Programmheft

Produktionswirtschaft in Zeiten des Wandels

Herbsttagung der Wissenschaftlichen Kommission für Produktionswirtschaft am 03./04. November 2023 an der Technischen Universität Berlin

VHB 1921-2021

Technische Universität Berlin

Freitag, 3. November 2023

Programm	
Ab 12:45	Eintreffen der Teilnehmenden, Mittagsimbiss
13:30	Begrüßung
13:40	Optimization of the Social Acceptance of Renewable Fuel Production Networks by Integrating Mathematical Optimization and Conjoint Analysis *T. Becker, M. Wolff, A. Linzenich, L. Engelmann, K. Arning, M. Ziefle, G. Walther*
14:15	Future circularity of a today-waste: the case of autoclaved aerated concrete *R. Volk, J. Steins*
14:50	Pause
15:10	Decentralized Collaborative Job Reassignments in Additive Manufacturing *M. Gansterer, D. Zehetner*
15:45	Behavioral Simulation of Blockchain-Enabled Market for Supplier Capacity Trading among Retailers *K. Wendt, V. Babich, D. Hellwig, A. Huchzermeier*
16:20	Pause
16:40	Plant-wide master production scheduling in the automotive industry: A MILP-approach and a simulation study *T. Krüger, A. Koberstein*
17:15	Verleihung des Horst-Wildemann-Preises 2023
Ab 19:00	Abendessen im Restaurant La Bocca di Culaccino

Samstag, 4. November 2023

Programm	
09:00	Kommissionssitzung
09:50	Predictive Intelligence am Beispiel der Prognose von Kundenaufträgen in der metallverarbeitenden Industrie *S. Junghans, M. Wichmann*
10:25	Mobile, zeitflexible Arbeitsgestaltung für Beschäftigte in der zerspanenden Fertigung *J. Weber, M.-A. Weber*
11:00	Pause
11:20	Model Factories for the Operations Management Education of Business Students *J. Schwarz*
11:45	Combining heuristics and reinforcement learning to solve the Westenberger-Kallrath problem *P. Willms, M. Brandenburg*
12:20	A Genetic Algorithm with LSTM-Based Fitness Function for Integrated Procurement and Scheduling Optimization in Hybrid Flow Shop Systems with Uncertainty *B. Rolf, A. Beier, T. Reggelin, H. Stuckenschmidt*
12:55	Verabschiedung
13:00	Mittagsimbiss

Optimization of the Social Acceptance of Renewable Fuel Production Networks by Integrating Mathematical Optimization and Conjoint Analysis

Tristan Becker, Michael Wolff, Anika Linzenich, Linda Engelmann, Katrin Arning, Martina Ziefle, Grit Walther*

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Renewable liquid fuels produced from biomass, hydrogen, and carbon dioxide are pivotal to achieving climate neutrality in the transportation sector. For large-scale deployment, there is the need for production and logistics infrastructure. To implement such a large-scale renewable fuel production network, the acceptance by citizens is crucial. We develop a bi-objective mixed-integer programming model to gain insights into the structure of efficient and socially acceptable renewable fuel production networks. We model the social acceptance of renewable fuel production networks as a second objective function based on the results from a conjoint analysis. The conjoint analysis considers several aspects related to the acceptance of renewable fuel production networks, including the regional topography, facility size, production pathway, and raw material transportation. Our results reveal significant trade-offs between the economic and social acceptance objective. The costs of reaching the ideal solution from a social acceptance perspective lead to costs that are almost twice as high compared to the minimum-cost solution. However, we find that it is possible to strongly increase acceptance at a moderate expense by carefully selecting sites with preferred regional topography.

Future circularity of a today-waste: the case of autoclaved aerated concrete

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An increased circularity of materials can help to reach a more sustainable consumption and production. In a circular economy, unwanted or harmful by-products, wastes and emissions are kept in the economy. However, it requires new technologies and fundamental changes in product designs, production methods and value chains.

Our contribution shows a new system design, assessment and optimization for an increased material circulation in a former linear production-consumption-disposal system in a case study. Autoclaved aerated concrete (AAC) is a widely used building material for masonry blocks. After its use it is currently landfilled. To reduce future raw material extraction and landfilling as well as energy demand in AAC production, we assessed different upcoming recycling processes with respect to their environmental impacts. The life cycle assessment (LCA) shows that especially closed-loop recycling of pd-AAC in AAC production has a high potential of improving environmental impacts. Moreover, we quantified post-demolition AAC on German and European level to design a more circular system of AAC production and usage. In the next decades, significant post-demolition AAC volumes can be expected. And, a mathematically optimized European recycling network shows a decentralized recycling plant structure with of smaller

capacity (100,000 t input/a) in the near future. With higher waste quantities being expected from 2030 onwards, plants with a larger capacity (200,000 t input/a) are added, especially in Poland, where the highest pd-AAC amount is expected. The results support decision-makers in fostering recycling and implementing a circular economy for post-demolition AAC.

Decentralized Collaborative Job Reassignments in Additive Manufacturing

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Cloud Manufacturing (CMfg) systems are considered to be powerful tools for decreasing costs while increasing supply chains' flexibility by applying the paradigm of the sharing economy. Especially in combination with Additive Manufacturing (AM), CMfg is seen as a key enabler of collaborative production systems. Although collaborative production planning is proven to decrease the costs of AM operations, there is still a lack of planning models that reduce entry barriers for collaborative systems. Therefore, we propose a decentralized collaborative production planning framework for AM. In our approach, machines autonomously select jobs from the existing production plan in order to forward them to other suppliers that can produce these parts more efficiently. A CMfg platform establishes job forwarding and creates promising bundles of digitally transferred parts. Manufacturing machines then autonomously bid on the packages via a combinatorial 2nd price reverse auction. Costs of the reallocated bundles are shared throughout a Shapley value-based approach without reporting critical information of the agents. In our computational experiments, we benchmark our proposed framework to a centralized planning approach. We observe that our framework reaches the effectiveness level of the benchmark solution. In terms of computational time, we demonstrate that the auction-based framework strongly outperforms the benchmark algorithm. We also show that the mechanism leads to individual rationality and that agents particularly benefit if they both offer and acquire production jobs through the auction.

Behavioral Simulation of Blockchain-Enabled Market for Supplier Capacity Trading among Retailers

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We study a supply chain distribution system (comprising a supplier and multiple retailers) and investigate experimentally how the trading by retailers of digital claims (tokens) on the supplier's capacity affects supply-demand mismatches. Creating markets for such tokens relies on advances in blockchain technology. Subjects play the role of retailers, who have heterogeneous valuations of goods, face random demands, and buy tokens on the supplier's capacity. Following demand realization, retailers trade these tokens with each other. We conduct six behavioral experiments (featuring two wholesale prices and three market sizes) and find that markets reduce excess inventory and shortages. Market-clearing prices are anchored to wholesale prices and do not

signal the value of goods in large markets. Players deploy novel ordering and trading strategies that differ from transshipper strategies, as studied in the literature. Applying unsupervised machine learning algorithms, we classify these strategies. In one strategy, players, whom we call spot buyers, buy a few claims initially, and after demand realization, use the market to satisfy it. Other players, whom we call spot sellers, buy more claims initially than the maximum demand, and once demand is known, sell their excess on the market. Both strategies reduce costs from demand uncertainty. Despite this benefit, the transshipper strategy is more profitable, due to lower exposure to liquidity shocks and trading mistakes. With markets, the initial orders to the supplier exhibit the pull-to-the-mean effect, and at the same time, have greater variability because of spot buyers and sellers. Retailers' average profit is higher with markets, but suppliers with low wholesale prices suffer from lower revenues because of the pull-to-the-mean effect. Our results provide guidance for the introduction of blockchain-enabled markets in practice.

Plant-wide master production scheduling in the automotive industry: A MILP-approach and a simulation study

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Existing approaches for short-term master production scheduling neglect the plant state, plant structure, and lead times; moreover, performance studies regarding their suitability for realistic applications are limited. Therefore, in this paper, we propose a new approach that considers the entire plant structure, its state, and order due dates. We model a fictional but realistic automotive plant using a discrete-event material flow simulation. Through a numerical study, we demonstrate the practical applicability of our approach. Furthermore, we reveal that it can anticipate the behavior of the plant well and can be used to make decisions that minimize due date deviation costs while regulating the shares of components in the plant. We demonstrate that this is particularly important after component blocking, as high additional costs can otherwise arise owing to rework or line stoppages.

Predictive Intelligence am Beispiel der Prognose von Kundenaufträgen in der metallverarbeitenden Industrie

S. Junghans, M. Wichmann*

Verschiedene Störereignisse, wie COVID-19 Pandemie oder der Ukrainekonflikt, sowie Digitalisierung und steigende Globalisierung sorgen für ein höchst instabiles und turbulentes wirtschaftliches Umfeld und damit für erhebliche Herausforderungen für die Unternehmensplanung. Der Einsatz von modernen Methoden des maschinellen Lernens kann ein Ansatz zur Verbesserung und Erweiterung der betrieblichen Planung in dynamischen Märkten sein. Aktuelle Studien zeigen jedoch eine geringe Erfolgsquote bei der Entwicklung und Einsatz von KI-Anwendungen. Die kritischen Faktoren für das Scheitern dieser Projekte liegen bei genauerer Betrachtung zu großen Teilen in der unzureichenden Methodik oder fehlenden Vorgehensmodellen. Bestehende Vorgehensmodelle reichen nicht aus, um detaillierte Hilfestellung bei der Entwicklung von einsatzfähigen KI-Anwendungen zu geben.

Ziel der Arbeit ist die Entwicklung eines Frameworks zur strukturierten Vorgehensweise hin zu einem dynamischen Prognosemodell, der sogenannten Predictive Intelligence, um Herausforderungen bei der Anwendung von Künstlicher Intelligenz zu begegnen. Anhand der Prognose von Kundenaufträgen in der metallverarbeitenden Industrie mit sporadischen Bedarfen und unbekannten Lieferketten wird das Framework validiert.

Mobile, zeitflexible Arbeitsgestaltung für Beschäftigte in der zerspanenden Fertigung

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Die Diskussion über neue Arbeitsmodelle und die Vorteile mobiler, zeitflexibler Arbeit bezieht sich häufig ausschließlich auf Beschäftigte in der Administration. Beschäftigte in der Produktion sowie in produktionsnahen Bereichen haben oft keine Möglichkeit, mobil und zeitflexibel zu arbeiten. Unternehmen stehen vor der Herausforderung, zu verhindern, dass dieses Ungleichgewicht die Zusammenarbeit zwischen den Beschäftigten oder die Unternehmenskultur negativ beeinflusst.

Im Beitrag werden Ergebnisse einer empirischen Erhebung vorgestellt, welche ein Meinungsbild von Beschäftigten und Führungskräften in der zerspanenden Fertigung zeigen und die Forschungsfrage beantworten soll, inwieweit eine mobile, zeitflexible Arbeitsgestaltung für Beschäftigte in der zerspanenden Fertigung möglich ist.

Für die Befragungsstudie wurde eine empirische Studie nach dem Mixed-Method-Design durchgeführt. Die erste quantitative Erhebung erfolgte mithilfe einer Online-Befragung, während die zweite qualitative Erhebung in Form eines Leitfadeninterviews durchgeführt wurde. An der Online-Befragung nahmen 61 Beschäftigte teil und an dem Interview 11 Geschäftsführer und Produktionsleiter. Sowohl die Beschäftigten als auch die Führungskräfte arbeiten in Unternehmen mit einer zerspanenden Fertigung in Schleswig-Holstein oder Niedersachsen.

Die Ergebnisse zeigen, dass unter anderem durch eine prozesssichere Automatisierung und Digitalisierung der Fertigungsabläufe die Beschäftigten in der zerspanenden Fertigung mobil und zeitflexibel Aufgaben bearbeiten können, während die Werkzeugmaschinen Werkstücke produzieren. Aufbauend auf den Ergebnissen wird ein Modell für die Gestaltung mobiler, zeitflexibler Arbeit in der zerspanenden Fertigung entwickelt und Restriktionen für dessen Anwendung aufgezeigt.

Model Factories for the Operations Management Education of Business Students

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Physical model factories are replicas of actual manufacturing systems, specifically designed for educating students in the field of operations management. Confronted with these physical factory models, students can train their modeling capabilities and gain realistic experience in choosing the appropriate level of detail for their decision-support models.

The implementation of own ideas and observable improvements in experiments with the model factory is expected to create a motivating learning environment. Working with model factories in the lab fosters the combination of problem-solving skills from the fields of operations management, data science, artificial intelligence, and scientific programming. By combining physical models with digital twins, education is expected to become more immersive and relevant to real-world challenges in operations and manufacturing.

While model factories have been employed in the education of mechanical and industrial engineers, their integration into business administration programs necessitates careful consideration of unique requirements. In contrast to conventional paper-based case studies, the construction and implementation of model factories lack established best practices and guidelines. We explore evidence from the literature that indicates the benefits of model factories and provide preliminary results and experiences from the establishment of a model factory at the University of Regensburg. An exemplary set of case studies and their corresponding learning goals for the integration of model factories into exercises, seminars, and theses is presented.

Combining heuristics and reinforcement learning to solve the Westenberger-Kallrath problem

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As the nature of chemical processes imposes multiple challenges on production planning and scheduling, related problems have been a major field of study for researchers and practitioners for decades. The Westenberger–Kallrath (WK) problem which was published in 2002 still serves as a benchmark for that industry. In the past, a vast number of mathematical models and solution

approaches made use of linear programming (LP) methods or metaheuristics. Nowadays, algorithmic advances in artificial intelligence (AI) provide new opportunities and combinations of modeling and solution methods. In this research, we investigate the application of reinforcement learning (RL) and propose a novel approach to solve the WK problem. Specifically, we develop a material requirements planning (MRP) and batching heuristic to preprocess the problem data and create chains of production orders. Next, we apply Proximal Policy Optimization (PPO) to train an agent to iteratively build a schedule based on those chains. At each step in one training episode, the agent executes a custom-built forward scheduling heuristic, following the objective of minimizing the makespan of the complete schedule. Our experiments show that the aggregation to chain level reduces considerably the modeling complexity and enables the application of RL algorithms. After training, the PPO agent manages to determine the best possible schedule for small problem instances. The iterative design of the RL process requires building and scheduling of a chain at each step in one episode of the RL environment, which imposes a computational challenge on training runtime and resources.

A Genetic Algorithm with LSTM-Based Fitness Function for Integrated Procurement and Scheduling Optimization in Hybrid Flow Shop Systems with Uncertainty

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We present an integrated approach to address the hybrid flow shop scheduling problem (HFSP) and the order allocation problem (OAP) simultaneously. Our objective is to generate synchronized procurement-scheduling decisions that minimize combined procurement and job tardiness costs. Our hybrid method employs a genetic algorithm with an LSTM-based supervised learning model as a replacement for the computationally expensive fitness function.

While much of the existing literature focuses on abstract, long-term decision problems, our model provides daily operational decision support using a real-world case study from the printed circuit board assembly industry. With its flexible formulation of the HFSP and the OAP, our approach can be applied to a wide range of industrial settings with minimal adjustment effort.

As an operational support system, our method must account for the effects of past decisions, such as pending orders, partially processed jobs, and occupied machines. We evaluate our approach using a rolling horizon approach, which provides a more realistic performance evaluation. This approach also enables us to incorporate stochastic events such as new job arrivals, lead time shifts, and machine failures.

We evaluate our method on instances of two sizes (small and large), two horizon types (fixed and rolling), and 72 cost scenarios. Our results demonstrate that our method performs close to optimally on small instances. On large instances, in the absence of an existing baseline for comparison, we compare our method to an approach that solves the HFSP and OAP sequentially and show that our integrated method achieves significant cost savings.