Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 41 (2016) 57 – 62
www.elsevier.com/locate/procedia

48th CIRP Conference on MANUFACTURING SYSTEMS - CIRP CMS 2015

Valid methodology for using discrete event simulation to improve the resource consumption for the manufacturing of masonry units

Toni Donhauser[a,]*, Tobias Rackow[a], Johannes Hirschbrunn[a], Peter Schuderer[b], Jörg Franke[a]

[a]*Institute for Factory Automation and Production Systems, University of Erlangen-Nürnberg (FAU), Egerlandstraße 7-9, 91058 Erlangen, Germany*
[b]*Technische Hochschule Ingolstadt (THI), Esplanade 10, 85049 Ingolstadt, Germany*

* Corresponding author. Tel.: +49-9131-85-27965; fax: +49-9131-302528. *E-mail address:* toni.donhauser@faps.fau.de

Abstract

Owing to a high inflexibility of the factory layout, manufacturers of masonry units are bound to organizational adjustments seizing optimization measures. Regarding such plants, having a given complexity based on a rigid concatenation of heterogeneous sub-processes with heavy goods to be transported, conventional measures such as Lean Management principles involve great efforts in execution. Therefore, an IT solution for planning and controlling the operational processes is to be developed. This solution will be implemented through simulation-supported optimization to support dealing with a higher complexity and setting up a more resource-efficient manufacturing process.
As a basis, a corresponding factory is mapped sufficiently accurate in every detail in a discrete event analysis (DEA) model. In this paper, a methodology, how to configure an arbitrary calcium silicate masonry unit (CS) plant in a simulation model, is presented for the first time. Relevant data is cataloged and modelling approaches for the controlling methods are pointed out.
Special regard is paid to optimization measures at the crucial point of the transition from bulk material to piece goods, which has not been regarded yet in discrete event simulation modelling. The major aspect is a comparison of a unit-based approach and a variable-controlled approach, regarding the runtime.
A case study follows conclusively, which aided in validating the methodology by simulating various scenarios. As a result, several strategic and operational optimization potentials were identified.

Peer-review under responsibility of the scientific committee of 48th CIRP Conference on MANUFACTURING SYSTEMS - CIRP CMS 2015

Keywords: Discrete event simulation; Production planning and control; Complexity management; Bulk material; Piece goods; calcium silicate masonry unit

1. Motivation

Even though the sub-processes for manufacturing calcium silicate masonry units (CS) are mostly fully automated, major deficiencies partly exist in the coordination of processes and relations. This is largely due to the lack of a holistic transparency regarding the interdependencies between manufactured goods and machines. As in other sectors, the CS manufacturing process is too complex in detail for people to specify prospectively the effects of minor modifications to influencing factors, without being assisted by computers.

One reason for the current imperfections in the process is the lack of significant IT-support in the production planning and control. This conventional approach leads on the one hand merely to a resource-*oriented* instead of a resource-*optimized* production planning, as the full potential of the production system is not identifiable by means of human analytical abilities, owing to the actual complexity. On the other hand, bottlenecks in the process, which appear on certain material-resource-assignments due to the concatenation of heterogeneous (and especially heavily temporally divergent) sub-processes, cannot be identified and thus be avoided in advance. An application that is known for solving these issues is the discrete event simulation (DES). [1]

A similar problem occurs regarding the strategic domain. The evaluation of the suitability of the current production system for the present product portfolio and the corresponding manufacturing technology can solely result from human discretion. When, for instance, in individual sub-processes a new technology has been implemented, initially organizational measures have to be taken in order to sustain a smooth production flow. The reason for this is the rigid

Peer-review under responsibility of the scientific committee of 48th CIRP Conference on MANUFACTURING SYSTEMS - CIRP CMS 2015
doi:10.1016/j.procir.2015.12.016

conveyor system, which has to be implemented for such heavy goods and which leads to a very inflexible plant layout. [2] However, extensions are possible, but require a lot of effort. Again, the evaluation of the benefit of such extensions must result from exemplary calculations or from human discretion, which does not necessarily meet the actual benefits oftentimes, owing to underlying assumptions. [3]

The inflexible plant layout stated above is another reason, why many measures originating in the Toyota Production System (TPS) [4] cannot be applied economically in CS plants. For instance, a later alignment of machines along the material flow or the avoidance of inventory between process steps are associated with great efforts. Therefore, TPS solutions are not regarded in this paper, but rather organizational measures, which are easier to implement.

In addition to the need for the establishment of an IT support to enhance transparency in the processes, this computer assistance is required for managing the complexity problems associated to the increasing product variety. Long setup times of up to eight hours, heavily fluctuating customer demand and the seasonal nature of the construction industry are major difficulties that can be encountered not only by adjusting the planning and control of the production, but also by taking appropriate measures for reducing complexity in the product management. However, a prerequisite for effective adjustments within the product portfolio is that one can exactly state the impact of an increase or reduction of the product range on the efficiency of processes. As a suitable method at least for a monetary analysis, in particular the activity-based costing has been established for this purpose [5], whereat a detailed modeling is required, which can be achieved only at great effort. [6] Usually, a more appropriate method is to access the utilization of a simulation tool. In addition to the possible monetary evaluation, such tools are able to predict precisely the impacts on resources or on capacity utilizations in production systems. [7]

All the denoted deficiencies reveal the need for an IT-solution aiding to analyze the complex procedures of the production process for CS and thus to facilitate the decision-making. Such a functionality can be found in decision support systems [8]. The required transparency serving as a basis for the optimization can be achieved by means of a material flow simulation.

In this context, the present paper describes, which process-related requirements exist for a simulation application concerning CS plants. Special consideration is assigned to the required constitution of the software, in order to be suitable for strategic and operational challenges like the determination of an optimal sequence of production orders, the responding to incidents or the analysis of product range adjustments.

2. Problem Statement

Concerning a particular production process, the correct relationship between the granularity of the model and the load on the system must be elaborated for the configuration of a DES. Only if an appropriate proportion is hit, one achieves significant results having a suitable simulation runtime for operational use at a reasonable configuration effort. [9]

2.1. Production Process

If one only regards the production process for CS starting at the raw materials and finishing with completed, packaged CS bundles, as it is described in [10] or depicted in Fig. 1, respectively, the complexity within the processes stated above does not directly become apparent.

But as soon as every single process step and in particular the intermediate material transports are explored in detail, as it is necessary for an exact modelling in a simulation, the inherent complexity becomes evident. Starting with fine granular raw material in the beginning, a bunch of piece goods with a high weight is existent at the end of the process, which has to be handled continuously.

After the mixing of the raw materials and the reaction of the compound, the first relevant conversion from bulk material to piece goods takes place when green bodies are pressed. Immediately following, the piece goods are bundled in a hardening car. Afterwards the hardening cars are transported to a hardening oven (autoclave) using a traverser, where the green bodies are cured for a time between 6 and 12 hours depending on format specific properties of the CS, after the autoclave was filled completely with hardening cars. For achieving the optimal level of energy efficiency, it has to be considered, that only formats with identical hardening times are in the same autoclaves at the same time. At the end of the hardening process – in consideration of a potential buffer for cooling down – the transport to the packaging line is conducted, where the bundles are dissolved and the CS are placed on palettes in smaller units, according to their size. Subsequently, they are packaged within some consecutive steps. At packaging lines, setup times incur once more, when variants in the sequence change. In order to achieve a maximal capacity utilization, setups are to be avoided.

Regarding the transport of goods, difficulties occur especially due to the great mass and the high volume of the products. The rigid plant layout includes very limited buffer space in many plants, so that the transport must take place

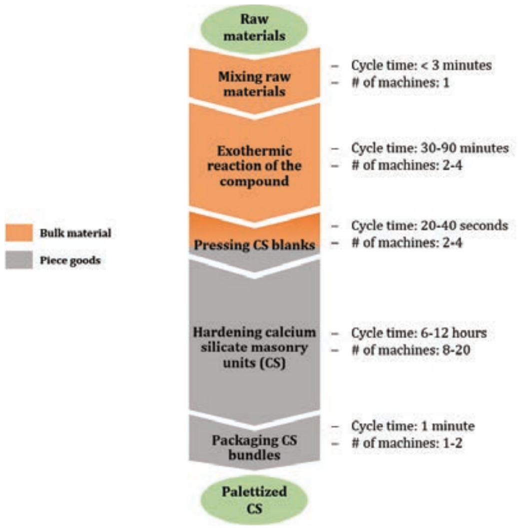

Fig. 1: Standard production process for CS

right after the termination of the preceding manufacturing process, in order to avoid the obstruction of machines. This fact is particularly critical at the transition from 8-20 autoclaves (cf. Fig. 1) to 1-2 packaging lines, which, therefore, requires extensive coordination planning the production. In addition, for the transport of CS on hardening cars, there usually exists a maximum of three traversers on maximum two tracks. Due to the nearly continuous use of the traversers, the speed of all its functions is of high relevance.

2.2. Parameters for modeling the simulation

According to standard VDI 3633 [11], simulation-relevant data can be categorized as follows:

- Input data (e.g. cycle times, buffer capacities)
- Experiment data (e.g. time horizon of the simulation)
- Internal model data (e.g. time for the next consideration of a workstation during the simulation)
- Simulation result data (e.g. filling levels, output)

For the model generation of a CS production process, at first only input data is relevant, which is assigned to the model parameters (= means of production) or serves as defining attributes for processing algorithms (e.g. operation mode of traversers), respectively. The data to be gathered can be categorized as follows:

- Information defining the plant layout
- Information regarding processing algorithms
- Temporal parameters
- Capacity related parameters
- Quality-relevant parameters
- Energy-relevant parameters
- Cost-relevant parameters

From this list, merely temporal and capacity related parameters are relevant for the deployment of an executable model. The last three bullet points are only for a significant interpretation of simulation results of major importance.

Overall, it is crucial for the efficient use of the simulation to consider, that solely the particular parameters, which are essential for the achievement of the objectives related to the use of a DES, are gathered for the integration into the model.

3. Objectives

The representations in the course of this paper are aimed at introducing a validated method to simplify and expedite the deployment of a simulation model supporting the decision-making in strategic and operational production process planning. This method serves to implement a comprehensive IT-solution for CS manufacturing plants, while the effort for the deployment is low. With minor adjustments, this methodology can be transferred to other areas of the masonry industry, e.g. the aerated concrete production. Even plants from other sectors with rigid process chains and a transition from bulk material to piece goods may benefit.

In this paper, special regard is paid to the achievement of a minimum possible runtime of the simulation kernel, in order to facilitate the operational use of the tool. Thus, it is suitable for both the weekly production planning tasks and for issues from the field of complexity management, for which a long simulation period is required. Moreover, certainly any user-defined scenario to uncover problems in the processes can be explored. The methodology is kept abstract enough to include most of the potential plant layout variants.

4. Implementation

The determination of parameters and processing algorithms required for the implementation of a DES was carried out deductively by modelling and simulating different plants in diverse simulation tools, resulting from various case studies. A continuous goal in the consecutive development of various models was to reduce the complexity in order to achieve a lean simulation model. Additionally, by developing the models consecutively, existing deficiencies in modelling could be identified and fixed.

4.1. Catalogue of relevant parameters and information

As a result of several case studies, an overview was elaborated, containing a comprehensive list of required parameters and information for the modelling of an average CS plant. This overview is depicted in the morphologic box Table 1, where the symbol # represents the term “number of“.

The table displayed contains all the parameters required to achieve an adequate representation of a plant. If more detailed information is to be obtained from the simulation, other parameters must be integrated, e.g. the consumption of resources, a grit recirculation or the storage processes.

To start a simulation run, a corresponding production program (quantities, resource allocation, schedule, etc.) for the simulated period is required as experiment data, which is used to determine the scenario to be simulated.

4.2. Assignment of process steps to standard modules

For the configuration of a model in commercial simulation tools, oftentimes certain standard modules are available. In Table 2, these standard modules are assigned to the corresponding sub-processes.

Since some of the processes in CS plants are very special, partly no exactly matching modules can be found. For this reason, the alternatives stated below have to be addressed in the following cases:

- **Hardening:** If only one buffer module is used to model an autoclave, then a processing algorithm must include a function, which states that the processing is triggered, when the autoclave is completely filled. This can be avoided by using a preceding buffer module collecting all the required hardening cars for the autoclave and transferring the contents comprehensively to the subsequent processing workstation, so that this workstation (= buffer module) can start the processing immediately.

- **From raw materials to reactor:** In DES, objects flow through the system. For this reason, bulk material cannot efficiently be handled, as it has to be modelled as countless units of small volume. Hence, this approach leads to exorbitant runtimes (cf. [12]). Therefore, a solution for circumventing this drawback had to be found, which is stated in the paragraph below.

Table 1: Relevant information and parameters for model generation

Category	Process step	Parameters
Information defining the plant layout	Raw materials	# silos, sort of raw material
	Mixing	# mixers, connected reactors, recipes
	Reacting	# reactors, connected presses
	Pressing	# presses, subsequent buffer (# hardening cars)
	Hardening	# autoclaves, one- or two-sided loading, subsequent buffer (# hardening cars)
	Packaging	# lines, precedent buffer (# hardening cars)
	Transport	# traversers, # tracks, connected workstations
Information regarding processing algorithms	Mixing	Prioritized reactor*
	Reacting	Trigger level
	Pressing	Cycles until placing on the hardening cars*
	Hardening	Logic for steam transfer, prioritization*, limitations*
	Packaging	Consecutive packaging cycles
	Transport	Prioritization*, inhibit state logic
Temporal parameters	Raw materials	Transport time to mixer
	Mixing	Weigh time for raw materials, cycle time
	Reacting	Time for reaction
	Pressing	Cycle time*, setup times♦
	Hardening	Waiting time for steam transfer, hardening times*, waiting time for handling doors, (un-)loading times
	Packaging	Cycle time, setup times*
	Transport	Transport time between workstations (unloaded and loaded traversers), lead times, (un-)loading times
	General	Shift times per workstation
Capacity related parameters	Raw materials	Capacity of silos
	Mixing	Volume per cycle
	Reacting	Capacity of reactor, maximum level (in %)
	Pressing	Scrap rate, green bodies per stroke*, green bodies per hardening car*
	Hardening	Capacity of autoclaves (# hardening cars)
	Packaging	Batch size*, material consumption per workstation*
	Transport	Traverser capacity (# hardening cars)
Quality-rel. parameters	General	Availability of machines (in %), mean time to repair, average # defects per day

* dependent of the product in progress

♦ dependent of the product in progress and of the subsequent product

Table 2: Recommended preset modules for modelling process steps

Process step	Modules
Raw material silo	Silos = buffers
Mixing	Mixer = assembly station
Reacting	Reactors = buffers
Pressing	Lead time = buffer
	Hydraulic presses = individual workstations
	Loading of the hardening cars = assembly stations
Hardening	Autoclaves = buffers
Packaging	Unloading track = buffer
	Packaging machine = assembly station
Transport	Conveyor belts = individual workstations or buffers
	traverser = vehicle on a track

4.3. Methods to reduce the simulation runtime

For identifying leverage points for reducing the simulation runtime, a simple experiment was executed. Using a reference model consisting of only one source, where moving objects were generated every 0.1 seconds, and one sink, where these objects were deleted, the effects of different approaches regarding the enlargement of the model could be explored.

In various tests, different adjustments were applied to the reference model in order to analyze the simulation runtime, while the simulated real-time was fixed at 100 hours. The results of this study are stated in Table 3. First, the addition of one individual workstation without further functionality was analyzed (test 1), while in test 2 a parallel workstation was added instead. After that, the impact of a short, executed algorithm on the source module was examined, which turned out to be of minor significance (test 3). The strongest impact could be identified in test 4, where ten times more objects were sent through the system compared to the reference model. In the end, the influence of data storing during the simulation was examined (test 5).

Table 3: Impacts of adjustments in a simulation model on the runtime

Model	Specification	Runtime [s]	Increase
Ref.	-	34.8	-
Test 1	Ref. + individual workstation	77.3	122 %
Test 2	Ref. + parallel workstation	80.7	132 %
Test 3	Ref. + algorithm on source object	38.2	10 %
Test 4	Ref. + factor 10 on generation of moving objects	363.7	945 %
Test 5	Ref. + saving 5 values 10 times per simulated hour	91.4	162 %

As the previous analysis shows, the focus for reducing simulation runtime should be put on minimizing the moving objects (= material, goods) within the model. Since bulk material flows in the simulation of CS plants between raw material silos and the presses, the major part of runtime-relevant calculations is caused in this area, as the implied bulk material was initially modelled as several 1 kg units. This means that 1 kg relates to one moving object in the simulation. Thus, assuming that four reactors with a capacity of 50 t exist, solely in this process step, 200.000 moving objects are located.

Drawbacks regarding the modelling of systems with numerous moving objects have also been identified in [12], where these issues were solved by using a continuous modelling approach, named discrete rate simulation (DRS), for mapping material flows. This approach was further advanced in [13], where the applicability in practice was demonstrated. According to [14], the DRS approach lacks in having more than one product type running through one node and in modelling bundles. Moreover, there is always a loss of information, when continuous models are used for simulating logistic flows, instead of discrete event models. For this reason, a mesoscopic model was presented in [14], which is a combination of both approaches, based on the continuous approach. In [15], an extension of the mesoscopic approach was developed, in order to simplify the modelling of supply chain planning problems. Nevertheless, since the mesoscopic approach is still based on a continuous model, it involves a lack of accuracy in information. Thus, in the present paper, a discrete approach is used as a basis, integrating continuous methods in certain objects. Like this, the loss in speed of the simulation owing to the discrete event approach during the continuous material flow (before pressing) can be diminished, while a high accuracy regarding the discrete steps in the downstream sub-processes can be achieved, which is more relevant for the whole process. In addition, companies modelling their production processes can employ DES tools which are more established than DRS tools.

For this reason, one must refrain from the previous modelling approach, and model whole mixer-batches (about 1-2 t) as one moving object instead. In this particular object, the current volume of the batch is saved as a variable, in order to enable to monitor the adherence to the reaction time and to execute algorithmically the partial deduction of material for the creation of single units.

The result of a comparison between the former unit-based and the new variable-controlled approach, only regarding the area between the filling of the reactor and the deduction of material-units over 100 hours, is shown in Table 4.

Table 4: Result of batching raw material in the simulation model

Specification	Runtime [s]	Savings
1 kg units for modelling the compound	414.0	-
One object for a mixer-batch with a variable specifying the volume	2.3	99.4 %

By virtue of the establishment of the new approach, the aggregation of smaller units to batches as big as possible in the model (e.g. hardening cars instead of individual units) is to be conducted in other areas of the simulation model, provided that these batches pass the subsequent process steps in common. For this reason, the loading of the hardening cars during the press process, for instance, is modelled as assembly stations, where the green bodies are deleted and hardening cars are used as moving objects for the remainder of the simulated process instead (cf. Table 2).

4.4. Validation of the models

For validating the models in the case studies, a procedure recommended in [16] was applied, where real data from the modelled plant was used as input data for the simulation. Subsequently, the results of the simulation are compared to recorded data from the examined plants.

In practice, the production program for days without major incidences were used as input data and the simulation results were compared to captured plant data. Due to minor deviations in multiple test runs, the generated models may be referred to as valid.

5. Case Study

The previously described method was applied in a case study regarding a plant with one mixer, three reactors and corresponding presses, twelve two-door autoclaves (for eight hardening cars) and two packaging lines. Buffers only exist for four hardening cars right behind each press and for eight hardening cars in front of one packaging line. There is one traverser for green bodies, containing two spots for hardening cars, and one traverser for hardened CS containing eight spots.

The objective of the simulation study consisted in fulfilling the following three requirements:

a) Evaluation of the benefits concerning the overall output of filling autoclaves with heterogeneous formats
b) Analysis regarding the effects of a reduction of failures in the packaging line
c) Extension of the buffer in front of the packaging line

Based on multiple actual production programs for a whole week, the investigation provided the following results:

a) As Fig. 2 shows, the actual situation, where only the first two autoclaves each day are filled heterogeneously, is better than filling all autoclaves hetero- or homogeneously. These effects are caused by the following facts: A completely heterogeneous loading leads to a bottleneck at the packaging line, as it has to be set up every time a different format arrives. In case of homogeneous loading, it takes a longer time to start the first autoclaves in the morning, so that all finishing times will be postponed.

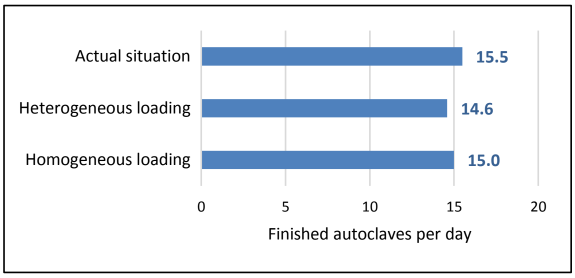

Fig. 2: Output depending on the loading mode

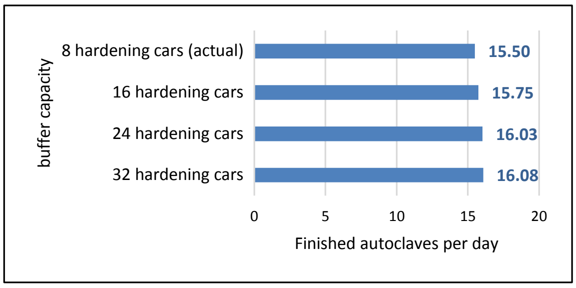

Fig. 3: Output depending on the capacity of the packaging line buffer

b) The evaluation has shown that a reduction of the actual failure rate by 50% leads to an output, increased from 15.5 to 15.9 autoclaves per day. If one assumes a failure rate of 0%, the output would be up to 17.5 autoclaves per day, which states an enormous potential for technical upgrades.

c) Receiving Fig. 3 as a result from multiple simulation runs, one can easily deduct a best practice regarding the extension of the buffer in front of the packaging line, while considering financial issues. With a triplication of the buffer capacity, the output increase by 3.4 %, for instance.

All the simulation runs concerning the evaluations conducted in the case study, required an average simulation runtime of 37 seconds for one production week (16 hours per day) on a standard single PC.

6. Conclusions and Outlook

The present approach shows a standardized procedure for modelling production processes in CS plants in a DES, which has established in several case studies. This methodology, which can be used as a basis for a simulation model of any CS plant and can even be easily transferred to other masonry plants, shows the required steps and parameters to be determined for the simulation model. Due to the detailed prerequisites for modelling, there is an enormous potential to save time implementing a DES application.

If people want to go more in detail or need to model plant-specific characteristics, this can be executed according to the present approach. As an example, stochastic incidences might be integrated in order to analyze the performance of the system in unforeseen cases. Moreover, an extension to the warehouse processes can lead to insights regarding occurring failures, affecting upstream production steps retrograde.

In order to find acceptance for an operational use of a predefined IT solution of the presented kind, first, the model must be refined to capture all procedures in better detail, and thus to be able to identify the specific causes of failures in the manufacturing process. In addition, it would be useful to be able to simulate the energy consumption associated with the production processes, in order to be capable of considering the energy efficiency in decision-making. A corresponding methodology has been presented in [17]. With this extension, the simulation can be integrated into an energy management system to support the controlling of energy consumption [18].

The linking of an optimization module, such as an Advanced Planning and Scheduling System [19] may increase the benefits of a DES for the purpose of process optimization. Such a module generates production programs representing scenarios for the simulation. These statically optimized scenarios are tested regarding their suitability in a time-dynamic context, in order to find the best applicable production program.

References

[1] März L, editor. Simulation und Optimierung in Produktion und Logistik: Praxisorientierter Leitfaden mit Fallbeispielen. Berlin Heidelberg: Springer; 2012.

[2] Ten Hompel M, Schmidt T, Nagel L, Jünemann R. Materialflusssysteme. Berlin Heidelberg: Springer; 2007.

[3] Bandte H. Komplexität in Organisationen: organisationstheoretische Betrachtungen und agentenbasierte Simulation. Wiesbaden: DUV|GWV; 2007.

[4] Ohno T. Toyota production system: beyond large-scale production. New York: Productivity press; 1988.

[5] Männel W, editor. Prozeßkostenrechnung. Wiesbaden: Springer Gabler; 1995.

[6] Reichmann T, editor. Controlling mit Kennzahlen: Die systemgestützte Controlling-Konzeption mit Analyse- und Reportinginstrumenten. 8th ed. München: Vahlen; 2011.

[7] Weber K. Der wissenschaftstheoretische Status von Simulationen. In: Frank U, editor. Wissenschaftstheorie in Ökonomie und Wirtschaftsinformatik. Wiesbaden: DUV|GWV; 2004. p. 191-210.

[8] Power DJ. Decision support systems: concepts and resources for managers. Westport: Greenwood Publishing Group; 2002.

[9] Feldmann K, Reinhart G, editors. Simulationsbasierte Planungssysteme für Organisation und Produktion: Modellaufbau, Simulationsexperimente, Einsatzbeispiele. Berlin Heidelberg: Springer; 2000.

[10] Rich H. Kalksandstein: die Maurerfibel. 7th ed. Düsseldorf: Verlag Bau und Technik; 2004.

[11] Richtlinie VDI 3633, Blatt 1: Simulation von Logistik-, Materialfluss- und Produktionssystemen – Grundlagen. Berlin: Beuth; 2014.

[12] Siprelle AJ, Phelps RA. Simulation of bulk flow and high speed operations. In: Proc 29th Winter Simul Conf. IEEE; 1997. p. 706-10.

[13] Damiron C, Nastasi A. Discrete rate simulation using linear programming. In: Proc 40th Winter Simul Conf. IEEE; 2008. p. 740-49.

[14] Reggelin T, Tolujew J. A mesoscopic approach to modeling and simulation of logistics processes. In: Proc 2011 Winter Simul Conf. IEEE; 2011. p. 1508-18.

[15]Terlunen S, Horstkemper D, Hellingrath B. Adaption of the discrete rate-based simulation paradigm for tactical supply chain decisions. In: Proc 2014 Winter Simul Conf. IEEE; 2014; p. 2060-71.

[16] Rabe M, Spieckermann S, Wenzel S. Verifikation und Validierung für die Simulation in Produktion und Logistik: Vorgehensmodelle und Techniken. Berlin Heidelberg: Springer; 2008.

[17] Kohl J, Spreng S, Franke J. Discrete event simulation of individual energy consumption for product-varieties. Proc CIRP; 2014. 17: 517-22.

[18] Rackow T, Javied T, Donhauser T, Martin C, Schuderer P, Franke J. Green Cockpit: Transparency on Energy Consumption in Manufacturing Companies. In.: Proc CIRP; 2015. 26: 498-503.

[19] Stadtler H, Kilger C, Meyr H, editors. Supply-Chain-Management und Advanced Planning. Berlin Heidelberg: Springer; 2010.