Simulation and Modelling in Supply Chains

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***Abstract*— This paper summarizes four 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 "Business Process Simulation Focusing Supply Chain Risk Management Aspects" by Schätter and Morelli in [1] focuses on the possibilities of using a business processes simulation in the field of supply chain risk management. Nowadays, supply chains are faced by lots of uncertainties, which makes risk management a key factor for success. Simulation has been used in the supply chain sector for a long time. The focus is mostly on efficiency aspects and less on risks and resilience. However, basically triggered by global trends and corresponding uncertainties, it is indispensable that a holistic management of supply chains is required which additionally respects risk aspects. Such a holistic management enables logistics managers to adjust their planning individually by steering and trading-off the degrees of efficiency and resilience within their supply chains. By following this development, the objective of the contribution is to introduce a practical approach that supports decision-makers in simulating the current and future resilience status of strategic supply chain processes. The approach couples a data-based supply chain model with a consequence-driven risk simulation. The data available within a company, which describe the strategic supply chain processes in terms of physical flows of goods, are translated into a data-based representation of the supply chain. This data-based model provides a platform for decision-making in resilient supply chain design. Firstly, companies can directly identify and analyze vulnerable parts of the supply chains as well as the consequences of specific risk events. Secondly, the suitability of logistics strategies (decision alternatives) to improve the current resilience status can be simulated within the model. Thereby, the consequence-driven risk simulation reverses the standard risk management cycle by identifying vulnerable parts within the supply chain (model) and subsequently backtracking possible triggering risk events instead of predicting such possible events first. The result of the approach is an easy-applicable procedure that allows companies to analyze and to improve the resilience status of their supply chains. Hence, the focus is switched from an efficient to a resilient supply chain management and the approach provides decision support for supply chain risk managers in this regard.

The second paper, "Can Simulation Prevent Companies from the Bullwhip Trap?" by Simon et al. in [2], deals with the understanding of the market. A coordinated communication with other market participants has a significant potential for costs savings in companies. How

high this savings potential is can exemplary be explained using the bullwhip effect (BWE): Strong fluctuations in terms of production and sales of the participants in a supply chain can be observed.

Thus, paper [2] addresses the question how to develop a simulation for the bullwhip effect in a step-by-step approach with commonly available tools. It may therefore serve as a source for practitioners to apply the findings to their own business. A detailed description of an imagined scenario is the starting point where the actual process and the business rules which trigger procurement and production are the most important components.

The first approach, an Excel based simulation model, served as a conceptual model. For each simulation period distinct calculations had to be defined. The authors found out that this solution does not scale very well. As an alternative, an executable Petri net model was developed that runs with the aid of the Process-Simulation. Center (P-S.C), a Petri net tool free to use for academic purposes. Both, Excel and Petri net solutions were used to validate each other. What must not be underestimated is the need for a meaningful visualization of the simulation results to solve the problem.

As an initial finding of the validation phase for this research, the authors found that individual variables such as demand distribution or output data in the market hardly played a role to generate the BWE. Further, the modelers could have imposed much tighter constraints. The simulation model itself is key. Thus, the models are most applicable to real-world data from enterprise users. Even with the arbitrary numbers, the simulations produce the bullwhip effect, which is clearly visible at the level of an individual participant.

Each approach can meet the users at their individual skills and supports the performance of what-if analyses and in running through different scenarios. This is the beauty of these approaches and paves the way for practical use.

All in all, the path proposed in paper [2] is sufficient for a first step to purposefully protect companies from the bullwhip trap. Indeed, simulation only leads the user to the core of the problem: small changes in configuration can have a significant impact on the outcome or users' incorrect assumptions about the market can lead to incorrect predictions about the bullwhip effect.

The paper “Simulative Comparison of Scheduling at Krones AG with Shortest Slack” by Herrmann in [3] analysed the planning at Krones AG, the world market leader in the beverage industry. Orders with very large area requirements have to be produced. Despite very high investments in suitable halls, the available area is a major bottleneck. This might be also the case for other companies.

Despite the use of planners, at least 21% of orders have consistently been late in recent years. Delays result in significant penalties and undermine the goal of getting every plant up and running on time. For many orders, delays were only avoided because process accelerations were made in the mostly long production processes through measures such as overtime.

Krones now wanted to know more precisely:

- How good is the actual quality of planning?
- How good is planning that (primarily) follows due dates?

Due to the improvement of planning within the production execution, the production result are not representative of the planning quality in terms of meeting due dates. Therefore, these questions are be answered by a simulation study.

A simulation tool was developed to analyse the possibilities for improvements with the slack rule. The simulation experiments so far show that planners often find a good balance between using the limited area and avoiding tardiness. In situations with high time pressure, a preference for meeting due dates will already provide better results through the slack rule. The two planners are therefore encouraged to consider an allocation decision through slack.

For further research, it must be taken into account that scheduling in the literature mainly considers just one bottleneck, quite often the limited capacity of the machines. Requirements for the use of limited area for the assembly of machines is dealt with in other publications. Responsible for this are different approaches to these two problem classes.

The results so far show a significant difference in the use of free areas. Therefore, combinations of priority rules to meet due dates with rules to avoid unused areas are to be designed and simulatively investigated.

The last paper in this session, “Optimisation Modelling with Excel and CMPL2” by Steglich in [4] introduces a new tool that combines Microsoft Excel with an optimisation environment in an interactive way.

In companies and other organisations, spreadsheet programs are essential tools for preparing and supporting decisions, as they are easy to use and available in most workplaces. For complex problems, optimisation software is used. This offers a wide range of modelling capabilities but relies on external data, such as that maintained in spreadsheets. It therefore makes sense to combine spreadsheets and optimisation software. Add-ins in spreadsheet programs such as Excel solver are relatively widespread. They allow interactive work, although the method of modelling using cell ranges does not seem to be suitable for complex models. Another possibility is to use the spreadsheet interfaces of algebraic modelling languages, which are excellent for modelling complex problems. Unfortunately, as pure data interfaces, they do not allow interactive work. There are some approaches that combine modelling languages with Excel in the form of an Excel add-in, thus combining interactive work with the modelling possibilities of the modelling languages. Unfortunately, these solutions are only available for Windows and some of them seem to have been discontinued. The consideration of all the advantages and disadvantages of the available tools led to the motivation to create an easy-to-use interface between the open-source modelling language CMPL and Excel, which allows interactive work and is available for Windows and macOS. This paper describes this interface.

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 and topics were identified.

- Development of easy applicable and cost-efficient procedures for simulation-based decision support in supply chain risk management.
- Need of focussing on resilient supply chains as a counterpart of efficiency-driven improvements.
- What are reasonable applications in supply chain management that can be elegantly solved by a combined application of the tools developed by the various research groups?
- Need of focussing on resilient supply chains as a counterpart of efficiency-driven improvements
- Need for scheduling algorithms taken advantage of highly restrictive technological constraints.
- Need for integrating easy to use programs (as spreadsheet programs) with high sophisticated optimisation software.

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