Newsletter

Dear readers;

Last year people might have hoped that the escalation of the Russian occupation attempts might not last too long, but the – perhaps naive – optimists have been disappointed. Worse, further latent conflicts have also escalated, starting with the terror attack of Hamas in Israel and recently with the Huthi attacks on the cargo traffic passing the Suez passage; most probably both with finance and military support from Iran, who is also supporting Russia for their occupation with arms and munition. The consequences are harm and desperation among the inculpable civil population, but also massive impacts on the global trade and supply. Thus, we face increasing transport costs, production losses due to materials arriving late or lost, and barriers to export goods, e.g., through the Black Sea. Logistics planners world-wide need to reconsider their strategies, conduct thorough risk analyses, and develop scenarios that can quickly be implemented when the situation calls for. At the conferences that I was able to visit last year as well as in the papers that I have received for comments or reviews, global transport and especially energy costs have been a major focus point. As a perfect fit, a new book on energy aspects of simulation with plenty application examples was set up by an ASIM working group and finally published by Springer in January 2024.

The time after the pandemic has given us great new chances for personal scientific contacts. Major events have been the Big Techday 2023 in Munich, the ASIM conference in Ilmenau, and the Winter Simulation Conference in San Antonio (TX); reports can be found below. Furthermore, we were successful in inviting Prof. Stephan Onggo from the University of Southampton for a two-week research stay in Dortmund to happen in May 2024.

Our research group with about 15 researchers is well developing, and we expect several theses to be submitted this year. Interesting results have been achieved, but also honors such as the Hans Uhde Award and the ASIM Simulation Award, both dedicated to our member Alexander Wuttke. Reports on ongoing research topics can be found in this newsletter. Several papers could be published in 2023 about our recent research, which you find listed in this letter. For now, we hope that you enjoy this little newsletter and stay healthy!

Teaching Concepts 2023

In 2023, the ITPL also further optimized teaching for the mechanical engineering, industrial engineering and logistics degree programs. The course "Planning and Implementation of IT Projects" was offered in a project format for the first time and evaluated extremely successfully.

In addition, the ITPL continues to offer Bachelor students information technology supplements with the two compulsory elective modules "Fundamentals of Simulation Technology" and "IT Systems in Industrial Production". The ITPL's modelling focus is supported by the module "Modelling of Digital Ecosystems in Production and Logistics". In addition, the ITPL has prepared the subject area of simulation for students on the Bachelor's degree program in Logistics as part of the course "Introduction to Logistics".

In the Master's degree program, the department continues to offer its own profile for the Mechanical Engineering degree program and was faced with great interest in 2023. The “Data Analysis and Knowledge Representation in Production and Logistics” course in particular, which teaches key skills such as data mining and database analyses, is very popular with an average of 100 participants in the examination. The other three master courses in our IT program are among the ten best-attended courses of our faculty, too.

Teaching Supported by Experts from Industry and Consulting

Collaborations with other departments, institutions and industry partners were again instigated as a core aspect of ITPL teaching formats in 2023.

Capgemini was acquired as a new cooperation partner for a master module on project planning in IT business. Dr. Christian Knobloch from Knobloch & Gröhn supported teaching on the Bachelor's degree course with his own teaching module on Process Modelling. Highly topical subjects, which are the focus of our research activities, could be brought into teaching through practical examples from industry. The lectures included topics such as test automation of Redbots and international guest lectures by Prof. Susan Sanchez and Prof. Dave Goldsman from the USA. We also had a very interesting guest lecture on signal processing from IVA Schmetz GmbH and were given an insight into how ChatGPT works by Prof. Stautner, Head of Research at ModuleWorks GmbH and professor at HRW.

The "Business Informatics Case Study", which has already been successfully carried out several times with the company CGI, continues to be a special institution. In 2023, around 20 students dealt with specific issues in the field of big data analytics and presented their results in small groups to a panel of experts at a colloquium day. We all really appreciate that CGI will be offering this very popular format again in 2024 under the personal direction of its director Kilian Hilpert.

Cooperation with Capgemini Deutschland GmbH on realistic case study for planning and implementation of IT projects (Adam Kampa, CAPgemini und Alexander Wuttke, ITPL)

Reference Model Based on the Value Stream Method

Sohny, T.: *Referenzmodell basierend auf der Wertstrommethode zur Bewertung von automatisierten Materialflusssystemen der Produktion in der Angebotsphase. Göttingen: Cuvillier 2023.*

Automated material flow systems in production are highly dynamic and at the same time very complex. Suppliers have the challenge of guaranteeing a minimum throughput performance for such customized material flow systems when submitting their offer. Over-dimensioning, however, to ensure throughput, resulting in additional costs, leads to decreased competitiveness.

With simulation technology, executable models can represent dynamic and stochastic aspects of systems. Thus, alternatives can be evaluated. However, simulation is too time-consuming and cost-intensive at the time of the bidding phase. Therefore, it is regularly used only after an order has already been placed. Possible planning errors are recognized late and lead to cost-intensive adjustments.

In this work, a reference model based on the value stream method is developed, which contributes to a reduced modelling effort of simulation models for automated material flow systems at the time of the bidding phase. For efficient modelling, the user of the reference model has a construction scheme developed for this purpose, consisting of individual model elements with defined structures and relationships. Each model element represents a real system element of an automated material flow system with its characteristic properties, represented by system states, logic aspects, and attributes. The description of the system elements, with a suitable granularity for the bidding phase, is based on the value stream method, which is proven to be successful in the industrial environment, extended by the aspect of dynamics. The modular structure of the construction scheme and the description method allows for an application-specific parameterization and the selection of specific model elements. The user is supported by a procedure for the specific use of the model elements, in a structured system analysis and the formal model description. With the execution of the modelling according to the reference model, the user receives a formalized model, which can be implemented simulator-specific in a simulation system without further explanation. This enables the supplier to secure his guaranteed throughput per offer in the shortest possible time and to increase his competitiveness by studying what-if scenarios.

The usability of the reference model is demonstrated by a simulation study of a real material flow system. It is shown that the given structure and the defined model elements support the designer in the system analysis and model formalization in an application-specific way and, thus, reduce the modelling effort. The reliability and sufficiently accurate representation is proven by a phased verification and validation and the comparison with a detailed model.

Series “Fortschritte in der IT in Produktion und Logistik”, Vol 5, available in book stores and online; print 84.90€; e-book 59.90€.

A Reference Model for Quantitative Sales Planning

Büttner, D.: *Referenzmodell für die quantitative Absatzplanung innerhalb der Supply-Chain-Planung. Göttingen: Cuvillier 2023.*

Companies in the consumer goods industry often produce their products on stock to be able to serve the end consumer demand arising on the market as quickly as possible. The sales quantities resulting from the end consumer demand are, thus, unknown at the time of production. For this reason, a planning function exists in the context of Supply Chain Planning (SCP) that generates forecasts of future sales. In practice, forecasting is carried out using quantitative and qualitative methods, whereby the use of quantitative methods should serve as the information basis for SCP. In the field of quantitative sales planning (SP), challenges exist resulting from the increasing complexity of supply chains, unclear planning processes, the variety and complexity of forecasting methods, and the data used. This dissertation develops a reference model for the sales planning function using quantitative methods. The following research-guiding question is investigated: How should a reference model be designed to support sales planning and the use of data within quantitative forecasting methods?

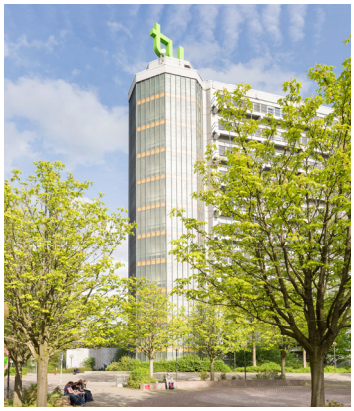
The goal of the reference model for quantitative sales planning (RSP) within SCP is to systematize the SP process, methods, and data. The RSP serves as a guideline for using company data to create sales forecasts. In doing so, the RSP supports the initial integration of SP as well as its further improvement. Defined maturity levels guide in the implementation of SP.

A theoretical and practical analysis of the challenges and the state of research in the field of SP forms the starting point for the development of the RSP. A procedure model for reference modeling was used and a requirements catalog for the RSP was defined. A derivation of necessary functions to fulfill the requirements forms the basis for the design and development of the RSP. The components of the RSP, consisting of a process module, a method module, and a data module, were initially developed separately and integrated into one model. A case study is used to examine the achievement of the research objectives and evaluate the utility of the RSP.

The result is a comprehensive model that consists of three maturity levels and provides context between the SP's process, methods, and data. In the first maturity level, SP is systematized to be as simple as possible so that it can be implemented by many companies. As the maturity level increases, the complexity of the SP increases. By realizing the second and third maturity level, more data is used in methods that are more complex and further influencing factors of sales are taken into account in the creation of forecasts. The process module represents a structured procedural approach in SP with the help of superordinate process steps and further detailed subprocess steps. The methods module evaluates and categorizes 24 quantitative forecasting methods based on their complexity. The data module systematizes the forecast data into information classes, which are grouped according to their context. Furthermore, the data module shows which data are optional or obligatory for SP and in which process step they are relevant.

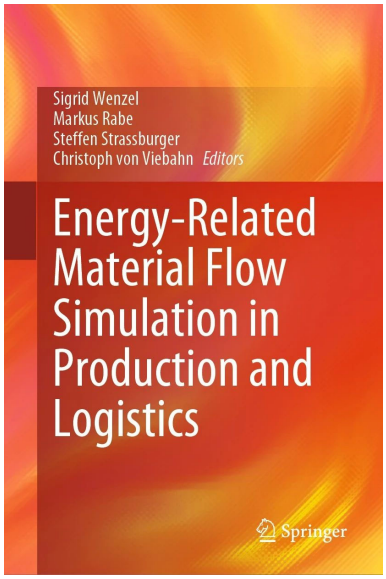
The RSP is the first reference model that systematizes the process, methods, and data of SP in a comprehensive way and, thus, provides orientation for practical integration in companies.

Series “Fortschritte in der IT in Produktion und Logistik”, Vol 6, available in book stores and online; print 99.90€; e-book 70.50€.



Energy-related Simulation

Material flow simulation has been successfully applied since about 50 years to analyze and improve first the material flow and later the related information flow, enabling engineers to gain deep insights into the behavior of complex modern production and logistics systems. Sometimes, energy-related aspects have been considered, but in most cases indirectly, e.g., reducing the runtime of equipment and in consequence decreasing the energy consumption.



However, in the last decade, the importance of respecting energy in the processes has become more and more important, and the pressure to reduce the environmental footprint of production and logistics systems will intensify in the upcoming decade. Therefore, enterprises have started to integrate the use of energy into their planning processes much more frequently than before, even constructing feedback loops, e.g., from energy control to production control. This receives additional attention with the increasing use of renewable, but less reliable, energy sources. Care must be taken to establish processes that aim to use energy when it is available. As an example, many industrial processes like melting or coating have significant energy demands, but could vary the point of time of its consumption within specific limits, leading to a very high complexity.

Simulation is the technology of choice for such complex interconnected systems. Nevertheless, there was no satisfying overview on the current approaches and applications of considering energy for production and logistics simulation. To fill this gap, a new book originating from an ASIM working group and published by Springer International introduces the approaches to model energy-related aspects in this context that are available today, discusses the construction and application of energy-specific performance indicators and analyses the input information that needs to be acquired before implementing suitable models. On this basis, the technical solutions are introduced.

For the practical implementation and illustration, a second part of the book is divided into six chapters, each related to one application field, such as automotive, perishables, or transportation. In each of these chapters, written by related experts, the specific performance indicators and required data are introduced, challenges to the conceptual modeling explained with their solution approaches, and, finally, examples given for the application of these approaches. Thus, these chapters can support the engineers of the related domains to understand the scope and tasks for a suitable simulation model, and to achieve an estimate of the effort it might require and the benefits it could yield.

The book is aimed at engineers and scientists investigating on energy use aspects that are connected to the material flow in production and logistics systems in a broad sense, including any kind of transport, buffering, and the control of interrelated processes. The provided state of the art helps engineers to select and understand modeling techniques that are suitable for their specific tasks. It also forms a sound base for further scientific research, and can be used in advanced teaching, e.g., for university masters, to educate engineers in this field with massively growing importance: Few engineers studying today will not be concerned with energy efficiency topics in their business career. For the practitioners, the chapters in the second part of the book give even more specific hints how to handle typical energy-related questions in the specific branches, and also provide an illustration of possibilities that engineers can take as sample or as a stimulus for their own work. Finally, managers that are responsible for decisions in the improvement of energy use and the application of simulation find precious samples and can improve their understanding of the technology's benefits and challenges.

Rabe, M.; Straßburger, S.; von Viebahn, C.; Wenzel, S. (eds.) Energy-related Material Flow Simulation in Production and Logistics. Cham: Springer International 2024, available in book stores and online; hardcover 149,790€; softcover 39,99€; Kindle 97,93€.

Hans-Uhde Award for Alexander Wuttke

ITPL is proud to report that our team member Alexander Wuttke has received the Hans-Uhde award 2023 for his outstanding master thesis on the topic "Development of a graph-based simulation tool for logistics networks in a data farming framework". The thesis discusses the need for novel simulation tools that are tailored towards processing highly connected graph data and simulation-based data generation. The certificate was awarded in May 2023 at the thyssenkrupp Uhde auditorium.

https://www.itpl.mb.tu-dortmund.de/publikationen/MA_2022_Wuttke.pdf

Alexander Wuttke and supervisor Joachim Hunker at the award ceremony in the thyssenkrupp Uhde auditorium

ITPL in the New World: Winter Simulation Conference and Around

In December 2023, we had the pleasure of presenting several papers at the famous Winter Simulation Conference in San Antonio, Texas, USA, a premier event in this field, which is bringing together experts and enthusiasts from around the globe to discuss the latest advancements and challenges in modeling and simulation (see publication list in this letter). Alexander Wuttke and Katharina Langenbach were able to present and discuss topics from their research. Joachim Hunker and Katharina Langenbach also had the honor of chairing a session each in the "Logistics, Supply Chain Management, and Transportation" track. In addition to chairing this track, Professor Rabe participated in the panel on the opportunities and challenges of using simulation in digital twins, which was received with great interest. Overall, the conference offered the opportunity to attain plenty new valuable contacts and

discuss with old friends and colleagues, as well as to engage in a number of highly interesting conversations and discussions of a really high-quality conference.

Alexander Wuttke during his talk

Fruitful discussions: Andrea Matta, Joachim Hunker, Katharina Langenbach, Alexander Wuttke, Markus Rabe

Katharina Langenbach chairing her session

Markus Rabe at the panel

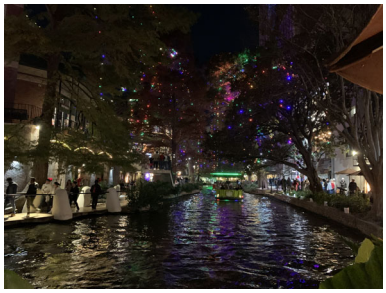
Before and after the conference, we also took the opportunity to explore a little bit of the south-west of the USA. We visited the cradle of jazz, New Orleans, explored the countryside on a swamp tour, got to know the wildlife of the USA in a gator park and learned about the history of the USA on a former slavery sugar plantation and by visiting ancient Spanish mission buildings, among other impressive sights. The city of San Antonio is world-famous for the five Spanish frontier missions from the 18th century, which are part of the world cultural heritage. The city also offered the opportunity to enjoy excellent Latin American cuisine and to network and exchange ideas with colleagues over dinner.

Never seen so many alligators in one pond ...

Katharina Langenbach and Alexander Wuttke caressing exotic animals

New Orleans, typical southern architecture

Louisiana swamps and wildlife



The famous San Antonio Riverwalk at night

The really beautiful mission San José

Old church of mission Conception outside San Antonio

Gardens of "The Alamo" mission area in San Antonio

Steel sailing ship ELISSA in Galveston

ASIM Conference in Ilmenau

Every two years, the ASIM Conference Simulation in Production and Logistics attract the German-speaking simulation community with high-quality talks and an excellent environment to discuss recent simulation developments with academic and industrial experts. The 20th conference in Ilmenau (Thuringia) was attended by Markus Rabe, Alexander Wuttke, Tobias Klima, and Katharina Langenbach, diving into 2½ intense days with up to four parallel talks and thrilling discussions. Due to the outstanding scientific quality, the audience was fully committed, and even at Katharina's talk, which was the very last one of the entire conference, the lecture room was completely full.

Katharina Langenbach during her talk

ITPL is especially proud that Alexander Wuttke has received the ASIM Simulation Award 2023. Every two years, ASM honors outstanding thesis in the field of simulation and is generously sponsored by SimPlan Group, InControl Enterprise Dynamics, and Siemens. Alexander was invited to present his research on the development of a graph-based simulation system in the plenary to the whole conference audience.

Award ceremony with the sponsors: Christoph Laroque, Geert-Jan van Nunen, Alexander Wuttke, Matthias Heinicke. Sven Spieckermann (© photo TU Ilmenau Dino Junski)

Big TechDay 2023

Every year, TNG Technology Consulting in Munich organizes a conference, where leading-edge developments in information technology are presented and discussed. The talks at the Big Techday 2023 covered, among others, fascinating topics like quantum computers, latent diffusion models, challenges moving regolith on the moon's surface, and surveying the Cheops pyramid. Participation to the Techday is only on invitation, and Alexander Wuttke and Katharina Langenbach were lucky to get hold of tickets. This was also a great chance to discuss our recent research with TNG Consulting's senior consultant Maik Deininger, who is alumni from ITPL with his Ph.D. in 2018. We express our gratitude to TNG Consulting for the invitation!

At the Big Techday 2023 in Munich: Alexander Wuttke, Katharina Langenbach, Maik Deininger

The Big Techday leaves a chance to Alexander Wuttke and Katharina Langenbach to get a spot on Munich, here in front of the "new major's house" in neo-Gothic architectural style

Research Project DIONA

The ITPL participates in the DIONA project, which started in 2023 and aims to design a digital ecosystem for a sustainable circular economy in the automotive industry. The importance of sustainability can be illustrated by the so-called "Earth Overshoot Day", which shifts from year to year towards the beginning of the year. It describes the day on which the natural resources of a year are consumed by mankind.

For this reason, sustainability is becoming increasingly important and is discussed in research, politics, and industry. Since 2015, when the United Nations agreed on both the 1.5- degree maximum earth warming target and the Sustainable Development Goals, the desired guard rails for further global sustainable development have been set. Germany, too, declared to become climate-neutral by 2045. However, the transportation sector in particular will not be able to meet the targeted emission reductions. The car as the main means of transport as well as the associated industry make a decisive contribution to emissions. Therefore, it seems necessary – also in the course of a transformation towards e-mobility – to understand products and production processes holistically and to share the knowledge gained in this way. In particular, the adaptation of a circular economy approach, i.e., a holistic product life cycle view, is explicitly part of the European and German sustainability strategies and promises to reduce both the need for raw materials and CO_2 emissions while promoting jobs and economic growth. Both decarbonizing the mobility sector and enabling sustainable, efficient, and innovative mobility is an explicit promise agreed among the ruling parties in the German coalition agreement for 2021–2025. However, the status quo shows that many companies are unable to benefit from these advances related to sustainable value streams. Research illustrates that there is a lack of widespread guidelines and methods for establishing sustainability in industrial activities, even though sustainability has a major impact on ecology, economy, and society. Therefore, the DIONA project addresses the need for a joint elaboration of sustainability measures to obtain a holistic understanding of sustainability, challenges, and problems. For a future sustainable development, it is necessary to identify best practices in the automotive industry as well as socio-political incentives or obstacles.

Currently, the ITPL focuses on setting up a simulation model for the hybrid simulation of a sustainable cycle process for hydrogen fuel cells in the automotive industry. The aim of the simulation is to gain detailed insights into different levels and aspects of these processes. An important aspect here is the reuse of fuel cell elements. Additionally, the ITPL contributes to the project by identifying stakeholder requirements regarding verification and validation of certain key performance indicators in the domain of environmental impact and sustainability. From these requirements, best practices for the self-evaluation of participants in the circular economy can be derived.

DIONA team meeting

The project is carried out in collaboration with the Fraunhofer Institute for Software and Systems Engineering (Dortmund) as well as the departments of Industrial Information Management (TU Dortmund), Sociology of Technology (TU Dortmund), Business Informatics (TU Chemnitz), and Alternative Vehicle Drives (TU Chemnitz). DIONA is funded by the German Federal Ministry of Education and Research under "The Future of Value Creation – Research on Production, Service and Work" initiative. The main contact person for this project at ITPL is Anne Antonia Scheidler.

DIONA

www.diona-hub.de

RUNNING RESEARCH

Reliability Prognosis of Residential Heating Systems

Sahil-Jai Arora (M. Sc.) is an external Ph.D. student at ITPL and currently works as a product owner of field data analysis at Bosch Home Comfort Group in Wernau, Germany.

Modern heating systems are often continuously exposed to loads over a long period of time – usually up to 20 years. Due to the variable operating conditions, the actual lifetime in the field can only be estimated to a very limited extent. In particular, the superimposition of different component-specific damage mechanisms and load profiles is challenging.

Defective components are replaced during scheduled service visits or due to unexpected failures. A possible predictive reliability approach can lead to optimized maintenance and service concepts on the manufacturer side by evaluating field data for predictive fault detection. At the same time, existing lifetime models can be optimized through data-driven relation of system and operating conditions. Recording field data at the customer's site and processing it into load profiles enables customer-oriented dimensioning of heating systems even on component level.

Different industries face the challenge of developing a reliability prognosis model, hence necessitating standardization of model development. The research addresses this challenge by developing a reference model for reliability prognosis of heating systems, which will enable the reuse of knowledge and practices in the form of a design scheme. This design scheme shall help the companies to define their roadmap in developing reliability prognosis models depending on their individual maturity level, but also define the step-by-step process from idea to reliability knowledge discovery and implementation.

Urban Logistics Systems Modelling

Jorge Chicaiza-Vaca (M. Sc.) is currently pursuing a Ph.D. at ITPL in the field of Urban Logistics Systems Simulation–Optimization Models. He currently leads the Transportation and Logistics Systems Research Center, a pioneering initiative within the private transportation sector in Ecuador. The center is at this time focused on two research projects: the integration of passenger and

freight transport using Quito's new metro infrastructure, and the establishment of a knowledge network for efficient energy in freight transportation. This collaborative effort involves 15 public and private companies and collaboration with the Ministries of Energy and Environment, supported by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The primary objective of the knowledge network is to promote understanding and dissemination of information regarding energy-efficient practices in freight transportation. By fostering collaboration among stakeholders, including industry professionals, researchers, and policymakers, the network aims to drive improvements in energy efficiency, reduce environmental impact, and encourage sustainable practices in the freight transportation sector.

His research focuses on automated parcel lockers (APL), such as packstations or locker boxes. Simulation and optimization techniques play a crucial role in delineating the APLs scheme as an urban logistics solution. His dissertation integrates a system dynamics simulation model with a facility location model, specifically tailored for the application of APLs in the cities of Dortmund (Germany) and Pamplona (Spain), serving as comprehensive case studies. In addition, in collaboration with Prof. Rabe and Prof. Gutenschwager (Ostfalia University of Applied Sciences), a book chapter and paper were presented in related research. The publications address connections between APLs and potential customer behavior, exploring a range of scenarios. An important oversight in existing APL studies is the omission of pollution arising from customers retrieving their parcels. The research has filled this gap by employing a simulation-based sensitivity analysis. The findings underscore that incorporating this final transport step into the calculations raises a notable shift in the environmental impact, especially in outer city districts. The proposed models endeavor to enhance the system representation of APLs, offering a novel evaluation tool to guide future implementations of APLs as an efficient last-mile logistics system with environmentally friendly practices.

Adapting Data Preprocessing for Data Mining

Florian Hochkamp (M. Sc.) is a research assistant at ITPL since November 2020. His research interests include knowledge discovery in databases, data mining, data preparation, and data quality.

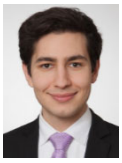
With growing amounts of data, knowledge discovery in databases is required to cope with analysis tasks. The fact that subject matter experts are also overwhelmed by the volume of data and that there is a shortage of subject matter experts at the same time underscores the relevance of more-sophisticated analysis methods such as data mining. For many manufacturing companies it is unclear, which methods to apply in data mining. An implementation of each data mining technology requires data preprocessing to match the specific data mining algorithm and to ensure a suitable data structure. Also, data quality deficiencies must first be identified and quantified so that suitable data preprocessing methods can be selected. Preprocessing the data takes up to 80 % of the time for a knowledge discovery process and prevents fast and precise analysis. To address this issue, more-developed preprocessing and data quality assessment methods are presented in the literature. These methods address automation potential in data preprocessing as well as increasing the overall preprocessing performance. The research focusses on an adaptation of the data preprocessing phase to create a framework combining advances in data preprocessing and data quality assessment methods in a structuring approach. This approach targets to reduce deficits in data preprocessing in order to improve the overall data mining result and, thus, provide a more valuable knowledge discovery.

Combining Data Farming and Mining in a Logistics Assistance System

Joachim Hunker (M. Sc.) is an external Ph.D. student at ITPL and currently working as deputy head of the department logistics at the Fraunhofer Institute for Software and Systems Engineering. His research interests include simulation-based data generation, non-relational databases, and knowledge discovery in databases.

Nowadays, supply chains are fairly complex systems. Due to the complexity, decision-makers in supply chain management are confronted with various logistics tasks that can no longer be answered manually. Therefore, decision makers are supported by IT systems such as logistics assistance systems. A key factor in supporting decisions in supply chain management is gaining and visualizing knowledge. One of the widely established methods in theory and practice is known under the term knowledge discovery in databases. The core phase of the knowledge discovery process is known as data mining. Applying successful data mining, e.g., to find useful and previously unknown patterns, relies heavily on a valid and preprocessed input data basis, which is usually stored in a database. A challenge is that these consist of mainly observational data, which leads to different flaws. Typical examples are low data quality, e.g., missing or out-of-range data. A way to address this problem is simulation-based data generation, called data farming. The process of data farming uses large-scale experiments to grow massive amounts of synthetic data as simulation output. This enables the application of analytical methods on a well-suited database to support decision makers in supply chain management in answering complex logistics tasks. In this context, Joachim Hunker focuses his research on combining data farming and data mining in a logistics assistance system to support decision makers in supply chain management.

Automated Machine Learning for Quality Control



Reza Jalali Sousanabady (Dipl.-Inf.) is an external Ph.D. student at ITPL and currently working as a Solution Architect for Accenture AG in Zurich, Switzerland.

In recent years, the world has embarked on a process of technological revolution, which is expected to significantly reshape the fundamental aspects of both individual and corporate life. This transformation, characterized by unprecedented dimensions in terms of scale, scope and complexity, is driving revolutionary changes in the operating paradigms of businesses across multiple sectors. Within this paradigm shift, manufacturing and logistics companies will be no exception. They face challenges such as increased competitive pressures, the need for faster time-to-market, stringent quality requirements, and the escalating intricacy of products and processes. The response to these challenges is the deliberate adoption of innovative tools and methodologies. Among these tools is machine learning as a means of gaining critical knowledge. This process involves the extraction and aggregation of critical data, the identification of patterns and the derivation of much sought-after new insights. Nonetheless, a significant drawback lies in the time-intensive procedures required for both data preparation and model development, coupled with the frequent absence of model reusability. In addition, considerations of model reusability and the significant resource allocation required to adapt pre-existing models are other factors that require attention. Automated Machine Learning (AutoML) can be applied to solve the problem of model development in a variety of cases. The use of AutoML increases the speed of model generation, but at the expense of result quality due to the lack of use of domain specific knowledge. The research focuses on overcoming this challenge for classification problems in the field of quality management in discrete manufacturing. The proposed methodology introduces a novel approach for integrating domain information into the AutoML learning process and improving its usability for domain experts.

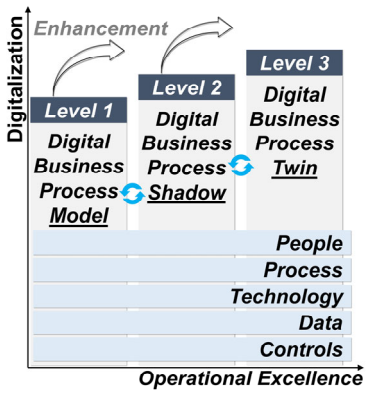
Digitalization of Control Processes in the Model Upgrade of Vehicles

Emre Kilic (M. Sc.) is an external Ph.D. student at ITPL and currently working at Volkswagen AG in Wolfsburg.

The automotive industry must deal with wide-reaching challenges and changes. A continuous gain of significant competitive advantages in a highly competitive market requires automotive manufacturers to produce new products with a large diversity of variants at ever-shorter time intervals. As a result, the frequency of series launches has increased and the need for a sophisticated vehicle project management and an efficient handling of vehicle changes and model updates along the product process has gained significant importance. However, current project management practices and frameworks utilized by automotive manufacturers do not effectively address this demand, e.g., the goal of increasing operational efficiency and productivity as well as establishing continuous improvement are not sufficiently achieved. While these goals are traditionally common place in certain fields of the automotive manufacturing, e.g., in production, logistics, or warehousing, their dedicated consideration in the vehicle change management and model update of vehicles has not been examined thoroughly in the required extend.

Final assembly line of the ID.3 in a production plant (photo: Volkswagen)

The conducted research aims to apply the concept of a traditional digital twin within the context of business processes. This results in the emergence of a new concept referred to as a digital business process twin. The novelty of this concept lies in the proposition that the development of a digital twin related to business processes should undergo an evolutionary progression through successive steps. The uniqueness of this research primarily arises from the integration of the terms digital model, digital shadow, and digital twin into a maturity-based concept, with a particular focus on business processes.



Evolutionary phases in the development of the digital twin in the context of business processes (maturity model)

Data Farming for Sales Planning in Multi-Channel Distribution

Tobias Klima (M. Sc.) is a member of the Graduate School of Logistics in Dortmund. He is conducting his doctorate research at the ITPL and is sponsored by the company Vorwerk & Co. KG.

In supply chain management, the focus has shifted to more sustainability and resilience. Demand forecasting is often the basis for process planning and has a major impact on production. In order to act in a more customer-oriented way and satisfy customer needs quickly, forecasting future sales based on historical data is essential for sales. Accurate sales planning helps to

provide the demanded products in advance of the emerging customer demand. The research of Tobias Klima investigates how simulation can support the creation of sales forecasts in multi-channel sales. For this purpose, it will be investigated whether simulation methods from logistics and production can be transferred to multi-channel sales and which other methods of forecasting can be combined with simulation. To validate the simulation model, it is applied to the product distribution of a large German household goods manufacturer. Sales and marketing data from the company are used to create the model.

Embedding Track & Trace Solutions

Henrik Körsgen (M. Sc.) is an external Ph.D. student at ITPL and currently working as a SCM IT consultant with dxk GmbH in Zurich, Switzerland.

Disruptions in the supply chain are not an exception anymore. Geopolitical tensions, the climate crisis and shorter life cycles demand for adequate logistical solutions. Traceability of the goods flow in the supply chain is considered a must today and – even more – in the future. Track & trace solutions are an important technical basis to reach this goal.

The question is how to implement track & trace solutions such that the logistics operations are covered holistically. Previously, a three-pillar digital enterprise architecture framework was designed. It guides enterprises that ship high-value goods, on where to start with the integration of track & trace solutions and which procedures to follow in their planning. By creating a track & trace demand catalogue, a first selection of the feasible technical options is achieved.

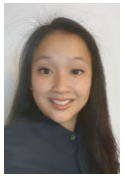
Currently, the focus is on blockchain technology for track & trace solutions. With the rapid introduction of new web3 applications, blockchain offers several advantages compared to other programmable technologies. The immutability, the security, and foremost the traceability of changes to each of the blocks are important advantages. The next step is to create a demonstration case that connects a logistics system landscape with a blockchain Hyperledger and to derive important insights on the implementation of track & trace applications based on blockchains.

Structured Selection of Methods Supporting Valid Decisions

Katharina Langenbach (M. Sc.) is a research assistant at ITPL since February 2023. Before that she studied Mechanical Engineering at TU Dortmund University and majored in modelling and simulation in Mechanics. Ms. Langenbach has been employed at ITPL as a student researcher since 2018. Her research interests include automation, simulation, procedure models, quality management, and NoSQL databases.

The use of decision support methods is facilitated by increasing amounts of available data and recent technologies. The choice of the right decision support method and the right level of detail depends not only on the objective, but also on the understanding of the system and the available data. For these reasons, a structured and iterative approach is required to select, implement, and refine a suitable decision support method. Verification and validation must also be considered to enhance the credibility of the results obtained. An iterative approach increases the understanding of the system to capture the objective of the decision support more precisely. Moreover, it may be necessary to apply several methods in such iterations, which change with increasing understanding of the system and the resulting objectives. Furthermore, data are available at various levels of granularity, ranging from operational IT systems from time-bound individual events to highly aggregated performance indicators in several dimensions. Aggregated values can be created by combining basic information or by making estimates based on aggregated performance indicators from the past. The challenge is that these data can be aggregated both too high and too low without established procedures for the systematic transfer of levels to enable the use so the data in the chosen method. When an iterative approach with adapting methods is selected for decision support and data have to be manipulated and aggregated or disaggregated, verification and validation must be embedded in the general approach. This should be done as automatically as possible in order to minimize the effort and maximize the acceptance of the implementation.

Automated Order Picking for Heavy Flatpacks in Retail and Wholesale



Trang Nguyen-Krogull (M. Sc.) is an external Ph.D. student at ITPL and currently working as Automation Integration Leader in Customer Fulfilment with Automation integration of INGKA IKEA.

The ongoing market and e-commerce developments, combined with the increasing customer expectations in omnichannel customer points and shorter lead time, the home furnisher companies have an increased interest in automated order picking systems. Although technologies for automated order picking processes are developing rapidly, picking of the unergonomically heavy flatpacks is mainly done manually. This is due to the flexibility of manual processes, but also to the long planning and evaluation time of these complex processes. Automated order picking solutions support the requirement of a more ergonomic working environment and can provide more density and productivity. But, it also makes the overall intralogistics process more complex, which leads to a more time-consuming and complex planning and evaluation process.

Currently, the planning and evaluation still involve years of preliminary studies, development projects, data collection, and evaluation to reach the successful implementation of an automated order picking process of heavy flatpacks. Furthermore, the existing

guidelines for the generic determination of performance availability leads to a time-consuming discussion in the specification phase, as they are not specifically dedicated to the technology that is used in intralogistics solutions for heavy flatpacks.

The aim of our research is to develop a reference model to contribute to a more efficient and less time-consuming planning and evaluation phase for automated order picking processes of heavy flatpacks. The reference model shall provide a conceptual framework with standard process descriptions and best-in-practices. It builds up the foundation by providing the planner an understanding of significant concepts, entities and relationships that needs to be considered. The usage of the reference model in combination with an early integration of simulation into the planning process has the benefit that the complex intralogistics solutions can be validated and verified in an early stage. The usage of simulation gives the possibility to consider the pre- and post-processes in addition to the generic guidelines.

Creating Customized Actions for the Simulation of Logistic Networks

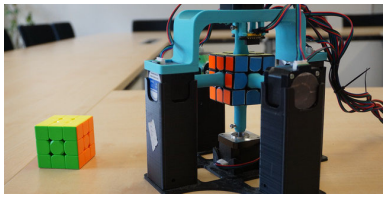
Dominik Schmitt (Dipl.-Inf.) serves as an external Ph.D. student affiliated with ITPL and is currently employed as a research associate at the Fraunhofer Institute for Material Flow and Logistics in Dortmund.

Today's logistics networks are intricate systems influenced by various internal and external factors. To ensure optimal performance and adaptability to these influences, continuous adjustments to the system's structure and configuration are necessary. The nature of these adjustments is determined by diverse objectives, such as profit maximization, altering the product range, or incorporating new suppliers.

Managing and optimizing such complex systems pose significant challenges for professionals. In response to this challenge, ITPL has developed a Decision Support System (DSS) designed to assist users by recommending strategic actions for their specific logistics network. This DSS addresses various logistics aspects and selects the most effective sets of integrated actions from a predefined catalog, considering their interdependencies.

However, the suggested changes in the DSS are typically predefined within the simulation program. To enhance the flexibility and user-friendliness of the DSS, a concept has been developed to derive specific actions from generic action types. Achieving this involves the creation of a method for generating, integrating, and executing user-generated generic action types.

ITPL is tackling this challenge by developing a formal description of changes in Discrete Event Simulation models for extensive logistics networks in the form of a domain specific language. Through this language, changes can be transformed from a highly technical level to a more intuitively accessible format, such as a graphical editor. On this abstraction level, users can modify or create new actions and seamlessly apply them to the simulation model.



Method for Real-time Forecasting of Production Key Figures

Erwin Sirovnik (Dipl. Wirt.-Ing.) is an external Ph.D. student at ITPL and working for thyssenkrupp Rasselstein GmbH in Andernach.

Nowadays the production scheduling pursues several objectives inside a flexible flow production in the steel industry, which are mainly located in the field of logistics. Besides an adherence to delivery dates, the primary target within a steel industry – characterized by capital-intensive plants – is represented by running at full capacity. Further objectives based on production key figures like maximized material productivity, minimized energy costs, improved quality, etc. are only covered to some extent, if any, manually by a responsible planner with few general rules. Although there are individual isolated solutions for specific plant-related objectives, e.g., on the subject of quality, a holistic view is still missing. These aspects are gaining importance – especially in situations of unplanned events like plant or material failures within an intermediate production step – regarding re-scheduling of the planning objects in the short-term.

Packaging steel (photo: thyssenkrupp Rasselstein)

In order to cover this resulting complexity, a production scheduling has to be developed that generates optimized production plans for each individual material unit at each production step considering all available data from the shop floor. Thereby, the multi-objective optimization must be supported by a real-time-capable forecasting of all relevant production key figures derived from machine learning and data mining approaches on data concerning quality, orders, maintenance and further relevant information. On this basis, transparency regarding all key performance indicators concerning the production as well as an immediate reaction to critical situations like insufficient target values will be enabled.

World's largest production site for packaging steel premises in Andernach (photo: thyssenkrupp Rasselstein)

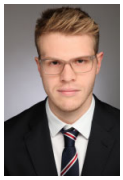
Modeling of Intralogistic Processes for the Implementation of WMS

Felix Stadler (M. Sc.) is external Ph.D. student at ITPL and working in the IT consultancy of Windmöller & Hölscher KG in Lengerich.

Due to the growing complexity of intralogistics systems, the use of warehouse management systems (WMS) is becoming increasingly attractive for companies. As an often business-critical management system of internal material flows, however, their implementation or change is complex and carries risks. Especially the insufficient knowledge of companies about their own processes leads to a high capacity and cost burden due to the time-consuming involvement of their own experts and, often, also contracted WMS consultants. In this context, models and modeling methods are gaining additional importance. But, particularly in intralogistics with its special demands and characteristics, there is a lack of methodological support for mapping and transferring process knowledge appropriate for the WMS implementation. The consequences, besides a low level of acceptance among the affected employees, are project abortions and production downtimes. Therefore, we developed a modeling methodology framework with dedicated components that support the specific requirements for modeling intralogistics processes for implementing WMS. Central components of the framework are a reference architecture that defines the content and scope of the modeling, a modeling methodology describing the mapping process and a modeling language that provides model elements for specific intralogistics modeling.

Photo TU Dortmund, Roland Baege

Simulation and Machine Learning for Agile Production Networks



Willian Vent (M. Sc.) is an external Ph.D. student at ITPL and currently working at the manufacturing department of the Gira Giersiepen GmbH & Co. KG in Radevormwald.

Determining ideal structures of production networks poses a challenging task for manufacturing companies nowadays. In order to gain competitive advantages, companies are attempting to make their production activities more agile.

In recent decades, the term agility has been coined by agile software development and adapted for various disciplines and applications. Currently, agility is experiencing a renaissance in the context of production and is seen as a promising field of research for the production of the future and as the answer to rapid and disruptive change. The challenge of agile production networks is characterized by a high degree of complexity due to the growth process, which usually continues for decades, the variety of influencing factors and the simultaneous multitude of design options. This results in individual production sites in the network, which rarely lead to an optimal and holistic design of a production network that fulfils the expectations of an agile production.

A way to address this problem is a combined approach of simulation and machine learning. As an approach, besides the generation of a database by simulation, machine learning can be used to generate design strategies for production networks that differ from known solutions patterns.

Condition-based Maintenance of Machines in a Digital Twin

Alexander Wuttke (M. Sc.) is a research assistant at ITPL since 2022. His research focuses on simulation, digital twins, and analytics on data collected by sensors.

Digital Twins have gained a lot of attention in research as well as in industrial applications. They are the virtual representation of real-world objects and used to find answers to numerous questions concerning their real counterparts. An important source of data for the Digital Twin is constituted by sensors at the objects themselves. A specific task that Digital Twins are useful for is condition-based Maintenance (CBM). For CBM, the object and its current state are monitored and analyzed to predict when maintenance is required rather than conducting maintenance reactively or by a fixed schedule. Utilizing CBM can result in a major saving of costs and is, therefore, of great interest for industrial applications. In cooperation with an industrial partner, a Digital Twin for the purpose of CBM of industrial furnaces is currently designed and implemented. This includes a simulation model, which is used to gain in-depth insights of the industrial furnace and to generate additional data for the data basis of proven methods for CBM.

Reference Model for Process-oriented Lot Sizing along the Value Stream

Gökhan Yücel (M. Eng.) is an external Ph.D. student and is working as director of operations at a manufacturer for safety systems. The globalization, the integration of supply chains, and the lean management philosophy represent challenges to the definition of lot sizes. The reduction of stocks and the just-in-time supply of customers show a considerable effect on supply chains. However, the past years have shown how sensitively global supply chains react to political developments and natural disasters. The recent events in Ukraine, Israel and the Red Sea and their impact on trade routes such as the Suez Canal also show how big the influences of such events are on supply chains and, thus, what influence they have on companies' production planning. Many companies are building up safety stocks despite the lean philosophy.

In this environment, the question arises whether lot sizing can remain a purely internal activity. Irrespective of the costs and the pass-through or process-oriented approach, the question arises whether the lot size modelling needs to be extended along the supply chain, and which factors have an influence on the consideration of the supply chain in the lot size calculation and have, therefore, to be taken into account. A simulation-supported reference model for process-oriented lot sizing along the value stream is under development to support the production planner in ensuring a continuous process flow and, thus, delivery reliability.

REPORT 2023

Lectures Given by ITPL

Bachelor

- Introduction to Programming
- Fundamentals of Simulation Technology
- IT-Systems in Industrial Production
- Modelling Digital Ecosystems in Production and Logistics
- Introduction to Logistics

Master

- Information Exchange of Manufacturing Companies
- IT Design in Production and Logistics
- Data Analysis and Knowledge Representation in Production and Logistics
- Case Study Information Systems
- Material Flow Simulation
- Planning and Implementation of IT Projects
- Lab “Programming of a Web-based IT System for the Complex Provision of Spare Parts”

Contributions to Bodies

Association of German Engineers (VDI)

- VDI GPL Fachausschuss 204 Modellierung und Simulation; Member Markus Rabe
- VDI International Gremium „Digital Information“ (IGDT), Member Markus Rabe
- VDI Richtlinienausschuss (Guideline Committee) 3633.13 “Verifikation und Validierung” (Verification and Validation); Chairman Markus Rabe
- VDI Richtlinienausschuss (Guideline Committee) 3633.3 „Experimentplanung” (Experiment Planning); Members Markus Rabe and Anne Antonia Scheidler

German Simulation Society (ASIM)

- Working Group “Simulation in Production und Logistics” (SPL); Deputy Chairman Markus Rabe
- Expert Group “Dedicated Conferences”; Chairman Markus Rabe
- Expert Group “Consideration of Energetic Impact Factors in SPL”; Member Markus Rabe

Conference Organization

- ASIM Dedicated Conference “Simulation in Produktion und Logistik”; Chairman Markus Rabe 1998, 2000, 2004, 2008, 2015
- ASIM Dedicated Conference “Simulation in Produktion und Logistik”; Program Committee Markus Rabe 1993-2023
- Winter Simulation Conference; Local Chair Markus Rabe 2012 (Berlin)
- Winter Simulation Conference; Lead Proceedings Chair Markus Rabe 2018; Proceedings Chair Markus Rabe 2019.
- Winter Simulation Conference; Track Chair Markus Rabe 2012, 2013, 2014, 2016–2024.

Board memberships

- Graduate School of Logistics; Board Member Markus Rabe

Journals

- Advisory Board Journal of Simulation (Taylor & Francis); Member Markus Rabe

Publications

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Theses and Scientific Project Works

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Fuest, T.: Erfassung und Verarbeitung von Vibrationsdaten zur präventiven Instandhaltung von Industrieöfen. Technische Universität Dortmund, Fachgebiet IT in Produktion und Logistik, Masterarbeit, 2023.

Kaufhold, M.: Digitalisierung des ganzheitlichen Versorgungsansatzes im ambulanten Versorgungssektor (4D-DHCS). Technische Universität Dortmund, Fachgebiet IT in Produktion und Logistik, Masterarbeit, 2023.

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All our student theses can be downloaded for free from our homepage at www.itpl.mb.tu-dortmund.de/rabe/?lang=en&page=theses.

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