Figure 8. Questions for V&V Element (5,2).

The V&V Element (6,2) validates Simulation Results against the Task Description and here again Prepared Data are necessary (Figure 9). A very general and generic test is the comparison of all requirements for experiment and presentation with the available results. More in detail, the compliance of the input parameters and the experimental design with the Task Descriptions needs to be checked. Closely related is the verification whether the Prepared Data named in the experimental design are in line with the Task Description. Specific aspects such as the simulation period need to be verified. Also part of this V&V Element is to validate that all output values are consistent with the Task Description and that all specified system variants can be analysed. At the very heart of this V&V Element is the consideration of the Simulation Results with respect to the overall purpose of the simulation study and the satisfaction of possibly given buy-off criteria. Last but not least, the Simulation Results are only of value for the stakeholder of the simulation study if they are presented and documented in an appropriate, comprehensible and clear manner.

5 Conclusions and Outlook

The quality-oriented application of simulation in production and logistics tasks requires that the sig-

- Have all requirements for the experimentation and for the presentation of the results been taken into account?
- Are the Prepared Data that are required according to the experimental design in line with the Task Description?
- Are the input parameters in the experimental design and in the simulation model in compliance with the Task Description?
- Does the simulation period match the Task Description?
- Are the output values in line with the requirements according to the Task Description?
- Are the simulation results suitable according to the purpose of the simulation study given in the Task Description?
- Is it possible to analyse all specified system variants?
- Do the results satisfy the buy-off criteria defined in the Task Description?
- Are the simulation results presented appropriately for the target group and documented in an understandable and clear manner?

Figure 9. Questions for V&V Element (6,2).

nificance of V&V is acknowledged, and the related activities are budgeted as an important part of the simulation study. In joint efforts, the members of the project team have to assure that models are sufficiently accurate, that the estimation of their credibility can be re-assessed at any time, and that the V&V activities are defined, systematically. Therefore, this paper proposes a well-structured procedure model, which increases the probability to recognise (early) if the task description, models, or result analysis could lead to invalid conclusions, and structures the steps to be done for V&V, thus providing the possibility to prove all activities at any later point of time.

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