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The impact of different levels of detail in manufacturing systems simulation models

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Abstract

Modelling and simulating manufacturing systems often involves several different organisational units. This can make data collection difficult and it can be hard to obtain data that allows for the model to be built with a consistent level of detail. To investigate the impact of a varying level of detail, a manufacturing system was modelled using different levels of detail. The first model was modelled at a high level of detail containing all elements in the system. The second model was an aggregation of some of the processes in the system and the third model consisted only of the main processes. The experiments performed with the models, aimed at finding differences between models' outputs that originated from the choice of the level of detail. The results show that there are significant differences between the models. The simulation models used for this paper are made in collaboration with a company in the mobile communications industry and deals with supply chain problems. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Simulation modelling; Level of detail; Output analysis

1. Introduction

Simulation is a powerful tool when analysing manufacturing systems. A simulation model can provide useful data from the modelled system otherwise difficult to obtain. The result of the simulation is however strongly dependent on how the simulation model was built and how the simulation study was conducted. Validation and verification are essential activities when determining the accuracy of the model and the accuracy of the simulation study as a whole. Validating and verifying aims at finding errors and correcting them by e.g. comparing model output with the manufacturing system's measured output. Validating and verifying a simulation model that contain several faults or errors, far from the description of the system, is a very time consuming task. It is therefore desirable to start the validation and verification activities with a model that closely represent the system in order to shorten the lead-time of the study. To use an appropriate level of detail is one of the cornerstones of a valid model. Assessing the appropriate level of detail is not an easy task. Sadowski and Grabau [1] state that, in order to deliver any simulation result, the level of detail should be kept at a minimum, keeping the model simple. The reason is that (i) a simple model can provide a result and (ii) an unimportant detail in the model is hard to remove despite the negative impacts on simulation execution time. Since the model is, by definition, an abstraction of the actual system under study, not all details are depicted in the model. Choosing to exclude the right details is, according to Rohrer [2], one of the keys to simulation success. Law and Kelton [3] state that the application of the simulation models must determine the appropriate level of detail. Even very simple models can provide useful results in some areas but be restricted in others due to the lack of detail. Choosing the appropriate level of detail seems to be a balancing act between, minimising the details on the one hand and, adding details to ensure usefulness of the model on the other hand. When reducing the level of detail, the model looses its ability to provide a useful result at some point. This critical level of model detail can cause a problem if a model is built unintentionally with fewer details than needed.

When modelling large systems, e.g. supply chains with many process steps and organisations involved, the option to use different levels of detail throughout the model can be useful. If data is available at different

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aggregated levels, then the model can be built accordingly. This means that it could be possible to model some plants in the network at a high level of detail and other plants at a lower level. Problems arise when some parts of the model need to be modelled at a very high level of detail apart from the rest of the model in order to find the proper outputs and the available data does not comply to this desire. Law and Kelton [3] identify this problem with a mismatch between the data that is available and the data that is desired. The ideal situation is, of course, to avoid different levels of detail. Otherwise, the varying levels of detail must be handled in some way.

Zülch et al. [4] discuss the problem with different levels of detail in a simulation model. When using few details, problems will occur mainly due to the fact that several operations in the actual system are aggregated into one in the model. This will lead to different resource allocations in models of the same system with a high or a low level of detail. Simulation models with a high level of detail will show a higher degree of freedom when it comes to model dynamics. Zülch et al. [4] also suggest a way to handle this situation by the coupling of models. The High Level Architecture (HLA) makes such a coupling of different simulation models possible [5]. HLA is a standard architecture that allows simulation models to communicate their state to other models. According to Zülch et al. [4], the HLA can provide the technical foundation for coupling of models with different levels of detail. By doing so, a simulation model can be divided into several sub-models, all with its own level of detail, and run as one model under the HLA. Work in this direction has also been conducted within the international Intelligent Manufacturing Systems (IMS) framework. The MISSION project aims at simulating globally distributed enterprises by coupling of simulation models in different simulation programming tools [6].

The purpose of this paper is to show that the choice of the model's level of detail has an important impact on the simulation results. The appropriate level of details can be determined by meeting the competing goals, on the one hand, of few details for cost reasons and on the other hand many details for reasons of usefulness. A secondary purpose to this paper is to provide and discuss guidelines for managing different levels of detail throughout a simulation model.

1.1. Methodology

The simulation methodology used for this paper is obtained from Persson [7]. The methodology is the same as covered in most textbooks on simulation, e.g. [3,8]. The methodology that was applied is a nine-step model, consisting of nine separate activities. All activities must be performed before the simulation study is complete. The use of such a methodology ensures a valid simulation result and assists the modeller in the development of the model. The activities used are listed below in the order they should be, and were, performed.

All projects and simulation studies start with a project plan. The time to carry out the project was estimated and the first sets of experiments were defined. The part of the actual system under examination was described in a simple flowchart and in a text document as a conceptual model. The objective was to capture the system logic and data necessary for the simulation modelling activity. It is in this activity the level of detail was decided. The manufacturing system in this study was described for the purpose of modelling the system using a high level of details. The conceptual model was validated, i.e. examined and corrected if necessary. The conceptual model was then transformed to a computer-based simulation model. This was done in the simulation language Taylor II [9]. Verification tested the computer-based model against the conceptual model. Validation tested the computer-based model against the system itself. The predefined experiments were executed and output data were collected. The data collected from the experiments were then analysed and a new set of experiments was defined and the experimentation phase repeated. The analysed output data were then used for the conclusions of this paper. Of vital importance are the validation and verification activities. If these activities fail to correct all model errors, the result of the simulation study can be questionable. It is therefore of the utmost importance to use proven methods for these activities.

In this paper, the same manufacturing system was modelled in different ways in three different simulation models. The models were built with different levels of detail. The first model contained all machines, servers, conveyors, and buffers present in the system. This model had a high level of detail. The second model showed a lower level of detail, but kept the notion of manufacturing lines without the possibility to store products in-between servers. The last model was built with a very low level of detail. Here, complete production lines were built as single servers, producing complete batches.

1.2. Paper outline

The paper is organised in the following way. First, the manufacturing system itself is described in brief. After that, the three simulation models are presented. The differences in modelling are highlighted and the experimental set-up is presented. The simulation results and analysis is included in the next section. The impact of the level of detail on simulation results is then briefly discussed. Last, conclusions and extensions are presented.