Proceedings of the 1998 Winter Simulation Conference
D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, eds.

COORDINATING ORDER PROCESSING IN DECENTRALIZED PRODUCTION UNITS USING HIERARCHICAL SIMULATION MODELS AND WEB-TECHNOLOGIES

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ABSTRACT

Increased dynamics and flexibility of order processing are considered the potentials of decentralized production systems. To feed these potentials a certain degree of partial autonomy is admitted. Nevertheless this given partial autonomy must be aligned to global company-wide objectives. One approach is supporting and co-ordinating decision-taking by using a simulation-based assistance system. Hierarchical modeling facilitates the suitable configuration of the simulation models and allows faster examination of larger production areas. Web-technologies, such as easy-to-use web-clients together with capable simulation-servers, make it possible for simulation-laymen to be supported in decision-taking by the assistance-system.

1 COORDINATION OF DECISION-TAKING

Efficient order processing in decentralized production units requires a great number of decisions, which have to be taken permanently and rapidly. Depending on the extent of partial autonomy admitted to the decentralized units, many of these decisions are token locally, such as decisions on the appropriate job-sequence-order or the right malfunction handling. These local decisions are driven by local objectives, e.g. the optimal utilization of the own machines or the optimal workload in the own unit.

In addition to local decisions others are token from a global point of view, such as the adaption of the product spectrum or the machine spectrum. These global decisions are driven by global objectives, e.g. the

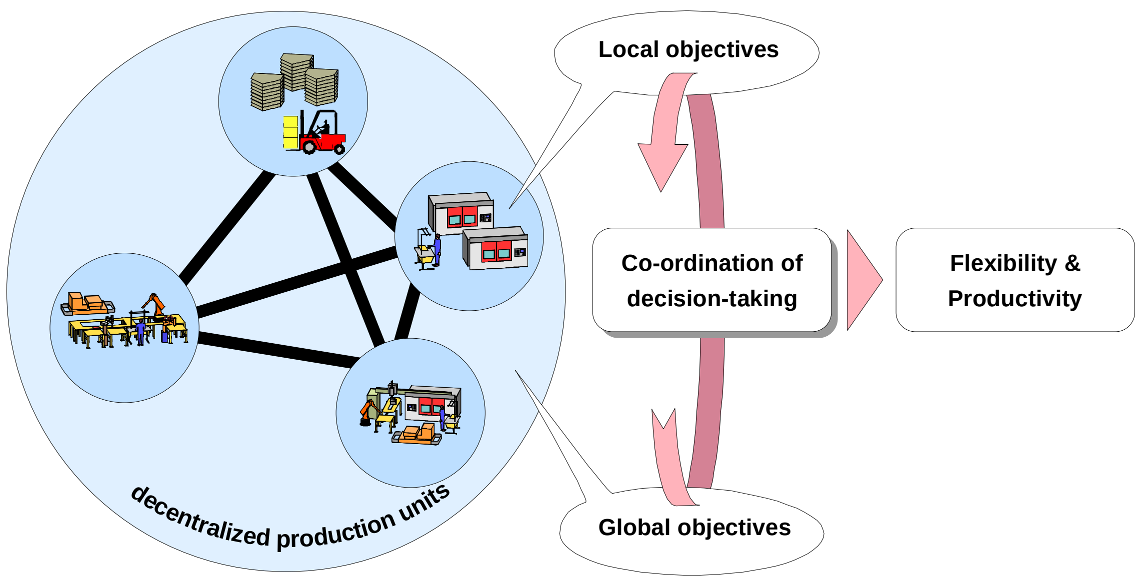

Figure 1: Coordination of Local and Global Decision-taking in Decentralized Units

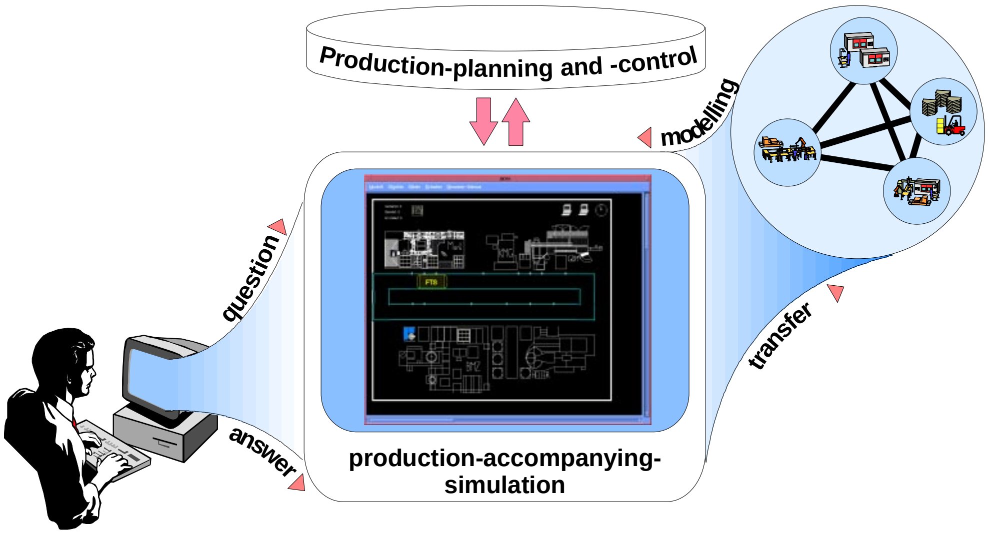

Figure 2: Production-Accompanying-Simulation as an Assistance-System for Decision-Support

attaining of short times of delivery or a high schedule adherency for all orders.

However the measure for partial autonomy and thus the equilibration between local and global decisions is selected, in any case both decision-taking-processes interact with each other. To guarantee the flexibility of the decentralized units, by permitting the local view, and to insure the productivity of the whole company, by considering the global view, coordination of decision-taking is affordable.

2 REQUIREMENTS FOR THE SUPPORT OF DECISION-TAKING

Decison-taking is dominated by either local or global objectives - depending on where decisions are token. A real coordination and balancing of both sides of objectives often doesn´t take place. Another problem are the hidden effects of token decisions - because even if local and global objectives are considered at the same time, due to the complex interactions the true effects often are not recognized.

Both aspects, dominating objectives and hidden effects complicate decision-taking and even lead to false decisions - the primarily planned characteristic of rapid and appropriate decision-taking and thus flexible and efficient order processing disappears.

To guarantee the positive characteristics of decentralized production systems and to support the local competence of employees, the decision-taking-process must be supported. An environment for experiments is required, where employees are enabled to analyse alternative decisions. Employees must be enabled to formulate typical decisions easily, if possible just by pressing buttons. As a result, the quality of the decisions and their effects on local and global objectives should be shown. In this environment for experiments it should be possible to oppose local and global objectives and to solve conflicts between them by the use of simple coordination mechanisms.

3 APPROACH FOR THE PROBLEM SOLVING

To meet these requirements the *Institute for Machine Tools and Industrial Management (iwb), Technische Universität München*, develops an assistance-system for production-accompanying-simulation, which gives the demanded support in decision-taking. The project, in which the assistance-system is developed, is part of the german research network *Forschungsverbund Simulationstechnik (ForSIM)*. The whole research network, as well as the project described here, is joined by a number of german enterprises.

Basis of the described assistance-system is a simulation-model, where the production-process to be examined is modelled (Figure 2).

Employees can have themselves supported in decision-taking, by examining the quality and the effects of decisions. The assistance-system checks the decisions and verifies possible effects. The result of this verification process is replied in form of logistic characteristic numbers, such as delivery time, schedule adherency of jobs or workload of machines.

Interfaces to the systems for production planning and control, which the enterprises already have, intitialize and actualize the simulation-model.

For implementing this assistance-system, two important aspects have to be considered. On the one hand,

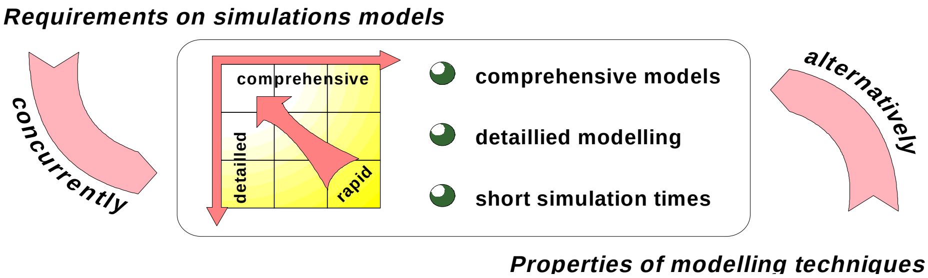

Figure 3: Requirements on and Properties of Modelling Techniques

sophisticated models have to be built, in order that the simulation is able to produce the required results in the demanded quality and in reasonable time. On the other hand, the user interaction must be easy to use and has to run on simple as well as cheap hardware plattforms.

The following article discusses both emphases - the development of suitable simulation-models (section 0) and the structure as well as the design of the user-interaction (section 0).

4 DEVELOPING HIERARCHICAL SIMULATION MODELS

4.1 Requirements on simulation models and properties of modelling techniques

For production-accompanying use of simulation, special demands on the design of the simulation models are made. On the one hand comprehensive models are required, which cover extensive production areas and permit detailed questions. On the other hand the models should be rapid

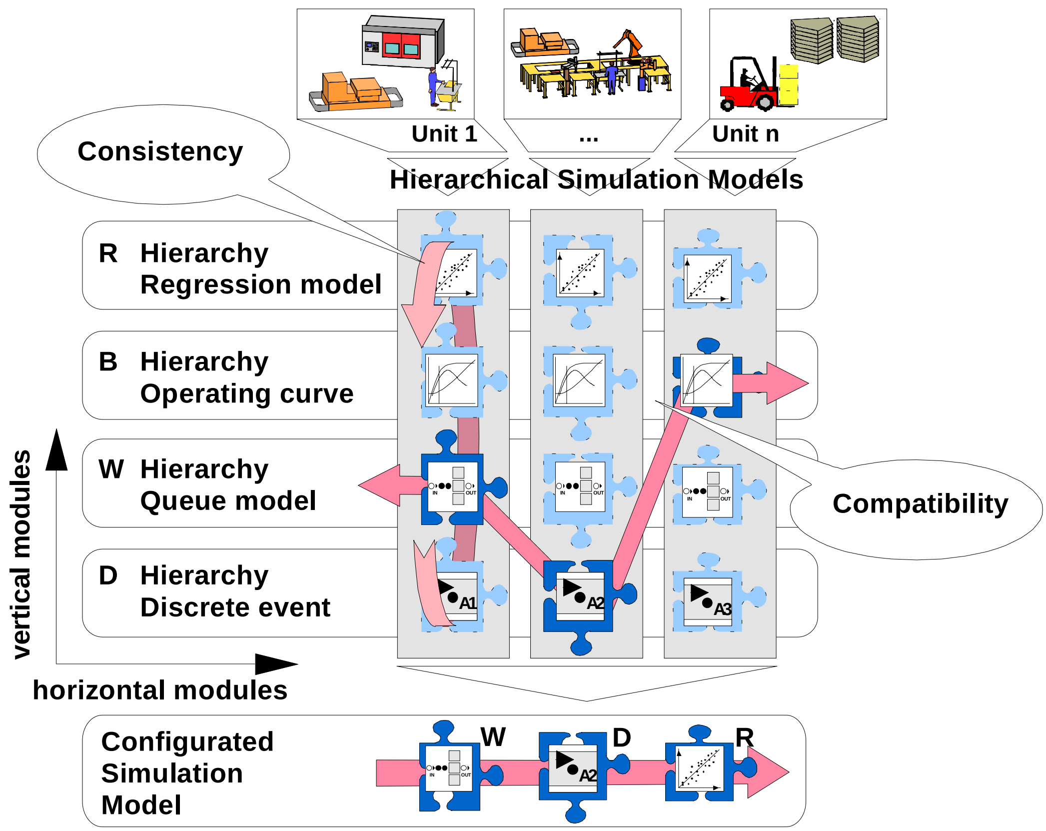

Figure 4: Horizontal and Vertical Modules of Hierarchical Simulation Models

enough, to be able to use the responses actually accompanying to the production process. Using only one modelling technique, these requirements cannot be met at one time (Figure 3).

Discrete event models for example allow detailled mapping of structure and dynamic behaviour of production systems. But if large production areas are concerned, they become complex and intransparent. Then they require simulations times, which are too long for a production-accompanying use of their results.

Queue models as a more abstract modelling technique, as well as operating curves or regression models, require less simulation time even if large areas are modelled. Therefore the examinable questions are often not detailled enough to support decision-taking and coordination in decentralized production units efficiently.

4.2 Integrating modelling techniques into hierarchical models

To solve the described dilemma between requirements on and properties of modelling, hierarchical simulation models where developed and different modelling techiques integrated.

The basic structure of these hierarchical models are horizontal and vertical modules (Figure 4).

The *horizontal modules* represent each production-unit by an own partial model. This facilitates the modelling and improves interpretation of the simulation results.

The *vertical modules* in each partial model represent different abstract hierarchical levels. The differing abstraction is reached by the use of the different modelling techniques: the most detailled level is modelled by discrete event techniques - as said, this allows the most detailled questions but requires the longest simulation times. Queue models are used for a more abstract modelling of dynamic interconnections of certain charteristics (access rate, operating rate, system size). Operation curves are utilized for a static view on the interconnection between the logistical characteristic numbers. Regression models are appointed, when interconnections between other data are desired to be described.

The decision, which hierarchical level is suitable, is taken by the user depending on the question to be examined. Parameters for this decision are the recommended accuracy of the simulation results, the available time or the logical distance of the production area, which has to be covered. For areas at a short logical distance (e.g. the own organisational unit) a detailled hierarchical level has to be used (e.g. the discrete event level). Areas at a long logical distance (e.g. storage facilities) can be modelled more abstract (e.g. by the use of a queue model).

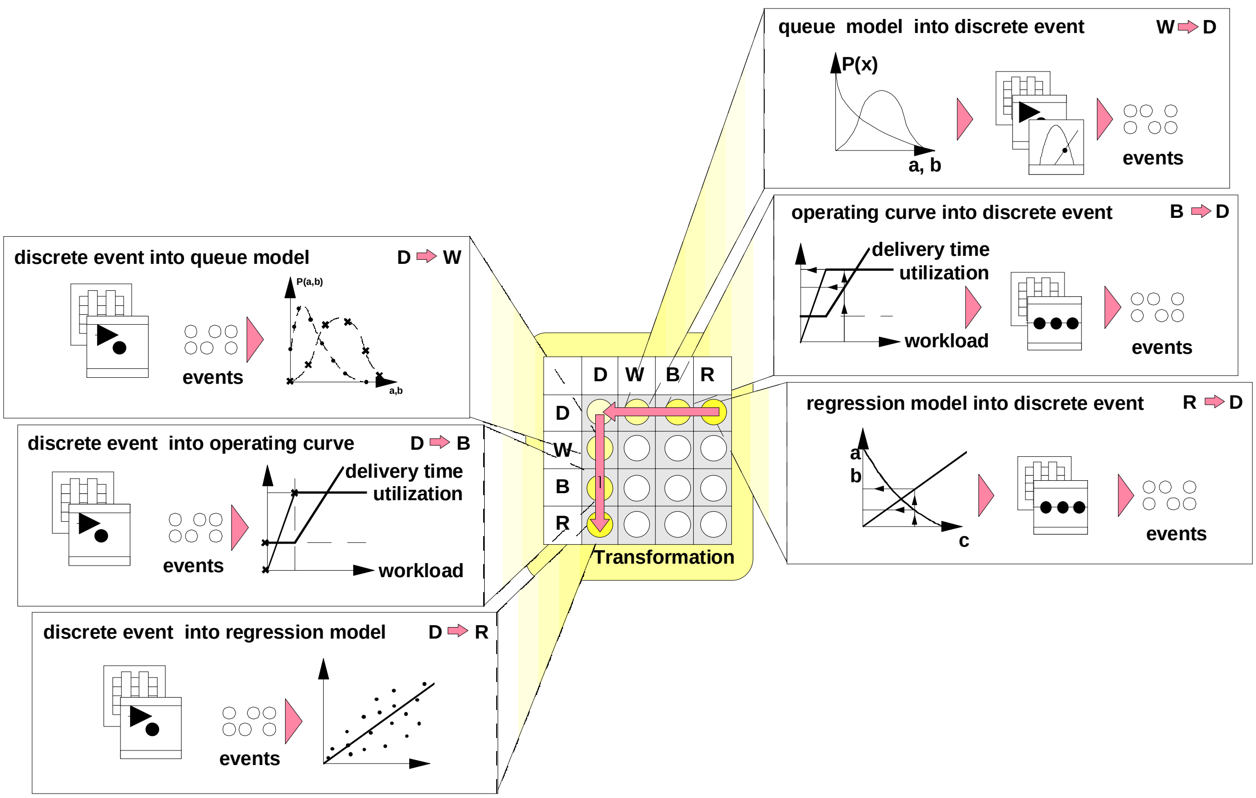

Figure 5: Transformation Functions for Consistency and Compatibility

4.3 Achieving consistency and compatibility

In order that the configuration of the hierarchical simulation models actually functions under "run-time", consistency within and compatibility between the several partial models are necessary (Figure 4).

Consistency between levels means, that model variations have to be mentioned in each level according to their specific modelling possibilities. Especially model levels with lower accuracy have to be adapted to alterations in model levels with higher accuracy: for example alterations in the discrete event level (or even in reality) must be considered in the queue-level etc.

Compatibility between partial models means, that the configuration of the entire simulation model has to be a process of „sticking together" several partial models, no matter which hierarchical levels in the different partial models are activated at that time.

Both, consistency and compatibility, are implemented by *transformation matrices*, which are assigned to each partial model. Every transformation matrix contains several *transformation functions* which translate the behaviour of one hierarchical level into another.

Figure 5 shows in exemplary fashion the transformation of discrete event behaviour (D) into the behaviour of the other modelling techniques (W, B, R). The transformation function D→W (Figure 5, left side, top) monitors the discrete event level and detects the distribution function and its parameters of the access rate, the operating rate and determines the size of the system. The transformation function D→B (Figure 5, left side, middle) monitors the discrete event level and approximates the operating curve out of characteristic numbers such as the maximum capacity, the minimum delivery time and the limiting workload. The transformation function D→R (Figure 5, left side, bottom) monitors the discrete event level and calculates the regression model of choosen events - as an extension to the queue model or the operating curve the events to be monitored can be choosen totaly free.

Figure 5 also shows the transformation of the queue model (W), the operating curve model (B) and the regression model (R) into the discrete event level (D) . The transformation function W→D generates events (such as creation of orders) - the basis therefore are the distribution functions of access rate and operating rate (Figure 5, right side, top). The transformation function B→D generates events too, but bases on the relationship between workload, utilization, delivery time and schedule adherency (Figure 5, right side, middle). So does the transformation function R→D, depending on the relation of the freely choosen numbers of the regression model (Figure 5, right side, bottom).

Of course there is a loss of accuracy, when detailled levels are transformed into more abstract levels and therefore less detailled views. One instead receives levels of discription, which produce the desired simulation results more rapidly or on the basis of less detailed master data. It is important to mention, that the level of abstraction of the entire simulation model can be variated by the user individually and according to his needs. Thus the user is able to choose the qualities of the modelling technique very precisely:

- If there is enough time for the simulation experiment, the period for the forecast is short, the master data is accurate, the production unit to be modelled is at a

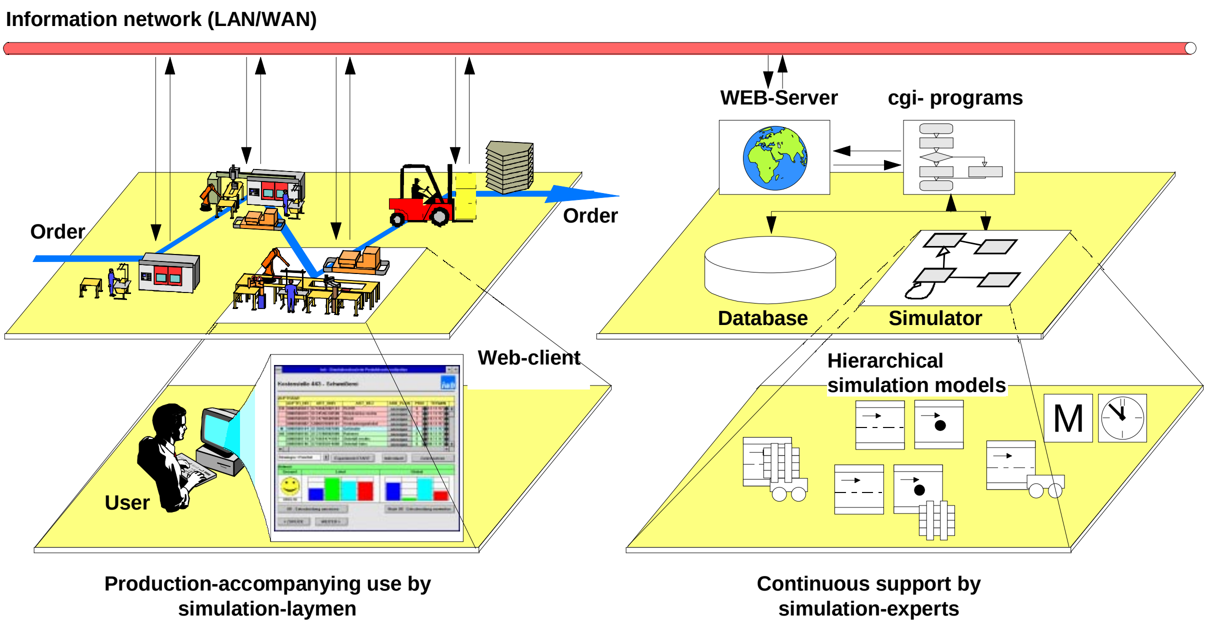

Figure 6: Structure of the Web-based Assistance-system InterSIM

short logical distance and the results have to be very explicit, more detailled modelling levels will be choosen

- If there is only little time, the period for the forecast is long, the master data are not very precise, the production unit to be modelled is at a long logical distance and if only basic statements are necessary, more abstract levels are sufficient

5 USING WEB-TECHNOLOGIES FOR EASY USER INTERACTION

With the described approach for hierarchical modelling it becomes possible to customize the properties of simulation-models as they are needed for production accompanying use. In addition to that capability, the assistance system must be applicable by employees during production process. Because of the fact, that the number of simulation experts in production areas is rather low, the user interaction must be orientated on the needs of simulation laymen. In particular the system-complexity, as described here in form of hierarchical models, must be concealed to them.

To meet these requirements the web-based assistance-system *InterSIM* (=Internet Simulation) was developed, which is divided into two areas, one for simulation-laymen and one for simulation-experts (Figure 6).

The *simulation-expert-area* contains the whole system-complexity. This is where the hierarchical-simulation-models are kept, as well as a database, a web-server and CGI-programs (=Common-Gateway-Interface). The web-server handles the whole communication between the database, the simulator and of course the HTML-interfaces, which are found in the simulation-laymen-area (see below). The web-server is addressed by a defined internet-adress (e.g. http://miro/InterSIM) and transmits the inquiries. For this purpose CGI-programs are used which operate the database and address the simulator. After the simulation run the web-server gathers the results, builds web-pages therefrom and transfers them to the users in the simulations-laymen-area.

The *simulation-laymen-area* contains purposely only simple HTML-based user-interfaces (Figure 7). Due to their structure (Information > Configuration > Experiment > Analysis) and design, which is orientated on the special needs of employees in decentralized production areas, it is possible to define experiments and read the results, transferred by the web-server (see above), easily.

6 SUMMARY AND PERSPECTIVE

The assistance system for production-accompanying-simulation described in this article provides an environment for experiments. In this environment the quality and the effects of decisions can be analyzed and modified before they are implemented in the real production area. The support of decision-taking bases on a dynamic and therefore realistic model - the real production process does not get disturbed. The global view as well as the local view on the supplied characteristic logistic numbers facilitates coordination of decentralized production units onto a common enterprise-wide goal.

The approach described in this paper enables to meet the competitive requests of *comprehensive* and *detailled* and *rapid simulation models*. The simulation models can be configurated under run-time and thus adapted to the momentary needs while decision taking. During the modelling process additional efforts are necessary of course, because different abstract and parallel valid levels have to be created. This additional effort is partially compensated by the developed modelling rules. Currently it is attempted to reduce the necessary efforts and, where possible, to partially automate the modelling process.

The developed web-based assistance-system enables employees to formulate simulation-experiments easily. Especially the separation of the assistance-system into simulation-laymen-area and simulation-expert-area and their interconnection by information technology contains great benefits for small- and mid-size enterprises: this gives them the possibility to use simulation technology without having too high expenses on simulation-plattforms, -software and –experts. Instead they can buy the needed simulation-competence from a simulation-service-center and can concentrate their own efforts on running their production efficiently.

ACKNOWLEDGEMENTS

The project described here is supported by the *Bayerische Forschungsstiftung* within the german research network *Forschungsverbund Simulationstechnik (ForSIM).*

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