# *ANNUAL REPORT 2017 RESEARCH & TEACHING*

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## 1 Introduction

Graduating from the University of Applied Sciences Südwestfalen with a Bachelor's degree in Industrial Engineering in 2004 and from the University Duisburg-Essen with two Master's degrees in 2006 and 2007 respectively, I began my scientific career as Research Associate at the Fraunhofer Institute for Material Flow and Logistics in Dortmund in conjunction with an appointment at the Chair of Factory Organization of TU Dortmund University where I was then promoted to the position of Executive Director ("Oberingenieur") of the Chair. In 2012, I successfully defended my PhD thesis on Cross-Company Capacity Exchange.

Based on an offer by the Industrial Performance Center of the Massachusetts Institute of Technology (MIT) I moved to the United States in 2013 to start working there first as a Postdoctoral Fellow and then as Research Fellow analyzing advanced manufacturing innovation ecosystems. In April 2016, I was appointed as Professor of Logistics Engineering, Technologies and Processes at Jacobs University Bremen. Currently, I am also a Research Affiliate at MIT focusing mainly on Industry 4.0 ecosystems.

My current research at Jacobs University focuses on supporting small and medium-sized enterprises in adopting Industry 4.0 related technologies. In this realm, I successfully applied for industry-sponsored grants and submitted several project proposals to different funding bodies in Germany and Europe.

## 2 Publications

Based on my research activities in 2017 and previous years, I wrote papers with the major results and findings that were accepted by renowned journals. Due to the long review processes of those journals there will always be a time lag between finishing a research project and getting its findings finally published. The following publications are based on research projects of the previous years.

- Strengthening Advanced Manufacturing Innovation Ecosystems: The Case of Massachusetts. In: Technological Forecasting and Social Change – An International Journal. 2017. https://doi.org/10.1016/j.techfore.2017.06.003 (w/ E. B. Reynolds)

This research paper examines the pathways and opportunities for building and fostering innovation capacity among Massachusetts manufacturers, with a particular focus on small and medium-sized enterprises (SMEs). We employed a systems approach to conduct analytic and empirical analyses that consider how knowledge and sources of innovation flow between key participants within the manufacturing innovation ecosystem. We found that the Massachusetts manufacturing innovation ecosystem is rich in terms of assets but relatively poor in terms of interconnectedness between those assets. In addition, rather than being focused on demand-driven innovation and technological upgrading for SMEs, non-market state-supported manufacturing intermediaries are primarily focused on supply-side and point solutions that work with individual firms rather than at a systems level.

- Simulation-based Performance Evaluation of the Cellular Transport System. In: Journal of Simulation. https://doi.org/10.1057/s41273-017-0061-1, pp. 1-14, 2017. (w/ M. Güller, E. Karakaya & T. Hegmanns)

This research paper examines the performance of Cellular Transport Systems under various pre-defined scenarios in order to support the design process. A Cellular Transport System that aims at coping with new requirements, such as real time changes in operations, agility in turbulent market environment, and reconfigurability in equipment, provides an efficient way to increase flexibility and changeability of intralogistics systems. Since analytical models have several simplifications and constraints, simulation is used to evaluate the real performance of the Cellular Transport System. Furthermore, the paper discusses how we apply situated agent-based simulation as a tool for modeling and implementing a decentralized control of the vehicle swarm. Simulation scenarios consist of different physical and environmental factors, such as varying the number of order lines, stochastic demand, number of aisles, number of racks, layout configuration, and number of automated guided vehicles in the system.

- Autonomous Manufacturing-related Procurement in the Era of Industry 4.0: In: F. Schupp & H. Wöhner (Eds.): Digitalisierung im Einkauf. Springer: Berlin, pp. 81-97, 2017. (w/ M. Ilie)

This paper analyzes the effect of intelligent manufacturing systems on procurement processes by distinguishung between procurement tasks that will likely stay in human hand and those that will be taken over by those intelligent machines and systems. Especially for the latter scenario, a concept for an operational, fully-automated, and manufacturing-related procurement system is developed and presented here. For this, we began by looking at the manufacturing-related procurement types in the era of Industry 4.0 that may be done by machines, followed by the discussion of innovation-based procurement practices that will require human input. We concluded by presenting the general concept of the autonomous manufacturing-based procurement system. Although the concept for this procurement system is fully developed, further research is needed to connect this system to intelligent machines to enable a fully autonomous procurement, especially to execute transactional relations and repetitive tasks.

Besides these publications several others based on my current research activities were submitted in 2017 that are supposed to be published this year due to long review processes of journals.

## 3 Grants in 2017

In 2017, I applied for funding at both the German Ministry for Economic Affairs and companies. Besides a rather small project on port operations, I could secure together with another colleague two major industry-sponsored research projects.

A global port operator in South Germany faces efficiency losses in their operations. The representatives did not have an overview of their processes which would be the first step for improving inefficient processes. So, I was asked to analyze and map the processes in one of their ports. Together with students we could develop a detailed map of processes and based on that we could show bottlenecks and inefficiencies. Based on discussions with the company, we came up with recommendations how best to tackle those issues. Thanks to the successful completion of this project, I was asked to perform the same analysis for another port in their network. Currently, I am working on this project.

Another company dealing with the design, planning, and manufacturing of large-scale steel plants expressed a need in optimizing the scheduling operations of steel making.

This company not only does the mechanical aspects of steel plant manufacturing but also offers software for production planning and control. Based on extensive discussions upfront, we came up with three main problems in scheduling. First, most of the accepted orders are delivered late, i.e. the developed schedule did not work out. This is mainly due to outdated and unrealistic planning values and no consideration of current capacities in manufacturing. Second, the current batching of orders to campaigns leads to inefficient plans that require additional effort in setting up the machines since the transitions are not taken into account properly. Thirdly, there occur cast aborts at the continuous casting machines that require re-scheduling which cannot be done with the current systems and algorithms. So, based on these problems, together with the stakeholders in the company we defined three use cases tackling each of those problems. In the first use case, we apply a performance enrichment analysis that will enable the planner to judge immediately if an order will be late or on time. In the second case, we will improve the existing systems by developing new algorithms. In the third case, we will develop yet other algorithms that are capable of generating new schedules after cast aborts. The project is currently being developed and will be terminated in 2019. Two doctoral students and one postdoctoral associate are assigned to this project.

An automotive first-tier supplier faces tough challenges in dealing with customer requirements. The globally spread customers, i.e. the car manufacturers, occasionally change their logistics-related requirements by just sending an updated version of their requirements manual which have more than 200 pages. Currently, a logistics expert downloads and compares the manuals manually, detects the changes and assigns the proper departments affected by this change and sends the document to those departments. In several cases, the departments turn out to be the wrong ones so that the logistics expert need to assign another department. This process takes several days. So, we were asked to automatize this process and make it more accurate. We examined different classification algorithms and used real-world data. Thus far, we proved the efficiency of some algorithms that speed up the whole process. This project will run 3 years and one doctoral student is assigned to it.

On a more theoretical level, I employed another doctoral student using my startup funds. Here, I am interested in examining the effects of Industry 4.0 technologies on workforce. Many companies and especially employees are concerned with the job destructing nature of disruptive technologies. Against the backdrop of this, we will analyze the losses and als gains by those new technologies. For this, we will conduct empirical analyses to understand the potentials and threats of those new technologies.

## 4 Teaching

In 2017, I gave lectures in 5 regular courses in the spring and fall semester for both undergraduate and graduate students.

- Advanced Production System Design (2.5 ECTS with ~50 participants)

This undergraduate-level course which I offered in the spring semester 2017 introduces students into the advanced methods of production system design. The course combines theoretical knowledge and hands-on exercises. Students are introduced to different production organization forms in different industries. Students learn to analyze products, calculate the required number of machines, cluster those to machine groups, determine their space requirements, and laying them out. Beyond

that students will learn a well-known technique for the optimization of production systems, namely value stream mapping.

- Process Modeling and Simulation (5 ECTS with ~50 participants)

In this undergraduate-level course that I offered in the spring semester 2017, various concepts of process modeling are introduced as well as modeling methods and modeling languages. Three method of process modeling are treated in detail to demonstrate how process modeling can support industrial engineers to implement optimization initiatives. Various exercises and simulation examples are practiced both in class and as homework with real process modeling and simulation tools.

- Industrial Engineering (5 ECTS with ~100 participants)

This undergraduate-level course that I offered in the fall semester 2017 gives a broad introduction in the Industrial Engineering field. Industrial Engineering is an application-oriented scientific discipline that deals with the creation and management of systems that integrate people and materials and energy in productive ways. The Industrial Engineering course establishes a foundation in four areas: human factors engineering, manufacturing systems engineering, operations research, and management systems engineering. The course covers topics such as production systems, production design, factory planning, industrial management and decision making. The students gain an understanding of both the theoretical and practical aspects of industrial engineering.

- Industrial Project for SCEM (10 ECTS with ~30 participants)

This graduate-level course that I offered in the fall semester 2017 focuses on a current research topic with high relevance for industrial practice. By combining theoretical knowledge with data from industrial practice, the course trains students to apply theoretical knowledge to real-life logistics and supply chain management problems. This year, real-life problems from partner companies served as starting points for the individual research projects. The students worked out a couple of presentations, scientific papers, and reports about their work. A kick-off meeting, several workshops as well as a final presentation and discussion in front of the company’s management were components of this seminar.

- Modeling and Simulation in Supply Chains (5 ECTS with ~50 participants)

In this graduate-level course that I offered in the fall semester 2017, students learn how to develop and conduct simulation experiments to analyze the behavior of discrete-event and continuous systems. This course gives an introduction into the theory of modeling and simulation, and shows how to analyze the output of a simulation study. In its associated lab course students learn how to develop and conduct simulation experiments to analyze the behavior of logistics systems. Decisions on the design and operation of logistics systems require a thorough understanding of the system's behavior. In many cases logistics systems are too complex to develop analytical methods that can be used to predict the system's behavior and any implementation of changes bears a great risk on the overall performance of the system. Simulation can be used to derive insight about the behavior of complex systems before changes are implemented.

## 5 Supervision of Theses

In 2017, I supervised 15 theses both on Bachelor and Master level (see table).

| # | Last Name | First Name | Topic | Level |
|---|---|---|---|---|
| 1 | Mudahigwa | Brian | Manufacturing-Based Capability Analysis for Industry-4.0-Technologies? | BA |
| 2 | Thakran | Nancee | Cocoa Supply Chain | BA |
| 3 | Espinoza | Kristian | Business Model Development | BA |
| 4 | Meiwen | Fu | Transport Management System | BA |
| 5 | Nasui | Teodora | Is implementing lean individually or as a system better? | BA |
| 6 | Yang | Canhuai | Analysis of cargo transport costs and time from Mombasa to Kampala along the Northern Corridor based on existing road and railway infrastructure | BA |
| 7 | Zhou | Zhuang | Potential problems and solutions of the supply chain in the fast fashion industry | BA |
| 8 | Tindjou | Stephanie | When Does Outsourcing Make Sense? A Critical Analysis of Risks, Costs, and Benefits. | MA |
| 9 | Singh | Manpreet | Implementation of Lean Management in Food Commodity supply chain | MA |
| 10 | Mata | Alan | Does Kanban increase inventory? | MA |
| 11 | Pawar | Mayank | Does Lean hamper Innoveation? | MA |
| 12 | Ravi | Ranjith | Re-structuring of a brown field plant by the example of manufacturing company dealing with filter technology | MA |
| 13 | Singh | Karamveer | Is Industry 4.0 Lean on Steroids? | MA |
| 14 | Manash | Ghimire | Lean Leadership | MA |
| 15 | Nandh | Danush | Supply Chain Resilience | MA |

Apart from that, I currently supervise four PhD theses as well

| # | Last Name | First Name | Working Title | Level |
|---|---|---|---|---|
| 1 | Lyutov | Alexey | Classification and Anticipation of Customer Requirements in a Global Automotive Network | PhD |
| 2 | Merten | Daniel | Implications of Physical Properties of Steel on Scheduling | PhD |
| 3 | Beladinejad | Sheila | Predicting Lateness in Steel Manufacturing Orders – A Performance Enrichment Analysis | PhD |
| 4 | Nosheen | Sumaira | Effect of Industry 4.0 on Workforce | PhD |

## 6 Executive Education

In addition to my curricular activities, I was also engaged in executive education not only on campus but also overseas in China.

A large company active in different industries, such as car engine manufacturing, bus manufacturing, yacht manufacturing, etc., got training in industry 4.0 related topics. For this, I held a seminar and workshop in China and gave lectures on campus.

Supervised by an industry association, company representatives from various Chinese companies also came to our campus to learn more about Industry 4.0. I held a workshop in Industry 4.0 technologies with hand-on exercises.

## 7 University Service

Besides my research and teaching obligations, I also participated in search committees for vacant professorships at our University, such as Organization, Lean Management, Industrial Engineering, and Supply Chain Management.

Apart from that, I took over the responsibility for our graduate study program Supply Chain Engineering and Management. I currently serve as the chair of this program.

## 8 Review Activities

In addition to the abovementioned tasks, I also serve as reviewer for both funding bodies and journals.

I actively review articles for several journals (see table).

| Journal Name | Publisher | Active since |
|---|---|---|
| Production & Manufacturing Research | Taylor & Francis (UK) | 2014 |
| International Journal of Production Research | Taylor & Francis (UK) | 2014 |
| Triple Helix: A Journal of University-Industry-Government<br>Innovation and Entrepreneurship | Springer (Germany) | 2014 |
| Industrie Management | Gito Publishing (Germany) | 2014 |
| Production Planning and Control | Taylor & Francis (UK) | 2013 |

Furthermore, I was approached by the Federal Ministry for Education and Research (BMBF) to review research proposals of consortium-based applications. The first program “Industry 4.0 Testbeds for SMEs” (Industry 4.0 Testumgebungen für KMU) consists of different rotations. Thus far, we completed 6 rotations. Except for one, I participated in all rotations ad reviewd almost 30 proposals in total.

| Program Name | Funding Body | Active since |
|---|---|---|
| Industry 4.0 Testbeds for SMEs | BMBF | 2016 |
| Deutsch-Tschechische Forschungsvorhaben auf dem Gebiet Industrie 4.0 | BMBF | 2017 |