Simulation and Modelling in Supply Chains

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***Abstract*— This paper summarizes three presentations in a session of the track "Simulation and Modelling in Supply Chains". The research work deals with the following key issues of this track:**

- **Simulation of process problems in supply chains.**
- **Modelling of business process problems in manufacturing.**
- **Optimisation of process problems in supply chains.**
- **Solutions of planning problems in supply chains.**
- **Simulation of business processes.**

This publication shows that the contributions in this track address research questions that are of high importance for industrial practice as well as current research directions such as stochastic optimization or the efficient search of large solution spaces.

Keywords: ***Data-based supply chain model; consequence-driven risk simulation; resilient supply chains; Logistics; Bullwhip effect, Petri nets; Excel; simulation of scheduling; unused area; tardiness; spreadsheet optimisation; algebraic modelling language; interactive decision-making process; optimisation***

I. INTRODUCTION

For enterprises, the control of all processes along the complete supply chain is essential. For many years, almost all enterprises have been using so-called Enterprise Resource Planning systems (ERP systems) for this purpose. Essentially, almost all tasks are performed in close coordination with such ERP systems. Among other things, these systems name the next upcoming orders, record the progress of work by means of confirmation messages and, in some cases, define tasks.

Essentially, by parameterizing such an ERP system, it can be used in almost all existing companies. Therefore, it is not surprising that special problems in companies are not solved by such ERP systems. Such ERP systems then serve as a backbone for IT systems used to control companies and special solution tools, which are mainly offered by smaller software companies, are deployed in a company through a connection to such an ERP system.

This motivates more and more researchers to develop concepts (including methods, models, procedures, process techniques) for problems along the supply chain around which ERP systems can be complemented. Often simulation techniques are directly or indirectly integrated into these processes. Presenting examples of such approaches is the subject of this special track.

II. SUBMISSIONS

The first paper about "A Case Study Concept for Supply Chain Resilience Analysis" by Schätter et al. in [1] presents a case study illustrating a practical two-step approach of resilience analysis and gives an outlook focusing on process mining. The background of the paper is that companies have experienced in recent crises that the strong characteristic of a supply chain to be resilient is an important success factor. However, logistic structures are complex, and it is difficult for companies to estimate where the vulnerable and, thus, critical parts of the supply chain are located. With the two-stage approach, the authors provide an applicable and easy-to-use method to assess the resilience status of the strategic design of the supply chain. The first stage refers to the data-based modelling of material flows in the supply chain. In this way, a company's network becomes transparent in terms of its inbound and outbound material flows from internal and external suppliers to internal and external customers. A set of eight so-called "Key Resilience Areas" (KRAs) is defined to assess the current state of supply chain resilience by revealing the vulnerabilities in the current structure. Such vulnerability insight is indeed important when implementing long-term strategies to assess the best supply chain design in terms of resilience and efficiency, but a deep understanding of the decisions and processes underlying this state is essential. Therefore, the second stage of analysis focuses on the actual management decisions related to the processes within the supply chain. Process mining has become an important approach in this regard. It is shown how process mining of current procurement event logs can provide further insight into decisions made by the company in the past and identify actions to improve the current state of resilience. In this way, possible future supply chain configurations can be simulated, providing strategic decision support to logistics managers. It should be noted that this second stage is a concept that has not yet been verified with real data in the form of event logs. However, the case study illustrates the applicability of transactional data in terms of assessing the strategic state of resilience of a supply chain. The case study considers a manufacturing company whose production warehouse is located in Hamburg, Germany, and the inbound material flows from tier 1 suppliers.

The second paper, "The Process-Simulation.Center" by Simon et al. in [2], deals with sustainability. Sustainability and plurality are becoming increasingly important for society and companies. This requires predicting and optimizing the

effects of management decisions on the environment and on people. For this purpose, multi-perspective simulations of different aspects of dynamic systems are becoming increasingly important. Thus, there is a need for appropriate tools and for people to perform this demanding modelling and simulation work.

The Process-Simulation.Center (P-S.C) is an Integrated Management System for enterprise-wide documentation and simulation of (business) processes using Petri nets, process maps and organization charts. It stores the models in a central database, the P-S.C Cloud, and allows all members of an organization to access the models according to an elaborated rights concept. To ensure regulatory requirements are met, the models go through an approval process. These aspects distinguish the P-S.C from other university projects for developing software for modelling and simulation and enable new applications of the Petri net methodology. It also goes beyond existing business process management software since it provides multiperspective access to nowadays problems. This contribution presents the current prototype and its application in research, teaching and practice.

A good first impression of this prototype is provided by the newly implemented approval process and the comprehensive rights (& roles) concept, which allows to use the P-S.C in a variety of ways. The tool supports numerous types of mandators form Academic to Professional purposes that account for different product categories.

In large-scale industrial projects, environmental protection and occupational safety requirements are reconciled with efficiency and effectiveness. With the aid of P-S.C industrial partners, the impacts of bottlenecks on planning parameters during the design of warehouses are considered. Further collaborations are planned. The question of user-friendly visualization with the help of interactive dashboards is elicited.

The added value from all these steps is used directly in teaching. Thus, it introduces students directly to the topic of process management with all aspects that are important in practice and leads to a new form of IMS that supports cross-model simulations.

The paper “Performance of Storage Strategies in a Highbay Warehouse” by Herrmann in [3] analyses storage strategies. In the industrial production huge warehouses, mostly as a highbay warehouse, are used for the coordination of procurement processes, production processes and distribution processes within an enterprise and also between enterprises along the logistic process chain. Beside this time bridging structure an inventory management becomes more and more important which realizes an efficient order related picking. Particularly, with an almost fully occupied automatic warehouse the performance necessary for the handling of goods is not reached for picking in the warehouse.

An important performance criterion is the maximization of the handling of goods in the warehouse, i.e. the warehouse should be able to transfer to stock or to remove from stock as many as possible storage unities within a given time span (e.g., an hour).

With automatic warehouses the product is stored in free-mounted racks. A rack feeder (RF) is used to access the stored product.

RF access the stored product usually stacked on palettes. A RF is an automated conveyor which simultaneously drives through a lane in a warehouse, heads for a certain rack shelf by the height H about a lifting device and moves its load suspension device (LSP) into the rack shelves of depth T in order to pick or lay bins.

A rack feeder, can be used with single cycle or double cycle. In the case of a transfer to stock, a bin is laid in the nearest free rack shelf. Afterwards the rack feeder returns to the transfer point. In the case of remove from stock, the needed rack shelf is headed and the bin is provided in the transfer point.

Different storages strategies with a rack feeder are simulated by a self-developed simulation tool.

State of the art in the literature about storage strategies are non-quantitative statements. By the simulation introduced here quantitative results for concrete enterprises, and warehouses respectively are delivered. Compared with the publishes results the investigation proves partly clearly higher performance in the handling of goods and probabilities of stock transfers.

For a specific small highbay warehouse, the one of Leopold Fiebig GmbH in Karlsruhe, Germany, actual driving times were used by simulation. The results differ significantly from those based on results published in the literature. Finally, such an effective and efficient implementation is a good basis for newer approaches.

To the concrete storage strategies it was proven, that, all together, a combination of the strategies zones and channel causes the best results.

Preliminary measurements suggest that similar results are observed in other warehouses. Further development of this into significant measurements and results is one of the tasks at the IPF.

Methodically quite demanding, but very interesting, is a generalization of these results for as many warehouse types as possible. The IPF will also continue to research this problem in the future.

III. CONCLUSION

Several research results on the use of simulation in manufacturing, especially for processes and for the analysis of planning algorithms, are presented. Further research of the authors has already been mentioned. For the research community as a whole, the following key questions were identified.

- How can we develop easily applicable and cost-efficient procedures for simulation-based decision support in supply chain risk management?
- What is the compromise between generation time for storage strategies, dispatching rules in general and objective fulfillment?
- How can we enable workers to be a key factor of production scheduling in tomorrow's industry?

Furthermore, we would welcome a discussion on the following topics:

- Which challenges in supply chain management could be solved elegantly if the tools developed by the various research groups are combined?
- What is a good compromise between a resilient and a highly efficient supply chain?
- How can we overcome restrictive technological constraints with the aid of scheduling algorithms?
- What are impactful visualizations of simulation results that help to optimize business and production processes?
- How can be improve simulation models if we automatically parameterize them with historical data?
- How can we reduce the barrier for using sophisticated optimisation software as low as for example using spreadsheet programs?

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